CLIMATE CHANGE & FOOD SECURITY IN WEST AFRICA

Edited by

Ahmadou Aly Mbaye
Fatou Gueye

Joachim von Braun
Alisher Mirzabaev

WASCAL
West African Science Service Centre on Climate Change and Adapted Land Use

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IN MEMORIAM

Professor Fatou Gueye Lefèvre who has played a pivotal role organizing the 2019 conference where all the chapters included in this volume had been previously presented, and editing this book, has passed away just hours before the book was released. This is a very sad moment for all her colleagues and students at the University Cheikh Anta Diop (UCAD) and elsewhere in Africa, with whom she has been interacting for more than 15 years. It is also a sad moment for WASCAL and the national GSP on climate change economics, where she was playing an important role, first as academic assistant, and then as director. Fatou was a hard-working lady whose work ethics and kind relationship to colleagues and students were praised by all partners of the GSP and UCAD. She was promoted the first lady to become economics professor at UCAD, only last year and was preparing to celebrate her 41th birthday on October 30 2021. She has left a heart-broken team and husband with three little children. We all pray the Almighty that her soul rest in peace.

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Combating Climate Change. Improving Livelihoods

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Ahmadou Aly Mbaye is professor of Economics and public policies at Cheikh Anta Diop University, in Senegal, where he is currently serving as Vice-Chancellor. Until recently, he was the Director of the West African regional graduate program in climate change economics, covering West-African countries. Previously, he had also served as the dean of the School of Economics and Management at Cheikh Anta Diop University and Chair of the francophone research network. He has been a consultant for many regional and international organizations. He has numerous publications on development economics and Africa. He is Non-Resident Senior Research Fellow at the Brookings Institution in Washington DC, and Senior Research fellow at the Center for Development Research (ZEF), University of Bonn (Germany).

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Joachim von Braun is a Director at the Center for Development Research (ZEF), Bonn University, and Professor of economic and technological changes. He received his doctoral degree in agricultural economics from the University of Goettingen, Germany. His research is focused on economic development, science and technology policy, poverty reduction, food and nutrition security, resource economics and trade. He has published more than 100 peer-reviewed publications in these fields. Von Braun is President of the Pontifical Academy of Sciences of the Vatican, and also a member of German National Academy of Science - Leopoldina, Academy of Science and Engineering (acatech), Academy of Arts and Science North Rhine-Westphalia, fellow of African Academy of Science and of American Association for the Advancement of Sciences. He is member of the Board of the Alliance for a Green Revolution in Africa (AGRA), and Vice-President of the German NGO "Welthungerhilfe". He is co-chair of the Malabo-Montpellier Panel on African food and agriculture policy, and co-chair of the International Committee on Bioeconomy. From 2002 to 2009, he was director general of the International Food Policy Research Institute (IFPRI) based in Washington DC. He was elected as president of the International Association of Agricultural Economists (IAAE), and has received honorary doctoral Degrees from the University of Stuttgart-Hohenheim and other awards.

Alisher Mirzabaev

Dr. Alisher Mirzabaev is a senior researcher at the Center for Development Research (ZEF), University of Bonn. Before joining ZEF, he was an economist with the International Center for Agricultural Research in the Dry Areas (ICARDA). Dr. Mirzabaev was a Coordinating Lead Author of the Chapter on Desertification of the IPCC Special Report on Climate Change and Land Use. He is currently co-leading the cross-chapter paper on "Deserts, semi-arid areas and desertification" under the IPCC Working Group 2. Dr. Mirzabaev was a lead researcher in several international projects with both global and regional focuses on Africa and Asia. He has a PhD Degree on Agricultural Economics from the University of Bonn, Germany. His research interests include climate change impacts and adaptation, economics of land degradation, and water-energy-food security nexus.

Fatou Gueye

Fatou Gueye was currently the Director of the West African regional graduate program in Climate Change Economics (GSP/CCE). She obtained her PhD in Economics in 2012 as part of the Interuniversity Postgraduate Program (NPTCI) at UCAD. She has been actively involved in the research project on the informal sector in West and Central Africa, undertaken by the Cheikh Anta Diop University for more than 12 years till now. She has also conducted research on various topics of sustainable development.

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Foreword

Climate change affects food security in West Africa in diverse and often complex ways. It not only affects food availability through its impacts on crop yields and livestock productivity, but also shifts in agricultural potentials due to climate change will have profound effects on crop and livestock choices and consequently on local food value chains. For many net food-buying households in the region, losses in crop yields and livestock productivity can often translate into reduced access to food due to higher food prices. Moreover, higher frequency of extreme weather events under changing climate, such as heatwaves, droughts, and floods, is already undermining the stability of West African food systems. Weather extremes are exacerbating the existing problems with food safety and nutritional security, posing particularly severe risks on the most vulnerable social groups. It is further projected that changing climatic conditions will facilitate the spread of infectious diseases in the region taking an increasing toll on nutritional security and human health.

Individual and policy choices made regarding food systems and diets have important implications for climate change adaptation and mitigation in West Africa. The populations in West Africa have historically shown strong ingenuity and resilience in the face of various social and climatic shocks. However, often unprecedented nature of climatic changes projected for the region and their food security implications may require new solutions combining innovative technological, socio-economic and policy responses.

Particularly for these reasons, this volume is unique as a source of the latest state-of-the-art research on climate change and its impacts on food security in West Africa, focusing not only on climate change impacts but even more also on innovative and cutting-edge solutions and insights for climate change adaptation and mitigation. This volume is also very timely and useful because it brings together the research by both experienced researchers and many highly promising early career climate change scientists from the region. The report clearly points to the large and growing climate science potential in West Africa, which we believe should be further supported but also properly reflected in international scientific collaborations on climate change, for example, by involving more African researchers in the work of the Intergovernmental Panel on Climate Change (IPCC) and other international scientific bodies.

There are three key takeaways from this volume. West Africa is one of the regions in the world which are most vulnerable to climate change impacts. However, there are numerous innovative solutions for climate change adaptation and mitigation currently being experimented and deployed in the region. Crucially, the region now possesses a strong cadre of young climate change researchers who undoubtedly will contribute to the climate resilient development in West Africa. We call on the international community to expand and strengthen scientific collaborations and development cooperation on climate change with the region.

Introduction

CLIMATE CHANGE AND FOOD SECURITY IN WEST AFRICA

Higher frequency of extreme weather events under changing climate, such as heatwaves, droughts, and floods, can undermine the stability of food systems and also exacerbate the existing problems with food safety and nutritional security in Western Africa, posing particularly severe risks on the most vulnerable social groups. Furthermore, changing climatic conditions facilitate the spread of infectious diseases taking an increasing toll on nutritional security and human health. Shifts in agricultural potentials due to climate change will have profound effects on crop and livestock choices and consequently on local food value chains. On the other side, individual and policy choices made regarding food systems and diets have important implications for climate change mitigation. The populations in Western Africa have historically shown strong ingenuity and resilience in the face of various social and climatic shocks. However, often unprecedented nature of climatic changes projected for the region and their food security implications may require new solutions combining innovative technological, socio-economic and policy responses.

This volume is a compendium of papers presented at the conference on climate change and food security in West Africa, jointly organized by the Center for Development Research (ZEF) at the University of Bonn, and the WASCAL Climate Change Economics Graduate Studies Program, hosted by the University Cheikh Anta Diop of Dakar. The conference has served as a platform for exchanging and discussing latest research findings on the relationship between climate change and food security in Western Africa, particularly on innovative and cutting-edge solutions and insights related to the Conference themes. Its objective was to bring together early career and experienced researchers from economics and other social sciences from the Western Africa region to promote mutual exchanges and collaborations on this crucial topic. Reflecting the diversity of background among conference participants, this volume gathers contributions using different approaches to analysing various aspects of the complex nexus between climate change and food security.

It consists of five different parts, which are shortly described below.

There is a degradation of natural environments linked to high population growth and significant pressures from agriculture and pastoralism. All these aspects contribute significantly to the disparities observed throughout Africa in the productivity of crops, livestock, forests, and even fisheries, leading to major social and economic constraints.

Situations of hunger and malnutrition vary from one country to another, but they are a barrier to progress in the fight against poverty and the achievement of sustainable development goals. The issue of water is added to this, both from a quantitative and qualitative point of view, as water resources are a major component of food security and the challenges are becoming increasingly heavy and difficult to overcome, particularly for the countries of sub-Saharan Africa. Energy security is also an important challenge for Africa. Despite significant hydropower resources that can cover all electricity needs, the use of fossil fuels continues to weigh heavily on the economies of most African countries. The use of those energies has significant social and economic implications, and adaptation as well as resilience-building policies generally do not prevent migration.

This first part is composed of four papers that focus on Africa in general and the West African region and the Sahel in particular :

1. Climate change and food security in West Africa: Which adaptation and which productive investment are sustainable?
2. Climate change economics, sustainable development and food security – global and African perspectives
3. Climate Change, Livelihoods and Migration in West Africa
4. Climate Change, Livelihoods and Conflicts in the Sahel.

Climate change is affecting agriculture and food security and these effects are becoming increasingly visible across different sectors and can be studied and analysed. In fact, rural households are the most affected, particularly in West Africa because their income depends mainly on agricultural and pastoral activities. It is therefore important to put in place climate change adaptation programmes and policies so that farm households can be spared. There is also a need to improve seasonal rainfall forecasts and ensure that rural households have access to them in order to enable them to make appropriate agricultural use.

Part two of the book addresses the impacts of climate change on agriculture, food security and related social and economic inequalities in West and Central Africa, including Senegal, Gambia, Ghana, Niger and Cameroon. It consists of ten articles :

1. Self-sustaining adaptation to climate change and food security in the Sudano-Sahelian zone in Cameroon
2. Rainfall variability and food insecurity in Senegal: the case of Upper CasamanceRainfall shocks effects on children malnutrition in Senegal
3. Impacts of Seasonal Climate Forecasts on Farm Household Income in Rural Senegal
4. Spatial diffusion of agricultural production in WAEMU: does climate change play a role ?
5. Impacts des changements climatiques sur la chaine de valeur viande bovine au Sénégal : Quels investissement pour quelles stratégies de résilience ?
6. Effect of Global Climate Change on Poverty and Inequality in Sub-Saharan Africa

7. Factors influencing Households' Food Security Status among rural Farmers in the Central River Region South of the Gambia
8. Household vulnerability to food insecurity due to climate change in Niger: a multinominal logistic regression of food insecurity categories on climate and socioeconomic factors
9. CO_2 emission and Economic growth in sub-Sahara countries: is there Kuznets curve?
10. The effects of Climate Variability on agricultural efficiency in Ghana.

The development of adaptation strategies is the best way to mitigate the effects of climate change and support local communities as a means of building resilience, because the effects induced by climate change are proving to be particularly constraining in West Africa. Floods, one example among many, which most affect the social and economic development of communities living in affected areas. Cooperation serves as a relevant adaptation strategy in rural areas of developing countries. In addition, the agricultural sector, which is a particularly affected, has low yields and the population fights to meet its primary food needs. In facts, national economies are heavily affected despite the strategies that have been put in place and tested in various countries, particularly in Senegal. There is also a lack of information and climate forecasts for local communities, which is an obstacle to the success of adaptation policies and strategies, despite the efforts made by the state and the good will of farmers.

Research within West Africa has shown that the most successful adaptation policies are those based on sustainable management and conservation of environmental resources. This is further proven by the development of certain export chains, such as the cashew nut export chain in Senegal, which generates significant financial resources while at the same time allowing for the preservation of forests and the mitigation of the effects of climate change.

The five articles that make up part three on climate change adaptation and mitigation strategies in West Africa will be illustrated with examples from Senegal, Ghana, Togo and Côte d'Ivoire :

1. Cooperation and Adaptation to Natural Risk : Evidence from Ghana
2. Climate change, agricultural output, household income and policies in Senegal
3. Group membership and adoption of climate change adaptation strategies: the case of dry cereal producers in the groundnut basin of Senegal
4. Impacts of Adaptation to Climate Change on farmers' income in the Savana Region of Togo
5. Analysis of the performance of an export sector and its impact in mitigating the effects of climate change: Case of cashew nuts in Senegal.

Climate change has become the single most serious environmental issue, affecting not only agricultural activities but also other human endeavours worldwide (Nwankwo et al., 2020). The potential for success in climate change mitigation requires the mobilisation of knowledge and innovative practices in all economic sectors and in particular the agricultural sector. This is confirmed by experiences in the sub-region, particularly in the Sudano-Sahelian zone of Nigeria (Bello & Tajudeen, 2012; Nwanneka Okoli & Comfort Ifeakor, 2014). Currently, insurance in agriculture is needed to develop and strengthen farmers' resilience to climate change. However, quality and reliable climate predictions must accompany strategies and innovations to enable the implementation of an intelligent agricultural calendar and the selection of suitable agricultural varieties (Douxchamps et al., 2016). In the Sahel, these innovations will be highly relevant because food agriculture is highly dependent on rainfall. In these countries where the staple food is millet, maize and sorghum, the promotion of innovative strategies in agriculture can help mitigate the effects of climate change.

Part four section consists of a set of seven (07) articles that focus mainly on innovations as strategies to respond to the effects of the changing climate cycle :

1. Multi-Crop Supply Response in a Risky Production Environment: Evidence from the Sudano-Sahelian Zone of Nigeria
2. Explaining farmers' willingness-to-insure farms and resilience to climate change in Ghana
3. Is Weather Index Insurance Sufficient for Smallholder Protection? Emerging Insights from Rainfall-Index Calibration of Maize Crop Losses in Central-West Nigeria
4. What drives the adoption of Climate Smart Agricultural Practices? Evidences from Maize Farmers in Northern Nigeria.
5. Factors influencing the adoption of Climate Smart Agriculture by farmers in Segou region in Mali

Impact of Climate Change on cereal yield and production in the Sahel: Case of Burkina FasoImpact of Climate-Smart Innovations on food security farming household in Benin: A case study of Drought Tolerant Maize (DTM) varieties

REFERENCES

Arouna, A., & Akpa, A. K. A. (2019). Water Management Technology for Adaptation to Climate Change in Rice Production: Evidence of Smart-Valley Approach in West Africa. In Sustainable Solutions for Food Security (pp. 211–227). Springer International Publishing. https://doi.org/10.1007/978-3-319-77878-5_11

Bello, B. O., & Tajudeen, G. (2012). Evidence of Climate Change Impacts on Agriculture and Food Security in Nigeria. International Journal of Agriculture and Forestry, 2(2), 49–55. https://doi.org/10.5923/j.ijaf.20120202.08

Binns, J. A., Maconachie, R. A., & Tanko, A. I. (2003). Water, land and health in urban and peri-urban food production: The case of Kano, Nigeria. Land Degradation and Development, 14(5), 431–444. https://doi.org/10.1002/ldr.571

De Longueville, F., Ozer, P., Gemenne, F., Henry, S., Mertz, O., & Nielsen, J. (2020). Comparing climate change perceptions and meteorological data in rural West Africa to improve the understanding of household decisions to migrate. Climatic Change, 160(1), 123–141. https://doi.org/10.1007/s10584-020-02704-7

Diouf, N. S., Ouedraogo, I., Zougmoré, R. B., Ouedraogo, M., Partey, S. T., & Gumucio, T. (2019). Factors influencing gendered access to climate information services for farming in Senegal. Gender, Technology and Development, 23(2), 93–110. https://doi.org/10.1080/09718524.2019.1649790

Dixon, R. K., Smith, J., & Guill, S. (2003). Life on the edge: Vulnerability and adaptation of African ecosystems to global climate change. Mitigation and Adaptation Strategies for Global Change, 8(2), 93–113. https://doi.org/10.1023/A:1026001626076

Douxchamps, S., Van Wijk, M. T., Silvestri, S., Moussa, A. S., Quiros, C., Ndour, N. Y. B., Buah, S., Somé, L., Herrero, M., Kristjanson, P., Ouedraogo, M., Thornton, P. K., Van Asten, P., Zougmoré, R., & Rufino, M. C. (2016). Linking agricultural adaptation strategies, food security and vulnerability: evidence from West Africa. Regional Environmental Change, 16(5), 1305–1317. https://doi.org/10.1007/s10113-015-0838-6

Feldman, A., Ho, W. K., Massawe, F., & Mayes, S. (2019). Bambara Groundnut is a Climate-Resilient Crop: How Could a Drought-Tolerant and Nutritious Legume Improve Community Resilience in the Face of Climate Change? In Sustainable Solutions for Food Security (pp. 151–167). Springer International Publishing. https://doi.org/10.1007/978-3-319-77878-5_8

Nwankwo, W., Ukhurebor, K. E., & Aigbe, U. O. (2020). Climate Change and Innovation Technology: A Review. Reports of Kansai University, 63(3), 383–391.

Nwanneka Okoli, J., & Comfort Ifeakor, A. (2014). An Overview of Climate Change and Food Security: Adaptation Strategies and Mitigation Measures in Nigeria. Journal of Education and Practice, 5(32), 13–19. www.iiste.org

Pule-Meulenberg, F. (2018). Solutions for food security in Africa through sustainable soil fertility management of ecosystems under climate change: Proceedings of the 17th African Association for Biological Nitrogen Fixation Conference held in Gaborone Botswana 17–21 October 2016. Symbiosis, 75(3), 165–166. https://doi.org/10.1007/s13199-018-0553-4

Thompson, H. E., Berrang-Ford, L., & Ford, J. D. (2010). Climate change and food security in Sub-Saharan Africa: A systematic literature review. Sustainability, 2(8), 2719–2733. https://doi.org/10.3390/su2082719

Young, H. R., Cornforth, R. J., Gaye, A. T., & Boyd, E. (2019). Event Attribution science in adaptation decision-making: the context of extreme rainfall in urban Senegal. Climate and Development, 11(9), 812–824. https://doi.org/10.1080/17565529.2019.1571401

PART I :

CLIMATE CHANGE AND FOOD SECURITY IN AFRICA : SETTING THE STAGE

Africa is cited as the continent most highly affected by the effects of climate change, yet the majority of these impacts come from other continents. Climate trends and projections in the continent in general and in West Africa in particular are rather worrying. The African continent is struggling to achieve efficient food security despite its large potential in natural resources. Extreme weather events, intensified by climate change, conflicts and low economic growth are the main causes of growing food insecurity, especially in developing countries.

There is a degradation of natural environments linked to high population growth and significant pressures from agriculture and pastoralism. All these aspects contribute significantly to the disparities observed throughout Africa in the productivity of crops, livestock, forests, and even fisheries, leading to major social and economic constraints.

Situations of hunger and malnutrition vary from one country to another, but they are a barrier to progress in the fight against poverty and the achievement of sustainable development goals. The issue of water is added to this, both from a quantitative and qualitative point of view, as water resources are a major component of food security and the challenges are becoming increasingly heavy and difficult to overcome, particularly for the countries of sub-Saharan Africa. Energy security is also an important challenge for Africa. Despite significant hydropower resources that can cover all electricity needs, the use of fossil fuels continues to weigh heavily on the economies of most African countries. The use of those energies has significant social and economic implications, and adaptation as well as resilience-building policies generally do not prevent migration.

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Climate change economics, sustainable development and food security – global and African perspectives

Joachim von Braun

ABSTRACT

Climate change affects food security in many ways. The consequences of extreme weather events for crop production are highly visible and well known. There is also an economic impact, as climate change leads to fluctuating food prices, which have an indirect negative effect on production, as these price fluctuations signal a risk and reduce incentives to invest in agriculture. Indeed, while emerging and different, the consequences of the climate crisis vary from one area to another, increasing yields in some temperate zones and decreasing them in some tropical, subtropical or arid zones. Areas particularly at risk are coastal regions where current levels of agricultural production are high. In recent months, there has also been an increase in rainfall and flooding in southern Africa, East Asia and the Caribbean. Food shortages are expected to affect LDCs the most. As a form of adaptation, CO_2 fertilisation has been the source of much research but also of controversy about its effectiveness. The objective of this paper is to review the different effects, adaptation methods around climate change impacts on food security, starting with a global analysis and then focusing on the African perspective. The study results show that climate policies must include adaptation to climate change and its prevention. The climate crisis requires policy, institutional and technological innovations. Climate policies that support sustainable development must have an integrated, regulatory and comprehensive approach, developed on the basis of the social market economy while following the principles of equity, justice and efficiency.

Keywords : climate change, food security, economics, impact, perspectives

RÉSUMÉ

Le changement climatique affecte la sécurité alimentaire sous plusieurs de ses formes. Les effets sur la production végétale des évènements climatiques extrêmes sont très visibles et connus. L'impact est aussi d'ordre économique, car ces changements climatiques entraînent une fluctuation des prix des denrées alimentaires, ce qui a un effet négatif indirect sur la production. Ces fluctuations de prix signalent en effet un risque et réduisent les incitations à investir dans l'agriculture. Bien qu'émergentes et différentes, les conséquences de la crise climatique varient d'une zone à une autre augmentant le rendement dans certaines zones tempérées et les diminuant dans certaines zones tropicales, subtropicales ou arides. Les zones le plus particulièrement menacées sont les régions côtières où les niveaux actuels de production agricole sont élevés. Ces dernières années, on a observé une augmentation des précipitations et de la fréquence des inondations en Afrique australe, en Asie de l'Est et dans les Caraïbes. Les PMA devraient être les plus touchés par les pénuries alimentaires. Comme forme d'adaptation, la fertilisation avec le CO_2 a fait l'objet de beaucoup de recherches, mais aussi de controverses quant à son efficacité. Le présent article fait une revue des différents impacts et des modèles d'adaptations face aux conséquences du changement climatique sur la sécurité alimentaire avec des recommandations partant d'abord d'une analyse globale avant de faire une fixation sur la perspective africaine. Les résultats montrent que les politiques climatiques doivent inclure l'adaptation au changement climatique et sa prévention. La crise climatique exige des innovations politiques, institutionnelles et technologiques. Une politique climatique soutenant le développement durable doit reposer sur une approche intégrée, réglementaire et globale, élaborée sur la base de l'économie sociale de marché tout en suivant les principes d'équité, de justice et d'efficience.

Mots-clés : changement climatique, sécurité alimentaire, impact, économie, perspectives

INTRODUCTION

Climate change is already having a serious impact on food security. In this context, food security should not be understood only in terms of calorie supply, but also as access to a healthy diet with an adequate supply of nutrients. Around 821 million people worldwide are affected by food insecurity. This number has been increasing since 2014, though the overall number today is still lower than it was 15 years ago. The main causes of increasing food insecurity are extreme weather events, which are intensified by climate change, as well as conflict and slowing economic growth in some developing countries[1]. These forces, climate stress and conflicts, may actually be linked in a re- enforcing relationship. As of 2018, 39 million people have been forced into acute food insecurity as a result of climate events, and 74 millions have been pushed into food insecurity by conflict, particularly in the Horn of Africa, including East Kenya, the Sahel, and Central Africa[2]. In 2017, extreme weather events caused worldwide economic losses totaling 326 billion US dollars.

Since the 1980s, climate change has already reduced crop yields by about 5-10% in some regions, including Europe[3]. Worldwide production of maize, rice, wheat, and soya is projected to fall 9% by 2030 and 23% by 2050[4].Figure 1, below, depicts the

1 FAO, IFAD, UNICEF, WFP, & WHO. (2018). The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition. Rome, Italy
2 Food Security Information Network (2018). Global Report on Food Crises 2018. Rome, Italy
3 Iizumi, T., & Ramankutty, N. (2016). Changes in yield variability of major crops for 1981–2010 explained by climate change. Environmental Research Letters, 11(3), 034003 ; and Moore, F. C., & Lobell, D. B. (2015). The fingerprint of climate trends on European crop yields. Proceedings of the National Academy of Sciences of the United States of America, 112(9), 2670–2675
4 Haile, M. G., Wossen, T., Tesfaye, K., & von Braun, J. (2017). Impact of Climate Change, Weather Extremes, and Price Risk on Global Food Supply. Economics of Disasters and Climate Change, 1(1),

percentage change in food crop yields between 2010 and 2050[5].

Besides its effects on food security, climate change also contributes to species extinction and irreversible loss of biodiversity, including agro-biodiversity. This makes it more difficult to maintain and innovatively develop crops.

The acute nutrition and economic challenges caused by heat shocks and extreme weather events mean that climate-focused hunger and nutrition policy cannot wait but is needed now.

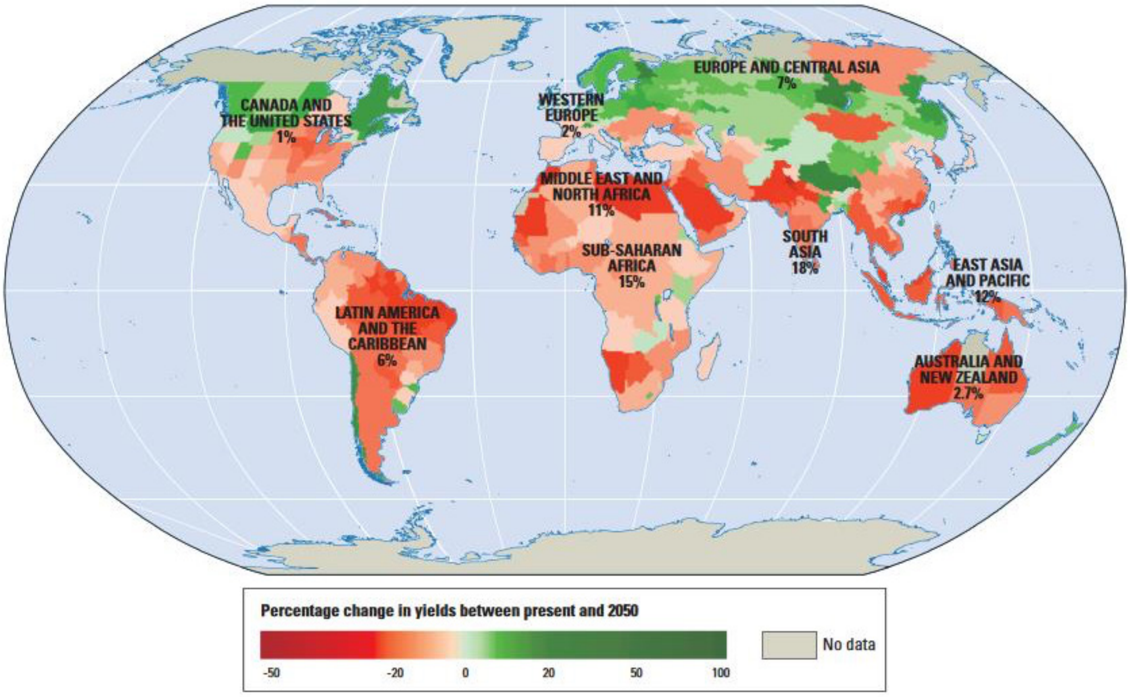

Figure 1. Crop Response Modelling: Impacts of climate change on the productivity of food crops in 2050. Source: World Bank Development Report, 2010.

EMERGING CLIMATE CRISIS

The effects of the climate crisis on agriculture and food systems are expected to vary by country and spatial scale. Climate change increases the yield potential in some temperate regions of the Northern Hemisphere, but reduces yields in the tropics, subtropics, and arid regions (due to droughts, floods, heat waves, and pests). Particularly threatened areas include coastal regions with high current levels of agricultural production, including Bangladesh and Vietnam, and drought-prone locations, such as larges parts of East and West Africa, Morocco, and parts of South Asia and China. Rainfall and flooding due to climate change are expanding, as has been observed in recent months in southern Africa, East Asia, and the Caribbean.

The CO_2 fertilisation effect[6] may be able to compensate for some crop yield losses,

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55–75

5 World Bank. (2010). World Development Report: Development and Climate Change

6 i.e. increased rate of photosynthesis in plants due to increased carbon dioxide emissions in the provided that sufficient water and soil nutrients are available. However, this is unlikely to be the case in many food insecure regions, which are already facing soil degradation and water scarcity (Lal et.al 2012). There are also indications that the CO_2 fertilisation effect can decrease plant nutrient content[7]. Declining zinc and iron concentrations in crops due to the CO_2 fertilisation effect may cause an additional loss of 126 millions healthy life years (Disability Adjusted Life Years, DALYs) between 2015 and 2050, especially in the least developed countries (LDCs)[8]. About 2 billion people are already affected by nutrient deficiency ("hidden hunger").

Although the agro-climatic potential for agricultural production is increasing in some northern latitude countries, e.g. Russia, the Scandinavian countries, Great Britain, Ireland, and Canada, these same countries should also expect increasing weather fluctuations[9]. This means that even if potential gains in crop production are able to partially offset losses elsewhere, the global food supply will still become more uncertain overall, leading to increased volatility in food prices. Overall, the net impact of climate change on total food production will be negative.

RISKS FOR FOOD SECURITY AND HEALTH

Analyses show that climate change directly reduces food production, but in addition there are indirect economic effects: climate change causes food price fluctuations, which have an indirect negative effect on production, as these price fluctuations signal risk and reduce incentives to invest in agriculture (Haile et.al 2017).

Today, the average cereal yield in Africa, at 1.6 t/ha, is still less than half the global average of 3.9 t/ha[10]. Current maize yields in sub-Saharan Africa are only about 15-27% of their potential[11]. By 2050, climate related yield losses in sub-Saharan Africa are estimated to be around -22% (maize), - 17% (millet and sorghum), and -8% (cassava)[12].

It is clear that agricultural yield increases will be needed worldwide and in in LDCs in particular : in 2050, the world population will increase by around 30%, with most growth projected to occur in countries with low income and higher levels of food insecurity. Growth in arid regions of sub-Saharan Africa, where many LDCs are located, is expected to double in the next 30 years[13]. To assure availability of food for 9 billion

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atmosphere

7Myers, S.S. et al. (2014). Rising CO_2 threatens human nutrition, Nature 510: 139-142

8 Weyant, C. et al. (2018). Anticipated burden and mitigation of carbon-dioxide-induced nutritional deficiencies and related diseases: A simulation modeling study. PLOS Medicine, 15(7), e1002586

9 Hoag, H. (2014). Russian summer tops "universal" heatwave index. Nature News, 29 October; Swinnen, J., Burkitbayeva, S., Schierhorn, F., Prishchepov, A.V., & Müller, D. (2017). Production potential in the "bread baskets" of Eastern Europe and Central Asia. Global Food Security, 14, 38–53

10Tadele, Z. (2017). Raising Crop Productivity in Africa through Intensification. Agronomy, 7(1), 22

11 Van Ittersum, M. K., van Bussel, L. G. J., Wolf, J., Grassini, P., van Wart, J., Guilpart, N., Cassman, K. G. (2016). Can sub-Saharan Africa feed itself ? Proceedings of the National Academy of Sciences of the United States of America, 113(52), 14964–14969

12 Schlenker, W., & Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. Environmental Research Letters, 5(1), 014010

13 Van der Esch, S. et al. (2017). Exploring future changes in land use and land condition and the impacts on food, water, climate change and biodiversity: Scenarios for the UNCCD Global Land Outlook. UNCCD Global Land Outlook people in 2050, total food production will have to increase by about 50% from current levels[14]. Current increases in agricultural productivity are not high enough to meet the additional demand.

Climate change will make sustainable land and water use more difficult. The FAO estimates that climate-induced soil degradation, salinization, and soil nutrient declines could lead to a loss of 250 millions hectares of cultivated land by 2050. Studies by ZEF have found that economic losses due to soil degradation total approximately 300 billion US dollars per year[15]. In addition, food system stability and food safety (fungal infestation) are negatively affected by extreme weather events such as floods and hurricanes, e.g. because transport and storage infrastructures are damaged and the food value chain is interrupted. This will make it more difficult to reduce the already high post- harvest losses of food in developing countries.

The LDCs are projected to suffer the most from food shortages. This is due to the fact that larger percentages of the population in LDCs are both more vulnerable and more exposed to the negative consequences of climate change. Many households spend a significant proportion of their budget on food and depend on agriculture as a source of income[16]. Depending on the future climate change and socio-economic development scenario, the projected number of people at risk of hunger in sub- Saharan Africa and South Asia may increase by 12 and 16 million respectively by 2050[17].

IMPLICATIONS FOR RESEARCH AND POLICY PRIORITIES

Climate policy needs to include technical innovations and institutional innovations. Institutional innovations and their economics did not get sufficient attention. They include climate finance, cooperation for adaptation and mitigation, research, knowledge and training, as well as trade policies. Food and agriculture trade policies need to be revisited and checked if they are climate proof. A rule-based and fair food and agriculture trade policy is an essential policy component of climate risk mitigation. Especially between EU and Africa a future trade arrangement must consider Africa's risks and opportunities more and EU policies must not hamper this with disincentives.

There are several international organizations that play an important role in developing solutions for food security under climate change conditions, including United Nations agencies such as FAO, WFP, IFAD, and UNFCCC. International research, such as the Consultative Group on International Agricultural Research (CGIAR), and increasingly also the African and Asian Academies of Sciences and Humanities play important roles in strategy development and innovation.

In Africa, the Alliance for a Green Revolution in Africa (AGRA) has assumed a significant

14 FAO. (2018). *The future of food and agriculture – Alternative pathways to 2050.* Rome

15 Nkonya, E., A. Mirzabaev, J. von Braun (ed.) 2016. *Economics of land degradation and sustainable land management.* Springer Publ.

16 Olsson, L. et al. (2014). *Livelihoods and poverty. In T. E. B. Field et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press

17 Hasegawa, T. et al. (2018). *Risk of increased food insecurity under stringent global climate change mitigation policy. Nature Climate Change, 8(8), 699–703.*

role in food security. The private sectors in Africa and Asia (including social enterprises and digital services) are playing growing roles as well, along with foreign direct investment in the agricultural and food sectors[18]. Initiatives supported by Germany, such as the West African Science Service Center on Climate Change and Adapted Land Use (WASCAL), contribute significantly to local capacity development. NGOs, such as Germany's WHH, also make an important contribution to food security by combining emergency aid for climate-related crises with support for long-term sustainable development.

German Development Cooperation is currently playing an important and leading role worldwide in promoting agricultural development and food security. Measures to minimise the negative impacts of climate change are an integral part of food security policy with partner countries. For example, as part of the special initiative A World Without Hunger, the BMZ is substantially investing in combating hunger and promoting rural development, including through more than 30 bilateral, regional, and global projects that address climate change issues. The programme includes the establishment of "green innovation centres" to improve the local availability of food. These promising initiatives should be expanded and consolidated, always with the clear objective of contributing to the achievement of the SDGs.

Yet additional public and private investment in the world's food system is still needed to increase yields, improve the efficiency of the system, and expand the supply of healthy food. Globally, higher priority must be given to agricultural, food system, climate, and ecological research (Fears et.al 2019). The entire agricultural and food system must become climate-smart; individual measures are not sufficient. In LDCs, adaptation of cultivation methods, promotion of renewable energy, mechanisation, and support for small-scale farms and indigenous knowledge may be part of the solution. In both MDCs and LDCs, increased adoption of plant-based diets and reduction of food waste is also important.

Improved cultivation methods are an important part of climate adaptation. Sustainable Land Management (internationally known as SLM) practices are necessary to prevent and reverse land degradation[19]. SLM measures also contribute to climate protection and the preservation of biodiversity[20]. These measures include conservation agriculture and the sustainable intensification of agricultural production (e.g. the expansion of efficient irrigation systems using solar energy)[21]. Other measures, such as breeding

18 Husmann, C. and Kubik, Z. (2019) Foreign direct investment in the African food and agriculture sector: trends, determinants and impacts, ZEF-Discussion Papers on Development Policy No. 274, Universität Bonn

19 Nkonya, E., Anderson, W., Kato, E., Koo, J., Mirzabaev, A., von Braun, J., & Meyer, S. (2016). Global Cost of Land Degradation. In Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development (pp. 117–165). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319- 19168-3_6

20 Sanz, M. J., Vente, J. de, Chotte, J.-L., Bernoux, M., Kust, G., Ruiz, I., ... Akhtar-Schuster, M. (2017). Sustainable Land Management contribution to successful land-based climate change adaptation and mitigation. A Report of the Science-Policy Interface. Bonn, Germany

21 Xie, H. et al. (2018) Can Sub-Saharan Africa feed itself? The role of irrigation development in the region's drylands for food security, Water International, 43(6), 796-814; PARI Policy Brief No 12 (Small-Scale Irrigation Potential In Sub-Saharan Africa) of climate-adapted plants, climate-friendly animal husbandry, precision farming, and sustainable nitrogen and phosphate fertilization will become increasingly necessary in developing countries as well.

In addition, production progress can be expected in larges parts of Africa and Asia as a result of agricultural mechanisation[22]. However, the availability of energy sources in remote regions must be taken into account. Therefore, the promotion of new and renewable energy in rural areas, expansion of infrastructure, and increased investment in agricultural research and innovation (both in plant and animal production) must accompany and support agricultural development[23].

Another vital area will be support of smallholder agricultural operations, which are and will remain the defining feature of African and Asian agriculture. Small farms can be an efficient and effective part of the food system, though they should not be idealised. Moving forward, resilience of small farming operations must be strengthened through cooperation and services (e.g. mechnisation, digital access to markets, and extension). Overall, there is a need for food and agricultural processing and small-scale agriculture to develop symbiotic relationships (e.g. knowledge flow, inputs, etc.), with secure and transparent land ownership plans put in place to protect small farmers.

Indigenous and local knowledge presents further opportunities to increase food security. For example, successful cases of land restoration and rehabilitation in West Africa have been facilitated by the use of indigenous and local knowledge (e.g. use of plant pits in the Sahel). ZEF's research work has identified many such agricultural practices[24].

In MDCs, the transition to a more plant-based diet (in line with healthy eating guidelines) could reduce global mortality by 6-10% and greenhouse gas emissions from food by 70% compared to the baseline scenario in 2050[25]. This change also has the potential to halve water consumption in agriculture[26].

Globally, about one third of the food produced is wasted or lost after harvesting. Food waste in LDCs is mainly generated in the production and early post-harvest phases, while in MDCs it is often generated by processors, supermarkets, and consumers. The fast urbanization in developing countries is changing that pattern and food waste is increasing in LDCs and MDCs too. Reducing such waste would proportionally reduce greenhouse gas emissions from food systems during production, storage, and transport.

There are a variety of price and other incentive instruments that can encourage adoption of plant- based diets and reduce food waste. These include taxes, regulations, and so-called "nudges", such as the provision of information on sustainable consumption and

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22 Malabo Montpellier Panel (2018). "Mechanized: Transforming Africa's Agriculture Value Chains"; ZEF-PARI Policy Briefs No. 5 (Smallholder agricultural mechanization in Africa)

23 Bioökonomierat. (2018). Genome editing: Europe needs new genetic engineering legislation. BÖRMEMO 07. Berli

24 Tambo, J. (2018) Recognizing and rewarding farmers' creativity through contests: experiences and insights from four African countries, ZEF Working Paper No. 166

25 Springmann, M. et al. (2016). Analysis and valuation of the health and climate change cobenefits of dietary change. Proceedings of the National Academy of Sciences, 113(15), 4146–4151

26 Aleksandrowicz, L. et al. (2016). The Impacts of Dietary Change on Greenhouse Gas Emissions, Land Use, Water Use, and Health: A Systematic Review. PLOS ONE, 11(11), e0165797

education campaigns aimed at inducing a conscious change in consumer behaviour. Sustainable consumption and the opportunities and limits of its positive external effects must become a research priority in industrialised countries.

CONCLUSION

Climate policy must include adaptation to and prevention of climate change. Above all, climate crisis demands innovation-political, institutional, and technological. Sound climate policy cannot be isolated, but must be part of overarching regulatory policy developed on the basis of the social market economy and following the ethical principles of fairness, justice, and sustainability.

Food security and climate protection measures should be pursued in parallel. Due to the dynamics of the climate system, some impacts of climate change on food systems are irreversible. Measures are therefore needed to adapt food systems to these changes. At the same time, action is needed to mitigate climate change, as higher levels of warming are associated with higher risks to food systems and food security[27]. Insurance schemes to cover drought, floods, and livestock losses should be extended.

With the global food supply seriously threatened by climate change, it is not possible to achieve sustainable development goals (SDGs) 1 and 2 (to overcome extreme poverty and hunger by 2030). To achieve SDGs 1 and 2, it is necessary to rapidly improve the productivity and resilience of the global food system.[28] A key first step is moving past the idea that climate-induced hunger is an isolated field in development cooperation.

Summary of Recommendations :

- The world food supply is threatened by climate change. Combatting this challenge requires globally effective measures. All nations should act. Europe and Germany can and should play an important role too.
- Agriculture in developing countries must be stabilised and put on a sustainable growth path. The future of over 3 billion people in rural areas of developing countries directly depends on it.
- SDG 2, to end hunger by 2030, is possible, but not under current levels of resources and policy measures. Considerably more effort, resources, and investment is needed. Innovation will be a central part of this effort.
- Development partners' investments, such as Germany's One World No Hunger initiative, should be perpetuated over the decade. Moreover, these investments should be complemented by attention to nutrition for children and vulnerable

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27 Adger, W. N. et al. (2014). Human security. In C. B. Field et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A(pp. 755–791). New York: Cambridge University Press.; Hoegh-Guldberg, O. et al. (2018). Chapter 3: Impacts of 1.5oC global warming on natural and human systems. In GLOBAL WARMING OF 1.5 °C. IPCC

28 InterAcademy Partnership, 2018. Opportunities for future research and innovation on food and nutrition security and agriculture. The InterAcademy Partnership's global perspective. Synthesis by IAP based on the four regional academy network studies. Trieste and Washington DC persons, i.e. they should go beyond production and processing.

- To improve agricultural productivity, greater emphasis should be placed on measures such as the expansion of sustainable irrigation (drip irrigation), mechanisation, investment in improved crop varieties, and sustainable land management, all adapted to the diverse agro-ecologies. Animal breeding and husbandry also require special attention, as the demand for animal products is growing rapidly in developing countries.
- A rule-based and fair food and agriculture trade policy is an essential policy component of climate risk mitigation. Especially between EU and Africa a future trade arrangement must consider Africa's risks and opportunities more and EU policies must not hamper this with disincentives.
- Coherent pricing of CO_2 is part of a sustainable portfolio in climate policy. Sustainable consumption in Germany and other MDCs, too, is necessary in the long term in order to achieve climate targets. Incentives for sustainable nutrition and reduction of food waste must be created.
- In moving away from a carbon-based economy and developing a sustainable bio-economy, research into alternative production materials is essential. Support must be expanded for the use of biological resources, products, processes, and services. Partners in developing countries are increasingly interested in this and could benefit from Germany's pioneering role in this area.

REFERENCES

Adger, W. N., Pulhin, J. M., Barnett, J., Dabelko, G. D., Hovelsrud, G. K., Levy, M., ... Vogel, C. H. (2014). Human security. In C. B. Field, V. R. Barros, D. J. Dokken, T. E. B. K.J. Mach, M.D. Mastrandrea, S. M. M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, & and L. L. W. P.R. Mastrandrea (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 755–791). Cambridge [England]; New York: Cambridge University Press.

Ahlheim, M., Börger, T., & Frör, O. (2012). The ecological price of getting rich in a green desert: A contingent valuation study in rural Southwest China. Retrieved from https://www.econstor.eu/handle/10419/60500

Aleksandrowicz, L., Green, R., Joy, E. J. M., Smith, P., & Haines, A. (2016). The Impacts of Dietary Change on Greenhouse Gas Emissions, Land Use, Water Use, and Health: A Systematic Review. PLOS ONE, 11(11), e0165797. https://doi.org/10.1371/journal.pone.0165797

Bioökonomierat. (2018). Genome editing: Europe needs new genetic engineering legislation. BÖRMEMO 07. Berlin.

Bremer, L. L., & Farley, K. A. (2010). Does plantation forestry restore biodiversity or create green deserts? A synthesis of the effects of land-use transitions on plant species richness. Biodiversity and Conservation, 19(14), 3893–3915. https://doi.org/10.1007/s10531-010-9936-4

Cheung, W. W. L., Jones, M. C., Reygondeau, G., & Frölicher, T. L. (2018). Opportunities for climate- risk reduction through effective fisheries management. Global Change Biology, 24(11), 5149–5163. https://doi.org/10.1111/gcb.14390

Doss, C., Meinzen-Dick, R., Quisumbing, A., & Theis, S. (2018). Women in agriculture: Four myths. Global Food Security, 16, 69–74. https://doi.org/10.1016/J.GFS.2017.10.001

Euler, M., Krishna, V., Schwarze, S., Siregar, H., & Qaim, M. (2017). Oil Palm Adoption, Household Welfare, and Nutrition Among Smallholder Farmers in Indonesia. World Development, 93, 219–235. https://doi.org/10.1016/J.WORLDDEV.2016.12.019

FAO. (2018). The future of food and agriculture – Alternative pathways to 2050. Rome. Licence: CC BY-NC-SA 3.0 IGO. Retrieved from http://www.fao.org/3/I8429EN/i8429en.pdf

FAO, IFAD, UNICEF, WFP, & WHO. (2018). The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition. Rome, Italy. Retrieved from http://www.fao.org/3/I9553EN/i9553en.pdf

Robin Fears, Volker ter Meulen and Joachim von Braun (Dec 2019). Global food and nutrition security needs more and new science. Editorial SCIENCE POLICY. In: Science Advances 13 Dec 2019: Vol. 5, no. 12, eaba2946 DOI: 10.1126/sciadv.aba2946

Food Security Information Network (2018). GLOBAL REPORT ON FOOD CRISES 2018. Rome, Italy. Global Green Growth Institute (2019). https://gggi.org/

Haile, M. G., Wossen, T., Tesfaye, K., & von Braun, J. (2017). Impact of Climate Change, Weather Extremes, and Price Risk on Global Food Supply. Economics of Disasters and Climate Change, 1(1), 55–75. https://doi.org/10.1007/s41885-017-0005-2

Harrington, L.J. & Otto, F.E.L. Attributable damage liability in a non-linear climate. Climatic Change 153(1-2): 15.20. https://doi.org/10.1007/s10584-019-02379-9

Hasegawa, T., Fujimori, S., Havlík, P., Valin, H., Bodirsky, B. L., Doelman, J. C., … Witzke, P. (2018). Risk of increased food insecurity under stringent global climate change mitigation policy. Nature Climate Change, 8(8), 699–703. https://doi.org/10.1038/s41558-018-0230-x

Hillebrand, H., Brey, T., Gutt, J., Hagen, W., Metfies, K., Meyer, B., & Lewandowska, A. (2018). Climate Change: Warming Impacts on Marine Biodiversity. In Handbook on Marine Environment Protection (pp. 353–373). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-60156- 4_18

Hoag, H. (2014). Russian summer tops "universal" heatwave index. Nature News, 29 October. https://doi.org/10.1038/nature.2014.16250

Hoegh-Guldberg, O., Jacob, D., Taylor, M., Bindi, M., Brown, S., Camilloni, I., … IPCC. (2018). Chapter 3: Impacts of 1.5oC global warming on natural and human systems. In GLOBAL WARMING OF 1.5 °C. IPCC. Retrieved from http://report.ipcc.ch/sr15/pdf/sr15_chapter3.pdf

Husmann, C. and Kubik, Z. (2019) Foreign direct investment in the African food and agriculture sector: trends, determinants and impacts, ZEF-Discussion Papers on

Development Policy No. 274, Universität Bonn, https://research4agrinnovation.org/publication/zef-dp-274/.

Iizumi, T., & Ramankutty, N. (2016). Changes in yield variability of major crops for 1981–2010 explained by climate change. Environmental Research Letters, 11(3), 034003. https://doi.org/10.1088/1748-9326/11/3/034003

InterAcademy Partnership, 2018. Opportunities for future research and innovation on food and nutrition security and agriculture. The InterAcademy Partnership's global perspective Synthesis by IAP based on the four regional academy network studies. Trieste and Washington DC.

Rattan Lal, K. Lorenz, R. F. Hüttl, B. U. Schneider, and J. von Braun Ed. (2012). Recarbonization of the Biosphere. Ecosystems and the Global Carbon Cycle. Dordrecht Heidelberg New York London: Springer http://dx.doi.org/10.1007/978-94-007-4159-1

Malabo Montpellier Panel (2018). "Mechanized: Transforming Africa's Agriculture Value Chains".

Mbow, C., Smith, P., Skole, D., Duguma, L., & Bustamante, M. (2014). Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. Current Opinion in Environmental Sustainability, 6, 8–14. https://doi.org/10.1016/J.COSUST.2013.09.002

Moore, F. C., & Lobell, D. B. (2015). The fingerprint of climate trends on European crop yields. Proceedings of the National Academy of Sciences of the United States of America, 112(9), 2670– 2675. https://doi.org/10.1073/pnas.1409606112

Myers, S.S., A. Zanobetti, I.Kloog,P. Huybers, A. D. B. Leakey, A. J. Bloom, E. Carlisle, L. H. Dietterich, G. Fitzgerald, T. Hasegawa, N. M. Holbrook, R. L. Nelson, M. J. Ottman, V. Raboy, H. Sakai, K. A. Sartor, J. Schwartz, S. Seneweera, M. Tausz,Y. Usui (2014). Rising CO_2 threatens human nutrition, Nature 510: 139-142, https://www.nature.com/articles/nature13179.pdf

Ngigi, M., Mueller, U., & Birner, R. (2016). Gender Differences in Climate Change Perceptions and Adaptation Strategies: An Intra-Household Analysis from Rural Kenya. ZEF-Discussion Papers on Development Policy (Vol. 210). https://doi.org/10.2139/ssrn.2747856

Nkonya, E., Anderson, W., Kato, E., Koo, J., Mirzabaev, A., von Braun, J., & Meyer, S. (2016). Global Cost of Land Degradation. In Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development (pp. 117–165). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-19168-3_6

Olsson, L., Opondo, M., Tschakert, P., Agrawal, A., Eriksen, S. H., Ma, S., … Zakieldeen, S. A. (2014). Livelihoods and poverty. In T. E. B. Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, S. M. M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, & and L. L. W. P.R. Mastrandrea (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University

Press.

Pontifical Academy of Sciences (2019). Conference on Food Loss and Waste Reduction, Casina Pio IV, Vatican, November 11-12, 2019 http://www.pas.va/content/accademia/en/events/2019/food_waste.html

Pörtner, H. O., & Knust, R. (2007). Climate change affects marine fishes through the oxygen limitation of thermal tolerance. Science (New York, N.Y.), 315(5808), 95–97. https://doi.org/10.1126/science.1135471

Rakib, M., & Matz, J. A. (2016). The Impact of Shocks on Gender-differentiated Asset Dynamics in Bangladesh. The Journal of Development Studies, 52(3), 377–395. https://doi.org/10.1080/00220388.2015.1093117

Ramanathan, V., Sorondo, M. S., Dasgupta, P., von Braun, J., & Victor, D. G. (2018). Climate Extremes and Global Health. Foreign Affairs, Julyl 31.

Sanz, M. J., Vente, J. de, Chotte, J.-L., Bernoux, M., Kust, G., Ruiz, I., ... Akhtar-Schuster, M. (2017). Sustainable Land Management contribution to successful land-based climate change adaptation and mitigation. A Report of the Science-Policy Interface. Bonn, Germany.

Schlenker, W., & Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. Environmental Research Letters, 5(1), 014010. https://doi.org/10.1088/1748- 9326/5/1/014010

Springmann, M., Godfray, H. C. J., Rayner, M., & Scarborough, P. (2016). Analysis and valuation of the health and climate change cobenefits of dietary change. Proceedings of the National Academy of Sciences, 113(15), 4146–4151. https://doi.org/10.1073/PNAS.1523119113

Swinnen, J., Burkitbayeva, S., Schierhorn, F., Prishchepov, A. V., & Müller, D. (2017). Production potential in the "bread baskets" of Eastern Europe and Central Asia. Global Food Security, 14, 38–53. https://doi.org/10.1016/J.GFS.2017.03.005

Tadele, Z. (2017). Raising Crop Productivity in Africa through Intensification. Agronomy, 7(1), 22. https://doi.org/10.3390/agronomy7010022

Tambo, J. A., & Wünscher, T. (2015). Identification and prioritization of farmers' innovations in northern Ghana. Renewable Agriculture and Food Systems, 30(06), 537–549. https://doi.org/10.1017/S1742170514000374

van der Esch S, B, ten B., E, S., M, B., A, S., A, B., ... van den Berg, M. (2017). Exploring future changes in land use and land condition and the impacts on food, water, climate change and biodiversity: Scenarios for the UNCCD Global Land Outlook. UNCCD Global Land Outlook.

van Ittersum, M. K., van Bussel, L. G. J., Wolf, J., Grassini, P., van Wart, J., Guilpart, N., ... Cassman, K. G. (2016). Can sub-Saharan Africa feed itself? Proceedings of the National Academy of Sciences of the United States of America, 113(52), 14964–14969. https://doi.org/10.1073/pnas.1610359113

Vijay, V., Pimm, S. L., Jenkins, C. N., & Smith, S. J. (2016). The Impacts of Oil Palm on Recent Deforestation and Biodiversity Loss. PLOS ONE, 11(7), e0159668. https://doi.org/10.1371/journal.pone.0159668

Watts, N., Adger, W. N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., ... Costello, A. (2015). Health and climate change: policy responses to protect public health. The Lancet, 386(10006), 1861–1914. https://doi.org/10.1016/S0140-6736(15)60854-6

Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Belesova, K., Berry, H., ... Costello, A. (2018). The 2018 report of the Lancet Countdown on health and climate change: shaping the health of nations for centuries to come. The Lancet, 392(10163), 2479–2514. https://doi.org/10.1016/S0140- 6736(18)32594-7

Wambui, G. et al. (2018) Women in African Agriculture: Integrating Women into Value Chains to Build a Stronger Sector, ZEF Working Paper 175, Universität Bonn, https://research4agrinnovation.org/publication/wp-175/.

Weyant, C., Brandeau, M. L., Burke, M., Lobell, D. B., Bendavid, E., & Basu, S. (2018). Anticipated burden and mitigation of carbon-dioxide-induced nutritional deficiencies and related diseases: A simulation modeling study. PLOS Medicine, 15(7), e1002586. https://doi.org/10.1371/journal.pmed.1002586

Xie, Hua, Perez, Nicostrato, Anderson, Weston, Ringler, Claudia & You, Liangzhi (2018) Can Sub- Saharan Africa feed itself? The role of irrigation development in the region's drylands for food security, Water International, 43:6, 796-814, DOI: 10.1080/02508060.2018.1516080; ; PARI Policy Brief No 12: Small-Scale Irrigation Potential In Sub-Saharan Africa.

Changement Climatique et sécurité alimentaire en Afrique de l'Ouest Quelle adaptation et quel investissement productif durables ?

Aminata Ndiaye

ABSTRACT

Climate change poses a serious threat to the economic growth and sustainable development of West African countries. This area, the northern part of which is mainly made up of semi-arid agricultural land, has experienced extreme rainfall variability in recent decades. This has resulted in a decrease in available water reserves, arable land, changes in the length of the vegetative growth period, and an increase in arid and semi-arid marginal lands for rainfed agriculture and grazing. Thus, despite significant progress in terms of management and prevention but also numerous initiatives in terms of political, institutional and scientific governance to provide responses to the challenges, these countries are going through food crises of various origins. Crises that have a dual origin, both cyclical and structural involving other factors of food security, accessibility, use of food resources, more precisely. Hence the need for a greater commitment of countries in the search for lasting solutions to all the causes of food insecurity; common commitments which imply getting rid of all barriers, not just political, but all the others for concerted effectiveness. All these issues are analyzed in this article, which aims to help increase knowledge about food security in West Africa.

Keywords : Climate change, food crisis, sustainable development, West Africa

RÉSUMÉ

Le changement climatique constitue une menace sérieuse pour la croissance économique et le développement durable des pays d'Afrique de l'Ouest. Cet espace dont la partie Nord est majoritairement constituée de terres agricoles semi arides a connu ces dernières décennies une extrême variabilité des pluies. Il s'en est suivi une diminution des réserves en eau disponibles, des terres cultivables, des modifications de la durée de la période de croissance végétative et une augmentation des terres arides et semi arides marginales pour l'agriculture pluviale et les pâturages. Ainsi, malgré d'importants progrès en matière de gestion et de prévention mais aussi de nombreuses initiatives en matière de gouvernance politique, institutionnelle et scientifique pour apporter des réponses aux défis, ces pays traversent des crises alimentaires aux origines diverses. Crises qui ont une origine double, à la fois conjoncturelle et structurelle impliquant les autres facteurs de la sécurité alimentaire, l'accessibilité, l'utilisation des ressources alimentaires, plus précisément. D'où la nécessité d'un plus grand engagement des pays dans la recherche de solutions durables à toutes les causes de l'insécurité alimentaire ; engagements communs qui supposent de se départir de tous les cloisons, pas seulement politiques, mais de tous les autres pour une efficacité concertée. Toutes ces problématiques sont analysées dans cet article qui se propose de contribuer à accroitre les connaissances sur la sécurité alimentaire en Afrique de l'Ouest.

Mots-clés: Changement Climatique, crises alimentaires, développement durable, Afrique de l'Ouest

INTRODUCTION

Cet article se propose de soumettre à réflexion les difficultés de l'Afrique de l'Ouest à conforter une gestion et une mise en valeur de ses ressources naturelles pour une sécurité alimentaire durable malgré l'immense potentiel dont elle regorge. Cette situation de précarité est observée sous l'optique du changement climatique qui, en même temps qu'il exerce un effet catalyseur, fait de cette partie du continent africain celle qui est la plus vulnérable aux effets induits d'un phénomène dont elle est loin d'être la cause. La revue de quelques initiatives réussies à des échelles spatiales différentes pourrait éclairer sur l'efficacité d'affectation des utilisations vers laquelle les décideurs devraient s'acheminer. Ce sont là, autant de problématiques, que tentera de soulever cette réflexion, tout en sachant que la vraie question, tient aux ruptures d'équilibre entre population et ressources naturelles dont l'eau, les sols et la végétation, fondamentaux pour une sécurité alimentaire durable ; ruptures dans un contexte d'enjeux écologiques planétaires, de croissance démographique brutale, d'urbanisation accélérée, de raréfaction de la ressource, et de demande accrue à laquelle les autorités sont appelées à apporter des réponses dans l'urgence.

QUELQUES ÉLÉMENTS DE CONTEXTE : NATURE ET MANIFESTATIONS DU CHANGEMENT CLIMATIQUE

Traiter des questions relatives aux ressources clés pour une sécurité alimentaire durable en Afrique de l'Ouest dans un contexte de changement climatique relève du pari impossible, le changement climatique n'échappant pas aux problématiques sociétales. Ses implications politiques, industrielles et donc économiques remettent en cause des mécanismes inhérents aux civilisations, d'où la difficulté de dépassionner la poblématique.

En Afrique de l'Ouest, la baisse tendancielle de la pluviométrie, observée, dans les années 1970, s'est manifestée par des extrêmes climatiques aux conséquences désastreuses sur les ressources naturelles, agricoles et pastorales. Actuellement, en dépit du retour notable d'hivernages pluvieux ces dernières années, les totaux pluviométriques annuels, restent toujours en deçà de ceux enregistrés dans les années 1960 et une mauvaise distribution spatio-temporelle des pluies, caractérisée par de longues pauses au cœur de la saison, continue d'entraver l'agriculture, essentiellement pluviale, et la sécurité alimentaire. Ainsi, cette variabilité du système climatique a fini par fragiliser davantage les écosystèmes de cette région éco-géographique, notamment dans sa partie sahélienne, présentement classée dans la catégorie des zones socialement vulnérables au changement climatique.

Dès lors, il est aisé de comprendre que, dans cette région où la productivité des terres arables reste encore très faible (seulement 59, 85 millions d'ha sur 607,84 millions d'ha de terres émergées) et où plus de la moitié de la population (60 %), a l'agriculture pluviale comme principale source de revenus, la variabilité pluviométrique soit accentuée par les contraintes environnementales telles que le déboisement, la déforestation, entre autres pressions sur le milieu. Les impacts de ces facteurs et processus aux causes multiples se font sentir, pratiquement, sur tous les aspects de la vie socio-économique, des rendements céréaliers à la santé humaine et animale, en passant par l'accessibilité et la disponibilité des ressources naturelles, les quatre dimensions qui fondent la sécurité alimentaire étant profondément affectées.

PERTURBATION DU CYCLE PLUVIOMÉTRIQUE : UN FACTEUR AGGRAVANT LA SITUATION DE PRÉCARITÉ

Malgré le « retour » des pluies, noté ces dernières années, les totaux enregistrés restent encore très en deçà de ceux de l'optimum des années 1960. Les conséquences ont conduit à des situations contraignantes, car certains éléments-clé régissant le fonctionnement des milieux se trouvent modifiés. On peut en indiquer quelques aspects à l'échelle régionale : baisse des disponibilités en eau fournie par les pluies ; rétrécissement de la saison des pluies utiles ; réduction du nombre de jours de pluie ; perturbations dans le déroulement de la saison (fig. 1).

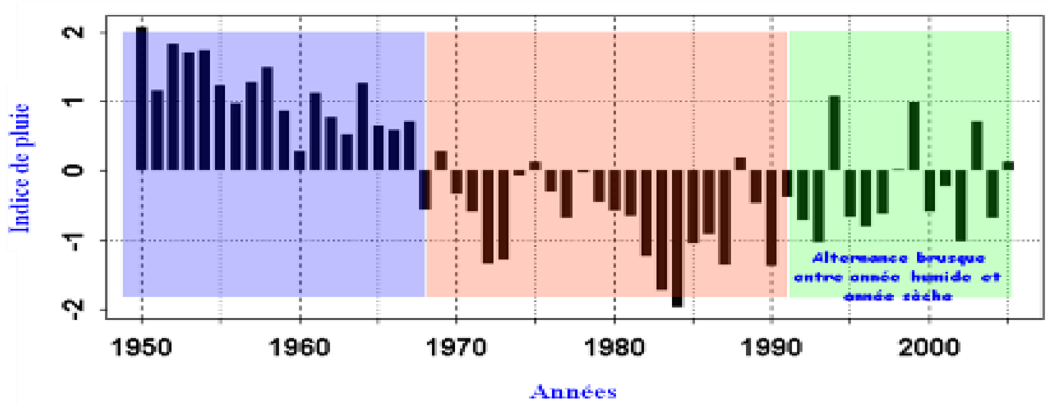


Figure 1 : Perturbations dans le déroulement de la saison pluvieuse à l'échelle régionale

A l'échelle locale, il est partout constaté un démarrage tardif ou un arrêt précoce de la saison des pluies (fig. 2), des périodes de rémission pluviométrique plus ou moins longues à l'intérieur de la saison, une récurrence des phénomènes extrêmes qui alternent sécheresses intenses et fortes pluies s'accompagnant d'inondations dans les zones basses exploitées en campagne et les bas-fonds anthropisés en milieu urbain. D'autres éléments du climat tels que le vent et les températures sont également affectés, car il est noté partout une intensification des phénomènes thermiques, les minimas principalement et une plus grande célérité du vent.

Concernant l'hydrologie continentale, il a été constaté que, depuis les années 70, les écoulements ont diminué d'environ 30 à 60% selon les bassins versants. Cette baisse observée jusque dans des latitudes habituellement pluvieuses, se traduit sur le module annuel et les extrêmes des débits (crue et étiage) avec des conséquences sur l'eau de consommation, ce qui à terme, expose les populations à des situations de vulnérabilité.

Comme l'eau disponible dépend, en grande partie des pluies, les variations et baisses continues de celles-ci impactent considérablement la recharge et la régulation des cours d'eau. L'effet direct est l'intrusion de la langue salée avec comme conséquence la salinisation des terres, des eaux de surface et des nappes souterraines, ce qui ne va pas sans compromettre les fondements de la sécurité alimentaire (eau et alimentation).

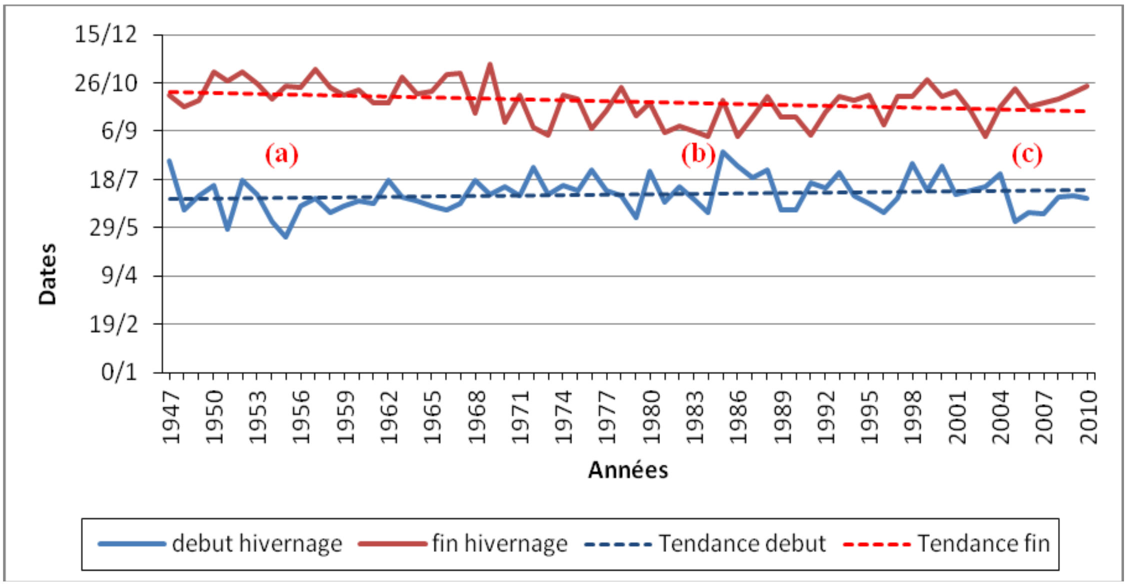


Figure 2 : perturbation du cycle pluviométrique à l'échelle locale (exemple du Sénégal)

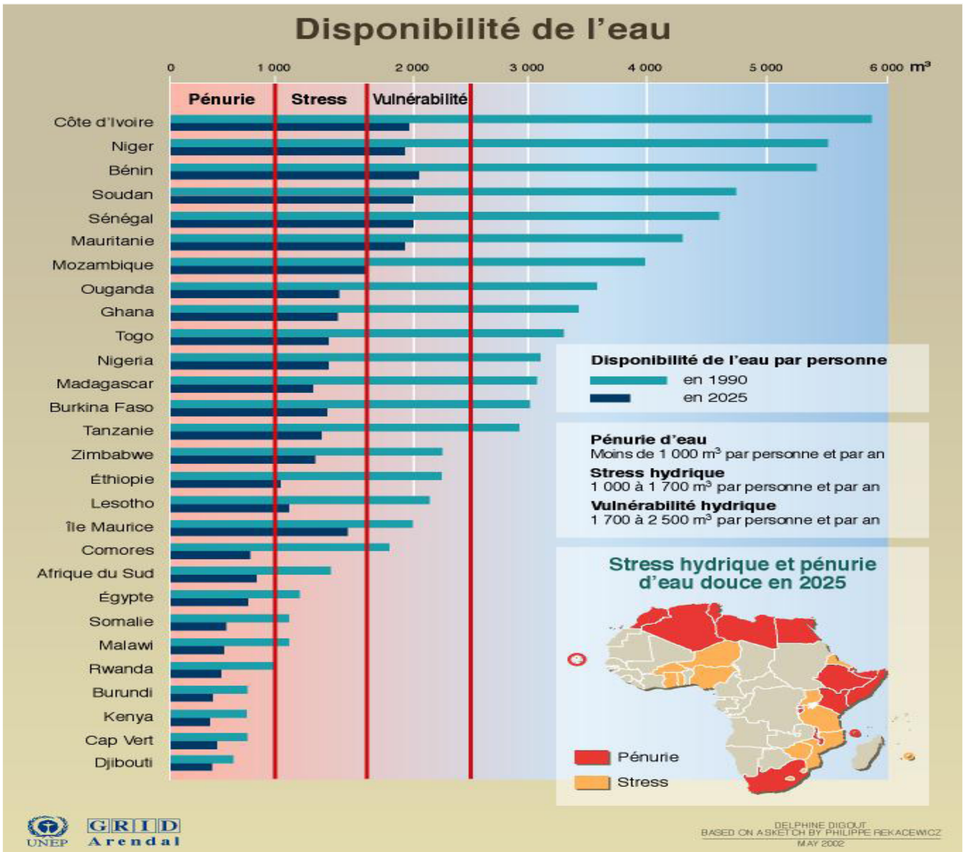
IMPACT SUR LA RESSOURCE FONDAMENTALE : L'ÉQUATION DE L'EAU

Dans un cadre plus global et depuis toujours, l'eau est essentielle à la survie des êtres humains. Les questions qu'elle englobe, en impliquant les multiples aspects de la vie, la placent au cœur du développement, faisant d'elle un enjeu fondamental. Cela se remarque encore plus en Afrique de l'Ouest, où le changement climatique se manifeste par une forte perturbation du cycle atmosphérique de l'eau, celle-ci étant l'élément fondamental pour l'agriculture et l'élevage dont dépendent la majorité des populations.

En Afrique de l'Ouest, eu égard à la pluralité des environnements que la région englobe, les ressources clés pour une sécurité alimentaire durable sont à la fois complexes, multidimensionnelles et constamment exposées aux variabilités spatio-temporelles du climat, de sa composante eau en particulier.

La composante hydrique du climat, les hydrométéores particulièrement, conditionnent le fonctionnement de tous les écosystèmes terrestres ou aquatiques de la région car tous les aspects de la vie socio-économique, en dépendent fortement.

En plus d'être source de déséquilibres aux effets induits (insécurité alimentaire, insalubrité, maladies liées à l'eau, etc.) et en raison des causes anthropiques (pollution industrielle : exploitation minière, off-shore, etc.), l'eau potable, élément fondamental de la sécurité alimentaire, commence à devenir de plus en plus rare en Afrique de l'Ouest aussi, à l'instar de partout ailleurs dans le monde. Indubitablement, la région enregistre un des taux d'accès à l'eau potable les plus faibles du monde, car le tiers de sa population n'a pas accès à un point d'eau aménagé, à l'exemple de plusieurs pays où la corvée d'eau continue à constituer un lourd fardeau, jusqu'à plusieurs kilomètres de marche quotidienne pour les femmes et les enfants, eu égard à la répartition des tâches au sein de l'économie domestique. Pourtant, cours d'eaux superficielles et nappes d'eaux souterraines ne manquent pas dans cette partie de l'Afrique, contrairement à la place qui lui est allouée par les images globalisantes sur les représentations de l'Afrique « continent de la soif ». Seulement, une distribution géographique particulièrement inégale de la ressource, accompagnée d'une gestion pas trop reluisante de cette situation de fait, exprimée par les nombreuses lacunes et insuffisances dans la gouvernance de l'eau, exposent les populations aux risques inhérents et les pays à une vulnérabilité caractéristique dans les projections à terme, après des phases de pénuries et de stress hydriques notoires (carte 1).



Source : Commission économique des Nations unies pour l'Afrique (UNECA), Addis Abeba, Avenir de l'environnement mondial 2000 (AEM), PNUE, Earthscan, Londres, 1999.

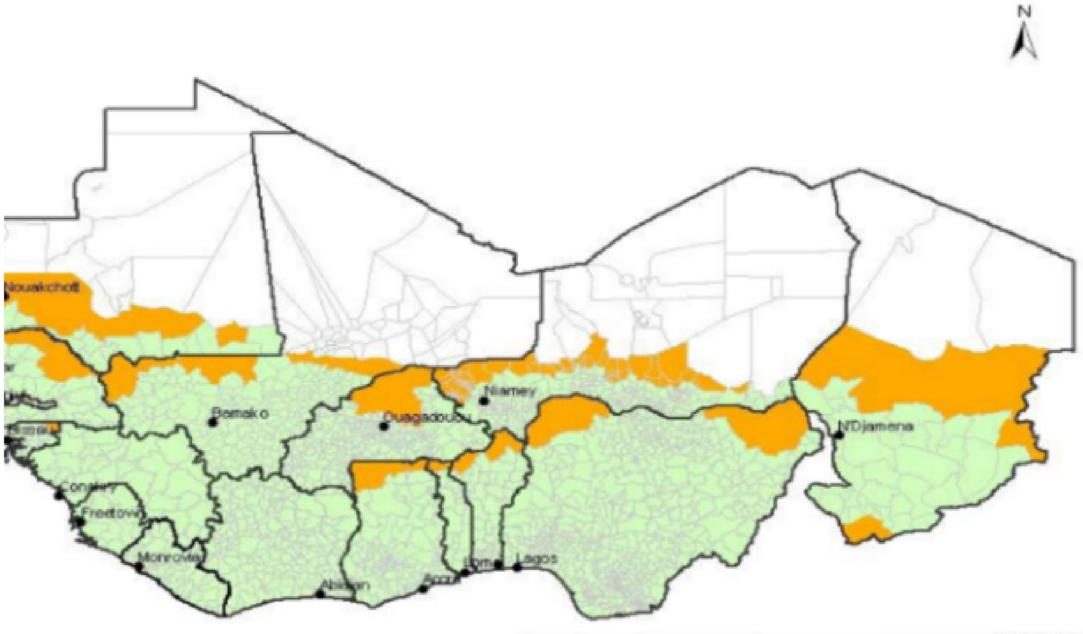
Carte 1 : vulnérabilité, pénurie et stress hydrique en Afrique en 2025

L'autre incohérence en rapport avec la ressource eau est le fait que beaucoup de cours traversent ou marquent la plupart des frontières des Etats. Le parcours latitudinal des grands systèmes hydrologiques fait que les ressources en eau sont souvent transfrontalières, suscitant ainsi d'énormes difficultés de gestion. Les ressources partagées représentent 80% des eaux de surface et sont à l'origine d'une interdépendance régionale très soutenue. A titre d'exemple, le Niger et la Mauritanie dépendent de 75% à 98%, de cours venant d'autres pays (FIDA, 2001). Dès lors, un problème d'utilisation efficiente de la ressource se pose entraînant souvent des conflits localisés entre acteurs concernés.

En plus de l'inégalité des pays face à la distribution de l'eau potable, il est noté une disponibilité très partiale selon que le milieu soit rural ou urbain, les citadins étant privilégiés dans ce sens, même si par ailleurs, ce léger avantage est compromis par l'insuffisante maîtrise de l'espace urbain et ses corollaires.

IMPACT ET EFFETS INDUITS SUR L'AGRICULTURE ET LA SÉCURITÉ ALIMENTAIRE

Sachant que l'agriculture pratiquée est généralement sous pluie, un hypothétique hivernage occasionne des pertes de semis. Il en résulte une production agricole réduite, souvent à l'origine de disettes. Une telle situation est mise en évidence sur la carte 2 où, exceptée la Côte d'Ivoire (politique d'incitation à la consommation locale réussie), tous les pays de l'UEMOA enregistrent des poches d'insécurité alimentaire récurrente.



Carte 2 : Risques agro-climatiques et insécurité alimentaire dans les pays de l'UEMOA

Dans ce contexte de baisse des rendements agricoles, de difficulté de commercialisation de la production et de paupérisation (Ndiaye et Sané, 2010), l'abandon généralisé des cultures de rente pour l'agriculture d'autoconsommation devient une panacée pour les paysans qui, désormais, se préoccupent plus d'assurer leur sécurité alimentaire en se consacrant davantage à la culture céréalière, à la diversification agricole (introduction de nouvelles cultures ,cultures de contre-saison, maraîchage) et à l'élevage de volaille et de petits ruminants, plus résistants au manque d'eau.

Dans le même temps ils abandonnent la jachère et versent dans une dynamique migratoire vers les villes ou autres localités plus propices (Yanon 2010). Jadis temporaire, la migration va désormais apparaître comme solution majeure à la situation de paupérisation du monde rural. Il s'en suit l'installation d'une érosion notoire de l'autorité parentale, remettant en question toute la dynamique organisationnelle qui s'effectuait autour de « projets migratoires » et qui mobilisaient les dignitaires de toutes les structures familiales concernées, pour la sélection du ou des membres potentiels au départ (Yanon 2010).

IMPACTS SUR LES RESSOURCES VÉGÉTALES

D'une manière générale, les espaces forestiers sont de plus en plus envahis par les populations paysannes créant une pression accrue sur les sols et les ressources en eau. La plupart des ruraux, fortement touchés par les effets néfastes de la dégradation du milieu, occupent les espaces forestiers, parfois même classés, pour étendre leur espace de culture, ou pratiquer une exploitation sélective d'espèces pour la construction et les combustibles mais aussi des prélèvements incontrôlés d'espèces relictuelles ou protégées particulièrement prisées pour l'artisanat et la médecine traditionnelle. Cette forte pression sur les ressources réduit considérablement l'espace forestier dont la dégradation est accentuée par le stress hydrique qui endommage énormément les formations végétales, les exposant souvent aux feux susceptibles de s'étendre sur plusieurs jours.

On assiste ainsi à une augmentation des surfaces cultivées qui s'est faite par des prélèvements sur le domaine non agricole. Cela correspond à une forme de compensation des mauvaises productions observées lors des mauvais hivernages même si la production n'a pas suivi l'accroissement des surfaces cultivées puisque le rendement moyen annuel des grands produits agricoles n'a quasiment pas évolué (Ndiaye et Ndiaye, 2013).

En ce qui concerne le couvert herbacé des parcours pastoraux en zone sahélienne, les observations ont montré une tendance à la baisse de la productivité, interrompue épisodiquement par une année exceptionnellement favorable. De plus, la multiplication des forages profonds contribue à activer la consommation des maigres ressources herbacées au-delà des limites de charge, dans la zone de polarisation de ces points d'eau.

Impacts sur les ressources animales

L'élevage étant globalement extensif, la capacité de charge liée à la longueur et à la sévérité de la saison sèche est souvent réduite en période de crise climatique, entraînant des effets négatifs sur la production animale.

Globalement, le cheptel a montré une évolution variable des effectifs suivant les espèces. Le cheptel bovin perd 18 % de l'effectif initial et s'étend plus dans les régions sud tandis que les ovins-caprins progressent légèrement de 5 % dans les régions du Nord (Ndiaye et Ndiaye, 2013). Cette tendance qui apparaît très nette pour l'élevage bovin au sud est la conséquence du repli stratégique rendu obligatoire du fait des mauvaises conditions climatiques dans la partie sahélienne et de la mortalité élevée qu'elles ont induite parmi le bétail.

La faune sauvage a également souffert des conséquences des années sèches successives de façon directe (destruction de l'habitat, réduction des points d'eau et des disponibilités alimentaires) et indirectes (extension des zones de culture et d'élevage, braconnage, etc.). Il en est de même pour la grande faune quasi inexistante au nord de la région.

VERS QUELLE EFFICACITÉ D'AFFECTATION DES UTILISATIONS ?

Initiatives locales

Les actions de reconversion positives par les populations sont généralement notées sur le littoral où, pour limiter la submersion fréquente des terres par l'eau de mer, elles construisent des diguettes. Cependant, la durabilité et l'efficacité de telles actions se posent avec acuité du fait du manque d'entretien permanent des ouvrages. Appuyées par certaines ONG, présentes sur place, les populations pratiquent également le reboisement de la mangrove, afin de régénérer cet écosystème de haute qualité environnementale, socio-économique et médicinale, (Ndiaye et Sané 2010).

Dans le même registre, des esquisses de solutions, plus ou moins efficaces ont été apportées par les autorités locales : politique de l'eau (barrages, forages, ouvrages d'amenée d'eau...), incitation à la reforestation (reboisement, introduction d'espèces), investissement dans la recherche d'espèces à cycle végétatif court, aménagements rationnels (prise en compte des impacts, exploitation et gestion durables), sensibilisation (approches participatives, stimulation à la privatisation).

Les autorités ont également tenté, au travers de plusieurs programmes de gouvernance environnementale, d'améliorer la gestion de l'eau et d'infléchir les impacts du changement climatique. Certaines de ces initiatives se sont révélées comme des réussites à perpétuer. D'autres en revanche, restent moins efficientes car souvent contraignantes ou partielles : approche réglementaire, dispositions juridiques et fiscales, décentralisation pas complètement effective, répression, délocalisation, etc. À cet égard, même s'ils ne paraissent pas absolus, les insuccès sont également nombreux et doivent souvent leur occurrence, aux options techniques et financières.

Cogestion à l'échelle régionale

Plusieurs initiatives globales ont été entreprises par des structures régionales. Ces expériences confortent l'idée que c'est l'échelle des États ou des groupements régionaux qui est sans doute appropriée pour élaborer et mener à bien des politiques de développement et de gestion des ressources naturelles, notamment lorsque celles-ci sont partagées. Cependant, une action réussie quelque part, peut-elle avoir le même succès ailleurs ? Les réalités géographiques sont telles qu'aucune expérience n'est reproductible sans un minimum d'adaptations techniques, culturelles, etc. Dans ce sens, depuis le milieu de la décennie 1990, la plupart des Etats africains avaient élaboré des PNAE, suite aux recommandations du Sommet de la Terre de Rio. La définition de domaines prioritaires d'intervention, l'engagement des pouvoirs publics constituent ainsi des prérequis de toute action en faveur de l'environnement même si, par ailleurs, la faiblesse institutionnelle des États, l'insuffisance des moyens matériels entravent, jusqu'à nos jours, la concrétisation de beaucoup de projets. Il est noté, cependant, que les actions régionales sont plus efficaces lorsqu'elles restent en synergie avec les politiques élaborées par les États membres.

Toutefois, les obstacles financiers en rapport avec la frilosité des investisseurs privés, gênés par un environnement politique parfois défavorable et le manque d'option politique bien défini, et donc d'engagement réel de la plupart des autorités étatiques, constituent des entraves pour les initiatives à grande échelle, qui restent encore très timides sur cette partie du continent africain (projets BAD, AFD, etc.)

Au demeurant, l'expérience montre que l'existence de moyens financiers dans un programme, s'accompagne parfois de facteurs latéraux déstabilisants tels que la récupération de la part d'acteurs, qui en pervertissent les fondements et le caractère vertueux de départ. L'absence d'audit financier et de suivi-évaluation (à mi-parcours et à terme) des programmes ne permet pas, non plus, d'inverser à temps les tendances négatives ou de contourner les obstacles, en cas de duplication.

Initiatives internationales

Les questions relatives à l'environnement dans sa globalité et au changement climatique et ses effets induits ont dépassé le contexte national faisant que, depuis plusieurs décennies, la situation internationale ordonne l'action concertée, sur une base multinationale qui sert de principe directeur. Sous cet angle, des projets ont été élaborés par différents bailleurs. Toutefois, même si des réussites ont été notées, la plupart de ces efforts ont été insuffisants pour créer des économies d'échelle porteuses de perspectives significatives dans le long terme, et dans une moindre mesure, de permettre ou susciter des velléités de projection d'atteinte des ODD ?

CONCLUSION

Il est crucial de confirmer que la maladaptation à la péjoration climatique et les facteurs anthropiques ont, pour beaucoup, exacerbé la dégradation des milieux en Afrique de l'Ouest. Il est tout aussi important de noter que la croissance démographique, la forte pression agricole et pastorale sur le milieu naturellement fragilisé font partie des principaux facteurs de dégradation de l'environnement et des conditions socio-économiques, dans ce contexte de crise climatique. Ces situations de déséquilibres en affectant grandement la productivité des cultures, le bétail, les forêts, (principaux moyens de subsistance en milieu rural) et même la pêche ont induit des contraintes partout en Afrique de l'Ouest. L'Augmentation de la faim et de la malnutrition avec leurs conséquences sanitaires induites, même si elles sont différenciées selon les pays et à l'intérieur des pays (accentuées en milieu rural), nuisent considérablement aux progrès sur la pauvreté et constituent un obstacle à l'atteinte aux objectifs du développement durable.

Globalement, concernant les questions environnementales, les programmes réussis sont rares en Afrique, surtout ceux qui se sont maintenus sur le long terme[29] ; la récurrence des échecs est prégnante, elle amène à la raison, à savoir revenir à la réalité qui consiste à ne pas confondre la perspective d'un mirage ayant l'apparence d'une oasis de solutions aux situations de vulnérabilité (Ndiaye et Ndiaye, 2013).

S'agissant de la problématique de l'eau, un bref historique aboutit à la constatation que, énormément d'expériences ont été tentées, de défis affrontés, de luttes conduites et de ressources exploitées avec l'espoir de faire face aux contraintes.

De toute évidence, la gestion des ressources en eau, une des composantes majeure de la question de la sécurité alimentaire est un des enjeux majeurs du millénaire naissant, l'eau étant vitale pour tous les êtres vivants animal et végétal et tout aussi fondamentale pour l'approvisionnement en produits alimentaires et industriels. Même

29 Le Cap Vert et le Botswana ont réussi toutefois, par le biais de bonne gestion de leur ressources naturelles et la bonne gouvernance de passer du statut de PMA à celui de pays à revenu intermédiaire (Nations Unies, 2012) si les ressources en eau disponibles (en surface et dans les nappes souterraines) ont depuis toujours assuré les besoins dans ce sens, l'eau disponible devient de plus en plus insuffisante, aussi bien en qualité qu'en quantité. Or la demande en eau ne cesse de croître à une échelle exponentielle dépassant de loin l'allure de la courbe du croît démographique, l'expression des besoins et les modes d'utilisations se faisant plus sophistiqués, d'où les multiples conflits d'usage, notamment dans les bassins producteurs d'eau de surface.

Il est donc fondamental pour les pouvoirs publics d'intégrer toutes ces dynamiques dans l'élaboration de leurs programmes car, de nos jours, aucune politique de développement et de gestion des ressources naturelles et environnementales sérieuse, ne peut se concevoir sans prise en compte de tout ce contexte à la fois géographique, sociétal et géopolitique.

L'une de ces dynamiques socio-économique et environnementales s'établit dans la croissance démographique et son corollaire direct, l'urbanisation (tendance à l'urbanité inversée dans la quasi-totalité des pays africains; record détenu par le Gabon avec près de 80% de population urbaine), phénomène d'ailleurs mal maîtrisé, partout dans le monde. Il est entendu que ces imbrications complexes pèsent et continueront à peser d'un poids décisif sur les relations entre les populations, leurs conditions socio-économiques et leur milieu de vie. Et il est attendu des autorités des réponses urgentes.

L'autre défi pour les décideurs ouest africains, dans ce contexte de mondialisation, de mutations des modes de vie et d'enjeux écologiques planétaires, relève de la problématique de l'énergie. Alors que partout dans la région sont notés des problèmes relatifs à la question énergétique, les ressources hydrauliques à elles seules peuvent couvrir tous les besoins en électricité. Or, la part de l'énergie tirée de la ressource dans la consommation globale reste encore très faible, à peine 7 % du potentiel étant aménagé sur l'ensemble du continent !

En définitive, les dynamiques socio-économiques et environnementales en cours génèrent des mutations peu avantageuses ; elles conduisent à des enjeux redoutables sur l'eau, la terre et toutes les autres ressources dites naturelles. L'avenir invite donc à inverser ou à conforter les tendances positives qui émergent. Concrètement, au regard des modèles de cogestion réussis, le défi pour l'Afrique en général, la région ouest africaine en particulier, consiste foncièrement, à élargir les frontières, pas seulement politiques, mais toutes les autres pour une efficacité concertée... En 60 ans, deux générations d'ouest africains se sont succédées : l'une s'est révoltée pour s'émanciper du colonialisme, l'autre a subi la désillusion du sous-développement chronique malgré la disponibilité de ressources naturelles aussi fondamentales que l'eau, la terre et une population jeune et valide. La prochaine génération est donc condamnée à relever le défi, en dépit de tous les indicateurs qui prédisent le contraire (Ndiaye et Thiaw, 2013) au regard de ces jeunes qui fuient leurs pays au péril de leur vie, si minime soit leur nombre.

RÉFÉRENCES BIBLIOGRAPHIQUES

Baiou R., 2012, L'Afrique et les changements climatiques, Université du Québec. Cours, Module 6, Etude de cas. http://benhur.teluq.uquebec.ca/SPIP/env1110/squelettes/assets/pdf/module6/Module6_txt2.pdf [Date d'accès : 1er septembre 2012].

Banque Ouest Africaine de Développement (BOAD), 2010, changements climatiques et sécurité alimentaire dans la zone UEMOA : défis, impacts, enjeux actuels et futurs, Rapport final.

Central Intelligence Agency, 2010, CIA.gov. https://www.cia.gov/library/publications/theworld-factbook/wfbExt/region_afr.html [Date d'accès : 1er septembre 2012].

Fonds International de Développement Agricole (FIDA) 2001, L'évaluation de la pauvreté rurale en Afrique de l'Ouest et du Centre. www.ifad.org/poverty/region/pa/french.pdf [Date d'accès : 1er septembre 2012].

Groupe d'experts Intergouvernemental sur l'Evolution du Climat (GIEC), 2007, Changements climatiques. Rapport de synthèse, OMM et PNUE.

Monnet V., 2012 L'eau, la guerre et le droit. Université de Genève. http://www.unige.ch/communication/Campus/campus108/recherche4/2RE4.pdf [Date d'accès : 1er septembre 2012].

Nations Unies, 2012, Rapport du groupe de travail spécial chargé d'étudier plus avant et de renforcer la transition sans heurt des pays sortant de la catégorie des pays les moins avancés. Assemblée générale. http://www.unohrlls.org/UserFiles/File/LDC%20Documents/AHWG%20on%20smooth%20transition/A-67-2%20final%20report%20of%20AHWG%20on%20smooth%20transition_french.pdf [Date d'accès : 1er septembre 2012].

Ndiaye A. et Ndiaye P., 2013, « Changement climatique, dégradation environnementale et quête d'utilisation des ressources naturelles : miracle ou mirage ? » Occasional Paper. African Capacity Building Foundation – 50 pages – ISBN: 978-1-77937-044-0, ACBF - Harare – Zimbabwe.

Ndiaye A. et Thiaw D., 2013, « Élargir les frontières : le prochain défi de l'Afrique ! » Revue «HOMMES d'Afrique Magazine»: L'O.U.A. : Cinquante ans après. Mensuel de l'actualité des personnalités africaines - Hors-série - 05-2013 – Rabat – Maroc.

http://environnement.mongroupe.ca/2014/02/20/le-manque-deau-potable-en-afrique-du-sud/ [Date d'accès : 18 septembre 2018].

Word Bank, 2004, The Atlas of the Children's Health and the Environment. http://www.who.int/ceh/publications/en/atlas.pdf [Date d'accès: 1er septembre 2012].

IPCC Special Report on Climate Change and Land: Implications for West Africa

Alisher Mirzabaev[30]

ABSTRACT

Sustainable land management has direct and far-reaching effects on the emission and sequestration of greenhouse gas emissions and climate change adaptation, with parallel impacts on food production and food systems. IPCC special report on Climate Change and Land is a major international scientific assessment exploring these linkages in detail. The findings of the report show that land is currently under a significant pressure due to human activities, resulting in wide-spread land use and land cover changes, degradation of land ecosystem services, with negative implications for food security, climate change mitigation and adaptation, and sustainable livelihoods. However, sustainable land management can contribute significantly to climate change mitigation and adaptation, with positive effects on sustainable development goals. Making this possible would depend on undertaking urgent efforts to promote sustainable land management technologies and practices, as well as accompanying institutional and policy frameworks. This article discusses the key findings of the report, with a particular focus on their implications for climate change adaptation and mitigation in West Africa.

Keywords : climate change, land, sustainable management, West Africa, IPCC

RÉSUMÉ

Une gestion durable des terres est très importante car elle agit sur l'émission et la séquestration des gaz à effet de serre, ce qui est une forme d'adaptation face aux changements climatiques. Elle a également des impacts positifs sur la production et les systèmes alimentaires. Ces éléments sont explorés en détails dans le rapport sur le changement climatique du GIEC qui démontre, d'une manière générale, la pression importante que subissent les terres du fait des diverses activités humaines. Ces pressions qui sont la cause des modifications dans l'occupation et la couverture des sols, amplifient la dégradation des écosystèmes terrestres, avec des conséquences négatives sur la sécurité alimentaire bloquant ainsi la lutte contre le changement climatique et l'adaptation à ce phénomène. Toutefois, la gestion durable des terres

30 All views expressed in this paper are solely of the author, and do not necessarily represent the position of the IPCC.

peut contribuer de manière significative à l'atténuation du changement climatique et à l'adaptation à celui-ci, avec des effets positifs sur les objectifs de développement durable. Pour que cela soit possible, il faut entreprendre des efforts urgents pour promouvoir les technologies et les pratiques de gestion durable des terres, ainsi que les cadres institutionnels et politiques d'accompagnement. Dans cet article, les principales conclusions du rapport sont analysées et discutées tout en mettant l'accent sur leurs implications pour l'adaptation au changement climatique et son atténuation en Afrique de l'Ouest.

Mots-clés : changement climatique, terres, gestion durable, Afrique de l'Ouest, GIEC,

INTRODUCTION

The Special Report of the Intergovernmental Panel on Climate Change (IPCC) on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems, shortly known as: IPCC Special report on Climate Change and Land, assessed the up-to-date literature on the interactions between climate change, land management and food systems (IPCC, 2019). The report consisted of seven chapters: 1) Framing and Context, 2) Land-Climate Interactions, 3) Desertification, 4) Land Degradation, 5) Food Security, 6) Interlinkages between desertification, land degradation, food security and GHG fluxes: Synergies, trade-offs and Integrated Response Options, and 7) Risk management and decision making in relation to sustainable development.

A key innovation in this report is an integrated analysis of how various factors affecting natural resource management interact with sustainable land management, water, food and energy securities and affect climate change. For example, chapters 3 and 4 assessed the literature on desertification and land degradation not only from biophysical perspectives, but also explored how the related processes of desertification and land degradation affect food security and poverty. The report evaluated a big number of response options related to markets, institutions for sustainable land management (SLM), food systems and value chains, SLM technologies and practices in terms of their contribution to climate adaptation and mitigation, and the simultaneous attainment of Sustainable Development Goals (SDGs) (Smith et al., 2019).

The key messages of the report underscore that land resources are already under severe human pressure, leading to their degradation in many places across the world. To illustrate, 75% of the global land surface area is already intensively used for human needs. The area under agricultural production has been rapidly increasing since 1960s which enabled to feed growing human population, but this has also come at the cost of exponentially growing inorganic fertilizer use (increased by 8 times since 1960s) and water use for irrigation (doubled since 1960s) (Arneth et al., 2019). At the same time, the population residing in areas experiencing desertification doubled since 1960s (Mirzabaev et al., 2019), and the extent of inland wetlands shrunk by almost 30% (Olsson et al., 2019). Climate change can increase this pressure on land and land ecosystem services even further (Jia et al., 2019). However, the land is also a part of the solution. If properly managed, the land could help provide sufficient food for growing human population even under climate change (Mbow et al., 2019), and also supply biomass for renewable energy further contributing to climate change mitigation efforts (Smith et al., 2019), in addition, to its major role as global carbon sink. In fact, due to numerous synergies, coordinated action to address climate change can at the same time help manage land more sustainably, enhance food security and nutrition, and help reduce hunger and poverty (Hurlbert et al., 2019).

The relationship between land degradation and climate change is one of two-way causality. On one hand, land degradation contributes to climate change, e.g. deforestation reduces the capacity of land to absorb carbon. In fact, the report finds that about one third of total greenhouse gas emissions come from Agriculture, Forestry and Other Land Use (AFOLU) (Jia et al., 2019), e.g. through such activities as livestock husbandry, rice production, fertilizer application for crops, processing and transportation of food. The report's findings show that about 50% of the nitrogen applied to agricultural land is not taken up by crops, resulting in nitrous oxide emissions (IPCC, 2019). On the other hand, climate change exacerbates land degradation (Olsson et al., 2019; Mirzabaev et al., 2019), through increased frequency, intensity and/or amount of heavy precipitation, and increased heat stress, increasing floods, drought frequency and severity, intensified cyclones, and sea-level rise, with outcomes being modulated by land management (IPCC, 2019). The report finds that already from 1.5 to 3.2 billion people live in areas affected with land degradation globally (24-29% of total land), of whom about 500 million in drylands which experienced desertification (about 9% of drylands) (Olsson et al., 2019; Mirzabaev et al., 2019). Since 1961, the annual area of drylands in drought has increased by slightly more than 1% per year (Mirzabaev et al., 2019).

Purposefully, the report is very much solutions-oriented, rather than discussing only risks and impacts coming from climate change. The report highlights that technological, institutional and policy solutions are available to avoid, reduce and reverse land degradation and desertification while also enhancing food security and contributing to climate change mitigation and adaptation. Such SLM technologies include, as some examples, water harvesting and micro-irrigation, agroforestry and other agroecologically focused farming methods, usually with regional and site specific impacts. Many of these technologies are economically profitable (Mirzabaev et al., 2019). In fact, investment in sustainable land management and land restoration in drylands were found to have positive economic returns with each dollar invested bringing back 3-6 dollars of return (Nkonya et al., 2016).

Being a global report, IPCC special report on Climate Change and Land provides the assessment information that is relevant for all regions. The next section highlights the findings and implications of the report for West Africa region.

IMPLICATIONS OF THE IPCC SPECIAL REPORT ON CLIMATE CHANGE AND LAND FOR WEST AFRICA REGION

Desertification and its extents

West Africa is a region where populations are very vulnerable to desertification and yield declines due to climate change (IPCC, 2019). As with the rest of the world, West

Africa region experienced rapid increases in agricultural areas since 1975 (doubling) till nowadays (Traore et al., 2014). Associated land use and land cover changes and unsustainable management of croplands and grazing lands have often led to high levels of land degradation and desertification across West Africa (Dimobe et al., 2015, Hiernaux 2019, Aladejana et al., 2018). Prăvălie (2016) shows that moderate and high severity land degradation areas cover half of the Senegal and Niger river basins, and more than two-thirds of the Volta river basin in the region. Despite current "greening" in some parts of West Africa, i.e. higher vegetation growth, local studies highlight that in some of these areas "greening" masks the underlying land degradation manifested by lower richness of plant species (Herrmann and Tappan, 2013).

Climate change projections and impacts

The climate change simulations show that temperatures would be increasing across the region under climate change (Mbow et al., 2019). Future waring could lead to higher water evaporation from global oceans intensifying West African monsoon and related precipitation over central Sahel (Schewe and Levermann, 2017) and eastern part of West Africa (Mbow et al., 2019). In contrast, the simulations also point to lower rainfall amounts as a result of climate change in western sections of the region. The modelling of the impact of large-scale tree planting in West Africa suggests surface-cooling effect of these tree planting efforts, e.g. by reducing the mean surface temperature by 1°C in savanna areas, potentially counterbalancing the warming in the deforested areas of West Africa (Abiodun et al. 2012). Similarly, the large-scale adoption of irrigation can decrease surface air temperatures in the irrigated areas of the region during the period of irrigation (Im et al., 2014).

The assessment of risk of global warming on crop yields show that under by 1.5°C global mean temperature increase, the risks for crop yields can already become high in West Africa (Hurlbert et al., 2019; Faye et al., 2018), even though these impacts are expected to be strongly affected by carbon fertilization in combination with precipitation (Mbow et al., 2019; Sultan and Gaetani, 2016). For example, peanut yields in Senegal may experience little change even under high levels of climate change (e.g. under Representative concentration pathway, RCP8.5) thanks to the carbon fertilization effect (Faye et al., 2018). The report finds that desertification has already reduced food and fodder production in many dryland areas. Moreover, recurrent droughts, including in West Africa, also have highly negative effects on food security and livelihoods. Another major coupled impact of desertification and climate change in West Africa highlighted in the report comes through sand and dust storms. However, despite likely huge impacts of dust and sandstorms on human health, infrastructures, crop and livestock productivity, there is currently very little research available documenting these impacts for West Africa region.

In addition to direct biophysical effects, desertification and climate variability have already had major impacts on poverty and food insecurity in the region. The losses associated with land degradation were estimated to reach 4.2 billion USD between 2006 and 2015 in Ghana (Diao and Sarpong, 2011), to equal 0.75 billion USD per year in Niger (Moussa et al., 2016), and 0.41 billion USD per year in Senegal (Sow et al., 2016). The impacts of climate change have strong gender dimensions, affecting women more than men in the region, for example, through increasing water scarcity and droughts (Ahmed et al. 2016). Gender-differentiated effects are also largely present in land restoration and land rehabilitation activities, where women are often excluded from decision-making processes. Agricultural households in West Africa were found to have responded to droughts through migration, diversification of livelihoods and engaging in off-farm employment (Barbier et al. 2009: Mirzabaev et al., 2019)

Response options to climate change and desertification

There were many initiatives in the past across the region to halt desertification, many of which failed to achieve their objectives (Benjaminsen and Hiernaux 2019). However, increasingly the countries of the region are learning from past efforts and changing their actions against desertification towards more comprehensive development strategies, e.g. under the Great Green Wall Initiative (Mirzabaev et al., 2019) and other programs and policies that promote the adoption of SLM technologies and practices, and of climate change adaptation measures. Adoption of SLM practices in West Africa was found to be strongly influenced by household resources, gender and social status (Theriault et al., 2017). Land tenure security can increase the adoption of the SLM technologies in the region, even though a study in Ghana found that SLM adoption did not significantly affect farm productivity (Abdulai et al., 2011).

SLM technologies with high potential for the conditions of West Africa highlighted in the report include integrated crop-soil-water management, rainwater harvesting, adoption of irrigation and of water use efficient irrigation technologies such drip and sprinkle irrigation, wider use of inter-cropping, and conservation agriculture practices, agroforestry, rotational grazing, and sand dune stabilization (Mirzabaev et al., 2019).

Socio-economic and policy responses for simultaneously combating land degradation, adapting to and mitigating climate change in West Africa include promoting the use of indigenous and local knowledge, stimulating farmer-led innovations, enhancing collective action for sustainable natural resource management, improving market access, expanding access to agricultural services and mechanization, strengthening land tenure security, empowering women especially by expanding their access to resources supporting SLM and climate change adaptation, establishing schemes for payments for ecosystem services and creating conditions for tapping into international carbon trading (Mirzabaev et al., 2019).

CONCLUSION

Poverty, food insecurity, water scarcity and land degradation are major challenges in West Africa. In addition, many countries in the region are currently facing growing social insecurity and migration-related risks. Although, the countries have several strategies and actions plans developed for climate change adaptation, and addressing desertification and land degradation, their implementation remains insufficient. To illustrate, National Adaptation Plan (NAP) processes are not adequately integrated across relevant focal areas and frequently fail to align with overall economic planning, creating bottlenecks to action. This inhibits a strategic approach that would yield greater impact and it discourages investment.

Climate variability and change, land degradation, lack of access to energy, instability and associated challenges continue to hinder sustainable development in West Africa, including efforts to reduce poverty and ensure food security. Thus, the efforts to address development challenges such as climate change and land degradation need to be "conflict-sensitive" and should not result in generating new tensions. There is a need for locally driven recommendations which provide a platform for engaging in evidence-based actions for SLM, climate change adaptation, peace and development in West Africa. This includes promoting numerous regionally tested climate change adaptation and SLM technologies and practices, creating enabling institutional and policy environments for their adoption, as well as making use of indigenous conflict resolution mechanisms and supporting the participation of women and youth in key economic activities. SLM, climate change adaptation, and renewable energy expansion are the highest return areas for investments toward achieving SDGs. Investments into soft and hard infrastructures can provide substantial multiplicative effects for job creation and economic growth in the region. Improving policy formulation and implementation can be achieved by setting achievable objectives with guaranteed (mostly own) funding and accompanying the policy implementation with strong monitoring and evaluation.

REFERENCES

Abdulai, A., V. Owusu, and R. Goetz, 2011: Land tenure differences and investment in land improvement measures: Theoretical and empirical analyses. J. Dev. Econ., 96, 66–78, doi:10.1016/J.JDEVECO.2010.08.002.

Abiodun, B.J., Z.D. Adeyewa, P.G. Oguntunde, A.T. Salami, and V.O. Ajayi, 2012: Modeling the impacts of reforestation on future climate in West Africa. Theor. Appl. Climatol., 110, 77–96, doi:10.1007/s00704-012-0614-1.

Ahmed, A., E.T. Lawson, A. Mensah, C. Gordon, and J. Padgham, 2016: Adaptation to climate change or non-climatic stressors in semi-arid regions? Evidence of gender differentiation in three agrarian districts of Ghana. Environ. Dev., 20, 45–58, doi:10.1016/J.ENVDEV.2016.08.002.

Aladejana, O.O., A.T. Salami, and O.-I.O. Adetoro, 2018: Hydrological responses to land degradation in the Northwest Benin Owena River Basin, Nigeria. J. Environ. Manage., 225, 300–312, doi:10.1016/J.JENVMAN.2018.07.095.

Arneth, A., F. Denton, F. Agus, A. Elbehri, K. Erb, B. Osman Elasha, M. Rahimi, M. Rounsevell, A. Spence, R. Valentini, 2019: Framing and Context. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press

Barbier, B., H. Yacouba, H. Karambiri, M. Zoromé, and B. Somé, 2009: Human vulnerability to climate variability in the Sahel: Farmers' adaptation strategies in northern Burkina Faso. Environ. Manage., 43, 790–803, doi:10.1007/s00267-008-9237-9.

Benjaminsen, T.A. and P. Hiernaux, 2019: From desiccation to global climate change: A history of the desertification narrative in the West African Sahel, 1900-2018. Glob. Environ., 12, 206–236, doi:10.3197/ge.2019.120109

Diao, X., and D.B. Sarpong, 2011: Poverty implications of agricultural land degradation in Ghana: An economy-wide, multimarket model assessment. African Dev. Rev., 23, 263–275, doi:10.1111/j.1467-8268.2011.00285.x.

Dimobe, K., A. Ouédraogo, S. Soma, D. Goetze, S. Porembski, and A. Thiombiano, 2015: Identification of driving factors of land degradation and deforestation in the wildlife reserve of Bontioli (Burkina Faso, West Africa). Glob. Ecol. Conserv., 4, 559–571, doi:10.1016/j.gecco.2015.10.006.

Faye, B. et al., 2018a: Impacts of 1.5 versus 2.0°C on cereal yields in the West African Sudan Savanna. Environ. Res. Lett., 13, 3, doi:10.1088/1748-9326/ aaab40.

Herrmann, S.M., and G.G. Tappan, 2013: Vegetation impoverishment despite greening: A case study from central Senegal. J. Arid Environ., 90, 55–66, doi:10.1016/J. JARIDENV.2012.10.020.

Hiernaux, P. et al., 2009: Trends in productivity of crops, fallow and rangelands in Southwest Niger: Impact of land use, management and variable rainfall. J. Hydrol., 375, 65–77, doi:10.1016/J.JHYDROL.2009.01.032.

Hurlbert, M., J. Krishnaswamy, E. Davin, F.X. Johnson, C.F. Mena, J. Morton, S. Myeong, D. Viner, K. Warner, A. Wreford, S. Zakieldeen, Z. Zommers, 2019: Risk Management and Decision making in Relation to Sustainable Development. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

Im, E.S. and E.A.B. Eltahir, 2014: Enhancement of rainfall and runoff upstream from irrigation location in a climate model of West Africa. Water Resour. Res., 50, 8651–8674, doi:10.1002/2014WR015592.

IPCC, 2019: Summary for Policymakers. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

Jia, G., E. Shevliakova, P. Artaxo, N. De Noblet-Ducoudré, R. Houghton, J. House, K. Kitajima, C. Lennard, A. Popp, A. Sirin, R. Sukumar, L. Verchot, 2019: Land–climate interactions. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M, Belkacemi, J. Malley, (eds.)]. In press.

Mbow, C., C. Rosenzweig, L.G. Barioni, T.G. Benton, M. Herrero, M. Krishnapillai, E. Liwenga, P. Pradhan, M.G. Rivera-Ferre, T. Sapkota, F.N. Tubiello, Y. Xu, 2019: Food Security. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press

Mirzabaev, A., J. Wu, J. Evans, F. García-Oliva, I.A.G. Hussein, M.H. Iqbal, J. Kimutai, T. Knowles, F. Meza, D. Nedjraoui, F. Tena, M. Türkes, R.J. Vázquez, M. Weltz, 2019: Desertification. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press

Moussa B., Nkonya E., Meyer S., Kato E., Johnson T., Hawkins J. (2016) Economics of Land Degradation and Improvement in Niger. In: Nkonya E., Mirzabaev A., von Braun J. (eds) Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer, Cham. https://doi.org/10.1007/978-3-319-19168-3_17

Nkonya E., Mirzabaev A., von Braun J. (2016) Economics of Land Degradation and Improvement: An Introduction and Overview. In: Nkonya E., Mirzabaev A., von Braun J. (eds) Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer, Cham. https://doi.org/10.1007/978-3-319-19168-3_1

Olsson, L., H. Barbosa, S. Bhadwal, A. Cowie, K. Delusca, D. Flores-Renteria, K. Hermans, E. Jobbagy, W. Kurz, D. Li, D.J. Sonwa, L. Stringer, 2019: Land Degradation. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

Prăvălie, R., 2016: Drylands extent and environmental issues. A global approach. Earth-Science Rev., 161, 259–278, doi:10.1016/J. EARSCIREV.2016.08.003.

Schewe, J., and A. Levermann, 2017: Non-linear intensification of Sahel rainfall as a possible dynamic response to future warming. Earth Syst. Dynam, 8, 495–505, doi:10.5194/esd-8-495-2017.

Smith, P., J. Nkem, K. Calvin, D. Campbell, F. Cherubini, G. Grassi, V. Korotkov, A.L. Hoang, S. Lwasa, P. McElwee, E. Nkonya, N. Saigusa, J.-F. Soussana, M.A. Taboada, 2019: Interlinkages Between Desertification, Land Degradation, Food Security *and Greenhouse Gas Fluxes: Synergies, Trade-offs and Integrated Response Options. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Portner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.*

Sow S., Nkonya E., Meyer S., Kato E. (2016) Cost, Drivers and Action Against Land Degradation in Senegal. In: Nkonya E., Mirzabaev A., von Braun J. (eds) Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer, Cham. https://doi.org/10.1007/978-3-319-19168-3_19

Sultan, B., and M. Gaetani, 2016: Agriculture in West Africa in the 21st century: Climate change and impacts scenarios, and potential for adaptation. Front. Plant Sci., 7, 1–20, doi:10.3389/fpls.2016.01262.

Theriault, V., M. Smale, and H. Haider, 2017: How does gender affect sustainable intensification of cereal production in the West African Sahel? Evidence from Burkina Faso. World Dev., 92, 177–191, doi:10.1016/J. WORLDDEV.2016.12.003.

Traore, S.B. et al., 2014: AGRHYMET: A drought monitoring and capacity building center in the West Africa region. Weather Clim. Extrem., 3, 22–30, doi:10.1016/J. WACE.2014.03.008.

Changement climatique, Moyens de Subsistance et Conflits au Sahel

Ahmadou Aly Mbaye, Fatou Gueye, Fama Gueye et Khady Yama Sarr

RÉSUMÉ

La disponibilité des ressources naturelles est affectée par la désertification, la sécheresse, les inondations, l'élévation du niveau de la mer, les troubles politiques graves et les menaces islamistes radicales, entre autres. Dans ce document, nous avons utilisé le Sahel comme cas d'étude pour montrer que les conflits ont de nombreux facteurs imbriqués. Les conflits au Sahel sont généralement motivés par différents éléments tels que la gouvernance, le favoritisme et les facteurs ethniques et religieux qui entrent tous en jeu, le changement climatique agissant de plus en plus comme un amplificateur qui contribue à déclencher la violence. L'adaptation au changement climatique, l'augmentation des fonds d'adaptation et l'accélération de leur utilisation sont des piliers importants des politiques visant à atténuer les conflits au Sahel.

Mots-clés : Catastrophes naturelles, vulnérabilité, subsistance, politiques d'adaptation, Sahel.

ABSTRACT

The availability of natural resources is affected by desertification, drought, flooding, sea level rise, severe political unrest, and radical Islamist threats, among others. In this paper, we have used the Sahel as a case study to show that conflicts have many intertwined factors. Conflicts in the Sahel are generally driven by different elements such as governance, favoritism, and ethnic and religious factors that all come into play, with climate change increasingly acting as an amplifier that helps trigger violence. Adapting to climate change, increasing adaptation funds and accelerating their use are important pillars of policies to mitigate conflict in the Sahel.

Keywords : Natural disasters, vulnerability, livelihoods, adaptation policies, Sahel.

INTRODUCTION

Les pays du Sahel, tout en partageant de nombreuses caractéristiques avec les autres économies d'Afrique subsaharienne, sont confrontés à des défis économiques uniques qui méritent une attention particulière. Les niveaux de revenu par habitant sont plus faibles, les exportations sont concentrées sur quelques produits de base, le climat est généralement sec et quatre des six pays concernés sont enclavés. Les taux de fécondité et la croissance démographique au Sahel ayant atteint des records mondiaux, les jeunes représentent plus de 65 % de la main-d'œuvre totale et sont pour la plupart au chômage ou sous-employés. L'image est encore assombrie par les faiblesses critiques liées à la gouvernance, les troubles politiques et les menaces islamistes radicales, qui ont provoqué de graves problèmes de sécurité à l'intérieur et entre les frontières nationales.

Au Sahel, les tendances climatiques régionales montrent une augmentation globale de la température, associée à une tendance assez irrégulière des précipitations. Dans l'ensemble, le Sahel est confronté à un nombre croissant de catastrophes naturelles, dont la fréquence et l'intensité devraient augmenter dans un avenir proche (Banque Mondiale, 2007). La désertification, la sécheresse, les inondations et l'élévation du niveau de la mer, entre autres, affectent également la disponibilité des ressources naturelles (World Bank, 2010 ; Blattman et Miguel, 2013), et dans un contexte où les ressources naturelles sont les principales sources de revenus, la dégradation de l'environnement a un impact significatif sur la résilience des populations et les rend très vulnérables (Raleigh et Kniveton, 2012; Hendrix et Salehyan, 2007).

Une partie de la littérature existante établit un lien clair entre ces tendances climatiques récentes et l'apparition et la persistance de conflits violents au Sahel (IPCC, 2007), en soulignant principalement la tendance naturelle des populations à recourir à la migration et à la lutte pour des de plus en plus rares, comme stratégie d'adaptation. D'autre part, un grand nombre de publications contestent cette conclusion et insistent sur le rôle que jouent les institutions défaillantes et la démographie, comme étant les causes profondes des conflits. Dans cet article, nous soutenons que, dans le Sahel, les conflits ont généralement de nombreux facteurs interdépendants, parmi lesquels la gouvernance, le favoritisme, ainsi que les facteurs ethniques et religieux, tous entrent en jeu, avec le changement climatique jouant de plus en plus comme un amplificateur, qui contribue généralement à déclencher la violence.

Le reste du chapitre est organisé comme suit : la section 2 présente la littérature dominante sur la relation entre le changement climatique et les conflits, la section 3 montre comment le changement climatique assèche les moyens de subsistance, favorisant, de ce fait les conflits. La section 4 met l'accent sur les défaillances institutionnelles présentées comme étant les causes profondes de conflit au Sahel. La section 5 présente le cas du Mali et la section 6 les besoins d'adaptation au changement climatique.

LA LITTÉRATURE SUR LE LIEN ENTRE LE CHANGEMENT CLIMATIQUE ET LES CONFLITS EST TRÈS PEU CONCLUANTE.

L'idée que le changement climatique est positivement associé aux conflits civils a reçu de nombreux soutiens empiriques dans la littérature, tout choc de 5 points de pourcentage sur la croissance du PIB entraînant une augmentation de moitié de la probabilité de conflit l'année suivante (Miguel and al., 2004). En combinant les projections des modèles climatiques sur les tendances futures des températures avec la réponse historique des conflits à la température en Afrique, il est estimé une augmentation de 54 % de l'incidence des conflits armés d'ici 2030, correspondant à 393 000 décès supplémentaires, en Afrique (Burke et al., 2009). De même, ces mêmes auteurs constatent qu'une augmentation de 1 °C de la température entraîne une augmentation de 4,5% de l'incidence de la guerre civile la même année et une augmentation de 0,9% l'année suivante. Selon eux, la température peut affecter les rendements agricoles à la fois par l'augmentation de l'évapotranspiration des cultures et par l'accélération du développement des cultures, dont les effets combinés ont réduit les rendements des cultures de base africaines de 10 à 30 % par °C de réchauffement. Et les chocs de revenus tels que la sécheresse ou les inondations entraînent une forte augmentation du nombre de meurtres en sorcellerie en Tanzanie (Miguel, 2005).

Bien que Miguel et ses coauteurs soient de loin les auteurs des résultats les plus directes sur le rôle du changement climatique dans les conflits, l'idée générale selon laquelle des conditions de vie difficiles engendrent la violence est au cœur de nombreuses analyses sur le même sujet. Le niveau de développement économique est généralement considéré comme le principal canal de transmission du changement climatique sur les conflits civils ; ce qui expliquerait pourquoi la guerre civile est si concentrée dans les pays les plus pauvres du monde. Par conséquent, plus le niveau de revenu par habitant est élevé, plus le risque de déclenchement d'une guerre civile est faible (Collier et Hoeffler, 2004). Lorsque la part des jeunes dans la population totale est élevée, l'impact des conditions économiques difficiles sur les conflits est encore plus important. En effet, une part plus importante de jeunes sans emploi ou sous-employés est associée à des taux plus élevés de crimes et d'instabilité sociale (Blattman, Fiala et Martinez, 2013). De même, certaines études montrent que les jeunes hommes pauvres et sans emploi affaiblissent les liens sociaux, réduisent l'engagement civique et augmentent le risque de troubles sociaux (World Bank, 2010; Blattman et Miguel, 2013).

Alors qu'un important segment de la littérature se concentre sur la structure d'incitation économique de la violence, une autre école de pensée conteste ces conclusions et met l'accent sur d'autres sources de conflit. Selon Raleigh, Choi et Kniveton (2015), les "institutions" et la capacité de l'État, représentée par la protection des droits de propriété, l'État de droit et l'efficacité du système juridique, sont plutôt les causes profondes de la guerre civile, et non le niveau de développement économique. En particulier, une amélioration des institutions, de la valeur médiane de leur échantillon au 75ème percentile, est associée à une réduction de 36 points de l'incidence de la guerre civile. De plus, une fois que les institutions sont incluses comme variable explicative de la guerre civile, le revenu n'a plus aucun effet statistiquement discernable, que ce soit directement ou indirectement. Au contraire, l'instabilité politique, la nature accidentée ou non du terrain et la taille de la population sont corrélés à la violence (Alexander et Harding, 2005). Un terrain accidenté fait référence à des endroits où les rebelles peuvent se cacher facilement, comme les montagnes. Dans le cas du Kenya, le "paradoxe de l'abondance" a été mis en évidence : il souligne que ce n'est pas la sécheresse mais l'abondance qui génère les conflits (Witsenburg et Adano, 2009). A contrario les institutions peuvent façonner les interactions humaines et la prévention des conflits en période de pénurie (Ostrom, 2007). En fait, "... plus la saison est humide, plus le nombre de personnes susceptibles de mourir lors de violents raids sur le bétail est élevé. En d'autres termes, plus de conflits et de meurtres ont lieu en saison humide, en période d'abondance relative, et moins en saison sèche, en période de pénurie relative, lorsque les gens concilient leurs différences et coopèrent (Djankov et Marta Reynal-Querol, 2010). Ils ajoutent : "L'éloignement et l'inaccessibilité du terrain affaiblissent les initiatives gouvernementales visant à assurer une sécurité adéquate, mais les arrangements locaux modèrent les conflits lorsque la pénurie atteint son paroxisme". Les conditions humides ont également un impact négatif sur les conflits, en particulier en Afrique où la violence est plus probable pendant les périodes humides que pendant les périodes sèches (Raleigh et Kniveton, 2012).

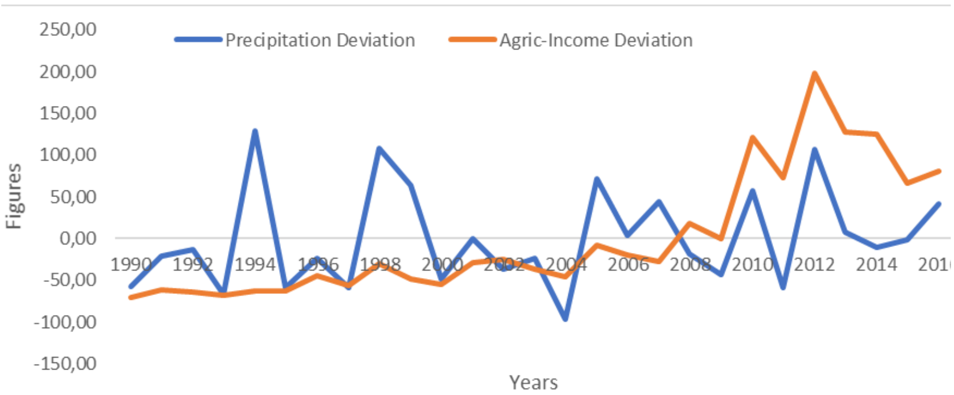
CHANGEMENT CLIMATIQUE, INSÉCURITÉ ALIMENTAIRE ET INSTABILITÉ AU SAHEL

Alors que l'effet du changement climatique sur la violence ne soit pas facile à documenter, son effet sur la sécurité alimentaire, en particulier, semble être plus perceptible, surtout en milieu urbain. Le changement climatique affecte la sécurité alimentaire de diverses manières. L'élévation du niveau de la mer, les catastrophes naturelles, les inondations, la sécheresse sont associées à l'insécurité alimentaire et menacent la sécurité, directement ou indirectement, à travers les migrations. Les deux manifestations majeures du changement climatique au Sahel, sont l'augmentation de la température et la variabilité des précipitations.

Le réchauffement climatique a de nombreux effets économiques et sociaux potentiels en Afrique, notamment au Sahel, qui contrastent avec la contribution minime de la région aux émissions mondiales de gaz à effet de serre (GES). L'exposition de beaucoup de pays africains aux effets du changement climatique devrait atteindre près de la moitié du PIB du continent (Okonjo-Iweala, 2019). En termes de superficie de terres arables, l'Afrique a des dotations beaucoup plus faibles par rapport à d'autres régions du monde, à l'exception des régions désertiques, dont la superficie diminue encore en raison du changement climatique.

Par conséquent, la sécurité alimentaire est menacée au Sahel. Les pays sahéliens sont mal classés par l'Indice Mondial de Sécurité Alimentaire (GFSI) de ''Economist Intelligence Unit''. Sur 113 pays, le Mali est classé 86, le Sénégal 87, le Burkina 97, le Niger 104 et le Tchad 108. Si l'insécurité alimentaire a de nombreux moteurs potentiels au Sahel, le changement climatique est probablement l'un des plus déterminants. Le graphique 1 montre la corrélation entre les précipitations et la production céréalière au Niger. Un schéma clair où les deux variables sont fortement corrélées, témoignant encore plus de l'effet négatif du changement climatique sur la sécurité alimentaire. En raison des variations de la production agricole, provoquées par le changement climatique et d'autres facteurs, les prix des denrées alimentaires montent en flèche au Sahel, compromettant encore davantage la sécurité alimentaire.

Graphique 1 : Précipitations et pénurie de ressources

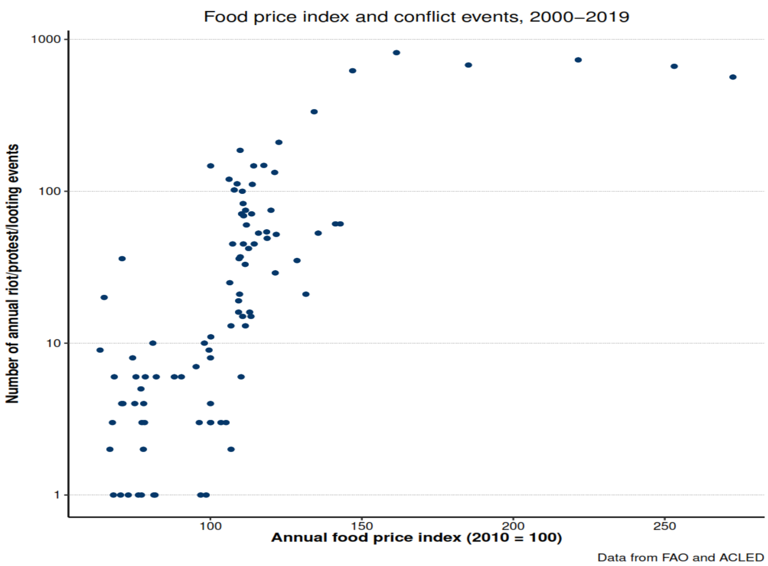


Source: Garba Hima (2019)

Dans les zones côtières aussi, le changement climatique représente sans aucun doute l'un des risques les plus importants pour la sécurité alimentaire en Afrique. En effet, selon des estimations récentes, le niveau des mers pourrait augmenter de 100 cm d'ici 2100 ce qui aggraverait encore les nombreux risques qui menacent la région. En Afrique, comme ailleurs dans le monde, les zones côtières ont tendance à être plus densément peuplées en raison des plus grandes opportunités économiques qu'elles offrent. Selon certaines estimations, la population africaine des zones côtières de faible élévation augmentera à un taux annuel de 3,3 % entre 2000 et 2030, soit plus du double de la moyenne mondiale. Environ 30 millions d'Africains vivent dans la zone inondable autour des océans Atlantique et Indien, dont 2 millions sont susceptibles d'être inondés chaque année (Dasgupta et al., 2010). Les inondations provoquent l'intrusion d'eau salée dans les zones côtières intérieures et ont un impact négatif sur la salinité des cours d'eau, et donc sur la disponibilité d'eau potable et d'eau d'irrigation, ce qui rend l'agriculture hors saison et la pêche en eau douce plus difficiles.

Bien qu'il existe de nombreuses controverses autour de la relation entre le changement climatique et la violence communautaire, il semble y avoir un lien plus direct entre les émeutes et l'augmentation des prix des denrées alimentaires induite par le climat. La figure 2 présente l'indice annuel des prix des denrées alimentaires et les émeutes au Sahel, montrant une nette tendance positive entre les deux variables.

Graphique 2 : Les prix alimentaires et les conflits sont corrélés au Sahel



CHANGEMENT CLIMATIQUE, FAVORITISME ET LE CONFLIT AU SAHEL

Alors que la défaillance de l'État est de plus en plus considérée comme le principal moteur de conflit au Sahel, elle se traduit de différentes manières en Afrique. Tout d'abord, elle se manifeste par le fait que la plupart des gouvernements ont un contrôle très limité sur leurs territoires. L'éloignement et l'inaccessibilité du terrain limitent la capacité des gouvernements à assurer la sécurité à l'intérieur des frontières nationales. Une importante implication de cette absence de contrôle sur le territoire est l'incapacité des États africains à fournir des services de base aux populations situées dans certaines régions éloignées.

Dans les territoires arides et semi-arides du Sahara et du Sahel, l'arrière-pays a souvent besoin d'être intégrés. De même, il est de notoriété publique que la fourniture de services et la représentation politique dans les régions éloignées sont bien en deçà de la moyenne en Afrique15 Deuxièmement, en raison de la nature clientéliste de la plupart des régimes africains, l'Etat tend à indument favoriser les groupes ethniques ou les districts qui votent pour le parti au pouvoir, marginalisant davantage les groupes qui sont considérés comme étant moins favorables.

En Afrique, où les options disponibles en matière d'adaptation au changement climatique, sont limitées, du fait d'un environnement hostile et changeant, d'un manque notoire d'actifs financiers, les conflits portant sur les ressources rares est exacerbée par la ségrégation due à l'appartenance ethnique et/ou politique. Par exemple, les données concernant la Corne de l'Afrique et le Sahel montrent que les groupes moins favorables au parti au pouvoir, sont exclus de l'agenda politique et s'installent généralement dans des zones marginales. Ces mêmes groupes, souvent trop faibles pour exercer la violence contre le gouvernement, le font généralement contre les communautés rivales favorables au parti au pouvoir.

Selon certaines estimations, jusqu'à 65 % des minorités ethno politiques d'Afrique sont défavorisées en termes d'accès aux postes de direction dans l'administration publique africaine ou au sein des armées. De même, l'hypothèse du patronage est également confirmée dans les démocraties africaines, en considérant les trois dimensions suivantes : le fort présidentialisme caractérisant la plupart des pouvoirs africains, le clientélisme pour l'accès aux emplois publics, l'allocation budgétaire, et l'octroi des marchés publics, etc.

Par conséquent, souvent au Sahel, le risque de conflit découlant du changement climatique est déterminé par des vulnérabilités préexistantes, où la politique de répartition des ressources et des risques affecte la stabilité sociale. Plutôt que le changement climatique, l'incapacité des Etats à gérer les rivalités sur les moyens de subsistance, couplée à la récente prolifération des armes, est la principale cause des conflits. En effet, la désintégration de la Libye dans de nombreuses zones de guerre rivales, associée à des frontières internationales poreuses et mal surveillées, a rendu la contrebande sur les armes beaucoup plus facile dans tout le Sahel.

L'absence de consensus dans la littérature sur le lien entre le changement climatique et les conflits tient beaucoup à l'usage de la pluviométrie dans beaucoup de modèles testant la corrélation entre les deux variables. Or, le changement climatique n'est pas toujours associé à la sécheresse. Il s'agit davantage de déviations extrêmes de précipitations (à la fois plus sèches et plus humides), toutes deux associées au conflit. D'un autre côté, de par sa nature même, le conflit a de nombreux facteurs entrelacés qui ne sont souvent pas facilement testables. Ainsi, bien que les régressions économétriques fournissent des informations heuristiques importantes, elles pourraient devoir être complétées par des analyses contextuelles approfondies pour tenir compte des particularités et d'autres facteurs qui ne sont pas correctement reflétés dans les données statistiques. L'absence de consensus dans la littérature sur le lien entre le changement climatique et les conflits tient beaucoup à l'usage de la pluviométrie dans beaucoup de modèles testant la corrélation entre les deux variables. Or, le changement climatique n'est pas toujours associé à la sécheresse. Il s'agit davantage de déviations extrêmes de précipitations (à la fois plus sèches et plus humides), toutes deux associées au conflit. D'un autre côté, de par sa nature même, le conflit a de nombreux facteurs entrelacés qui ne sont souvent pas facilement testables. Ainsi, bien que les régressions économétriques fournissent des informations heuristiques importantes, elles pourraient devoir être complétées par des analyses contextuelles approfondies pour tenir compte des particularités et d'autres facteurs qui ne sont pas correctement reflétés dans les données statistiques.

LE CAS DU MALI

Dans cette section, nous documentons le cas du delta du fleuve Niger au Mali, qui offre une excellente illustration de la manière dont le changement climatique et les institutions interagissent pour alimentent les conflits au Sahel. Le Mali est un pays enclavé du Sahel, à faible revenu, dont le taux de pauvreté est estimé à 47,8 %, alors que la moyenne en Afrique subsaharienne est de 41 % (World Bank, 2018).

Actuellement, le Mali souffre de violences et d'instabilité politique principalement dans le Nord, qui ont des répercussions économiques importantes dans tout le pays. Il existe deux principaux ensembles territoriaux juxtaposés au Mali. Le Nord (le Sahara) est presque vide, avec ses trois régions septentrionales : Tombouctou, Gao et Kidal. Ces régions représentent les deux tiers du territoire national mais ne comptent que dix pour cent (10%) de la population malienne. Le Sud (le Sahel) est plus peuplé avec une agriculture dynamique. Entre les deux zones, Mopti représente la frontière entre le Nord occupé par les djihadistes et le Sud contrôlé par le gouvernement. En 2012, tout le Nord du Mali est passé sous le contrôle des groupes djihadistes Ansar Dine et du Mouvement pour l'Unité et le Jihad en Afrique de l'Ouest (MUJAO). Avançant vers le Sud en direction de la capitale, Bamako, ces groupes ont atteint la ville de Kona dans la région de Mopti en janvier 2013. Le gouvernement malien a alors déclaré l'état d'urgence et a lancé un appel à la France, qui a lancé l'opération Serval, arrêtant les djihadistes et les forçant à se retirer plus au Nord.

Le delta est la principale source de moyens de subsistance pour les agriculteurs, les éleveurs et les pêcheurs. Il englobe un bassin hydrographique qui couvre environ 30 000 km2, où les inondations dépendent principalement des précipitations. Les agriculteurs et les éleveurs coexistent depuis longtemps au Sahel, et les institutions locales ont toujours arbitré les conflits. Cependant, depuis l'indépendance, le gouvernement malien a toujours favorisé les agriculteurs par rapport aux éleveurs. Par exemple, le président Modibo Keïta avait, à de nombreuses reprises, exprimé sa préférence pour l'industrie et l'agriculture, à la place du nomadisme, pour faire avancer son agenda socialiste. Son successeur, Moussa Traoré, n'a pas fait grand-chose pour apaiser la frustration des nomades dans le temps.

Au Mali, une ligne de démarcation claire détermine les moyens de subsistance en fonction de l'appartenance ethnique, avec une division sociale du travail principalement basée sur l'appartenance ethnique. Par exemple, les Peuls et les Touareg ont tendance à être des éleveurs, tandis que les Songhaïs et les Bambaras ont tendance à être des agriculteurs. Les Peuls et les Touaregs sont musulmans, tandis que les Bambaras et les Songhaïs sont des animistes (religion traditionnelle africaine). Les modèles récents de conflits communautaires au Mali illustrent comment les facteurs ethniques et religieux, ainsi que les échecs du gouvernement, interagissent avec le changement climatique pour provoquer des conflits.

Le fleuve Niger est le siège d'une intense activité agricole, tant pour les agriculteurs que pour les éleveurs. Tandis que les agriculteurs cultivent le riz, les éleveurs cultivent le Burgu, une culture fourragère qui est la principale source d'alimentation animale pendant la saison sèche. Le Burgu pousse dans des eaux plus profondes que le riz, et pendant les périodes sèches, qui sont de plus en plus fréquentes en raison du changement climatique, les riziculteurs empiètent souvent sur les champs de Burgu, ce qui déclenche des conflits communautaires. Depuis les années 1950, un quart des champs de Burgu ont été convertis en rizières en raison de la diminution des précipitations.

Récemment, les Peuls et les Touaregs se joignent de plus en plus à l'insurrection djihadiste dans le Nord du Mali en raison de la double pression exercée par la prétendue discrimination gouvernementale et le conflit pour l'eau exacerbé par le changement climatique. Amadou Koufa, le chef de l'Unité et le Jihad en Afrique de l'Ouest MUJAO, est peul. Dans ce contexte, les attaques djihadistes déclenchent des représailles de la part des agriculteurs bambara et songhaï, aggravant le cercle vicieux de la haine et de la violence.

BESOINS D'ADAPTATION AU CHANGEMENT CLIMATIQUE

Le changement climatique est une cause immédiate importante de conflit au Sahel, aggravant les causes profondes : les défaillances étatiques et institutionnelles. L'adaptation au changement climatique est donc essentielle pour atténuer les conflits, ainsi que les mises à niveau institutionnelles. L'adaptation englobe de nombreuses couches d'options politiques. Diversifier les moyens de subsistance loin des activités dépendantes des conditions météorologiques, telles que la pêche artisanale et l'agriculture traditionnelle, est essentiel. Cet objectif peut être atteint en transformant les cultures traditionnelles et les produits primaires de manière à ce qu'ils progressent dans l'échelle des chaînes de valeur mondiales. De plus, l'intégration de l'innovation dans le processus de production en introduisant des variétés de cultures plus tolérantes à la sécheresse et aux inondations, et en incluant des équipements et technologies modernes, peut renforcer cette stratégie. Construire des granges pour permettre d'avoir de l'ombre et une meilleure circulation de l'air pourrait protéger les animaux des températures plus élevées.

Les travailleurs familiaux informels, les travailleurs indépendants et les travailleurs des microentreprises dominent massivement le paysage des activités rurales et semi-urbaines dans l'agriculture, l'élevage et la pêche, qui sont les plus affectées par le changement climatique. L'autonomisation de ces acteurs devrait être un aspect important de toute stratégie d'adaptation. Cela comprend le développement de programmes bien ciblés, y compris des programmes de financement adéquats, le développement des compétences et l'incubation, pour aider ces entreprises fragiles à croître et à se consolider.

Étant donné les faibles contributions de l'Afrique aux émissions mondiales, contrastant avec son exposition beaucoup plus élevée au changement climatique, il existe un quasi-consensus sur le fait que l'adaptation devrait être davantage prise en compte dans l'allocation du financement climatique. Alors que la communauté internationale s'est engagée à accroître considérablement son soutien à l'adaptation au changement climatique, les ressources disponibles pour soutenir l'adaptation en Afrique sont encore très limitées, se cumulant à moins de 2 milliards de dollars. En revanche, on estime que les investissements nécessaires pour soutenir l'adaptation en Afrique sont de l'ordre de 300 milliards de dollars, et l'entretien annuel de l'ordre de 3 milliards de dollars. Le renforcement du financement de l'adaptation et l'amélioration des mécanismes d'allocation pour les rendre plus efficaces que les méthodes classiques d'aide au développement devraient être une priorité clé du développement.

CONCLUSION

La relation entre le changement climatique et les conflits génère des controverses considérables dans la littérature. Alors que certains auteurs considèrent que la rareté des ressources induite par le climat provoque des conflits, un nombre croissant de preuves empiriques mettent l'accent sur les échecs institutionnels. Dans cet article, nous avons utilisé le Sahel comme étude de cas pour montrer que le conflit a de nombreux facteurs interdépendants, principalement liés à l'échec de l'État, à la démographie et à la recherche de rente.

Le changement climatique exacerbe les rivalités existantes et contribue à l'apparition de la violence. Ainsi, l'adaptation au changement climatique devrait être un pilier important des politiques visant à atténuer les conflits au Sahel. L'adaptation englobe de nombreuses dimensions, notamment une diversification des économies qui réduirait la dépendance des ressources naturelles brutes, une meilleure intégration de l'innovation et l'appui aux travailleurs informels qui sont plus exposés aux effets du changement climatique.

RÉFÉRENCES BIBLIOGRAPHIQUES

Adano, W. R., Dietz, T., Witsenburg, K., & Zaal, F. (2012). Climate change, violent conflict and local institutions in Kenya's drylands. Journal of peace research, 49(1), 65-80.

African Union Commission, "African Gender Scorecard," December 2015, https://au.int/sites/default/files/documents/31260 -doc-2015_auc_african_gender_scorecard_en.pdf.

Ahmadou Aly Mbaye, "Confronting the Challenges of Climate Change on Africa's Coastal Areas," Brookings Institution, January 16, 2020, https://www.brookings.edu/blog/africa-in-focus/2020/01/16/confronting-the-challenges-of-climate-change-on-africas-coastal-areas/;CharleneWatson and Liane Schalatek, "Climate Finance Thematic Briefing: Adaptation Finance," Climate Finance Fundamentals Brief #10, February 2019, https://climatefundsup date.org/publications/climate-finance-the matic-briefing-adaptation-finance-2018/.

Alisher Mirzabaev, "IPCC Special Report on Climate Change and Land: Implications for Western Africa," Proceedings of the UCADZEF Conference on Climate Change and

Food Security in West Africa, November 18–19, 2019, http://wascal.ucad.sn/images/wascal /Wascal_conf/dakar_alisher%20mirzabaev.pdf.

Barbelet, V., & Goita, M. D. (2015). Marchés en crise: le conflit au Mali. Overseas Development Institute. https://www.odi.org/sites/odi.org .uk/files/odi-assets/publications-opi nion-files/10214.pdf.

Bauer, M., Blattman, C., Chytilová, J., Henrich, J., Miguel, E., & Mitts, T. (2016). Can war foster cooperation? Journal of Economic Perspectives, 30(3), 249-74.

Benjaminsen, T. A., & Berge, G. (2004). Une histoire de Tombouctou.

Benjaminsen, T. A. (2008). Does supply-induced scarcity drive violent conflicts in the African Sahel? The case of the Tuareg rebellion in northern Mali. Journal of Peace Research, 45(6), 819-836.

Benjaminsen, T. A., Alinon, K., Buhaug, H., & Buseth, J. T. (2012). Does climate change drive land-use conflicts in the Sahel? Journal of peace research, 49(1), 97-111.

Ben Wisner, Piers Blaikie, Terry Cannon, and Ian David, At Risk: Natural Hazards, People's Vulnerability and Disasters, 2nd ed. (New York: Routledge, 2004); Siri H. Eriksen, Katrina Brown, and P. Mick Kelly, "The Dynamics of Vulnerability: Locating Coping Strategies in Kenya and Tanzania," The Geographical Journal 171, no. 4 (2005): 287–305.

Burke, M. B., Miguel, E., Satyanath, S., Dykema, J. A., & Lobell, D. B. (2009). Warming increases the risk of civil war in Africa. Proceedings of the national Academy of sciences, 106(49), 20670-20674.

Coast, E. (2002). Maasai socioeconomic conditions: a cross-border comparison. Human ecology, 30(1), 79-105.

Collier, Paul, and Anke Hoeffler (2004). "Greed and grievance in civil war." Oxford economic papers 56.4: 563-595.

Coulibaly, H., & Lima, S. (2013). Crise de l'État et territoires de la crise au Mali. EchoGéo.

Dasgupta, S., Laplante, B., Murray, S., & Wheeler, D. (2011). Exposure of developing countries to sea-level rise and storm surges. Climatic Change, 106(4), 567-579.

Defrance, D., Ramstein, G., Charbit, S., Vrac, M., Famien, A. M., Sultan, B., ... & Vanderlinden, J. P. (2017). Consequences of rapid ice sheet melting on the Sahelian population vulnerability. Proceedings of the National Academy of Sciences, 114(25), 6533-6538.

Djankov, S., & Reynal-Querol, M. (2010). Poverty and civil war: Revisiting the evidence. The Review of Economics and Statistics, 92(4), 1035-1041.

Famine Early Warning Systems Network, "FEWS NET Data Center," https://fews.net/fr/fews-data/337; Armed Conflict Location & Event Data Project (ACLED), "The Armed Conflict Location & Event Data Project," https://acleddata.com/#/dashboard.

Garba Hima, Mamane Bello (2019). Analyse économique de la rareté des ressources induite par les Changements Climatiques et les conflits armés au Niger. Université Cheikh Anta Diop, Thèse de Doctorat. https://wascal.ucad.sn/fr/these_doctorat

Hendrix, Cullen S., and Idean Salehyan. "Climate change, rainfall, and social conflict in Africa." Journal of peace research 49.1 (2012): 35-50".

IPCC., A. S. (2007). Climate change 2007: synthesis report. Summary for Policymakers.

Jeffrey Herbst (200). States and Power in Africa: Comparative Lessons in Authority and Control (Princeton, NJ: Princeton University Press).

Kouyaté, S. (2006). Etude des enjeux nationaux de protection du basin du fleuve Niger [Study of the national challenges in protecting the river basin of the Niger river]. Report to Groupe de Coordination des Zones Arides (GCOZA). Bamako: GCOZA.

Krystel M. R. Dossou and Bernadette Glehouenou-Dossou, "The Vulnerability to Climate Change of Cotonou (Benin): The Rise in Sea Level," Environment & Urbanization 19, no. 1 (2007): 65–79; Bastien Alex and Francois Gemenne, "Impacts du Changement Climatique sur les Flux Migratoires a l'Horizon 2030," Observatoire des Enjeux Geopolitiques de la Demographie, May 2016, https://www.iris-france.org/wp-content/uploads/2016/09/2016-mai-Etude-Impact-du-changement-climatique-sur-les-flux-migratoires-%C3%A0-lhorizon-2030.pdf;Francois Gemenne, Julia Blocher, Florence de Longueville, Sara Vigil Diaz Telenti, Caroline Zickgraf, Dalila Gharbaoui, and Pierre Ozer, "Changement Climatique, Catastrophes Naturelles et Deplacements de Populations en Afrique de l'Ouest," Geo-Eco-Trop 41, no. 3 (2017): 317–37.

Marcus Alexander and Matthew C. Harding,"Is Poverty to Blame for Civil War? Evidence from Nonlinear Fixed Effects Estimation,"Paper presented at the Econometric Society World Congress, 2005,https://www.researchgate.net/profile/Marcus_Alexander3/publication/313794808_Is_poverty_to_blame_for_civil_war_New_evidence_from_nonlinear_fixed_effects_estimation/links/58a62e9e92851cf0e3b4b61a/Is-poverty-to-blame-for-civil-war-New-evidence-from-nonlinear-fixed-effects-estimation.pdf.

Mbaye, "Confronting the Challenges"; Watson and Schalatek, "Climate Finance Thematic Briefing"; Jochen Hinkel, Sally Brown, Lars Exner, Robert J. Nicholls, Athanasios T. Vafeidis, and Abiy S. Kebede, "Sea-Level Rise Impacts on Africa and the Effects of Mitigation and Adaptation: An Application of DIVA," Regional Environmental Change 12, no. 1 (2012): 207–24.

Mbaye, A. A. (2019). Africa's climate crisis, conflict, and migration challenges. Brookings: The Brookings Institution. https:// www.brookings.edu/blog/africa-in-focus /2019/09/20/africas-climate-crisis-conflict -and-migration-challenges/

Miguel, E., & Zaidi, F. (2003). Do politicians reward their supporters? Regression discontinuity evidence from Ghana. Retrieved June, 8, 2008. https:// www.international.ucla.edu/media/files Miguel_Zaidi.pdf.

Miguel, E., Satyanath, S., & Sergenti, E. (2004). Economic shocks and civil conflict: An instrumental variables approach. Journal of political Economy, 112(4), 725-753.

Miguel, E. (2005). Poverty and witch killing. The Review of Economic Studies, 72(4), 1153-1172.

Mondiale, B. (2007). Les pays en voie de développement se préparent à faire face au changement climatique.

N. Diop, "Pêche Maritime et Changement Climatique," mémoire ISE/UCAD, 2007; V. W. Y. Lam, W. W. L. Cheung, W. Swartz, and U. R. Sumaila, "Climate Change Impacts on Fisheries in West Africa: Implications for Economic, Food and Nutritional Security," African Journal of Marine Science 34, no. 1 (2012): 103–17.

Ngozi Okonjo-Iweala (2019), '' Africa can play a leading role in the fight against climate change''. https://www.brookings.edu/wp-content/uploads/2020/01/ForesightAfrica2020_Chapter4_20200110.pdf

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. Proceedings of the national Academy of sciences, 104(39), 15181-15187.

Ostrom, E. (2007). Challenges and growth: the development of the interdisciplinary field of institutional analysis. Journal of Institutional Economics, 3(3), 239-264.

Pelling, M., & Dill, K. (2006). Natural'disasters as catalysts of political action. Media Development, 53(4), 7. http://www.disasterdiplomacy.org/pb /pellingdill2006.pdf.

Raleigh, C., Linke, A., Hegre, H., & Karlsen, J. (2010). Introducing ACLED: an armed conflict location and event dataset: special data feature. Journal of peace research, 47(5), 651-660.

Raleigh, C., & Kniveton, D. (2012). Come rain or shine: An analysis of conflict and climate variability in East Africa. Journal of peace research, 49(1), 51-64.

Raleigh, C., Choi, H. J., & Kniveton, D. (2015). The devil is in the details: An investigation of the relationships between conflict, food price and climate across Africa. Global Environmental Change, 32, 187-199.

Rajendra K. Pachauri and Andy Reisinger,eds., "Climate Change 2007: Synthesis Report,"Intergovernmental Panel on Climate Change, 2008, https://www.ipcc.ch/site/assets /uploads/2018/02/ar4_syr_full_report.pdf.

Scarritt, J. R., & McMillan, S. (1995). Protest and rebellion in Africa: Explaining conflicts between ethnic minorities and the state in the 1980s. Comparative Political Studies, 28(3), 323-349.

Unit, E. I. (2018). Global Food Security Index 2018: Building Resilience in the Face of Rising Food Security Risks. Global food Seciruty Index.

Witsenburg, K. M., & Adano, W. R. (2009). Of rain and raids: Violent livestock raiding in northern Kenya. Civil Wars, 11(4), 514-538.

World Bank (2010). Young People in Arab Countries: Promoting Opportunities and Participation, (Marseilles, 2010).

World Bank (2018). "Poverty and Shared Prosperity Prosperity 2018: Piecing Together the Poverty Puzzle,"https://openknowledge.worldbank.org/bitstream/handle/10986/30418 /9781464813306.pdf;

Institut National de la Statistique (INSTAT), "Comptes Economiques du Mali, 1999–2013," August 2015, http:// www.instat-mali.org/contenu/pub/compnat 99-13_pub.pdf.

Climate Change, Livelihoods and Migration in West Africa

Alex de Sherbinin

ABSTRACT

Based on the UN list of least developed countries, West Africa is one of the world's least developed regions and has among the highest rates of population growth. This creates challenges that, when overlaid with climatic changes, may engender significant redistribution of population within the region. Given the role that environmental factors have played in mobility patterns in the past, we can expect that they will continue to play a similar role in the future. Indeed, it is likely that climate variability and extremes in the landlocked portions of the Sahel are likely to drive new climate migration into the coastal zone, which will only increase the exposure of populations to the effects of sea level rise and storm surge. As in the past, climate impacts may arrive in the form of disturbances that are hard to predict, and whose ramifications for the socio-ecological system and migration are even harder to predict. This chapter presents climate trends and projections and a review of existing evidence for climate and environmentally induced migration in the region both in dryland areas and in the coastal zone.

Keywords: Vulnerability, Coastal Zones, Climate migration, West Africa

RÉSUMÉ

Sur la base de la liste des pays les moins développés établie par les Nations unies, l'Afrique de l'Ouest est l'une des régions les moins développées du monde et affiche l'un des taux de croissance démographique les plus élevés. Cela crée des défis qui, lorsqu'ils se superposent aux changements climatiques, peuvent engendrer une redistribution significative de la population au sein de la région. Étant donné le rôle que les facteurs environnementaux ont joué dans les schémas de mobilité par le passé, on peut s'attendre à ce qu'ils continuent à jouer un rôle similaire à l'avenir. En effet, il est probable que la variabilité et les extrêmes climatiques dans les parties enclavées du Sahel soient à l'origine de nouvelles migrations climatiques vers la zone côtière, ce qui ne fera qu'accroître l'exposition des populations aux effets de l'élévation du niveau de la mer et des ondes de tempête. Comme par le passé, les impacts climatiques peuvent arriver sous la forme de perturbations difficiles à prévoir, et dont les ramifications pour le système socio-écologique et la migration sont encore plus difficiles à prévoir. Ce chapitre présente les tendances et les projections climatiques ainsi qu'un examen des preuves existantes concernant les migrations induites par le climat et l'environnement dans la région, tant dans les zones arides que dans la zone côtière.

Mots clés: Vulnérabilité, Zones côtières, Migration climatique, Afrique de l'Ouest

INTRODUCTION

West Africa is one of the most mobile regions of the world owing to a long history of trade (trans-Saharan and intra-regional), nomadic pastoralism, dry season migration for livelihood diversification, legacies of colonialism (labor expropriation from the interior towards coastal plantations), and economic linkages to former colonial powers. Migration has been greatly facilitated by an enabling policy framework, the free movement protocol of the Economic Community of West African States (ECOWAS), which enshrines the ability of West African citizens to live and work in any country of the region. The region also has experienced and is likely to experience in the future some of the worst impacts of climate change, including rising temperatures, erratic rainfall, increasingly intense rainfall events, flooding, and coastal erosion owing to heightened storms and sea level rise. When coupled with the high dependence of most coastal countries on the agriculture and fisheries sectors, as well as the high concentration of people and assets along the coast, the economy and livelihoods of West African countries are highly vulnerable to climate variability and change. Development practitioners and humanitarians are concerned that climate impacts over the coming decades may spur even higher rates of migration – both the kinds of migration that are an adaptation to climate change and bring more stable livelihoods and higher incomes, and distress migration from intolerable situations that leave the migrants impoverished and with few options (Black et al. 2011).

This paper provides a brief overview on West Africa's climate trends and projections before turning to a review of the literature on climate impacts on migration in dryland and coastal areas.

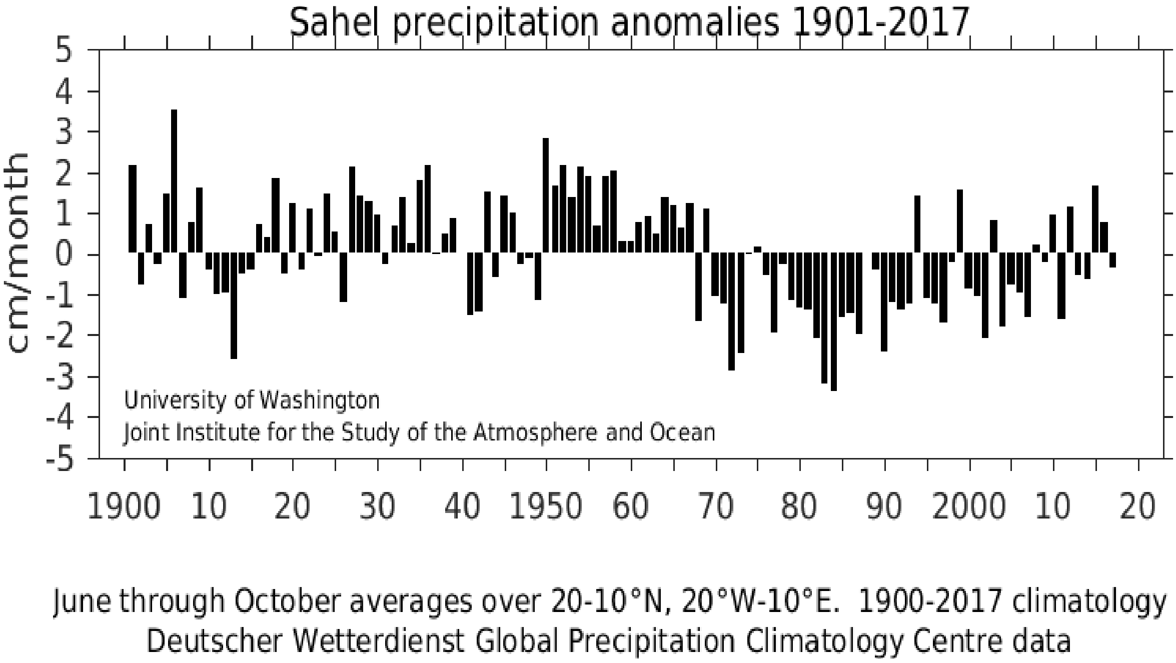
CLIMATE TRENDS AND PROJECTIONS

West Africa is one of the world regions that has been most frequently identified as a hotspot of current and future climate impacts (Turco et al. 2015, Muller et al. 2014, Niang et al. 2014). Major impacts identified in the literature include rising temperatures, heat waves, erratic rainfall (delays in monsoon onset or dry periods during the rainy season), increasingly intense rainfall events, flooding, and coastal erosion owing to heightened storms and sea level rise. In terms of local livelihoods, these trends are exacerbated by a degraded natural resource base owing to rising population densities sustained by low input agriculture.

The Sahel has been known for a series of widespread droughts with extreme impacts on food security in the region and humanitarian crises which have led to displacement and migration. The analysis of long-term rainfall time-series over the Sahel (Figure

1) shows the interannual persistence of dry conditions starting in the late 1960s and lasting until the 2000s, while the previous 50 years (roughly 1920–1968) were much wetter. These oscillations, which occur in roughly 10-year increments, are referred to as "decadal variability." The coastal zone has not experienced the persistence of the dry conditions to the same degree, and a similar analysis (not shown) shows a stronger interannual variability there, although a long-term decline is noticeable.

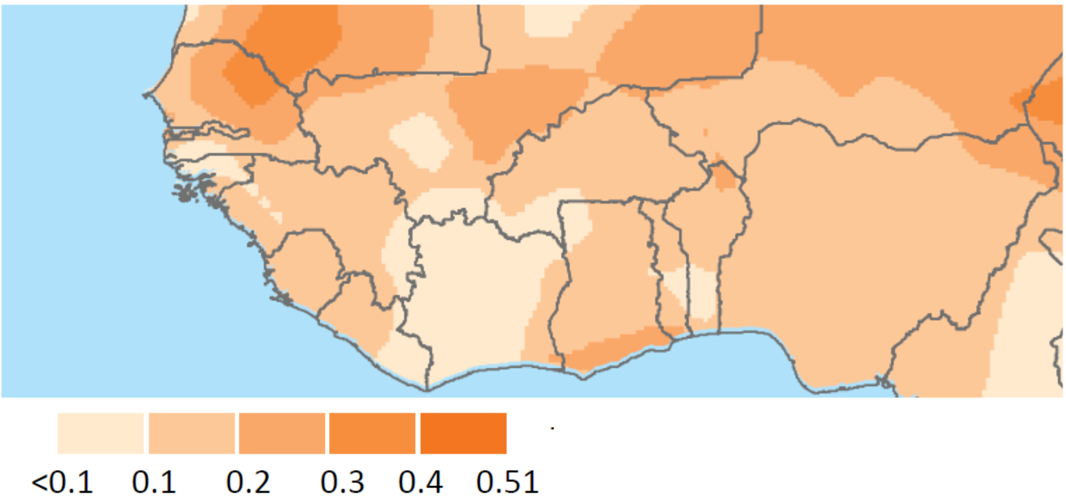
Figure 1. Long-term evolution of seasonal rainfall in the Sahel. Bars represent rainfall averaged over June–October seasons (in cm/month) over the area 10º–20ºN, 20ºW–10ºE, from 1900–2017. Source: JISAO.



The great Sahelian droughts were initially attributed to the local changes in vegetation and land use and their subsequent feedback on monsoon dynamics (Charney et al. 1975). However, this mechanism cannot explain sporadic increases in rainfall during the dry epoch as well as a more recent return of rainfall to more average conditions. Thus the early claims that declining precipitation in the region was due to a land surface feedback owing to land degradation from population pressures have largely been put to rest (Kandji et al. 2006). Research since the 1990s has demonstrably shown that the source of this decadal variability lies in the decadal variability of global sea surface temperatures (SSTs) (Janicot et al. 2001) with a potential impact of the Indian Ocean (Bader and Latif 2003), while the vegetation feedback plays only a secondary role (Zeng et al. 1999). Seasonal rainfall amounts have partially recovered since the major droughts of the 1980s, but rainy season characteristics have changed: rainfall is more intense and intermittent and wetting is concentrated in the late rainy season and away from the west coast (Biasutti 2019).

The existence of decadal variability in the Sahel—and to a lesser extent in the coastal region—masks potential longer-term temperature and rainfall trends in West Africa. In terms of temperature, the drier years of the droughts in the 1970s and 1980s have tended to be hotter than average. Furthermore, temperature levels recorded over the past 20 years are only slightly higher than the temperatures recorded in the 1920s and 1930s. While further monitoring of temperatures is needed to assess the impact of anthropogenic climate change, all of West Africa has experienced temperature increases and there are areas– northeastern Senegal and southern Mauritania, eastern Mali, northern Benin, and coastal Ghana – that have experienced higher temperature changes of up to 1.5-2.0oC from 1950 to 2013 (Figure 2). According to research by Turco et al. (2015), regional climatic changes – including changes in temperature (trends and extremes), precipitation (total and variation) since 1950-81 – have been extreme enough to qualify West Africa as one of a handful of global observed climate change hotspots.

Figure 2. Temperature change in degrees Celsius per decade from 1951-2013. (source: Zomers et al. 2016)



Whether changes are due to anthropogenic warming or natural variability is still the subject of some debate, and several modeling studies have attempted to discriminate between these factors in the Sahel. If some studies attributed the multidecadal drying of the Sahel to changes in atmospheric composition (Biasutti and Giannini 2006), others have shown that only 10% of the Sahelian drying in the twentieth century was attributable to anthropogenic climate change and global warming, and that long-term variations in SSTs are significantly more influential (Mohino et al. 2011). Most studies highlight the current difficulty in robustly attributing and quantifying the role of competing influences over the region (Ting et al., 2009; Caminade and Terray, 2010).

Turning to future climate projections, there is high confidence that warming will continue (Knutti and Sedlacek 2012). Temperature projections over West Africa for the end of the 21st century from global climate simulation range between 3 and 6°C above the late 20th century baseline depending on the emission scenario (Riede et al. 2016, Niang et al. 2014), and the increase is projected to be higher in the Sahelian than in the coastal region. This will have significant impacts on water availability and crop production, since higher temperatures drive higher rates of evapotranspiration no matter what the future trends in rainfall. Temperature extremes alter the optimal growing conditions of a plant and negatively affect plant reproduction, resulting in reduced yields (Battisti and Naylor 2009); furthermore temperature is more difficult to control than soil moisture, which can be altered through irrigation (Dillon et al. 2011). By 2050, it is expected that 70-90% of summer average temperatures in West Africa will exceed the highest summer temperature observed on record (Battisti and Naylor 2009).

In terms of rainfall projections, multi-model means from the Coupled Model Intercomparison Project phase 5 (CMIP5) archive suggest a drying in the coastal portions of West Africa and wetting in the eastern Sahel for the rainy season. But the models generally do not agree and hence results are not considered robust (Knutti and Sedlacek 2012). For the Sahel region as whole, climate projections show a slight increase of total precipitation and a longer rainy season with a drier phase within (Riede et al. 2016). Yet capturing the West African monsoon remains a challenge to climate modeling groups. Most models do not produce sufficient precipitation across the Sahel in summer (Biasutti et al. 2008) despite the fact that they tend to overestimate the length of Sahelian rainy season, starting the monsoon too early and extending it too late (Biasutti and Sobel 2009). They also fail to reproduce the fast shift between the coastal and the Sahelian locations of the rainbelt. Several important features of the monsoon itself are not well represented, mostly due to the coarse resolution of the models. That said, while uncertainty in future projections remains, confidence in them is encouraged by the recognition that overall rainfall depends on large-scale drivers of atmospheric circulations that are well resolved by current climate models (Biasutti 2019).

REVIEW OF EVIDENCE FOR ENVIRONMENTAL AND CLIMATE MIGRATION

The West Africa region has long had high levels of internal and intra-regional migration owing to a history of seasonal and longer-term migration as a livelihood strategy (Bruning and Piguet 2018, Tacoli 2011), especially between the semi-arid Sahel region and the tropical coastal countries to their south. The long history of migratory movements – short-term, circular, seasonal, and longer-term – has affected the culture in significant ways, such that some speak of a “migratory culture” and migration as a “rite of passage” for young men (Bruning and Piguet 2018, Romankiewicz and Dovenspeck 2015). Yet, as these same authors note, environmental, social and economic changes are affecting these longstanding cultural forms in new ways – and disentangling which factors are most important gets to the crux of contemporary research on environmental migration. Culturally embedded understandings and perceptions of the changes themselves may be more important than the objective changes themselves (Romankiewicz and Dovenspeck 2015).

Research in the Drylands of West Africa

The majority of research on environmental migration centers on the large dryland areas of the Sudano-Sahel zone. Research on drylands adaptation strategies in Africa suggests that migration is one of a suite of coping / adaptation measures that households adopt in the face of environmental changes and shocks, but is generally not the most important (Wiederkehr et al. 2018). Crop, livestock, soil and water management are by far the most common, while migration, livelihood diversification, food aid, social networks and religious activities are also widely used. Job seeking and livelihood diversification definitely influence migrant decision making in the Sahel (Neumann & Hermans 2015), but a growing body of research has found evidence that these decisions are in turn influenced by climate change and variability that impact livelihoods (van der Land et al. 2018). Climate, land scarcity and degradation, operate indirectly on economic factors (e.g. through variable and declining crop yields) which affects food availability and incomes at the household level.

Yet, connections between climate and migration are complex (Borderon et al. 2018). The costs and risk associated with migration as an adaptation strategy are the root causes of this complexity. Hardship from crop failure may increase the appeal of migration but reduce the resources needed to migrate. Conversely, improved livelihoods, e.g. after good crop yields, may provide sufficient resources to enable a family member to migrate and further diversify and insure future family incomes. Consequently, prior research has found complex relations between climate factors and migration.

In a study of the 1983-85 drought in Mali that severely stressed families, Findley et al. (1993) found that short-distance, seasonal movements of people increased, but that costly international migration rates dropped. Using data from a long-term demographic observatory in Niakhar district of Senegal, Lalou and Delauney (2017) find that temporary migration, especially among men, has kept a fairly strong sensitivity to climatic variations. They note, however, that internal migratory movements from the peanut basin have long been linked with high population density and environmental shocks, and long-term migration is still relatively rare. Grace et al. (2018), in a panel study from 1981-2009 in two villages in eastern Mali, find that a decrease in rainfall does not directly lead to a higher out-migration, but they posit that in areas where circular seasonal migration is the norm, drought may induce more people to stay put. They hypothesize that resources may be too scarce to migrate, and that local migration destinations would be similarly drought affected, providing fewer work opportunities. Romankiewicz and Dovenspeck (2015) use multi-level ethnographic approaches to examine environmental migration in northern Senegal and eastern Mali, finding that local meanings and perceptions of environmental change are important for understanding migration motivations. They observe that increases in rainfall do not automatically lead to better crop yields, since a number of other factors intervene, including its distribution within the rainy season (as discussed above) as well as access to inputs (seeds, pesticides and fertilizer), decreasing soil fertility, insufficient cropland and equipment, and lack of labor.

Using available census data for 10 countries in Sub-Saharan Africa (4 of which are in West Africa), Garcia et al. (2015) find that climatic variables have only a limited impact on migration, but with strong heterogeneity across countries in the sample. In Burkina Faso, Gray and Wise (2016) observe that rising temperatures (associated with declining crop yields) correlate with lower migration, both domestic and international, suggestive of reduced resources to migrate. By contrast, lower levels of precipitation seem to positively affect international migration. Also in Burkina Faso, a nationally representative retrospective study on rainfall and migration conducted from 2000 to 2002 (Henry et al., 2004) found that people from drier northern regions are more likely to migrate temporarily and to a lesser extent permanently to other rural areas (rural-rural migration) compared with people from wetter areas. Rainfall deficits were found to increase rural-rural migration but, in contrast to Gray and Wise, decrease international migration, with no changes in urban-rural migration. Other evidence from northern Burkina Faso suggests that recent droughts have led pastoralists in the Sahel province to either abandon livestock raising and move west or to urban centers, or to move herds to more vegetation-abundant low lying areas resulting in the degradation of the few fertile areas left (Traoré and Owiyo 2013). Consistent with Widerkehr et al., for households facing drought migration is mentioned as an adaptation strategy by 41% of households, behind modification of food consumption (87%), sell property

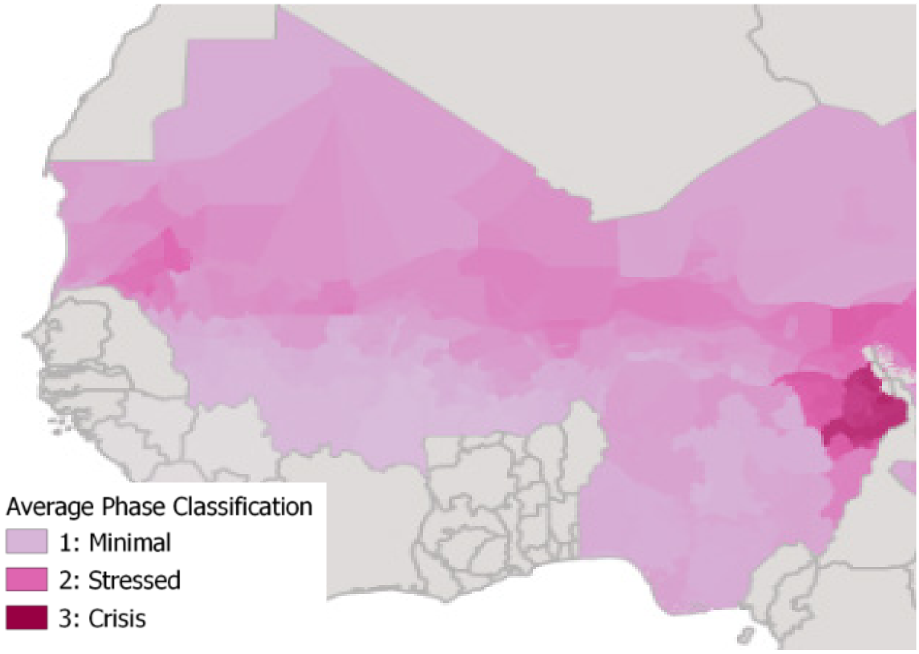
(79%), spend less money (73%), and receive support (51%). Finally, Dillon et al. (2011) find that higher temperatures are associated with increased migration in Northern Nigeria, positing that such temperature increases reduce agricultural yields.

As reflected in recent systematic reviews (Wiederkehr et al. 2018, Borderon et al. 2018, van der Land et al. 2018, Bruning and Piguet 2018), there is little consensus on the importance of climate variables as drivers of migration owing to a diversity of methods employed, differences in local contexts, and hypotheses. These studies are also limited insofar as they don't address future impacts of climate change, which are likely to be significant in the Sahel. There are also differences in theoretical framings between quantitative analyses and anthropological approaches, with anthropologists and others adopting a political ecology perspective critiquing more data-driven approaches as insufficiently aware of local contexts (power dynamics, market access, culture, local perceptions of the "environment") and overly willing to ascribe causality to climate factors (Ribot et al. 2020, Hochleithner and Exner 2018, Romankiewicz and Dovenspeck 2015). The latter studies are sometimes accused of "climate determinism", but this moniker itself may be an over-simplification. This is because both camps agree that climate factors do not operate in isolation but work through existing migratory systems and the economic and social factors that are the proximate determinants of migration (Bruning and Piguet 2018, Foresight 2011). Very few studies argue that climate factors are among the pre-eminent drivers.

A report on the potential for "high end" climate change (+4oC this century) to impact on resources and society in ways that might trigger migration and displacement (New et al. 2011) found that five West African countries (Senegal, Guinea, The Gambia, Sierra Leone, and Mauritania) are at risk of multiple impacts affecting water supplies, agriculture, and coastal zones (owing to sea level rise), which places them in the top 30 of such countries around the world. White (2011), on the other hand, suggests that if the Sahel tips toward a "greener" and moister state, migration, if correlated with drying, could actually decline. Kniveton et al. (2012) conducted agent-based modeling for Burkina Faso based on multiple population change and migration scenarios and find that most of the scenarios show that the percentage of people migrating (from the original population) declines owing to a "wetting rainfall trend" in the ensemble scenarios, but that drier scenarios do produce enhanced migration. They find that with increasing levels of projected population growth, the climate change signal is enhanced, producing more migration.

Whatever the average rainfall trends for the Sahel, the number of extreme events is likely to increase, including both floods and droughts (IPCC 2012, Warner et al. 2012). The UK Government's Foresight project on migration and environmental change finds that under two scenarios of future climate and economic change there is a substantial risk of increased population displacement from river flooding in the region, along with displacement from sea level rise and flooding in the coastal zone (Foresight 2011). Drought risks remain a significant threat to the region, as evidenced by recurring droughts and associated food insecurity in the region (Figure 3), and are likely to drive displacement in the future, unless adaptive responses are developed. Cervigni et al. (2016) find that the number of vulnerable people in drylands in Niger will more than triple between now and 2030, and will more than double in Liberia, Senegal, and Togo.

Figure 3. Average value of quarterly reports of the Integrated Phase Classification for food security from 2009-2018. (Source: FEWSNET data processed by CIESIN)



Research in the Coastal Zone of West Africa

Climate change impacts will also have repercussions for the coastal zone, including the humid southern regions of West Africa, insofar as migrants from the interior may be attracted to urban areas along the coasts (Bruning and Piguet 2018, Adepoju 1995). In recent years, southward migration and urbanization have continued in the forest and savannah countries, with climatic factors contributing to the movement (Van der Geest et al. 2010, UNEP 2011, Rademacher-Shulz and Mahama 2012). A global migration modeling effort found that roughly 10.6 million people left the West African drylands from 1970 to 2000, whereas a nearly equivalent number, 9.2 million, migrated to coastal ecosystems (CIESIN 2011). Of the 9.2 million migrants to the coastal ecosystems, some 6.6 million people moved to the low elevation coastal zone (the area from 0–10 m above sea level), mostly to urban areas, which suggests that many of West Africa's migrants are moving toward areas at risk of sea level rise (de Sherbinin et al., 2012). Consistent with this finding, urban growth rates have generally outstripped rural population growth rates in the region by 2-3 times in magnitude (UNDESA 2018), and most of the region's largest urban areas are situated in the coastal zone.

Approximately 10.8 million people in the region live in the low elevation coastal zone under 5 meters in elevation, and 19 millions (or seven percent of the population) live between 0-10 meters (CIESIN 2013), and those numbers are increasing over time owing to a combination of natural increase and migration. As in much of the world, West Africa's coastal zone hosts the largest cities and is a magnet for new migrants (de Sherbinin et al. 2007 and 2012). The impact of sea level rise and increased storm surge have yet to actually register in terms of increased outmigration from the coast except in limited areas such as St. Louis, Senegal (Zickgraf 2018), and Cotonou, Benin (Dossou and Glehouenou-Dossou 2007). Research in Ghana's Volta Delta, for example, has found a relatively modest levels of out-migration largely driven by the search for employment and not environmental hazards, though these hazards are reported to put livelihoods at risk (Ayamga et al. 2019).

Data on sea level rise is generally sparse in the region owing to the lack of tide gauge data. A study by Melet et al. (2016) found that sea levels have risen by 3.21 mm per year from 1993-2012 at Cotonou, with most of this change owing to thermal expansion of the oceans and land ice loss in response to climate change. Sea level rise projections for West Africa vary depending on the model used from 0.4 to 0.5 meters by 2090 (Brown et al. 2016), but these do not take into account storm surge and increased wave action (Melet et al. 2018). Wave action in particular has an important impact on coastal erosion in the region. Appeaning Addo (2013) developed a Coastal Vulnerability Index (CVI) for Accra based on the methodology of Gornitz et al. (1994), which provides a numerical basis for ranking sections of coastline based on potential change as a result of several factors, including SLR, geology, wave action, and geomorphology (Gornitz et al., 1991). A vulnerable coastline is characterized by low coastal relief, subsidence, extensive shoreline retreat, and high wave/tide energies. Appeaning-Addo (2013) categorized the vulnerability of the Accra coast as moderate. Hinkel et al. (2012) applied the Dynamic Interactive Vulnerability Assessment (DIVA) model to the West African coast, finding that Nigeria, Guinea-Bissau, Guinea, Benin, Ghana, Sierra Leone, Gambia, Liberia, and Côte d'Ivoire are ranked among the top 15 most-vulnerable countries in Africa.

Flood risk is an issue in many coastal areas of West Africa and particularly affects urban areas (Dickson et al. 2012, GCLME 2010, Douglas et al. 2008, Action Aid 2006). In 2009, many West African cities experienced torrential rains that caused loss of life and the destruction of important socioeconomic infrastructure (GCLME 2010). In Nigeria, floods represent a major issue for urban areas due to the low-lying topography, limited capacity of drainage systems, and blockage of waterways and drainage channels (Adeoye et al. 2009). The frequency and magnitude of urban flooding and its impacts have more than doubled in recent time, owing to population growth and settlement in flood-prone areas (e.g., Agbola and Agunbiade 2009) and the more intense and frequent rainstorms potentially associated with climate change. For example, in a flood impact assessment in Nigeria, Adeoye et al. (2009) determined that the impacts of floods have increased from significant to threatening during the past three decades, based on flood records from the National Emergency Management Agency (NEMA) and records of flood events recorded in Nigerian newspapers.

CONCLUSION

Based on the UN list of least developed countries, West Africa is one of the world's least developed regions (with 13 of 16 countries classified accordingly) and has among the highest rates of population growth. This creates challenges that, when overlaid with climatic changes, may engender significant redistribution of population within the region (Xu et al. 2020). Given the role that environmental factors have played in mobility patterns in the past, we can expect that they will continue to play a similar role in the future. Indeed, it is likely that climate variability and extremes in the landlocked portions of the Sahel are likely to drive new climate migration into the coastal zone, which will only increase the exposure of populations to the effects of sea level rise and storm surge. As in the past, climate impacts may arrive in the form of disturbances that are hard to predict, and whose ramifications for the socio-ecological system and migration are even harder to predict. Decision makers should view internal climate migration as a cross-cutting issue to be integrated into policy and planning based on the country's development context, institutional capacity, and climate vulnerabilities.

REFERENCES

Abu, M., Codjoe, S.N.A., and Sward, S. (2013). Climate change and internal migration intentions in the forest-savannah transition zone of Ghana. Population and Environment, 35(4), 341–364.

ActionAid. (2006). Climate change, urban flooding, and the rights of the urban poor in Africa: Key findings from six African cities. ActionAid.

Adeoye, N. O., Ayanlade, A., & Babatimehin, O. (2009). Climate change and menace of floods in Nigerian cities: Socioeconomic implications. Advances in Natural and Applied Sciences, 3(3), 369-377.

Adepoju, A. (1995). Migration in Africa: An overview. In J. Baker & T. A. Aina (Eds.), The migration experience in Africa (pp. 87–108). Retrieved from http://www.neaculture.it/MigrationinAfrica.pdf

Agbola, T., & Agunbiade, E. M. (2009). Urbanization, slum development and security of tenure: The challenges of meeting Millenium Development Goal 7 in metropolitan Lagos, Nigeria. de Sherbinin, A., Rahman, A., Barbieri, A., Fotso, J. C. & Zhu Y. (Eds.), Urban Population- Environment Dynamics in the Developing World: Case Studies and Lessons Learned. Paris: Committee for International Cooperation in National Research in Demography (CICRED).

Appeaning Addo, K., Nicholls, R.J., Codjoe, S.N.A., and Abu, M. (2018). A biophysical and socioeconomic review of the Volta delta, Ghana. Journal of Coastal Research, 34(5), 1216–1226.

Appeaning Addo, K. (2013). Assessing coastal vulnerability index to climate change: The case of Accra–Ghana. Proceedings of the 12th International Coastal Symposium (Plymouth, England), Journal of Coastal Research, (65), 1892-1897. Retrieved from 10.2112/si65-320.1

Ayamga, J., Das, S., & Banerjee, S. (2019). Climate change, migration and adaptation in deltas: Key findings from the DECCMA project. DEltas, vulnerability & Climate Change: Migration & Adaptation (DECCMA). Canada: IDRC. Retrieved from http://hdl.handle.net/10625/57543

Bader, J., & Latif, M. (2003). The impact of decadal-scale Indian Ocean sea surface temperature anomalies on Sahelian rainfall and the North Atlantic Oscillation. Geophysical Research Letters, 30, 2169. Retrieved from http://dx.doi.org/10.1029/2003GL018426

Battisti, D. S., & Naylor, R. L. (2009). Historical warnings of future food insecurity with unprecedented seasonal heat. Science, 323(5911), 240-244.

Biasutti, M. (2019). Rainfall trends in the African Sahel: Characteristics, processes, and causes. WIRES Climate Change, DOI: 10.1002/wcc.591

Biasutti, M., & Sobel, A. H. (2009). Delayed Sahel rainfall and global seasonal cycle in a warmer climate. Geophysical Research Letters, 36, L23707. Retrieved from http://dx.doi.org/10.1029/2009GL041303

Biasutti, M., Held, I. M., Sobel, A. H., & Giannini, A. (2008). SST forcings and Sahel rainfall variability in simulations of the twentieth and twenty-first centuries. Journal of Climate, 21, 3471–3486. Retrieved from http://dx.doi.org/10.1175/2007JCLI1896.1

Black, R., S.R.G. Bennett, S.M. Thomas, and J.R. Beddington. (2011). Migration as adaptation. Nature 478 447–9.

Borderon, M., P. Sakdapolrak, R. Muttarak, E. Kebede, R. Pagogna, R. and E. Sporer, (2018). A systematic review of empirical evidence on migration influenced by environmental change in Africa. IIASA Working Paper WP-18-003, July 24, 2018.

Brown, S., Nicholls, R. J., Lowe, J. A., & Hinkel, J. (2016). Spatial variations of sea-level rise and impacts: An application of DIVA. Climatic Change, 134(3), 403-416.

Bruning, L., and E. Piguet. (2018). Changements environnementaux et migration en Afrique de l'Ouest. Une revue des etudes de cas. Belgeo. doi:10.40000. belgeo.28836

Caminade, C., & Terray, L. (2010). Twentieth century Sahel rainfall variability as simulated by the ARPEGE AGCM, and future changes. Climate Dynamics, 35, 75-94. http://dx.doi.org/10.1007/s00382-009-0545-4

Cervigni, R., Morris, M., Fallavier, P., Guo, Z., Boehlert, B., & Strzepek, K. (2016). Chapter 4. Vulnerability in Drylands Tomorrow: Business as Usual Raising Ominous Prospects. Confronting Drought in Africa's Drylands: Opportunities for Enhancing Resilience, African Development Forum Report 37. Washington DC: Agence Francaise de Developpement & World Bank Group.

Charney, J., Stone, P. H., & Quirk, W. J. (1975). Drought in the Sahara: A biogeophysical feedback mechanism. Science, 187, 434–435. Retrieved from http://www.sciencemag.org/content/187/4175/434.abstract

CIESIN (Center for International Earth Science Information Network, Columbia University). (2013). Low Elevation Coastal Zone (LECZ) Urban-Rural Population and Land Area Estimates, Version 2. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H4MW2F2J.

CIESIN (Center for International Earth Science Information Network, Columbia University). (2011). MR4: Estimating net migration by ecosystem and by decade: 1970–2010. In: Migration and Global Environmental Change. London: Foresight Project on Environmental Migration.

de Sherbinin, A., Levy, M., Adamo, S., MacManus, K., Yetman, G., Mara, V., Razafindrazay, L., Goodrich, B., Srebotnjak, T., Aichele, C., & Pistolesi, L. (2012). Migration and risk: Net migration in marginal ecosystems and hazardous areas. Environmental Research Letters, 7, 045602.

de Sherbinin, A., A. Schiller, and A. Pulsipher. 2007. "The Vulnerability of Global Cities to Climate Hazards." Environment & Urbanization, 19(1): 39-64.

Dickson, E., Baker, J. L., Hoornweg, D., & Tiwari, A. (2012). Urban risk assessments: Understanding disaster and climate risk in cities. Washington, D.C.: World Bank.

Dillon, A., Mueller, V., & Salau, S. (2011). Migratory responses to agricultural risk in northern Nigeria. American Journal of Agricultural Economics, 93(4), 1048-1061.

Dossou, K. M., & Glehouenou-Dossou, B. (2007). The vulnerability to climate change of Cotonou (Benin) the rise in sea level. Environment and Urbanization, 19(1), 65-79.

Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., Mclean, L., & Campbell, J. (2008).

Unjust waters: Climate change, flooding and the urban poor in Africa. Environment and Urbanization, 20, 187-205.

Findley, S. E. (1994). Does Drought Increase Migration? A Study of Migration from Rural Mali during the 1983–1985 Drought. International Migration Review 28(3): 539–53.

Foresight. (2011). Migration and Global Environmental Change. Final project report. London, UK: The Government Office for Science.

Garcia, A. J., D.K. Pindolia, K.K. Lopiano and A.J. Tatem. (2015). Modeling internal migration flows in sub-Saharan Africa using census microdata. Migration Studies, 3(1), 89-110.

GCLME. (2010). State of the coastal and marine ecosystems in the guinea current large marine ecosystem region: Interim Guinea Current Commission with the assistance of GEF/UNIDO/UNDP/UNEP/US-NOAA/NEPAD/FAO and IMO.

Gornitz, V.M., Daniels, R.C., White, T.W., & Birdwell, K.R. (1994). The development of a coastal risk assessment database: Vulnerability to sea-level rise in the U.S. Southeast. Journal of Coastal Research, 327-338. doi:10.2307/25735608.

Gornitz, V., White, T.W., & Cushman, R.M. (1991). Vulnerability of the U.S. to future sea-level rise. Coastal Zone '91. In Proceedings of Seventh Symposium on Coastal and Ocean Management (pp. 2354-2368): ASCE.

Grace, K., V. Hertrich, D. Singare, and G. Husak. (2018). Examining rural Sahelian out-migration in the context of climate change: An analysis of the linkages between rainfall and out-migration in two Malian villages from 1981 to 2009, World Development 109, 187-196.

Gray, C. and E. Wise. (2016) Country-specific effects of climate variability on human migration. Climatic Change, 135:555-568. Retrieved from https://doi.org/10.1007/s10584-015-1592-y

Henry, S., P. Boyle, and E. F. Lambin. (2003). Modelling Inter-Provincial Migration in Burkina Faso, West Africa: The Role of Socio-Demographic and Environmental Factors." Applied Geography 23(2): 115–36.

Henry, S., B. Schoumaker, and C. Beauchemin (2004a). The Impact of Rainfall on the First Out-Migration: A Multi-Level Event-History Analysis in Burkina Faso." Population and Environment 25(5): 423–60,.

Henry, S., V. Piché, D. Ouédrago, and E. F. Lambin. (2004b). Descriptive Analysis of the Individual Migratory Pathways According to Environmental Typologies." Population and Environment 25(5): 397–422.

Hinkel, J., Brown, S., Exner, L., Nicholls, R.J., Vafeidis, A.T., & Kebede, A.S. (2012). Sea-level rise impacts on Africa and the effects of mitigation and adaptation: an application of DIVA. Regional Environmental Change, 12(1), 207-224. doi:10.1007/s10113-011-0249-2

Hochleithner, S., and A. Exner. (2018). Theories of Migration in and From Rural Sub-Saharan Africa: Review and Critique of Current Literature. Swedish International Centre for Local Democracy (ICLD) Working Paper No. 14. Stockholm: ICLD.

IPCC. (2012). Managing the risks of extreme events and disasters to advance climate change adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, C. B. Field, V. Barros, T. F. Stocker,

D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor, & P. M. Midgley (Eds.). Cambridge, UK, and New York, NY, USA: Cambridge University Press. Retrieved from http://ipcc-wg2.gov/SREX/

Janicot, S., & Sultan, B. (2001). Intra-seasonal modulation of convection in the West African Monsoon. Geophysical Research Letters, 28, 523–526.

Kandji, S.T., Verchot, L., & Mackensen, J. (2006). Climate change and variability in the Sahel region: Impacts and adaptation strategies in the agricultural sector. Nairobi: Word Agroforestry Centre (ICRAF) and United Nations Environment Programme (UNEP). Retrieved from http://www.unep.org/ecosystemmanagement/Portals/7/Documents/ClimateChangeSahelCombine.pdf.

Knutti, R., & Sedlácek, J. (2013). Robustness and uncertainties in the new CMIP5 climate model projections. Nature Climate Change, 3(4), 369.

JISAO (Joint Institute for the Study of the Atmosphere and Ocean, University of Washington) (2017), Sahel Rainfall Index (20-10N, 20W-10E), 1900-October 2012. Retrieved on 22 July, 2019 from http://jisao.washington.edu/data/sahel/

Kniveton, D. R., Smith, C. D., & Black, R. (2012). Emerging migration flows in a changing climate in dryland Africa. Nature Climate Change, 2, 444–447. http://dx.doi.org/10.1038/nclimate1447

Lalou, R., & Delaunay, V. (2017). "Seasonal migration and climate change in rural Senegal: a form of adaptation or failure to adapt?" Chapter 14 in: Sultan, B., et al. Rural societies in the face of climatic and environmental changes in West Africa. Marseille, France: IRD Editions.

Melet, A., Meyssignac, B., Almar, R., & Le Cozannet, G. (2018). Under-estimated wave contribution to coastal sea-level rise. Nature Climate Change, 8(3), 234.

Melet, A., Almar, R., & Meyssignac, B. (2016). What dominates sea level at the coast: a case study for the Gulf of Guinea. Ocean Dynamics, 66(5), 623-636.

Mohino, E., Janicot, S., & Bader, J. (2011). Sahel rainfall and decadal to multi-decadal sea surface temperature variability. Climate Dynamics, 37, 419–440. Retrieved from http://dx.doi.org/10.1007/s00382-010-0867-2

Muller, C., Waha, K., Bondeau, A., Heinke, J. (2014). Hotspots of climate change impacts in sub-Saharan Africa and implications for adaptation and development. Glob. Chang. Biol. 20, 2505–2517.

Neumann, K., and F. Hermans. (2017). "What Drives Human Migration in Sahelian Countries? A Meta-analysis." Population, Space and Place 23, no. 1: e1962.

New, M., Anderson, K., Fung, F., & Thornton, P. (2011). The possible impacts of high levels of climate change in 2060 and implications for migration. UK Government's Foresight Project, Migration and Global Environmental Change.

Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham, and P. Urquhart. (2014). Africa. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1199-1265.

Rademacher-Schulz, C., Schraven, B., & Mahama, E. S. (2014). Time matters: shifting seasonal migration in Northern Ghana in response to rainfall variability and food insecurity. Climate and Development, 6(1): 46-52.

Rademacher-Schulz, C., & Mahama, E. S. (2012). Where the Rain Falls Project. Rainfall, food security, and human mobility. Case study: Ghana. Results from Nadowli District, Upper West Region. No. 3, November 2012. United Nations University, Institute for Environment and Human Security (UNU-EHS).

Ribot, J., P. Faye, M.D. Turner. (2020). Climate of Anxiety in the Sahel: Emigration in Xenophobic Times. Public Culture, 32 (1): 45–75. https://doi.org/10.1215/08992363-7816293

Ribot, J. (2018). Social Contract Failures as Causes of Sahelian Emigration: The Case of Eastern Senegal. Presentation to the World Bank, 26 March 2018.

Riede, J. O., Posada, R., Fink, A. H., & Kaspar, F. (2016). What's on the 5th IPCC Report for West Africa?. In Adaptation to Climate Change and Variability in Rural West Africa (pp. 7-23). Springer, Cham.

Romankiewicz, C., & Doevenspeck, M. (2015). Climate and Mobility in the West African Sahel: Conceptualising the Local Dimensions of the Environment and Migration Nexus. In Grounding Global Climate Change (pp. 79-100). Springer, Dordrecht.

Romankiewicz, C., M. Doevenspeck, M. Brandt and C. Samimi. (2016). Adaptation as by-product: migration and environmental change in Nguith, Senegal. Die Erde, 147(2):95-108. Retrieved from https://www.die-erde.org/index.php/die-erde/article/view/287

Tacoli, C. (2011). Not only climate change: Mobility, vulnerability, and socio-economic transformations in environmentally fragile areas of Bolivia, Senegal and Tanzania. In Human Settlements Working Paper Series-Rural-Urban Interactions and Livelihood Strategies. IIED.

Ting, M., Kushnir, Y., Seager, R., & Li, C. (2009). Forced and internal twentieth-century SST trends in the North Atlantic. Journal of Climate, 22, 1469–1481. Retrieved from http://dx.doi.org/10.1175/2008JCLI2561.1

Traore, S., & Owiyo, T. (2013). Dirty droughts causing loss and damage in Northern Burkina Faso. International Journal of Global Warming, 5(4), 498-513.

Turco, M., Palazzi, E., Von Hardenberg, J., & Provenzale, A. (2015). Observed climate change hotspots. Geophysical Research Letters, 42(9), 3521-3528.

UNDESA (United Nations, Department of Economic and Social Affairs), Population Division (2018). World Urbanization Prospects: The 2018 Revision, Online Edition.

UNEP. (2011). Climate change, conflict, and migration in the Sahel. Nairobi, Kenya: United Nations Environmental Programme.

Van der Geest, K. (2011). North-south migration in Ghana: what role for the environment? International Migration, 49(69–94), 2011.

Van der Geest, K., Vrieling, A., & Dietz, T. (2010). Migration and environment in Ghana: A cross-district analysis of human mobility and vegetation dynamics. Environment and Urbanization, 22, 107–123. Retrieved from http://eau.sagepub.com/content/22/1/107.abstract

Van der Land, V., C. Romankiewwicz, and K. van der Geest. (2018). Chapter 13. Environmental Change and Migration: A Review of West African Case Studies. In:

Routledge Handbook of Environmental Displacement and Migration, R. McLeman and F. Gemenne eds , New York: Routledge (pp. 163-177).

Warner, K., Afifi, T., Henry, K., Rawe, T., Smith, C., & de Sherbinin, A. (2012). Where the rain falls: Climate change, food and livelihood security, and migration. Bonn, Germany: United Nations University and CARE.

White, G. (2011). Climate change and migration. New York, NY: Oxford University Press.

Wiederkehr, C., M. Beckmann, and K. Hermans. (2018). "Environmental change, adaptation strategies and the relevance of migration in Sub-Saharan drylands." Environmental Research Letters 13, no. 11: 113003.

Xu, C., T.A. Kohler, T.M. Lenton, J.-C. Svenning, M. Scheffer. (2020). Future of the human climate niche. Proceedings of the National Academy of Sciences May 2020, 201910114; DOI: 10.1073/pnas.1910114117

Zeng, N., Neelin, J. D., Lau, K.-M., & Tucker, C. J. (1999). Enhancement of interdecadal climate variability in the Sahel by vegetation interaction. Science, 286, 1537–1540. Retrieved from http://www.sciencemag.org/content/286/5444/1537.abstract

Zickgraf, C. (2018). "The Fish Migrate And So Must We": The Relationship Between International And Internal Environmental Mobility In A Senegalese Fishing Community. Medzinarodne vztahy (Journal of International Relations), 16(1):5-21. Retrieved from https://journals.indexcopernicus.com/api/file/viewByFileId/464215.pdf

Zomers, Z., K. van der Geest, A. de Sherbinin, S. Kienberger, E. Roberts, G. Harootunian, A. Sitati, and R. James. (2016). Loss and Damage: The role of Ecosystem Services. Nairobi, Kenya: United Nations Environment Programme (UNEP).

PART II :

IMPACT OF CLIMATE CHANGE ON AGRICULTURE AND LIVELIHOODS

Climate change is affecting agriculture and food security and these effects are becoming increasingly visible across different sectors and can be studied and analysed. In fact, rural households are the most affected, particularly in West Africa because their income depends mainly on agricultural and pastoral activities. It is therefore important to put in place climate change adaptation programmes and policies so that farm households can be spared. There is also a need to improve seasonal rainfall forecasts and ensure that rural households have access to them in order to enable them to make appropriate agricultural use.

This section addresses the impacts of climate change on agriculture, food security and related social and economic inequalities in West and Central Africa, including Senegal, Gambia, Ghana, Niger and Cameroon. It consists of eleven articles :

1. Self-sustaining adaptation to climate change and food security in the Sudano-Sahelian zone in Cameroon
2. Rainfall variability and food insecurity in Senegal: the case of Upper CasamanceRainfall shocks effects on children malnutrition in Senegal
3. Impacts of Seasonal Climate Forecasts on Farm Household Income in Rural Senegal
4. Spatial diffusion of agricultural production in WAEMU: does climate change play a role?
5. Impacts des changements climatiques sur la chaine de valeur viande bovine au Sénégal : Quels investissement pour quelles stratégies de résilience ?
6. Effect of Global Climate Change on Poverty and Inequality in Sub-Saharan Africa
7. Factors influencing Households' Food Security Status among rural Farmers in the Central River Region South of the Gambia
8. Household vulnerability to food insecurity due to climate change in Niger: a multinominal logistic regression of food insecurity categories on climate and socioeconomic factors
9. CO_2 emission and Economic growth in sub-Sahara countries: is there Kuznets curve?
10. The effects of Climate Variability on agricultural efficiency in Ghana

Adaptation autonome aux changements climatiques et sécurité alimentaire en zone soudano-sahélienne au Cameroun

Tagang Tene Nelson Sergeo, Tsambou André Dumas et Fouopi Djiogap

ABSTRACT

The Sudano-Sahelian zone of Cameroon is an essential part of the local ecosystem, potentially vulnerable to climate change. This vulnerability raises concerns about the food security of agricultural households. As a result, the adaptation implemented by agricultural households could partially reduce this vulnerability. Thus, the objective of this paper is to assess the effect of climate change adaptation on the food security of agricultural households in the Sudano-Sahelian zone of Cameroon. We used the endogenous switching regression model to estimate the impact of adopting adaptation strategies on the food security of agricultural households. This method makes it possible to address selectivity bias while taking into account the differential impact of adaptation strategies between adopting and non-adopting households. We use survey data from 721 farms in the northern and extreme northern regions (Sudano-Sahelian zone) of Cameroon, carried out in 2014 as part of the Northern Agrosystems Debt Reduction and Development Contract (C2D) project (Actions 6 and 7).

The results of this study show that adaptation to climate change has a significantly positive effect on the food security of agricultural households. The relevance of these results enriches the debate on the need to implement planned climate change adaptation program and policies in line with the concerns of agricultural households.

Keywords : Adaptation; climate change; agricultural household; food security.

RÉSUMÉ

La zone soudano-sahélienne du Cameroun est une partie essentielle de l'écosystème local, potentiellement vulnérable aux changements climatiques. Cette vulnérabilité soulève des inquiétudes quant à la sécurité alimentaire des ménages agricoles. De ce fait, l'adaptation mise en œuvre par les ménages agricoles pourrait atténuer en partie cette vulnérabilité. Ainsi, l'objectif de ce papier est d'évaluer l'effet de l'adaptation aux changements climatiques sur la sécurité alimentaire des ménages agricoles dans la zone soudano-sahélienne du Cameroun. Nous avons utilisé le modèle de régression à commutation endogène (endogenous switching regression model) pour estimer l'impact de l'adoption des stratégies d'adaptation sur la sécurité alimentaire des ménages agricoles. Cette méthode permet de traiter le biais de sélectivité tout

en prenant en compte l'impact différentiel entre les ménages adoptants et non-adoptants des stratégies d'adaptation. Nous utilisons les données d'enquête auprès de 721 exploitations agricoles des régions du Nord et de l'Extrême-nord (zone soudano-sahélienne) du Cameroun, réalisées en 2014 dans le cadre du projet du Contrat de Désendettement et de Développement (C2D)[31] agrosystèmes du Nord (Actions 6 et 7).

Les résultats de cette étude montrent que l'adaptation aux changements climatiques a un effet significativement positif sur la sécurité alimentaire des ménages agricoles. La pertinence de ces résultats enrichit le débat sur la nécessité de mettre en œuvre des programmes et des politiques d'adaptation planifiées aux changements climatiques, en adéquation avec les préoccupations des ménages agricoles.

Mots clés : Adaptation ; changement climatique ; ménage agricole ; sécurité alimentaire

INTRODUCTION

La question de la sécurité alimentaire est au cœur du débat actuel sur les implications des changements climatiques en Afrique Subsaharienne. Dans cette partie du continent, les ménages agricoles pratiquent l'agriculture de subsistance, généralement faite sur des parcelles de moins d'un hectare et dont la production est basée sur des cultures vivrières dans des conditions extrêmement difficiles. Le système de production est caractérisé par une combinaison de la productivité de la terre et des conditions climatiques difficiles. Il en résulte de faibles rendements et une insécurité alimentaire (Di Falco et Chavas, 2009 ; Di Falco et al., 2011).

La sécurité alimentaire est un concept large qui s'appréhende par la disponibilité, la stabilité et l'utilisation des denrées alimentaires. Dans cette étude, nous mettons l'accent sur l'un des déterminants clés de la sécurité alimentaire qu'est la disponibilité dans un contexte d'agriculture de subsistance au Cameroun : la productivité alimentaire (FAO, 2002). La disponibilité ou encore l'accès aux denrées alimentaires est déterminé par la productivité alimentaire des ménages. Elle représente environ 60% de la production agricole nationale dont 80% est consommée par ces ménages (Banque Mondiale, 2006).

Les économies des pays de l'Afrique subsaharienne sont peu diversifiées et dépendent fortement de l'agriculture pluviale, ce qui lie les perceptives de développement de leur économie au climat. Cline, (2007) ; Parry et al. (2005) ; Rosenzweig et Parry, (1994) mettent en évidence le fait que les changements climatiques devraient réduire la productivité alimentaire. D'un autre côté, le quatrième rapport du Groupe d'Expert Intergouvernemental sur l'évolution du Climat (GIEC, 2007) définit les changements

31 Le programme Agrosystème est un projet de l'IRAD qui vise la conception, l'évaluation et la diffusion des agrosystèmes performants et durables en milieu rural du grand nord Cameroun. Ces actions permettront de contribuer à l'amélioration durable de la productivité des petites exploitations de polyculture du Nord Cameroun tout en préservant la fertilité des sols par des propositions techniques adaptées et performantes proposées aux structures de développement.

climatiques comme étant un changement de l'état du climat identifiable par des changements de la moyenne et/ou de la variabilité de ses propriétés qui persiste pendant une période prolongée, généralement des décennies ou plus. De plus, il indique que dans les zones tropicales sèches, la productivité alimentaire devrait diminuer même pour de faibles augmentations de températures (0,5 à 2°C). De même, l'accès à l'alimentation sera fortement affecté suite à une diminution d'environ 50% des rendements de l'agriculture de subsistance d'ici 2020 (GIEC, 2007).

Face à cette situation peu reluisante, l'identification des innovations à l'épreuve du climat et des stratégies d'adaptation est essentielle pour soutenir la production des cultures vivrières et assurer la sécurité alimentaire (Bryan et al., 2009 ; GIEC, 2014). L'adaptation de l'agriculture aux changements climatiques, se définit donc comme l'ajustement des pratiques agronomiques, des processus agricoles et des investissements en capital en réponse aux menaces observées ou prévues des changements climatiques (Easterling et al., 2007). Dans de nombreux pays en développement, les ménages agricoles ont adopté de manière autonome des pratiques de gestion agricole pour lutter contre les aléas climatiques. Cette autonomie dans l'adaptation aux changements climatiques peut être définie comme étant celle qui se produit dans un système de façon naturelle et non comme une adaptation planifiée qui est le produit des décisions politiques délibérées (Smith et al., 2000 ; Stage, 2010). Il est donc évident que les ménages agricoles s'adaptent aux changements climatiques en modifiant le calendrier agricole, en cultivant diverses espèces et variétés de cultures, en adoptant des pratiques de conservation du sol et de l'eau, en diversifiant les activités et en mettant sur pied un système d'irrigation (Asseng et Pannell, 2013 ; Devkota et al., 2017 ; Niles et al., 2016 ; Zhang et al., 2015). C'est le cas des ménages agricoles camerounais qui ont traditionnellement utilisé les connaissances indigènes pour faire face aux aléas climatiques sur la base d'observations et d'interprétations des phénomènes naturels. Nous pouvons mentionner la hauteur d'un nid de fourmis dans les arbres, ou la couleur des grenouilles pour prévoir l'apparition et la cessation de la saison des pluies de même que la quantité de pluies (Molua, 2006).

Au Cameroun, l'agriculture est l'activité principale qui occupe plus de 60% de la population et contribue à hauteur de 21% du produit intérieur brut (PIB) (FAO, 2017). Selon le modèle HadCM3 (Gordon et al., 2000 ; Johns et al., 2003), les températures devraient augmenter de 0,7 à 0,8 °C d'ici 2020. Le modèle Goddard Institute for Space Studies (GISS) (Hassan et al., 1998) prévoit que cette augmentation va doubler au cours de la même période. Quant aux précipitations, le modèle GISS prévoit une nette tendance à la baisse d'ici l'année 2080 dans la zone soudano-sahélienne (Tingem et al., 2008c). On note également, une insécurité alimentaire de plus en plus grandissante en zone rurale (22%) contrairement à la zone urbaine (10,5%) avec de fortes disparités entre les régions. La zone soudano-sahélienne est la plus touchée par l'insécurité alimentaire avec un taux de prévalence de 33,7% (FAO, 2017). Ces forts taux font suite à une faible productivité alimentaire, se caractérisant par de faibles niveaux d'intrants, de faibles subventions gouvernementales et l'utilisation d'outils rudimentaires (Molua et Utomakili, 1998).

Il existe une littérature abondante sur l'impact des changements climatiques sur la production alimentaire (Pearce et al., 1996 ; Parry et al., 2004 ; Stern et al., 2007). Les résultats de ces études sont essentiels pour apprécier l'ampleur du problème et concevoir des stratégies d'atténuation appropriées. Plusieurs études ont également analysé l'impact de l'adaptation sur la production agricole au niveau des ménages et des exploitations agricoles (Timgem et al., 2008 ; Di Falco et al., 2011 ; Huang et al., 2016 ; Khanal et al., 2016 ; Khanal et al., 2018a). Cependant, en majorité ces études ne distinguent pas l'adaptation autonome de l'adaptation planifiée. De plus, on note une quasi-absence d'étude sur le sujet au Cameroun. Comme nous l'avons dit plus haut, l'accent mis sur la productivité alimentaire est motivé par ses implications pour la réalisation de la sécurité alimentaire. D'où la question de savoir : quel est l'effet de l'adaptation autonome aux changements climatiques sur la sécurité alimentaire des ménages agricoles de la zone soudano-sahélienne au Cameroun ?

Ainsi, notre contribution à la littérature existante sur l'adaptation aux changements climatiques sera axée sur plusieurs points. Premièrement, nous examinons l'impact de l'adaptation autonome sur la productivité alimentaire au niveau des ménages agricoles. Deuxièmement, nous utilisons le modèle de régression à commutation endogène avec l'analyse du contrefactuel afin d'examiner ce que les ménages agricoles auraient produit s'ils n'avaient pas adopté une stratégie d'adaptation spécifique. Troisièmement, à partir de cette étude, nous essayerons d'apporter une modeste contribution à la littérature empirique relative aux changements climatiques et à son impact sur la productivité alimentaire et par conséquent sur la sécurité alimentaire. D'un autre côté, il sera important de vérifier si l'adaptation autonome aux changements climatiques améliore la sécurité alimentaire des ménages de la zone soudano-sahélienne au Cameroun. En outre, les réactions des ménages agricoles aux changements climatiques varient d'un endroit à un autre en fonction des conditions climatiques, sociales, économiques et institutionnelles spécifiques (Deressa et al., 2009 ; Khanal et al., 2018b). Il est donc important d'étudier les pratiques d'adaptation locales et leur impact sur la productivité alimentaire pour une planification efficace de l'adaptation au niveau local.

MÉTHODOLOGIE

En réponse à la problématique de cette recherche, la méthodologie présentée dans ce travail va s'articuler sur la source de données et la modélisation de l'adaptation aux changements climatiques et à la sécurité alimentaire (productivité alimentaire).

Sources de données

Les données concernant l'étude proviennent de l'enquête auprès de 721 exploitations agricoles retenues dans les régions du Nord et de l'Extrême-nord constituant la zone soudano-sahélienne camerounaise. Ces données ont été collectées dans le cadre du projet du contrat de désendettement et de développement C2D agrosystèmes du Nord (Actions 6 et 7) réalisé en 2014. Un échantillon de 200 exploitations agricoles par terroir (MOWO, SIRLAWE, ZERA et SANGUERE) a été défini. Ces données comportent des sections sur les caractéristiques socio-économiques des exploitations, les conditions de vie des ménages, les facteurs de production, l'environnement socio-institutionnel des exploitations agricoles, la perception par ménage des changements climatiques et enfin les différentes stratégies d'adaptation adoptées face aux changements climatiques.

Modélisation de l'adaptation aux changements climatiques et à la productivité alimentaire.

Selon Di Falco et al. (2011), une décision d'adaptation aux changements climatiques et ses effets sur la productivité alimentaire peuvent être simulés en utilisant un cadre en deux étapes (Khanal et al., 2018a ; Huang et al., 2015 ; Khanal et al., 2018b).

Dans un premier temps, nous avons utilisé un modèle de sélection pour les décisions relatives à l'adaptation aux changements climatiques. Il suppose que les ménages agricoles peu enclins à prendre des risques mettront en œuvre des stratégies d'adaptation aux changements climatiques s'ils en tirent des avantages nets, et que ces avantages nets peuvent être représentés par une variable latente A^*.

$$A_i^* = Z_i\alpha + \eta_i \qquad \text{Avec} \quad A_i = 1, \text{ si } A_i^* > 0 \text{ et } A_i = 0, \text{ si non} \quad (1)$$

Cela signifie que le ménage agricole choisit de s'adapter (Ai =1), si $A^* > 0$, et 0 sinon. Le vecteur Z représente les variables qui affectent les décisions d'adaptation des ménages agricoles. Selon la littérature empirique sur les déterminants des décisions des ménages en matière d'adaptation aux changements climatiques, (Khanal et al., 2018a ; Deressa et al., 2009 ; Di Falco et al., 2011), cette étude est fondée sur les variables explicatives des caractéristiques des ménages agricoles et sur les informations climatiques fournies par les agents de vulgarisation. Les caractéristiques du ménage comprennent le sexe, l'âge, l'éducation, la part de travail, la superficie cultivée et la connaissance du climat. L'information fournie par le gouvernement comprenait principalement la météo, les avertissements de pluie et de sècheresse.

Dans un deuxième temps, l'effet de l'adaptation sur la productivité alimentaire a été modélisé grâce à la technologie de production. L'approche la plus simple aurait été d'utiliser la méthode des moindres carrés ordinaires (MCO), en prenant l'adaptation comme une variable muette dans l'équation de productivité alimentaire. Toutefois, l'évaluation de l'impact de l'adaptation sur la productivité alimentaire au moyen de l'approche MCO peut avoir créé de nombreux problèmes potentiels. Car l'adaptation peut être potentiellement endogène, ce qui, si elle est vraie, conduira à des estimations biaisées (Di Falco, 2011). De plus, des problèmes tels que le biais de sélection de l'échantillon et des estimations incohérentes pourraient augmenter et confondre les résultats (khanal et al., 2018a).

Selon Di Falco et al., (2011), un modèle d'équation simultanée de l'adaptation aux changements climatiques et son impact sur la productivité alimentaire avec commutation endogène a été estimé avec une probabilité maximale d'informations complètes. Dans notre étude, nous utilisons comme instrument, la variable liée à la perception des changements climatiques. Nous établissons la validité de cet instrument en effectuant un simple test de falsification. Ainsi, si une variable est un instrument valide, alors elle aura une incidence sur la décision d'adaptation, mais ne l'aura pas sur la productivité alimentaire des exploitations agricoles qui ne se sont pas adaptées. Dans le présent travail, nous avons choisi le modèle de régression à commutation endogène pour estimer l'impact de l'adaptation aux changements climatiques sur la productivité alimentaire. Les ménages adaptateurs et les non-adaptateurs ont des fonctions de productivité alimentaires différentes.

Le modèle de régression est défini comme celui de Di Falco et al., (2011).

$$\text{ménages non-adoptants : } y_{2i} = X_{2i}\beta_2 + \varepsilon_{2i} \quad \text{si } A_i = 0$$

(2a)

ménages adoptants : $y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i}$ si $A_i = 1$
(2b)

Où, y_i représente la quantité produite par hectare dans les régimes 1 et 2, X_i représente le vecteur d'intrants et les caractéristiques du ménage, celles de l'exploitation agricole et des facteurs climatiques. β_1 et β_2 sont les vecteurs des paramètres à estimer, les termes ε_{1i} et d'erreur dans l'équation de sélection et de résultat sont supposés avoir une distribution normale trivariée, avec une moyenne nulle et la matrice de covariance $\sum$ c'est-à-dire $(\eta, \varepsilon_{1,}\varepsilon_2): N(0,\Sigma)$ (Di Falco et al., 2011 ; Khonje et al., 2015 ; Khanal et al., 2018).

$$\text{Avec} \quad \sum = \begin{pmatrix} \sigma^2_{\eta} & \sigma_{\eta 1} & \sigma_{\eta 2} \\ \sigma_{1\eta} & \sigma^2_{1} & . \\ \sigma_{2\eta} & . & \sigma^2_{2} \end{pmatrix}$$

Après, Di Falco et al., (2011) et Khanal et al., (2018), les valeurs attendues de ε_{1i} et ε_{2i} sont non nulles, données comme :

$$E\left[\varepsilon_{1i} \middle| A_i = 1\right] = \sigma_{1\eta} \frac{\phi(Z_i\alpha)}{\Phi(Z_i\alpha)} = \sigma_{1\eta}\lambda_{1i} \qquad (3a)$$

$$E\left[\varepsilon_{2i} \middle| A_i = 0\right] = \sigma_{2\eta} \frac{\phi(Z_i\alpha)}{1-\Phi(Z_i\alpha)} = \sigma_{2\eta}\lambda_{2i} \qquad (3b)$$

Ou, $\phi(.)$ est la fonction de densité de la probabilité normale standard, $\Phi(.)$ la fonction de densité cumulative normale, et $\lambda_{1i} = \frac{\phi(Z_i\alpha)}{\Phi(Z_i\alpha)}$; $\lambda_{2i} = \frac{\phi(Z_i\alpha)}{1-\Phi(Z_i\alpha)}$.

Si les covariances estimées $\hat{\sigma}_{1\eta}$ et $\hat{\sigma}_{2\eta}$ sont statistiquement significatives, alors la décision d'adaptation et la quantité produite par hectare sont corrélées, c'est-à-dire que l'on trouve des preuves de commutation endogène et de rejet de l'hypothèse d'absence de biais de sélectivité de l'échantillon. Ce modèle est défini comme « un modèle de régression de commutation avec commutation endogène » (Manddala et Nelson, 1975 ; Di Falco et al., 2011).

Une méthode efficace pour estimer les modèles de régression à commutation endogène est l'estimation maximale probable de l'information complète (Lee and Trost, 1978). La fonction de vraisemblance logarithmique, compte tenu des hypothèses précédentes concernant la distribution des termes d'erreur, est la suivante :

$$\ln L_i = \sum_{i=1}^{N} A_i \left[\ln \Phi\left(\frac{\varepsilon_{1i}}{\sigma_1}\right) - \ln \sigma_1 + \ln \Phi(\theta_{1i})\right] + (1-A_i)\left[\ln \Phi\left(\frac{\varepsilon_{2i}}{\sigma_2}\right) - \ln \sigma_2 + \ln\left(1-\Phi(\theta_{2i})\right)\right] \qquad (3)$$

Ou, $\theta_{ji} = \frac{(Z_i\alpha + \rho_j\varepsilon_{ji}/\sigma_j)}{\sqrt{1-\rho_j^2}}$, J=1,2, avec ρ_j signifiant le coefficient de corrélation entre le terme d'erreur η_i de l'équation de sélection (1) et les termes d'erreur ε_{ji} des équations (2a) et (2b), respectivement.

Selon Di Falco et al., (2011), le modèle de régression à commutation endogène peut être utilisé pour étudier quatre attentes conditionnelles de la productivité alimentaire.

$$E\left(y_{1i} / A_i = 1\right) = X_{1i}\beta_1 + \sigma_{1\eta}\lambda_{1i}, \tag{4a}$$

$$E\left(y_{2i} / A_i = 0\right) = X_{2i}\beta_2 + \sigma_{2\eta}\lambda_{2i}, \tag{4b}$$

$$E\left(y_{2i} / A_i = 1\right) = X_{1i}\beta_2 + \sigma_{2\eta}\lambda_{1i}, \tag{4c}$$

$$E\left(y_{1i} / A_i = 0\right) = X_{2i}\beta_1 + \sigma_{1\eta}\lambda_{2i}, \tag{4d}$$

L'équation (4a) représente la productivité alimentaire attendue des ménages agricoles qui se sont adaptés par rapport aux ménages agricoles qui ne se sont pas adaptés (4b). Quant à (4c), elle représente la productivité alimentaire attendue dans le cas hypothétique contrefactuel des ménages agricoles adoptants s'ils ne s'étaient pas adaptés, et (4d) les ménages agricoles non-adoptants s'il s'étaient adaptés. De plus, à la suite de Heckman et al., (2001), nous calculons l'effet du traitement « s'est adapté » sur le traité (TT) comme la différence entre (4a) et (4c), qui représente l'effet de l'adaptation aux changements climatiques sur la productivité alimentaire des exploitations agricoles qui se sont réellement adaptées aux changements climatiques.

$$\begin{aligned} TT &= E\left(y_{1i} \middle| A_i = 1\right) - E\left(y_{2i} \middle| A_i = 1\right) \\ &= \mathrm{X}_{1i}\left(\beta_1 - \beta_2\right) + \left(\sigma_{1\eta} - \sigma_{2\eta}\right)\lambda_{2i} \end{aligned} \tag{5}$$

De même, nous calculons l'effet du traitement sur les exploitations agricoles non traitées (TU) qui ne se sont pas réellement adaptées aux changements climatiques comme étant la différence (4d) et (4b).

$$\begin{aligned} TU &= E\left(y_{1i} \middle| A_i = 0\right) - E\left(y_{2i} \middle| A_i = 0\right) \\ &= \mathrm{X}_{1i}\left(\beta_1 - \beta_2\right) + \left(\sigma_{1\eta} - \sigma_{2\eta}\right)\lambda_{2i} \end{aligned} \tag{6}$$

Plus de détails sur le modèle de régression à commutation endogène peuvent être trouvés dans Di Falco et al. (2011).

RÉSULTATS ET DISCUSSIONS

Déterminants de l'adaptation

Les résultats de cette étude montrent (troisième colonne du tableau 1) que les principaux moteurs de la décision des ménages agricoles d'adopter certaines stratégies en réponse aux changements climatiques sont représentés par la perception des ménages aux changements climatiques ; la fourniture de l'information sur le climat par la radio, les vulgarisateurs, les organisations de producteurs et les ménages ayant des revenus. Le revenu des ménages augmente la probabilité de 66,2%, 43,8% et de 37,2% d'adopter des pratiques d'adaptation respectivement. Ce qui stipule que plus le revenu des ménages augmente, plus ils sont susceptibles d'adopter des pratiques d'adaptation. Le rôle de la perception que les ménages ont des changements climatiques et de l'information climatique semble également très pertinent. Force est de relever que les ménages agricoles qui ont perçu des changements au niveau des températures et des précipitations sont susceptibles de s'adapter à 124,5% aux changements climatiques. De même, ceux qui reçoivent des informations (radio, vulgarisateur, organisation de paysans) sur le climat sont susceptibles de s'adapter à 98,5% ; 107% et 94,4% respectivement aux changements climatiques. Cela signifie que le manque d'accès aux informations radio, aux services de vulgarisation et aux informations provenant des organisations de paysans sont des obstacles majeurs à l'adaptation. Ces résultats sont conformes à celui de (Bryan et al., 2009) sur l'Ethiopie et l'Afrique du Sud. Nous constatons également que les dépenses en investissements (insecticides, pesticides, etc.) sont négatives et significatives à l'adoption des pratiques d'adaptation. Cela signifie qu'une augmentation de 1% de l'utilisation des pesticides et des insecticides réduit de 13,7% la probabilité d'adopter des stratégies d'adaptation. Ce qui confirme la littérature qui met en évidence les dangers de l'utilisation de ces produits pour la préservation de la qualité du sol.

Tableau 1 : Résultats de la régression de commutation endogène pour l'adaptation et l'impact de l'adaptation sur la productivité alimentaire.

Variables	Designation	Adaptation	Productivité Alimentaire (log)	
			Non-adopteurs	Adopteurs
Fertilisants	Utilisation d'engrais chimique	-0.00234 (0.0254)	0.0270 (0.0801)	0.0470*** (0.0160)
Travail	Quantité de main d'œuvre utilisée	0.0373** (0.0167)	-0.117** (0.0507)	0.00451 (0.0106)
Capital	Dépenses d'investissements	-0.137*** (0.0484)	0.553*** (0.160)	-0.0317 (0.0212)
Exploitation d'élevage	Exploitations d'élevage du ménage	-0.120 (0.156)	-0.271 (0.469)	0.0267 (0.0953)
Terrain	Superficie des terres cultivées	0.595*** (0.140)	-1.230*** (0.448)	-0.308*** (0.0778)
Sexe du chef de ménage	Homme	0.737*** (0.208)	-0.0853 (0.642)	0.0650 (0.164)
Age du chef de ménage	Moins de 30 ans	-0.157 (0.244)	0.890 (0.730)	0.139 (0.147)
	De 30 à 50 ans	0.154 (0.194)	-0.407 (0.636)	0.221** (0.101)
Niveau d'éducation du chef de ménage	Primaire	-0.526*** (0.191)	0.720 (0.628)	0.0246 (0.102)
	Secondaire	-0.436** (0.223)	0.541 (0.788)	0.0985 (0.117)
Statut matrimoniale du chef de ménage	Marié	0.189 (0.220)	-0.489 (0.669)	0.180 (0.164)
Religion du chef de ménage	Chrétien		-1.259* (0.736)	0.725*** (0.179)
	Traditionaliste		-1.348 (0.857)	0.720*** (0.196)
Taille du ménage	Moins de 06 ans	0.270*** (0.0686)	0.00396 (0.240)	0.0300 (0.0246)
	De 6 à 14 ans	-0.0150 (0.0459)	0.255* (0.155)	0.0470** (0.0231)
	De 15 à 21 ans	-0.0225 (0.0506)	0.0778 (0.214)	0.0149 (0.0252)
	De 22 à 50 ans	-0.0200 (0.0290)	0.343*** (0.132)	0.0804*** (0.0174)
Appartenance à un groupe	Réseau de paysans		0.474 (0.593)	-0.136 (0.103)

Revenu du ménage	Moins de 50 m	0.662*** (0.209)	-0.419 (0.667)	-0.169 (0.118)
	De 50 à 100 m	0.438* (0.232)	0.400 (0.732)	0.159 (0.131)
	De 100 à 200 m	0.372* (0.219)	-1.194* (0.704)	0.167 (0.120)
Migration d'un membre du ménage	Migration			0.160* (0.0900)
Source d'information	Radio	0.985*** (0.192)		
	Vulgarisateurs	1.070*** (0.204)		
	Organisation de paysans	0.944*** (0.177)		
Perception des changements climatiques		1.245*** (0.413)		
Constant		-0.955 (0.687)	-0.962 (2.052)	5.648*** (0.332)
σ			2,489*** (0,277)	1,03*** (0,0294)
ρ			-0,934 (0,316)	-0,203 (0,114)

*Note : Erreurs-types entre parenthèses. *Significatif au niveau de 10% ; **significatif au niveau de 5% ; ***significatif au niveau de 1%*

Productivité alimentaire

La productivité alimentaire moyenne de la zone soudano-sahélienne est de 1006,9 kg/ha, ce qui est inférieur à la productivité alimentaire moyenne du Cameroun de 1269,5 kg/ha (INS, 2015). La majorité des parcelles de culture est alimentée par des pluies, ce qui peut être la raison d'une faible productivité. De plus, la productivité des adoptants des pratiques d'adaptation aux changements climatiques (4546,5 kg/ha) est significativement plus élevée que celle des non-adoptants (2351 kg/ha). Ce constat est conforme à d'autres études (Di Falco, Kohlin et Yesuf, 2012 ; Zhou et Turvey, 2014 ; Khanal et al., 2018a) qui estiment que la mise en œuvre des stratégies d'adaptation améliore la productivité alimentaire. Toutefois, cette approche ne tient pas compte du biais de sélection.

Les résultats présentés dans les deux dernières colonnes du tableau 1 tiennent compte du changement endogène dans la fonction de productivité alimentaire. Les coefficients estimés des termes de corrélations ne sont pas significativement différents de zéro, ce qui indique que l'hypothèse d'absence de biais de sélectivité de l'échantillon dans l'adaptation ne peut être rejetée (Di Falco et al., 2011 ; Khanal et al., 2018a). Toutefois, les différences dans les équations de productivité alimentaire entre les ménages adoptants et les non-adoptants montrent la présence d'hétérogénéité dans l'échantillon. Conformément aux prévisions de la théorie économique, les intrants tels que les fertilisants et le travail sont associés de manière significative à une augmentation de la productivité alimentaire des ménages qui se sont adaptés aux changements climatiques. Plusieurs variables ont des effets significatifs sur la productivité alimentaire des adoptants. C'est le cas de l'utilisation des engrais qui augmente de 47 % la productivité alimentaire. Contrairement à la superficie des terres cultivées qui réduit de 30,8% la productivité alimentaire. Cela peut s'expliquer par un problème d'utilisation optimale des facteurs de production (la terre et la main-d'œuvre) au sein des ménages qui s'adaptent. De plus la migration des membres du ménage d'une localité à une autre accroit leur productivité alimentaire. Face aux effets néfastes des changements climatiques, les membres d'un ménage se déplacent d'une localité à une autre à la recherche non seulement des terres fertiles mais également des conditions climatiques favorables. Quant aux variables, âge de l'exploitant, religion de l'exploitant et taille de la famille, elles sont positives et significatives. Autrement dit, elles accroissent la productivité alimentaire respectivement de 22,1%, 72,5% et 8,04%.

Le tableau 2 quant à lui, présente la productivité alimentaire prévue dans des conditions réelles et contrefactuelles. Les cellules (a) et (b) représentent la productivité alimentaire observée dans l'échantillon. La productivité alimentaire prévue pour les adoptants est d'environ 4546,356 kg/ha, et de 2352,582 kg/ha pour les non-adoptants. Cette simple comparaison peut toutefois être trompeuse et amener les chercheurs à conclure qu'en moyenne, les ménages adoptants ont produit environ 93, 24% (soit 2193,774 kg/ha) de plus que les ménages non-adoptants. La dernière colonne du tableau 2 présente les effets moyens du traitement, qui montrent l'impact de l'adaptation sur la productivité alimentaire. Ces effets de traitement expliquent le biais de sélection découlant de la probabilité que les ménages adoptants et non-adoptants soient systématiquement différents (Abdulai et Huffman, 2014). La cellule (c) représente la productivité alimentaire prévue à l'hectare des ménages adoptants s'ils avaient décidé de ne pas s'adapter et la cellule (d) représente la productivité alimentaire prévue à l'hectare des ménages non-adoptants, s'ils avaient décidé de s'adapter. Les ménages qui ont effectivement adopté auraient produit 1649,724 kg/ha (soit 56,95%) de moins s'ils n'avaient pas adopté des stratégies d'adaptation.

Tableau 2 : productivité alimentaire moyenne prévue à l'hectare ; effets du traitement

	Etape de décision		
Sous-échantillon	S'adapter	Ne pas s'adapter	Effet de traitement
ménage adaptateur	**(a)** 4546.356 (7125.129)	**(c)** 2896.632 (5214.088)	TT= 1649.724*** (10476.85)
ménage non-adaptateur	**(d)** 7091.413 (7513.013)	**(b)** 2352.582 (8893.83)	TU= 4738.831*** (9713.874)

*Note : Erreurs-types entre parenthèses. *Significatif au niveau de 10% ; **significatif au niveau de 5% ; ***significatif au niveau de 1%*

De même, les ménages agricoles qui n'ont pas effectivement adopté auraient produit 4738,831 kg/ha (soit 49,64%) de plus s'ils avaient adopté des stratégies d'adaptation. Ces résultats impliquent que l'adaptation aux changements climatiques augmente considérablement la productivité alimentaire. Cependant, l'effet de l'hétérogénéité transitoire est négatif (TT-TU), ce qui signifie que l'effet est beaucoup plus faible pour les ménages agricoles qui se sont effectivement adaptés que pour ceux qui ne se sont pas adaptés. Ces résultats sont similaires aux travaux de Di Falco et al., (2011) en Ethiopie ; Khanal et al., (2018a) au Népal et de Quan et al., (2019) en Chine.

CONCLUSION

Cette étude compare la productivité alimentaire entre les ménages agricoles qui adoptent les pratiques d'adaptation aux changements climatiques et ceux qui ne les adoptent pas dans la zone soudano-sahélienne camerounaise. Lorsque nous analysons les résultats pour les deux groupes (adoptants et non-adoptants), des tendances intéressantes se dégagent. Les ménages agricoles qui ont eu recours aux pratiques d'adaptation ont tendance à produire plus que ceux qui ne se sont pas adaptés dans le cas hypothétique où ils ne se seraient pas adaptés. De même, l'impact de l'adaptation sur la productivité alimentaire est plus faible pour les ménages qui se sont effectivement adaptés que pour les ménages qui ne se sont pas adaptés dans le cas hypothétique qu'ils se seraient adaptés. Force est de constater que si les deux groupes de ménages agricoles bénéficiaient de la mise en œuvre de stratégies d'adaptation, ce sont les ménages agricoles qui ne se sont pas adaptés qui bénéficieraient le plus de cette adaptation. Cet effet bénéfique de l'adaptation s'avère important. Si les ménages agricoles qui ne se sont pas adaptés s'étaient adaptés, ils auraient produit plus que les ménages agricoles qui se sont adaptés. Par conséquent, les stratégies d'adaptation semblent particulièrement importantes pour les ménages les plus vulnérables, ceux qui ont déjà le moins de capacités de production alimentaire, en les aidant à combler l'écart de production avec des ménages agricoles moins vulnérables.

Ces résultats sont particulièrement importants pour la conception des politiques visant à élaborer des stratégies d'adaptation efficaces pour faire face aux impacts potentiels des changements climatiques. Les politiques publiques peuvent jouer un rôle important pour aider les ménages agricoles à diffuser l'information sur le climat. De même, les services de vulgarisation sont d'une importance capitale dans la mise en œuvre des stratégies d'adaptation, qui pourraient aboutir à une plus grande sécurité alimentaire pour tous les ménages agricoles, indépendamment de leurs caractéristiques non observables. Lesdits services de vulgarisation constituent une importante source d'information et d'éducation. C'est le lieu de noter les changements de cultures et les mesures spécifiques de conservation des sols (fertilisation) qui peuvent apporter des gains de productivité alimentaire. La recherche prospective est nécessaire pour mieux comprendre la dimension comportementale du processus d'adaptation. Il serait plus intéressant d'axer la recherche sur la distinction du rôle des différentes stratégies d'adaptation et l'identification des stratégies les plus efficaces.

RÉFÉRENCES BIBLIOGRAPHIQUES

Abdulai, A., & Huffman, W. (2014). The adoption and impact of soil and water conservation technology: An endogenous switching regression application. Land Economics, 90(1), 26-43.

Adger, W. N., Huq, S., Brown, K., Conway, D., & Hulme, M. (2003). Adaptation to climate change in the developing world. Progress in development studies, 3(3), 179-195.

Alam, G. M., Alam, K., & Mushtaq, S. (2016). Influence of institutional access and social capital on adaptation decision: Empirical evidence from hazard-prone rural households in Bangladesh. Ecological Economics, 130, 243-251.

Aryal, A., Brunton, D., & Raubenheimer, D. (2014). Impact of climate change on human-wildlife-ecosystem interactions in the Trans-Himalaya region of Nepal. Theoretical and applied climatology, 115(3-4), 517-529.

Aryal, A., Shrestha, U. B., Ji, W., Ale, S. B., Shrestha, S., Ingty, T., . . . Raubenheimer, D. (2016). Predicting the distributions of predator (snow leopard) and prey (blue sheep) under climate change in the Himalaya. Ecology and evolution, 6(12), 4065-4075.

Asseng, S., & Pannell, D. J. (2013). Adapting dryland agriculture to climate change: Farming implications and research and development needs in Western Australia. Climatic change, 118(2), 167-181.

Bahinipati, C. S., & Patnaik, U. (2015). The damages from climatic extremes in India: do disaster-specific and generic adaptation measures matter? Environmental Economics and Policy Studies, 17(1), 157-177.

Bahinipati, C. S., & Venkatachalam, L. (2015). What drives farmers to adopt farm-level adaptation practices to climate extremes: Empirical evidence from Odisha, India. International Journal of Disaster Risk Reduction, 14, 347-356.

Bandara, J. S., & Cai, Y. (2014). The impact of climate change on food crop productivity, food prices and food security in South Asia. Economic Analysis and Policy, 44(4), 451-465.

Biggs, E. M., Tompkins, E. L., Allen, J., Moon, C., & Allen, R. (2013). Agricultural adaptation to climate change: observations from the Mid-Hills of Nepal. Climate and Development, 5(2), 165-173.

Bryan, E., Deressa, T. T., Gbetibouo, G. A., & Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environmental science & policy, 12(4), 413-426.

Butt, T. A., McCarl, B. A., Angerer, J., Dyke, P. T., & Stuth, J. W. (2005). The economic and food security implications of climate change in Mali. Climatic change, 68(3), 355-378.

Challinor, A. J., Watson, J., Lobell, D. B., Howden, S., Smith, D., & Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change, 4(4), 287.

Coromaldi, M., Pallante, G., & Savastano, S. (2015). Adoption of modern varieties, farmers' welfare and crop biodiversity: Evidence from Uganda. Ecological Economics, 119, 346-358.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change, 19(2), 248-255.

Devkota, R. P., Pandey, V. P., Bhattarai, U., Shrestha, H., Adhikari, S., & Dulal, K. N. (2017). Climate change and adaptation strategies in Budhi Gandaki River Basin, Nepal: a perception-based analysis. Climatic change, 140(2), 195-208.

Di Falco, S., & Veronesi, M. (2013). How can African agriculture adapt to climate change?

A counterfactual analysis from Ethiopia. Land Economics, 89(4), 743-766.

Di Falco, S., Veronesi, M., & Yesuf, M. (2011). Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. American Journal of Agricultural Economics, 93(3), 829-846.

Di Falco, S., Yesuf, M., Kohlin, G., & Ringler, C. (2012). Estimating the impact of climate change on agriculture in low-income countries: household level evidence from the Nile Basin, Ethiopia. Environmental and Resource Economics, 52(4), 457-478.

du Cameroun, I. A. S. (2017). Yaoundé: Institut national de la statistique; 2013.

Easterling, W. E., Aggarwal, P. K., Batima, P., Brander, K. M., Erda, L., Howden, S. M., . . . Schmidhuber, J. (2007). Food, fibre and forest products. Climate change, 273-313.

Field, C. B. (2014). Climate change 2014–Impacts, adaptation and vulnerability: Regional aspects: Cambridge University Press.

Finger, R., Hediger, W., & Schmid, S. (2011). Irrigation as adaptation strategy to climate change—a biophysical and economic appraisal for Swiss maize production. Climatic change, 105(3-4), 509-528.

Fosu-Mensah, B., MacCarthy, D., Vlek, P., & Safo, E. (2012). Simulating impact of seasonal climatic variation on the response of maize (Zea mays L.) to inorganic fertilizer in sub-humid Ghana. Nutrient Cycling in Agroecosystems, 94(2-3), 255-271.

Gordon, C., Cooper, C., Senior, C. A., Banks, H., Gregory, J. M., Johns, T. C., . .. Wood, R. A. (2000). The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments. Climate dynamics, 16(2-3), 147-168.

Hassan, H., Hanaki, K., & Matsuo, T. (1998). A modeling approach to simulate impact of climate change in lake water quality: phytoplankton growth rate assessment. Water Science and Technology, 37(2), 177.

Hassan, R. M., & Nhemachena, C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. African Journal of Agricultural and Resource Economics, 2(311-2016-5521), 83-104.

Heckman, J. J., & Vytlacil, E. (2001). Policy-relevant treatment effects. American Economic Review, 91(2), 107-111.

Huang, J., Wang, Y., & Wang, J. (2015). Farmers' adaptation to extreme weather events through farm management and its impacts on the mean and risk of rice yield in China. American Journal of Agricultural Economics, 97(2), 602-617.

Huang, K.-T., & Hwang, R.-L. (2016). Future trends of residential building cooling energy and passive adaptation measures to counteract climate change: The case of Taiwan. Applied energy, 184, 1230-1240.

Huq, S., Reid, H., Konate, M., Rahman, A., Sokona, Y., & Crick, F. (2004). Mainstreaming adaptation to climate change in least developed countries (LDCs). Climate Policy, 4(1), 25-43.

Hyde, K. D., Nilsson, R. H., Alias, S. A., Ariyawansa, H. A., Blair, J. E., Cai, L., . . . Goonasekara, I. D. (2014). One stop shop: backbones trees for important phytopathogenic genera: I (2014). Fungal Diversity, 67(1), 21-125.

II, I. P. o. C. C. W. G. (2014). Climate change 2014: impacts, adaptation, and vulnerability:

IPCC Working Group II.

Islam, S., Cenacchi, N., Sulser, T. B., Gbegbelegbe, S., Hareau, G., Kleinwechter, U., . . . Robinson, S. (2016). Structural approaches to modeling the impact of climate change and adaptation technologies on crop yields and food security. Global Food Security, 10, 63-70.

Johns, T., Gregory, J., Ingram, W., Johnson, C., Jones, A., Lowe, J., . . . Stevenson, D. (2003). Anthropogenic climate change for 1860 to 2100 simulated with the HadCM3 model under updated emissions scenarios. Climate dynamics, 20(6), 583-612.

Kaiser, H. M., Riha, S. J., Wilks, D. S., Rossiter, D. G., & Sampath, R. (1993). A farm-level analysis of economic and agronomic impacts of gradual climate warming. American Journal of Agricultural Economics, 75(2), 387-398.

Kassie, B., Van Ittersum, M., Hengsdijk, H., Asseng, S., Wolf, J., & Rötter, R. P. (2014). Climate-induced yield variability and yield gaps of maize (Zea mays L.) in the Central Rift Valley of Ethiopia. Field Crops Research, 160, 41-53.

Khanal, P. N., Grebner, D. L., Munn, I. A., Grado, S. C., Grala, R. K., Henderson, J. E., & Measells, M. K. (2016). Nonindustrial private forest landowner beliefs toward climate change and carbon sequestration in the southern United States. Journal of Forestry, 114(5), 524-531.

Khanal, U., Wilson, C., Hoang, V.-N., & Lee, B. (2018). Farmers' adaptation to climate change, its determinants and impacts on rice yield in Nepal. Ecological Economics, 144, 139-147.

Khanal, U., Wilson, C., Lee, B. L., & Hoang, V.-N. (2018). Climate change adaptation strategies and food productivity in Nepal: a counterfactual analysis. Climatic change, 148(4), 575-590.

Khonje, M., Manda, J., Alene, A. D., & Kassie, M. (2015). Analysis of adoption and impacts of improved maize varieties in eastern Zambia. World Development, 66, 695-706.

Kumar Sarkar, U., Kumar Pathak, A., Kumar Tyagi, L., Mohan Srivastava, S., Prakash Singh, S., & Kumar Dubey, V. (2013). Biodiversity of freshwater fish of a protected river in India: comparison with unprotected habitat. Revista de biologia tropical, 61(1), 161-172.

Kurukulasuriya, P., & Mendelsohn, R. (2008). How will climate change shift agro-ecological zones and impact African agriculture? : The World Bank.

Lacy, S. M., Cleveland, D., & Soleri, D. (2006). Farmer choice of sorghum varieties in southern Mali: Managing Unpredictable Growing Environments and Resources. Human Ecology, 34(3).

Lane, S., Tayefi, V., Reid, S., Yu, D., & Hardy, R. (2007). Interactions between sediment delivery, channel change, climate change and flood risk in a temperate upland environment. Earth Surface Processes and Landforms: The Journal of the British Geomorphological Research Group, 32(3), 429-446.

Lee, L.-F., & Trost, R. P. (1978). Estimation of some limited dependent variable models with application to housing demand. Journal of Econometrics, 8(3), 357-382.

Lehmann, N., Finger, R., Klein, T., Calanca, P., & Walter, A. (2013). Adapting crop management practices to climate change: Modeling optimal solutions at the field scale. Agricultural Systems, 117, 55-65.

Liu, P., Cai, H., & Wang, J. (2010). Effects of soil water stress on growth development, dry-matter partition and yield constitution of winter wheat. Research of Agricultural Modernization, 31(3), 330-333.

Lobell, D. B., & Field, C. B. (2007). Global scale climate–crop yield relationships and the impacts of recent warming. Environmental research letters, 2(1), 014002.

Lokshin, M., & Sajaia, Z. (2004). Maximum likelihood estimation of endogenous switching regression models. The Stata Journal, 4(3), 282-289.

Maddala, G. (1983). Methods of estimation for models of markets with bounded price variation. International Economic Review, 361-378.

Maddala, G. S., & Nelson, F. D. (1975). Switching regression models with exogenous and endogenous switching. Paper presented at the Proceedings of the American Statistical Association.

Mendelsohn, R., & Seo, N. (2007). Changing farm types and irrigation as an adaptation to climate change in Latin American agriculture: The World Bank.

Mendola, M. (2007). Agricultural technology adoption and poverty reduction: A propensity-score matching analysis for rural Bangladesh. Food policy, 32(3), 372-393.

Molua, E., & Utomakili, J. (1998). An analysis of resource-use efficiency in banana production in the south west province of Cameroon. Int J Trop Agric, 16, 113-118.

Molua, E. L. (2006). Climatic trends in Cameroon: implications for agricultural management. Climate Research, 30(3), 255-262.

Morton, T. (2007). Ecology without nature: Rethinking environmental aesthetics: Harvard University Press.

Niles, M. T., Brown, M., & Dynes, R. (2016). Farmer's intended and actual adoption of climate change mitigation and adaptation strategies. Climatic change, 135(2), 277-295.

Othniel Yila, J., & Resurreccion, B. P. (2013). Determinants of smallholder farmers' adaptation strategies to climate change in the semi arid Nguru Local Government Area, Northeastern Nigeria. Management of Environmental Quality: An International Journal, 24(3), 341-364.

Parry, M. L., Carter, T. R., & Konijn, N. T. (2013). The impact of climatic variations on agriculture: volume 1: assessment in cool temperate and cold regions: Springer Science & Business Media.

Piao, S., Ciais, P., Huang, Y., Shen, Z., Peng, S., Li, J., . . . Ding, Y. (2010). The impacts of climate change on water resources and agriculture in China. Nature, 467(7311), 43.

Piya, L., Maharjan, K. L., & Joshi, N. P. (2013). Determinants of adaptation practices to climate change by Chepang households in the rural Mid-Hills of Nepal. Regional environmental change, 13(2), 437-447.

Quan, S., Li, Y., Song, J., Zhang, T., & Wang, M. (2019). Adaptation to Climate Change and its Impacts on Wheat Yield: Perspective of Farmers in Henan of China.

Sustainability, 11(7), 1928.

Reid, S., Smit, B., Caldwell, W., & Belliveau, S. (2007). Vulnerability and adaptation to climate risks in Ontario agriculture. Mitigation and Adaptation Strategies for Global Change, 12(4), 609-637.

Reidsma, P., Ewert, F., Lansink, A. O., & Leemans, R. (2010). Adaptation to climate change and climate variability in European agriculture: the importance of farm level responses. European journal of agronomy, 32(1), 91-102.

Reilly, J. M., & Schimmelpfennig, D. (1999). Agricultural impact assessment, vulnerability, and the scope for adaptation. Climatic change, 43(4), 745-788.

Rosenzweig, C. (1989). Global climate change: Predictions and observations. American Journal of Agricultural Economics, 71(5), 1265-1271.

Rosenzweig, C., & Parry, M. L. (1994). Potential impact of climate change on world food supply. Nature, 367(6459), 133.

Sarker, M. A. R., Alam, K., & Gow, J. (2017). Performance of rain-fed Aman rice yield in Bangladesh in the presence of climate change. Renewable Agriculture and Food Systems, 1-9.

Sarker, S., Scholz-Romero, K., Perez, A., Illanes, S. E., Mitchell, M. D., Rice, G. E., & Salomon, C. (2014). Placenta-derived exosomes continuously increase in maternal circulation over the first trimester of pregnancy. Journal of translational medicine, 12(1), 204.

Seo, S. N., & Mendelsohn, R. (2008). Measuring impacts and adaptations to climate change: a structural Ricardian model of African livestock management 1. Agricultural economics, 38(2), 151-165.

Smit, B., Burton, I., Klein, R. J., & Wandel, J. (2000). An anatomy of adaptation to climate change and variability Societal adaptation to climate variability and change (pp. 223-251): Springer.

Stage, J., Stage, J., & McGranahan, G. (2010). Is urbanization contributing to higher food prices? Environment and Urbanization, 22(1), 199-215.

Thornes, J. E. (2002). IPCC, 2001: Climate change 2001: impacts, adaptation and vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, edited by JJ McCarthy, OF Canziani, NA Leary, DJ Dokken and KS White (eds). Cambridge University Press, Cambridge, UK, and New York, USA, 2001. No. of pages: 1032. Price:£ 34.95, ISBN 0-521-01500-6 (paperback), ISBN 0-521-80768-9 (hardback). International Journal of Climatology: A Journal of the Royal Meteorological Society, 22(10), 1285-1286.

Tingem, M., Rivington, M., Bellocchi, G., Azam-Ali, S., & Colls, J. (2008). Comparative assessment of crop cultivar and sowing dates as adaptation choice for crop production in response to climate change in Cameroon. The African Journal of Plant Science and Biotechnology, 2(1), 10-17.

Tingem, M., Rivington, M., & Colls, J. (2008). Climate variability and maize production in Cameroon: simulating the effects of extreme dry and wet years. Singapore Journal of Tropical Geography, 29(3), 357-370.

Waha, K., Müller, C., Bondeau, A., Dietrich, J., Kurukulasuriya, P., Heinke, J., & Lotze-

Campen, H. (2013). Adaptation to climate change through the choice of cropping system and sowing date in sub-Saharan Africa. Global Environmental Change, 23(1), 130-143.

Wang, J., Wang, E., Yang, X., Zhang, F., & Yin, H. (2012). Increased yield potential of wheat-maize cropping system in the North China Plain by climate change adaptation. Climatic change, 113(3-4), 825-840.

Xie, W., Xiong, W., Pan, J., Ali, T., Cui, Q., Guan, D., . . . Davis, S. J. (2018). Decreases in global beer supply due to extreme drought and heat. Nature plants, 4(11), 964.

Yorobe Jr, J., Rejesus, R., & Hammig, M. (2011). Insecticide use impacts of integrated pest management (IPM) farmer field schools: Evidence from onion farmers in the Philippines. Agricultural Systems, 104(7), 580-587.

Zhang, H.-L., Zhao, X., Yin, X.-G., Liu, S.-L., Xue, J.-F., Wang, M., . . . Chen, F. (2015). Challenges and adaptations of farming to climate change in the North China Plain. Climatic change, 129(1-2), 213-224.

Zheng, X., Su, L., Hu, S., Ye, Z., & He, J. (2015). Legendre wavelet for power amplifier linearization. Analog Integrated Circuits and Signal Processing, 84(2), 283-292.

Zhou, L., & Turvey, C. G. (2014). Climate change, adaptation and China's grain production. China Economic Review, 28, 72-89.

ANNEXES

Annexe 1 : définition et statistiques descriptives des variables

Variable	Definition	Moyenne	Ecart-type
Productivité alimentaire	Production agricole en kg a hectare	4302.978	37383.12
Fertilisant	Utilisation d'engrais chimique a hectare	46015.91	32721.27
Travail	Utilisation de la main d'œuvre a hectare (jour)	10745.45	11575.88
Capital	Dépense d'investissement (pesticides, semences...) a hectare	20650.15	13866.51
Exploitation d'élevage	Total des exploitations d'élevage du ménage en unité standard d'élevage	0.3120666	0.4636585
Terrain	Superficie des terres cultivées a hectare	2.621637	2.099153
Sexe	Sexe du chef de ménage (homme)	0.8987517	0.3018666
Age du chef de ménage	Moins de 30ans	0.1636616	0.370225
	De 30 a 50 ans	0.5409154	0.4986691
Niveau d'éducation	Primaire	0.331484	0.4710734
	Secondaire	0.260749	0.439348
Statut matrimonial	Chef de ménage a un statut de marié	0.9056865	0.2924672

Religion du chef de ménage	Chrétien	0.6823856	0.4658718
	Traditionaliste	0.257975	0.4378239
Taille du ménage	De 06 a 14ans	1.697642	1.79818
	De 15 a 20ans	1.801664	1.996747
	De 21 a 50ans	1.409154	1.772592
Appartenance à un groupe	Réseau de paysans	0.2094313	0.4071852
Revenu du ménage	Moins de 50m	0.2857143	0.4520676
	De 50_100m	0.1525659	0.3598182
	De 100_200m	0.1719834	0.3776279
Migration	Migration d'un membre du ménage	0.3037448	0.460193
Source d'information	radio	0.2149792	0.4110931
	Vulgarisateur	0.2857143	0.4520676
	Réseau de paysans	0.2343967	0.4239152
Perception des changements climatiques	Croyance climatique	0.9861304	0.117031

Variabilité pluviométrique et insécurité alimentaire au Sénégal : le cas de la Haute Casamance

Issa Mballo et Oumar Sy

ABSTRACT

Upper Casamance has farmland estimated at 2 million hectares. Agricultural activities mobilize about 80 % of the region's workforce during wintering (79.8% in rural areas and 20.2% in urban areas). However, the spatio-temporal variability of rainfall, initiated since 1970, has considerable impacts on agricultural activities. Indeed, the disruption of the rainy season (heavy rain or showers, recurrence of rain breaks, late start and early end of wintering) is not without effects on crop productivity. This article analyses rainfall variability in upper Casamance and its influence on agricultural production. The methodology adopted is based, first, on a statistical approach using the Pettitt test (1979) of the Standardized Rainfall Index (SPI) (Mckee et al., 1993), the deviation from the series average. The study is also based on field work (household survey and interviews) which made it possible to analyse food insecurity in the area and to identify mitigation strategies developed. Through the Pettitt test, we observed two ruptures overall in 1968 (Vélingara, Kounkané, Bonconto, Dabo and Médina Yéro Foulah) and in 1970 (Kolda). This unfavourable rainfall trend has, however, had an impact on agriculture in the area. Indeed, analysis of correlation matrices between rainfall and yield showed that rainfall is not the only factor that explains the variation in yields.

Keywords : climate variability, food insecurity, Upper Casamance, Senegal

RÉSUME

La Haute Casamance dispose de terres cultivables estimées à 2 millions d'hectares. Les activités agricoles mobilisent environ 80 % des actifs de la région pendant l'hivernage (79,8 % en milieu rural et 20,2 % en milieu urbain). Cependant, la variabilité spatio-temporelle de la pluviométrie, amorcée depuis les années 1970, a eu des impacts considérables sur les activités agricoles. En effet, le dérèglement de la saison pluvieuse (fortes pluies ou averses, récurrence des pauses pluviométriques, début tardif et fin précoce de l'hivernage) n'est pas sans effets sur la productivité des cultures. Le présent article se propose d'analyser la variabilité pluviométrique en Haute Casamance et son influence sur la production agricole. La méthodologie adoptée est basée, d'abord sur une approche statistique avec l'utilisation du test de Pettitt (1979) de l'Indice Pluviométrique Standardisée (IPS) (McKee et al., 1993), de l'écart par rapport à la moyenne de la série. L'étude s'appuie également sur des travaux de terrain (enquête-ménages et entretiens) qui ont permis d'analyser l'insécurité alimentaire dans la zone et d'identifier les stratégies de mitigation développées. A travers le test de Pettitt, nous avons globalement observé deux ruptures en 1968 (Vélingara, Kounkané, Bonconto, Dabo et Médina Yéro Foulah) et en 1970 (Kolda). Cette évolution pluviométrique défavorable a cependant des impacts sur l'agriculture de la zone. En effet, l'analyse des matrices de corrélation entre pluviométrie et rendements a montré que la pluviométrie n'est pas l'unique facteur qui explique la variation des rendements.

Mots clés : Variabilité climatique, insécurité alimentaire, Haute Casamance, Sénégal

INTRODUCTION

La variabilité climatique, pluviométrique en particulier, est l'un des phénomènes les plus importants de notre ère. En Afrique, elle représente une grande menace pour la croissance et le développement (Atidegla et al., 2017). Dans la plupart des pays et régions du continent africain, on s'attend à ce que la production agricole et l'accès à la nourriture soient sérieusement compromis par la variabilité du climat.

Au Sénégal, comme du reste dans la plupart des pays africains, les impacts de la variabilité pluviométrique sont prouvés. Depuis plusieurs décennies, les questions relatives à la variabilité climatique préoccupent les communautés scientifiques et les décideurs politiques, en raison de leurs effets dommageables sur les écosystèmes et les activités humaines. Ce risque est amplifié par les perturbations climatiques que connaît la planète dans son ensemble (Janicot et al., 2001, Noufé et al., 2016).

Les écosystèmes agricoles de la Haute Casamance ont connu des dynamiques sociales et environnementales au cours des quatre dernières décennies. Ces dernières ont entraîné une baisse des rendements agricoles et rendu plus complexes les objectifs d'autosuffisance alimentaire. La situation d'insécurité alimentaire relève des bouleversements écologiques notamment de la péjoration climatique (sécheresse), mais elle est accentuée par des actions anthropiques (Sané, 2003). Malgré ses potentialités physiques et humaines, la Haute Casamance est confrontée à des contraintes d'ordre climatique, pédologique, technique, organisationnel et socioéconomique.

Globalement, en Casamance, la baisse des précipitations de ces dernières décennies marquées par une moyenne annuelle de 1 270 mm entre 2010-1988 contre 1 540 mm sur la période 1949-1968 (Dacosta, 1989) n'a fait qu'accélérer et intensifier la perturbation des processus pédogénétiques. Les recherches expérimentales effectuées jusque-là en milieu tropical révèlent que les répercussions des changements climatiques sur les rendements des cultures vont varier considérablement (Doukpolo, 2014). Ces répercussions dépendent des espèces et des variétés cultivées, des caractéristiques des sols, de l'ampleur de l'action des ravageurs et des agents pathogènes, des effets directs du dioxyde de carbone (CO_2) sur les plantes, du stress hydrique, de la nutrition minérale, des réactions adaptatives (Faye, 2017).

En tant que problème mondial qui menace l'existence humaine dans différentes parties du monde, le changement climatique est une importante question environnementale, sociale et économique qui menace la réalisation des objectifs de développement durable. De ce fait, de nombreuses études ont été menées à travers le monde pour trouver des moyens de réduire la menace de la variabilité climatique (Farauta et al., 2012, Faye, 2017).

Les pesanteurs sociopolitiques et économiques à caractère endémique, associés aux mutations environnementales et au stress hydro-thermique, risquent d'impacter de façon durable les communautés agricoles de la Haute Casamance. Pour y faire face, plusieurs politiques ont été initiées par l'Etat du Sénégal pour booster les productions agricoles et atténuer la vulnérabilité socioéconomique dans le monde rural. Parmi ces politiques, on peut citer les aménagements hydroagricoles, la mécanisation agricole et la subvention des intrants (Mballo et al., 2019).

La relance de la production agricole constitue une préoccupation majeure de l'Etat du Sénégal dans un contexte marqué par une crise alimentaire et une vulnérabilité socioéconomique et environnementale des ruraux (Sène, 2018). L'analyse de la corrélation entre pluviométrie et rendements agricoles, suscite une interrogation : quels sont les impacts potentiels de la variabilité pluviométrique sur la quête d'une sécurité alimentaire en Haute Casamance ?

L'étude caractérise le climat de la région, analyse les impacts des aléas climatiques sur les rendements agricoles et indique des stratégies d'adaptation développées dans une posture de réduction des risques.

MATÉRIELS ET MÉTHODES

Zone d'étude

La Haute Casamance, actuelle région de Kolda, se situe au Sud du Sénégal entre les latitudes 12°20 et 13°40 nord et les longitudes 13° et 16° ouest. Elle s'étend sur une superficie de 13 721 km^2, soit 7 % du territoire national. Elle est limitée au Nord par la Gambie, à l'Est par la région de Tambacounda, à l'Ouest par la région de Sédhiou et au Sud par la Guinée Bissau et la République de Guinée (fig.1). Les enquêtes ont été menées dans 12 communes de la région de Kolda, soit quatre communes par département. Au total, 441 chefs de ménages sont interrogés. La commune est l'unité d'échantillonnage. Le village constitue l'unité déclarante et le ménage, l'unité de référence.

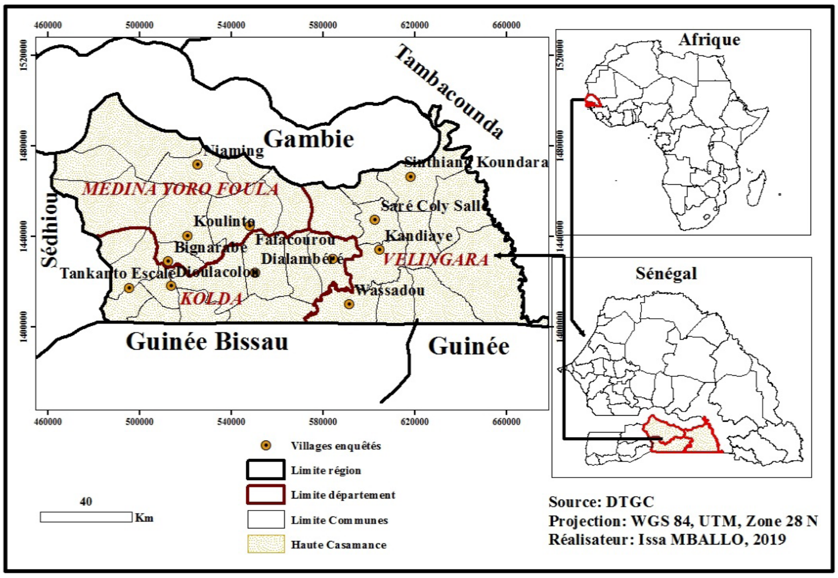


Figure 1: Localisation de la région d'étude. Mballo, 2019

Cadre conceptuel

L'expression «Variabilité climatique» qui est un des éléments intégrateurs du changement global, a été définie par plusieurs auteurs dont Boko (1988), reprise par Beltrando (1995) et Brou (2005). Elle fait pressentir la mobilité ou la variation du schéma climatique moyen et d'autres statistiques (écarts standards, normalités, phénomènes extrêmes, etc.) du climat à toutes les échelles temporelles et spatiales au-delà des phénomènes climatiques individuels. La variabilité peut être due à des processus internes naturels au sein du système climatique (variabilité interne), ou à des variations des forçages externes anthropiques. Elle se réfère à la variation naturelle intra et inter-annuelle du climat (CCNUCC, 1992). Le degré de variabilité climatique peut être décrit par les différences entre les valeurs moyennes à long terme des paramètres climatiques (pluie, température, humidité, durée des saisons) et les valeurs observées prises à différentes échelles temporelles et spatiales.

La vulnérabilité des territoires face aux risques de toute nature est une préoccupation des sociétés contemporaines (George P et al., 2009). Etymologiquement, la vulnérabilité est le fait d'être sensible aux blessures, aux attaques ou d'éprouver des difficultés pour recouvrer une santé mise en péril. Cette définition implique la prise en compte de deux effets de la vulnérabilité aux risques naturels : les dommages potentiels ou la capacité d'endommagement des phénomènes naturels menaçants ; les difficultés qu'une société mal préparée rencontre pour réagir à une crise, puis restaurer l'équilibre (perturbations directes et indirectes, immédiates et durables).

La « sécurité alimentaire est atteinte quand toutes les personnes ont, à tout moment, un accès physique, social et économique à une nourriture suffisante, saine et nutritive leur permettant de satisfaire leurs besoins énergétiques et leurs préférences alimentaires pour mener une vie saine et active. La sécurité alimentaire des ménages correspond à l'application de ce concept au niveau de la famille, les individus qui composent le ménage étant le centre d'attention » (Fao, 2010). L'insécurité alimentaire est donc atteinte lorsque les personnes n'ont pas un accès physique, social et économique à une nourriture suffisante.

Indice standardisé des précipitations (ISP)

La compréhension qu'un déficit pluviométrique a un impact différent sur les eaux souterraines, le stockage des réservoirs, l'humidité du sol et le flux d'écoulement a conduit au développement de l'indice standardisé des précipitations (ISP) (McKee et al., 1993). L'ISP est un indice simple qui est adopté en 2009 par l'organisation mondiale de la météorologie (OMM) comme un instrument destiné à mesurer les sécheresses météorologiques (Jouilil et al., 2013). Il est exprimé mathématiquement comme suit : $ISP = \frac{(P_i - P_m)}{S}$ $ISP = \frac{(P_i - P_m)}{S}$, avec P_i : la pluie du mois ou de l'année i ; P_m : la pluie moyenne de la série sur l'échelle temporelle considérée ; S : l'écart-type de la série sur l'échelle temporelle considérée.

Tableau 1 : Classification des séquences de sécheresse selon l'ISP

Valeurs de l'ISP	Séquences sèches	Valeurs de l'ISP	Séquences humides
0,00< ISP <-0,99	Légèrement sèche	0,00< ISP <0,99	Légèrement humide
-1,00< ISP <-1,49	Modérément sèche	1,00< ISP <1,49	Modérément humide
-1,50< ISP <-1,99	Sévèrement sèche	1,50< ISP <1,99	Sévèrement humide
ISP < -2,00	Extrêmement sèche	2,00< ISP	Extrêmement humide

Source : McKee et al, 1993, Jouilil et al., 2013

RÉSULTATS ET DISCUSSIONS

Résultats

Fréquence des classes de pluie et détection des ruptures de stationnarité

La détection des ruptures de stationnarité a été effectuée par le test de Pettitt (1979) qui s'est révélé significatif au seuil de 95 %. Ce test a permis d'observer une modification dans l'évolution des pluies dans les différentes stations à partir de 1968 (Tab.2).

Tableau 2 : Résultats des tests d'homogénéité sur les pluies annuelles de 1951 à 2016 dans la région d'étude

Stations et postes pluviométriques	Années de rupture	Moyenne avant rupture (mm)	Moyenne après rupture (mm)	Ecart	Déficit (%)
Kolda	1970	1090,5	858,2	232,3	21,30
Vélingara	1968	1117,0	844,0	273	24,44
Kounkané	1968	1160,3	933,6	226,7	19,54
Dabo	1968	1233,4	955,5	277,9	22,53
Médina Yéro Foulah	1968	1065,8	834,8	231	21,67
Bonconto	1968	1231,3	959,5	271,8	22,07

Source : Résultats de traitement des données pluviométriques, Mballo, 2019

Globalement, on note un déficit pluviométrique dans les six stations durant la période 1951-2016. Il est de 21,3 % à Kolda, de 19,54 % à Kounkané et de 21,67 % à Médina Yéro Foulah, soit une baisse supérieure à 19 % pour l'ensemble des stations considérées.

Indices standardisés des précipitations

Les précipitations de la Haute Casamance sont soumises à de fortes variations dues aux facteurs globaux et aux dynamismes régionaux et continentaux. A l'instar des mécanismes généraux qui régulent le climat tropical, le régime pluviométrique de cette région dépend en grande partie de la mousson dite de la zone de convergence intertropicale (ZCIT). La méthode des indices standardisés des précipitations a été appliquée et a permis de bien apprécier la variabilité pluviométrique dans la région d'étude (Tableau3).

Tableau 3 : Fréquences des occurrences de sécheresse des stations retenues de 1951 à 2016.

Séquences	Kolda	Vélingara	Dabo	Kounkané	MYF	Bonconto
Extrêmement humide	1,5	4,5	3,1	1,5	3,0	1,5
Sévèrement humide	3,0	4,5	6,2	3,0	3,0	3,0
Modérément humide	7,6	7,6	9,2	13,6	9,1	6,1
Légèrement humide	39,4	34,8	27,7	28,8	31,8	24,2
Légèrement sèche	31,8	33,3	38,5	40,9	33,3	27,3
Modérément sèche	10,6	12,1	10,8	7,6	15,2	6,1
Sévèrement sèche	4,5	3,0	4,6	3,0	4,5	1,5
Extrêmement sèche	1,5	0,0	0,0	1,5	0,0	30,3
Total	100	100	100	100	100	100

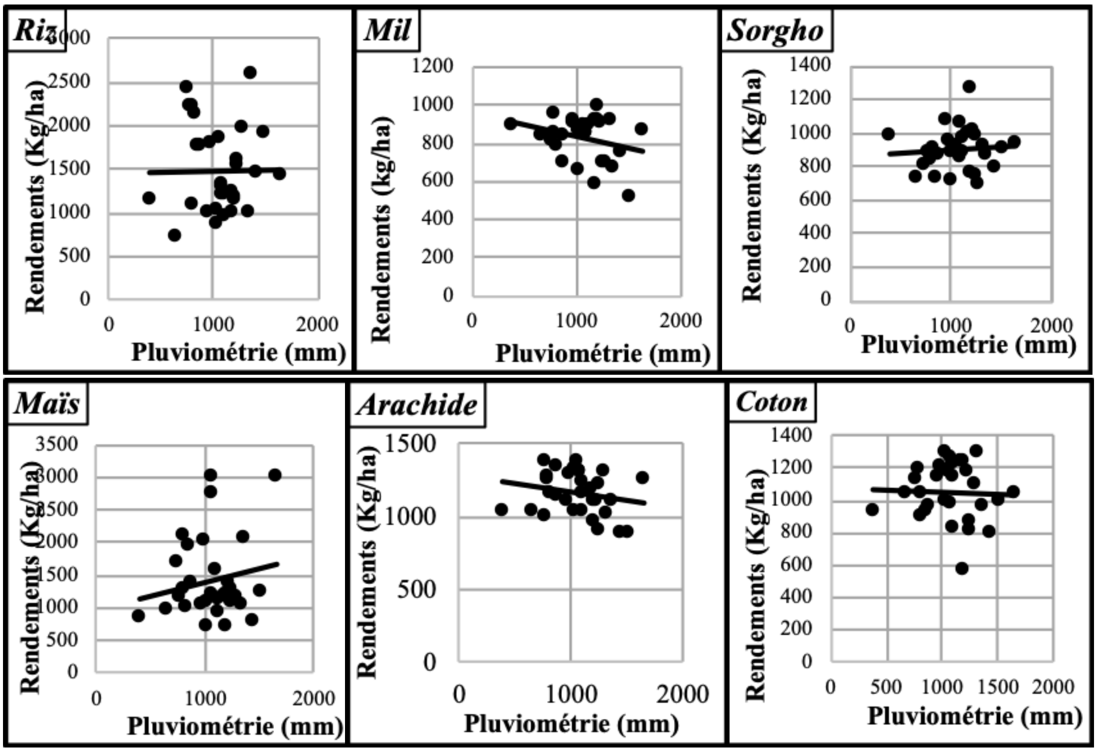
Source : Traitement de données climatiques. Mballo, 2019

Les ISP utilisés pour l'évaluation du déficit pluviométrique de 1951 à 2016 montrent une importante fluctuation des périodes sèches et humides avec une forte tendance à la sécheresse, notamment sur la période 1971-2000. L'examen du tableau 3 montre que la station de Kolda a enregistré l'ensemble des catégories de sécheresse (légère avec 31,8 %, modérée avec 10,6 %, sévère avec 4,5 % et extrême avec 1,5 %). Il en est de même pour les postes pluviométriques de Kounkané (légère avec 40,9 %, modérée avec 7, 6 %, sévère avec 3 % et extrême avec 1,5 %), et de Bonconto (légère avec 27,3 %, modérée avec 6,1 %, sévère avec 1,5 % et extrême avec 30,3 %). Par opposition, toutes les stations et les postes ont enregistré l'ensemble des séquences humides de 1951 à 2016 en Haute Casamance. On note une humidité globalement légère parce que la moyenne est de 31,1 %. La fréquence de l'humidité extrême est très faible car elle est de 1,5 % à Kolda, à Bonconto et à Kounkané, de 4,5 % à Vélingara, de 3,1 % à Dabo, de 3 % à Médina Yéro Foulah (tableau.3). On peut noter que la partie nord de la Haute-Casamance est moins arrosée en précipitations que la zone méridionale, car la pluviométrie est inférieure à 1000 mm pour la période 1951-2016.

Test de corrélation entre pluviométrie annuelle et rendements agricoles

Nous avons représenté de façon simultanée les deux variables sur les graphiques en nuage de points. La commodité de ce type de représentation offre une bonne lecture de l'interdépendance ou non des variables étudiées. Il est toutefois intéressant de rappeler que la corrélation n'implique pas de facto la causalité car une relation entre deux paramètres peut être la conséquence d'un troisième facteur causal. L'analyse des graphiques de corrélation réalisée sur les cultures (fig.2) montre qu'il y a une grande dispersion des points quasiment pour les rendements de toutes les cultures étudiées.

Figure 2: Relations pluies annuelles et rendements agricoles (arachide, riz, sorgho, mil, coton et maïs)



La dispersion des points montre que la variabilité pluviométrique n'a pas une grande influence sur les rendements comme en témoignent les graphiques. Cela signifie qu'il ya d'autres facteurs qui contribuent à l'explication de la variation des rendements agricoles au fil des années. Parmi ces facteurs, on peut considérer la répartition spatio-temporelle des précipitations, la pauvreté des sols, l'ensablement des vallées, les problèmes techniques.

- **Matrice des corrélations**

La matrice est réalisée à partir des corrélations entre la pluviométrie, les productions et les rendements agricoles de quelques cultures industrielles (Arachide et coton) et céréalières (mil, riz, sorgho et maïs). La corrélation est globalement très faible et parfois négative entre la pluviométrie et les productions agricoles (Tableau.4).

Tableau 4 : Matrice des corrélations pluviométrie, rendements et productions de mil

Mil	Pluviométrie	Rendements	Productions
Pluviométrie	1,00		
Rendements	-0,27	1,00	
Productions	-0,43	0,51	1,00
Riz	Pluviométrie	Rendements	Productions
Pluviométrie	1,00		
Rendements	0,01	1,00	

Productions	-0,20	0,56	1,00
Arachide	Pluviométrie	Rendements	Productions
Pluviométrie	1,00		
Rendements	-0,21	1,00	
Productions	-0,17	0,38	1,00
Sorgho	Pluviométrie	Rendements	Productions
Pluviométrie	1,00		
Rendements	0,08	1,00	
Productions	-0,11	0,48	1,00
Maïs	Pluviométrie	Rendements	Productions
Pluviométrie	1,00		
Rendements	0,17	1,00	
Productions	0,19	0,93	1,00
Coton	Pluviométrie	Rendements	Productions
Pluviométrie	1,00		
Rendements	-0,04	1,00	
Productions	0,21	0,68	1,00

Source : Résultats Traitement SPAD. Mballo, 2019

L'analyse du tableau 4 montre que la corrélation entre la pluviométrie et le maïs est la seule positive. Toutes les autres spéculations sont négativement corrélées à la pluviométrie. Globalement, on note une corrélation très faible entre la pluviométrie et les différentes cultures industrielles et céréalières. Elle est successivement de 0,21 et de 0,19 entre la pluviométrie et les productions de coton et de maïs. La corrélation est négative entre la pluviométrie et les productions de mil (-0,43), de riz (-0,20), d'arachide (-0,17) et de sorgho (-0,11). L'Analyse en Composantes Principales (ACP) des variables (riz, mil, maïs, arachide, coton, sorgho et pluviométrie) a permis d'évaluer leur niveau d'influence. La faiblesse de la corrélation permet de déduire que la pluie n'est pas le seul facteur explicatif de l'irrégularité des rendements agricoles dans la région.

Quelques indicateurs d'insécurité alimentaire en Haute Casamance

La répartition spatiale des indicateurs d'insécurité alimentaire a permis de voir des disparités à l'échelle des communes en termes de niveau de vulnérabilité des populations de la Haute Casamance. En fonction des indicateurs, on peut avoir des schémas différents. Globalement, ces indices sont élevés en Haute Casamance, particulièrement dans le département de Médina Yéro Foulah (communes de Fafacourou, de Niaming et de Koulinto). Les communes situées dans le bassin de l'Anambé sont les moins affectées par l'insécurité alimentaire car les populations développent d'autres activités (petit commerce, manœuvre, transport, maraîchage) sous l'influence du marché hebdomadaire de Diaobé. Les populations y viennent quotidiennement pour développer des activités telles que le petit commerce, le transport en commun (voitures, charrettes ou encore taxi-moto). Pratiquement durant toute l'année, les populations trouvent des activités à développer pour mener à bien leur vie et ainsi réduire leur vulnérabilité.

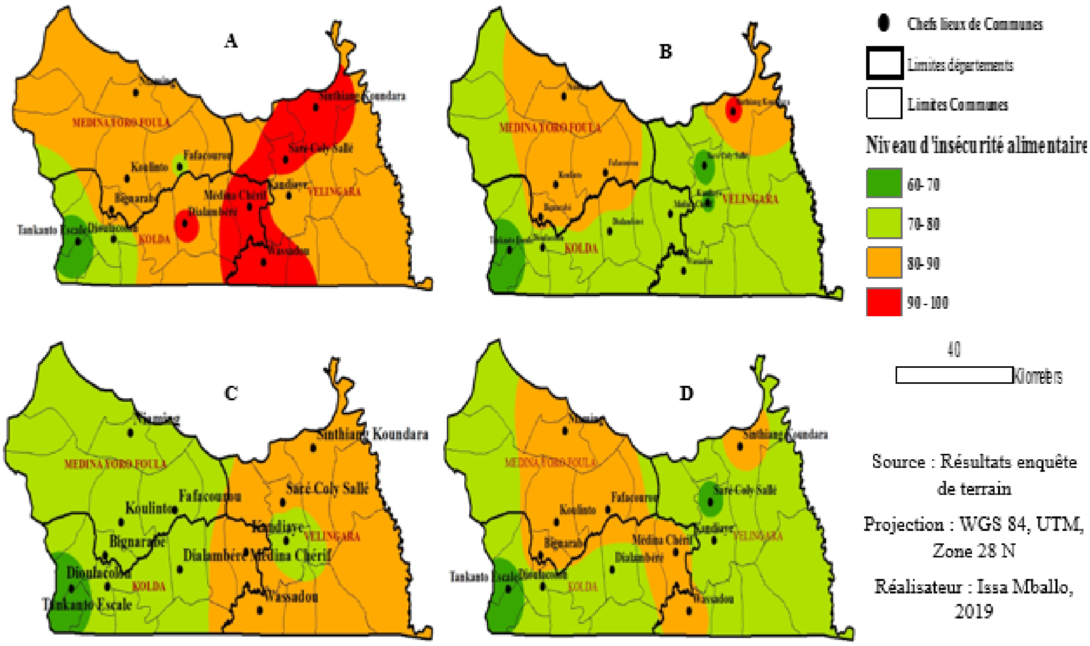


Figure 3 : A : ménages ayant épuisé leur stock de nourriture, B : ménages sous contrainte d'un manque de nourriture, C : ménages ayant manqué de nourriture sans avoir les moyens d'en acheter et D : ménages ayant réduit le nombre de repas. Mballo, 2019

La figure 3.A montre une distribution inégale des ménages ayant une fois épuisé leur stock de nourriture. La moyenne est relativement élevée car elle est de 85,1 % dans la région. Parallèlement, le pourcentage le plus élevé et le plus faible sont notés successivement à Wassadou (95,8 %) et à Tankanto Escale (60,5 %). Dans la région, cette situation est généralement observée en saison sèche. Cela entrave quelquefois, l'entame de la saison de l'hivernage, car les responsables des ménages accordent évidemment une priorité à la quête de la nourriture. Cela semble être logique, parce qu'un paysan affamé ou mal nourri est moins efficace qu'un paysan bien nourri avec moins de souci de survie. Par mesure stratégique, certains responsables de ménages, pour augmenter la durée de vie de leur stock de nourriture, préfèrent réduire le nombre de repas.

Le taux de ménages, sous crainte d'un manque de nourriture, est de 89,5 % à Fafacourou, de 60,5 % à Tankanto Escale et de 67,9 % à Saré Coly Sallé (fig.3.B). Les pourcentages les plus élevés sont notés dans la partie nord-ouest de la région qui, géographiquement, présente la plus faible pluviométrie. Les problèmes liés à l'enclavement, à la faible présence des acteurs du monde rural (ONG, Projets et Sociétés), aux litiges fonciers très tendus quelquefois, à l'interdiction de défrichement anarchique des écosystèmes forestiers et à la concurrence entre allochtones et autochtones sur les ressources naturelles, constituent des facteurs limitants au développement des activités agricoles. Le nombre de ménages atteints par la faim varie en fonction des communes. Le niveau de vulnérabilité le plus élevé est noté à Médina Chérif (89,2 %) et le plus faible à Tankanto Escale (63,2 %), soit une moyenne de 77,8 % pour les 12 communes (figure.3.C).

La figure 3.D montre une distribution du nombre de ménages ayant réduit le nombre de repas au cours de l'année. Sur les 12 communes ciblées, la moyenne est de 78,1 %. Le pourcentage le plus élevé a été noté à Bignaraabé (89,5 %) et le plus faible à Tankanto Escale (60,5 %). Cette stratégie permet généralement à la plupart des chefs de ménage d'assurer leur alimentation.

Adaptation des pratiques culturales

Les enquêtes auprès des producteurs ont montré que les paysans de la Haute Casamance sont très vulnérables aux conséquences de la variabilité climatique. En réponse aux perturbations climatiques, les agriculteurs ont adopté des stratégies d'adaptation dont les plus répandues sont : les rotations culturales (pratiquée par 91 % des personnes interrogées), l'adaptation variétale, la modification des dates de semis, la mise en valeur des bas-fonds et la jachère (pratiquée par 38 % des producteurs). On note également l'usage de produits chimiques et du fumier pour améliorer les rendements agricoles. Le croît démographique a entraîné le morcellement des parcelles et la raréfaction des champs en jachère. Plusieurs projets d'aménagement hydroagricole (barrages, digues) sont engagés pour mieux gérer les quantités d'eau enregistrées durant l'hivernage.

Discussion

L'évolution pluviométrique défavorable aux activités humaines, notée depuis les années 1970 dans le Sahel n'a pas épargné la partie soudanienne du Sénégal (Ndong, 1995 ; Sagna, 1995, 2007, Faye et al., 2018). Cette évolution s'est manifestée par un basculement des isohyètes vers le sud entraînant la disparition de l'isohyète 1200 mm du territoire. Cette période de sécheresse a entraîné des incidences néfastes sur les productions agricoles et dramatiques sur les conditions d'existence des populations rurales, car le degré de leur vulnérabilité n'a cessé de s'accroître (Sarr, 2006).

La baisse de la pluviométrie en Haute Casamance, couplée à l'action anthropique, induit une dégradation des systèmes écologiques. Cette situation se traduit par une réduction de la production des terres ; ce qui affecte négativement les conditions de vie des populations (Sané, 2003). L'agriculture étant essentiellement pluviale, la modification du régime des précipitations entraîne des perturbations agricoles brutales qui ont des répercussions profondes sur la vie des populations en général et celles des agriculteurs en particulier.

L'analyse des données pluviométriques montre une évolution irrégulière qui ne joue pas en faveur des activités agricoles. Les ruptures de stationnarité sont notées entre 1968 et 1970 dans la région. Cela corrobore les travaux de Sané (2003) qui avait alerté sur la dégradation des écosystèmes de la Haute Casamance à cause de la variabilité climatique. D'autres études, à l'échelle nationale, ont révélé un déficit pluviométrique depuis 1970, lequel représente une menace sérieuse pour l'agriculture pluviale, la plus pratiquée au Sénégal (Dione, 1996 ; Sow, 2007 ; Sagna, 2005 ; Faye et al., 2015 ; Faye et al., 2017).

L'évolution climatique défavorable s'est fortement répercutée sur les activités socioéconomiques car l'agriculture, principale source de revenu des ménages ruraux et garante de la sécurité alimentaire de la population, est largement tributaire des paramètres climatiques et particulièrement de la pluviométrie. En effet, la faiblesse des volumes annuels de précipitations, la fréquence des épisodes secs et le raccourcissement de la saison des pluies affectent considérablement le cycle végétatif des cultures. Les conséquences écologiques de cette variabilité spatio-temporelle de la pluviométrie sont aussi accentuées par la pression croissante de la population sur les ressources naturelles déjà fragilisées par les phases de sécheresse quasi-cycliques.

En dehors de la variabilité pluviométrique, l'appauvrissement des sols constitue aussi une contrainte pour une meilleure productivité des cultures. Les paysans exercent une forte pression sur les terres alors que les possibilités de maintenir la fertilité des sols sont limitées (FAO, 1976 ; Ndiaye, Touré, 2010).

Ce contexte socio-environnemental peu favorable est marqué également et principalement par une nouvelle orientation politique agricole amorcée depuis les années 1980 dans le cadre des plans d'ajustement structurel dictés par la Banque Mondiale (BM) et le Fonds Monétaire International (FMI), qui s'est avérée peu favorable aux paysans (Fall, 2014, Faye et al., 2018). Devant la déprise agricole en Haute Casamance, plusieurs stratégies sont développées pour, au moins, réduire les impacts de la variabilité pluviométrique (pratiques culturales, aménagements hydroagricoles). Toutefois, malgré cette batterie de stratégies, les populations locales sont vulnérables socialement et économiquement, car il faut rappeler que l'agriculture constitue la principale activité dans la région.

CONCLUSION

L'étude des impacts de la variabilité pluviométrique sur la production agricole et par conséquent sur la sécurité alimentaire reste encore d'actualité dans les régions sénégalaises. En ce qui concerne l'évolution de la pluviométrie, l'Indice Pluviométrique Standardisé (IPS) a montré une fluctuation de la pluie dans les séries chronologiques. Ainsi distinguons-nous des phases humides et des phases sèches dans les différentes stations et postes pluviométriques. La chute des quantités de pluies est confirmée par le test de rupture de Pettitt (1979) qui s'est révélé significatif au seuil de 95 %. La moyenne pluviométrique avant rupture était de 1090,5 mm à Kolda, de 1 117 mm à Vélingara et de 1 065,8 mm à Médina Yéro Foulah. Au terme de ce travail, nous pouvons retenir que les rendements sont liés d'une part à la variabilité et à l'inégale répartition spatio-temporelle des pluies, à la fréquence des séquences sèches pluviométriques, et d'autre part à des facteurs structurels liés à l'utilisation des techniques et outils rudimentaires. En effet, la faible mécanisation agricole conjuguée aux effets de la dégradation du couvert végétal et de la baisse de la fertilité des sols constitue des contraintes réelles pour le développement agricole.

RÉFÉRENCES BIBLIOGRAPHIQUES

Atidegla et al., (2017). Variabilité climatique et production maraîchère dans la plaine inondable d'Ahomey-Gblon au Bénin, International Journal of Biological and Chemical Sciences, 16p.

Dacosta H. (1989). Précipitations et écoulements sur le Bassin de la Casamance, Thèse de troisième cycle en Géographie, UCAD, PDF, 283p.

Doukpolo B. (2014). Changements climatiques et productions agricoles dans l'Ouest de la République Centrafricaine, Thèse de troisième cycle, Université d'Abomey-Calavi (UAC), République du Bénin, PDF, 338p.

Faye C. et al., (2017). Une évaluation comparative des séquences de sécheresse météorologique par indices, par échelles de temps et par domaines climatiques au senegal, J. Wat. Environnement Science Vol. 1, N°1, p.11-28

Faye M., Fall A., Faye G., Hecke E. V. (2018). La variabilité pluviométrique et ses incidences sur les rendements agricoles dans la région des Terres Neuves du Sénégal oriental, revue belge de géographie, 18p.

Jouilil, I., K. Bitar H. Salama I. Amraou A. Mokssit et Tahiri M.(2013). Sécheresse météorologique au bassin hydraulique OUM ER RBIA durant les dernières décennies. Larhyss Journal, 12, 109-127.

Mahaman Bachir SALEY et al., (2009). Variabilité spatio-temporelle de la pluviométrie et son impact sur les ressources en eaux souterraines : cas du district d'Abidjan (sud de la Côte d'Ivoire), Université de Cocody, PDF, 18p.

Mballo et al., (2019). Aménagements agricoles et sécurité alimentaire au senegal : cas de la Haute Casamance (sénégal), revue Espace géographique et société marocaine, N°27, 19p.

Ndiaye D.S, Touré A. (2010). Best practices : Recueil d'expériences de gestion durable des terres au Sénégal, Dakar, Projet LADA/FAO- CSE, 98 p.

Noufé D et al., (2016). Impact de la variabilité climatique sur la production du maïs et de l'igname en zones Centre et Nord de la Côte d'Ivoire, Agronomie Africaine, N° Décembre, p.241-256.

Sané T. (2003). La Variabilité climatique et ses Conséquences sur l'environnement et les activités humaines en Haute-Casamance, Thèse de Doctorat de troisième cycle de Géographie, UCAD, 372p.

Sarr B. (2006). INSTAT+ en bref Manuel d'utilisation destiné aux Ingénieurs en agrométéorologie et en météorologie aéronautique, CILSS, Centre régional Agrhymet, 74 p.

Sène, A. (2018). Aménagement et dégradation des rizières des bas-fonds dans un contexte de changement climatique dans la région de Ziguinchor. Revue Espace Géographique et Société Marocaine, No20/21, Janvier 2018, p. 129-144.

Rainfall shocks effects on children malnutrition in Senegal

Ahmadou Ly

ABSTRACT

The links between rainfall shocks and child nutrition remain insufficiently documented in literature and there are dearth of studies exploring its effects in the Senegalese context. To assess these effects, a survey of 3,645 children (0-5 years) living in 1,627 rural households in Senegal was conducted in 2014. Three main indicators of nutritional status based on anthropometric measures were considered: weight-for-age, weight-for-height and height-for-age. It is found that rainfall shocks occurring before birth have a significant and positive effect on child malnutrition as they mainly reduce the z-scores of height-for-age. Income by crop and the use of the mother's time were relevant transmission channels through which rainfall shocks have negative effects on the nutritional status (stunting, wasting, under-weight) of children.

Keywords : Children, Malnutrition, Rainfall, Senegal

RÉSUMÉ

Les liens entre les chocs pluviométriques et la nutrition des enfants restent insuffisamment documentés dans la littérature et les études explorant leurs effets dans le contexte sénégalais sont rares. Documentés dans la littérature et il y a une pénurie d'études explorant ses effets dans le contexte sénégalais. Pour évaluer ces effets, une enquête a été menée en 2014 auprès de 3 645 enfants (0-5 ans) vivant dans 1 627 ménages ruraux au Sénégal. Trois principaux indicateurs de l'état nutritionnel basés sur des mesures anthropométriques ont été considérés : poids pour l'âge, poids pour la taille et taille pour l'âge. Il s'avère que les chocs pluviométriques survenant avant la naissance ont un effet significatif et positif sur la malnutrition des enfants car ils réduisent principalement les z-scores de la taille pour l'âge. Le revenu par culture et l'utilisation du temps de la mère sont des canaux de transmission pertinents par lesquels les chocs pluviométriques ont des effets négatifs sur l'état nutritionnel (retard de croissance, émaciation, insuffisance pondérale) des enfants.

Mots clés : Enfants, Malnutrition, Pluie, Sénégal

INTRODUCTION

In West Africa, recurrent droughts in the 1970s' and 1980s' have resulted to serious losses for farmers and pastorals. Between 30% and 50% of production decline are attributed to climate factors. Thus, the occurrence of negative rainfall shocks may affect agricultural yields and further reduce households income (Leight et al., 2015). While malnutrition is recognized as one of the five largest health outcomes caused by climate change. This could even get worse and may persist with the presence of long term effects until adulthood (Maccini and Yang, 2009; Hoddinott, 2009; Barker, 1990). Exploring rainfall relationships with respect to children malnutrition is very relevant in developing countries' settings. Malnutrition is a major public issue in developing countries, especially in Sub-Saharan Africa. Moreover, particularly in rural areas, rain-fed agriculture plays a dominant role in households livelihoods. Agriculture accounts for a large share of the households' income and contributes significantly to their food security. During the last three decades, rainfall patterns have been subjected to significant changes. In this study, we explored the effects of prenatal and postnatal shocks on children's nutritional status in Senegal. We also identified the causal transmission channels through which rainfall shocks can exert significant effects on children's malnutrition. This paper therefore investigates whether rainfall shocks exerts significant effects on children's malnutrition in Senegal.

Barker (1990), in a seminal paper shed light on the effects prenatal conditions could have in determining the well-being of the future child. Findings emphasize that in-utero living conditions may have impacts on child health. A finer analysis on prenatal and postnatal rainfall shocks on children's malnutrition yielded to mixed evidence. The rationale of such a finding is explained by the fact that male foetuses are more vulnerable to climatic shocks than female foetuses. The main contributions of this paper are based on three evidence gaps. First, we assessed rainfall shocks' effects on three malnutrition indicators (stunting, wasting, under-weight) in a West African context. Second, the mixed evidence on critical period of vulnerability led us to have a closer look on prenatal and postnatal rainfall shocks. This strategy sheds light on which period public policies should care about. Third, we investigated two causal transmission channel effects through which these shocks may have an impact on malnutrition: the household income and the women time used in agricultural activities, this we believed will supplement the dearth of literature.

METHODS

Socio-economic data

This paper uses socioeconomic data from the USAID-Feed the Future baseline survey. The program was aimed at providing support to government, with multiple interventions, to tackle poverty and food insecurity issues. They collected data in October-December 2014 which refer to a set of detailed household and individual socioeconomic information. Interviews cover modules pertaining to household information, agriculture outcomes, household income and expenditures, health, and many more. The sampling strategy targeted 2500 households distributed among 13 administrative regions with 250 villages. In each village, 10 households were selected randomly and the heads of households were, in priority, targeted for interviews.

Regarding women independence and children modules, head of household spouses and any woman older than 15 years were also taken into account. The survey resulted to a collection of 4357 children data regarding their gender, age, anthropometric measures. We performed four main treatments to the original dataset to fit in with our estimations strategy. First, we only considered rural areas in the sub-sample of this paper. This exclusion is necessary because the analysis is more relevant for rural areas where agricultural systems are mostly rain-fed. Second, we restricted the sample only to households having children aged 60 months or below. Third, we did not take into account data related to the region of Diourbel for outliers issues in data collection. Finally, we removed observations for children having z-scores over 6 or below -6 standard deviations. These extreme values probably result from data misreporting and potentially lead to biased estimates. Our final sub-sample size refers to 3645 children aged between 0 and 60 months living in 1627 households.

We used the anthropometric module to calculate variables pertaining to children's nutritional status. In the module, data regarding age, gender and children measurements such as height, weight were useful to compute these outcomes of interest. Our three key indicators are: weigh-for-height, height-for-age and weight-for-age :

$$Z\ score\ = \frac{Observed\ value - median\ value\ of\ the\ reference\ population}{Standard\ deviation\ value\ of\ the\ reference\ population}$$

$$Z\ score\ = \frac{Observed\ value - median\ value\ of\ the\ reference\ population}{Standard\ deviation\ value\ of\ the\ reference\ population} \quad (1)$$

We computed z-scores using age, gender, weight and height of the children. We rely on our three outcomes of interest, which are continuous and normally distributed, for our estimations. Children with a z-score less than -2 Standard Deviations (SD) are considered as malnourished for the indicator considered. Likewise, children having a z-score lower than -3 SD are considered as severely malnourished.

We harnessed income and women's independence modules to account for transmission channels analysis. Income is defined at the household level and is a combination of all activities (on-farm and off-farm) generating financial resources from active members. We calculate on-farm income by valuing crop production with the current price in the nearest market. All other activities yielding revenues for the household are included in the off-farm income.

Rainfall and agricultural calendar data

Rainfall data are measured in mm and monthly available from a set of stations. The available data refer to 17 stations spanning from 2000 to 2014.

Following Maccini and Yang (2009) estimation procedure, we defined rainfall shocks in three steps. Firstly, we calculate a decadal rainfall index (ten years) on each station covering the 2004-2009 period. This decadal rainfall index will be considered as the long-term mean rainfall. We should calculate the index on a 20-year period at least, but data collected did include years before 2000.

Secondly, we set an annual rainfall index for each station which is the cumulative sum of precipitations occurred during the rainy season. In Senegal, the rainy season is usually between June and October, whereas the dry season extends over seven months from November to May. However, we included for each station only relevant months, depending on when the rainy season starts and when it ends. Finally, we estimate the rainfall shocks variable with the following equation:

$$P_{iht} = \frac{s_{iht} - s_{ih}}{s_{ih}} P_{iht} = \frac{s_{iht} - s_{ih}}{s_{ih}} \quad (2)$$

With SS referring to annual rainfall index and $\bar{S}\bar{S}$ the decadal rainfall index. For each child, we matched rainfall shocks data from the closest station and the corresponding year (gestation year, first year of the child depending on the age recorded in the dataset). In the case there is no close rainfall station (around 50km), data of the second closest station will be assigned.

Empirical strategy

We carry out the empirical strategy under two stages. This procedure will firstly explore empirical relationships between shocks and nutritional status, and in a second stage will highlight the effects of the transmission channels. We now set up our regression equation as follows :

$$Y_{iht} = \alpha + \theta P_{iht} + \delta X_{iht} + \varepsilon_{iht} Y_{iht} = \alpha + \theta P_{iht} + \delta X_{iht} + \varepsilon_{iht} \quad (3)$$

YY represents the outcome of interest assessing the nutritional status of children. As exposed earlier, we consider three children outcomes referring to three anthropometric indicators: height-for-age, weight-for-age and weight-for-height. PP represents the rainfall shock and XX is a vector of control variables. The following indices ii , hh , cc, tt and krepresent respectively the child, the household, the village, the season considered. We included age and gender clustering to check the presence of fixed effects regarding these variables.

In the second stage of the empirical strategy, we tested the relationship between the transmission channels we identified earlier (household income and allocation of mother work time) and rainfall shocks. This empirical estimation will be performed with the following equations :

$$R_{iht} = \alpha + \gamma P_{iht} + X_{iht} + \varepsilon_{iht} R_{iht} = \alpha + \gamma P_{iht} + X_{iht} + \varepsilon_{iht} \quad (4)$$

$$W_{iht} = \alpha + \gamma P_{iht} + X_{iht} + \varepsilon_{iht} W_{iht} = \alpha + \gamma P_{iht} + X_{iht} + \varepsilon_{iht} \quad (5)$$

Equations 6 and 7 refer to the transmission channels and are used for the estimation of rainfall shocks, respectively, on income and the allocation of mother time. R R represents household income and WW (from equation 7) refers to the mother percentage of time allocation within different activities undertaken the day prior the survey. PP is the variable related to rainfall shocks and XX is a vector of control variables. The indices ii , hh, cc and tt represent respectively the child, the household concerned, the village in which the child lives and the season considered.

RESULTS

Effects of prenatal rainfall shocks on nutritional status

We reported results derived from equation (5) in Table 1 for our three malnutrition indicators. We included rainfall shocks variable of the current year besides in-utero rainfall shocks for each child. We made the assumption that, beyond income mother allocating time effects, there are transitory effects that might arise (Popkin, 1980; Mendiratta, 2015). While positive shocks may positively affect in the long run in the children's well-being through the income channel, a higher amount of rainfall in the shorter-run might increase the probability of environmental diseases. Findings display a significant effect of prenatal rainfall shocks on height-for-age and weight-for-age z-scores respectively at 1% and 10% level. Effects are slightly more predominant on weight-for-age as a 1% increase in prenatal rainfall shocks would likely increase children weight-for-age z-score by 0.261. Current rainfall shocks also exert significant but negative effects on height-for-age and weight-for-age z-scores. Unlike positive effects of in-utero shocks, the negative coefficient of current season shocks proves children are prone to rainfall related diseases when there is an excess of rainfall (Ledli et al; 2018). The observed current rainfall coefficient is by far greater than the prenatal shock coefficient. It means diseases stemming from current an excess of rainfall can have dangerous implications on children well-being that positive in-utero positive shocks may not counterbalance. These findings refer to children older than 12 months because, as explained earlier, translation of shocks into detectable effects may require a certain amount of time (Mendiratta, 2015). We also introduced season birth fixed effects to estimate their implications on our outcomes. However, no significant effect was detected when we considered these birth season fixed effects.

Table 1: Effects of prenatal shocks on nutritional status

	(1)	(2)	(3)
VARIABLES	Height-for-age (Stunting)	Weight-for-age (Underweight)	Weight-for-height (Wasting)
Prenatal rainfall shock	0.261***	0.126*	-0.0101
	(0.0897)	(0.0693)	(0.0738)
Current year rainfall shock	-0.742***	-0.339**	0.137
	(0.178)	(0.137)	(0.146)
Number of dependent children	0.00136	-0.000557	0.000185
	(0.00916)	(0.00708)	(0.00754)
Household size	-0.00925***	-0.00311	0.00286
	(0.00348)	(0.00269)	(0.00286)
Farm size	7.15e-06	-2.31e-05	-7.11e-05
	(0.000144)	(0.000111)	(0.000118)
Is the child up to date with vaccinations (1=Yes)	0.0808	0.00211	-0.0738
	(0.0638)	(0.0493)	(0.0525)
Monogamous household (1=Yes)	0.0569	0.0208	-0.0361
	(0.0539)	(0.0417)	(0.0444)
Reported diarrhea in the last 15 days (1=Yes)	-0.277***	-0.224***	-0.106**
	(0.0545)	(0.0421)	(0.0449)
Household wealth index	-0.107***	-0.104***	-0.0655***
	(0.0281)	(0.0217)	(0.0231)

Constant	-1.431***	-1.168***	-0.532***
	(0.105)	(0.0810)	(0.0862)
Observations	2,688	2,688	2,688
R-squared	0.026	0.024	0.009

*Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*
Source: Author data

Effects of rainfall shocks occurring during the first year of life on current nutritional status

Table 2 reports the empirical results on rainfall shocks effects occurring during the first year of life on current nutritional status of children. We found, among our three indicators considered, rainfall shocks only affect height-for-age (stunting). A 1% reduction of rainfall, compared to its average long term, implies a 0.192 reduction of height-for-age z-score of children. It appears with introducing birth season clustering that rainfall shocks have no longer significant effects on height-for-age. However, at the 10% level of significance, a positive postnatal shock will likely shrink weight-for-height. This finding is surprising as we expected a positive coefficient sign. However, we should be more cautious on the robustness of the result rather than the result itself. The low level of significance (10%) may be a hint on the necessity to dig deeper to see whether this finding still holds.

Table 2: Shock effects precipitation of the first year of life on malnutrition indicators for children over 12 months

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Height-for-age (Stunting)	Weight-for-age (Underweight)	Weight-for-height (Wasting)	Height-for-age (Stunting)	Weight-for-age (Underweight)	Weight-for-height (Wasting)
Postnatal rainfall shock	0.192**	0.0296	-0.0923	0.193	0.0311	-0.0913*
	(0.0882)	(0.0679)	(0.0727)	(0.226)	(0.133)	(0.00869)
Current year rainfall shock	-0.664***	-0.301**	0.126	-0.664	-0.301	0.126
	(0.170)	(0.131)	(0.140)	(0.299)	(0.128)	(0.0574)
Number of dependent children	0.00479	-0.00118	-0.00362	0.00503	-0.000908	-0.00343
	(0.00897)	(0.00690)	(0.00739)	(0.0126)	(0.00367)	(0.0156)
Household size	-0.00853**	-0.00204	0.00396	-0.00860	-0.00212	0.00391
	(0.00341)	(0.00263)	(0.00281)	(0.00393)	(0.00260)	(0.000775)
Farm size	2.22e-06	-2.51e-05	-6.90e-05	2.26e-06	-2.50e-05	-6.90e-05**
	(0.000145)	(0.000112)	(0.000120)	(0.000151)	(7.74e-05)	(3.03e-06)
Monogamous household (1=Yes)	0.0632	0.0346	-0.0203	0.0622*	0.0334**	-0.0212
	(0.0527)	(0.0406)	(0.0435)	(0.00853)	(0.00127)	(0.00465)

Reported diarrhea in the last 15 days (1=Yes)	-0.270***	-0.227***	-0.115***	-0.271	-0.228*	-0.116*
	(0.0533)	(0.0410)	(0.0439)	(0.0607)	(0.0290)	(0.0138)
Household wealth index	-0.107***	-0.0918***	-0.0463**	-0.107	-0.0919**	-0.0464
	(0.0273)	(0.0210)	(0.0225)	(0.0194)	(0.00192)	(0.0141)
Constant	-1.366***	-1.170***	-0.598***	-1.364**	-1.169*	-0.597*
	(0.0913)	(0.0703)	(0.0753)	(0.0960)	(0.108)	(0.0843)
Birth season fixed effects	No	No	No	Yes	Yes	Yes
Observations	2,862	2,862	2,862	2,861	2,861	2,861
R-squared	0.023	0.020	0.007	0.023	0.020	0.007

*Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*
Source: Author data
Transmission channels

Effects on household income
In Table 3, we reported findings rainfall shocks effects through income transmission channel. We defined rainfall shocks here with data from the year prior to the survey to account for lags to observe for the detection of any significant effect. Findings show that household income is not a strong transmission channel to explain children nutrition outcomes changes. We exepected a positive and significant effect on household income as positive rainfall shocks could induce higher income which would improve children nutritional status. However, no significant was detected either on household income, farm income or off-farm income.

Table 3: Effects of rainfall shocks on annual household income

	(1)	(2)	(3)
VARIABLES	Household income	Farm income	Off-farm income
2013 rainfall shocks	216,745	373,144	-156,400
	(278,299)	(259,824)	(95,339)
Observations	3,645	3,645	3,645
R-squared	0.020	0.007	0.054

*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.*
Source: Author

We paid a closer attention to agricultural income to explore what are what its effects on each crop revenue following the research of Jensen, (2000). Rainfall shocks on revenue for each crop are detailed on Table 4. Unlike Table 3 findings on gross household income, we found rainfall shocks do have significant positive effects on 4 out of 5 majors crops. Effects are significant at 1% level on peanut and millet while level of significance is at the 5% and 1% respectively for maize and soghum. In the case of negative rainfall shocks, children living in households dependent to peanut production may be at risk regarding their nutritional status (Sahn and Stifel, 2010). The coefficient related to peanut changes induce rainfall shocks is large enough, with 230,104 FCFA for a 1% increase in shocks, to deeply affect children nutritional scores. The same observation is applied to millet with a coefficient of 66,296 FCFA[32].

Table 4 : Rainfall shocks effects on income per crop

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Rice income	Maize income	Sorghum income	Peanut income	Millet income
2013 rainfall shocks	-227,572	9,851**	1,045*	230,104***	66,926***
	(249,842)	(3,988)	(612.9)	(18,488)	(6,095)
Observations	3,645	3,645	3,645	3,645	3,645
R-squared	0.003	0.011	0.003	0.093	0.036

*Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*
Source: Author

Effects on the allocation of time relative to the working mother
We analyzed in this subsection how the mother responds to a rainfall shock for her working time allocation. The analysis intended is to see whether the mother allocates more time on the child-caring or working more in the field (household economic activities) to maintain at least constant the household income in presence of shocks. All five major activities groups are significantly affected at the 1% level by rainfall shocks as reported by Table 5. All coefficients but time for resting are positive. A 1% increase in rainfall would induce a 23% decrease on time devoted to resting for the mother. The coefficient of time allocated for income-generating activities is the largest one and suggest a higher sensitivity for mothers to allocate more time to these activities when rainfall conditions are better (Rucker and Schoeni, 2011). The same rationale can arguably be applied to time for household economic activities. Moreover, a 1% increase of rainfall shocks may increase by 4.98% the time for housework which encompasses child-caring related activities.

Table 5: Shock Effects rainfall on working time allocated to the mother of income generating activities

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Time for housework	Time for income-generating activities	Time for household economic activities	Time for resting	Time for leisure
2013 rainfall shocks	4.982***	9.558***	4.090***	-23.00***	1.667***
Observations	3,607	3,607	3,607	3,607	3,607
R-squared	0.021	0.056	0.014	0.134	0.017

Source: Author

32 Stands for « Franc de la Communauté Financière Africaine" which is the Senegal currency shared with other countries in West Africa. 1 US dollar is equivalent to 500 FCFA.

CONCLUSION

This paper provides informative and consistent insights on the relationship between rainfall patterns and children well-being in rural settings. Evidence in the literature is mixed regarding prenatal and postnatal rainfall shocks effects on children malnutrition. Findings show that prenatal have significant and positive effects on stunting. A 1% decrease of rainfall during in-utero period, compared to its average long term run, would decrease height-for-age z-score by 0.216. Postnatal rainfall shocks will also likely affect stunting as a 1% decrease of these shocks would decrease height-for-age z-score by 0.192.

We explored transmission channels effects induced by rainfall shocks, namely the household income and the mother time use. For household income, findings do not firstly show significant effects induced by rainfall shocks. However, estimates with income per crop show rainfall shocks would have an impact for households growing peanut, millet, maize and sorghum. For time use, positive shocks will affect all activities undertaken by the mother. A positive shock is likely to reduce time used for resting while increasing activities related to housework, income generating activities, leisure.

These results can contribute to draw effective policy implications to tackle malnutrition in Senegal. The recurrence of extreme events should create incentives for policies support emerging and innovative solutions such as index insurance, but also to provide incentives for its scaling-up. Insurance has the potential to prevent agricultural investments from being affected by rainfall shocks. In addition, in-utero shocks may lead to long term effects on children stunting. Health programs aiming to closely monitor mother mother pregnancy should be promoted.

However, for addressing robustness issues with findings, we need to carry out additional research questions. There is a scope of interest to explore in details interrelations between both transmission channels identified in this paper. For instance, how time for childcaring changes induced by rainfall shocks would affect income (and vice versa). What are their net effects on children malnutrition?

REFERENCES

Akresh, R., Luchetti, L., & Thirumurhy, H. (2012). Wars and child health: Evidence fromthe Eritrean–Ethiopian conflict. Journal of Development Economics, 330-340.

Barker, D. J. (1990). The fetal and infant origins of adult disease. British Medical Journal.

Bonjean, C. A., Brunelin, S., & Simonet, C. (2012). Impact of climate related shocks on child's health in Burkina Faso. Clermont Ferrand: CERDI.

Hoddinott, J. (2009). Early childhood nutrition increases adult wages. Eurochoices, 34-37.

Hoddinott, J., & Kinsey, B. (2001). Child Growth in the Time of Drought. Oxford Bulletin of Economics and Statistics, 409-436.

Jensen, R. (2000). Agricultural volatility and investments in children. The American Economic Review, 399-404.

Kim, Y. S., & Lafortune, J. (2010). The Impact of Rainfall on Early Child Health.

Ledli, N., Alderman, H., Leroy, J. L., & You, L. (2018). Rainfall shocks are not necessarily a sensitive early indicator of changes in wasting prevalence. European Journal of Clinical Nutrition, 177-178.

Leight, J., Glewwe, P., & Park, A. (2015). The Impact of Early Childhood Rainfall Shocks on the Evolution of Cognitive and Non Cognitive Skills.

Maccini, S., & Yang, D. (2009). Under the Weather: Health, Schooling, and Economic Consequences of Early-Life Rainfall. American Economic Review, 1006-1026.

Mendiratta, V. (2015). Impact of Rainfall Shocks on Child Health: Evidence from India. PSE Working Paper.

Popkin, B. M. (1980). Time allocation of the mother and child nutrition. Ecology of Food and Nutrition, 1-13.

Rucker, C., & Schoeni, R. F. (2011). Early-Life Origins of Adult Disease: National Longitudinal Population-Based Study of the United States. American Journal of Public Health, 2317-2324.

Sahn, D., & Stifel, D. (2010). Parental Preferences for Nutrition of Boys and Girls: Evidence from Africa. Journal of Development Studies, 21-45.

Thai, T. Q., & Falaris, E. M. (2014). Child Schooling, Child Health, and Rainfall Shocks: Evidence from Rural Vietnam. The Journal of Development Studies, 50(7), 1025-1037.

World Bank. (2018). Male outmigration and women's work and employment in agriculture: The case of Nepal and Senegal. Washington D.C.

Impact of the Seasonal Climate Forecasts on Farm Household Income in Rural Senegal

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ABSTRACT:

The seasonal climate forecasts are often regarded as a key strategic tool in terms of reducing the negative impact of climate variability and shocks on crop yields. Nevertheless, there is a dearth of empirical evidence on the impact of climate forecasts on farmers' livelihoods in rural Senegal. The data used in this study come from the "Enquête Ruralesurl'Agriculture, la Sécuritéalimentaire et la Nutrition" (ERASAN) conducted in 2014 by three state structures with the support from the World Food Program. The main objective of ERASAN was to evaluate the 2014/2015 the crop season, but also to understand the prevalence of food insecurity and malnutrition among rural children aged 6 to 59 months. Propensity score matching method was used to estimate the impact of climate services on farm households' income in rural Senegal. Findings indicate that using climate services results in an average gain of farm income, ranging from 988 to 1221 euros per household. However, the results are not significant. This suggests that seasonal forecasts are not, in their current form, an effective instrument for improving the farm households' living conditions.

Keywords: Seasonal climatic forecasts, Propensity score matching, Senegal

RÉSUMÉ

Les prévisions climatiques saisonnières sont souvent considérées comme un outil stratégique essentiel pour réduire l'impact négatif de la variabilité et des chocs climatiques sur les rendements des cultures. Néanmoins, il y a un manque de preuves empiriques sur l'impact des prévisions climatiques sur les moyens de subsistance des agriculteurs dans les zones rurales du Sénégal. Les données utilisées dans cette étude proviennent de l'»Enquête Ruraleurl'Agriculture, la Sécuritéalimentaire et la Nutrition» (ERASAN) menée en 2014 par trois structures étatiques avec le soutien du Programme Alimentaire Mondial. L'objectif principal d'ERASAN était d'évaluer la campagne agricole 2014/2015, mais aussi de comprendre la prévalence de l'insécurité alimentaire et de la malnutrition chez les enfants ruraux âgés de 6 à 59 mois. La méthode d'appariement par score de propension a été utilisée pour estimer l'impact des services climatiques sur le revenu des ménages agricoles dans les zones rurales du Sénégal. Les résultats indiquent que l'utilisation des services climatiques entraîne un gain moyen de revenu agricole, allant de 988 à 1221 euros par ménage. Cependant, les résultats ne sont pas significatifs. Ceci suggère que les prévisions saisonnières ne sont pas, dans leur forme

actuelle, un instrument efficace pour améliorer les conditions de vie des ménages agricoles.

Mots clés : Prévisions climatiques saisonnières, Propensity score matching, Sénégal

INTRODUCTION

Despite their historical adaptation to weather fluctuations, farmers have been increasingly faced with the problem of climate change over the past two decades (Morton, 2007; Senaratne& Scarborough, 2011). The length of rainy season varies as well as the number of rainy days (Sultan &Janicot, 2003; Traore, et al., 2013). Farmers in sub-Saharan Africa and South Asia are particularly affected by the climate change, because these regions already have high temperatures and low adaptive capacity (Schmidhuber & Tubiello, 2007). Like other Sahelian countries, Senegal has experienced seventeen times of drought over a period of 30 years, and the rainfall has declined by 30-40% over the last three decades. The temperatures have increased by 9°C (degrees Celsius) since 1975 across the country. This climatic variability is likely to lead to an irreversible desertification process resulting in lower crop yields. The seasonal climatic forecasts are a key strategic tool for farmers to reduce the negative impact of climate variability on crop production (Roncoli, 2006; Nyong, et al., 2007), as they include the expected starting and ending dates of the rainy season, the duration of the season and that of dry spells (Klemma & McPhersona, 2016; Traore et al., 2014).

In addition, the seasonal climatic forecasts help farmers to foster better decisions about their crop diversification strategies (Crane, et al. 2010). Besides, these forecasts can be an endogenous system of climatic information which enables farmers to choose plots of land to be cultivated, types of crop varieties and planting date (Zongo, et al., 2016). Hence, an effective climatic forecast reduces uncertainty. It does so first by reducing the spread of possible outcomes for the upcoming season relative to the climatological distribution, and then by conveying shifts in the central tendency of climatic outcomes (Meza, et al., 2008).Moreover, farmers having access to weather information tend more to make change regarding their farming practices (Wood, et al., 2014), as seasonal forecasts have considerable potential for improving livelihoods in areas with high inter annual variability of precipitation (Roncoli, 2006; Ash, et al ., 2007; Hansen, et al ., 2011).

In Senegal, it is estimated that a 50% drop in precipitation and a 5°C rise in temperatures could decrease crop yields by 86% compared to current yields, which would negatively affect the farm income (U.S. Agency for International Development-USAID, 2009). Under these circumstances, we believe that seasonal climate forecasts can have positive impact on farmer's income, and, hence, rigorous impact evaluation analyses are critical to fully harness the potential benefits associated with such forecasts and to understand the limits of their application. Our article focuses on this perspective. It aims at evaluating the impact of seasonal climate forecasts on farm household income of agricultural households in rural Senegal. We find that seasonal climate forecasts positively influence farm income. However, the results are not significant.

The rest of the article is organized as follows. A review of the literature is presented in the second section. The third section describes the empirical framework. The fourth section presents the data and the descriptive statistics. The fifth section reports the econometric results while the sixth section concludes.

LITERATURE REVIEW

Understanding how climate variability influences agricultural decision-making provides a basis for predicting the mechanisms by which advanced climate information in the form of seasonal forecasts can benefit agriculture. In recent decades, climatologists have improved their ability to predict seasonal climate (Palmer & Anderson 1994, Martin et al., 2000, Murphy et al., 2001). These seasonal climate forecasts are based on the ocean-atmosphere interaction, so that the temperatures of surface of the sea determine the future states of atmospheric disturbance (Washington & Downing, 1999). Seasonal forecasting methods can provide information beyond the seasonal average conditions over large areas (Gong, et al., 2003, Moron, et al., 2006). The total precipitations for a season are the result of the frequency of precipitation and average intensity (Klemma & McPhersona, 2016). At the local level, the predictability of total seasonal precipitation is determined by the predictability of precipitation frequency (Morton 2007, Mishra et al.2008).

In Senegal, from July to September, Moron, et al., (2006) find that i) the seasonal frequency and the seasonal quantity of rains are predictable from SST; (ii) the daily average intensity of the precipitation is spatially inconsistent and largely unpredictable on a regional scale; (iii) point estimates of the predictability and proficiency of seasonal precipitation are subject to high sampling variability. A number of seasonal forecasting systems have been developed recently. Most of these systems use the phenomenon El Niño Oscillation southern (ENSO) in association with other climate indicators such as cloud cover, water vapor and agronomic data (Hammer &Holzworth, 1996; Meinke& Hammer, 1997; Podbury, et al., 1998; Orlove, and al., 2000).There are myriads of literature explaining the economic impact of the seasonal forecasts on the agricultural systems (Byerlee & Anderson, 1982; Fox, et al., 1999; Mjelde& Dixon, 1993; Hammer & Holzworth, 1996; Roudier, 2012; Sultan, et al., 2013). These authors have shown that farmers who use seasonal forecasting are not only less vulnerable to agricultural risks but also earn higher incomes. However, an experience in south-western Burkina Faso suggests relatively limited economic gains for farmers (Dabiré, et al., 2011).

The importance of seasonal forecasts in agricultural activities is sometimes difficult to assess because their impact depends on many factors, including farmers' risk attitudes, insurance, the political environment and the scale of adoption (Meza, et al., 2008). Research suggests that African farmers are particularly interested in the seasonal forecast. However, the communication systems responsible for dissemination are poorly developed (Archer, 2003; Eakin, 2000; Kirshen & Flitcroft, 2000; Vogel, 2000; Phillips, et al., 2001; Ziervogel, 2004; Ingram, et al., 2002). As forecasts are not widely used, it is difficult to assess their impact on agriculture (Ziervogel and Calder, 2003).

EMPIRICAL FRAMEWORK

Following Rosembaum & Rubin (1983), we use the propensity score technique to evaluate the impact of the seasonal climate forecasts on farmers' incomes. This method relies on matching individuals based on the propensity score.

The score, denoted by $P(X) = \Pr(T = 1|X)\, P(X) = \Pr(T = 1|X)$, refers to the probability of receiving the treatment as a function of observable characteristics X.

We have two groups: the treated, i.e. farm households that incorporate information from seasonal forecasts into their farming activities, and the untreated or comparison group, i.e. farm households that do not use information from seasonal forecasts.

Let T be a binary variable equal to 1 if the farmer integrates information about seasonal climate forecasts and 0 if not, and Y the outcome variable which is the annual income of the farmer.$Y_0 Y_0$is the income of the untreated farmer and $Y_1 Y_1$captures that of the treated. The effect of the treatment on the treated farmers is :

$$\Delta\overline{Y} = E[Y_1|T = 1, P(X)] - E[Y_0|T = 1, P(X)]$$
$$\Delta\overline{Y} = E[Y_1|T = 1, P(X)] - E[Y_0|T = 1, P(X)] \quad (1)$$

$\Delta\overline{Y}\Delta\overline{Y}$cannot be estimated a priori because the component $E[Y_0|T = 1, P(X)]$ $E[Y_0|T = 1, P(X)]$is unobserved. However, the propensity score method is based on the conditional independence assumption that the farmer's income is independent of the treatment, which is conditional on the propensity score. Formally, the assumption can be written as follows :

$$(Y_0, Y_1) \perp T|P(X)(Y_0, Y_1) \perp T|P(X) \quad (2)$$

From this assumption, we deduce :

$$E[Y_0|T = 1, P(X)] = E[Y_0|T = 0, P(X)]E[Y_0|T = 1, P(X)] = E[Y_0|T = 0, P(X)] \quad (3)$$

Thus, the impact of the treatment on the treated farmers becomes :

$$\Delta\overline{Y} = E[Y_1|T = 1, P(X)] - E[Y_0|T = 0, P(X)]$$
$$\Delta\overline{Y} = E[Y_1|T = 1, P(X)] - E[Y_0|T = 0, P(X)] \quad (4)$$

First, we estimated the propensity score by a logit model. Given the binary nature of the treatment variable, the score can be estimated either by a probit or a logit model. The choice of variables for estimating the propensity score is also an important step. In accordance with the conditional independence assumption, we only include variables which are supposed to have a significant influence on both the probability of receiving treatment and the outcome variable (Caliendo & Kopeinig, 2008; Smith &Todd, 2005). More specifically, we select variables that can explain both farmers' incomes and their propensity to integrate seasonal forecasts information into the farming activities. These variables include household characteristics (age of the household head, the gender of household head, the household size, the number female and male farmers within the household) and shocks affecting the household (Out-of-season rains, poor rains, pests invasion, increase in price of inputs) and geographical variables (i.e. the regions).

Second, we evaluate the quality of the propensity score based on both determining the balancing property[33] and the common support area[34].

33 If the propensity score is properly estimated, there should no longer be significant differences between the treated group and the control group after matching.

34The existence of a common support area implies that for any set of independent variables (X), there

Third, we finally perform the matching using several methods to ensure the robustness of the results. More specifically, we use the nearest neighbor method, the kernel matching method as well as the radius matching method. The purpose here is to artificially construct a counterfactual (i.e., a control group) comparable to the treated group so as to have an unbiased estimate of the effect of the treatment on the treated.

METHODS

The data used in this study come from the "EnquêteRuralesurl'Agriculture, la Sécuritéalimentaire et la Nutrition" (ERASAN) conducted in 2014 by three state structures with the support from the World Food Program. The main objective of ERASAN was to evaluate the 2014/2015 the crop season, but also to understand the prevalence of food insecurity and malnutrition among rural children aged 6 to 59 months.

The survey includes a household questionnaire with nine sections. However, considering the orientation of our study which is to determine the impact of the seasonal forecast on farmers' income, only six sections are used. These are: Identification, Composition and Agricultural Activities of the Household, Agricultural Equipment and Processing of Agricultural Products, Income and Household Spending and Meteorology.

The ERASAN sampling frame consists of a stratified sample of 5989 farm households residing in rural areas. The two-stage sampling has been used in the survey. A total of 861 Enumeration Areas (EA) were drawn in the first degree in the 42 rural departments of the country. In the second degree, it was drawn by simple random sampling about 7 households in each EA. Finally, our sample consists of 1056 farm households divided into two groups, depending on whether or not farmers integrate seasonal climate forecasts in their farming activities. We have 430 farm households in the first group (the treated group) and 626 in the second group (the control group).

RESULTS AND DISCUSSION

Descriptive Statistics

The descriptive statistics of all the variables used in this study was presented in Table 1. Results are presented for all farm households in the sample and separately for treated and untreated the farm households. We found that households in the treatment group have a higher annual income than those in the control group. Thus, taking climate information into account seems to have a positive impact on farmers' income. Most farm households are managed by men, with 96.5% in the treated group and 96.9 % in the control group. The average age of the household head is about 52 years in the first group and 51 years in the second group. These two groups are almost identical in size. However, treated households have almost female farmers and more male farmers than untreated households. Besides, treated households suffer more from shocks such as the increase in price of inputs and out-of-season rains. On the other hand, untreated households are more exposed to the pests invasion and poor rains. The geographical

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must be a treatment and control in order to ensure the validity of the matching process (Rosenbaum and Rubin, 1983).

distribution also reveals that treated households are more concentrated in Louga (23.7%), Ziguinchor (19.5%), Kaffrine (18.1%) and Diourbel (12.7%). Thus, seasonal climate forecasts are more frequently used in these regions.

Table 1 : Descriptive statistics

Variables	Total		Treated households		Untreated households	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Outcome variable						
Annual inccome (in euros)	1922	432.6	2318	993.21	1650	259.82
Independent variables						
Characteristics of the household						
Male-headed household	.967	.005	.965	.008	.969	.006
Age of head	51.375	.443	51.818	.664	51.072	.592
Household size	15.151	.293	15.388	.497	14.988	.357
Number of female farmers	3.461	.086	3.197	.120	3.642	.119
Number of male farmers	4.303	.097	4.318	.160	4.292	.123
Shocks affecting the household						
Increase in price of inputs	.731	.013	.741	.021	.723	.017
Pests invasion	.456	.015	.455	.024	.456	.019
Poor rains	.833	.011	.820	.018	.841	.014
Out-Of-season rains	.129	.010	.202	.019	.079	.010
Regions						
Dakar (b)	.005	.002	.009	.004	.003	.002
Diourbel (b)	.169	.011	.127	.016	.198	.015
Fatick (b)	.043	.006	.009	.004	.067	.0100
Kaffrine (b)	.260	.013	.181	.018	.314	.018
Kaolack (b)	.092	.008	.104	.014	.084	.011
Kédougou (b)	.006	.002	-	-	.011	.004
Kolda (b)	.004	.002	-	-	.007	.003
Louga (b)	.165	.011	.237	.020	.116	.012
Matam (b)	.027	.005	.020	.006	.031	.007
Saint-Louis (b)	.021	.004	.006	.004	.031	.007
Sédhiou (b)	.035	.005	.055	.011	.020	.005
Tambacounda (b)	.041	.006	.009	.004	.063	.009
Thiès (b)	.032	.005	.041	.009	.025	.006
Ziguinchor (b)	.092	.008	.195	.019	.022	.005

Source: Authors' calculations based on the survey data

Propensity score estimation

As mentioned, we estimated the propensity score using the logit model. However, it is important, before presenting the econometric results, to ensure the quality of the estimated propensity score. We evaluate this based on the balancing test and the common support area.

Table 2 in appendix gives the results of the balancing test materialized by comparison tests of average or percentage depending on the quantitative or qualitative nature of the variables. Propensity score matching is of good quality if there are no significant differences in mean or percentage between the two household groups. In many cases, the comparison of pre- and post-matching results reveals that the initial differences between the treated and control households significantly decreased after matching. These results show that the matching procedure is correct in that it balances the characteristics of the two groups of farmer.

Table 2 : Descriptive statistics (continued)

Variables	Total		Households treated		Households untreated	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Region						
Kédougou (b)	.006	.002	-	-	.011	.004
Kolda (b)	.004	.002	-	-	.007	.003
Louga (b)	.165	.011	.237	.020	.116	.012
Matam (b)	.027	.005	.020	.006	.031	.007
Saint-Louis (b)	.021	.004	.006	.004	.031	.007
Sédhiou (b)	.035	.005	.055	.011	.020	.005
Tambacounda (b)	.041	.006	.009	.004	.063	.009
Thiès (b)	.032	.005	.041	.009	.025	.006
Ziguinchor (b)	.092	.008	.195	.019	.022	.005

Source: Authors' calculations based on the survey data

The graph 1 in appendix shows also a good overlap in the distribution of the propensity scores of farmers in the treated and control groups. This indicates the existence of a fairly large common support area, which reveals that the two groups are quite comparable. Besides, Graph 2 in appendix shows a clear difference in the distribution of propensity scores before matching. On the other hand, we note that these overlap after the matching procedure, which means that matching has made the two farmers groups comparable. Based on the results in Table 2 and graphs 1 and 2, we can use the propensity score estimates to assess the impact of seasonal forecasts on farm income. It is worth mentioning that farm households not included in the common support area are excluded from the rest of the study. Of the 1056 farm households in our initial sample, 613 households in the control group and 429 in the treated group are in the common support area, leading to a final sample of 1042 farm households.

The results of the logit model determining the probability of a rural farm household to integrate seasonal climate forecasts into its farming activities are reported in Table 3 below. We find that the size of the farm household, the number of female famers within the household, the increase in price of inputs, the out-of-season rains are the main factors that influence farmers' propensity to take into account the climate information. More specifically, it appears that larger households are more likely to use climate information for their agricultural activities. However, farmers' propensity to take into account seasonal climate forecasts decreases with the number of female farmers within the household. Households facingshocks such as increase in price of inputs and out-of-season rains are more likely to use seasonal climate forecasts in their farming activities, perhaps to better cope with these types of shocks.

Table 3: Estimation of the propensity score: Logit model

Variables	Coef.	St. Err.	P-value
Characteristics of the household			
Male-headed household	-.507	.331	0.125
Age of head	.0021	.005	0.683
Household size	.019	.009	0.030**
Number of female farmers	-.111	.033	0.001***
Number of malefarmers	.003	.027	0.909
Shocksaffecting the household			
Increase in price of inputs	.694	.221	0.002***
Pests invasion	-.108	.158	0.494
Poor rains	-.044	.217	0.839
Out-of-season rains	.845	.220	0.000***
Regiona	Yes	Yes	Yes
Number of observations	1042		
Pseudo R2	0.1768		
LR chi2 (20)	171.17		

Source: Authors' calculations based on the survey data.

*Notes: * significant at 10%; ** significant at 5%, *** significant at 1%. Standard Errors are robust to heteroscedasticity. [a]A series of binary variables capturing the regions is also included to take into account the geographical heterogeneity.*

Estimating the average treatment effect on the treated

In this section, we estimate the average treatment effect on the treated. More precisely, we aim at assessing the impact of the use of seasonal climate forecasts on farm income. Table 4 below presents the results on the basis of three different estimation methods. The standard errors are obtained by the bootstrap method with 100 replications. The results indicate that taking climate information into account has a positive effect on farmers' income, regardless of the method used. The increase in farmers' income incorporating climate forecasts varies between 988 euros and 1221 euros depending on the method used to perform the matching. However, this positive impact is not statistically significant if one refers to the confidence intervals. Thus, there are no income differences between farmers integrating climate information in their farming activities and those who did not. This result is contrary to those of Byerlee & Anderson (1982), Fox et al. (1999), Roudier (2012) and Sultan et al. (2013) indicating that the use of seasonal climate forecasts improves farmers' income. That being said, the result does not prove surprising to some extent. Indeed, among farmers who integrate climate information into their farming activities, only 39% of them consider it to be generally satisfactory.

Table 4: Impact of climate forecasts on farmers' incomes

	Nearest Neighbor	Kernel matching	Radius matching
Annual income[a]	1108 euros	988 euros	1221 euros
Confidence interval	[-561398.9; 2035950]	[-641259.8 ; 1955465]	[-712012.2; 2336687]
Number of observations	1,042	1,042	1,042
Number of replications	100	100	100

[a]The annual income is expressed in CFA in the database, but we converted it to euros at the rate of 665.3.

Source: Authors' calculations from the survey data.

CONCLUSION

In this study, we evaluated the impact of the seasonal climate forecasts on farmers' incomes, using a sample of 1042 farm households in rural Senegal. Based on a logit model, we found that the propensity of farmers to take seasonal climate forecasts into account decreases with the number of female farmers within the household but increase with the household size. The propensity to use climate information is also higher among households facing shocks such as increase in price of inputs and Out-of-season rains. Furthermore, while the descriptive statistics indicate that farm households incorporating climate information into their farming activities have higher annual incomes than those that do not integrate this information, we found from different matching methods that the differences in income between the two groups are not statistically significant. However, the result is not surprising to some extent as among farmers who integrate climate information into their farming activities, less than half (39%) rate it as satisfactory on the whole. This suggests that the seasonal climate forecasts do not, in their current form, improve farmers' living conditions.

In this context, policy makers should help farmers to better use climate data for agricultural business planning and water resource optimization. Using such data in real-time would enable better decision-making in crop management and boost agricultural productivity for rural households. That said, the fostering of climate forecasting services cannot be dissociated from other climate-smart tools, such as crop insurance. Their combination is critical to keep farmers resilient while allowing them to increase their productivity.

REFERENCES

Archer, E. (2003). Identifying underserved end-user groups in the provision of climate information. Bulletin of the American Meteorological Society, 84(11), p. 1525–1532.

Ash, A. et al. (2007). Constraints and opportunities in applying seasonal climate forecasts in agriculture. Australian Journal of Agricultural Research, Volume 58, *p. 952–965.*

Banque Mondiale (2014). Situation Economique et Sociale du Sénégal : Apprendre du passé pour un avenir meilleur.

Banque Mondiale (2014). Agriculture, valeur ajoutée (% du PIB). Retrieved from http://donnees.banquemondiale.org.

Byerlee, D. & Anderson, J. R. (1982). Risk, utility and the value of information in farmer decision making. Review of Marketing and Agricultural Economics, 50(3), pp. 231-246.

Caliendo, M., & Kopeinig, S. (2008). Some practical guidance for the implementation of propensity score matching. Journal of Economic Surveys 22: 31–72.

Crane, T. A. et al. (2010). Forecast skill and farmers' skills: seasonal climate forecasts and agricultural risk management in the Southeastern United States. Weather, Climate, and Society, Volume 2, p. 44–59.

Dabiré, W., Barbier, B. & Andrieu, N. (2011). Evaluation ex-ante de la prévision saisonnière climatique en petit paysannat burkinabé. Revue d'élevage et de médecine vétérinaire des pays tropicaux, 64(1-4), pp. 43-50.

Direction de la prévision et des études économiques (DPEE). (2013). Politique Agricole, Productivité et Croissance à Long Terme au Sénégal, Document d'Etude.

Eakin, H. (2000). Smallholder maize production and climatic risk: a case study from Mexico. Climatic Change, Volume 45, p. 19–35.

Fox, G., Turnera, J. & Gillespie, T. (1999). The value of precipitation forecast information in winter wheat production. Agricultural and Forest Meteorology, 95(2), pp. 99-111.

Funk, C. C. & Brown, M. E. (2009). Declining global per capita agricultural production and warming oceans threaten food security. Food Security, Volume 1, p. 271–289.

Gong, X. F., Barnston, A. G. & Ward, M. N. (2003). The effect of spatial aggregation on the skill of seasonal precipitation forecasts. Journal of Climate, Volume 16, p. 3059–3071.

Gourdji, S. M. et al. (2013). An assessment of wheat yield sensitivity and breeding gains in hot environments. Proc. R. Soc. Lond. B, Volume 280, pp. 2012-2190.

Hammer, G. L. & Holzworth, D. (1996). The value of skill in seasonal climate forecasting to wheat crop management in a region with high climatic variability. Australian Journal of Agricultural Research, 47(5), pp. 717-737.

Hansen, J. W., Mason, S. J., Sun, L. & Tall, A. (2011). Review of Seasonal Climate Forecasting for Agriculture in Sub-Saharan Africa. Experimental Agriculture, 47(2), pp. 205-240.

Hathie, I., Amikuzuno, J., MaCarthy, D. S. & Diancoumba, M. (2013). Economic Impacts of Climate change on farmers in Nioro du Rip, Senegal: An integrated assessment. AgMIP, UKaid.

Ingram, K. T., Roncoli, M. & Kirshen, P. (2002). Opportunities and constraints for farmers of West Africa to use seasonal precipitation forecasts with Burkina Faso as a case study. Agricultural Systems, 74(3), p. 331–349.

Kirshen, P. & Flitcroft, I. (2000). Use of seasonal precipitation forecasting to improve agricultural production in the Sudano-Sahel: an institutional analysis of Burkina Faso. Natural Resources Forum, Volume 24, p. 185–195.

Klemma, T. & McPhersona, R. A. (2016). The development of seasonal climate forecasting for agricultural producers. Agricultural and Forest Meteorology, 232(2017), p. 384–399.

Marteau, R. et al. (2011). The onset of the rainy season and farmers' sowing strategy for pearl millet cultivation in Southwest Niger. Agricultural and Forest Meteorology, 151(10), pp. 1356-1369.

Martin, R. V., Washington, R. & Downing, T. E. (2000). Seasonal maize forecasting fo Zimbabwe derived from an agro climatological model. Journal of Applied Meteorology, Volume 39, pp. 1473-1479.

Meinke, H. & Hammer, G. L. (1997). Forecasting regional crop production using SOI phases: an example for the Australian peanut industry. Australian Journal of Agricultural Research, Volume 48, pp. 789-793.

Meza, F. J., Hansen, J. W. & Osgood, D. (2008). Economic Value of Seasonal Climate Forecasts for Agriculture: Review of Ex-Ante Assessments and Recommendations for Future Research. Journal of applied meteorology and climatology, Volume 47, pp. 1269-1286.

Mishra, A. et al. (2008). Sorghum yield prediction from seasonal rainfall forecasts in Burkina Faso. Agric. Forest Meteorol, Volume 148, p. 1798–1814.

Mjelde, J. W. & Dixon, B. L. (1993). Valuing the lead time of periodic forecasts in dynamic production systems. Agricultural Systems, Volume 42, pp. 41-55.

Moron, V., Robertson, A. W. & Ward, M. N. (2006). Seasonal predictability and spatial coherence of rainfall characteristics in the tropical setting of Senegal. Monthly Weather Review, Volume 134, p. 3248–3262.

Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. Proc. Natl Acad. Sci, 104(50), p. 19680–19685.

Murphy, S. et al. (2001). Seasonal forecasting for climate hazards: prospects and responses. Natural Hazards, Volume 23, p. 171–196.

Nicholls, N. (1999). Cognitive illusions, heuristics, and climate prediction. Bulletin of the American Meteorological Society, Volume 80, p. 1385–1397.

Nyong, A., Adesina, F. & Osman, E. B. (2007). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitigation and Adaptation Strategies for Global Change, 12(5), pp. 787-797.

O'Brien, K., Sygna, L., Naess, L., Kingamkono, R., & Hochobeb, B. (2000). Is information enough? User responses to seasonal climate forecasts in Southern Africa. CICERO.

Orlove, B. S., Chiang, J. C. H. & Cane, M. A. (2000). Forecasting Andean rainfall and crop yield from the influence of El Nino on Pleiades visibility. Nature, Volume 402, pp. 68-71.

Palmer, T. & Anderson, D. (1994). The prospects for seasonal forecasting – a review paper. Quarterly Journal of the Meteorological Society, Volume 120, p. 755–793.

PAM (2010). Analyse Globale de la Vulnérabilité, de la Sécurité Alimentaire et de la

Nutrition (AGVSAN) au Sénégal

Phillips, J. G., Makaudze, E. & Unganai, L. (2001. Current and potential use of climate forecasts for resource-poor farmers in Zimbabwe. In: Impacts of El Nino and Climate Variability on Agriculture, American Society of Agronomy Special Publication Series, Volume 63, p. 87–100.

Podbury, T., Sheale, T. C., Hussain, I. & Fisher, B. S. (1998). Use of El Nino climate forecasts in Australia. American Journal of Agricultural Economics, 80(5), pp. 1096-1101.

Quiggin, J., Adamson, D., Chambers, S. & Schrobback, P. (2010). Climate change, uncertainty, and adaptation: the case of irrigated agriculture in the Murray-Darling basin in Australia. Can. J. Agr. Econ., Volume 58, p. 531–554.

Roncoli, C. (2006). Ethnographic and participatory approaches to research on farmers' responses to climate predictions. Climate Reshearch, 33(1), pp. 81-99.

Rosenbaum, P., & Rubin, D. (1983). The central role of the propensity score in observational studies for causal effects. Biometrika, 70(1), 41–55.

Roudier, P. (2012). Climat et agriculture en Afrique de l'Ouest : Quantification de l'impact du changement climatique sur les rendements et évaluation de l'utilité des prévisions saisonnières, Paris: Ecole des Hautes Etudes en Sciences Sociales (EHESS).

Schmidhuber, J. & Tubiello, F. N. (2007). Global food security under climate change. Proc. Natl Acad. Sci., 104(50), p. 19703–19708.

Senaratne, A. & Scarborough, H. (2011). Coping with climatic variability by rain-fed farmers in dry zone, Sri Lanka: towards Understanding adaptation to climate change. Paper presented at the 55th annual national conf. for Australian Agricultural and Resource Economics Society (AARES), 8–11 February, p. 23.

Smith J., & Todd P. (2005), "Does Matching Overcome LaLonde's Critique of Non experimental Estimators?", Journal of Econometrics, 125(1-2),305-353.

Sovacool , B. K. (2011). Hard and soft paths for climate change adaptation. Climate Policy, 11(4), p. 1177–1183.

Sultan, B. & Janicot, S. (2003). The West African Monsoon Dynamics. Part II: The preonset and onset of the summer monsoon. American Meteorological Society, Volume 16, pp. 3407-3427.

Sultan, B., Roudier, P. & Quirion, P. (2013). Les bénéfices de la prévision saisonnière dans l'agriculture en Afrique de l'Ouest. Sécheresse, 24(4), pp. 304-313.

Traore, B. et al. (2013). Effects of climate variability and climate change on crop production in southern Mali. European Journal of Agronomy, Volume 49, pp. 115-125.

USAID (2009). Projet Croissance Economique. La chaine de valeur mil&sorgho : Options stratégiques de développement au Sénégal. International Resources Group (IRG).

Vogel, C. (2000). Usable science: an assessment of long-term seasonal forecasts among farmers in rural areas of South Africa. South African Geographical Journal, Volume 82, p. 107–116.

Washington, R. & Downing, T. E. (1999). Seasonal forecasting of African rainfall:

prediction, responses and household food security. The Geographical Journal, Volume 165, p. 255–274.

Wood, S. A. et al. (2014). Smallholder farmer cropping decisions related to climate variability across multiple regions. Global Environmental Change, Volume 25, p. 163–172.

Ziervogel, G. (2004). Targeting seasonal climate forecasts for integration into household level decisions: the case of smallholder farmers in Lesotho. The Geographical Journal, 170(1), p. 6 –21.

Ziervogel, G. & Calder, R. (2003). Climate variability and rural livelihoods: assessing the impact of seasonal climate forecasts. Area, 35(4), p. 403–417.

Zongo, B. et al. (2016). Farmers' Perception and Willingness to Pay for Climate Information in Burkina Faso. Journal of Agricultural Science, 8(1), pp. 175-187.

APENDIX A

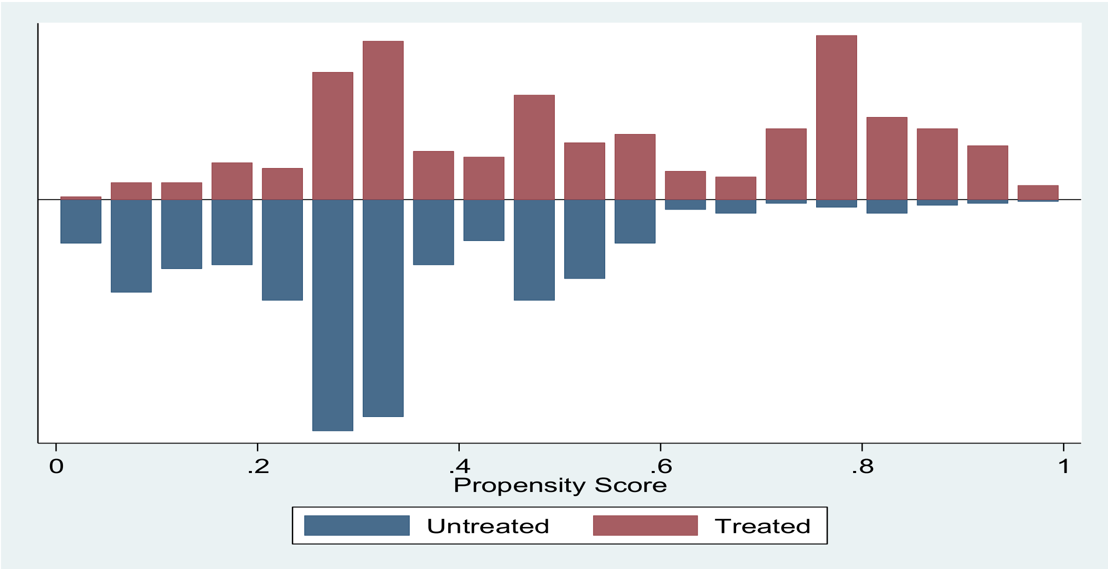
Table 2 : Balancing test

		Mean		%reduct		t-test	
Variables	Sample	Treated	Control	%bias	|bias|	t	P>|t|
Male headed household	Before matching	.96503	.969	-2.2		-0.35	0.723
	After matching	.96462	.95729	4.1	-84.8	0.55	0.582
Age of the head of household	Before matching	51.818	51.132	4.8		0.77	0.444
	After matching	51.587	52.016	-3.0	37.5	-0.46	0.644
Household size	Before matching	15.343	14.992	3.7		0.59	0.556
	After matching	15.394	14.902	5.1	-40.3	0.76	0.449
Number of active women in the household	Before matching	3.2051	3.6166	-15.3		-2.41	0.016
	After matching	3.2193	3.1744	1.7	89.1	0.26	0.794
Number of active men in the household	Before matching	4.289	4.2936	-0.1		-0.02	0.981
	After matching	4.2972	4.7486	-14.3	-9728.3	-1.87	0.062
Increase in prices of inputs	Before matching	.74359	.72757	3.6		0.58	0.565
	After matching	.74057	.69161	11.1	-205.6	1.58	0.114
Invasion of insects or birds	Before matching	.45455	.46003	-1.1		-0.17	0.861
	After matching	.45047	.48055	-6.0	-448.1	-0.88	0.381
Poor rains	Before matching	.82051	.8385	-4.8		-0.76	0.446
	After matching	.82311	.71442	28.9	-504.3	3.78	0.000
Off-season rains	Before matching	.2028	.07993	35.8		5.88	0.000
	After matching	.1934	.14991	12.7	64.6	1.68	0.093
Region	Before matching	7.69	5.5759	54.7		8.84	0.000
	After matching	7.6156	7.9116	-7.7	86.0	-1.01	0.313

Source: Authors' calculations from the survey data

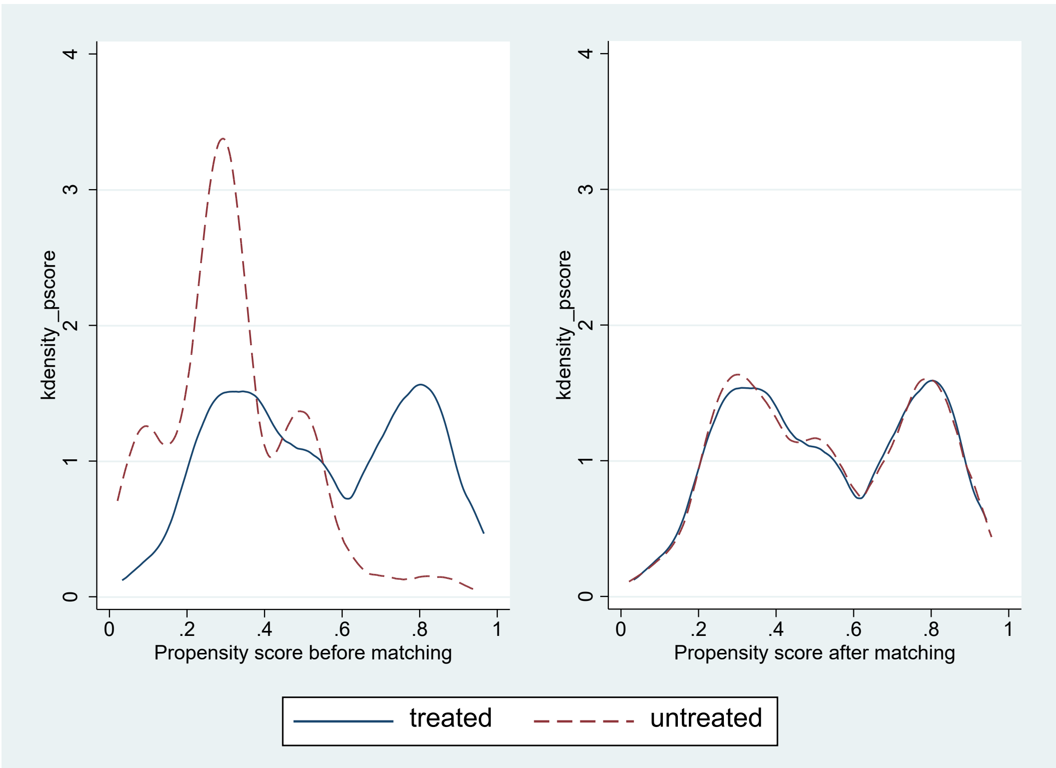
APPENDIX B

Graph 1 : Common support area



Source: illustration of the authors from the survey data

Graph 2 : Distribution of propensity scores before and after matching



Source: illustration of the authors from the survey data

Spatial diffusion of agricultural production in WAEMU : Does climate change play a role ?

Elom Kpomblekou and Akoété Ega Agbodji

ABSTRACT

This paper analysed spatial diffusion of agricultural production in West African Economic and Monetary Union (WAEMU) and to see if climate change plays a role. We used recent data from the union over the period 1996 – 2016 culled from World Banks' Word Development Indicators. The spatial autoregressive model revealed that agricultural production spreads spatially and positively in the union, and it is beneficial to the whole union. Climate change and climate policies could play an important role, as a country can copy climate policy of another country of the union to improve its agricultural production through spatial spill over effects. Improvement of climate and agricultural policies of countries was beneficial to agricultural development of the whole area.

Keywords: Spatial diffusion, Agricultural production, Climate change, WAEMU

RÉSUMÉ

Cet article a analysé la diffusion spatiale de la production agricole dans l'Union économique et monétaire ouest-africaine (UEMOA) et pour voir si le changement climatique joue un rôle. Nous avons utilisé des données récentes de l'union sur la période 1996 - 2016 tirées des indicateurs de développement mondial de la Banque mondiale. Le modèle autorégressif spatial a révélé que la production agricole se propage spatialement et positivement dans l'union, et qu'elle est bénéfique à l'ensemble de l'union. Le changement climatique et les politiques climatiques pourraient jouer un rôle important, car un pays peut copier la politique climatique d'un autre pays de l'union pour améliorer sa production agricole grâce aux effets d'entraînement spatiaux. L'amélioration des politiques climatiques et agricoles des pays est bénéfique au développement agricole de toute la zone.

Mots clés : Diffusion spatiale, Production agricole, Changement climatique, UEMOA

INTRODUCTION

The economic growth of the West African Economic and Monetary Union (WAEMU) is declining with a rate of 6.8% in the year 2018. While activity is mainly driven by the tertiary sector, food crops and cash crops well above the average of the previous five seasons and the food and beverage industry is up 14.5%, according to the latest report on monetary policy in WAEMU of the Central Bank of West Africa (BCEAO). Favourable rainfall during the 2018-2019 crop year and food production increases by 8.3% in 2018-2019 in the WAEMU zone has helped to increase to nearly 65 million tonnes (Mt), with an increase of nearly 11% for cereals and 15.4% for other crops mainly horticulture. Compared to the average of the previous five years, the 2018-2019 crop year crops are up 19.5%. At the level of cash crops, all crops are growing, with the exception of cocoa, which for some, like coffee had substantial increases. Coffee production climbed 167.3% to 137,726 tonnes, but the BCEAO is returning to normal after the weak 2017-2018 season following the heavy rains.

Cotton production gained 3.1% at 2.509 Mt while groundnut production increased by 3.7% to 3.302 Mt, among other growing crops, cashew nuts (+ 4%) to 1.186 Mt and rubber (+ 5.8%) to 613,900 tonnes. On the other hand, cocoa production fell by 3.7% to 1,969 Mt but remain above the average of these five previous seasons. While crops are growing, the prices of the main agricultural raw materials exported by WAEMU have been less favorable. The WAEMU industrial production index rose by 5.4% in 2018 as a result of the improvement in manufacturing industries (+ 10.2%) driven by chemicals (+ 26.2%) but also food and beverages (+ 14.5%). The current economic realities emphasize the existence of spatial interactions in the economic and social phenomena observed between countries, mainly when these countries are geographically contiguous, closed to each other or belong to the same union (Anselin, 1988, Le Gallo, 2002, Tobler, 1979). An economic phenomenon occurring in one country may well affect the other country closed to it. Membership of the same union thus raises relevance of spatial diffusion of many economic phenomena between WAEMU countries, especially that of agricultural production. We ask ourselves whether and how agricultural production spreads spatially between countries of the union, given the free movement of goods and services and individuals, the international exchanges between them and the economic cooperation that connects them. Does geographical proximity of countries, geographical contiguity of countries, membership of the same monetary union, similar adoption and copies of policies related to climate change explain this spatial diffusion of agricultural production in the union if it really exists?

Spatial interaction is today a very relevant and insightful central economic issue of economic analysis. This article explores the spatial diffusion of agricultural production in WAEMU countries.

The interest of the research is therefore to analyze from a spatial autoregressive model a new economic phenomenon: "the spatial interaction of agricultural production in WAEMU". The work thus extends explicitly by also analyzing the form of spatial diffusion retained in the union. A second interest is to appreciate the economic cooperation between countries, the policy of free movement of goods and services and individuals between them, this belonging to the same union, climate change in the union and the policies related to this climate change. The analysis should normally awaken the minds of economic decision-makers, provide relevant policy perspectives to economic emergence of the union and policies to promote better agricultural progress, when we determine the form of spatial diffusion. Indeed, if we detect that agricultural production is spreading positively in the union, that is agricultural production of a country remains favourable to agricultural production of another country of the union, we can conclude that economic cooperation, free trade, copies of agricultural policies and policies related to climate change are currently very advantageous for the union, and our countries must always grow in agriculture, always develop good economic cooperation to start a satisfactory agricultural development of the whole area. If not, it will be interesting to provide best recommendations for a better economic emergence of the union.

WAEMU countries belong to the same union and are close. They can thus copy agricultural policies and climate change policies to improve their agricultural production, as they often develop similar policies. Copies of climate change policies may then explain this spatial diffusion of agricultural production in the union. Our article is organized in three sections. A first section presents the review of the literature and a second section focuses on empirical analysis. The conclusion and prospects for economic policies are presented in the third section.

Historically, it was Cliff and Ord (1973), after a series of papers in the late sixties and early seventies, who produce a book summarizing spatial statistics and econometrics. After this initial phase of recognition, the late 1970s and early 1980s were characterized by the refinement of Cliff and Ord's original framework of analysis and more particularly by the development of the theory of estimation and testing (Ord, 1975, Anselin, 1988; Le Gallo, 2002). According to Anselin and Bera (1998), spatial autocorrelation can be defined in a general way as the correspondence between the similarity of values taken by a variable of interest and the proximity of the spatial units where these same values are observed. More precisely, it reflects the existence of a functional relation between the observations made at the level of the different localizations of the space studied. Tobler (1979) said that "everything is connected to everything and closer things are more". This reflects that in economic phenomena, there are indeed spatial interactions between them essentially when localities studied are closer. Spatial diffusion therefore refers to the fact that an economic phenomenon occurring in one country or locality can have a significant impact on another country or another locality. This is the case, for example, with the spatial diffusion of agricultural growth between countries that will, for example, try to develop similar economic policies to support their agricultural growth (for example, the same agricultural policy or free movement of goods (including intermediate goods of production), services and individuals to promote growth as the case of WAEMU countries). This article attempts to analyze the spatial diffusion of agricultural production in WAEMU from a spatial autoregressive model. But before this empirical analysis, it is important to present what literature tells us about the process of spatial diffusion and some spatial effects.

Economic realities always emphasize that there are often spatial interactions in economic phenomena, especially when countries studied are closer, neighbors or belong to the same economic union (Tobler, 1979).

Empirically, growth performance is probably not insensitive to the location of countries, even if the economic literature has been very little inspired by questions from consideration of space. Recently (although the economic literature is weak), empirical studies have been proposed to explicitly integrate effects of space on country growth (Ertur, Le Gallo and Baumont, 2006; Conley and Ligon, 2002). Results obtained from this work have well underlined existence of spatial interactions in economic growth of countries for these authors. Other authors have also discussed the spatial diffusion of growth in countries. Niang (2010) analyzing the spatial convergence of African regions shows a significant positive relationship between them. The same studies of spatial interactions were carried out by Le Gallo and Dall'erba (2005), then by Ertur and Thiaw (2005) from a spatial autoregressive model on developed and developing regions. Results of different studies have highlighted existence of spatial interactions in growth phenomenon of these countries. Consideration of spatial effects is motivated by the fact that there are a large number of factors such as sub-regional integration effects, inter-regional migrations, spatial spill over effects which can be the cause of strong interdependencies between economies. In this case, observations are made by processes that link the localities and that can lead to a particular organization of activities in space (Le Gallo and Dall'erba, 2005). From Romer growth model (1986), we analyze in the following section the current regional spatial diffusion of agricultural production in WAEMU countries.

2. METHODS

Basic model

The objective of this paper is to analyze spatial distribution of agricultural production in WAEMU countries, taking into account effect of other countries in the same zone with which a country shares economic relations, that is, the spatial spill over effect. For example, agricultural production in Benin can also affect agricultural production in Togo, etc., and vice versa, thanks to the effects of copying policies, and since these countries are closer, belonging to the same economic and monetary union, sharing individuals, goods and services and economic relations, and having similar development policies. Taking into account spatial effect is a step forward and increases our study. We analyze whether agricultural production in a WAEMU country leads to agricultural production in another country of the union thanks to spatial spill over effects and spatial externalities produced.

The spatial spill over effects could also be explained by copies of climate change policies. If a country improves its climate policy to have more agricultural production, another country of the union can copy the policy to also have more agricultural production at home. On the other hand, better climate with better rainfall in the union, as assessed in recent years, can also be at the origin of a better agricultural production in those countries. In order to take better account of the effects related to these spatial externalities, we will use a spatial autoregressive model which makes it possible to explain the spatial diffusion of agricultural production between countries. Our spatial autoregressive model that analyzes the spatial distribution of agricultural production among WAEMU countries can be written in general as follows :

Equation 1

$$y = \lambda(I_T \otimes W_N)y + X\beta + u$$

Where y is the $NT \times 1$ vector of the observations of the dependent variable, X a $NT \times k$ matrix of observations of the k model explanatory variables, I_T the dimension T identity matrix, W_N the $N \times N$ weight matrix having on its diagonal the value 0 (according to the configuration standards of weight matrix), and λ the spatial parameter. The noise vector is the sum of two terms :

Equation 2

$$u = (i_T \otimes I_N)\mu + \varepsilon$$

Where i_T is a $T \times 1$ vector composed of the value 1, I_N an $N \times N$ identity matrix, μ a vector of specific effects (non spatially autocorrelated), and ε a vector of spatially autocorrelated errors on the following spatial autoregressive process :

Equation 3

$$\varepsilon = \rho(I_T \otimes W_N)\varepsilon + \upsilon$$

With ρ ($|\rho| < 1$) the spatial autoregressive parameter on the error, W_N the $N \times N$ weight matrix, $\upsilon_{it} \rightarrow IID(0, \sigma_\upsilon^2)$ and $\varepsilon_{it} \rightarrow IID(0, \sigma_\varepsilon^2)$.

In the panel literature, specific effects can be treated as fixed or random effects. Implementation of maximum likelihood or generalized method of moments on the spatial model with random effects and on the fixed effects model makes it possible to obtain efficient results, since in spatial regression, ordinary least squares become very inefficient. Apart from presence of spatial dependence on the dependent variable and / or on error, one can also have spatial dependence on specific effects and an autocorrelation of the error (Baltagi et al., 2009).

For all cases of spatial interactions, Baltagi, Song and Koh (2003) provided consistency and better specification tests of spatial model estimated when squeezing a spatial interaction in economic phenomenon studied. In order to normalize the effect of weight matrices and to have the sum of each row of matrices equal to 1, we will use standardized weight matrices according to standardization in spatial econometric analysis (line-standardization) which is in the following form: $W_{ij}\ s\tan dardised = \frac{w_j}{\sum_i w_j}$ (line i and column j) (Le Gallo, 2002). All weight matrices also have zero diagonal entries to capture exactly average influence of other countries j on country i (this simply means that $W_{ij} = 0$ if i = j). Three weighting matrices are used in our study: (i) the geographic contiguity matrix of the WAEMU countries (W1), which captures spatial effect between neighbouring countries; (ii) matrix of inverse of the geographical distance between countries of the union (W2) which makes it possible to capture spatial effect taking into account distance between countries and (iii) matrix of the square of the inverse of the geographical distance between countries (W3) that captures the spatial effect by taking into account distance squared between countries to see magnitude of the effect of distance to explain spatial externalities.

Matrices are represented as follows :

$$W_1 = \begin{cases} 1 f \quad countries\ are\ geographically\ contiguous\ and\ f \quad i \neq j \\ 0 f \quad countries\ are\ not\ geographically\ contiguous\ and\ f \quad i = j \end{cases}$$ Equation 4

$$W_2 = \begin{cases} \frac{1}{d_{ij}} f \quad countries\ are\ dis\tan t\ \ from\ each\ other\ and\ f \quad i \neq j \\ 0\, f \quad i = j \end{cases} \qquad \text{Equation 5}$$

$$W_3 = \begin{cases} \frac{1}{d_{ij}^2} f \quad countries\ are\ dis\tan t\ \ from\ each\ other\ and\ f \quad i \neq j \\ 0\, f \quad i = j \end{cases} \qquad \text{Equation 6}$$

Our dependent variable is the logarithm of agricultural value added (denoted LVAAGRI). The explanatory variables in the model are logarithm of gross capital formation (denoted LGCF), logarithm of the labour force (represented by those aged 16 and over) (noted LLABFORCE), foreign trade represented by the sum of exports and imports as a share of GDP (TRADE), the log of government expenditure (noted LG), inflation captured by GDP deflator (noted INFLATION).

To better describe this model of spatial distribution of agricultural production in WAEMU countries, it is important to first carry out the pre-estimation spatial tests (see Table 1) in order to retain the best specification of the model. For these spatial tests, the Baltagi et al. (2007) analysis of the spatial and serial dependence of errors under random effects and the Baltagi et al. (2003) analysis of the real presence of random effects in model to be estimated as well as Hausman spatial test of choice between fixed and random effects in the model, which make it possible to retain the best form of spatial diffusion and the best econometric specification of the model, provide following results.

Table 1: Spatial pre-estimation tests

Tests	LM value				p-value		
	W1	W2	W3		W1	W2	W3
Baltagi et al. (2007) tests							
Ha: Spatial dependence in error terms, sub random effects and serial correlation (test C.1)							
Response							
(df = 1)	0.0068781	0.0085261	0.0043029		0.9339	0.9264	0.9477
Ha: Serial correlation in error terms, sub random effects and spatial dependence (test C.2)							
Response							
(df = 1)	59.586	59.586	72.412		1.17e-14	1.17e-14	< 2.2e-16
Ha: Random effects or serial correlation or spatial dependence in error terms (test J)							
Response							
(df = 3)	685.76	686.06	687.56		< 2.2e-16	< 2.2e-16	< 2.2e-16
Baltagi et al. (2003) tests							
Ha: Presence of random effects							

Response	25.969	25.969	25.969		< 2.2e-16	< 2.2e-16	< 2.2e-16
Hausman spatial test							
Ha: One model (with random effect or fixed effects) is inconsistent							
	Chi2 value		p-value				
Response							
(df = 5)	0.84382	0.46563	1.529		0.9742	0.9933	0.9097

Note: W1, W2 and W3 correspond respectively to the geographic contiguity matrix, matrix of inverse of the geographical distance between countries and matrix of square of the inverse of the geographical distance, all standardized.

Source: Calculation of authors from data.

From tests of Baltagi et al. (2007), there is no spatial dependence in error term with a serial dependence (test C.1 and C.2). And because of acceptance of hypothesis of presence of random effects in the model to be tested by Baltagi et al. (2003), we retain the random effects in the model, and the best specification of the model is the RESAMSC (Random Effetcs Spatial Autoregressive Model with Serial Corrrelation).
Our model tested with consistency is specified as follows :

Equation 4

$$y = \lambda(I_T \otimes W_N)y + (i_T \otimes I_N)\mu + X\beta + \varepsilon$$

$$\varepsilon_{it} = \psi\varepsilon_{i\,t-1} + e_{it}$$

Data and estimation methods

For our work, we used recent data from World Bank (2019) over the period 1996 - 2016. Mostly data used came from World Bank's World Development Indicators World Development Index-WDI-, (2019). Descriptive statistics of variables can be presented as follows (Table 2) :

Table 2: Descriptive statistics

Variable	Observation	Mean	Std. deviation	Minimum	Maximum	Source
LVAAGRI	168	27.13107	0.7826242	25.32049	28.73897	WDI, 2019
LGCF	168	26.78605	1.241605	23.38632	28.97376	WDI, 2019
LLABFORCE	168	15.31973	0.7518495	13.34241	16.30192	WDI, 2019
TRADE	168	0.6287632	0.1844245	0.3073252	1.250278	WDI, 2019
LG	168	26.62703	0.9718752	24.44711	28.32049	WDI, 2019
INFLATION	168	0.0376592	0.0804821	-0.1073023	0.8089967	WDI, 2019

Source: Calculation of authors from data.

For estimation method, we used maximum likelihood method with random effects for the model, which analyzes the spatial diffusion of agricultural production in WAEMU countries. As ordinary least squares cannot give consistent results in spatial analysis, maximum likelihood method provides robust estimations.

RESULTS AND DISCUSSION

Results of estimation are presented in Table 3 shows that the independent variables (LGCF, LLABFORCE, LG and TRADE) are all positive and significant, except for INFLATION with expected signs or direction.

Table 3: Results of regression from Equation 4 - Dependent Variable: LVAAGRI

Variables	Maximum likelihood		
	W1	W2	W3
λ	0.537704***	0.482187***	0.388665***
	(9.4661)	(7.5835)	(6.4731)
Constant	3.866102***	3.212639***	4.120504***
	(4.0279)	(3.0609)	(3.8871)
LGCF	0.158000***	0.184247***	0.186039***
	(6.6758)	(7.1276)	(6.9263)
LLABFORCE	0.555781***	0.654341***	0.753285***
	(8.8165)	(9.4940)	(10.7801)
TRADE	0.360392***	0.423640***	0.398501***
	(3.1429)	(3.3812)	(3.0896)
LG	0.145903***	0.143957***	0.140459***
	(6.7995)	(6.1425)	(5.7644)
INFLATION	-0.149230	-0.095479	-0.163494
	(-1.1722)	(-0.6867)	(-1.1308)
Obs	168	168	168
Adj. R2	51.37%	52.89%	51.47%

, ** and * represent respectively thresholds of significance at 10%, 5% and 1%. Z-statistics are in parentheses.*

Source: Estimations and calculations of authors from data.

Results of analysis (Table 4) show that there is significant spatial diffusion of agricultural production in WAEMU, whether countries are neighbouring or distant (Coefficient λ). Agricultural production in one country of the union leads to agricultural production in another country of the union. These spatial externalities are well explained by copies of policies between countries. It means if a country tries to grow in agriculture, another country of the union copies this policy and also tries to grow at home. This advantageous spatial diffusion of agricultural production in the union can also be explained by current improvement of the climate and the rainfall in the union. Also, this spatial diffusion can be explained by copies of climate policies. If a country develops a better climate change policy to improve agricultural production, another country of the union copies this policy to improve its agricultural production. Agricultural production and agricultural policy developed by WAEMU countries become thus advantageous factors for economic development.

Table 4: Matrix of correlations

	LVAAGRI	LGCF	LLABFORCE	TRADE	LG	INFLATION
LVAAGRI	1.0000					
LGCF	0.7653	1.0000				
LLABFORCE	0.9189	0.8192	1.0000			
TRADE	0.2146	0.1352	0.1570	1.0000		
LG	0.5729	0.8187	0.6290	-0.1055	1.0000	
INFLATION	-0.2997	-0.1856	-0.3477	-0.0534	-0.0822	1.0000

Source: Calculation of authors from data.

CONCLUSION

In this article, we analyzed spatial diffusion of agricultural production in WAEMU countries. After theoretical background, results of studies show that agricultural production spreads spatially positively in the union, whether countries are neighbours or distant.

In terms of prospects for economic policies, it is important that our countries develop better agricultural policies at home to have better agricultural production not only at home but throughout the union from spatial spill over effects. Each country must also always grow in agriculture, improve its policy related to climate change so that by copies of policy, other countries of the union can also benefit from a country's policy to grow in agriculture, and this should be beneficial for the whole union in terms of agricultural development, thanks to positive spatial externalities produced.

REFERENCES

Anselin, L. (1988). Spatial Econometrics: Methods and Model, Kluwer Academic Publisher, Dordrecht. Studies in operational regional science, 4. www.worldcat.org

Anselin, L. & Bera, A. K. (1998). Spatial dependence in linear regression models with an introduction to spatial econometrics" in A. Ullah, & D. Giles, Eds., Handbook of applied Economic Statistics. Marcel Dekker, New York. https://dces.wisc.edu/wp- content/uploads/sites/128/2013/08/W7_AnselinBera1998.pdf

Baltagi, B. H., Egger, P., Pfaffermayr, M. (2009). A Generalized Spatial Panel Data Model with Random Effects. Working Paper 113, Center for Policy Research 53, Syracuse University, https://EconPapers.repec.org/RePEc:max:cprwps:113, https://surface.syr.edu/cpr/53

Baltagi, B. H., Song, S. H., Jung, B. C., Koh, W. (2007). ''Testing for Serial Correlation, Spatial Autocorrelation and Random Effects Using Panel Data''. Journal of Econometrics, Vol. 140, Issue 1, pages 5-51.

Baltagi, B. H., Song, S. H., Koh, W. (2003). ''Testing Panel Data Regression Models with Spatial Error Correlation''. Journal of Econometrics, Vol. 117, Issue 1, pages 123-150.

Cliff, A. D., Ord, J. K. (1973). Spatial Autocorrelation: Pion, Londres. Progress in Human Geography, Vol. 19, Issue 2, pages 245-249.

Dall'erba, S. & Le Gallo, J. (2005). ''Dynamique du processus de convergence régionale en Europe'', Région et Développement, Vol. 2005, Issue 21, pages 119-139. https://doi.org/10.1177/030913259501900205

Ertur, C., Le Gallo, J. Baumont C. (2006). The European Regional Convergence Process, 1980-1995: Do Spatial Regimes and Spatial Dependence Matter?, International Regional Science Review, Vol. 29. Issue 1, pages 2-34.

Ertur, C. & Thiaw, K. (2005). ''Croissance, capital humain et interactions spatiales : une étude économétrique'', Document de travail du LEG, Université de Bourgogne, No. 2005-04. Laboratoire d'Economie et de Gestion, CNRS, Université de Bourgogne.

Le Gallo, J. (2002). ''Économétrie spatiale : l'autocorrélation spatiale dans les modèles de régression linéaire'', Économie & prévision, n°155, Vol. 2002, Issue 4, pages 139-157.

Niang A.-A. (2010). ''Growth and convergence in Africa: The impact of spatial effects'', Munick Personal RePEc Archive. MPRA Paper No. 24059.

Ord, J. K. (1975). "Estimation methods for models of spatial interaction", Journal of the American Statistical Association, Vol. 70, Issue 17, pages 120-126.

Tobler W. (1979). ''Cellular geography'', in S. Gale et G. Olsson, Eds., Philosophy in Geography, pages 379-386, Reidel, Dordrecht. www.springer.com

APPENDIX

Appendix 1 : Matrix of correlations

Table 4: Matrix of correlations

	LVAAGRI	LGCF	LLABFORCE	TRADE	LG	INFLATION
LVAAGRI	1.0000					
LGCF	0.7653	1.0000				
LLABFORCE	0.9189	0.8192	1.0000			
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LG	0.5729	0.8187	0.6290	-0.1055	1.0000	
INFLATION	-0.2997	-0.1856	-0.3477	-0.0534	-0.0822	1.0000

Source: Calculation of authors from data.

Impacts du changement climatique sur la chaîne de valeur viande bovine au Sénégal : Quels investissements pour quelles stratégies de résilience ?

Waoundé Diop et Assane Beye

ABSTRACT

The aim of this paper is to analyze the impact of climate change on the beef value chain in order to identify the investments necessary to strengthen the resilience of stakeholders. The value chain approach was adopted to (i) map the beef value chain, (ii) identify climate risks and (iii) analyze investment options for stakeholder resilience. Structured and semi-structured interviews were carried out in Dakar, Touba and in Ferlo. The results show that the Senegalese beef value chain is characterized by a multitude of actors including breeders, who are more exposed to the vagaries of the weather. Storage of livestock feed and mobility appear to be the main resilience strategies of pastoralists. Investments should therefore be made by the public authorities to maintain the mobility of pastoralists and facilitate access to support services for pastoral farming.

Keywords: Pastoralism, Value Chain, Climate risks, Resilience, Senegal

RÉSUMÉ

L'objectif de cet article est d'analyser l'impact du changement climatique sur la chaîne de valeur viande bovine afin d'identifier les investissements nécessaires pour renforcer la résilience des acteurs. L'approche chaîne de valeur a été adoptée pour (i) cartographier la chaîne de valeur viande bovine, (ii) identifier les risques climatiques et (iii) analyser les options d'investissement pour une résilience des acteurs. Des entretiens structurés et semi-structurés ont été réalisés à Dakar, à Touba et dans le Ferlo. Les résultats montrent que la chaîne de valeur viande bovine du Sénégal est caractérisée par une multitude d'acteurs dont les éleveurs, qui sont plus exposés aux aléas climatiques. Le stockage d'aliments de bétail et la mobilité apparaissent comme étant les principales stratégies de résilience des éleveurs. Ainsi, des investissements devraient être faits par les pouvoirs publics pour maintenir la mobilité des éleveurs et faciliter l'accès aux services de soutien de l'élevage pastoral.

Mots clés : Pastoralisme, Chaîne de valeur, Risques climatiques, Résilience, Sénégal

INTRODUCTION

Les zones arides et semi-arides sont caractérisées par de faibles précipitations hautement variables qui limitent la productivité primaire et la fertilité des sols en raison de la biomasse limitée. Ainsi, si le changement climatique menace tous les secteurs économiques, les activités d'élevage devraient en souffrir davantage en raison de leur forte dépendance aux aléas climatiques mais aussi leur exposition à une multitude d'incertitudes (Wane, 2010). En effet, la variabilité ou le manque de précipitations, à court terme, influe généralement sur les activités d'élevage, soit par une baisse de la productivité, soit par l'épuisement des troupeaux avec des conséquences potentiellement désastreuses pour le bien-être (Fabricius et al., 2008). Une telle situation se déteint sur les chaînes de valeur des principaux produits d'élevage et affecte sensiblement le développement économique des pays semi-arides en raison du poids de sa contribution dans la création de richesse et d'emplois et dans la lutte contre l'insécurité alimentaire et nutritionnelle.

Au Sénégal, l'élevage constitue une forme privilégiée de mise en valeur des régions arides et semi-arides qui sont faiblement arrosées et où l'agriculture pluviale serait trop aléatoire (Sandford, 1983). Il est pratiqué par 29,5% des ménages sénégalais, soit 476 668 ménages[35], auxquels il offre de grandes opportunités en termes de revenus, d'emplois et de renforcement de la résilience face aux différents chocs et crises. L'élevage constitue la deuxième activité du secteur agricole avec une contribution moyenne de 28,5% et 4,3%, respectivement, à la valeur ajoutée du secteur primaire et au PIB (Ministère de l'Élevage et des Productions Animales, 2015). L'essentiel de cette production est issu du système extensif mis en œuvre dans la zone sylvopastorale qui couvre 30% du territoire national et abrite 22 à 30% du cheptel national de bovins et de petits ruminants (Direction de l'Élevage, 2015). Le principal produit des activités d'élevage est la viande bovine qui occupe une place prépondérante dans l'alimentation des ménages sénégalais, par rapport aux autres types de viande. La chaîne de valeur est approvisionnée essentiellement, à partir de systèmes d'élevage extensifs transhumants. Le Ferlo qui a été identifié comme étant une zone particulièrement vulnérable au changement climatique est la région d'élevage, par excellence, du Sénégal (Intergouvernemental Panel on Climate Change, 2007). Avec sa croissance démographique élevée, les faibles ressources naturelles augmenteraient probablement davantage la forte pression exercée sur ces ressources locales (Hein et Metzger, 2009). Notons que cette zone couvre plus de la moitié de la superficie du Ferlo et constitue le principal moyen de subsistance des communautés rurales.

Dans cette zone marquée par une forte prévalence des extrêmes climatiques, on note souvent un assèchement des abreuvoirs et une rareté des fourrages, ce qui entraîne la mortalité du cheptel. Ainsi, si ces risques ne sont pas identifiés puis traités avec des instruments de politiques appropriés et des modèles économiques résilients, ils pourraient affecter la stabilité économique et sociale de ces zones. Dans ce contexte, quels sont les principaux risques climatiques qui pèsent sur la chaîne de

35 Recensement Général de la Population, de l'Habitat, de l'Agriculture et de l'Elevage (RGPHAE), 2013 valeur viande bovine ? Et quels sont les investissements nécessaires pour garantir sa résilience ? L'objectif de cet article est d'étudier la manière dont le changement climatique affecte la chaîne de valeur de la viande bovine au Sénégal afin d'identifier les options d'investissement pour renforcer la résilience des communautés pastorales et agropastorales des zones arides et semi-arides.

Dans la littérature, certains privilégient la cartographie des vulnérabilités, la surveillance du climat, les prévisions et l'alerte rapide des événements climatiques extrêmes comme étant les meilleures stratégies pour atténuer leur impact négatif sur l'humanité, les biens et l'environnement ainsi que pour tirer parti de tout impact positif (Marigi, 2017). D'autres, préconisent la mobilité comme déterminant principal de l'adaptation pour le renforcement de la résilience des ménages ruraux en Afrique semi-aride au changement et à la variabilité climatiques (Carabine et Simonet, 2018). Dans cet ordre d'idées, de nombreux auteurs ont fait valoir que la mobilité, moyen d'adaptation à long terme à la variabilité climatique, devrait continuer à jouer un rôle primordial dans les stratégies de subsistance en zone rurale (Sanou et al, 2018). Cependant, certaines stratégies d'adaptation peuvent ne pas aboutir aux résultats positifs escomptés, ce qui se traduit par une adaptation insuffisante ou une mal adaptation qui exacerbe la vulnérabilité du groupe cible ou des communautés voisines (Debela et al, 2019). Toutefois, les impacts du changement climatique vont, certes, engendrer plusieurs entraves au développement économique et social, mais à bien des égards, offrir des opportunités, notamment dans la redéfinition des politiques de développement surtout dans les secteurs clés des économies des zones arides et semi-arides (Wade et al., 2015).

MÉTHODOLOGIE

La méthodologie utilisée dans le cadre de cette étude privilégie l'approche chaîne de valeur. Contrairement aux approches de l'Organisation des Nations unies pour l'alimentation et l'agriculture (FAO) et de l'Agence des États-Unis pour le développement international (USAID) qui ont été initiées pour des analyses de chaîne de valeur sans distinction de lieu, l'approche VC-ARID « Value Chain Analysis for Resilience in Drylands » a été développée pour une meilleure prise en compte des spécificités des zones arides et semi-arides (Carabine et Simonet, 2018). En effet, l'intérêt de cette approche innovante et interdisciplinaire réside dans la reconnaissance de la variabilité écologique et socioéconomique comme différences structurelles par rapport aux autres systèmes de production.

Cette approche pose cependant plusieurs défis en zones arides et semi-arides dont la non uniformité des systèmes et la nécessité de comprendre les corrélations dynamiques entre les différents maillons de la chaîne. D'abord, notre analyse reconnaitra explicitement la multitude des sous-chaînes qui peuvent conduire à un développement économique résilient au changement climatique. Ensuite, les corrélations dynamiques et la saisonnalité inhérentes aux systèmes semi-arides seront prises en compte de même que les arbitrages le long de la chaîne de valeur pour éviter l'uniformité. Enfin, les effets spatiaux de la mobilité saisonnière et rurale-urbaine seront pris en compte dans les analyses des chaînes de valeur. Dans la pratique, la mise en œuvre de cette approche passe par trois étapes :

- **Étape 1 : Cartographie de la chaîne de valeur**
  Elle est conforme à l'analyse de chaîne de valeur standard notamment les approches développées par USAID et FAO. Ainsi, une revue de la littérature a d'abord permis d'identifier l'ensemble des acteurs qui s'activent le long de la chaîne de valeur à travers les différents maillons d'approvisionnement, de production, de commercialisation, de transformation et de distribution. Par la suite, des guides d'entretien ont été élaborés et administrés aux différents acteurs de la chaîne de valeur (éleveurs, commerçants et transformateurs). Ces entretiens ont ainsi été menés dans la zone sylvopastorale qui est une zone de production, à Touba qui est une zone de consommation avec des équipements de transformation industrielle récemment installés et à Dakar qui est la plus grande zone de consommation du Sénégal.
- **Étape 2 : Identification et évaluation des risques climatiques.**
  Elle consiste en l'identification des risques climatiques ainsi que leur impact sur la chaîne de valeur viande-bovine. Pour cela, une revue de littérature rendant compte des connaissances actuelles en termes de changement climatique dans la zone sylvopastorale du Sénégal a d'abord été menée. Résumée en une matrice, cette revue non exhaustive de la littérature rend compte des changements climatiques observés et projetés. Ensuite, les principaux risques climatiques identifiés et leurs impacts le long de la chaîne de valeur viande-bovine ont été analysés. Enfin, les résultats des enquêtes quantitative et qualitative permettent de dresser une liste des décisions d'adaptations privées mises en œuvre par les acteurs économiques le long de la chaîne de valeur.
- **Étape 3 : Analyse des options d'adaptation et des opportunités d'investissement**
  Elle est essentiellement basée sur la discussion des résultats à travers des entretiens avec des personnes ressources clés de la chaîne de valeur et des ateliers de partage des résultats. C'est ainsi que des entretiens spécifiques ont d'abord été menés avec des spécialistes pour confirmer les résultats précédents, affiner les options d'adaptation et surtout formuler des réponses politiques aux défis rencontrés par tous les acteurs de la chaîne de valeur viande-bovine au Sénégal. Ensuite, deux ateliers ont été organisés avec les différents acteurs de la chaîne de valeur.

RÉSULTATS ET DISCUSSION

Cartographie de la chaîne de valeur bovine

La chaîne de valeur bétail-viande reste caractérisée par la présence d'une multitude d'acteurs au niveau des différents maillons de la production, de la commercialisation, de la transformation et de la distribution (Figure 1). Les éleveurs sont les principaux acteurs de la production. Ils vendent le bétail sur pieds généralement aux dioulas de brousse (commerçants), aux téfankés (intermédiaires qui garantissent les transactions entre acheteurs et vendeurs) ou aux bouchers (abattants basés au niveau local). L'autre partie de la production est assurée par les importateurs de viande des pays européens ou sud-américains et les Dioulas qui importent des animaux sur pieds du Mali et de la Mauritanie. Le maillon de la commercialisation est marqué par la présence d'intermédiaires dont les téfankés qui s'approvisionnent directement chez les dioulas de brousse et assurent la vente de bétail aux chevillards et aux bouchers ; les dioulas de brousse qui collectent directement le bétail auprès des éleveurs et les dioulas de ville qui se chargent de l'approvisionnement des centres urbains. La transformation des animaux en viande se fait au niveau des abattoirs modernes construits dans les villes ou les abattoirs artisanaux où les bouchers se chargent de la transformation sous la supervision d'un inspecteur vétérinaire pour la certification du produit. Enfin, le maillon de la distribution est constitué des chevillards qui sont souvent basés dans les abattoirs et approvisionnent les bouchers abattants qui officient dans les zones rurales et achètent le bétail sur pieds auprès des dioulas ou éleveurs et s'occupent aussi bien de l'abattage que de la vente de viande et les bouchers-détaillants qui achètent la viande au kilogramme auprès des chevillards.

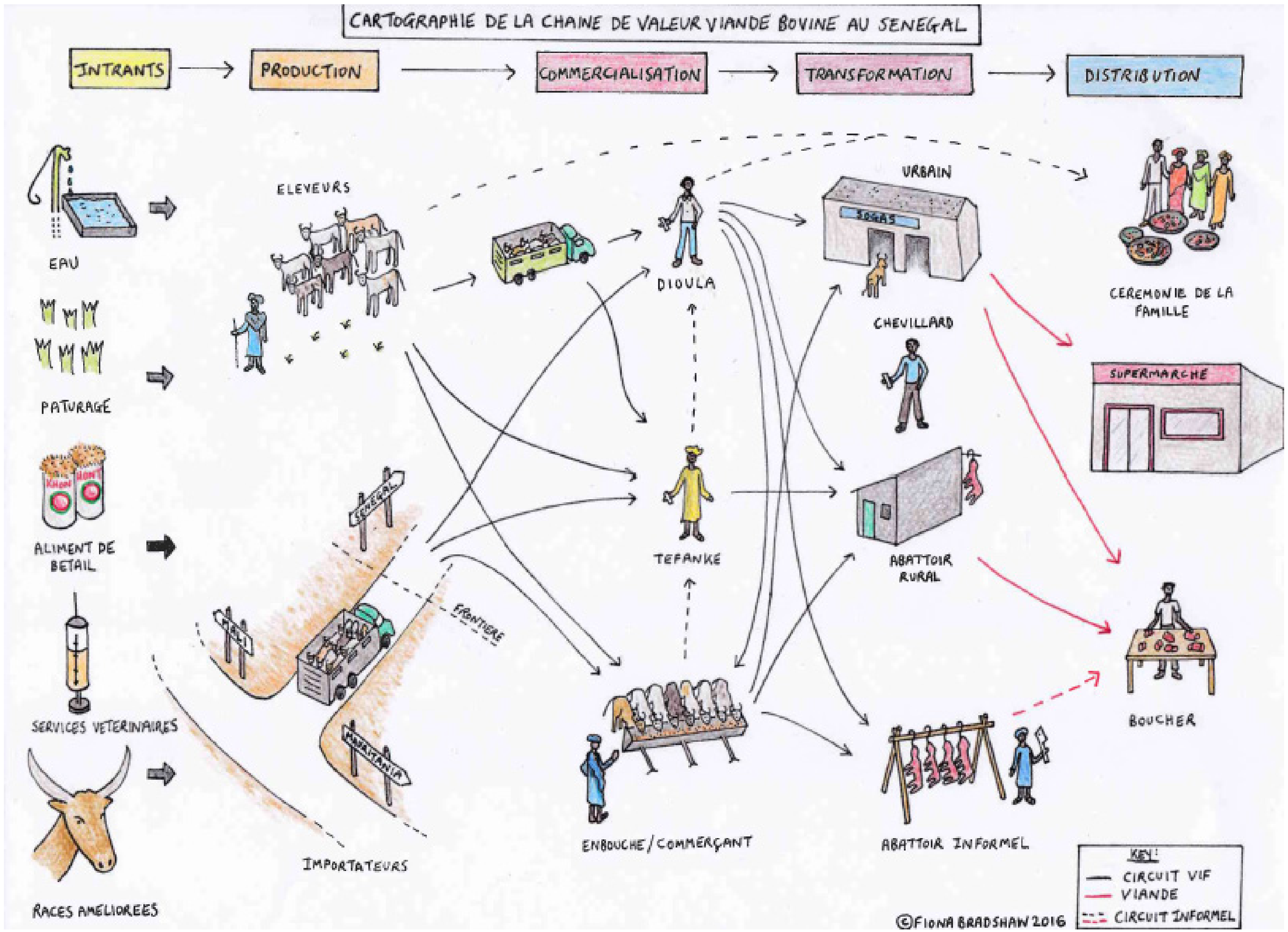
Dans le système extensif, l'alimentation des animaux est prioritairement assurée par des parcours naturels, herbacés et ligneux mais l'irrégularité et la rareté des pluies qui entraînent une période de soudure plus longue, poussent à des compléments alimentaires sous des formes diverses. D'ailleurs, il est ressorti des discussions que les éleveurs transhumaient pour trois raisons: la recherche de pâturage pour nourrir les animaux, la recherche de points d'eau pour leur abreuvement et l'évitement des conflits avec les agriculteurs dans la gestion de l'espace. Toutefois, la non application de programmes de vaccination régulière et globale et l'accès très limité aux soins vétérinaires sont encore des causes d'une forte mortalité et d'une faible productivité. Le prix des animaux dépend de plusieurs facteurs dont la demande, le poids de l'animal, sa race, son sexe, son âge et sa performance. Le changement climatique n'est pas sans conséquence sur l'élevage à travers des sécheresses et des pluies hors saison.

La coordination verticale des acteurs de la chaîne de valeur viande bovine est caractérisée par l'intervention de certains acteurs sur plusieurs maillons de la chaîne notamment les bouchers. Aussi note-t-on une intégration verticale entre certains acteurs de la production et de la commercialisation en fonction des saisons. Il s'agit notamment des éleveurs, des téfankés et des dioulas. Il convient, par ailleurs, de remarquer l'existence d'associations professionnelles qui regroupent tous les types d'acteurs qui sont sur la chaîne de valeur comme le Conseil National de la Maison des Éleveurs (CNMDE) et l'Association Nationale des Professionnels de la Viande Bovine au Sénégal (ANPROBVS) qui pourraient jouer un rôle dans la coordination verticale de la chaîne de valeur. Au niveau du maillon de la production, la coordination horizontale se manifeste principalement par le partage de l'information sur la disponibilité d'eau et de fourrage entre les bergers à travers l'usage des nouvelles technologies de l'information et de la communication, notamment les téléphones portables. Il faut noter en outre, l'élevage collectif à travers le recrutement, pendant la transhumance, d'un berger au sein d'une même famille ou d'un village, pour prendre en charge les animaux pendant la période de soudure, recutement qui permet de réaliser des économies d'échelle. Aussi, les relations entre les bouchers qui se manifestent par le partage des matériaux de travail et aussi la mise en commun des méventes dans des frigos pour la conservation de la viande sont tout aussi remarquables.

Impact des risques sur la chaîne de valeur

Les modèles globaux et régionaux étant contradictoires sur certaines tendances,

Figure 1: Cartographie de la chaîne de valeur bovine au Sénégal



Source : Auteurs à partir des entretiens

l'analyse se concentre sur les informations nationales disponibles ainsi que sur la zone sylvopastorale. C'est ainsi que le modèle régional utilisé et validé au Sénégal dans la Contribution Prévue Déterminée du Sénégal (CPDN, 2015) a permis d'identifier les principaux risques climatiques qui pèsent sur la chaîne de valeur viande bovine. Il s'agit entre autres de la sécheresse ; de la courte saison des pluies ; des pauses pluviométriques ; des inondations ; des pluies hors saison ; des vagues de froid, de chaleur et des vents violents. La figure 2 de la page 8 décrit les risques climatiques et leurs impacts sur le secteur de l'élevage en général et sur la chaîne de valeur bovine en particulier. Ces risques présentent des effets négatifs sur le secteur de l'élevage.

Sur les intrants, l'impact est directement subi par les facteurs de production. D'une part, on observe un rétrécissement des pâturages, un assèchement des points d'eau et une baisse de la qualité et de la quantité des pâturages, induite par la sécheresse ou les variabilités tendancielles du climat (Hausse des températures et baisse de la pluviométrie). D'autre part, on assiste à une croissance des maladies dues aux pluies hors saison entraînant ainsi une augmentation des frais vétérinaires (vaccins, etc.)

Sur la production, les risques climatiques ont des impacts directs et négatifs. En effet, en cas de sécheresse, d'une hausse de la température ou d'une mauvaise saison des pluies, les éleveurs sont victimes d'une baisse de la qualité et de la quantité de la production (voire une baisse de la reproduction) de bovins. Concernant les pluies hors saison, elles entraîneraient une forte croissance de la mortalité du cheptel.

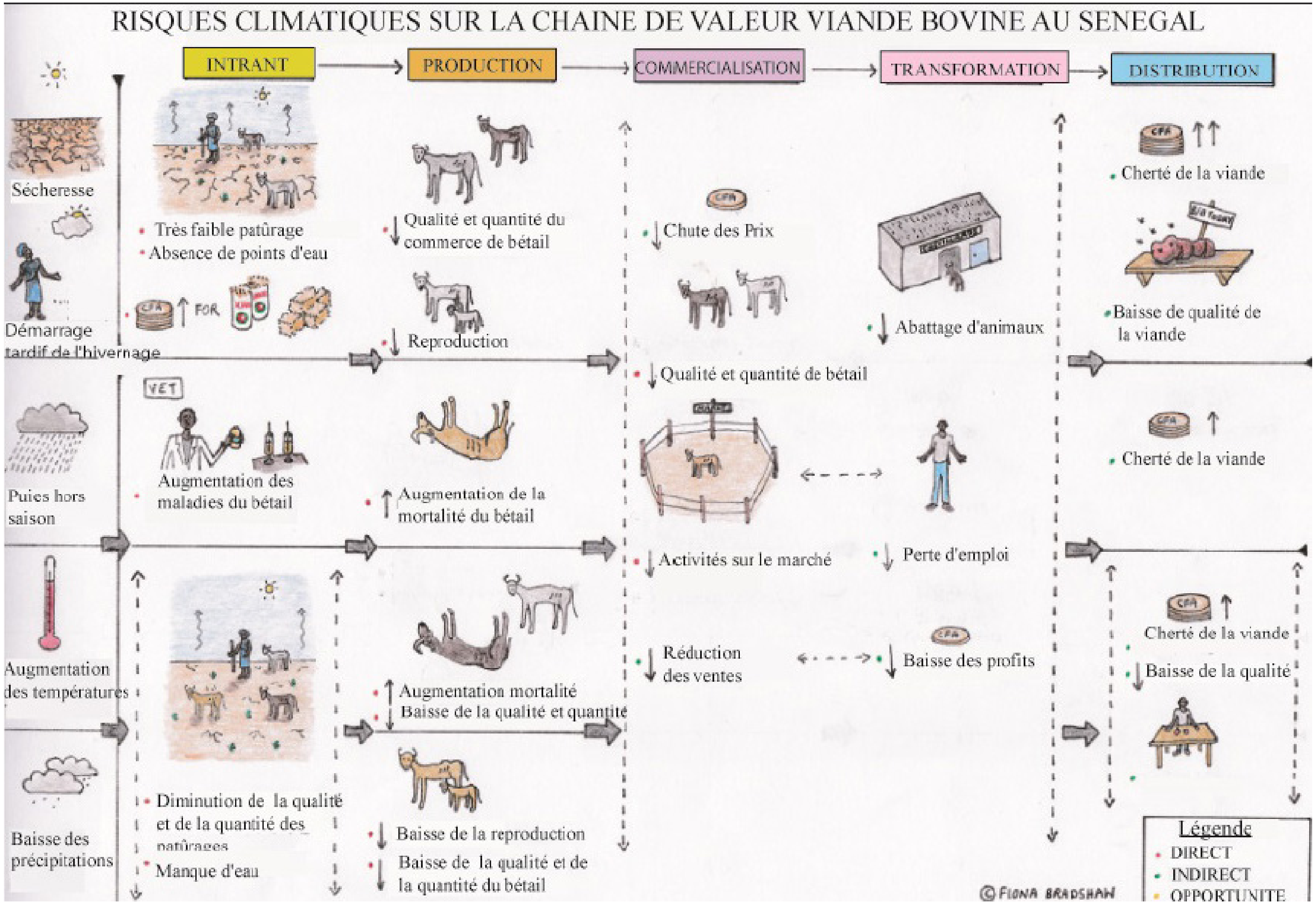
Sur la commercialisation, les risques climatiques affectant le maillon de la commercialisation sont directs et se manifestent d'une part, par une baisse de l'activité au niveau du marché due aux pluies hors saison et d'autre part par une baisse du cheptel en quantité et en qualité du fait du retard de la saison des pluies ou indirects, marqués par une baisse du prix du bovin et une réduction de l'activité des commerçants. Le caractère indirect des impacts sur le maillon de la commercialisation s'explique par la flexibilité et l'informalité des acteurs qui se positionnent en fonction des saisons et de leurs intérêts.

Sur la transformation, les impacts des risques climatiques sont principalement indirects et entraînent une baisse des animaux à abattre, des pertes d'emplois et une baisse des bénéfices des acteurs.

Dans ce dernier maillon de la chaîne de valeur bovine, les risques climatiques agissent indirectement sur la quantité et la qualité de la viande disponible au niveau du marché local. En effet, en cas de sécheresse, de retard dans la saison des pluies ou d'une augmentation de la température, l'impact sur le panier ménager se fait sentir à travers une hausse du prix de la viande. Toutefois, ces impacts peuvent être atténués par la possibilité d'importer de la viande.

Au terme de l'analyse, il est noté que les producteurs, plus précisément les éleveurs, sont les acteurs les plus exposés au changement climatique.

Figure 2 : Risques climatiques sur la chaîne de valeur bovine au Sénégal



Source : Auteurs à partir des entretiens

Identification des stratégies de résiliences et des options d'investissements

L'identification des stratégies de résilience des acteurs est retracée par la figure 3 de la page 10. L'accent doit être mis sur la production d'aliments de bétail, le maintien de la mobilité et l'accès aux services de soutien.

- **Promouvoir la production d'aliments de bétail et de fourrage**

D'après les entretiens, le stockage d'aliments de bétail constitue la première stratégie de résilience des éleveurs face aux changements climatiques. Durant les périodes de soudure, les éleveurs sont confrontés à d'énormes difficultés pour assurer la nourriture de leurs animaux. Certes, après la sécheresse de 2014, les éleveurs du Ferlo ont bénéficié du soutien de l'État à travers l'opération sauvegarde du bétail avec des subventions d'aliments de bétail qui restent cependant insuffisantes pour réduire les conséquences des risques climatiques. Pour une chaîne de valeur résiliente, l'accent doit être mis en premier lieu, sur la création de banques d'aliments de bétail dans ces zones marquées par des sécheresses fréquentes. En plus, pour une gestion efficace de ces banques d'aliments, il s'avère nécessaire de mettre en place des comités de gestion entre les éleveurs et les unités pastorales. En second lieu, développer des cultures fourragères près des points d'eau gérés par la population locale permettra aux éleveurs de disposer d'herbe pendant toute l'année et contribuera à la vulgarisation de l'élevage dans cette zone. Enfin, nouer des partenariats entre les organisations d'éleveurs et les sociétés agricoles ou industrielles permettra d'acheter de la graine de coton ou des résidus de récolte à moindre coût.

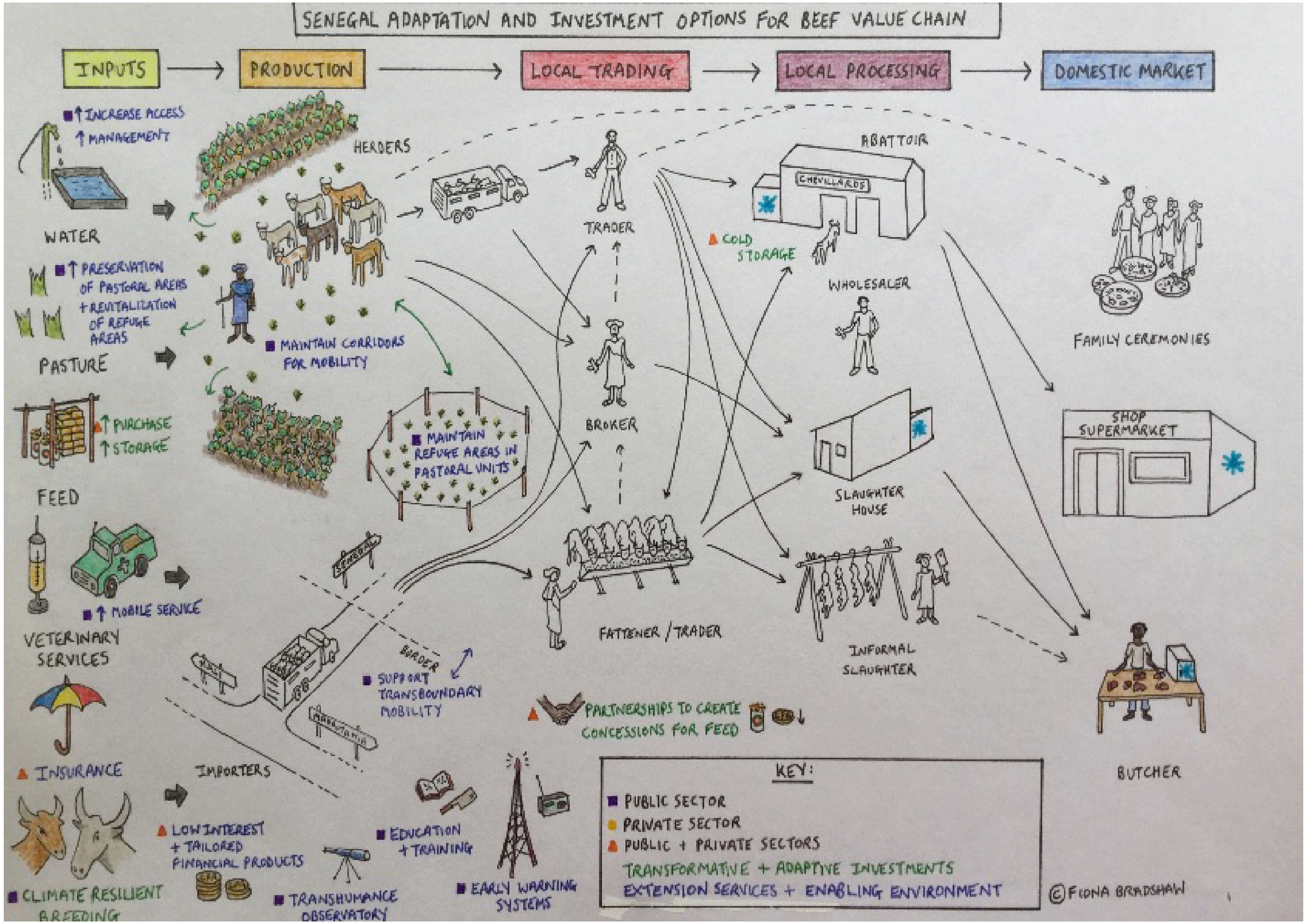
- **Maintenir la mobilité**

Les entretiens ont montré que la mobilité est la deuxième stratégie de résilience des éleveurs après le stock d'aliments. Ce résultat est conforme aux résultats de Sanou et al., (2018), Carabine et Simonet, (2018). D'où l'importance pour les décideurs de la prendre en compte dans leur programme de développement de l'élevage pastoral pour son maintien. La création et la protection des zones dédiées à l'élevage dans les localités d'accueil et de transit des transhumants peut faciliter la mobilité du bétail. Les autorités doivent mettre en place aussi des couloirs de passages pour le bétail afin d'éviter les conflits entre agriculteurs et éleveurs. La mise en place d'un observatoire chargé de la transhumance (corridors et refuges) facilitera aussi la mobilité.

- **Faciliter l'accès aux services de soutien**

Dans la zone du Ferlo, la sécheresse de 2014 reste encore dans la mémoire des éleveurs d'après les enquêtes. Ainsi, l'accès aux services de vulgarisation de la chaîne de valeur bovine et les enseignements de la sécheresse de 2014 ont permis aux éleveurs de réduire les risques (limiter les pertes) et d'être plus résilients face aux intempéries. Sur ce, la mise en place d'un système climatique adaptable dédié à l'élevage, en mettant l'accent sur les systèmes d'alerte précoce, chez les éleveurs est primordiale à l'heure actuelle et peut renforcer la résilience. En outre, la promotion des canaux de dissémination (sms, radio, etc.) entre les ménages pastoraux peut s'avérer très efficace pour faciliter le partage de l'information en temps réel dans ces zones très reculées. Enfin, le renforcement du capital humain en adoptant une éducation itinérante pour les transhumants, mérite d'être pris en compte dans les projets et programmes de développement de l'élevage au Sénégal.

Figure 3 : Adaptation et options d'investissement sur la chaîne de valeur bovine au Sénégal



Source : Auteurs à partir des entretiens

CONCLUSION

Au terme de cette analyse, les impacts du changement climatique sur la chaîne de valeur bovine selon une approche chaîne de valeur ont été étudiés à travers trois étapes dont la cartographie de la chaîne de valeur bovine, l'intégration d'informations climatiques (pour voir les risques) et l'analyse des stratégies de résiliences et d'opportunités d'investissement.

Pour ce faire, des entretiens ont été effectués auprès des acteurs le long de la chaîne de valeur dans les zones de consommation, de transformation et de production de la chaîne de valeur. L'analyse des risques climatiques de la chaîne de valeur bovine a permis de voir que les éleveurs sont les acteurs les plus vulnérables et pourraient subir des impacts directs face au changement climatique. En cas de sécheresse, d'une hausse des températures ou d'une baisse de la pluviométrie, l'impact est direct et négatif sur les éleveurs. En effet, ces risques réduisent la qualité et la quantité de la production bovine voire la reproduction. En outre, le stockage de la production d'aliments et la mobilité sont les principales stratégies de résiliences face aux aléas climatiques.

Au regard des résultats auxquels l'étude a abouti, un certain nombre de recommandations peuvent être formulées pour une chaîne de valeur plus résiliente au changement climatique :

- **La production d'aliments de bétail et de fourrages :** Le stockage d'aliments de bétail constitue une stratégie individuelle majeure des éleveurs contre le changement climatique. L'augmentation de la productivité des éleveurs pastoraux nécessite la création de zones de refuge destinées aux unités pastorales mais aussi la construction de magasins de stockage d'aliments de bétail au niveau local. Les expériences du projet pilote de mise en œuvre de la composante « aliment du bétail » financé par la Communauté Economique des Etats de l'Afrique de l'Ouest (CEDEAO) au Niger pourraient être mises à contribution. En outre, la mise en place de partenariats entre les organisations d'éleveurs, les industriels et les sociétés agricoles (Société de Développement et des Fibres Textiles du Sénégal (SDFTS), Compagnie Sucrière Sénégalaise (CSS)) pourrait faciliter l'accès et l'achat d'aliments de bétail et de résidus de récolte à moindre coût. La viabilité économique des magasins de récolte dépend de tels partenariats. Aussi l'Etat doit t-il s'investir dans la facilitation de tels partenariats. L'expérience du Réseau Bilital Maroobé (RBM) dans le cadre d'un projet pilote PROBILAB (financement de la CEDEAO) pourrait constituer un point de départ intéressant pour de telles initiatives.
- **Le maintien de la mobilité : il semble être indispensable :** Toutefois, elle pose plusieurs questions relatives à la gouvernance foncière aussi bien dans les parcours que dans les zones d'accueil. Au Sénégal, le code pastoral qui doit consacrer la reconnaissance du pastoralisme comme mode de mise en valeur des terres et donc du droit d'accès des éleveurs aux ressources foncières tarde à être appliqué. Ainsi, l'État et ses instances décentralisées doivent assurer la mise en place d'un observatoire du pastoralisme chargé d'identifier les espaces pastoraux, de les cartographier, de les inscrire dans les registres pastoraux et d'assurer la bonne application du code en zone pastorale.

- **L'accès aux services de soutien** : il s'avère nécessaire de mettre en place un système d'alerte précoce par la promotion des canaux de dissémination adaptés en milieu rural (radio ou sms). Agronomes et Vétérinaires sans Frontières (AVSF) et ses partenaires comme Auvergnes Rhones Alpes, Pasa Loumakaf et le Centre de suivi Ecologique (CSE) ont travaillé pour la mise en place d'un système d'alerte précoce. Il a été conçu dans le cadre du projet lutte « contre la désertification par l'appui au pastoralisme dans le Ferlo », dont les aléas sont axés sur les maladies animales, les infrastructures en panne (forages et abreuvoirs), les feux de brousse, le vol du bétail, les pluies hors saison, les sécheresses et autres calamités. L'accent doit être mis aussi sur l'accès au crédit des éleveurs sans fonds de garantie.

RÉFÉRENCES BIBLIOGRAPHES

Agence Nationale de la Statistique et de la Démographie (2013). "Recensement Général de la Population et de l'Habitat, de l'Agriculture et de l'Élevage (RGPHAE) "République du Sénégal Ministère de l'économie, des Finances et du Plan.

Carabine, Elizabeth, et Catherine Simonet (2018). Value Chain Analysis for Resilience in Drylands (VC-ARID): identification of adaptation options in key sectors. Londre: Pathways to Resilience in Semi-arid Economies (PRISE).

CPDN (2015). Contribution Prévue Déterminée au niveau National. Document politique. M. d. l. e. e. d. d. durable. République du Sénégal.

Dia-Ndiaye N., Diop, Waoundé et Beye, Assane (2018). Impact du changement climatique, options d'adaptation et opportunités d'investissement dans le secteur de l'élevage au Sénégal – Chaine de valeur lait au Sénégal. PRISE Working Paper. Dakar: IED Afrique.

Debela, Nega, David McNeil, Kerry Bridle et Caroline Mohammed (2019). «Adaptation to Climate Change in the Pastoral and Agropastoral Systems of Borana, South Ethiopia: Options and Barriers.» American Journal of Climate Change 8: 40-60.

Fabricius K. E., De'ath G., Lee Puotinen M. Done T., Cooper T. F. and Burgess S. C. (2008) "Disturbance gradients on inshore and offshore coral reefs caused by a severe tropical cyclone" Limnol. Oceanogr., 53(2), 2008, 690–704 E 2008, by the American Society of Limnology and Oceanography, Inc

Hein, Lars, et Marc J. Rik Leemans Metzger .(2009). «The local impacts of climate change in the Ferlo, Western Sahel.» Climatic Change (DOI 10.1007/s10584-008-9500-3) 93 (Springer): 465–483.s.d.

Intergovernmental Panel on Climate Change (IPCC) (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. Geneva, Switzerland: IPCC.

Intergovernmental Panel on Climate Change (2007). The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of the IPCC (ISBN 978 0521 88009-1 Hardback; 978 0521 70596-7 Paperback)

Kangalawe, Richard Y. M., et James G. Lyimo. (2013). «Climate Change, Adaptive

Strategies and Rural Livelihoods in Semiarid Tanzania.» 4 (http://www.scirp.org/journal/nr): , 266-278.

Marigi, Samwel N. (2017). «Climate Change Vulnerability and Impacts Analysis in Kenya.» American Journal of Climate Change 6: 52-74.

Mbaye, M. and M. Niang (2013). Evolution des exportations de bétail malien au Sénégal suite aux récentes crises. Projet de Mobilisation des Initiatives en matière de Sécurité Alimentaire au Mali – Phase II (PROMISAM II), APCAM/MSU/USAID 43 pages.

MEPA and CEP (2015). Recueil de statistiques d'élevage. C. d. E. e. d. l. P. C. Ministère de l'Elevage et des Productions Animales (MEPA). www.countrystat.org / www.sigel.gouv.sn/fronts: 07 pages.

DIREL (2015). Rapport annuel d'activités 2013. Ministère de l'élevage, Ministère de l'élevage et des productions animales: 68 pages.

Sandford, Stephen (1983). Management of pastoral development in the Third Word Londre.

Sanou, C.L, Daniel N. Tsado, André Kiema, Julia O. Eichie, et Appollonia A. Okhimamhe. (2018). «Climate Variability Adaptation Strategies: Challenges to Livestock Mobility in South-Eastern Burkina Faso.» Open Access Library Journal 5, e4372 (Open Access Library Journal).

Wade, C. T., et al. (2015). Gestion des risques climatiques Recherche pour des futurs résilients au climat. P. l. R. d. E. e. Z. Semi-Arides. PRESA, Innovation Environnement Développement (IED).

Wane Abdourahmane (2010). « Commercialisation des produits d'élevage : Cas du Ferlo (Sahel sénégalais) » Rapport de projet, CIRAD-PPZS.

Effect of Global Climate Change on Poverty and Inequality in Sub-Saharan Africa

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ABSTRACT

This research assessed how climate change impacted on poverty and inequality in Sub-Saharan Africa. To this end, parametric and semi-parametric models of a triangular system of the partially linear functional coefficient model were applied to panel data from 20 Sub-Saharan African countries covering the period from 2000 to 2016. The Generalised Joint Regression Modeling (GJRM) procedure was used to estimate this model. The results of the estimation showed that temperature has a negative and significant nonlinear effect on inequality and positive on poverty by taking the form of inverted "N" when temperatures are between 18°C and 25°C while 'it follows the shape of an' N 'between 25°C and 30°C. In addition, the results showed a positive and significant non-linear relationship between climate change, poverty and inequality in SSA. Therefore, it is recommended that climate change be mainstreamed into economic programmes and policies to reduce poverty and inequality in Sub-Saharan Africa.

Key words: Poverty, Inequality, Climate change, Sub-Saharan Africa

RÉSUMÉ

Cette recherche a évalué l'impact du changement climatique sur la pauvreté et les inégalités en Afrique subsaharienne. À cette fin, des modèles paramétriques et semi-paramétriques d'un système triangulaire du modèle de coefficient fonctionnel partiellement linéaire ont été appliqués aux données de panel de 20 pays d'Afrique subsaharienne couvrant la période de 2000 à 2016. La procédure de modélisation de la régression conjointe généralisée (GJRM) a été utilisée pour estimer ce modèle. Les résultats de l'estimation ont montré que la température a un effet non linéaire négatif et significatif sur l'inégalité et positif sur la pauvreté en prenant la forme d'un « N « inversé lorsque les températures sont comprises entre 18°C et 25°C alors qu'elle suit la forme d'un « N « entre 25°C et 30°C. En outre, les résultats ont montré une relation non linéaire positive et significative entre le changement climatique, la pauvreté et l'inégalité en ASS. Par conséquent, il est recommandé d'intégrer le changement climatique dans les programmes et politiques économiques afin de réduire la pauvreté et les inégalités en Afrique subsaharienne.

Mots clés : Pauvreté, Inégalité, Changement climatique, Afrique sub-saharienne

INTRODUCTION

Climate change is a global and cross-cutting issue that disproportionately affects the world's most vulnerable communities and countries (Mendelsohn, et al., 2006). Poor households are more vulnerable to natural shocks and may also experience greater poverty and inequality than those who are less affected (Fothergill and Peek 2004; Krueger et al., 2010). This is largely due to the fact that these households are more dependent on the natural environment and small-scale agriculture for their subsistence (Bowen, et al., 2012). The causes of increased inequality are sometimes harder to pin down and sometimes they lead to skepticism about our ability to make accurate comparisons of living standards between very different countries such as poor countries in Africa and rich countries (Deaton 2010). Indeed, the poor communities who live mostly in Sub-Saharan Africa (SSA) and engage in subsistence farming are hit hard by climate change, which has a dangerous impact on agricultural crops and access to food. In doing so, food accessibility remains conditional on the income of agriculture, which, because of climate precariousness and declining yields, is leading to a rise in food prices while widening the gap in inequality. This increase in economic inequality has a strong impact on health and economic growth, the very serious consequences of which today lead some economic agents to migrate to wealthier economic centers or to join terrorist organizations.

However, Berthe and Elie, (2015) raised questions about the role of inequality in worsening climate change. The impact of climate change on agriculture is expected to be more pronounced on the African continent if nothing is done to reduce greenhouse gas (GHG) emissions and define appropriate adaptation strategies (IPCC 2014; Rosenzweig 1994, Egbendewe et al., 2017). A previous study (Rosenzweig, 1994) showed that countries in the northern hemisphere will only be marginally affected by climate change in terms of their ability to produce food from agriculture. At the same time, those in the southern hemisphere, especially those in the tropics, will be affected by climate change on food production from agriculture. While there is evidence that southern countries will be more affected by climate change in terms of weakening their ability to produce food from agriculture (Egbendewe, et al., 2017). Faced with this situation, the risks associated with climate change will lead to increased inequality and poverty and put poor households in Sub-Saharan African countries in a sort of trap of poverty that can annihilate all development efforts.

Fosu (2015) is of the opinion that this assertion is technically correct, even if, it does not reflect the heterogeneity of trends in the poverty rate over time. It appears that Sub-Saharan Africa's performance on poverty since 1981 has not been uniform. While the incidence rate of poverty at the level of $ 1.25 increased by approximately 6.6 percentage points between 1981 and 1996, it decreased by 6.0 percentage points between 1996 and 2005 and by , 6 percentage points between 2005 and 2010. According to a UNDP (2017) report, although SSA showed a 3.4 percentage point decrease in the Gini unweighted coefficient between 1991 and 2011, remains one of the regions with the highest levels of global inequality. Inequality and poverty are important factors in social exclusion, whereas conflict, social unrest and instability are the causes, and most countries with a poverty rate of over 60% also experience serious or severe conflict situations. (UNDP, 2017).

However, according to AFDB (2018), the shortage in job growth has slowed down the reduction of poverty. Although the proportion of poor people in Africa dropped from 56% in 1990 to 43% in 2012, the numerical incidence of poverty has increased. Inequality has also increased, with the Gini coefficient increasing from 0.52 in 1993 to 0.56 in 2008. The negative effects of climate change have led to interventions aimed at enhancing resilience in drought-prone regions. Youth unemployment requires immediate attention: more than 70% of the population is under 30 years of age. Although in 2013, unemployment was low among 15- to 29-year-old (6.8%), it was higher among urban youth (23.3%) than in the global urban population (AFDB, 2018). Previously an author like (Thorbecke, 2013) thinks that there has been no progress in SSA where half of the population remained below the poverty line in 2005, unlike in other parts of the world.

The objective of this research is to assess how climate change can impact on poverty and inequality in SSA Specifically, our objectives specifically include (1) identifying climatic factors that impact on poverty and (2) those that have an impact on the inequality of the countries of SSA. Because the perception of poverty in SSA has not changed much since the 1980s known as structural adjustment and the people of SSA believe that living conditions continue to deteriorate despite all the efforts of policy against poverty and sustainable development. In our opinion, how can we assess the link between the impact of climate change and poverty and inequality in SSA? And climate change is nowadays the first concern of the IPCC (2017), which has agreed to present a special report for 2018 on the consequences of a global warming of 1.5°C compared to pre-industrial levels and related evolutionary profiles. Global emissions of greenhouse gases, in the context of strengthening the global response to climate change, sustainable development and poverty reduction (IPCC, 2017). This article is intended as an analytical contribution in trying to provide an assessment of the links between climate change and agricultural production on the one hand and on the other hand trying to control the sensitivity of climate change, inequalities and poverty in SSA. To answer these research questions, a rural household model was developed for the countries of SSA. Our research is organized as follows: in Section 2, we give an overview of the literature on the determinants of civil war. In Section 3, we describe in detail the methodological approaches used in the study to answer the above research questions and in Section 4 we discuss the estimation strategy. Section 5 contains empirical results and further analysis of econometric identification and Section 6 presents a conclusion.

The world is now confronted with several problems that undermine the development of populations, but two major aspects have important consequences on the well-being of economic agents. These are climate change and economic inequality. Both of these have a very disproportionate impact on poor communities in the world and particularly in the countries of SSA. To fight both of these aspects, it is imperative to involve the reduction of vulnerabilities and inequalities related to poverty. It may then be surprising that a substantial literature examines whether these two objectives are compatible (Berthe and Elie, 2015; Grunewald, et al. 2017; Isaksen, 2017 and Wiedenhofer et al., 2017). This review is based on two streams of research analysis on inequality, poverty and climate change. On the one hand we make a research that evaluates the influence of income inequality on environmental pollution by examining the existence of the Kuznet environmental curve, including Torras and Boyce (1998); Shao et al. (2011), and Golley (2012), on the other hand the research that examines the relationship between income inequality and environmental quality based on the refutation of

Kuznet's theory of the environmental curve (Torras and Boyce, 1998 and Boyce 2010). According to Grunewald, et al. (2017) for low- and middle-income economies, higher income inequality is associated with lower carbon emissions, while in middle- and high-income countries; income inequality increases per capita emissions.

The first contribution on the links between climate and poverty, mainly influenced by the research of Udry (1995), and refers to the potential impact of exogenous factors (i.e. climate variability) on vulnerability to poverty. However, the vast literature has not yet assessed the effect of climate on the probability of a household becoming or remaining poor in the foreseeable future, and it is therefore expected that negative impacts on food security will occur. in areas highly dependent on local food production and with fewer opportunities for internal and external insurance (Herrera, et al., 2018). Another approach used to study the impacts of climate variability is to focus on the effect of climate variability on the main rural assets, mainly through land prices and such an analysis is based on the economic rationality according to which farmers maximize their profits, land prices are directly correlated to the (future) income capacity of the land (Mendelsohn, et al., 2006; Masters and McMillan 2001; Herrera, et al., 2018). Thus, climate change can have a very negative impact on incomes, sown areas and household assets. Another approach, which is often used to analyze the link between climate change and poverty, chooses a measure of well-being and examines the impact of climate change directly on household incomes (Herrera, et al., 2018). To this end, Tol (2009) uses a comparative welfare model to show the effects of climate change on income poverty in the different regions affected, and finds that the most important effects are recorded in areas where poverty is high. Since the IPCC (2017), the comprehension on the relationship between climate change, poverty and vulnerability has increased significantly. There is no doubt that the most vulnerable people are already, and will continue to be, the most concerned by climate change, including changing trends and more frequent and extreme events (Tschakert, 2016).

Torras and Boyce, (1998) research has focused on environmental policies and adopted water quality indicators and has empirically proven that income inequality would lead to environmental degradation. They used sulfur dioxide models, smoke and dust as environmental quality indicators, and found that increasing income gaps and environmental quality degradation coexist in low-income countries, opening the way for research on income inequality (Hao, et al, 2016). In similar studies, (Grossman &Krueger 1991; Shafik & Bandyopadhyay, 1992 and Selden & Song, 1994) also found that income inequality would lead to a shift in environmental policies, and that rich communities, who often had more political power, only considered economic costs and benefits, while the terrible environmental cost was mostly borne by poor communities, and such environmental policies would exacerbate pollution (Hao, et al, 2016). Authors like Ravallion et al. (2000) also tried to study the relationship between income inequality and environmental quality by constructing a demand function for individual and income-based carbon emissions. They pose the problem of the supply and demand for environmental goods. For example, Martinez-Alier (1995) has analyzed the influence of income inequality on the quality of the environment from the point of view of supply and demand, and argues that "vulnerable communities sell cheap products. Which means they are more likely to underestimate the value of environmental goods compared to other goods due to the lack of environmental goods in all markets.

To deepen the empirical relationship between the income gap and environmental quality in China, authors such as Hao et al. (2016) used panel data for 23 provinces from 1995 to 2012, taking carbon emissions as the indirect indicator of environmental pollution, and performed GMM regression. They concluded that the rise in per capita CO_2 emissions is widening the income gap in 25 provinces of China. Thus, the results of the GMM regression indicate that the influence of regional income inequality on CO_2 emissions is more important in the East. Per capita CO_2 emissions would increase dramatically with income expansion, while growth would be relatively slow in non-eastern regions (Hao, et al., 2016). Finally, they concluded that the relationship between real GDP per capita and CO_2 emissions per capita is likely to be a "U" shaped curve. However, they believe that a relatively high population density would reduce per capita CO_2 emissions, but the effect is not significant. The research of Bimonte (2002) used cross-sectional data from 35 European countries as samples, reflecting the distribution of income by Gini coefficient, and measured the condition of environmental protection. The results revealed a negative correlation between income inequality and environmental protection. He added that the more equitable income distribution tilts the CEK to the left, i.e. in an environment where the distribution of income is relatively equal; the CEK inflection point will be reached at a lower level. The research of Shao et al. (2011) also verified that the inverted N-shaped relationship between energy-related industrial CO_2 emissions and GDP per capita in Shanghai City, China.

Another major category of empirical studies has examined the relationship between income inequality and environmental quality based on the refutation of EKC theory. With the increase in the availability of data quality in a group of specific regression equations. However, this relationship was not statistically significant in the other regression equations. Gawande et al. (2001) empirically analyzed the relationship between US household income and toxic waste disposal sites. Research has indicated that under the EKC relationship, wealthy families would live far from sources of pollution. People who became rich were more likely to leave polluted areas than to influence public policies to reduce pollutant emissions. To a certain extent, this confirmed Boyce's (1994) argument that income inequality would affect people's temporal preference for the use of the environment. Studies by Torras & Boyce, (1998) and Boyce (2010) have shown that the environmental demands of the population must be combined with its purchasing power and purchasing penchant. In this case, purchasing power referred to a realistic restriction of environmental concerns, and the inclination to purchase referred to the subjective restraint of environmental concerns. L'inégalité des revenus différenciait le pouvoir d'achat des personnes de différents groupes de revenus.As the income gap widened, low-income groups were more likely to overexploit natural resources to generate income, which would intensify environmental destruction; whereas high-income groups were inclined to settle in areas where the environmental risks were lower and their wish to pay for the management of the environment was low. As a result, with the widening income gap, the consent to pay for the environment was low for low-income and high-income groups, exacerbating environmental pollution. All of this evidence confirmed that EKC did not exist. However, according to Hao, et al, (2016), very few studies have investigated the relationship between income inequality and the quality of the environment in China, and they believe that many studies use panel data, but only few studies focused on China to empirically examine the relationship between the income gap and environmental performance.

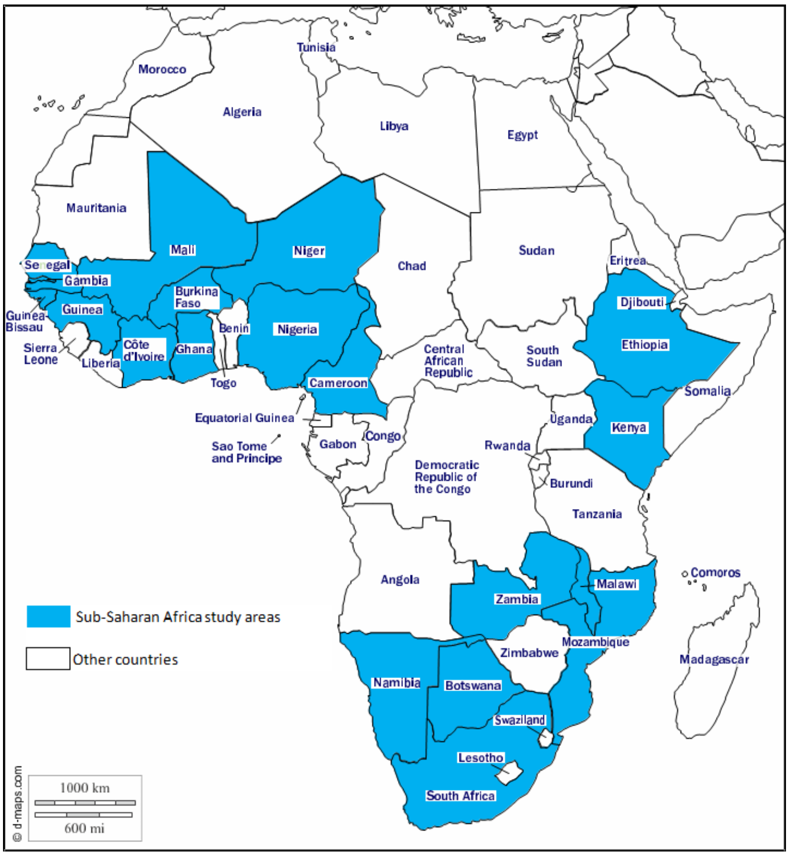
METHODS

Scope and analytical framework

The scope of the study covers the sub-Saharan area (SSA). The countries include: South Africa, Botswana, Burkina Faso, Cameroon, Ivory Coast, Ethiopia, Gambia, Ghana, Guinea-Bissau, Guinea, Kenya, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Senegal, Togo, Zambia.

Empirical data were obtained on the types of interactions between levels of poverty $(Y_{it})(Y_{it})$and inequality$(X_{it})(X_{it})$and the effect of climate change captured by the vector $(Z_{it})(Z_{it})$ on these interactions. As a result, a very general semi-parametric simultaneous system model is proposed using endogenous explanatory variables (Newey et al., 1999, Blundell and Powell 2003, Ai and Chen 2003, Su and Ullah, 2008; Martins-Filho and Yao, 2012).The problem of endogeneity of regressors is widely encountered in empirical models in economics, mainly due to measurement error or simultaneity that results from individual choices or market equilibrium (Geng, Martins-Filho and Yao 2015). Thus, the development of estimation procedures that take into account the endogeneity of regressors has permeated much of modern econometrics research. Doing it in the context of fully parametric models can be misleading because of the high probability of poor model specification that can lead to inconsistent estimators and erroneous inference. Therefore, a useful trade-off is to consider partially linear models that take advantage of any known parametric functional form information while retaining the flexibility of non-parametric structures for the other components of the regression (Robinson, 1988, Hardle et al. 2000).

Figure 1: Map of the study area.



Source : author’s construction from www.d-maps.com

The specification and estimation of non-parametric and semi-parametric regression models using "endogenous" regressors has received considerable attention in econometrics (Newey et al., 1999, Blundell and Powell, 2003; Ai and Chen, 2003; Su and Ullah; 2008 and Martins-Filho and Yao, 2012). We start with the basic model of Newey; and Ozabac, Henderson and Su (2014). They considered a triangular system of the following partially linear functional coefficient model :

$$Y_{it} = g(X_{it}, Z_{it}) + \theta_{it}' V_{it} + \varepsilon_{it} \tag{1}$$

$$X_{it} = m(Z_{1,it}, Z_{2,it}) + \Psi_{it} V_{it} + U_{it} \tag{2}$$

$$E(U_{it} | Z_{1,it}, Z_{2,it}, V_{it}) = 0 \tag{3}$$

$$E(\varepsilon_{it} | Z_{1,it}, Z_{2,it}, U_{it}, V_{it}) = E(\varepsilon_{it} | U_{it}); \qquad E(\varepsilon_{it}) = 0$$

$$E(\varepsilon_{it} | Z_{1,it}, Z_{2,it}, U_{it}, V_{it}) = E(\varepsilon_{it} | U_{it}); \qquad E(\varepsilon_{it}) = 0 \tag{4}$$

When $X_{it} = (X_{1,it}, \dots, X_{dx,it}) X_{it} = (X_{1,it}, \dots, X_{dx,it})$ is avector $dx \times 1 dx \times 1$ of endogenous regressors, $Z_{1,it} = (Z_{1,it}, \dots, Z_{d1,it}) Z_{1,it} = (Z_{1,it}, \dots, Z_{d1,it})$ is a vector $d1 \times 1\, d1 \times 1$ of exogenous regressors "included", $Z_{2,it} \equiv (Z_{2,it}, \dots, Z_{d2,it})$ $Z_{2,it} \equiv (Z_{2,it}, \dots, Z_{d2,it})$ is a vectror $d2 \times 1\, d2 \times 1$ Exogenous explanatory variables "excluded", g(-, -) indicates the structural function of really unknown interest, $m_{it} \equiv (m_{1,it}, \dots, m_{dx,it}) m_{it} \equiv (m_{1,it}, \dots, m_{dx,it})$ is a vector $dx \times 1 dx \times 1$ smooth functions of the instruments $Z_{1,it} Z_{1,it}$, $Z_{2,it}; Z_{2,it};$ et $\varepsilon_{it} \equiv (\varepsilon_{1,it}, \dots, \varepsilon_{dx,it})$ $\varepsilon_{it} \equiv (\varepsilon_{1,it}, \dots, \varepsilon_{dx,it})$ and$U_{it} \equiv (U_{1,it}, \dots, U_{dx,it}) U_{it} \equiv (U_{1,it}, \dots, U_{dx,it})$ are error terms . $V_{it} V_{it}$, is a vector $k \times 1 k \times 1$ ofexogenous variables, $\theta_{it}$is a parameter vector$k \times 1$ $\theta_{it}$is a parameter vector$k \times 1$ and $\Psi_{it} = (\psi_{1,it}', \dots, \psi_{dx,it}') \Psi_{it} = (\psi_{1,it}', \dots, \psi_{dx,it}')$ is a matrix $dx \times k dx \times k$ of parameters in the reduced form regression for X. To avoid the problem of dimensionality, we will suppose that $m(Z_{1,it}, Z_{2,it}) m(Z_{1,it}, Z_{2,it})$, $g(X_{it}, Z_{1,it})$ $g(X_{it}, Z_{1,it})$ and $E(\varepsilon_{it} | U_{it}) E(\varepsilon_{it} | U_{it})$ have additive forms. Newey, Powell and Vella (1999) are interested in a coherent estimation of $g(X_{it}, Z_{1,it}) g(X_{it}, Z_{1,it})$. Andhave shown that $g(X_{it}, Z_{1,it}) g(X_{it}, Z_{1,it})$ can be identified up to an additive constant under the key identification conditions that $E(U_{it} | Z_{1,it}, Z_{2,it}, V_{it}) = 0 E(U_{it} | Z_{1,it}, Z_{2,it}, V_{it}) = 0$ and $E(\varepsilon_{it} | Z_{1,it}, Z_{2,it}, U_{it}, V_{it}) = E(\varepsilon_{it} | U_{it}) E(\varepsilon_{it} | Z_{1,it}, Z_{2,it}, U_{it}, V_{it}) = E(\varepsilon_{it} | U_{it})$. If these conditions are met. Ozabac. Henderson and Su (2014) notice that the results

$$E(Y_{it} |\ X_{it}, Z_{1,it}, Z_{2,it}, U_{it}, V_{it}) = g(X_{it}, Z_{it}) = E(\varepsilon_{it} | U_{it}) + \theta' V_{it} = g(X_{it}, Z_{it}, U_{it}) = \theta' V_{it} \tag{6}$$

$$E(X_{it} |\ Z_{1,it}, Z_{2,it}, V_{it}) = m(Z_{1,it}, Z_{2,it}) + \Psi_{it} V_{it} \tag{7}$$

Given a random sample $\{(Y_{it}, X_{it}, Z_{1,it}, Z_{2,it}, U_{it}, V_{it}), i = 1, \dots, nett = 1, \dots, T\}$ $\{(Y_{it}, X_{it}, Z_{1,it}, Z_{2,it}, U_{it}, V_{it}), i = 1, \dots, nett = 1, \dots, T\}$, we can continue to use the Generalised Joint Regression Modeling (GJRM) procedure to estimate the model above. Indeed, the GJRM offers functions to adapt general models of joints in various situations. The estimation approach is based on a very generic framework based on penalized maximum likelihood, where any (parametric) distribution can in principle be used, and the smoothers (representing several types of covariate effects) are implemented using penalized regression curves (Marra and Radice, 2018).

Empirical specification

In this research, it is estimated that the vector of current and future climate variables ($Z_{it}Z_{it}$) have direct effects on agricultural value added through effects on yields, prices and other sources of income (Sesmero, Ricker-Gilbert and Cook 2017). Previous work has shown that households that tend to be more dependent on cereal production may, in a context of adverse climatic conditions, fall into a climate-induced poverty trap (Dercon and Christiaensen 2011). To estimate the empirical models, we used two models based on two (2) poverty lines of $ 3.10 and $ 1.90. Thus, starting from

$$pov310_{it} = vmi_{it} + vmz_{it} + vsg_{it} + pmi_{it} + pmz_{it} + psg_{it} + dal_{it} + fpc_{it}$$

$$gini_{it} = vmi_{it} + vmz_{it} + vsg_{it} + pmi_{it} + pmz_{it} + psg_{it} + dal_{it} + fpc_{it} + mpm_{it} + gdp_{it} + edp_{it} + sal\_5_{it} + brq_{it} + cor_{it} + gsb_{it} + s(ztp)_{it}$$

$$pov190_{it} = vmi_{it} + vmz_{it} + vsg_{it} + pmi_{it} + pmz_{it} + psg_{it} + dal_{it} + fpc_{it}$$

$$gini_{it} = vmi_{it} + vmz_{it} + vsg_{it} + pmi_{it} + pmz_{it} + psg_{it} + dal_{it} + fpc_{it} + mpm_{it} + gdp_{it} + edp_{it} + sal\_5_{it} + brq_{it} + cor_{it} + gsb_{it} + s(ztp)_{it} + s(zpl)_{it} \qquad (9b)$$

Sources of data

As part of this research, the empirical model is estimated using a semi-parametric model of simultaneous equations. It is based on panel-based data on Sub-Saharan African countries through vectors of climatic and non-climate variables and on several indicators of poverty and inequality. The panel data used in this research covers the period 2000-2016 for 20 Sub-Saharan African countries. The data sources and descriptive statistics for the variables are presented in the table (attached). The sources for the Gini Index data were collected from the World Fact book (https://www.cia.gov/library/publications/the-world-factbook).Regarding climate variables such as temperatures (in degrees Celsius) and Precipitation (in mm/m^3) were collected at the World Bank Climate Change Knowledge Portal (http://sdwebx.Worldbank.org/climateportal).These variables are important for understanding the impacts of climate change on poverty and inequality. They matter because, compared to case studies and comparative analyzes of the poor in poor countries, the literature on climate change and debates about the poor in developed countries and their experiences with a changing climate have been surprisingly dumb. Poverty and inequality in SSA have been poorly documented and represented in international poverty indicators and in-depth climate change surveys. We also used other variables including, among others, prices, agricultural value added, etc., from the basis of FAOSTAT 2018 (http://www.fao.org/faostat/en/#home). Descriptive statistics are listed in Table1.

Table 1: Overall description of model variables

Variable	Designation	Obs	Mean	Std.Dev.	Min	Max
gdp_{it}	Current GDP per capita (in US $)	340	1597,87	1916,57	111,36	8229,73
$pov310_{it}$	poverty line at US $ 3.10 / pers / day (%)	340	69,36	15,24	34,68	92,04
$pov190_{it}$	poverty line at US $ 1.90 / pers / day (%)	340	45,15	16,97	16,56	80,36
$gini_{it}$	Gini inequality index	340	8,99	2,39	2,90	13,00

dal_{it}	food availability (Kcal / pers / day Average / 3 years)	340	147,65	93,06	24,00	453,00
fpc_{it}	total fertility rate (births / woman)	340	5,16	1,15	2,49	7,68
mpm_{it}	mortality rate (per 1000 inhabitants)	340	11,66	2,76	5,84	18,29
edp_{it}	number of puplis enrolled in elementary school	340	3876,00	5173,23	0,24	26167,50
sal_5_{it}	Prevalence of malnutrition (% of children <5 years old)	340	20,73	11,52	3,60	53,60
vmi_{it}	Value added of millet (in millions of US dollars)	340	93,55	202,83	0,00	1386,95
vmz_{it}	Value added of corn (in millions of US $)	340	198,64	276,90	0,09	1299,95
vsg_{it}	Value added of sorghum (in millions of US $)	340	109,62	229,41	0,57	1203,31
pmi_{it}	100-based index of millet price (in US $)	340	380,75	260,19	64,30	1158,33
pmz_{it}	100-based index of corn price (in US $)	340	296,86	221,30	52,50	1405,90
psg_{it}	100- based index of sorghum price (in US $)	340	334,05	253,62	52,50	2103,10
zpl_{it}	average annual precipitation (in mm / m3)	340	76,86	37,97	12,00	179,30
ztp_{it}	average annual temperature (in ° C)	340	25,49	2,99	17,61	29,75
brq_{it}	Government inefficiency (from 0 = low to 4 = high)	340	1,33	0,74	0,00	2,50
cor_{it}	control of corruption (from 0 = low to 6 = high)	340	2,12	0,63	0,50	4,00
gsb_{it}	government instability (from 0 = low to 12 = high)	340	8,28	1,52	4,46	11,58

Source : Author's construction from 2000-2016 SSA data

RESULTS AND DISCUSSION

The econometric results are presented to gradually achieve the objectives of the research starting with the results of the parametric models to finish with the results of semi-parametric models. The estimated parametric models are derived from equations (8a, 9a) and (8b, 9b) for the $ 3.10 and $ 1.90 thresholds for both inequality and poverty interactions. The estimated nonparametric models were derived from said equation.

Parametric analysis of the relation between poverty and inequality

The estimated parametric model is that of a structural semi-parametric equation model of partially linear functional coefficient (equations 8a, 9a and 8b, 9b).The estimate was made using the GJRM function (Marra and Radice, 2018).The analysis of the results of the estimation of parametric models at the poverty line of $ 1.90 and $ 3.10 are listed in Tables 2 and 3.The results show that the effects of cereals (millet, corn and sorghum) vary according to poverty lines in both equations (poverty and inequality).As a result, when the poverty line is $ 1.90, only the agricultural value added of sorghum has a significant negative effect on both poverty and inequality, but the effects of maize and sorghum remain only negative and significant in regard to poverty on inequality when the threshold is $ 3.10.As for the agricultural value of millet, it positively and significantly affects poverty if the poverty line remains at $ 1.90 and as soon as this threshold reaches $ 3.10, its effect is no longer significant. The results in relation to the price effect of millet remained positive and significant on inequalities at the $ 1.90 and $ 3.10 levels, as well as on poverty when the threshold was set at $ 3.10. However, the price effect of maize is rather positive and significant for poverty and it is negative for inequality regardless of the poverty line set. Authors such as Harttgen, et al., (2015) found that rising maize and / or staple food prices increase food poverty, particularly among poor and urban populations who cannot change their mode of food consumption in favor of other food products (generally more expensive). These results on the correlation between poverty and inequality have been associated with changes in the socio-economic variables that have been the subject of several studies, such as those of Beteille, (2003), who state that poverty and inequality do not evolve at the same pace, and they can even evolve in opposite directions. Indeed, a decrease (increase) in poverty is not always accompanied by a decrease (increase) of inequality, it can actually be accompanied by an overall increase (decrease) of inequality (see Table 2).

On the other hand, the magnitude of food availability has an inverse effect on the level of poverty while it significantly and positively affects inequality at both $ 1.90 and $ 3.10 level (see Table 3).Indeed, when the scale of food availability increases by 1%, it negatively affects the level of poverty by -0.10% but leads to an increase of about + 0.03% of inequalities in SSA.As a result, the prevalence of under-five malnutrition positively affects poverty with a very high significance at the $ 3.10 level. In terms of inequality, the effects remain negative at both the $ 3.10 and $ 1.90 thresholds. At the socio-economic level, the results highlight the relationship, negative (positive) and significant, between the domestic product per individual and the level of poverty (inequality). In doing so, it is understood that the decline in per capita income is one of the economic causes that exacerbates poverty and at the same time its rise causes an increase in inequalities in SSA. It is often assumed that people in developed countries enjoy universal food security, the main conditions being economic prosperity and the ability to produce abundant food (Richards, et al., 2016), thus economic inequalities increase worldwide, including in economically developed countries (Jaumotte et al., 2013). It has been argued that increasing social inequality, especially poverty, leads to food insecurity and that food security is primarily a question of unequal distribution of resources (Carolan, 2013; Sen, 1981).

Table 2: Results of parametric model estimation at the $ 3.10 poverty line

Variables	pov310		Gini310		Pov310		Gini310	
	coef(1)	prob(1)	coef(1)	prob(1)	coef(2)	prob(2)	coef(2)	prob(2)
Constant	-17,240	0,118	13,730	0,000	-11,340	0,148	13,770	0,000
vmi_{it}	0,006	0,298	0,000	0,390	0,006	0,233	0,000	0,470

vmz_{it}	-0,006	0,171	0,000	0,646	-0,007	0,014		
vsg_{it}	0,003	0,771	-0,004	0,000			-0,004	0,000
pmi_{it}	0,008	0,140	0,001	0,000	0,009	0,028	0,001	0,000
pmz_{it}	0,015	0,014	-0,001	0,046	0,013	0,018	-0,001	0,025
psg_{it}	-0,009	0,003	0,000	0,637	-0,009	0,003	0,000	0,572
dal_{it}	-0,141	0,072	0,027	0,000	-0,102	0,069	0,027	0,000
sal_5_{it}	1,443	0,032	-0,248	0,000	1,105	0,022	-0,243	0,000
fpc_{it}	11,570	0,000	-0,470	0,000	11,120	0,000	-0,456	0,000
mpm_{it}	0,387	0,468	-0,053	0,000			-0,054	0,000
gdp_{it}	-0,001	0,009	0,000	0,003	-0,001	0,005	0,000	0,001
edp_{it}	0,000	0,810	0,000	0,000			0,000	0,000
brq_{it}	-2,910	0,023	0,666	0,000	-2,244	0,014	0,670	0,000
cor_{it}	6,054	0,000	0,027	0,746	6,108	0,000		
gsb_{it}	-1,114	0,012	0,120	0,000	-1,000	0,021	0,127	0,000
n	340		340		340		340	
σ	53.3 (46.1,61.2)	0.372 (0.317,0.429)	53.6 (45.7,62.8)	0.372 (0.326,0.439)				
τ		-0.0069 (-0.183,0.183)		0.0464 (-0.0465,0.147)				
θ		-0.0108 (-0.283,0.283)		0.0728(-0.073,0.229)				
Total edf		70.3				65.7		

Source: Author's construction from 2000-2016 SSA data.

The results of the parametric estimate, at the thresholds of $ 1.90 and $ 3.10, show that the total fertility rate has a very significant positive effect on the increase in poverty respectively for both 13.82 % and 11, 12% thresholds. On the other hand, total fertility and mortality rates have a negative inverse effect on inequalities. Indeed, the research of Flegg (1982); Rodgers, (1979) and Waldmann, (1992) have shown that countries with high inequalities have higher infant mortality rates than countries where the national product per capita is similar but the income distribution is more equal. However, another very significant negative effect at the parametric model level is captured by one of the very important institutional variables that is the control of corruption on poverty at the thresholds of $ 1.90 and $ 3.10.In other words, the lack of control over corruption is a factor that aggravates poverty and increases inequalities by about 6.10% and 0.67% respectively. However, variables such as the stability of government and the efficiency of bureaucracy contribute negatively and significantly to the increase of poverty respectively to -2.24% and -1.00% in SSA. At the same time, the results of the inequality equation show an effect of the stability of the government is positive and significant of + 0.02% against a significant negative effect of the efficiency of the bureaucracy of -0.24%. Indeed, the research of Gupta, et al., (2002) provided evidence that high and rising corruption increases income inequality and poverty, and came to an important conclusion that good control of corruption will most likely also reduce income inequality and poverty.

Table 3: Results of parametric model estimation at the $ 1.90 poverty line

Variables	pov190		Gini190		Pov190		Gini190	
	coef(1)	prob(1)	coef(1)	prob(1)	coef(2)	prob(2)	coef(2)	prob(2)
Constant	-42,300	0,000	13,730	0,000	-42,790	0,000	13,820	0,000
vmi_{it}	0,026	0,000	0,000	0,418	0,027	0,000		
vmz_{it}	-0,004	0,425	0,000	0,672				
vsg_{it}	-0,026	0,016	-0,004	0,000	-0,029	0,000	-0,004	0,000
pmi_{it}	0,006	0,324	0,001	0,000			0,001	0,000
pmz_{it}	0,016	0,019	-0,001	0,045	0,018	0,000	-0,001	0,036
psg_{it}	-0,003	0,352	0,000	0,621				
dal_{it}	-0,060	0,488	0,027	0,000	-0,077	0,240	0,027	0,000
sal_5_{it}	14,120	0,000	-0,470	0,000	0,768	0,179	-0,248	0,000
fpc_{it}	-0,283	0,619	-0,053	0,000	13,820	0,000	-0,451	0,000
mpm_{it}	-0,002	0,008	0,000	0,003			-0,054	0,000
gdp_{it}	0,000	0,117	0,000	0,000	-0,002	0,013	0,000	0,000
edp_{it}	0,636	0,394	-0,248	0,000	0,000	0,032	0,000	0,000
brq_{it}	-2,554	0,074	0,667	0,000	-2,978	0,005	0,671	0,000
cor_{it}	5,403	0,000	0,027	0,745	5,373	0,000		
gsb_{it}	-0,441	0,387	0,121	0,000	-0,533	0,287	0,127	0,000
n	340		340		340		340	
σ	76.6 (65.2,86.1)	0.372 (0.33,0.438)	76.5 (65.7,87.9)	0.373 (0.323,0.43)				
τ		0.102(-0.0693,0.251)		0.0834 (-0.0156,0.222)				
θ		0.16(-0.109,0.385)		0.131 (-0.0245,0.342)				
Total edf		68.1				60.5		

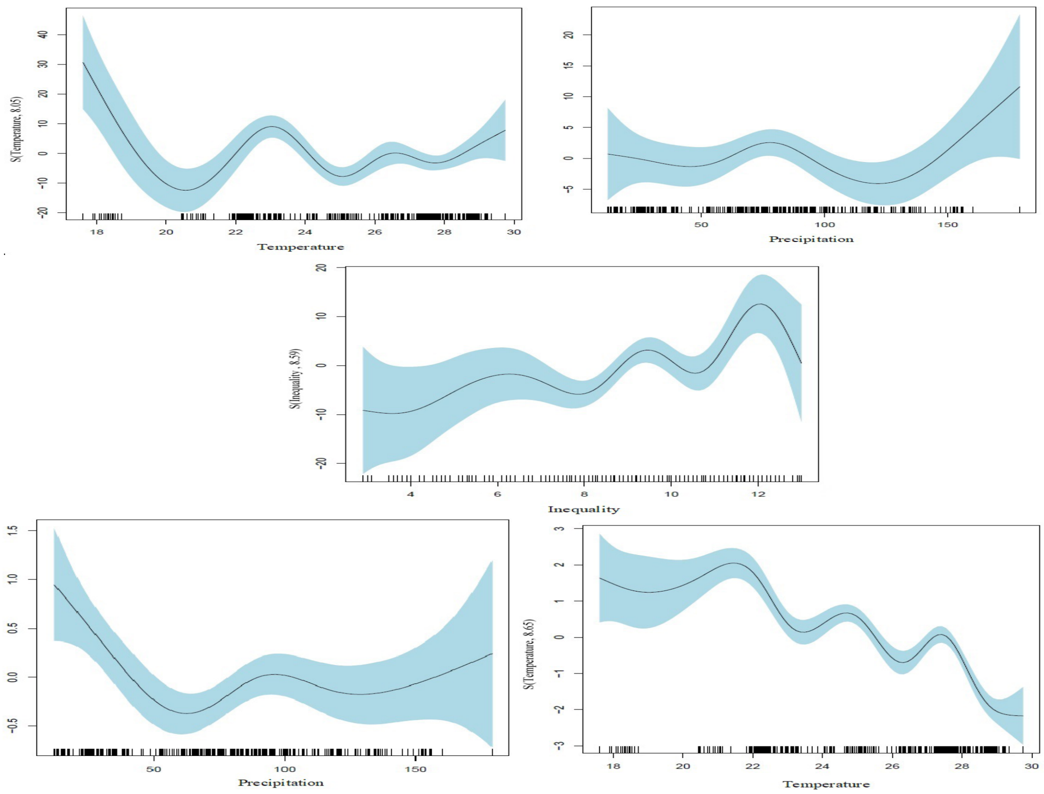
Source: Author's construction from 2000-2016 SSA data.

Semi-parametric analysis of the poverty-inequality relationship and climate change

The results of the semi-parametric analysis show that the relationship between climate variables (temperature and rainfall), poverty and inequalities in SSA is rather a complex relationship that is very often in the form of a non-linear relationship. To do this we have estimated a semi-parametric model in a triangular system of partially linear functional coefficient (equations 8a, 9a and 8b, 9b) and the estimated coefficients of the non-parametric model, on which our interest is mainly focused, reveal the relation nonlinear between inequalities, poverty and climate change through temperature and rainfall variables, with several thresholds (See Figure 2). The total degrees of freedom (edf) of the estimated bi-varied model are 70.3 and 65.7 for models (1) and (2) at the \$ 3.10 threshold. By modifying the threshold at \$ 190, the total edf are respectively 68.1 and 60.5 for both models (1 and 2). Indeed, Marra and Radice (2017) recall that when the edf is equal to 1, the respective estimated effect is linear, so that the covariate can enter the model parametrically, but when the edf is higher , the estimated curve is more complex. In addition, our estimates of the specific distribution parameters for the poverty and inequality equations are respectively $\sigma_{2.1}$ =$\sigma_{2.1}$ = 53.6(45.7≤ $\sigma_{2.1}$ ≤≤ $\sigma_{2.1}$ ≤62.8) et $\sigma_{2.2}$ =$\sigma_{2.2}$ =0.372(0.326≤ $\sigma_{2.2}$ ≤≤ $\sigma_{2.2}$ ≤0.439) for model (2) at the level of3,10\$et de $\sigma_{2.1}$ =$\sigma_{2.1}$ =0.0464(-0.0465≤ $\sigma_{2.1}$ ≤≤ $\sigma_{2.1}$ ≤0.147) et $\sigma_{2.2}$ =$\sigma_{2.2}$ =0.0728(-0.073≤ $\sigma_{2.2}$ ≤≤ $\sigma_{2.2}$ ≤0.229) at the level of1,90\$.The value of Kendall's τ is 76.5(65.7≤ τ ≤≤ τ ≤87.9) and0.373(0.323≤ τ ≤≤ τ ≤0.43)for the two respective thresholds and the results show positive and very significant degrees of dependence, between poverty and inequality, given by the parameter $\theta\theta$ that is $0.0834\ (-0.0156 \leq \theta \leq 0.222) 0.0834\ (-0.0156 \leq \theta \leq 0.222)$at the level of 310 \$ and$0.131(-0.0245 \leq \theta \leq 0.342) 0.131(-0.0245 \leq \theta \leq 0.342)$ at the level of1,90\$.

The results of temperature, rainfall, and the Gini inequality coefficient in the poverty and inequality equations show different degrees of non-linearity. Figure 1 shows the effects of temperature, rainfall, and inequality on poverty and inequality. The graphs show a nonlinear effect with maximum and minimum peaks and show that on average, poverty (at \$ 3.10 and \$ 190 thresholds) takes the form of inverted "N" when temperatures are between 18°C and 25°C while it follows the form of an "N" between 25°C and 30°C.At the same time, rainfall has more complex effects on poverty and inequality in that it tends to cyclically affect them. Regarding the endogenous effect of inequalities on poverty, the results show a positive and significant non-linear relationship between them. Indeed, the results show that the probability of remaining in poverty increases inequalities regardless of the thresholds of \$ 3.10 and \$ 1.90 in SSA.On the other hand, in terms of the inequality equation, the results highlight a negative and significant nonlinear effect of temperature on inequalities at both poverty lines of \$ 3.10 and \$ 1.90.In previous research, the results of Herrera, et al., (2018) also showed a negative impact of fluctuations in precipitation and temperature on household income and the level of poverty. Indeed, according to the argument of Heshmati, et al., (2015), despite the fact that an increase in rainfall is expected to increase agricultural value added the overall negative impact of rising temperatures is more than compensate for the limited positive impact due to increased rainfall.

Figure 2: Estimation of the smooth effects of temperature, precipitation, and inequality index on poverty and inequality with 95% confidence intervals



Source: Author's construction from 2000-2016 SSA data

CONCLUSION

This paper is an attempt to provide an answer to the following basic research question: how to assess the relationship between the impact of climate change on poverty and inequality in SSA?. Results at the parametric model have shown the negative effects of some agricultural value added (sorghum and maize) on poverty and inequality while millet has a positive effect on poverty. It also appears that cereal prices significantly increase levels of poverty and inequality. At the level of availability when the scale increases by 1%, then it affects poverty by -0.10% but leads to an increase of about + 0.03% of inequality in SSA. In addition, the results also showed that the total fertility rate has a very significant positive effect on the increase of poverty a negative inverse effect on inequalities. Finally, the control of corruption is a factor that aggravates poverty and increases inequalities by about 6.10% and 0.67% respectively, while the stability of the government and the efficiency of the bureaucracy reduce -2.24 % and -1.00% poverty in SSA.

The results of the nonparametric model showed that temperature has a negative and significant nonlinear effect on inequality and positive on poverty by taking the form of inverted "N" when temperatures are between 18°C and 25°C while it follows the shape of an "N" between 25°C and 30°C.Rainfall has also been shown to have more complex effects on poverty and inequality. Finally, results have shown a positive and significant nonlinear relationship between poverty and inequality in SSA. In order to fight poverty and inequality it is imperative that governments integrate the climate dimension into economic programs and policies to reduce poverty and inequality in SSA. Future research that assesses the relationships between parametric models and semi-parametric models using, for example, Monte Carlo simulations, may improve the results of such searches.

REFERENCES

AFDB, (2018). Perspectives Economiques en Afrique, s.l.: Banque africaine de dévelopement. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/African_Economic_Outlook_2018_-_FR.pdf.

Ai, C. & Chen, X., (2003). Efficient Estimation of Models With Conditional Moment Restrictions Containing Unknown Functions. Econometrica, Vol. 71, Issue 6, pages. 795-1843.

Berthe, A. & Elie, L., (2015) Mechanisms explaining the impact of economic inequality on environmental deterioration. Ecological Economics, p. 191–200.

Beteille, A.,(2003). Poverty and Inequality. Economic and Political Weekly, Vol. 38, Issue 4, pages. 4455-4463.

Bimonte, S. (2002). Information access, income distribution, and the Environmental Kuznets Curve. Ecological Economics, 41(1), 145-156.

Blundell, R. & Powell, J. L., (2003). Endogeneity in nonparametric and Ssemiparametric regression models. Cambridge: Econometric society monographs.publisher, Cambridge University Press.

Bowen, A., . Cochrane, S. & Fankhauser, S., (2012). Climate change, adaptation and economic growth. Climatic Change, Vol. 113, Issue 2, pages 95–106.

Boyce, J., (1994). Inequality as a cause of environmental degradation.. Ecologial Economics, Vol. 11, Issue 3, pages 69–178.

Boyce, J., (2010). Economic Inequality and Environmental Quality: Evidence of Pollution Shifting in Russia. PERI Working Papers, p. 189.

Carolan, M. S., (2013). Reclaiming Food Security. 1st Edition éd. London: Routledge. ISBN-13: 978-0415816960.

Deaton, A., (2010). Price Indexes, Inequality, and the Measurement of World Poverty. American Economic Review, Vol. 100, Issue 1, pages. 5-34.

Dercon, S. & Christiaensen, L., (2011). Consumption Risk, Technology Adoption and Poverty Traps: Evidence from Ethiopia. Journal of Development Economics, Vol. 96, Isssue 2, pages 159–173.

Egbendewe, et al., (2017). Can intra-regional food trade increase food availability in the context of global climatic change inWest Africa?. Climatic Change.Vol.145, Issue 1, pages 101-116.

Flegg, A., (1982). Inequality of Income, Illiteracy, and Medical Care as Determinants of Infant Mortality in Developing Countries. Population Studies, Vol. 36, Issue 3, pages 441-458.

Fosu, A. K., (2015). Growth, Inequality and Poverty in Sub-Saharan Africa: RecentProgress in a Global Context. Oxford Development Studies, Vol. 43, Issue 1, pages 44-50.

Fothergill, A. & Peek, L. A., (2004). Poverty and Disasters in the United States: A Review of Recent Sociological Findings. Natural Hazards, Vol. 32, Issues 1, pages 89–110.

Gawande, K., Robert, P. & Alok, K., (2001). A consumption-based theory of the environmental Kuznets curve. Ecological Economics, Vol. 37 1, pages 101-112.

Geng, X., Martins-Filho, C. & Yao, F., (2015). Estimation of a Partially Linear Regression in Triangular Systems, West Virginia University: Department of Economics. Economics Facultty Working Series, 12. Document Number 10-05. https://researchrepository.wvu.edu/econ_working-papers/12

Golley, J. & Meng, X., (2012). Income inequality and carbon dioxide emissions: The case of Chinese urban households. Energy Economics, Vol. 34, Issue 6, pages 1864–1872.

Grossman, G. & Krueger, A., (1991). Environmental Impacts of a North American Free Trade Agreement. NBER Working Paper No. 3914, page 57. National Bureau of Economic Research, Inc. https://ideas.repec.org/p/nbr/nberwo/3914. html.

Grunewald, N., Klasen, S., Martınez-Zarzoso, I. & Muris, C., (2017). The trade-off between income inequality and carbon dioxide emissions. Ecological Economics, Vol. !42, Issue C, page 249–256. https://EconPapers.repec.org/RePEc:eee:ecolec

Gupta, S., Davoodi, H. & Alonso-Terme, R., (2002). Does corruption affect income inequality and poverty?. Economics of Governance, Vol. 3, Issue 1, pages 23–45.

Hao, Y., Chenb, H. & Zhang, Q., (2016). Will income inequality affect environmental quality? Analysis basedon basedon China's provincial panel data. Ecological Indicators, ELSEVIER Ltd, Vol. 67, pages 533–542.

Hardle, W., Liang, H. & Gao, J., (2000). Partially Linear Models.. Berlin: Springer-Verlag. www.springer.com, https://www.springer.com/gp/book/9783790813005

Harttgen, K., Klasen, S. & Rischke, R., (2015). Analyzing nutritional impacts of price and income related shocks in Malawi: Simulating household entitlements to food. Food Policy. Discussion Paper 166. Courant Research Centre PEG.https://ideas.repec.org/p/got/gotcrc/166.html.

Herrera, C., Ruben, R. & Dijkstra, G., (2018). Climate variability and vulnerability to poverty in Nicaragua. Journal of Environmental Economics and Policy, 7(3), pp. 324-344.

Heshmati, A., Maasoumi, E. & Wan, G., (2015). Poverty Reduction Policies and Practices in Developing Asia: Economic Studies in Inequality, Social Exclusion and Well-Being. Springer International Publishing AG éd. s.l.:Asian Development Bank. ISBN-13: 978-9812874191. ISBN-10: 9812874194

IPCC, (2014). Climate change impacts, adaptations and vulnerability, contribution of working group 2 to the fifth assessment report of the Intergovernmental Panel on Climate Change., Cambridge: Cambridge University Press,.

IPCC.(2017). Le GIEC définit les grandes lignes de son sixième Rapport d'évaluation, Suisse: Secrétariat du GIEC. https://archive.ipcc.ch/pdf/press/PR_P46_Press_

Conf_fr.pdf

Isaksen, E. T. & Narbel, P. A., (2017). A carbon footprint proportional to expenditure—A case for Norway?. Ecological Economics,Vol. 131, pages 152–165..

Jaumotte, F., Lall, S. & Papageorgiou, C., (2013). Rising Income Inequality: Technology, or Trade and Financial Globalization?. MF Economic Review, Vol. 6 Issue 2, pages 271–309.

Krueger, D., Perri, F., Pistaferri, L. & Violante, G. L., (2010). Cross sectional facts for macroeconomists. Review of Economic Dynamics, Vol.13, Issue 1, pages 1-14.

Marra, G. & Radice, R., (2017). Bivariate copula additive models for location, scale and shape. Computational Statistics and Data Analysis, Volume 112, pages 99-113.

Marra, G. & Radice, R., (2018). Generalised Joint Regression Modelling. CRAN packages "GJRM", 14 Novembre.p. 112.

Martinez-Alier, J., (1995). Political Ecology, Distributional Conflicts, and Economic Incommensurability. New Left Review, p. 70–88.

Martins-Filho, C. & Yao, F., (2012). Kernel-based estimation of semiparametric regression in triangular systems. Economics Letters, Vol. 115, Issue 1, pages 24-27.

Masters, W. & McMillan, M., (2001). Climate and Scale in Economic Growth. Journal of Economic Growth, Vol. 6, Issue 3, pages 167–186.

Mendelsohn, R., Dinar, A. & Williams, L., (2006). The distributional impact of climate change on rich and poor countries. Environment and Development Economics, Vol. 11, Issue 2, pages 159-178.

Newey, W., Powell, J. L. & Vella, F., (1999). Nonparametric estimation of triangular simultaneous equations models. Econometrica, Vol. 67, Issue 3, pages 565-603.

Ozabac, D., Henderson, D. J. & Su, L., (2014). Additive Nonparametric Regression in the Presence of Endogenous Regressors. Journal of Business & Economic Statistics, Vol. 32, Issue 4, pages 555-575.

Ravallion, M., Heil, M. & Jalan, J., (2000). Carbon emissions and income inequality. Oxford Economic Papers, Vol. 52, Issue 4. pages 651-669.

Richards, C., Unni, K., & Jostein, V. (2016). Food security in welfare capitalism: Comparing social entitlements to food in Australia and Norway. Journal of Rural Studies, 61-70.

Robinson, P. M., (1988). Root-n consistent semiparametric regression. Econometrica, Vol. 56, Issue 4, pages 931–954.

Rodgers, G. B., (1979). Income and inequality as determinants of mortality: An international cross-section analysis. Population Studies , Vol. 33, Issue 2, pages 343-352..

Rosenzweig, C. & Parry, M., (1994). Potential impact of climate change on world food supply.. Nature, Vol. 367, pages 133–138. doi:10.1038/367133a0

Selden, M. T. & Song, D., (1994). Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions?. Journal of Environmental Economics and Management, Vol. 27, Issue 2, pages 147-162.

Sen, A., (1981). Poverty and famines: An Essay on Entitlement and Deprivation. Oxford, UK: Clarendon Press, Oxford University Press, Oxford, UK, 1981, page 257. Food Policy, ELSEVIER, Vol. 8, Issue 1, pages 94-95.

Sesmero, J., Ricker-Gilbert, J. & Cook, A., (2017). How do African farm households respond to changes in current and past Weather patterns? A structural panel Data analysis from Malawi. American Journal of Agricultural Economic, Vol. 100, Issue 1, pages 115-144.

Shafik, N. & Bandyopadhyay, S., (1992). Economic Growth and Environmental Quality: Time-series and Cross-country Evidence, s.l.: World Bank Raport. WPS 904 http://documents1.worldbank.org/curated/en/833431468739515725/pdf/multi-page.pdf

Shao, S., Yang, L., Yu, M. & Yu, M., (2011). Estimation, characteristics, and determinants of energy-related industrial CO_2 emissions in Shanghai (China), 1994–2009. Energy Policy, Vol. 39, Issue 10, pages 6476-6494.

Su, L. & Ullah, A., (2008). Local Polynomial Estimation of Nonparametric Simultaneous Equations Models. Journal of Econometrics, Vol. 144, Issue 1, pages. 193–218.

Thorbecke, E. (2013). The Interrelationship Linking Growth, Inequality and Poverty in Sub-Saharan Africa. Journal of African Economies, i15-i48.

Tol, R., (2009). The Economic Effects of Climate Change. Journal of Economic Perspective , Vol. 23, Issue 2, pages 29–51.

Torras, M. & Boyce, J. K., (1998). Income, inequality, and pollution: a reassessment of the environmental Kuznets Curve. Ecological Economics,Vol. 25, Issue 2, pages. 147-160.

Tschakert, P., (2016). Shock Waves: Managing the Impacts of Climate Change on Poverty: The Role of Inequality in Climate-Poverty Debates. Development Economics; Policy Research Working Paper 6290, Issue WPS7677, pages 1-54.

Udry, C., (1995). Risk and Saving in Northern Nigeria. The American Economic Review,Vol. 85, Issue 5, pages 1287–1300..

UNDP, (2017). Inégalités de revenus en Afrique subsaharienne: Tendances divergentes, déterminants et conséquences, Nexw York: s.n. https://www.undp.org/content/dam/rba/docs/Reports/Overview-Income%20inequality%20Trends%20SSA_FR-web.pdf

Waldmann, R. J., (1992). Income Distribution and Infant Mortality. Quarterly Journal of Economics, Vol. 107, Issue 4, pages 1283–1302.

Wiedenhofer, D., Dabo, G., Zhu, L., Jing, M., Ning, Z., & Yi-Ming, W. (2017). Unequal household carbon footprints in China. Nature Climate Change, 75–80.

Factors Influencing Households' Food Security Status among Rural Farmers in The Central River Region South of The Gambia

Mamma Sawaneh and Momodou Badjie

ABSTRACT

Food insecurity is a major challenge in The Gambia especially for rural farmers who depend largely on rain-fed agriculture for their livelihoods. Therefore, this research investigates the factors influencing households' food security status. Semi structured questionnaires were used to collect data from 219 rural farm households. Using a logistic regression model, the result show that, age of household head, household income, household assets, household economic activities, assistance, remittance and household land ownership had significant effect on households' food security status. Therefore, food insecurity remains a challenge that affects rural farmers in the southern part of central river region of The Gambia. Thus, households need be encouraged to diversify their farming practices such as growing food crops and engagement in other economic activities to attain food security.

Keywords: Food insecurity, Logistic regression, Rural Farmers, The Gambia

RÉSUMÉ

L'insécurité alimentaire est un défi majeur en Gambie, en particulier pour les agriculteurs ruraux qui dépendent largement de l'agriculture pluviale pour leurs moyens de subsistance. Par conséquent, cette recherche examine les facteurs qui influencent le statut de sécurité alimentaire des ménages. Des questionnaires semi-structurés ont été utilisés pour collecter des données auprès de 219 ménages agricoles ruraux. En utilisant un modèle de régression logistique, le résultat montre que l'âge du chef de ménage, le revenu du ménage, les actifs du ménage, les activités économiques du ménage, l'assistance, les transferts de fonds et la propriété foncière du ménage ont un effet significatif sur le statut de sécurité alimentaire des ménages. Par conséquent, l'insécurité alimentaire reste un défi qui affecte les agriculteurs ruraux dans la partie sud de la région fluviale centrale de la Gambie. Les ménages doivent donc être encouragés à diversifier leurs pratiques agricoles, notamment en cultivant des produits alimentaires et en s'engageant dans d'autres activités économiques pour atteindre la sécurité alimentaire.

Mots clés : Insécurité alimentaire, Régression logistique, Agriculteurs ruraux, Gambie.

INTRODUCTION

Household food security continues to be a global concern especially in Sub-Sahara Africa due to rapid population growth and because factors affecting households' food security status are complex and multidimensional. There are no universal causes of food insecurity, instead, the phenomenon varies between countries, culture groups and from one household to an individual, depending on their coping strategies. Although there are efforts to improve food security at national and household levels several factors are responsible for household food insecurity in The Gambia. Citing FAO (2012), Zakari et al.(2014) stated that approximately 870 million people globally are estimated to have been undernourished (in terms of dietary energy supply) in the period 2010 –2012, representing 12.5% of the world's population. A large proportion of the undernourished live in developing countries, with sub-Saharan Africa is having the highest prevalence. Climate change is among the many factors affecting the achievement of food security and Sustainable Development Goals (SDGs) across the world negatively with major impacts in the developing countries. Despite diverse adaptation efforts employed at all levels, the effects of climate change are adverse and are mostly felt in developing countries, especially in the rural areas due to insufficient capacities and capabilities to effectively adjust or adapt to its variability (Ochieng et al. 2016). As illustrated by Mendelsohn (2008); FAO (2009) and Ozor N. et al. (2015), the most affected sector by climate change in Sub-Saharan Africa countries is agriculture. This is due to the high dependence on rainfall for household food production.

Climate change extremes such as floods, drought, changes in temperature and precipitation, which in turn reduces vegetation cover, water resource availability, soil quality and changes in land-use practices, such as conversion of land use, pollution and depletion of soil nutrients are among the factors affecting crop yield or food production. Land degradation is considered as one of the most severe environmental and socio-economic problems of recent times in Sub-Saharan Africa (Abdi et al., 2013; The World Bank, 2008). Meanwhile, if there are uncertainties concerning the direct effects of climate change on human well-being, then, negative aspects are most likely to be pronounced. Sub-Saharan and tropical regions of African countries are more susceptible to food instability as a result of reduction of croplands under production and productivity, rainfall irregularity and intensity, land degradation and loss of soil/land fertility resulting from erosion (Brauch 2010). Climate change and variability will, therefore, exacerbate and negatively affect all the domains of food security—availability, accessibility, utilization and stability—thus, increase in food prices affects food accessibility and affordability for the poor people (FAO, 2009). Thus this study helps to underscore the underlying factors affecting food insecurity among rural farmers in the Gambia considering their over dependence on rainfed agriculture which is climate driven.

Factors influencing Household Food Security Status

Factors influencing household food security status are complex and multidimensional. There are no universal causes of food insecurity but the phenomenon varies from country and cultures and from one household to individual, depending on their coping strategies. Several factors are responsible for household food insecurity in the study area. This was clear during the survey that factors such as the socio-economic characteristics of the household are crucial in determining household food security. The most vulnerable groups to food security are rural households who depend on crop production for livelihood. Moreover, the relationship between food insecurity and poverty are strongly correlated. Poverty not only leads to food insecurity but also decreases purchasing power for other goods and services such as housing, energy and water needed for their household.

Household food insecurity means that people either do not have access to food or are unable to purchase food needed for family consumption. In either case, they had to suffer from the hardships of hunger and poverty as a result of food insufficiency. Earlier researches and literatures suggests that the causes of household food insecurity include among others, long period of poverty, lack of adequate productive resources, corruption, fiscal imprudence, huge debts and policy inconsistency, number of extension visits, access to proper irrigation facilities, sustainable land management, access to market information and market infrastructure, good electricity systems to transform and store food items, good road network systems and above all, early warning systems to adapt and mitigate the effects of climate change on food security dimensions. Moreover, the age of household members, household education level, the size of the household, household income, the main economic activities of the household, access to market, access to credit, household access to assistance, remittances and food aid as well as household assets and land ownership as lamented by Mango et al. (2014) are among the other factors that are likely to influence household food security status. This argument was supported by Asghar and Muhammad, (2013) who reported that low household income is a major element that can negatively affect household food status. This is evident in fact that, households with low income lack sufficient funds to purchase food items during food shortage and thus, are likely to face food insecurity.

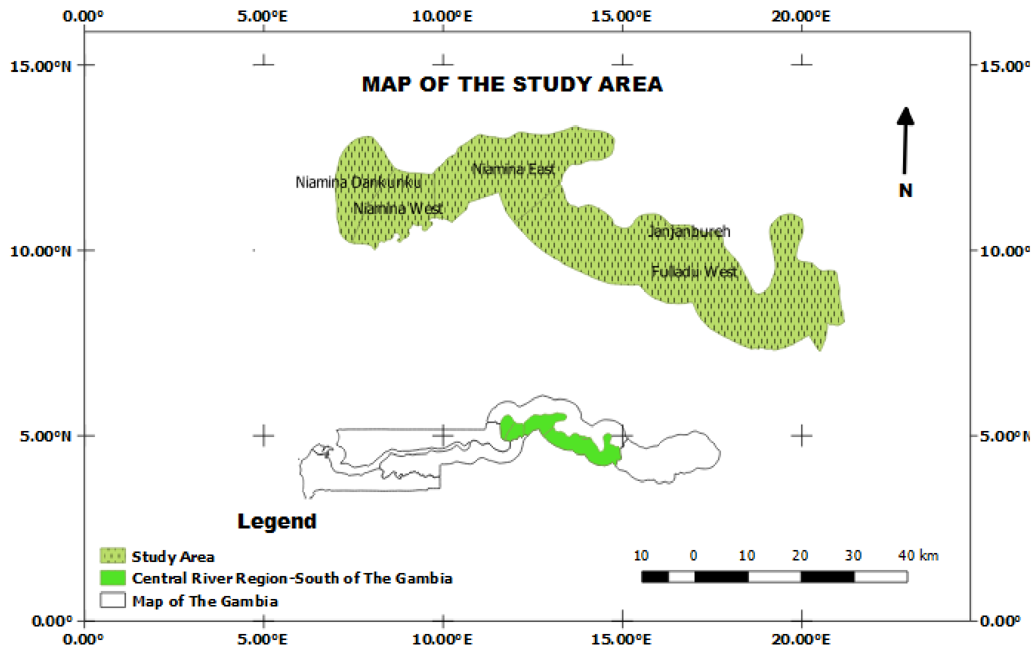
Furthermore, ownership of land, access to credit and assistance (cash or kind) combined with advance agricultural technologies have the potential to increase agricultural production and productivity of households who depend on rain-fed agriculture for their food production (Kassie et al. 2011). The findings further revealed that improved in agricultural technologies such as use of improved crop varieties, and overall improvement in agronomic practices that are geared towards increasing crop yields can significantly mitigate and reduce household food insecurity. (Kassie et al. 2012) also opined that the risk of crop failure can be mitigated through water use efficiency technologies, for example (drip) irrigation thereby increasing household food production.

MATERIALS AND METHODS

Description of the Study Area

The study is conducted in the Central River Region-South of The Gambia. It lies on the southern part of River Gambia, stretching from Sofaa Naima Bolong (Pakaliba Bridge) in the West to Farato Village in the East. Specifically, three districts in the region were studied. This is shown in Figure 1. The study was conducted in three randomly selected districts of the region.

Figure 1: Map of the Study Area



Source: Field Survey, (2017). Author's construct

Like other regions of The Gambia, almost all the residents of the Central River Region-South depend directly or indirectly on agricultural activities (Loum and Fogarassy, 2015). The main crops grown include groundnut, maize, early millet, rice, sorghum and sesame. Equally, they also depend on small livelihood activities such as traditional souvenirs, basket making, bead making, petty trading, carving, fishing and household vegetable production. Some households in the region also engage in animal husbandry such as cattle, goat, sheep and poultry. These activities vary during the dry season, making them more vulnerable to food insecurity. The Central River Region-South is selected as a case study due to three major reasons. First, it can be classified among the most vulnerable regions to climate variability and food poor due to their large dependence on rain-fed agriculture for food production as their livelihoods. Second, not many studies have been done on the effects of climate change and variability on household food security. Third, the spatial settlement of the communities makes it difficult for rural infrastructural and socio-economic development. Therefore, this research focused on the effects of climate variability on household food security among rural farmers in Central River Region-South of The Gambia.

Sampling procedure and data collection

A multistage sampling method was used for this study. The first stage was the purposive selection of one region in country. The Central River Region-South was selected due to its climate sensitivity, high food poverty levels and high participation in farming which is predominantly rain-fed and subsistence. In the second stage, purposive sampling technique was used to select three districts from the six districts in the region. Using the socio-economic data obtained from GBOS, three most vulnerable districts and food poor in Central River Region-South were purposively selected. These are Niamina West, Niamina East and Lower Fulladu West districts. Names of each village and population in each selected district was imputed in the Microsoft excel statistical tool using the randomization formula to select the villages. Three villages were selected from each district using simple random sampling procedure, making a total of 9 villages for the entire study area. The selected communities are Kumbaney Buniadu, Sambang Mandinka Kunda and Katamina from Niamina West district; Sambel Kunda, Sotokoi and Kerewan Touray from Niamina East; and Sinchu Magai (Mara Magai), Medina Ceesay Kunda and Sankuleh Kunda from Lower Fulladu West district. Simple random sampling was used to select households from each community as the last stage. In each selected household, the household head was interviewed. In the absence of the household head, any adult member (more than 25 years) was allowed to answer the questionnaire on behalf of the head. In all, 219 household heads were interviewed for the entire study. The study used a primary data that was collected using questionnaire. The data include socio-demographic characteristic of households, household food security components (availability, accessibility, utilization) household coping strategies to food shortages, perception on climate change, household preferred sources of climate information, and the challenges farmers faced in their farming systems.

Data Analysis

Logistic regression model was used to analyze the various factors influencing household food security status in the study area. Various researchers including Abdullah et al.,(2017) have used this model to analyze different factors influencing household food security. The model was used to describe the relationship between one or more independent variables (e.g., age, household income, asset index, remittance, etc.) where there is a binary response variable – the likelihood of attaining household food security within the communities – which is expressed as a probability. The dependent variable, food security status, is dichotomous, which means that it only takes two values either a household is food secured or it is not, so by pursuing the conventional method of binary response it will either take the value of one (1) and zero (0). In this study, a household is classified as 1 if the household is food secured and 0 if food insecure. This can be achieved by using the linear probability model (LPM). But this LPM is plagued by many problems including heteroscedasticity of the error term, the possibility of 'y' lying outside the range (0, 1). To avoid the problems associated with the LPM, the relationship was modelled in such a way that 'y' is unobservable variable and the relationship is given by ;

$y = 1$ if $y > 0$
0 if $y < 0$

Where 1 stands for food security and zero for food insecurity. Logistic regression technique is used to model the relationship between the dichotomous dependent variable and set of independent variables that are hypothesized to affect the outcome. The log odd of the outcome in logit model is a linear combination of the predictor variables. The simple form of logistic model, according to Peng et al. (2002) is shown below :

Logit(Y) = natural log (odds) = $\ln\left(\frac{\pi}{1-\pi}\right)\left(\frac{\pi}{1-\pi}\right) = \alpha+\beta xi$ ....Equation (1)

This equation helps us to predict the likelihood of the occurrence of the result of interest. This is using antilog in both sides of equation (1) as shown below :

Where;
π= probability outcome of interest
x= Y intercept
β= regression coefficient
e= 2.71828 (the base of natural logarithms)
x= binary or continuous variables

Description of the model

Logistic regression model was applied to examine the effect of various independent variables. The food security status was modeled as a binary response variable where 1 = food secured and 0 = food insecure. The overall predictive power of the model was significant, indicating that dependent variables had significant impact in explaining the food security status. The independent variables which had significant effect on household's food security status were household income, household assets, household economic activities, assistance and remittance.

Each of the regression coefficients describes the size of the contribution of that factor to the securing household food status. In other words, the coefficients illustrate how much the logit changes are based on the values of the predictor variables. A positive regression coefficient means that the explanatory variable increases the probability of the outcome, while a negative regression coefficient means that the variable decreases the probability of that outcome (see Table 1).

Variables Dependent variable	**Description and Measurement**
Food Security Status (FS)	D = 1 if HH is food secure; 0 = otherwise
Independent Variables	
Education (ED)	D = 1 if HH head is literate; 0 = otherwise
Household Size (HS)	D= Number of household members
Age (A)	D= Age of HH head in number of years
Household Income (HI)	D= Household income
Asset Index (AI)	D= Number of Household assets
Economic Activities (EA)	D= 1 if HH main economic activity is crop production; 0= otherwise
Land ownership (LO)	D= 1 if HH own land; 0= otherwise
Assistance (AS)	D= 1 if HH receive assistance; 0= otherwise
Remittances (RM)	D=1 if HH receive remittances; 0= otherwise
Access to Market (AM)	D= 1 if HH has access to market; 0 = otherwise
Access to Credit (AC)	D= 1 if HH has access to credit; 0 = otherwise
Food Aid (FA)	D= 1 if HH received food aid; 0= otherwise

Table 1: Description of the variables used in the model

Source: Field Survey, 2017

RESULTS AND DISCUSSION

Gender

Out of the 219 households surveyed, the results indicated that 83.1% of the households were male headed while 16.9% were headed by females as shown in table 4.1. This shows the dominance of male headed household in the study area. This affects and limits their access to most natural resources such as land thus affecting their involvement in commercial agricultural production. Despite their substantial contribution to household food security, cultural beliefs limit women in practicing permanent food crops or plants.

Marital Status

As shown in Table 2, 70.3% of the surveyed households were involved in monogamous married and 21.9% were in polygamous married. The results also show that 4.6% of the respondents were widowed while 3.2% were single. In terms of food production, this has a positive implication especially for households that are involved in agricultural activities. This is because married farmers who are engaged in active farming activities could have the support of their spouse(s) in terms of labour and also help supplement the income needed to acquire agricultural input. Ozor N. et al. (2015) illustrated that marriage encourages, support and promote adaptation efforts among farming communities, thus improving household livelihoods.

Age

Majority (30.6%) of the respondents were within the age bracket of 37-48 years and 31.1% were within 49-60 years old. There suggest that the majority of the respondents in the study area were predominantly in their middle ages hence, are economically active and thus can provide manpower for food crop production.

Household Size

The data revealed that majority (46.6%) of the surveyed respondents had household sizes between 10-17 persons while 37.9% and 11.9% had household sizes of 2-9 and 18-25 person respectively with the average household size of 12 persons per household. This indicates that most of the households within the surveyed area have fairly larger family sizes. The lowest family size was 2 while the largest was 40 persons. Although the large household size would be a source of labour for crop production, it also suggests that there are mouths to feed, hence the need for food production. The challenge would be to find a balance between feeding the large household size and the labour they provide.

Education

The results revealed that 58.4% of households have attended lower basic education in English and Arabic education known as 'Madrassa' while 8.2% and 5.0% have attended Upper Basic School in English or Arabic education systems respectively. In addition, the results also illustrated that 24.7% of household had no form of education. It can be inferred from this that the majority of the respondents in the study area are literates although their level of literacy differs.

Abid et al. (2015) reported that acquisition of formal education will enhance the adaptation of improved agricultural technologies that are expected to positively improve their livelihood, thus food security. Household education can contribute significantly to the household's resilience. This implies that a household with a highly educated head would have high resilience to the impacts of climate change than those without education. This is similar to the study by Nyangas and Chingonikaya (2017) which found that respondents attaining various trainings or formal education are able to increase their income by undertaking skilled non-farm activities, which are less climate-sensitive compared to farming and grazing, thereby helping the households to avert climate risks and hence increase their household resilience to the impact of climate change.

Variables	Frequency	Percentage (%)
Gender (n=219)		
Male	182	83.1
Female	37	16.9
Age of household head (n=219)		
25 -36	20	9.1
37-48	67	30.6
49-60	68	31.1
61-72	50	22.8
73 and above	14	6.4
Marital status (n=219)		
Single	7	3.2
Married monogamous	154	70.3
Married polygamous	48	21.9
Widowed	10	4.6
Household size (n=219)		
2-9	83	37.9
10-17	102	46.6
18-25	26	11.9
26-37	7	3.2
33 and Above	1	.5
Educational level of Household head (n=219)		
Never attended school	54	24.7
LBS/Madrasa	128	58.4
UBS/Madrasa	18	8.2
Secondary	11	5.0
Tertiary	8	3.7
Economic activity (n=219)		
Crop production	195	89.0
Petty trading	3	1.4

Fishing/hunting	4	1.8
casual works	9	4.1
Others	8	3.7

Table 2: Demographic and Socio-economic characteristics of the respondents
Source : Field Survey, 2017

Household Main Sources of Food

The main sources of food in the household can be categorized into two; own production and from purchase. Out of the 219 respondents interviewed, an overwhelming proportion (90%) of them reported that their primary source of food consumed in the households is from their own production while 10% of the respondents reported that purchase is the first source of household food supply. Considering that the study is conducted in farming communities, it was expected that majority of the households would engage in crop production primarily for household consumption. Though the findings revealed that the majority of households were engaged in farming, almost all households are net food buyers. Most of the households do not produce sufficient food quantities to cover the household consumption needs throughout the year. Some of them sell part of their production to cover the production expenses and other income needs such as children school fees and other social events. The vulnerability to food insecurity is more severe during poor harvest seasons in which most households were unable to produce enough food to keep feeding their members throughout the year.

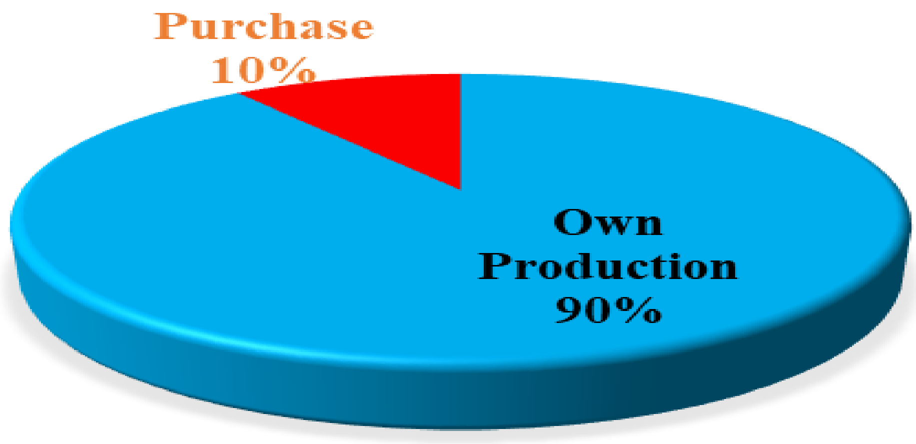


Figure 2: Distribution of Households' Main Sources of Food
Source: Field Survey, 2017

Crop diversification practiced by households can be seen as a measure taken to adapt to adverse effects of climate change, considering uncertainties facing onset and cessation as well as the distribution of rainfall. This was further manifested by household heads and stakeholders during FGD in the study area. In The Gambia, most of agricultural activities employed by farmers are labour intensive, time consuming with little returns. Muzamhindo (2015) also opined that the development of labour-saving technologies, improved access to credit and extension will increase the likelihood of adaptation to climate change by vulnerable farmers who depend largely on rain-fed agriculture. A similar study conducted by Ozor et al. (2015) illustrated that household who practice crop diversification and household gardening are more resilient to food insecurity. Household food production is a key instrument in determining food availability. Any activity within the capacity of household to secure food can be considered as production. FGD further revealed that the majority of the households sell a large proportion of the farm produce to the market to supplement other household needs such as providing education and other basic needs of the household. In addition, petty trading constituted 10.5% and livestock 11.0% respectively contribute greatly in generating household income needed to complement household food needs.

Household Food Availability Status

Findings from household interview revealed that, most of the respondents (72%) reported that farm produce can only cater for less than 5 months for family consumption while 26.9% of the surveyed respondents explained that their farm produce can only cater for 6-8 months. Findings further revealed that only 0.5% of the respondents narrated that their farm produce can cater for 9-12 and more than 12 months respectively. This can be further attributed to the family sizes and poor harvest among many other factors. Most of the respondents expressed their views during FGD that climate variability and lack of adequate farm inputs are the main contributing factors to poor yields. Poor storage and processing facilities was also highlighted due to fact that most of the interviewed communities lack these facilities. To attain household food security, efficient assessment is vital to highlight the number of months on which households depend on their own farm production is important. In most cases, household food production is inadequate to feed the entire family all year, even in normal rainfall years. This is mainly as a result of extended families depending on a single source of livelihood. This compelled most households to struggle to get additional food from other sources such as remittance and neighbourhood assistance during months of food shortage. Due to their large dependence on rain-fed agriculture, climate variability is expected to exacerbate and further complicate the number of months of food shortage for households by lowering crop yields which is subsequently caused by unreliable rainfall pattern and shorter growing seasons. During FGD, the majority of the respondents affirmed that food security is a serious challenge and it severely affects livelihoods as the majority of the respondents expressed that their own farm produce cannot feed their household for the whole year. The probable reason why their own food production is not enough to feed the family may be a function of many different factors, like climatic condition, loss of soil fertility, or the loss of household productive assets or some other related challenges. With regards to the surveyed population, most of the factors contributing to household food insecurity can be identified as unreliable rainfall pattern and lack of farm inputs.

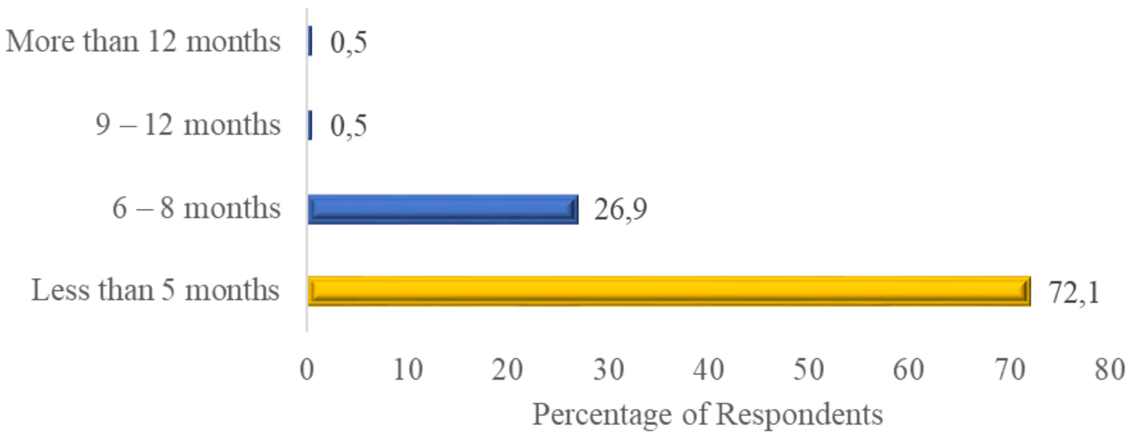


Figure 3 : Distribution of Respondents' Time Periods that their Farm Produced Lasts
Source: Field Survey, 2017

Factors Influencing the Household Food Security Status in the study area
The logistic regression model results indicated that education, age household income and household economic activities (crop production, livestock rearing and petty trading), land ownership, assistance form friends or relatives and remittances were found to have positive significant on food security status.

Table 3: Logistic regression coefficient showing the factors influencing the household food security status

Food Security Status	Coef.	Std. Err.	Z	P-value
Education	1.116957***	.9102449	1.23	0.002
Household Size	-.0272264	.054765	-0.50	0.619
Age	.0433891	.0267083	1.62	0.004
Household Income	.0001868*	.0001031	1.81	0.070
Asset Index	.0403017**	.0197466	2.04	0.041
Economic Activity	-2.272404***	.859962	-2.64	0.008
Land Ownership	.5826386**	1.157704	0.50	0.010
Assistance	-1.934729**	.9704878	-1.99	0.046
Remittance	2.29223***	.8067339	2.84	0.004
Access to Market	.4612084	.6913773	0.67	0.505
Access to Credit	.1758985	.424602	0.41	0.679
Food Aid	1.168522	1.218525	0.96	0.338

*The significance level are denoted as follows: ***1%, **5% and *10%*
Source: Field Survey, 2017

The results from the model indicated that education has a positive influence on household food security status (P = 0.002). This implies that the more educated a household head is, the more likely food secured the household would be compared to the less educated household. The findings corroborate with the research conducted by Asghar and Muhammad, (2013) which substantiated that education played a key role in enhancing household food security status. Educational attainment by the household head could lead to awareness of the possible advantages of modernizing agriculture by means of technological inputs etc. this will enable and encourage diversification of household incomes which, in turn, would enhance households' food supply. Education provides knowledge, awareness and increases the chances of obtaining paid job to effectively adapt to climate effects and food shortage periods, thus enhancing household livelihood.

Age is another important factor which determines and influence household food security status. The resulted from the models shows that age was positive (P=0.004). It can be noted that household food insecurity varies significantly among different age groups. The assumption here is that, the older the head of the household is, the higher the chance to enhance the food security status as there may be many options of making food available from both agricultural and non-farm opportunities. This is evident that older people are more committed to agricultural activities than the younger ones. The younger ones on the other hand, are not fully engage in agricultural production even though younger household heads are stronger and are expected to undergo more stress to cultivate large size farm than their older counterparts. This is due to the fact that the substantial movement of the youths within the country and outside the country through (back-way), seeking for good paid jobs is a major contributing factor to this phenomenon. Since rural livelihood depends largely on their farm production, those who are fully engaged in agricultural activities are more likely to be food secured than those who are less involved.

This result further illustrated that household with higher income earnings are more likely to have a higher purchasing power and are more likely to be food secured than household with low income earning while households whose primary occupation is crop production are more likely to be food secured than those who do not grow crops.

Household assets were found to have a significant effect on household's food security status. Assets in this case comprises car, motorbikes, carts, mobile phones, wheelbarrow, television set, radio/tape generator/solar. From the data, it was found out that most of the respondents have household assets. The result demonstrated that households having assets were more likely to be food secured compared to non-assets holders. This finding is in conformity with the study conducted by Chang et al. 2014 which outlined that the lack of resources is associated with increased food insecurity at all levels.

It could be further noted that assistance and remittance play a significant role in enhancing food security status. In recent decades, remittance becomes one of the important sources of income and external financial source for many people in The Gambia. The effect of remittances was found positively significant ($P = 0.004^{***}$) while assistance was found significant with ($P = 0.046^{**}$). It is evident in the study area that people, receiving assistance or remittances, were more likely to be food secured than those who are not receiving assistance or remittance. This demonstrated that remittance can increase the purchasing power of household (Akano et al. 2013). Those household who receive remittances are more likely to increase their purchasing power of food varieties and are also more likely to be food secured, while household who do not receive remittances are less likely to be food secured. Assistance and remittances are considered an important source of additional earnings that can support and enhance household food security.

Moreover, land ownership is also another important variable in determining household food security. The model indicated that land ownership was positive (P = 0.010). This depicts that household who own land are likely to be more food secured than household with no land ownership. Land ownership will allow household to have access to land and can sell the land to enhance household food security status. However, the rapid population growth and land fragmentation can negatively affect access to land for agricultural activities.

CONCLUSION

Factors affecting household food security status in the study area are complex and dimensional. From the logistic regression model, it can be concluded that the factors that influence household food status include, age, household income, household assets, household economic activity, access to finance assistance and remittance, and land ownership. These factors have affected the ability of household to adequately address household food status. It must be noted that household food insecurity is high among rural farmers in the study area

Attaining food security is among the most significant development challenges faced by government of The Gambia. In fact, there is sufficient evidence to admit that it is the most urgent task faced by many countries today. Attaining sustainable food security requires a complex and a holistic approach from both public and private sectors and other actors. It implies reaching a number of development goals, including motivating agricultural production, intensifying livelihood opportunities, increasing incomes, and improving nutrition directly at household level. Currently food security had become virtually synonymous with development.

Households need to be encouraged to diversify their farming practices such as growing other non-traditional food crops. Introduce other non-traditional crops, and livestock, that are climate-tolerant; for example, short-season maturing crops, drought-tolerant crops, aquaculture, high milk-yielding livestock, and poultry production, all aimed at diversifying food production systems thereby enhancing household food security status.

Farmers, Government and institutions should help to establish cereal banks that would enhance the coping mechanisms toward food availability throughout the year. It is evident that climate change extremes such as rainfall, temperature have repercussion on major cash and cereal crops production. Therefore, establishment of cereal banks in Central River Region-South of The Gambia will help households to store their food items for a long period of time and use them whenever needed, especially during critical months of the year that are considered “the hungry season.” The stored food will serve as buffer against high food prices during the critical months of the year.

Government, Non-Governmental Organizations and institutions should facilitate easy access to micro-credit and farmer insurance systems where farmers can easily recover from any climate-induced food shocks. Micro-credit plays a very important role in enhancing household food security status. Farmers can use micro-credit to purchase farming equipment that can be used to boost production and productivity. This can be done through establishment of farmers associations and micro-financed groups among rural farmers where loans can be easily access and managed by themselves with the support of government or financial institution. Farmer insurance systems need to be established and extended to cover rural farmers. Since farmer insurance systems covers and compensate victims, will help farmers recover from any climate-induced losses of crops, thus enhancing their resilience and coping mechanisms to food shortage periods.

REFERENCES

Abdullah, Zhou, D., Shah, T., Ali, S., Ahmad, W., Din, I. U., & Ilyas, A., (2017). "Factors affecting household food security in rural northern hinterland of Pakistan". Journal of the Saudi Society of Agricultural Sciences (2017), doi: http://dx.doi.org/10.1016/j.jssas.2017.05.003R.

Abid, M., Scheffran, J., Schneider, U. A., & Ashfaq, M. (2015). "Farmers' Perceptions of and Adaptation Strategies to Climate Change and their Determinants": The Case of Punjab Province, Pakistan. Earth System Dynamics, Vol. 6, Issue 1, pages 225–243. http://doi.org/10.5194/esd-6-225-2015.

Akano, Y., (2013). "Effects of Remittance Inflows on Economic Growth of Nigeria". Developing Country Studies Vol. 3, Issue 3, pages 113–123. ISSN 2224-607X (Online) www.iiste.org.

Asghar, Z., Muhammad, A. & Ahmad, M., 2013. "Socio-economic Determinants ofHousehold Food Insecurity in Pakistan". Online at http://mpra.ub.uni-muenchen.de/21510/ MPRA Paper No. 21510.

Brauch, H.G., (2010). Coping with Global Environmental Change, Disasters and Security Threats, Challenges, Vulnerabilities and Risks vol. 5. Eds. Hans Günter Brauch, Úrsula Oswald Spring, Czeslaw Mesjasz, John Grin Patricia Kameri-Mbote, Béchir Chourou, Pál

Dunay, Jörn Birkmann. DOI: 10.1007/978-3-642-17776-7. ISBN: 9783642177750.Chang, Y., Chatterjee, S., & Kim, J., (2014). "Household finance and food insecurity". Journal of Family and Economic Issues Vol. 35, Issue 4, pages 499-515. https://doi.org/10.1007/s10834-013-9382-z.

FAO, (2009). The State of food and agriculture, Available at: http://choicereviews.org/review/ doi: 10.5860/CHOICE.46-5950.

Kassie, M., Shiferaw, B., & Muricho, G., (2011). Agricultural technology, crop income, and poverty alleviation in Uganda. World Development, Vol. 39, Issue 10, pages 1784-1795.

Kassie, M., Jaleta, M., Shiferaw, B. A., Mmbando, F., & De Groote, H., (2012). Improved maize technologies and welfare outcomes in smallholder systems: evidence from application of parametric and non-parametric approaches. Paper presented at the 2012 Conference, August 18-24, 2012, Foz do Iguacu, Brazil.

Loum, A., & Fogarassy, C., (2015). The effects of climate change on cereals yield of production and food security in Gambia. Applied Studies in Agribusiness and Commerce. https://doi.org/10.19041/apstract/2015/4/11.

Mango, N., Zamasiya, B., Makate, C., Nyikahadzoi, K., & Siziba, S., (2014). Factors influencing household food security among smallholder farmers in the Mudzi district of Zimbabwe. Development Southern Africa, Vol. 31, Issue 4, pages 625 640 doi.org/10.1080/0376835X.2014.911694. Routledge Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK.

Mendelsohn, R., (2008). The Impact of Climate Change on Agriculture in Developing countries. Journal of Natural Resources Policy Research, Vol. 1, Issue 1, pages 5–19. doi:10.1080/19390450802495882.

Muzamhindo, N., (2015). Factors Influencing Smallholder Farmers ' Adaptation to Climate Change and Variability in Chiredzi District of Zimbabwe. Journal of Economics and Sustainable Development, Vol. 6, Issue 9, pages 1–9.

Nyangas, J.A. & Chingonikaya, E.E., (2017). Farmers Resilience to Climate Change inMeatu and Iramba District , Tanzania. International Journal of Scientific Research and Innovative Technology, ISSN: 2313-3759, Vol. 4, Issue 6, pages 39–49.

Ochieng, J., Kirimi, L., & Mathenge, M., (2016). The case of small scale farmers in Kenya. NJAS - Wageningen Journal of Life Sciences. https://doi.org/10.1016/j.njas.2016.03.005.

Ozor, N., Umunakwe, P. C., Ani, A. O., & Nnadi, F. N., (2015). Perceived impacts of climate change among rural farmers in Imo State , Nigeria. African journal of Agricultural Research, Vol. 10, Issue 14, pages 1756–1764.

Piya, L., Maharajan, K L & Joshi, N.R., (2012). Vulnerability of rural household to climate change extremes; analysis of Chepang household in Mid-hills of Nepal. Selected paper prepared for presentation at International Associations of Agriculture Economics (AAE)

Yerennial conference, fozdo Iguaca, Brazil, pages 18-24 August 2012. Zakari, S., Ying, L. & Song, B., (2014). "Factors Influencing Household Food Security in West Africa: The Case of Southern Niger". Sustainability, Vol. 6, Issue 3, pages 1191–1202. doi:10.3390/su6031191.

Household vulnerability to food insecurity due to climate change in Niger : a multinomial logistic regression of food insecurity categories on climate and socioeconomic factors

Elhadji Iro Illa

ABSTRACT

The aim of this research is to identify a number of variables that characterize the dimensions of classic analysis of food security at household level. Secondary data from Niger's National Institute of Statistics was used. It is a national database drawn from the socioeconomic national survey on vulnerability to food insecurity. It includes data on rural households' perception of climate and environmental change and resulting shocks, agricultural and livestock information, coping strategies, social networks, infant feeding and gender. The survey is conducted in rural areas across all regions except for the north (Agadez) because of security issues in this region located in the desert. The variables identified for this purpose are food consumption score, livestock ownership and expenses. After multinomial logistic regression, the probability for a household to be severely food insecure, moderate or at risk decreases with the following: animal possession, age, land area cultivated, agricultural/tools/seeds spending, consumption of milk/fruits/meat. Similarly, probability for a household to be severely food insecure, moderate or at risk, increases with household size, share of household spending devoted to education and the experience of climate stress with the occurrence of flood and drought.

Keywords: Food insecurity, climate stress, rural households.

RÉSUMÉ

L'objectif de cette recherche est d'identifier un certain nombre de variables qui caractérisent les dimensions de l'analyse classique de la sécurité alimentaire au niveau des ménages. Des données secondaires provenant de l'Institut National de la Statistique du Niger ont été utilisées. Il s'agit d'une base de données nationale tirée de l'enquête nationale socio-économique sur la vulnérabilité à l'insécurité alimentaire. Elle comprend des données sur la perception par les ménages ruraux des changements climatiques et environnementaux et les chocs qui en résultent, les informations sur l'agriculture et l'élevage, les stratégies d'adaptation, les réseaux sociaux, l'alimentation des nourrissons et le genre. L'enquête est menée dans les zones rurales de toutes les régions, à l'exception du nord (Agadez) en raison des problèmes de sécurité dans cette région située dans le désert. Les variables identifiées à cet effet sont le score de consommation alimentaire, la possession de bétail et les dépenses. Après une régression logistique multinomiale, la probabilité qu'un ménage soit en situation d'insécurité alimentaire sévère, modérée ou à risque diminue en fonction des variables suivantes : possession d'animaux, âge, terres, etc. possession d'animaux, l'âge, la surface cultivée, les dépenses agricoles/outils/semences, la consommation de lait/fruits/fruits de rente, la consommation d'eau et d'énergie, consommation de lait/fruits/viande. De même, la probabilité pour un ménage d'être en insécurité alimentaire sévère, modérée ou à risque, augmente avec la taille du ménage, la part des dépenses du ménage consacré à l'éducation et l'expérience du stress climatique avec l'apparition d'inondations et de sécheresses.

Mots clés: insécurité alimentaire, stress climatique, ménages ruraux.

INTRODUCTION

In Niger, climate change worsens increasingly the livelihoods of the population given that more than 80% of people rely on agriculture. According to (Ramasamy and Moorthy, 2012), low agricultural productivity exacerbates the incidence of more poverty and hunger meaning that whatever the cause, Poverty and food security are intertwined (Rukhsana, 2011). Climate change can cause vulnerability to poverty in several ways. For instance, higher fluctuation in rainfall can result in drought or flooding which in turn may adversely affect households' assets and agricultural produce, leading to increment in poverty (Oluoko-Odingo and Alice, 2009). The variability of climatic factors makes it difficult for countries to grant food security for his people (Ahmad et al., 2011). Climate change is a real threat for agriculture as it affects crop yields, crop nests, diseases and soil fertility (Greg et al., 2011).

The Saharan zone receives less than 150 mm of rain per year and extends over 77% of the total land area. Niger, a sahelian-landlocked country in West Africa, covers an area of 1,267,000 km^2. Three-quarters of the country is desert, including the Ténéré desert, which is one of the world's most austere deserts. The rainfall is characterized by a high variability in space and time from south to north. The Sahel Sudan zone, which represents 1% of the total land area, receives between 600 and 800 mm of rain in normal years; which is conducive to agricultural and livestock production. The Sahelian zone covers 10% of the total land area with 350 to 600 mm of rain per year and is dominated by agriculture and pastoralist. The Sahel Saharan zone receives 150 to 350 mm of precipitation per year on average and covers 12% of the total land area; this area is characterized by moving livestock.

The scenario in the Niger therefore supports high variability in climate change as a result of rainfall dispersions; this can therefore lead to reduction in food both to man and animals in the area, hence, the need for this research. The main objective of this paper is to assess the vulnerability of rural households to food insecurity given socioeconomic and climate factors as depicted in figure 1 below. This was carried out by estimating the probability of the occurrence of the different food insecurity categories. This study is therefore targeting policy makers as it provides solutions on key variables of food insecurity and provision of solution in form of adaptation measures to food insecurity and poverty in the Niger.

In the Sahelian countries in 1953, heavy rainfall destroyed crops and resulted in famine that persisted for the first nine months of 1954 and put the lives of about five million people in western and south-central Niger, northern Nigeria and northern Cameroon (Grolle, 1997) at risk. Since the two last decades, rainfall in the Sahel seemed to recover and floods have become more frequent than usual, most notably from 1995 to 2010 (Cook et al., 2011). Paeth et al., (2009) analyzed the conditions associated with widespread flooding in the region in 2007 and associated this phenomenon with a number of factors, including anomalous heating in the tropical Atlantic. In 2005, the number of Niger citizens suffering from severe food shortage was estimated to be 3.2 million, of which 800,000 reached a critical threshold of food precariousness (SAP system d'alerte precause, and USAID FEWNET, 2007). In 2009, the cereal production deficit coupled with two consecutives forage deficits (31% of needs in 2008 and 67% in 2009) have resulted in a food crisis that has affected 7.1 million of people, of which 3.3 million ere categorized as severe (SAP: Système d'Alerte Précoce). In both cases, children were the most affected with global acute malnutrition rates above the emergency threshold of 15%.

The food crisis of 2010 saw food prices rise to a level where they have remained since 2008. The terms of trade have followed a sharp degradation of the order of 30% compared to the average of the last five years during the peak of the lean pastoral period. Climate change and its variability affect significantly agricultural productivity resulting in several consequences such as food insecurity, hunger and poverty. The combination of environmental events (degradation of arable area, decreasing ground water, incredible wind, drought) and socioeconomic factors (rising population, rising price of food grains, increasing cost of cultivation, low education level of farmer, etc.) makes it difficult for vulnerable households to get rid of negative multidimensional, multi-processing, and complex phenomenon vulnerability (Shakeel et al., 2012).

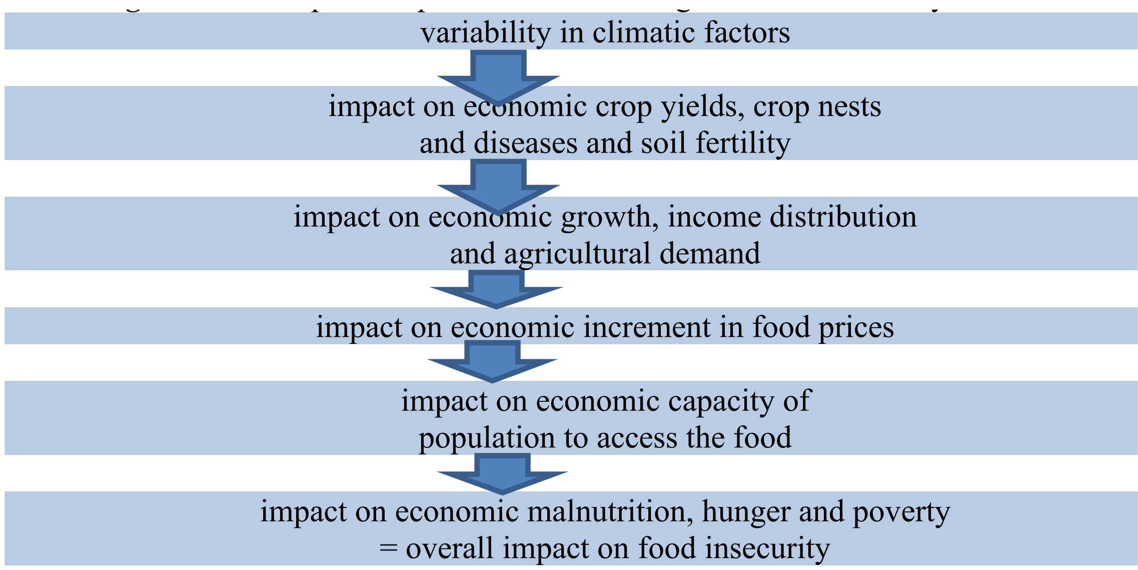


Figure 1 : Conceptual impact of climate change on food insecurity

Source: author, 2018

All the economic sectors are negatively affected after a climate disaster resulting in severe shocks on economic growth, income distribution and agricultural demand (Schmidhuber and Tubiello, 2007) as well as volatility of food prices (Greg et al., 2011). Climate change exacerbates malnutrition, malaria and health problems resulting in hunger, food insecurity, poverty and malnutrition. Agricultural households are both exposed to environmental shocks and socioeconomic vulnerability as a result of demography, conflict with livestock breeders, illiteracy and poverty (Shakeel et al., 2012).

Literature on climate change vulnerability assessment focuses on three conceptual and theoretical frameworks, summarized as socioeconomic or social vulnerability - describing the adaptive capacity of a system, biophysical vulnerability - describing a system's sensitivity and exposure and finally, the combination of both approaches, known as the integrated assessment approach. Nelson et al., (2010a) defines vulnerability as the susceptibility to disturbances determined by exposure to perturbations, sensitivity to perturbations, and the capacity to adopt. According to Cutter et al. (2009), vulnerability refers to the susceptibility of a given population, system, or place, to harm from exposure to hazards which directly affects the ability to prepare for, respond to, and recover from hazards and disasters. The SAR (second assessment repot) of the IPCC (intergovernmental panel on climate change) defines vulnerability as the extent to which climate change may damage or harm a system; not only a system's sensitivity is taken into account but also its adaptive capacity (Watson, Zinyowera, & Moss, 1996). From the definition given by the IPCC TAR (third assessment report), vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects to climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2001). IPCC AR4 is consistent with the definition of vulnerability given by TAR.

Biophysical vulnerability approach

The point of view of IPCC SAR is in line with the 'end point' analysis in which the vulnerability of people is linked with external events depending on the development of possible climate scenarios and future climate trend. Hence, the level of vulnerability follows from studying the biophysical impacts of such climate changes, and finally, any residual adverse consequences despite collective actions taken after identification of adaptive capacity options (Kelly & Adger, 2000). From the point of view of end-point analysis, exposure and sensitivity cause linear impact leading to biophysical vulnerability. In the 'end point' analysis, researchers focus on biophysical drivers originating from extreme climatic events that are not under control of policy makers, such as drought, flood, temperature, and precipitation, and they view vulnerability as the resulting effect on the system after the climate hazard. For instance, modeling farm income on climate variables can help measure the monetary impact of climate change on agriculture (Mendelsohn, Nordhaus, and Shaw 1994; Polsky and Esterling, 2001; Sanghi, Mendelsohn, Dinar, 1998).

By the same token, modeling crop yield and climate variables can help measure the yield impact of climate change (Adams 1989; Kaiser et al. 1993; Olsen, and Jensen 2000). Biophysical vulnerability assessment have been used in a variety of contexts, including the United States Agency for International Development (USAID), Famine Early Warning System (FEWS-NET) (USAID, 2007a), the World Food Program's Vulnerability Analysis and Mapping tool for targeting food aid (World Food Program, 2007), and a variety of geographic analysis that combine data on poverty, health status, biodiversity, and globalization (O'Brien et al., 2004; UNEP, 2004; Chen et al., 2006). The Human Development Index, for example, incorporates life expectancy, health, education, and standard of living indicators for an overall assessment of national well-being (UNDP, 2007). Biophysical vulnerability assessment also includes the impact of climate change on human mortality and health terms (Martens et al. 1999), on food and water availability (FAO 2005; Xiao et al. 2002), and on ecosystem damage (Forner 2006; Villers-Ruiz and Trejo-Vázquez 1997). Füssel (2007) referred to this approach as a risk-hazard approach, while Adger (2000) referred to it as an approach responding to research questions such as "What is the extent of climate change problem?" and "Do the cost of climate change exceed the cost of greenhouse mitigation?". The biophysical approach has its limitation because it only accounts for physical losses, such as yield, income etc., without mentioning particular effective reductions due to climate change for different people or regions. In other words, it focuses more on sensitivity and exposure of individuals or social groups to climate change rather than adaptive capacity, which is explained more by their inherent characteristics Adger (1999), leading to uncertainty in vulnerability assessment (Nelson et al., 2010a). This method is therefore criticized because it treats humans as passive receivers of hazards.

Socioeconomic vulnerability approach

Many of the initial studies have focused on the adaptive capacity at the national level (Haddad, 2005; Adger & Vincent, 2005; Brooks et al., 2005; Adger et al., 2004; Yohe & Tol, 2002) and few of the latter studies have been focused at the sub national level (Jakobsen, 2011; Nelson, et al., 2010b; Gbetibouo & Ringler, 2009). Social vulnerability assessment accounts for internal socioeconomic characteristics of people (Adger, 1999; Füssel, 2007) as individuals' status varies depending on education, gender, political power, social capital, etc. Thus, people are not socially vulnerable to the same extent because of their relative human-environmental properties that allow them to cope with changes, hence, setting up vulnerability to their adaptive capacity (Vincent & Cull, 2010; Vincent, 2004; Adger & Kelly, 1999; Adger, 1999).

This type of vulnerability is called 'starting point' or present-day vulnerability, meaning individuals' internal characteristics before they are hit by hazard event (Allen 2003; Kelly and Adger, 2000) which itself originates from socioeconomic perturbations (Adger and Kelly, 1999). For example, Adger and Kelly (1999) used this in Vietnam when they considered environmental factors in a district to coastal lowlands as given and then measured individuals' vulnerability only depending on their intrinsic socioeconomic patterns. Although social vulnerability approach accounts for differences among individuals in society, it has its own limitation because people do not vary only due to socioeconomic characteristics, but also to environmental factors (Deressa et al., 2008). This approach neglects the environment-based intensities, frequencies, and probabilities of environmental shocks, particularly drought and flood. The divergence of academics' debate about the two approaches has resulted in the complexity of the term 'Biophysical' vs. 'Social vulnerability' (Vincent, 2004; Brooks, 2003) because the first approach cannot be completed without the latter nor the latter without the former given that hazard specificity is their common point. Therefore, combining both of them (integrated vulnerability assessment) simultaneously links social vulnerability (adaptive capacity) with biophysical aspects of climate change (exposure and sensitivity) to design a complete picture of vulnerability is the best methodological approach (Nelson et al., 2010b; Gbetibouo & Ringler, 2009; Cutter, 1996).

Integrated vulnerability approach

In this approach, both socioeconomic and biophysical factors are jointly considered to assess vulnerability, similarly like the example of hazard-of-place model (Cutter, Mitchell, and Scott, 2000) and mapping approach (O'Brien et al., 2004). The IPCC (2001) framework, which conceptualizes vulnerability to climate change as a function of adaptive capacity, sensitivity and exposure, is conducive with the integrated vulnerability assessment (Füssel and Klein, 2006; Füssel, 2007). Deressa et al., (2008) used the integrated vulnerability approach to assess farmer's vulnerability to climate change in Ethiopia. However, this approach has limitations. This approach does not allow for any standard method that helps combine indicators of biophysical and socioeconomic data sets. There is much to do to provide common metric for defining the relative importance of social and biophysical vulnerability and the relative importance of each individual variable. Furthermore, it does not account for the dynamism in vulnerability. To take advantage of opportunities, adaptive capacity options are to include the continual change of strategies (Campbell, 1999; Eriksen and Kelly, 2007); this dynamism is missing under the integrated assessment approach.

METHODOLOGY

Analytical framework

In order to estimate household food insecurity, the first measure used estimates the expected level of caloric consumption, based on household, human, physical assets and capabilities, and compares it with the observed level of caloric consumption, below 2100 calories per capita per day into 3 categories of risk :

i. Extreme chronic level (A) of food insecurity level reflects both observed and expected levels of consumption below the minimum level of caloric consumption.

ii. Vulnerability to chronic level (B) food insecurity summarizes the share of households with observed consumption levels below minimum level of caloric consumption, but have the human and physical assets that would allow them to consume adequate level of calories. However, they do not consume because of particular circumstances like droughts.

iii. Vulnerability to food insecurity level (C) that summarizes the share of households exposed to risk and uncertainty, which had affected their levels of consumption. They are those who are expected to consume less than 2100 calories per capita a day in response to a shock, but manage to consume more.

iv. The overall level of food insecurity is measured by the sum of chronic (A) and transient food insecurity.

The second measure, named Dietary diversity calculates the food variety index. This index is a simple, or weighted, count of foods or food groups consumed over a given reference period. It emphasizes the importance of consuming a wide variety of food to enhance dietary quality. The main disadvantage of this method is that it does not take into account the quantity of food consumed or controls for diets regarding caloric composition. However, developing countries have a positive correlation of dietary diversity and nutrient adequacy.

The third measure uses the principal component analysis to reduce multidimensional data sets to lower dimensions for analysis of different outcomes."[36]

Data

Secondary data from Niger's National Institute of Statistics was used. It is a national database drawn from the socioeconomic national survey on vulnerability to food insecurity. It includes data on rural households' perception of climate and environmental change and resulting shocks, agricultural and livestock information, coping strategies, social networks, infant feeding and gender. The survey is conducted in rural areas across all regions except for the north (Agadez) because of security issues in this region located in the desert.

Analytical technique

Description of food insecurity scores by national institute of statistics

The methodology adopted is to identify a number of variables that characterize the dimensions of classic analysis of food security. The variables identified for this purpose are food consumption score, livestock ownership and expenses.

36 Source: See Coates, Adams (1989);); McCarthy et al., (2001); Polsky and Esterling (2001); Chaudhuri and Suryahadi (2002); Webb and Houser (2003); Allen (2003; Former (2006); Vincent (2004).

vi. For each indicator, a reference threshold based on the existing secondary data was calculated. The household were ordered in increasing order against each indicator and divided into five homogeneous groups. Each group has about 20% of households. For each group of 20%, a value average was calculated. These average values are the thresholds for each indicator.[37]

a) The food consumption score

It is calculated by combining all foods consumed in 10 groups: cereals, tubers, legumes, protein, milk, egg, vegetables, fruits, sugar, and oil.

The maximum score is 7x10 = 70. The score for each household is divided by 70 (this value may be lower if one considers less groups or greater if one considers more groups, either way the thresholds are the same). The entire household were then ordered in relation to this standard score and divided into 4 groups. For each group, an average of scores was calculated and resulted in the following threshold :

very poor consumption (score between 0 and 0.27; rank = 1),
poor consumption (score between 0.27 and 0.43; rank = 2),
average consumption (score between 0.43 and 0.52; rank = 3),
acceptable consumption (score greater than 0.52; rank = 4).

b) Livestock ownership

Livestock ownership in TLU (tropical livestock unit) for adding goats, sheep, oxen... One TLU equals to a 250kg cow; heifer beef = 0.8 TLU; bull = 0.8 TLU; young bull = 0.8 TLU; calf = 0.8 TLU; camel = 0.8 TLU; sheep = 0.8 TLU; goat = 0.8 TLU. To take account of different life system, this indicator was inversely weighted according to the weighting coefficients of the early warning system institution (0.6 for the pastoral zone, 0.32 for agropastoral zone, and 0.06 for agricultural zone. For instance, a household having 2 TLU in pastoral zone will have a value of 2/0.6 = 3.33 and will have 2/0.06 = 33.33 in agricultural zone. The thresholds for this indicator are the following:

0 TLU does not own animals (rank = 1);
between 0 and 0.05 have very few animals (rank = 2);
between 0.05 and 0.21 have some animals (rank = 3);
greater than 0.21 have many animals (rank = 4).

c) Household spending

The following thresholds were considered for expenses:
< 0.4 US $ / day / person, very expense low (rank = 1);
> 0.4 US $ / day / person and < 0.6 US $ / day / person, low expense (rank = 2);
> US $ 0.6 and < 0.8 US $, average expense (rank = 3);
> 0.8 US $ / day / person, high expense (rank = 4).

For each household, the value for each indicator was compared with the calculated thresholds and rank has assigned.

37 *Some variables underwent preliminary transformations*

vii. Principal component analysis based on the assigned ranks was calculated so as to define a set of homogeneous households based on the indicators.
viii. Adjustment and consolidation of households obtained on the basis of additional indicators characterizing household food security and the livelihood risk.
ix. Characterization household profile affected by food insecurity or risk to their livelihoods.
x. Identification of departments, regions, agroecological zones based on the proportions of households in food insecure.

Description of the model

The dependent variable, food security status is a categorical variable. Food security categories used were: 0 = safe; 1 = moderate; 2 = at risk; 3 = severe

In our case, it can be set as following :

$$\mathbf{Prob}(\mathbf{Y_i} = \mathbf{j}|\mathbf{w_i}) = \frac{e^{w_i' \alpha_j}}{\sum_{j=0}^{3} e^{w_i' \alpha_j}} = \mathbf{Prob}(\mathbf{Y} = \mathbf{1}|\mathbf{X_i}), j = 0, 1, \dots, 3 \qquad (1)$$

The estimated equations provide a set of probabilities for the J + 1 choices for a decision maker with characteristics w_i.

Before proceeding, we must remove an indeterminacy in the model. A convenient normalization that solves the problem is $\alpha_0 = 0$. (This arises because the probabilities sum to one, so only J parameter vectors are needed to determine the J + 1 probabilities.) Therefore, the probabilities are :

$$\mathbf{Prob}(\mathbf{Y_i} = \mathbf{j}|\mathbf{w_i}) = P_{ij} = \frac{e^{w_i' \alpha_j}}{1+\sum_{j=1}^{J} e^{w_i' \alpha_j}} = \mathbf{Prob}(\mathbf{Y} = \mathbf{1}|\mathbf{X_i}), j\ 0, 1, \dots, J \qquad (2)$$

In this model, the coefficients are not directly tied to the marginal effects. The marginal effects for continuous variables can be obtained by differentiating (2) with respect to a particular factor w_m to obtain :

$$\frac{\partial P_{ij}}{\partial w_{im}} = ((P_{ij}\ (\mathbf{1}(\mathbf{j} = \mathbf{m}) - P_{im})), m = 0, 1, \dots, J \qquad (3)$$

It is clear that through its presence in Pij and Pim, every attribute set w_m affects all the probabilities. One might prefer to report elasticities of the probabilities. The effect of attribute k of choice m on Pij would be :

$$\frac{\partial lnP_{ij}}{\partial lnw_{mk}} = w_{mk}(P_{ij}\ (\mathbf{1}(\mathbf{j} = \mathbf{m}))\alpha_k \qquad (4)$$

In the multinomial logit model, we estimate a set of coefficients, α (1), α (2), and α (3), corresponding to each outcome :

$$\mathbf{Prob}\ (\mathbf{y} = \mathbf{1}) = \frac{e^{w'\alpha(1)}}{e^{w'\alpha(1)} + e^{w'\alpha(2)} + e^{w'\alpha(3)}} \qquad (5)$$

$$\mathbf{Prob}\ (\mathbf{y} = \mathbf{2}) = \frac{e^{w'\alpha(2)}}{e^{w'\alpha(1)} + e^{w'\alpha(2)} + e^{w'\alpha(3)}} \qquad (6)$$

$$\mathbf{Prob}\ (\mathbf{y} = \mathbf{3}) = \frac{e^{w'\alpha(3)}}{e^{w'\alpha(1)} + e^{w'\alpha(2)} + e^{w'\alpha(3)}} \qquad (7)$$

Setting α (1) = 0, the equations become :

$$\textbf{Prob } (y = 1) = \frac{1}{1+e^{w'\alpha(2)}+e^{w'\alpha(3)}} \tag{8}$$

$$\textbf{Prob } (y = 2) = \frac{e^{w'\alpha(2)}}{1+e^{w'\alpha(2)}+e^{w'\alpha(3)}} \tag{9}$$

$$\textbf{Prob } (y = 3) = \frac{e^{w'\alpha(3)}}{1+e^{w'\alpha(2)}+e^{w'\alpha(3)}} \tag{10}$$

For instance, the relative probability of y = 2 to the base outcome is :

$$\frac{\textbf{Prob } (y=2)}{\textbf{Prob } (y=1)} = e^{w'\alpha(2)} \frac{\textbf{Prob } (y=2)}{\textbf{Prob } (y=1)} = e^{w'\alpha(2)} \tag{11}$$

Let's call this ratio the relative risk. The relative risk ratio for a one-unit in w_i is then $e^{\alpha(2)}e^{\alpha(2)}$. Thus, the exponential value of a coefficient is the Relative-Risk Ratio (RRR) for a one-unit change in the corresponding variable (risk is measured as the risk of the outcome relative to the base outcome). In terms of the process for choosing the best model, it is based on the log likelihood. We used an ascending procedure starting to put in the model, among the explanatory variables, a variable which is the most associated with the dependent variable according to the bivariate descriptive analysis. Then, the other variables are successively added to the model according to their degree of association revealed in the descriptive analysis; if the addition of a variable increases the log-likelihood it is kept in the model. The final model is one that maximizes the likelihood log and contains the maximum of variables of which at least one modality is statistically significant.

RESULTS AND DISCUSSION

In Table 1, at 10% confidence level, all the independent are associated to food insecurity except age, daily milk expense and daily meat expense. Regarding the sex of household head, female is slightly the most affected by food insecurity than male: severe 8.6% against 6.0%, moderate 7.1% against 7.5%, at risk 34.9% against 29.6%, secure 49.4% against 57%. The table shows that households who possess the most animals are less affected by severe food insecurity than households without animals: 5.1% against 12.7%.

In the last 12 months, the following is the proportion of households in severe food insecurity: households who have operated field or gardens 6.0% against 9.4% who have not, households who have spent in education 5.8% against 6.9% who have not, households who have spent in agricultural tools or seeds 5.0% against 5.5% who have not. Households who have experienced flood over the last or the last 3 years are less food secure 52.7% than households who did not 80.9%. The severe food insecurity affects those who are the most exposed to drought occurrence 11.5% than those who are not 5.4% and are those whose households are less food secure 53.0% against 56.7%. The table shows the depth of food insecurity in rural areas whether it is severe, moderate or risky. The conclusion is that food insecurity sets apart no body when it occurs (see Table 1).

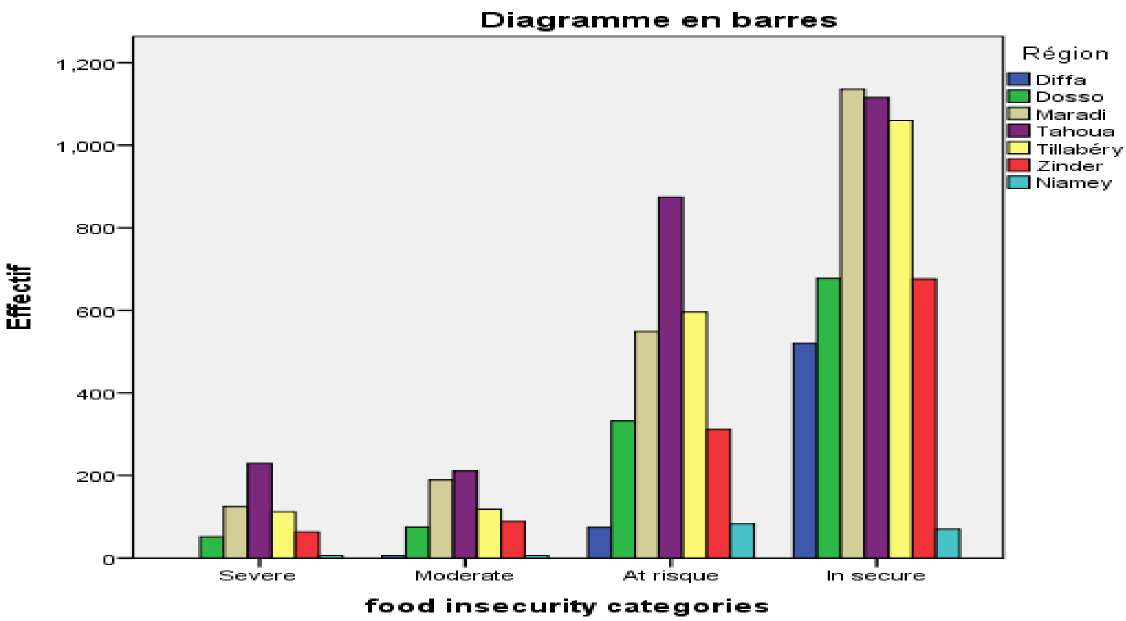
Table 1: Bivariate descriptive analysis test between dependent and independent variables

Independent variables	**Dependent variable** : Food security categories				
	Severe	Moderate	At risk	safe	**P value Chi 2**
Household size					0.000
Age					.266
Household sex					.000
1 = Male (outcome)	6.0%	7.5%	29.6%	57%	
2 = Female	8.6%	7.1%	34.9%	49.4%	
Animal possession	5.1%	6.5%	27.8%	60.6%	
1 = yes	12.7%	12.3%	42.7%	32.3%	.000
2 = no (outcome)	6.0%	7.2%	29.9%	56.9%	
	9.4%	7.4%	31.9%	48.7%	
Number of fields / gardens operated					.082
Education spending last 12 month					
1 = yes	5.8%	7.9%	30.0%	55.3%	
2 = no (outcome)	6.9%	7.1%	30.2%	56.9%	
		7.9%	30.0%	55.3%	
		7.1%	30.2%	56.9%	
Agricultural/tools/seeds spending this year					
1 = yes	5.0%	5.9%	28.7%	60.3%	.000
2 = no (outcome)	8.0%	9.5%	31.9%	57.1%	
Flood					
1 = yes	9.0%%	8.1%%	30.1%	52.7%	.000
2 = no (outcome)	5.5%%	7.2%	30.1%	80.9%	
Drought					
1 = yes	11.5%	6.9%	28.5%	53.0%	.000
2 = no (outcome)	5.4%	7.5%	30.3%	56.7%	
Daily milk consumption expense					.456
Daily fruits consumption expense					.087
Daily meat consumption expense					.293
Daily cooked food consumption expense					.002

Source: author, 2018

The distribution of food insecurity in rural areas in the different regions is shown in Figure 2. The figure shows that households in food secure are larger than those at risk and only few of them are in severe or moderate food security. Niger is ranked among the poorest in the world and its economy remains dominated by the primary sector. Despite its importance, agriculture is struggling with its modernization and is largely dependent on weather conditions. In addition, the high population growth of the country is increasing pressure on land with a resulting continuous farms fragmentation and the expansion of crops on marginal land with decreasing returns. This heavy dependence on rain-fed agriculture predisposes the country to a great food vulnerability and years of low agricultural production generally result in recurrent food crisis whose breadth and depth vary depending on the level of deficit and the prevailing cyclical factors. The year 2009/2010 was a year of acute pastoral and nutrition food crisis which affected the half population of Niger. The crisis has also resulted in large losses of animals due to lack of pasture, high rainfall and flooding.

Figure 2: Food insecurity in rural areas by regions
Source: Author, 2018.



The interpretation of our results concerns the relative risk ratios (RRR) instead of regression coefficients the probability threshold is set at 10%. The numerical values of the coefficients do not have direct interpretation; however, their positive or negative signs are interpretable. The sign indicates whether the probability of observing a particular category of the dependent variable is an increasing or decreasing function of the corresponding predictor or explanatory variable (all other things being equal). Thus, the results of the table above call for several comments. The coefficient regression of household size is significantly positive: the number of household members increases the probability for a household to be severely food insecure. Age is a factor that reduces the probability for a household to be severely food insecure or at risk. The probability for a household to be severely food insecure, moderate or at risk, decreases with animal possession. The number of fields or gardens cultivated reduces the probability for a household to be exposed to food insecurity (severe, moderate or at risk).

The share of household spending devoted to education exposes a household to food insecurity vulnerability. Agricultural/tools/seeds spending make household better off with against food insecurity. Experiencing climate stress event such as flood and drought increases the probability for a household to be severely food insecure, moderate or at risk. Food insecurity is moderate for households who spend in milk, fruits and meat consumption. The value of the relative risk is interpreted as follow: if the factor studied does not play a causal role, there should be no difference in incidence between those exposed and non-exposed: in this case, the relative risk must be equal to 1; if it is greater than 1, this means that the presence of factor causes an increase in the probability of occurrence of the disease (or a decrease in the probability if it is less than 1). A relative risk of 3 (or 10) should be interpreted as follows: the subjects exposed to the risk factor have a probability 3 times (10 times) higher to have the disease than the non-exposed.

The term relative risk is that the incidence is a measure of the risk of disease in the population (recall that the risk is the probability of an event).

The relative risk is the ratio of two risks (the risk for the exposed and the risk for the unexposed). A RRR < 1 indicates a beneficial effect, a RRR > 1 indicates a negative effect, a RRR = 1 indicates that the event frequency is the same for the exposed group and the unexposed group.

The analysis of the different climatic projections by AGRHYMET indicates that food security is far from being provided in the future. There is a visible gap between the food needs of a fast-growing population and probable agricultural production. Under the influence of population pressure, the gap could, in the long term, have an exponential trend (resulting in a demand/probable production balance sheet) that will always be negative because millet, sorghum and cowpea are incredibly sensitive to their environmental conditions and production. The major impact of rainfall decline will be soil degradation, decline in agricultural production, and chronic distribution of food supply. There is also an expected continuous large-scale movement of populations, an increase in diseases, and an important loss in terms of biodiversity. The evolution of agricultural production in the Sahel countries, in general, and in Niger, in particular, during the last twenty years showed that one out of two years resulted in a deficit. Indeed, if the crop year 2005/2006 was characterized by a grain surplus of 21.000 tons at the national level, that of 2004/2005 recorded a deficit of about 223.000 tons.

All other things being equal, compared with food security, households with higher size have a probability 1.087 times higher to be severely food insecure in the exposed group than in the unexposed group. Compared with food security, heads of household with higher age have a probability 0.989 times lower to be severely food insecure and a probability 0.994 times lower to be at risk in the unexposed group than in the exposed group respectively. Compared with food security, the probability is 0.217 to 0.356 times lower to be food insecure or at risk for households possessing animals than households without animals. In relation to food security, households with higher number of cultivated fields are more than .9 times less likely to be severely food insecure, moderate or at risk in the unexposed group than in the exposed group. When compared with food security, households who spend in the education of their children in the last 12 months have a probability more than 1.394 higher to be affected by severe food insecurity, moderate or at risk than households who devote any part of their budget in the education of their children in the last 12 months. Compared with food security, the probability of being in severe food insecurity, moderate or at risk, is more than 0.470 lower for households who spent in agriculture in the year than households who spent any part of their budget in agriculture.

Table 2: Multinomial logistic regression coefficients

Multinomial logistic regression			Number of obs = 3182			
				LR chi2(39) = 278.47		
				Prob > chi2 = 0.0000		
Log likelihood = -2998.6656		McFadden R 2 or Pseudo R2 = 0.0444				
	Dependent variable: Food security categories: safe is taken as the reference category					
Independent variables	Severe		Moderate		at risk	
	Coef	P value	Coef	P value	Coef	P value
Household size	.084*	0.000	.027	0.178	.015	0.211
Age	-.010***	0.080	-.001	0.788	-.005**	0.040
Household sex						
1 = Male (reference)						
2 = Female						
	.340	0.279	-.279	0.377	.173	0.290
Animal possession						
1 = yes						
2 = no (reference)						
	-1.526*	0.000	-1.032*	0.000	-1.147*	0.000
Number of fields / gardens operated	-.191**	0.006	-.370*	0.000	-.095*	0.001
Education spending last 12 month						
1 = yes						
2 = no (reference)						
	.494***	0.009	.509*	0.001	.332*	0.000
Agricultural/tools/seeds spending this year						
1 = yes						
2 = no (reference)						
	-.554**	0.002	-.753*	0.000	-.171***	0.056
Flood occurrence this year						
1 = yes						
2 = no (reference)						
	.647*	0.001	.751*	0.000	.073**	0.500
Drought occurrence this year						
1 = yes						
2 = no (reference)						
	.456**	0.050	.042	0.841	.192	0.123
Daily milk consumption expense	.017	0.779	-.141***	0.090	.010	0.743
Daily fruits consumption expense	-.055	0.872	.134	0.141	-.411***	0.067

Daily meat consumption expense	.064	0.641	-.379**	0.043	-.095	0.274
Daily cooked food consumption expense	-.032	0.661	.064	0.166	-.025	0.464

Source: author, 2018. *, ** and *** indicates the 1%, 5% and 10% significance level of regression coefficient for respective variables in the table.

Compared with food security, households who experienced flood occurrence in the year, have a probability 1.910 times higher, 2.120 times higher and 1.076 times higher to be affected by food insecurity whether it is severe, moderate or at risk respectively than households who did not suffer from flood occurrence in the year. Compared with food security, households who suffered from drought occurrence in the year, have a probability 1.577 times higher to be severely food insecure than households who did not experience drought occurrence in the year.

In comparison with food security, households with higher daily milk consumption expense are 0.868 less likely to be affected by food insecurity (moderate) in the unexposed group than in the exposed group. Compared with food security, households with higher daily fruits consumption expense are 0.662 less likely to be affected by food insecurity (at risk) in the unexposed group than in the exposed group. Compared with food security, households with higher daily meat consumption expense are .684 less likely to be affected by food insecurity (moderate) in the unexposed group than in the exposed group.

Table 3: Relative risk associated to food insecurity

Multinomial logistic regression		Number of obs = 3182				
				LR chi2(39) = 278.47		
				Prob > chi2 = 0.0000		
Log likelihood = -2998.6656 McFadden R 2 or Pseudo R2 = 0.0444						
	Dependent variable: Food security categories: safe is taken as the reference category					
Independent variables	Severe		Moderate		at risk	
	RRR	P value	RRR	P value	RRR	P value
Household size	1.087*	0.000	1.028	0.178	1.015	0.211
Age	.989***	0.080	.998	0.788	.994**	0.040
Household sex						
1 = Male (reference)						
2 = Female	1.405	0.279	.756	0.377	1.188	0.290
Animal possession						
1 = yes	.217*	0.000	.356*	0.000	.317*	0.000
2 = no (reference)						
Number of fields / gardens operated this year	.825*	0.006	.690*	0.000	.908*	0.001
Education spending this year						
1 = yes	1.640*	0.009	1.665*	0.001	1.394*	0.000
2 = no (reference)						

Agricultural/tools/seeds spending this year						
1 = yes	.574**	0.002	.470*	0.000	.842***	0.056
2 = no (reference)						
Flood occurrence this year						
1 = yes	1.910*	0.001	2.120*	0.000	1.076**	0.500
2 = no (reference)						
Drought occurrence this year						
1 = yes	1.577**	0.050	1.043	0.841	1.212	0.123
2 = no (reference)						
Daily milk consumption expense	1.017	0.779	.868***	0.090	1.010	0.743
Daily fruits consumption expense	.945	0.872	1.144	0.141	.662***	0.067
Daily meat consumption expense	1.066	0.641	.684**	0.043	.908	0.274
Daily cooked food consumption expense	.968	0.661	1.066	0.166	.974	0.464

Source: Author, 2018. *, ** and *** indicates the 1%, 5% and 10% significance level of regression coefficient for respective variables in the table.

This study shows that the number of individuals to feed exposes a household to severe food insecurity. This situation is due to the fact that more than seven in ten households live in poverty in poverty, in rural areas, the majority of households (71%) have their income below the poverty line (Illa, 2015) and poor households are the most exposed to food insecurity (Kimani Murage-EW et al, 2014; Chinnakali P. et al, 2014; Vogt and Tarasuk V. J, 2009). Any policy encouraging the reduction of household members can increase the probability for the household to be food secure. The age of the household head has positive and significant relationship with household food security (Fekadu Beyene and Mequanent Muche, 2010). Age is a factor that reduces vulnerability to food insecurity because of the experiences accumulated in the past in agricultural practices.

Animal possession and number of fields operated make households better off as they can sale few animals and/or fields as coping strategies to protect themselves against food insecurity. In rural areas, larger livestock and/or fields are important indicator of wealth. Households possessing larger livestock and fields are found to be less vulnerable to food insecurity in Ethiopia (Fekadu Beyene and Mequanent Muche, 2010). Extending arable and grazing land area can contribute to reduce the probability of households to be food insecure. Education expenses are a burden for food insecure households, this seems logical since the education expenses reduce the share of food expenditures for households who struggle to achieve food security. Agricultural expenditure on seeds and fertilizers improve soil fertility and crop yields resulting in food insecurity reduction. Policy implication granting seed and fertilizer subsidies will increase the probability of households to be food secure.

Drought and flood are constant threats to food insecurity affecting several sectors and resulting in income losses. The supply reduction causes food prices to rise making it difficult for the households to meet the food needs of its members. Food insecurity has become more frequent in recent years because of drought and flood occurrence with many severe impacts including crop losses, lower yields in both crops and livestock production, land degradation and soil erosion.

CONCLUSION

This study has showed the determining factors that are significantly linked to food insecurity in rural areas. The most affected households are those having large size, those who devote a part of their expenses in the education of their children in the year preceding the food insecurity occurrence, and those who have experienced flood and drought event in the year preceding the food insecurity occurrence. From the model results, we learn that animal possession, the number of cultivated fields, expenses on agricultural tools and seeds reduce the risk of exposure to food insecurity. In view of these results, for the effectiveness of the fight against food insecurity, a political from authorities that strives to master the control factors associated with it is needed. Policies and strategies that involve the control of agricultural input prices and subsidies on chemical fertilizers and seeds are essential to sustain the fight against food insecurity. The lack of such a policy could make it difficult for households to purchase agricultural inputs if there is a rise of input prices because of the depletion of food supply as a result of drought or flood. It is important to study the determinants of food insecurity but it is also interesting, for further research, to find out what are the strategies developed firstly by households in food security to address food insecurity and secondly by those who suffer.

REFERENCES

Adams, R. M. (1989). Global climate change and agriculture: An economic perspective. American Journal of Agricultural Economics Vol. 71, Issue 5, pages 1272–1279.

Adger, W. N. (2000). Social and ecological resilience: are they related? Progress in Human Geography. Sage Journals, Vol. 24, Issue 3, pages 347-364.

Adger, W. N., (1999). Social Vulnerability to Climate Change and Extremes in Coastal Vietnam, 1999. World Development Vol.27, Issue.2, pages. 249-269, 1999.

Adger, W. N., & Vincent, K. (2005). Uncertainty in Adaptive Capacity. C R Geoscience, Vol. 337, Issue 4, March 2005, pages 399 - 410.

Adger, W. N., N. Brooks, G. Bentham, M. Agnew and S. Eriksen (2004). New indicators of Vulnerability and adaptive capacity. Norwich, UK: Tyndall Centre for Climate Change. Technical report, 7.

Adger, W. N., & Kelly, P. M. (1999). Social Vulnerability to Climate Change and the Architecture of Entitlements. Mitigation and Adaptation Strategies for Global Change, Springer, Vol. 4, Issue 3, pages 253 - 266.

Ahmad, J, A. Dastgir, and S. Haseen (2011), 'Impact of climate change on agriculture and Food security in India', International Journal of Agricultural Environmental and Biotechnology, Vol. 4, Issue 2, pages 129-137.

Allen, K. (2003). Vulnerability reduction and the community-based approach: A Philippines study. In Natural Disasters and Development in a Globalizing World, ed.

M. Pelling, pages 170–184, New York: Routledge, Taylor & Francis Group, chapter 11|15 pages.

Brooks, N., W. N. Adger, and P. M. Kelly. (2005). The determinants of vulnerability and adaptive Capacity at the national level and the implications for adaptation. Global Environmental Change, Vol. 15, Issue 2, pages 151–163.

Brooks, N. (2003). Vulnerability, Risk and Adaptation: A Conceptual Framework. Working Paper 38. Norwich: Tyndall Centre for Climate Change Research.

Campbell, D. (1999). Response to Drought among Farmers and Herders in Southern Kajiado District, Kenya: A Comparison of 1972-1976 and 1994-1995. Human Ecology, Vol. 27, Issue 3, pages 377-416. Retrieved October 14, 2020, from http://www.jstor.org/stable/4603327.

Chaudhuri, S., J. Jalan, and A. Suryahadi. (2002). Assessing household vulnerability to poverty: A Methodology and estimates for Indonesia. Department of Economics Discussion Paper 0102-52. New York: Columbia University.

Chen, J.T., Rehkopf, D.H., Waterman, P.D., Subramanian, S.V., Coull, B.A., Cohen, B., Ostrem, M., Krieger, N., (2006). Mapping and measuring social disparities in premature mortality: The impact of census tract poverty within and across Boston neighborhoods, 1999-2001. Journal of Urban Health, 2006, Nov: Vol. 83, Issue 6, pages 1063-1084. doi: 10.1007/s11524-006-9089-7, PMID: 17001522.

Coates, J., P. Webb, and R. Houser (2003). 'Measuring Food Insecurity: Going Beyond Indicators of Income and Anthropometry'. Washington, DC: Food and Nutrition Technical Assistance Project. FHI 360, 2003. Academy for Educational Development. www.fantaproject.org.

Cook et al., (2011). Forced and unforced variability of twentieth century North American droughts and pluvials. Clim. Dyn., Vol. 37, pages 1097-1110, doi:10.1007/s00382-010-0897-9.

Cutter, S. L., Emrich, C. T., Webb, J. J., & Morath, D. (2009). Social Vulnerability to Climate Variability Hazards: A Review of Literature. Final Report to Oxfam America. CiteSeer^{X}. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.458.7614

Cutter, S. L. (1996). Vulnerability to Environmental Hazards. Progress in Human Geography, Vol.20, Issue 4, pages 529 - 539.

Cutter, S.L., Jerry T. Mitchell & Michael S. Scott (2000) Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina, Annals of the Association of American Geographers, Vol.90, Issue 4, pages 713-737. DOI: 10.1111/0004-5608.00219.

Deressa, Temesgen & Hassan, Rashid & Ringler, Claudia & Alemu, Tekie & Yesuf, Mahmud. (2008). Analysis of the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia [in Amharic] : International Food Policy Research Institute (IFPRI), Research briefs, Vol. 15, Issue 9.

Eriksen, S. H., and P. M. Kelly. (2007). Developing credible vulnerability indicators for climate Adaptation policy assessment. Mitigation and Adaptation Strategies for Global Change, Vol. 12, Issue 4, pages 495–524. DOI: 10.1007/s11027-006-3460-6.

Fekadu Beyene & Muche, Mequanent, (2010). "Determinants of Food Security among Rural Households of Central Ethiopia: An Empirical Analysis," Quarterly Journal of International Agriculture, Humboldt-Universitaat zu Berlin, Vol. 49, Issue 4, pages 1-20.

Forner, C. (2006). An introduction to the impacts of climate change and vulnerability of forests. Background document for the South East Asian meeting of the Tropical Forests and Climate Change Adaptation (TroFCCA) project. Bogor, West Java (May 29–30).

Füssel, H.-M., and R. J. T. Klein. (2006). Climate change vulnerability assessments: An Evolution of conceptual thinking. Climatic Change Vol. 75, Issue 3, pages 301–329. DOI : 10.1007/s10584-006-0329-3.

Füssel, H. (2007). Vulnerability: A generally applicable conceptual framework for climate change Research. Global Environmental Change, Vol. 17, Issue 2, pages 155-167.

Gbetibouo, G. A., & Ringler, C. (2009). Mapping South African Farming Sector Vulnerability to Climate Change and Variability. A Sub National Asssessment. IFPRI Discussion paper 00885.

Greg, E.E., B.E. Anam, M.F. William, and EJC Duru (2011), Climate change, food security and agricultural productivity in African: Issues and policy directions', International Journal of Humanities and Social Science, Vol. 1, Issue 21, pages 205-223.

Grolle, J. (1997). 'Heavy rainfall, famine, and cultural response in the West African Sahel: the "Muda" of 1953–54', Geo Journal, Vol. 43, No. 3, pages. 205–214.

Haddad, B. M. (2005). Ranking the adaptive capacity of nations to climate change when socio-Political goals are explicit. ILLA, E.I. (2015). Integrated assessment of vulnerability of rural households to climate stress across regional levels in Niger. Global Environmental Change, Vol. 15, pages 165-176.

IPCC, Intergovernmental panel on Climate Change. (2001). Climate change 2001: Impacts, Adaptation and Vulnerability. Cambridge University Press.

International Food Policy Research Institute (IFPRI) (2009). Mapping South African farming sector vulnerability to climate change and variability. Assessment. IFPRI Discussion Paper 00885. Washington, DC. Ifpridp00885 1.

Jakobsen, K. (2011). Livelihood asset maps: a multidimensional approach to measuring Risk- Management capacity and adaptation policy targeting-a case study in Bhutan. Regional Environmental Change, Vol. 12, Issue 2. DOI 10.1007/s10113-012-0320-7.

Kaiser, H. M., S. J. Riha, D. S. Wilks, D. G. Rossiter, and R. K. Sampath. (1993). A farm-level Analysis of economic and agronomic impacts of gradual warming. American Journal of Agricultural Economics, Vol. 75, Issue 2, pages 387–98. https://doi.org/10.2307/1242923

Kelly, P. M., and W. N. Adger. (2000). Theory and practice in assessing vulnerability to climate Change and facilitation adaptation. Climatic Change, Vol. 47, Issue 4, pages 325-352.

Kimani-Murage E. W, Schofield L, Wekesah F, Mohamed S, Mberu B., Ettarh R, Egondi T, Kyobutungi C, Ezeh A. (2014), « Vulnerability to Food Insecurity in Urban Slums: Experiences from Nairobi, Kenya, Journal of Urban Health: Bulletin of the New York Academy of Medicine, , Vol. 91, Issue 6, pages 1098-113. doi:10.1007/s11524-014-9894-3.

Martens, P., R. Kovats, S. Nijhof, P. de Vries, J. Livermore, D. Bradley, et al. (1999). Climate Change and future populations at risk of malaria. Global Environmental Change, Vol. 9, Issue 1, pages 89–107.

McCarthy, J., O. F. Canziani, N. A. Leary, D. J. Dokken, and C. White, eds. (2001). Climate Change 2001: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Third assessment report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press. https://library.harvard.edu/sites/default/files/static/collections/ipcc/docs/27_WGIITAR_FINAL.pdf.

Mendelsohn, R., W. Nordhaus, and D. Shaw. (1994). The impact of global warming on Agriculture: A Ricardian analysis. The American Economic Review. Vol. 84, pages 753-771. https://www.jstor.org/stable/2118029.

Nelson, R., Kokic, Crimp, S., Meinke, H., & Howden, S. M. (2010a). The vulnerability of Australian Rural Communities to Climate Change Variability and Change. Environmental Science & Policy, volume 13, Issue 1, February, 2010, pages 8-17.

Nelson, R., Kokic, P., Crimp, S., Martin, P., Meinke, H., Howden, S. M., et al. (2010b). The Vulnerability of Australian Rural Communities to Climate Variability and Change: Part II - Integrating Impacts with Adaptive Capacity. Environmental Science and Policy, Vol.13, pages 18-27.

O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., Javed, A., Bhadwal, S., Barg, S., Nygaard, L., West, J., (2004). Mapping vulnerability to multiple Stressors: climate change and globalization in India. Global Environmental change, Vol. 14, pages 303-313.

Olsen, J. E., P. K. Bocher, and Y. Jensen. (2000). Comparison of scales of climate and soil data for Aggregating simulated yields in winter wheat in Denmark. Agriculture, Ecosystem and Environment, Vol. 82, issue 3, pages 213–228.

Oluoko-Odingo, and A. Alice (2009), 'Determinants of poverty: lessons from Kenya', Geo Journal, Vol.74, pages 311–331. DOI 10.1007/S10708-008-9238-5.

Paeth, H., Fink, A. and Samimi, C. (2009). The 2007 Flood in sub-Saharan Africa: Spatio-Temporal characteristics, potential causes, and future perspective, EMS Annual Meeting Abstracts, Vol. 6, EMS 2009-103.

Polsky, C., and W. E. Esterling. (2001). Adaptation to climate variability and change in the US Great Plains: A multi-scale analysis of Ricardian climate sensitivities, Vol. 85 Issue 1-3, pages 133–144.

Ramasamy, J., and P. Moorthy (2012), Managing food insecurity and poverty in India in the area of globalization, International Journal of Multidisciplinary Research, Vol. 2, Issue 1, ISSN 2231 5780.

Rukhsana (2011), 'Dimension of food security in a selected state Uttar Pradesh', Journal of Agricultural Extension and Rural Development Vol. 3, Issue 2, pages 29-41.

Sanghi, A., R. Mendelsohn, and A. Dinar. (1998). The climate sensitivity of Indian agriculture. In measuring the impact of climate change on Indian agriculture, ed. A. Dinar et al. (Technical Paper 402). Washington, DC: World Bank.

Schmidhuber, J., and F.N. Tubiello (2007), 'Global food security under climate change', Proceedings of the National Academy of Sciences of the United States of America. Vol. 104, Issue 50, pages 581-596.

Shakeel, A., A. Jamal, and M.N. Zaidy (2012), 'A regional analysis of food security in Bundelkh and region Uttar Pradesh (India)', Journal of Geography and Regional Planning, Vol. 5, Issue 9, pages 252-262.

Temesgen Deressa, Rashid M. Hassan and Claudia Ringler. (2008). Measuring Ethiopian Farmer's Vulnerability to Climate Change across Regional States.

UNDP, (2007). Human development reports. http://hdr.undp.org/en/ (accessed 25 December 2007).

UNEP. (2004). Poverty-biodiversity mapping applications. In: Presented at: IUCN World Conservation Congress, Bangkok, Thailand, pages 17-25 November 2004.

USAID (2007a). Famine Early Warning Systems-NETwork (FEWS-NET). http://www.fews.net/ (Accessed 24 December 2007). Villers-Ruiz, L., and I. Trejo-Vázquez. 1997. Assessment of the vulnerability of forest Ecosystems to climate Change in Mexico. Climate Research 9 (December): pages 87–93.

Vincent, K. (2004). Creating an index of social vulnerability to climate change for Africa. Working Paper 56. Norwich: Tyndall Center for Climate Change Research.

Vincent, K., & Cull, T. (2010). A Household Social Vulnerability Index (HSVI) for Evaluating Adaptation Projects in Developing Countries. Paper presented in PEG Net Conference 2010, Policies to Foster and Sustain Equitable Development in Times of Crises, Midrand, 2nd -3rd September 2010.

Watson, R. T., Zinyowera, M. C., & Moss, R. H. (1996). Adaption and Mitigation of Climate Change. Scientific-Technical Analysis, Cambridge University Press, 1996, ISBN 0 521 56431 X (hb), 0 521 56437 9 (pb)

World Food Program. (2007). Vulnerability Analysis and Mapping tool for targeting food aid. https://docs.wfp.org/api/documents/WFP-0000040024/download/

Xiao, X., et al., (2002). Transient climate change and potential croplands of the world in the 21st Century. Massachusetts Institute of Technology, Joint Program on the Science and Policy of Global Change, Report No. 18. Cambridge: MIT. https://dspace.mit.edu/handle/1721.1/3631

Yohe, G., & Richard S.J Tol (2002). Indicators for social and economic coping capacity-moving toward a working definition of adaptive capacity. Global Environmental Change Vol. 12, pages 25-40.

CO_2 Emission and Economic growth in Sub-Sahara countries : Is there a Kuznets curve ?

Owodon Afo-Loko

ABSTRACT

Could there be an environmental Kuznets curve between economic growth and carbon dioxide emissions (CO_2) in sub-Sahara countries? This paper explored the puzzle using data from 2010 to 2017. The study used the GMM (Generalized Method of Moments) model to determine the relation between CO_2 emission and economic growth. Secondary data were extracted from the databases of the World Bank. The variables used to measure economic growth were National Gross Domestic Product (GDP) and agricultural value added. The results showed that for both variables, there is no inverted U-shaped environmental Kuznets curve between CO_2 emissions and economic growth in sub-Saharan countries. However, an Inverted N shaped curve was obtained. Therefore, more actions must be taken in the growth and development procedure of Sub-Saharan countries in order to protect the environment through adaptation or mitigation strategies.

Keywords: Carbon dioxide emissions, Economic growth, Environmental Kuznets curve, GMM, Sub-Saharan Africa

RÉSUMÉ

Pourrait-il y avoir une courbe de Kuznets environnementale entre la croissance économique et les émissions de dioxyde de carbone (CO_2) dans les pays sub-sahariens ? Cet article a exploré cette énigme en utilisant des données de 2010 à 2017. L'étude a utilisé le modèle GMM (Generalized Method of Moments) pour déterminer la relation entre les émissions de CO_2 et la croissance économique. Les données secondaires ont été extraites des bases de données de la Banque mondiale. Les variables utilisées pour mesurer la croissance économique étaient le produit intérieur brut (PIB) national et la valeur ajoutée agricole. Les résultats ont montré que pour les deux variables, il n'existe pas de courbe de Kuznets environnementale en forme de U inversé entre les émissions de CO_2 et la croissance économique dans les pays subsahariens. Cependant, une courbe en forme de N inversé a été obtenue. Par conséquent, davantage d'actions doivent être entreprises dans la procédure de croissance et de développement des pays subsahariens afin de protéger l'environnement par des stratégies d'adaptation ou d'atténuation.

Mots clés : Émissions de dioxyde de carbone, croissance économique, courbe de Kuznets environnementale, GMM, Afrique subsaharienne.

INTRODUCTION

Global warming is a natural reality with severe impacts on mankind's welfare (Wallace, Held, Thompson, & Trenberth, 2014). To cope with its negative effect, a lot of means are required particularly financial resources to implement projects which can help to adapt and mitigate climate change (Stern, 2007). Hence, Economic growth and development are relevant in achieving environmental protection. However, there is a traditional view that economic growth and environmental quality are conflicting views because it seems that economic activities release greenhouse gases which contribute to environment degradation. Besides, (Beckerman, 1992) have come up with more explanations showing that it's only a high level of economic growth or development which can ensure good environment quality. He then claim that, "there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best and probably the only way to attain a decent environment in most countries is to become rich.

Economic growth, comprehended as an increase in the production capacity of a country's achievement is always having external effects on the environment irrespective of the source of growth; either industrialization, land cultivation, transports; it is followed by emission of greenhouse gases which pollutes the environment (Smith & Martino, 2007). The environment, on the other hand, offers a wide variety of benefits to people. Therefore, the creation of environmental pollution to achieve economic growth has created a situation in the long term which acts against individuals' wellbeing (Ward, 2006). Carbon dioxide (CO_2) emissions, which we consider to be indicative of environmental pollution in our study finds its source in both natural resources and human activities. Whilst economic activities are taking place, pollution of the environment also rises. Consequently, two researchers (Grossman & Krueger, 1991) and (Shafik & Bandyopadhyay, 1992) found it relevant to examine the relationship between environmental pollution and economic growth. The results of these studies are linked to the Environmental Kuznets Curve (EKC); which is considered to be an inverted U-shaped relationship between per capita income and environmental degradation. These were their findings in the early 1990's through cross-country analysis.

The economy of Sub-Sahara countries has shown enormous growth during the last decade (Commission Economique pour l'Afrique, 2017). Consequently, the energy consumption especially in industrial sector has added pollution to the environment, in addition to pollution coming from agricultural sector which mainly contribute to sub-Saharan economic growth. Nevertheless, it is noticed that the agricultural sector is facing great challenges such as lack of irrigation system, pesticides, extension services, infrastructures and financing of research to adapt and cope with climate change effect which makes more farmers vulnerable. As for industrial sector, according to (Goujon & Kafando, 2012) even if industrial sector is less developed the total proportion of industries to GDP is about 25.1%. Middle Industry proportion is about 21.0% while manufacture is 8.4 %. Regarding all this, it is relevant to examine whether there exists an environmental Kuznets curve between economic growth and CO_2 emission in sub-Saharan Africa in order to be able to know the required policy to be implemented to ensure sustainable development. To that end this question arises: Economics Growth and CO_2 emission in sub-Saharan countries: Is there a Kuznets curve?

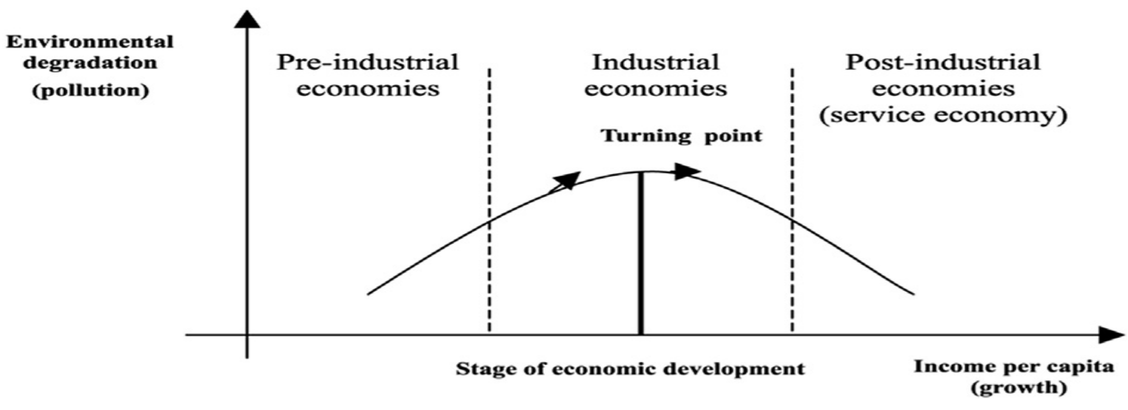
The general objective of this paper is to find the existence of an inverted U shape curve between CO_2 emission and economic growth for sub-Saharan countries. Specifically, it consists of 1-Determining the existence of Kuznets curve between CO_2 emission and economic growth (GDP per LCU) for sub-Saharan countries. 2-Find how agricultural value added impacts environment in a Kuznets curve framework. Numerous studies have been conducted word widely to find the existence of environmental Kuznets curve for both developed and developing countries ((Adu & Denkyirah, 2018), (Aldy, 2005), (Khalid & Wei, 2012)). Many of them just try to know whether there is a Kuznets curve between economic growth and CO_2 emission. This paper in addition is investigating the relation which can exist between agricultural value added and environment degradation since the agriculture sector mainly contribute to economic development in sub-Sahara Africa, and also release a huge amount of CO_2 up 14% of the total CO_2 emitted globally of all sectors. The remaining section of the paper is organized as follow: The first section presented the introduction and the literature review while the second section expounded on the Methodology used in the study and the third section presented the results which was followed by conclusion.

This section presents the theoretical and empirical review around the environmental Kuznets curve. The environmental Kuznets curve is an inverted U-shape relationship between economic growth and environmental degradation. There are others greenhouse gases which can be used to measure environment degradation like CH4, and N2O but in this study CO_2 was considered for environmental degradation measurement. Various econometric approaches are used to test such hypothesis like Autoregressive-Distributed Lag (ARDL), Vector Error Correction Model (VECM), GMM and fixed or random effect findings in the empirical review.

Environmental Kuznets Curve: What does the theory say?

The Environmental Kuznets Curve (EKC) hypothesis has gained the attention of lots of researchers provoking a large body of theoretical and empirical literature. An inverted U-shape relationship between economic growth and environmental degradation is described by the EKC meaning that, environmental degradation increases with economic growth, reaches its maximum level and decreases when the economy reaches the given critical high level of income. The following figure will illustrate the explanation made above.

Figure 1: Environmental Kuznets Curve



Source : Panatoyou (1993)

The Environmental Kuznets Curve (EKC) concept was introduced in the early 1990s by Grossman and Krueger (1991). The main idea was, as the economic growth is increasing, it is also necessary that environmental quality is maintained or improved (World Commission on Environment and Development, 1987). In fact, as revenue increases, the demand for improvements in environmental quality will rise. Beckerman (1992) gave an explanation for this that, "there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best and probably the only way to attain a decent environment in most countries is to become rich". Thus, the traditional view that economic growth and environmental quality are conflicting purposes depends on the scale effect. Indeed, according to (Panatoyou, 1993), the argument of Environmental Kuznets curve is that "at higher levels of development, structural changes towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology, and higher environmental expenditures, result in leveling off and gradual declining of environmental degradation".

Empirical background on carbon dioxide emission and economic growth in a Kuznets curve framework

Many studies have been done to determine the existence of environmental Kuznets curve between CO_2 emission and economic growth, both for developed countries and developing countries. Some of them confirm the existence of the environmental Kuznets curve while others did not (Alsan, Destek, & Ilyas, (2017); Lacheheb, Rahim, & Sirag, (2015); AraBegum, KaziSohag, Abdullah, & Jaafar, (2015).

Others (Alsan, Destek, & Ilyas, 2017) examine the validity of inverted U-shaped Environmental Kuznets Curve by investigating the relationship between economic growth and environmental pollution for the period from 1966 to 2013 in the USA. Their study uses bootstrap rolling window estimation method to detect the possible changes in causal relations and also obtain the parameters for sub-sample periods. The results show the existence of inverted U-shaped Environmental Kuznets Curve in the USA. (Lacheheb, Rahim, & Sirag, 2015), study examines the existence of environmental Kuznets curve (EKC) hypothesis between economic growth and carbon dioxide (CO_2) emission in Algeria for the period 1971-2009 using autoregressive distributed lag co-integration framework. Data were retrieved from World Bank Development Indicators. Findings reveal that EKC hypothesis does not exist.

(AraBegum, KaziSohag, Abdullah, & Jaafar, 2015), investigates the dynamic impacts of GDP growth, energy consumption and population growth on CO_2 emissions using econometric approaches for Malaysia. Empirical results from ARDL bounds testing approach show that over the period of 1970–1980, per capita CO□emissions decreased with increasing per capita GDP (economic growth); however, from1980 to 2009, per capita CO_2 emissions increased sharply with a further increase of per capita GDP.This is also supported by the dynamic ordinary least squared (DOLS) and the Sasabuchi–Lind–Mehlum U (SLM U test) tests. Consequently, the hypothesis of the EKC is not valid in Malaysia during the study period.

(Khalid & Wei, 2012) Investigated the EKC between carbon emission and other four variables (energy consumption, economic growth, trade openness and population) using auto regressive distributed lag (ARDL) methodology for Pakistan from the period of 1971 to 2008. The results do not support EKC in a short-run, whereas the long-run inverted U-shaped hypothesis was confirmed between carbon emission and growth, energy consumption, trade openness and population density. (Saboori n, Sulaiman, & Mohd, 2012) attempt to establish a long-run as well as causal relationship between economic growth and carbon dioxide (CO_2) emissions for Malaysia. For the period (1980 to 2009), the Environmental Kuznets Curve (EKC) hypothesis was tested utilizing the Auto-Regressive Distributed Lag (ARDL) methodology. The findings suggest the existence of a long-run relationship between per capita CO_2 emissions and real per capita Gross Domestic Product (GDP). An Inverted-U shape relationship between CO_2 emissions and GDP was found in both short and long-run. (Aldy, 2005) made additional contributions to the EKC literature by using a novel data set self-constructed of state-level. The results based on standard EKC specifications illustrate that per capita CO_2 emissions may follow an inverted U-pattern with respect to per capita income for the United States during the 1960 to 1999 period.

METHODS

This section consists of presenting the model used for analysis while justifying its choice and then data sources accompanied with variables descriptive statistic. The GMM is used in the study to avoid all the bias which can appear and related to autocorrelation of errors or endogeinity between CO_2 emission and economic growth : The data used in the study are secondary data from world bank on sub-Sahara countries spanning the period of 2010 to 2017. The analytical model will be first presented followed by data sources and then descriptive statistics.

The Model

This study follows ((Baek & Krueger, 2013), (Grossman & Krueger, 1995), (Bandyopadhyay & Shafik, 1992))'s approach for analyzing the impact of economic growth on environment degradation in sub-Sahara countries using GMM model. The GMM is usually practiced in the setting of semi-parametric models in which the parameter of interest is finite dimensional. We use the lagged differences of variables and the constant for the variables as instruments to control multi-collinearity because the lagged dependent variable creates an endogeneity problem, the other dynamic estimators such as Mean Group and Pooled Mean Group, Maximum likelihood may not give robust and consistent results. For example, time invariant unobserved effects, which are included in the error term, will be correlated with the lagged dependent variable causing a dynamic panel bias. Hence, Arellano Bond's (1991) GMM technique is suitable for dynamic panels. A GMM estimator is also efficient when T (time) is short and N (countries) is large. To control for the validity of the instrumental variables for the GMM model the Sargan test will be conducted. Indeed, it is a Chi-square test which determines whether the residuals are correlated with the instrumental variables. We conclude that the instruments are valid and thus there is no indication of instrument mis-specification when we cannot reject the null hypothesis of the Sargan test (Arellano & Bond, 1991).

Empirical evidence for EKC

The data used in these studies are panel data. Therefore, we use the following reduced form model derived from ((Baek & Krueger, 2013), (Grossman & Krueger, 1995), (Bandyopadhyay & Shafik, 1992)) to test the various possible relationships between CO_2 emission and economic growth :

$$y_{it}= \alpha_i+\theta_t +\beta_1 x_{it} +\beta_2 x_{it}{}^2 +\beta_3 x_{it}{}^3+\beta_4 x_{it}\beta_4 x_{it} + \varepsilon_{it} \qquad (1)$$

Where: y y is CO_2 emission, x x is GDP per lcu. Here, the subscript i and t stands for the countries and the time periods, respectively.$\alpha\alpha$is constant and$\beta_k\beta_k$is the coefficient of the polynomials of income variable. The country specific terms capture all fixed factors inherent to each country, which are not considered in the model. The parameter θ_t $\theta_t$denotes a time-varying intercept. x is a vector of variables which can contribute to environmental degradation. This study considers trade of gdp and manufacturing.

$$y_{it}=\alpha_i+\theta_t+\beta_1 x_{it}+\beta_2 x_{it}{}^2+\beta_3 x_{it}{}^3+\beta_4 x_{it}+\Phi y_{(it-1)}+\varepsilon_{it} \qquad (2)$$

The second equation is the GMM equation, which is essentially a dynamic panel equation that accommodates additionally dynamic effects of the dependent variable,

The econometric model we construct above allow us to test several forms of hypothesis between environment and economic growth (DINDA, 2004):

i. $\beta_1=\beta_2=\beta_3=0$ (3)

A flat pattern or no relationship between and

ii. $\beta_1>0$ $\beta_2=\beta_3=0$ (4)

A monotonic increasing relationship or a linear relationship between and

iii.$\beta_1<0$ $\beta_2=\beta_3=0$ (5)

A monotonic decreasing relationship between and

iv. $\beta_1>0$ $\beta_2<0$ $\beta_3=0$ (6)

An Inverted-U-shaped relationship, i.e., EKC.

v.$\beta_1<0$ $\beta_2>0$ $\beta_3=0$ (7)

U-shaped relationship.

vi.$\beta_1>0$ $\beta_2<0$ $\beta_3>0$ (8)

A cubic polynomial or N-shaped curve.

vii.$\beta_1\beta_1<0$ $\beta_2\beta_2>0$ $\beta_3\beta_3<0$ (9)

An inverted N-shaped curve.

Data source

The data uses in this study are secondary data from the World Bank data for 45 sub-Saharan countries from 2010 to 2017.The dependent variable is CO_2 emission kg per purchasing power parity per gdp (CO_2ppgdp); while the explanatory variables are gdp per capita in local currency(gdpcap); agricultural value added ofgdp(Vaagric); trade per gdp(tradeofgdp); manufacturing per gdp (manufact). The descriptive statistics of these variables are given in the following section (Table 1).

Table 1: Descriptive Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
CO_2 ppgdp	1096	0.202	0.191	0.007	1.355
Vaagric	1030	26.465	16.899	0.891	93.977
Gdpcap	1188	406861	974056.6	54.111	39.4649
tradeofgdp	1.140	76.341	46.505	11. 087	531.737
manufact	963	11.233	46.505	11. 087	531.737

Source: Author computation from Stata 14 base on World Bank Data(2010 to 2017)

Note: CO_2 ppgdp means CO_2 emission per gdp; Vaagric is agricultural value added ofgdp; gdpcap is gdp per capital in lcu; tradeofgdp is trade per gdp; manufact is manufacturing per gdp

RESULTS AND DISCUSSION

Economic growth and carbon dioxide emissions

Regarding the results, we can firstly say that the instruments are valid since the Sargantest is significant. Furthermore, we can notice that there is no U-shaped Environmental Kuznets curve between CO_2 emission and economic growth for sub-Saharan countries. Indeed, while examining first the coefficients of CO_2 emission and agricultural value added, we have β_1=-0.002687 β_2= 0.000883 β_3=-8.03e^{-7}which does not respect an inverted U shaped curve conditions according to (Dinda,2004) hypothesis but rather respects an inverted N shaped curve condition where β_1<0 β_2 >0 β_3<0.This means that despite the fact that agricultural value added contributes enough to economic growth in sub-Saharan countries, the level growth cannot reduce environment degradation. There still enough riches to create to improve environment quality (see Table 2).

Table 2: Dynamic panel-data estimation, two-step system GMM for CO_2 emission and dgp per cap (lcu)

Variables Dep. Variable : CO_2pppgdp	**GMM Estimation**	
	Coef.	P>|t|
CO_2 pppgdp_1	.952	0.000
Gdpcap	-2.44e-08	0.000
gdpcap2	1.08e-14	0.000
Gdpca	-1.07e-21	0.000
Tradeofgdp	.001	0.000
Manufact	.023	0.000
Cons	.009	0.000
Arellano-Bond test for AR(1) in first differences	z = -3.25	Pr> z = 0.001
Sargan test	chi2(4) = 10.32	Prob> chi2 = 0.35

Source: Author Estimate from STATA 14 base on World Bank Data (2010 to 2017)

Agricultural value added and carbon dioxide emissions

The same result is observed while examining the existence of an inverted U shaped curve between CO_2 emission and gross domestic product. The coefficients are as followed with the following signs$\beta_1 \beta_1$=-2.44$e^{-8}\beta_2 e^{-8}\beta_2$= 1.08$e^{-14}\beta_3 e^{-14}\beta_3$=-1.07 $e^{-21} e^{-21}$.The non-existence of inverted U shaped relation goes in line with(Lacheheb, Rahim, & Sirag, 2015)and (AraBegum, KaziSohag, Abdullah, & Jaafar, 2015) who also found the non-existence of inverted U shaped curve respectively in Algeria and Malaysia. These results also confirm the existence of an inverted N shaped curve between CO_2 emission and gross domestic product in sub-Saharan countries which explain the view of Beckerman (1992) for whom ''developing countries are too poor to green''. As for controlling variables like trade per gdp and manufacturing per gdp the regression result is showing that they have positive impact on CO_2 emission meaning that as countries trade level increases and manufacturing increase the degradation level also increases (Table 3).

Table 3: Dynamic panel-data estimation, two-step system GMM for CO_2 emission and agricultural value added

Variables Dep. Variable : CO_2 **pppgdp**	GMM System	
	Coef.	P>|t|
CO2pppgdp_1	.9518679	0.000
Vaagric	-.002687	0.000
vaagric2	.0000883	0.000
vaagric3	-8.03e-07	0.000
Tradeofgdp	0.034	0.000
Manufact	0.0112	0.000
_cons	.0237787	0.000
Arellano-Bond test for AR(1) in first differences	z = -3.28	Pr> z = 0.001
Arellano-Bond test for AR(2) in first differences	z = -1.40	Pr> z = 0.161

Source : Author Estimate from Stata 14 base on World Bank Data (2010 to 2017)

CONCLUSION

The purpose of this study is to find whether it exists an environmental U shaped relation, first between CO_2 emission and gross domestic product and then between CO_2 emission and agricultural value added since the agricultural sector mainly participated to the economic growth of sub-Saharan countries up to 40% of GDP and also heavily emit greenhouse gases such CO_2. It emits up to 14% of the total greenhouse gases (smith et al 2007). The World bank data for 45 sub- Saharan countries was used for the period of 1990 to 2017. The Generalized Method of Moments was used following ((Baek & Krueger, 2013), (Grossman & Krueger, 1995), (Bandyopadhyay & Shafik, 1992)) framework and the results for both estimations (relation between CO_2 emission and GDP or CO_2 emission and agricultural value added) was showing the non -existence of an inverted U shaped environmental Kuznets curve for sub-Saharan countries. The existing relation found is the existence of an inverted N shaped curve between CO_2 emission and agricultural value added and gross domestic product.

Sub-Saharan countries must consequently make additional effort to clean the environment and adapt to climate change effects in their development process. More finance must be granted for research and development or Projects implementation in order to encourage environmental protection programs since cleaning the environment is very costly. Besides preventing the environment for global warming is a must since mankind cannot leave aside his environment. There are some limitations to our study. First the study just considers CO_2 as greenhouse gaze for environmental degradation measurement further studies may consider others greenhouse gases while drawing the Environmental Kuznets curve. Secondly the relation between environmental degradation and economic growth can be analyzed using semi parametric tools or spatial analysis tools. These tools can help knowing how CO_2 emitted in the region can affect the emission of others or the how the growth level of one country can affect the emission level of other countries.

REFERENCES

Acar, Y., Gürdal, T., & Ekeryılmaz, S. (2018). Environmental Kuznets Curve for CO_2 emissions : An analysis for developing, Middle East, OECD and OPEC countries. Environmental & Socio-economic Studies, Sciendo, Vol. 6, Issue 4, pages 48-58.

Adu, D., & Denkyirah, E. (2018). Economic growth and environmental pollution in West Africa:Testing the environmental Kuznets Curve Hypothesis. Kasetsart Journal of Social Sciences, Vol. 40, Issue 2, pages 281-288..

Aldy, J. (2005). An Environmental Kuznets Curve Analysis of U.S. State-Level Carbon Dioxide Emissions. The Journal of Environment Development 2005, Vol. 14, Issue 1, pages 48-72.

Alsan, A., Destek, M.A., & Ilyas, O. (2017). Bootstrap rolling window estimation approach to analysis of the Environment Kuznets Curve hypothesis:evidence from the USA. Environ Sci Pollut Res. Vol. 25, Issue 3, pages 2402-2408. doi: 10.1007/s11356-017-0548-3

AraBegum, R., KaziSohag, Abdullah, S. M., & Jaafar, M. (2015). CO_2 emissions, energy consumption, economic and population growth in Malaysia. Renewable and Sustainable Energy Reviews, Vol. 41, Issue C, pages 594-601.

Arellano, M., & Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. The Review of Economic Studies, Vol. 50, No.2, pages 277-297, HYPERLINK "https://doi.org/10.2307/2297968" \t "_blank" \o "This link opens in a new window" https://doi.org/10.2307/2297968 .

Bandyopadhyay, S., & Shafik, N. (1992). Economic growth and environmental quality : Time series and cross-country evidence. Policy Reseacrh Working paper, Series 904,The World Bank.

Beckerman, W. (1992). Economic growth and the environment:Whose growth ? Whose environment? World development, Vol. 20, Issue 4, pages 480-498.

Goujon, M., & Kafando, C. (2012). Caractéristiques Structurelles et Industrialisation en Afrique : Une première exploration. Halshs-00659824.Vol. 2, pages 32-49.

Grossman, G., & Krueger, A. (1991). Environmental Impacts of a North American Free Trade Agreement. NBER Working Paper N0.3914.

Grossman, G., & Krueger, A. (1995). Economic growth and Environment. The quarterly Journal of Economics, Vol. 110, Issue 2, pages 353-377.

Khalid, A., & Wei, L. (2012). Environmental Kuznets Curve and Pakistan: An Empirical Analysis. Procedia Economics and Finance, Vol. 1, Issue 1, pages 4-13, DOI: HYPERLINK"https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2FS2212-5671(12)00003-2"\t"_blank"10.1016/S2212-5671(12)00003-2 .

Lacheheb, M., Rahim, A., & Sirag, A. (2015). Economic Growth and Carbon Dioxide Emissions: Investigatingthe Environmental Kuznets Curve Hypothesis in Algeria. International Journal of Energy Economics and Policy, Vol.5, Issue 4, pages 1125-1132.

L'Afrique, C. E. (2017). Industrialization and Urbanization-United Nations Economic Commission for Africa. https://www.uneca.org/sites/default/files/uploaded-documents/ERA/ERA2017_Fr/era-2017_fr_fin_jun2017.pdf

McConnll, K. (1997). Income and the demand for environmental quality. Environment and Development Economics, Vol. 2, Issue 4, pages 383-399.

Omojolaibi, A. J. (2010). Environmental quality and economic growth in some selected west african countries. Journal of Sustainable Development in Africa, 5. Corpus ID: 154570060

Panatoyou, T. (1993). Empirical Tests and Policy analysis of environmental degradation at different stages of economic development. Geneva: International Labor Office. pages 42

Rawshan, A., Kazi, S., Sharifah, M., & Mokhtar, J. (2014). CO_2 emissions, energyconsumption,economicandpopulation. Renewable and Sustainable Energy Reviews, ELSEVIER, Vol. 41, Issue C, pages 594-601.

Saboori n, B., Sulaiman, J., & Mohd, S. (2012). Economic growth and CO_2 emissions in Malaysia: A cointegration analysisof the Environmental Kuznets Curve. Energy Policy, ELSEVIER, Vol. 51, Issue C, pages 184-191.

Shafik, N., & Bandyopadhyay, S. (1992). Economic Growth and Environmental Quality:time series and cross country evidence, Policy Research Working Paper Series 904, The World Bank..

Smith, p., & Martino, D. (2007). Mitigation of Climate Change.Contribution of Working Group III to the Intergovernmental panel on Climate Change(IPCC).fOURTH Assessment Report. Cambridge: Cambridge University Press.

Stern, N. (2007). The Economics of Climate Change. Cambrigde University Press. Online ISBN: 9780511817434, DOI: HYPERLINK "https://doi.org/10.1017/CBO9780511817434" https://doi.org/10.1017/CBO9780511817434

Wallace, J., Held, L., Thompson, D., & Trenberth, K. (2014). Global warming and winter weather. Science, Vol. 343, Issue 6172, pages 729-730.

Ward, F. (2006). Environmental and Natural Resource Economics. Pearson Prentice Hall. XIII, 610 pages, ISBN:013113163X.

The effects of climate variability on agricultural efficiency in Ghana

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ABSTRACT

This paper presents the results of investigation of the effects of climate variables on agricultural output in Ghana, using a secondary data in form of a time series data merged from two sources production data from Food and Agriculture Department, Accra and climatic data from the Ghana Meteorological Service Department from 1980 to 2011. Using a Cobb-Douglas specification of the stochastic frontier approach, an economic efficiency model was estimated. The results showed that, land, labour, pesticides, tractor cost, livestock value, rainfall, rainfall squared, temperature and temperature squared had significant effect on crop production. Rainfall and temperature were also found to have a significant effect on economic efficiency. The study concluded that while in the past, relatively low levels of temperature and rainfall were needed to increase agricultural productivity, in recent times and perhaps in future, for output to continue to increase; higher levels of the climatic factors are needed. For farmers to be economically efficient however, temperature levels must reduce while rainfall levels must rise. To achieve agricultural productivity growth, the study recommends policies that would increase rainfall or its substitute (such as irrigation) but would reduce temperature.

Keywords : Climate variability, Agricultural production efficiency, Ghana

RÉSUMÉ

Cet article présente les résultats de l'étude des effets des variables climatiques sur la production agricole au Ghana, en utilisant des données secondaires sous forme de séries chronologiques fusionnées à partir de deux sources : les données de production du Département de l'alimentation et de l'agriculture, Accra, et les données climatiques du Département du service météorologique du Ghana, de 1980 à 2011. Un modèle d'efficacité économique a été estimé en utilisant une spécification Cobb-Douglas de l'approche de la frontière stochastique. Les résultats montrent que la terre, la main-d'œuvre, les pesticides, le coût du tracteur, la valeur du bétail, les précipitations, le carré des précipitations, la température et le carré de la température ont un effet significatif sur la production agricole. Les précipitations et la température ont également un effet significatif sur l'efficacité économique. L'étude a conclu que si dans le passé, des niveaux relativement bas de température et de précipitations étaient nécessaires pour augmenter la productivité agricole, récemment et peut-être à l'avenir, pour que la production continue à augmenter, des niveaux plus élevés de facteurs climatiques sont nécessaires. Cependant, pour que les agriculteurs soient économiquement efficaces, les niveaux de température doivent diminuer et les niveaux de précipitations doivent augmenter. Pour parvenir à une croissance de la productivité agricole, l'étude recommande des politiques qui augmenteraient les précipitations ou leurs substituts (comme l'irrigation) mais réduiraient la température.

Mots clés : Variabilité climatique, efficacité de la production agricole, Ghana

INTRODUCTION

There is no doubt on the central role agriculture plays in developing country's economy. Thus, World Bank (2008) indicated that the growth and development in developing countries (Ghana inclusive) is dependent on agricultural development. There is also a worldwide consensus that the best and surest approach to minimize poverty and protect the environment is through agricultural development (Ministry of Food and Agriculture-MOFA, 2013). Similarly, there is no reservation on the variability of the production environment especially the climatic conditions. Global mean temperature is reported to have been increasing with anticipated serious impacts on food availability, food accessibility, food utilization and food system stability (Food and Agriculture Organization-FAO, 2008). Prevailing evidence also suggests that in semi-arid regions of Africa, rainfall distribution over the past few years is low and highly variable, spatially and inter-temporally (Amikuzuno and Donkoh, 2012). The implication thereof is that while agriculture would continue to be an essential element of Ghana's economy, the varying climate conditions are likely to have a dwindling effect on productivity. The effect of changes in climate is noted to be felt in the production side through market for agricultural goods. These impacts would hard-hit areas where supply chains are disrupted, market prices increase, assets and livelihood opportunities are lost, purchasing power falls, human health is endangered, and affected people are unable to cope (FAO, 2008). We should by now understand that, farm household's face the greatest risk of productivity loses and by extension, welfare loses due to climate change. And hence factors that influence agricultural development, including rainfall and temperature, have relevance to Ghana's development.

Ghana's agriculture is already under stress due to degradation of resources and insufficient public spending especially on rural infrastructure development. After Maputo Declaration of 10% public expenditure investment in agriculture, Ghana's average expenditure for 2001-2011 was 9.3% (MOFA, 2013). Of course, this fell short of the target. Unfortunately, the impact of climate change is seen to worsen this further. Several studies including Deressa et al., (2008); Shah et al., (2008); and Nellemann et al., (2009) therefore considered climate change as posing the utmost threat to agriculture and food security particularly in sub-Saharan Africa (SSA). Reports from MOFA (2013) already suggests that yields of cereals (maize, millet, sorghum) and legumes (cowpea and sorghum) have decreased due to the effect of erratic rainfall in the northern part of the country. Unfortunately, efficiency studies (Nkegbe, 2012;

Adzawla et al., 2013; Donkoh et al., 2013; Asante et al., 2014; Al-Hassan, 2008) has been concentrated on micro basis; mostly on a particular crop and/or a particular geographical area. Similarly, studies on climate change have been concentrated on adaptation and mitigation (Mabe et al., 2012) rather than the direct effects of the climatic variables on crop production. Against these backdrops, this study examined the effects of climate variables, specifically, rainfall and temperature on efficiency in Ghana.

METHODS

Study area

The study was carried out in Ghana. The total land area of the country is 238,533 sq.km; 227,533sq.km land and 11,000sq.km water (World Factbook, 2014). Available arable land is 20.12% of the country's total land area (as at 2011) with permanent crop cover of 11.74% and other crops as 68.14%. The three main sources of household income in Ghana are income from agricultural activities, wage income from employment and income from self-employment. Agriculture is largely by smallholder farmers with about 90% of farm holdings are less than 2 hectares in size. The climatic condition of the country also varies from the south to the north. Annual average temperatures range from 26.1^{o}C in places near the coast to 28.90C in the extreme north.

Data

The study used a secondary data from two main sources (1) production data from Food and Agriculture department, Accra and (2) climatic data from the Ghana meteorological service department. This was combined/merged this study used as time series data from 1980 to 2011 (Ghana living standards survey-GSS-, 2008); (Ghana Statistical Service-GSS-, 2012). In the case of the former data source, total land area cultivated for the 32 years, total labour used, total fertilizer, total pesticides, total tractor services cost and total livestock value were obtained. The total crop value obtained in Ghana cedis was also obtained from a list of crops. This included maize, rice, millet, sorghum, groundnut, tomatoes, pepper, beans, yam, cocoyam, plantain, cassava, cocoa, rubber, coffee, oil palm, coconut, banana, cashew nuts, pineapple and oranges. In the case of the latter, monthly minimum and maximum temperature and rainfall values were collected for each year in 2 selected districts in each region. The annual minimum and maximum as well as their average values were then calculated.

Data analysis

In a classical production function, it is always assumed that production is efficient. This may not be the case in most real-life situations. Therefore, in this study, we adopt the stochastic frontier model that was propounded by Aigner et al., (1977); Meeusen and Van den Broeck (1977) and used by Farrell (1957). In this case, the maximum production level is assumed to be stochastic to allow for estimating the effect of exogenous shocks. This introduces an additional error term to the usual one-sided error term in classical production functions. From Battese and Coelli (1995), the stochastic frontier is assumed to be distributed as truncated normal random variables and generally given as :

$$InY = Inf(x_i;\beta) + v_i - u_i \qquad (1)$$

Introducing a time dimension, Pitt and Lee (1981) re-specified this equation as started below :

$$InY_t = Inf(x_{it};\beta) + v_{it} - u_{it} \qquad \text{i=1, 2,...,N and t=1,2,...,T} \tag{2}$$

In this model, the usual noise term is divided into two: (1) the v_{it} which is actually the error term in a classical function. These are random variables that are normally distributed, thus, $\text{iid}N(0,\sigma_v^2)$; and (2) the u_{it} which is non-negative, also assumed to be independently distributed as half-normal; $u_i \sim N(\mu_i, \sigma_u^2) u_i \sim N(\mu_i, \sigma_u^2)$. The latter component measures the departure of each time period from the frontier. $f(x_{it};\beta)_t$ is a suitable production function with x_{it} as a vector of variables and β as a vector of parameters interested by the researcher. According to Coelli et al. (1998) if the value of crop output, rather than the physical quantities, are used as the dependent variable, then the efficiency scores are economic rather than technical efficiency. This is the case in this study. The empirical model adopted a Cobb-Douglas specification as follows :

$$Output\ value = \beta_0 + \beta_1 Land + \beta_2 Labour + \beta_3 Fertilizer + \beta_4 Pesticides + \beta_5 Tractor\ cost + \beta_6 Livestock + \beta_7 Temperature + \beta_8 Tems\ squared + \beta_8 Rainfall + \beta_9 Rain\ squared + u_1 \tag{3}$$

The efficiency model is also given as :

$$Inefficiency\ (u) = \gamma_0 + \gamma_1 Temperature + \gamma_2 Rainfall + u_2 \tag{4}$$

RESULTS AND DISCUSSION

Description of variables

The descriptive statistics of the variables used in the study are provided in Table 1. On the average, the crop value from crop production was GH cedi 17,028,510.56. This is obtained through the cultivation of 13,663,720 ha of land, employing10,024 laborers, using 18,901.90 kilograms of fertilizer 53,710.24 liters of pesticides, tractor expenditure of GH cedi 1,927.19 and a livestock value of GH cedi 7,026,388.25. The mean temperature and rainfall for the 32 years period was 27.25 ^{0}C and 3.085mm respectively.

Table 1: Descriptive statistics of variables

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Crop value	33	6193600	32685925	17028510.56	8332577.60
Land (000Ha)	32	12000	15900	13663.72	1336.33
Labour	33	6662	13622	10023.73	2080.81
Fertilizer	31	2700	101006	18901.90	25227.95
Pesticides	32	2350	370868.25	53710.24	81526.29
Tractor cost	26	1807	2004	1927.19	45.88
Livestock value	32	4992500	11142575	7026388.25	1850184.88
Temperature	32	25.175	28.215	27.255	0.78
Rainfall	32	2.1203	3.6319	3.085	0.38

Source: GSS, 2008.

Determinants of economic efficiency

From the result (see Table 2), all variables except fertilizer were significant. While land, temperature and rainfall levels had a negative coefficient, the other variables were positive. This means that while an increase in the positive variables leads to increased crop value, an increase in the negative variables lead to a reduced crop value. In other words, variables with positive coefficient must be increased to achieve higher crop value while those with negative coefficient must be reduced to achieve the same objective. With the climate variables, while their real values were negative, their squares had a positive coefficient. In the case of the inefficiency model, while temperature was positive, rainfall was negative. This implied that while higher levels of rain improved efficiency, higher levels of temperature reduced efficiency. There was a little variation in the efficiency levels across the time periods. The mean efficiency level obtained was 0.96. Figure 1 shows the efficiency trend over the 32 years period.

Table 2: Maximum likelihood estimation of determinants of economic efficiency

Variable	Coefficient	Standard error	T-value
Crop value			
Constant	1.380	1.201	1.115
Land	-2.795 ***	0.530	-5.268
Labour	2.772 ***	0.197	14.043
Fertilizer	0.005	0.005	1.022
Pesticides	0.055 ***	0.020	2.724
Tractor cost	0.021 ***	0.006	3.856
Livestock value	0.648 **	0.259	2.503
Temperature	-1713.744 ***	0.899	-1906.290
Temperature squared	857.431 ***	0.489	1753.762
Rainfall	-973.006 ***	0.895	-1087.433
Rainfall squared	486.471 ***	0.449	1082.913
Inefficiency			
Constant	-2.959 **	1.168	-2.534
Temperature	0.118 ***	0.041	2.854
Rainfall	-0.245 ***	0.074	-3.288
Variance parameters			
Sigma squared	0.0186 ***	0.0040	4.7130
Gamma	0.9999 ***	0.0000	26912.3010

*Note: ** and *** indicates significant levels at 5% and 1% respectively*

Source: GSS, 2008

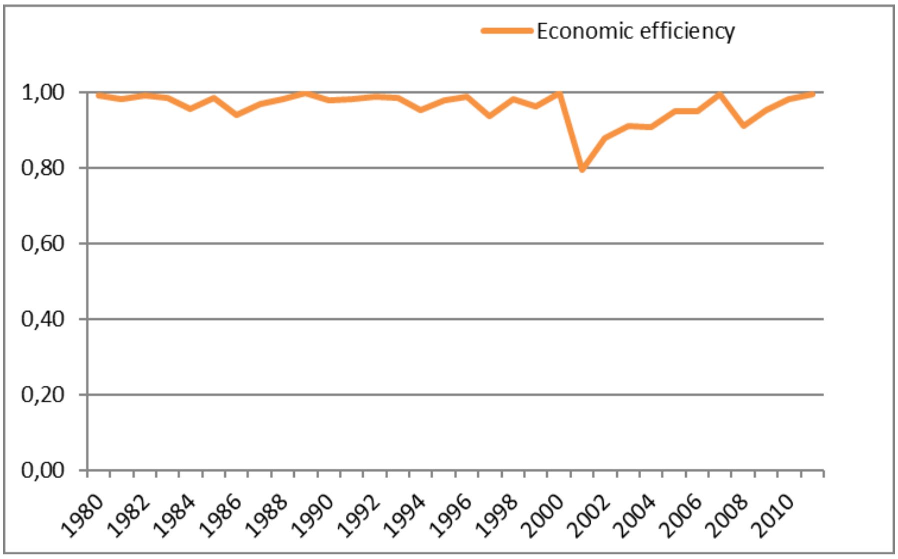

Figure 1: Economic efficiency trend of Ghana

Source: GSS, 2012

The negative coefficient of land in this study suggest that there is diminishing marginal returns to the factor. This therefore suggest for policies or interventions that aimed at intensification of crop production rather than extensification (improving the productivity of a unit area of land other than expanding land usage). This is consistent with the work of Djokoto (2012). Labour maintained a positive effect on crop value. The implication is that more labour is required for increasing crop value in the country. Empirically, Auci and Vignani (2014) estimated that the number of days worked on the farm have a negative impact on crop production. The study found that increasing usage of pesticides would lead to increasing output value in Ghana. This is an important finding since in recent times, pest management have become a major concern to crop farmers in the country, especially post-harvest pest management. This justifies calls for the use of pesticides in crop production. It is important to note that this study does not provide the recommended level of the input usage; therefore, policy measures and farmers are advice to know the appropriate levels in order not to contaminate their crop produce.

A diminishing threshold on the cost of tractor usage in the country has not been reached since the variable, tractor cost, has an estimated positive coefficient. This finding suggests that in order to increase crop value, more cost should be incurred on tractor services. Thus, more tractor services are required for increasing output. In other words, this study justifies support for commercial crop farming where the use of capital inputs such as the tractor is much required. In their study also, International Food Policy Research Institute-IFPRI-, (2011) found that, number of ploughing oxen, number of hoes used and number of ploughs used all have a positive effect on crop production. This is also similar to the findings in Djokoto (2012). It is important to note that crop production in Ghana currently is more labour intensive than capital intensive and requires transformation. Recognizing that agriculture is a rural activity in most developing economies, Todaro and Smith (2003) in relation to agriculture's role in development eminently asked 'What is the process by which traditional low-productivity peasant farms are transformed into high-productivity commercial enterprises?'; this remained a major concern.

Livestock value in this study was also positive and significant. The implication of this finding is that crop-livestock integration is necessary for higher returns from crop production. From Vilrla et al., (2003), there is a long-term effect of mechanized annual crop production and even with the traditional rotation system. This effect includes restructuring as well as reduction of organic matter and increase in the number of biotic crop pest species. Also, in most parts of the country especially in the north where livestock-crop integration is well practiced, farmers usually used proceeds from the livestock sales in crop production, which is mainly for subsistence. As stated earlier, the objective of this study is to examine the effect of rainfall and temperature on crop production in Ghana. From the result, both rainfall and rainfall squared respectively had negative and positive significance on crop value. Similarly, temperature and temperature squared had negative and positive significance effect on crop value respectively. This means that current crop production requires minimal amounts of these climatic variables. However, higher amounts may be needed for higher crop value in the [near] future. This demonstrates a mix effect of climate change on crop production; thus, current and future productions have varying response. Also, this is an indication that current measures to mitigate the impact of climate change on crop production may not be effective or even necessary in times to come. IFPRI (2011) also found in their work that, the amount of rainfall received 12 months before survey had a positive effect on crop value in Ethiopia. They argued that the extent of damage caused by rainfall in agriculture is well manifested through frequent food shortages during periods of low rainfall in the country. On his part also, Oyekale (2012) found rainfall and minimum temperature to respectively have negative and positive effect on cocoa production in Nigeria.

Effect of climate variables on efficiency

The effect of climatic variables discussed in the previous section aimed at their role in shifting the production frontier; outward or inward. However, with the inefficiency effect, the aim is to examine the effect of these climatic variables is shifting Ghana's agriculture sector to the frontier. Therefore, the negative significance of rainfall means that inefficiency reduces with higher levels of rainfall. On the other hand, the positive significance of temperature means that inefficiency increases with higher levels of the variable. In other words, increasing levels of rainfall and decreasing levels of temperature are necessary for improving efficiency in crop production in Ghana. Consistent with their study, Auci and Vignani (2014) found rainfall to have a negative effect on inefficiency in Italy while temperature had no significant effect, although positive. One potential area that has to be explored or given much attention is irrigation farming to supplement the low levels of rainfall (Keane, et al., 2009). Ghana's agricultural production is highly efficient considering a mean efficiency of 96%; minimum of 0.78 (78%) and a maximum of 1 (100%). This is higher than the estimated 0.82 average efficiency by Djokoto (2012). IFPRI (2011) also found an average efficiency of 45.7%; although their study involved a panel data. However, this does not suggest that all is well with crop production in the country. Rather, more efforts and commitments should be seen in intensifying and improving the production practices. The trend in efficiency of crop production over the 32 year period is quite stable (minimal variation) except in 2001 where there was the minimal efficiency level.

CONCLUSION

This present study delineates the direct impact of climate change on agricultural production in Ghana; using the stochastic frontier approach. From an AIC test, the study examined rainfall and temperature's role in shifting agriculture production frontier as well as closing or widening the gap between efficiency and inefficiency in production. Crop production in Ghana is economically efficient considering a mean efficiency score of 0.96. Conclusively, while in the past, relatively low levels of temperature and rainfall were needed to increase agricultural productivity, in recent times and perhaps in future, for output to continue to increase; higher levels of the climatic factors are needed. For farmers to be economically efficient however, temperature levels must reduce while rainfall levels must rise. Thus, while more rainfall is necessary for both growths in agricultural productivity and economic efficiency of farmers, more temperature, though good for agricultural productivity growth, does not augur well for economic efficiency. Since agricultural productivity growth is a means to farmers' economic efficiency, we recommend policies that increase rainfall or its substitute (such as irrigation) but reduce temperature. We recognized that research and development variables such as technology could influence efficiency. Therefore, further studies that are able to incorporate these variables may be recommended.

REFERENCES

Adzawla, W. Fuseini, J. and Donkoh, S.A (2013). Estimating technical efficiency of cotton production in Yendi Municipality, Northern Ghana. Journal of Agriculture and Sustainability Vol.4, Issue 1, pages 115-140.

Aigner, D. K., C. K. Lovell, and P. Schmidt, (1977). Formulation and Estimation of Stochastic: Frontier Production Function Models. J. of Econometrics, Vol. 6 Issue 1, pages 21-37.

Al-Hassan S. (2008). Technical efficiency of rice farmers in northern Ghana. AERC Research paper 178. African Economic Research Consortium, Agricultural Science, Vol. 5, No.4.

Amikuzuno, J. and Donkoh, SA (2012): Climate Variability and Yields of Major Staple Food Crops in Northern Ghana. African Crop Science Journal, Vol. 20, Issue 2

Asante, B. O., Osei, M. K. Dankyi, A. A.. Berchie, J. N Mochiah, M. B. Lamptey, J. N. L. Haleegoah, J. Osei K. and Bolfrey-Arku G. (2013). Producer characteristics and determinants of technical efficiency of tomato based production systems in Ghana. Journal of Development and Agricultural Economics Vol. 5, Issue 3, pages 92-103.

Auci, S. and Vignani, D. (2014). Climate change effects and agriculture in Italy: a stochastic frontier analysis at regional level. MPRA paper No. 53500. Online at: http://mpra.ub.uni-muenchen.de/53500/.

Battese, G. E. and Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Economics, Vol. 20, pages. 325-32. https://doi.org/10.1007/BF01205442.

Coelli, T.J., P. Rao, D. S, Battese, G. E. (1998). An Introduction to Efficiency and Productivity Analysis. London: Kluver Academic Publishers.XVI. 275 pages, ISBN: 0792380606.

Deressa, T., Hassan, R.M., Alemu, T., Yesuf, M. and Ringler, C. (2008). Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. IFPRI Discussion Paper 00798. Environment and Production Technology Division, Ethiopia.

Djokoto, J. G. (2012). Technical efficiency of agriculture in Ghana: a time series stochastic frontier estimation method. Journal of agricultural science, Vol. 4, Issue 1, pages 154-163.

Donkoh, S. A., Tachega, M. and Amowine, N. (2013). Estimating Technical Efficiency of Tomato Production in Northern Ghana. American Journal of Experimental Agriculture, Vol. 3, Issue 1, pages 56-75.

FAO (2008). Food and Agriculture Organization of the United Nations Rome, 2008, climate change and food security: a framework document. www.fao.org.

Farrell, M. J. (1957). The Measurement of Productive Efficiency. Journal of the Royal Statistical Society, Vol. 120, Issue 3, pages 255-281.

GSS (2008). Ghana living standards survey report of the fifth round (GLSS 5). Ghana Statistical Service, September 2008. https://www2.statsghana.gov.gh/docfiles/glss5_report.pdf

GSS. (2012). Ghana Statistical Service. 2010 population and housing census summary report of final results May, 2012. https://www.statsghana.gov.gh/gssmain/storage/img/marqueeupdater/Census2010_Summary_report_of_final_results.pdf.

IFPRI (2011). Sources of Inefficiency and Growth in Agricultural Output in Subsistence Agriculture: A Stochastic Frontier Analysis. By F. Nisrane, G. Berhane, S. Asrat, G. Getachew, A. S. Taffesse, and J. Hoddinott. Ethiopia Strategy Support Program II (ESSP II), ESSP II Working Paper 019.

Keane, J., Page, S. Kergna, A. and Kennan, J. (2009). Climate change and developing country agriculture: An overview of expected impacts, adaptation and mitigation challenges, and funding requirements. ICTSD–IPC Platform on Climate Change, Agriculture and Trade, Issue Brief No.2. Geneva, Switzerland. Available at: http://www.agritrade.org/Publications/documents/JKEANEweb_FINAL.pdf.

Mabe F.N. Sarpong D.B., Osei-Asare Y. (2012). Adaptive capacities of farmers to climate change adaptation strategies and their effects on rice production in the Northern region of Ghana. Russian journal of agricultural and socio-economic sciences, Vol.11 Issue 11, pages 1-9.

Meeusen, W. and J. Van den Broeck, J. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. International Economics Rev., Vol. 18, Issue 2, pages 435-444.

MOFA (2013). Ministry Of Food and Agriculture. Agriculture in Ghana. Facts and Figures (2012). Statistics, Research and Information Directorate (SRID), August, 2013.

Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., Svihus, B., Prins, A. and Kaltenborn, B. (eds) (2009). The Environmental Food Crisis. The environment's role in averting future food crises. A UNEP rapid response assessment. Arendal, UNDP. https://www.gwp.org/globalassets/global/toolbox/references/the-environmental-crisis.-the-environments-role-in-averting-future-food-crises-unep-2009.pdf, 104 pages.

Nkegbe, P. K. (2012). Technical efficiency in crop production and environmental resource management practices in northern Ghana. Environmental Economics, Volume 3, Issue 4.

Oyekale, A. S. (2012). Impact of Climate Change on Cocoa Agriculture and Technical Efficiency of Cocoa Farmers in South-West Nigeria. J Hum Ecol, Vol. 40, Issue 2, pages 143-148.

Shah, M., Fischer, G. and van Velthuizen, H. (2008) Food Security and Sustainable Agriculture. The Challenges of Climate Change in Sub- Saharan Africa. In: [[Climate Change and Economic Development in Sub-Saharan Africa - AERC Senior Policy Seminar X, Addis Ababa, Ethiopia, 7-9 April 2008: Seminar Papers]], African Economic Research Consortium, Nairobi, Kenya..

Todaro, M. P. and Smith, S. C. (2003). Economic development. 11th edition. Library of Congress Cataloging-in-Publication Data. https://mediasrv.aua.gr/eclass/modules/document/file.php/AOA215/Economic%20Development%20-%20Todaro%20and%20Smith.pdf.

Vilrla L., Macedo M. C. M, Júnior G. B. M. and Kluthcouski J. (2003). Crop-Livestock integration benefits. Available from: www.fao.org/ag/AGP/AGPC/doc/integration/papers/...

World Bank (2008). The Growth Report: Strategies for Sustained Growth and Inclusive Development. Washington, DC. https://openknowledge.worldbank.org/handle/10986/6507.

World Factbook (2014). Ghana. Retrieved from: https://www.cia.gov/library/publications/the-world-factbook/geos/gh.html. Last update, June, 2014. Retrieved on 15th March, 2015.

PART III :

MITIGATION AND ADAPTATION STRATEGIES IN AFRICA

The development of adaptation strategies is the best way to mitigate the effects of climate change and support local communities as a means of building resilience, because the effects induced by climate change are proving to be particularly constraining in West Africa. Floods, one example among many, which most affect the social and economic development of communities living in affected areas. Cooperation serves as a relevant adaptation strategy in rural areas of developing countries. In addition, the agricultural sector, which is a particularly affected, has low yields and the population fights to meet its primary food needs. In facts, national economies are heavily affected despite the strategies that have been put in place and tested in various countries, particularly in Senegal. There is also a lack of information and climate forecasts for local communities, which is an obstacle to the success of adaptation policies and strategies, despite the efforts made by the state and the good will of farmers.

Research within West Africa has shown that the most successful adaptation policies are those based on sustainable management and conservation of environmental resources. This is further proven by the development of certain export chains, such as the cashew nut export chain in Senegal, which generates significant financial resources while at the same time allowing for the preservation of forests and the mitigation of the effects of climate change.

The six articles that make up this section on climate change adaptation and mitigation strategies in West Africa will be illustrated with examples from Senegal, Ghana, Togo and Côte d'Ivoire:

1. Cooperation and Adaptation to Natural Risk: Evidence from Ghana
2. Climate change, agricultural output, household income and policies in Senegal
3. Group membership and adoption of climate change adaptation strategies: the case of dry cereal producers in the groundnut basin of Senegal
4. Impacts of Adaptation to Climate Change on farmers' income in the Savana Region of Togo
5. Analysis of the performance of an export sector and its impact in mitigating the effects of climate change: Case of cashew nuts in Senegal

Cooperation and Adaptation to Natural Risk : Evidence from Ghana

Ebo Botchway and Antonio Filippin

ABSTRACT

This paper investigates the causal effect of exposure to flood risk on the inclination to cooperate and on risk aversion among sample of farmers in Ghana. Experiments were designed and executed. The results show that highly exposed individuals exhibit a pronounced inclination to contribute to a public good as well as higher degree of risk aversion. A strong positive correlation between cooperation and risk aversion also emerged, suggesting that cooperation may act as a form of self-insurance in an environment where classic forms of insurance are not available. However, a causal mediation analysis shows that only a small proportion of the change in the inclination to cooperate is explained by risk aversion. Therefore, cooperation can be considered as a spontaneous and relevant adaptation strategy in Ghana.

Keywords: Cooperation, Risk aversion, Natural disaster, Adaptation strategy

RÉSUMÉ

Cet article étudie l'effet causal de l'exposition au risque d'inondation sur l'inclination à coopérer et sur l'aversion au risque parmi un échantillon d'agriculteurs au Ghana. Des expériences ont été conçues et exécutées. Les résultats montrent que les individus fortement exposés présentent une inclinaison prononcée à contribuer à un bien public ainsi qu'un degré plus élevé d'aversion au risque. Une forte corrélation positive entre la coopération et l'aversion au risque est également apparue, suggérant que la coopération peut agir comme une forme d'auto-assurance dans un environnement où les formes classiques d'assurance ne sont pas disponibles. Cependant, une analyse de médiation causale montre que seule une petite proportion du changement dans l'inclination à coopérer est expliquée par l'aversion au risque. Par conséquent, la coopération peut être considérée comme une stratégie d'adaptation spontanée et pertinente au Ghana.

Mots clés : Coopération, Aversion au risque, Catastrophe naturelle, Stratégie d'adaptation

INTRODUCTION

The scale of destruction from natural shocks has increased over the past decades. According to Intergovernmental Panel on Climate Change (IPCC, Climate Change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change, 2014), these natural shocks are expected to have an even more profound impacts especially in developing countries, where rural livelihoods are inextricably linked to the environment (Mensah & Adu, 2015). In particular, weather shocks such as flood and droughts can exacerbate poverty both directly and indirectly (Carter & Barrett, 2006). Building resilience through adaptation is, therefore, considered as the most important policy option in reducing the impact of natural shocks (IPCC, Climate Change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change, 2014). In principle, there are several conceivable ways to cope with the risk of natural disasters. Investing in innovative production processes or in new and more resistant crops is one of the possibilities. Alternatively, an effective climate risk management (e.g. through insurance) may improve livelihoods in unfavourable years and enable farmers to take the productive risks necessary to ensure a bountiful return in favourable years (Norton, et al., 2014). While access to financial, human and physical capital is important to foster resilience, these adaptation strategies need to be consistent with the behavioural traits of the recipient in order to succeed. For instance, risk averse farmers may not be receptive to innovative programs (Boucher, Carter, & Guirkinger, 2008; Dercon & Christiaensen, 2011).

In developing countries, the classic indemnity-based insurance is typically unavailable due to problems of adverse selection, moral hazard, and long delays in implementation. Index-based insurance is a theoretically appealing second-best that however turns out to be extremely costly for small farmers (Carter, De Janvry, Sadoulet, & Sarris, 2014). The correlated nature of the risk implied by natural disasters also hinders the use of alternative and informal insurance arrangements, too. Risk such as that of burglary, illness, injury, malfunctioning of equipment affects individuals in an idiosyncratic manner. This type of risk can be pooled even in case of incomplete markets through a variety of informal risk-sharing mechanisms documented in remote rural communities around the world, including gift giving, food sharing, remittances, rotating savings, and unstructured loans (Fafchamps, 2003; Cherry, Howe, & Murphy, 2015). In contrast the risk implied by natural disasters like floods and droughts affects virtually every individual in the community and cannot be pooled locally (Lohse, Robledo, & Schmidt, 2012; Friedl, De Miranda, & Schmidt, 2014). A risks that cannot be avoided, diversified, or insured against has been labelled as background risk in literature. It has been shown that background risk makes individuals less tolerant towards other, avoidable risks (Pratt & Zeckhauser, 1987; Kimball, 1993; Eeckhoudt, Gollier, & Schlesinger, 1993).

The collective effort of the members of a community constitutes a major strength of rural households in reducing the impact of natural shocks on their livelihoods. Therefore, not only risk aversion but also the inclination to cooperate of farmers is a crucial behavioural trait that needs to be assessed to identify the more appropriate adaptation strategies to the risk of natural disasters. Public goods can even contribute to risk reduction. For example, dams, embankments, and drainage systems can work as a form of insurance against droughts and floods. Therefore, the interplay between the willingness to contribute to a public good and risk aversion also needs to be investigated.

A growing body of research has introduced behavioural hypotheses into public choice theory (Ostrom, 1998; Lohse, Robledo, & Schmidt, 2012; Teyssier, 2012; Friedl, De Miranda, & Schmidt, 2014). For instance, Lohse, et al. (2012) posit that a high risk averse person will demand more self-insurance to reduce the size of a loss in the wake of idiosyncratic risk. Such a conclusion can be extended to the case of correlated risk as long as the utility function depends on individual's payoff only. Indeed, risk averse individuals display higher demand for self-insurance in the presence of background risk (Konrad & Skaperdas, 1993). The natural question then is to investigate whether the demand for self-insurance also triggers a stronger inclination to cooperate in case of correlated background risk.
Available experimental evidence displays mixed evidence concerning the correlation between individuals' risk preferences and their contributions to public goods. Charness & Villeval (2009) report that older and more risk averse employees are more cooperative than younger and risk averse employees. Sabater-Grande & Georgantzis (2002) find that high risk aversion relates positively with the frequency of collusive outcomes. Other studies find instead that risk aversion reduces individuals' contributions in public goods experiments (Bohnet & Zeckhauser, 2004; Schechter, 2007; Heinemann, Nagel, & Ockenfels, 2009; Teyssier, 2012)[38].These studies typically assume that preferences are a stable construct. However, there is a growing body of research showing that shocks in the living environment heavily shape individual preferences. For instance, several studies show that the living environment influence risk preferences (Eckel, El-Gamal, & Wilson, 2009; Olbrich, Quaas, Haensler, & Baumgärtner, 2012; Voors, Nillesen, Verwimp, Bulte, Lensink, & Van Soest, 2012; Cameron & Shah, 2015; Kahsay & Osberghaus, 2018)and time preferences (Bchir & Willinger, 2014; Callen, 2015).

A few contributions consider how the environment shapes the inclination to cooperate, but without providing clean evidence on their relationship with risk attitudes. Afzal, et al. (2015) show that frequent floods of relatively low intensity have a positive significant effect on cooperation, while single disastrous floods negatively affect cooperation. However, no clear pattern emerges as far as the relationship with risk aversion is concerned. A possible interpretation of this result is that the sample in Afzal, et al. (2015) is large but characterized by substantial heterogeneity. Voors, et al. (2012) investigate the effect of exposure to the risk of conflict on both cooperation and risk preferences, but separately. Belfor (2014) report no significant relationship between exposure to disaster and pro-social preferences. However, exposure to a natural disaster in the past year was found to significantly decrease contribution amounts towards public goods (Belfor, 2014).

The main goal of this paper is to fill this gap by investigating the causal effect of exposure to flood risk on the inclination to cooperate, on risk aversion, and their interplay. In particular, our main research question is to assess whether farmers exposed to higher degree of risk exhibit a more/less pro-social behaviour and how

38 Entitlement may also play a relevant role in this relationship.Wunsch & Strobl (2018) show that individuals who choose a risky option are less likely to share their income than subjects who receive their income by pure chance much of the change is due to a change in their risk preferences. Toward this goal we considered communities that are more exposed to the risk of flood as our treated group and those less susceptible to floods as our control group. We believe that our approach improves upon the existing literature, as it constitutes the first attempt to assess the impact of exposure to background risk on risk preferences and cooperation in a comprehensive manner.

We found that preferences are affected by a different exposure to the risk of natural disaster. In particular, more exposed individuals display a more pronounced inclination to cooperate as well as higher degrees of risk aversion. While the result about risk aversion confirms a well-known effect of background risk, our paper provides interesting insights concerning its effect on cooperation, something that is less established in the literature. On the one hand, our results show that exposure to the risk of natural disasters clearly increase the inclination to cooperate. Furthermore, we also found a positive and strong correlation between cooperation and risk aversion. At first glance, the fact that more risk averse individuals contribute more to the public good lends support to cooperation as a form of self-insurance, in line with Lohse, et al. (2012) and Konrad & Skaperdas (1993). According to this interpretation, individuals react to the exposure to background risk by increasing their risk aversion and then using cooperation as a form of self-insurance in an environment where classic forms of insurance are not available. However, a causal mediation analysis shows that, only a small fraction 6.3% of the change in cooperation may be ascribed to the increased level of risk aversion, while the bulk of the effect is direct. According to our findings cooperation, therefore, emerges as a crucial adaptation strategy in rural areas of developing countries, something that should be taken in due consideration to design effective policies.

The structure of the paper is as follow. Section 2 describes the experimental design and procedure, while the results of the paper are presented in Section 3. Section 4 concludes with potential policy implications and directions for future research.

METHODS

Design

The loss of control implicit in exploiting natural events in the field requires particular attention in the design of the experiment along two dimensions : a) ensuring that the event under investigation representing the risk of natural disaster properly mimics the intended treatment ; b) avoiding confounding factors across experimental conditions.

From the first point of view we exploited floods in the North of Ghana as the treatment meant to capture a different exposure to the risk of natural disasters. The Ministry of Food and Agriculture has estimated that, in this region, the 2007 flood affected about 70,500 hectares of farmlands, resulting in an estimated loss of 144,000 metric tonnes of food crops including maize, rice, millet, sorghum, yam, cassava and groundnuts (Armah, Odoi, Yengoh, Obiri, Yawson, & Afrifa, 2011). There has been an increase in the occurrence of flood in this part of the country in the last decades. In 2012, for instance, floods destroyed a total of 1,725 farmlands in the northern region alone while temporary displacing about 3,152 persons. In all, approximately 22,008 people were affected by the flood resulting in the death of 3 persons.[39]

39 https://www.modernghana.com/news/419147/floods-kill-three-affect-22008-people-in-northern-

The area where the experiment took place is the Tolon-Kumbungu district, where floods are a recurrent but not systematic phenomenon. Severe floods occurred in this area during the months of July to September in 1995, 1997, 2004, 2007, 2008, 2009, 2010 and 2012 (Musah & Oloruntoba, 2013; Jakpa, 2015).The worst flood was that of August 2007, which resulted in the loss of 6 human lives, loss of property, and temporarily rendering more than 1,300 households homeless. Over 3000 hectares of farmlands were destroyed in this district with many buildings submerged. In addition, the floods also caused outbreak of water-borne diseases including diarrhoea, cholera and malaria, particularly among children (Musah & Oloruntoba, 2013). More recently severe floods have devastated communities along the White Volta in the northern region of Ghana in 2017[40], when the experiment took place, and in 2018 temporary displacing about 100,000 people[41].Less destructive floods are a recurrent phenomenon, occurring more often than what is reported in the news.The precipitation pattern in this part of the country is not easily predicted, with flood being potentially very destructive to crops leaving households in the wake of famine. As such, people in this area face an impending risk of dealing with natural disasters.

From the second point of view mentioned above, uniformity across treatments is a necessary condition to properly infer causal relationships. In the laboratory, confounding factors in the ex-ante characteristics of the subjects across experimental conditions are ruled out through the randomization of the treatment. In our case, the hypothesis of random assignment to the probability of natural disasters is clearly violated. As explained by Guala (2005), however, uniformity in experimental subjects can also be achieved through matching with the explicit aim of achieving groups that are as similar as possible ex ante. Guala (2005) also argues that matching should take into consideration both the characteristics of the subjects and the experimental environment. In our setting, uniformity through matching requires to find groups that are similar in all domains except for their exposure to risk.

In this respect, the Tolon-Kumbungu district provides an environment with the necessary features for several reasons. In this rural area, the population relies almost entirely upon agriculture for their survival, implying that the risk cannot be avoided. Furthermore, this district is homogeneous from a cultural perspective, as about 95% of the inhabitants are Muslim. The communities in this district follow a patrilineal system of inheritance and the land used for farming is typically acquired through inheritance. To make sure to avoid problems of self-selection through mobility only farmers who have stayed in the communities for more than 20 years are considered for the experiment. In order to further reduce potential heterogeneity and confounds, participants in each community are randomly selected only among male Muslim farmers. Maize and cassava are the predominant crops, cultivated to be sold, while other crops (sorghum, rice, millet, yam, groundnut, cowpea) represent a low share of total production and are typically used for subsistence reasons (GSS, 2012).

upper-e.html

40 https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Northern-Region-floods-unprecedented-Minster-562928

41 http://floodlist.com/africa/ghana-floods-northern-regions-september-2018

Treatment

Even though the whole district is a flood-prone area, the degree of exposure to such a risk is not homogeneous, with communities closer to the White Volta being more exposed than communities that are far from the river. The communities that are more prone to flood are known to suffer larger losses and are therefore considered as the treated group. Out of the 22 flood prone communities identified in this district, 5 communities (Kuli, Sheegbuni, NawumiAfayili, and Tampia) are selected as our treated group based on their proximity to the river and easy access. A total of 5 communities (Wantugu, Gummon, Koblimahigu, Tali and Sabiegu), which are least susceptible to flood are instead selected as control groups (see Figure 1).

Figure 1: Study area (Black squares represent treated groups; white squares represent control groups). Source: Google map

Experimental tasks

Public Good

Public goods are defined by two well-known properties of non-excludability (individuals cannot be excluded from the consumption of the good irrespective of their contribution to its production) and non-rivalry (individual consumption does not reduce the amount available to others). In the experimental literature the conflict between the selfish option to free ride and the socially desirable outcome represented by full cooperation has been extensively investigated mostly using the linear Voluntary Contribution Mechanism (VCM). A very robust result of this experiment is that a large majority of individuals voluntarily cooperate even though the Nash equilibrium is to contribute nothing to the public good. However, this rate of cooperation declines as the game isrepeated(Isaac, et al., 1985; Andreoni, 1988; Ledyard, 1994; Teyssier, 2012, among others).

The level of contribution is commonly interpreted as the inclination to cooperate in order to achieve a common goal. In the communities considered the provision of a public good could be represented for instance by the construction of an embankment, which would be effective only if protecting all the farmlands from floods. The benefits would accrue to everyone regardless of the level of the individual contribution. Given the relevance of cooperation in rural communities, particularly when exposed to the risk of natural disasters, we administer a public good game in its VCM incarnation.

Groups of four participants are formed randomly before the start of the experiment. Each member of the group is given an envelope containing an endowment of 10 tokens, with each token worth 1 Ghana cedi[42]. Each participant then decides individually how many tokens to keep for himself and how many to leave in the envelope. The tokens left in the envelope represent his contribution to the group ($c_i c_i$). Participants are told that the tokens they keep directly represent a private payoff. In contrast, the tokens in all the four envelopes are then put in a box, doubled by the experimenter, and then shared equally among the four members of the group regardless of whether someone contributed or not. The resulting payoff function is therefore

$$\pi_i = (10 - c_i) + 0.4\left(c_i + \sum_{j \neq i} c_j\right) \quad (1)$$

The game is repeated 10 times, and the total contribution of the group in every round is shown to the members before the subsequent round. Participants are instructed that in case this is the task selected for the final payment one round will be chosen randomly at the end of the experiment to determine the individual payoff. The research goal is to test whether higher exposure to the risk of natural disasters shapes the individual inclination to cooperate. Since cooperation may indeed represent a form of collective insurance (e.g. building an embankment can be seen as a premium paid to reduce the risk) in the experiment we also elicit farmers' risk attitudes.

Risk Preferences

The measurement of risk preferences is a problematic endeavour in general because a low consistency and a weak external validity of the answers have been extensively documented (Isaac & James, 2000; Dave, Eckel, Johnson, & Rojas, 2010; Crosetto & Filippin, 2016; Charness, Garcia, Offerman, & Villeval, 2019). These problems can only be exacerbated in rural areas of developing countries due to the lower numeracy of the subjects involved. Therefore, the choice of a simple and comprehensible task is of utmost importance (Charness & Viceisza, 2016). For this reason we administer a further simplified version of the Bomb Risk Elicitation Task (Crosetto & Filippin, 2013).

In this task, participants are presented a winding road (as shown in Figure 2) in which participants earn 0.5 Ghana cedi for every step taken in numerical order. A time bomb is hidden behind one of the 100 steps. If a participant steps on the bomb all the earnings are wiped out. The bomb can be behind any of the 100 steps with the same probability, but its position is unknown to the participants and to the experimenters.

42 The exchange rate at the time of the experiment was 1 Ghana cedi =$0.225.

The location of the bomb is blindly determined by each participant at the end of the experiment drawing a number from a bowl containing 100 numbered and folded pieces of paper. Participants have to indicate every step they take by crossing all the numbers until they reach the step where they want to stop. They also have to confirm their choice writing the number of steps that they decide to take in the box below the winding road.

If the number drawn from the bowl, which represents the position of the time bomb, is greater than the number of steps the participant decides to take it means that the participant did not step on the bomb. Therefore, he earns 0.5 Ghana cedi for each step taken. Conversely, if the number drawn from the bowl is lower than or equal to the number of steps chosen, the participant does not earn anything. In this risk elicitation task the higher the number chosen, the larger the potential earnings but also the probability of getting zero. The choice reveals the respondent's risk preferences, with 50 corresponding to a risk neutral decision, and lower numbers representing higher degrees of risk aversion.

Start here

1									
2	3	4	5	6	7	8	9	10	11
									12
22	21	20	19	18	17	16	15	14	13
23									
24	25	26	27	28	29	30	31	32	33
									34
44	43	42	41	40	39	38	37	36	35
45									
46	47	48	49	50	51	52	53	54	55
									56
66	65	64	63	62	61	60	59	58	57
67									
68	69	70	71	72	73	74	75	76	77
									78
88	87	86	85	84	83	82	81	80	79
89									
90	91	92	93	94	95	96	97	98	99
									100

Number of steps : Bomb Location :

Experimental procedure

The experiment took place in September 2017 in the Tolon-Kumbungu district, in the Northern part of Ghana, involving 200 participants. A total of 10 experimental sessions were organised in 10 different communities, 5 closer to the White Volta river (Kuli, Sheegbuni, Nawumi, Afayili, and Tampia), which constitutes our treatment group, and 5 further away used as controls (Wantugu, Gummon, Koblimahigu, Tali and Sabiegu). A recognizance visit to the study area was made in February 2017. The first contact was the regional director of the Ministry of Food and Agriculture. The district director then instructed an officer to accompany an experimenter to the villages. Among the villages visited during the recognizance visit were Afayili, Nawumi, Kuli, Wantugu, Tampia, Gummon, Sabiegu, Koblimahigu,Sheegbuni and Tali.The first contact in the villages was the community head, who after listening the description of the experiment gave us the permission to hold a session in the village.

To grant a clear understanding of the experiment, the tasks and the questionnaire were administered in the local language (Dagbani). Two district officers of the Ministry of Food and Agriculture were thus trained on how to administer the tasks and the questionnaire. The community head was informed in advance about the timing of the experiment and asked to gather the male farmers in the community telling them that the participation was limited to 20 people. Before the beginning of the experiment we asked each farmer whether he has been staying in that community for more than 20 years, something that indeed characterized everybody. We then put in a bowl numbered and folded pieces of papers corresponding to the total number of people gathered, and then asked the farmers to draw one number at random. Those drawing the numbers from 1 to 20 were selected as the participants to the experiment in that community.

In each session, the public good game was administered first.The groups were formed putting 20 folded pieces of paper numbered from 1 to 5 (each number 4 times) in a bowl.The participants randomly selecting the same number were grouped together. Subject then played the Bomb task[43].Finally, an exit questionnaire was administered in a face-to-face interview format to obtain the socio-economic characteristics of the respondents, as well as their self-reported willingness to pay for different goods (insurance, investment in drainage systems and fertilizers).

Subjects were told in advance that the experiment involved a pay-one-at-random protocol among the tasks, on top of a show up fee of 10 Ghana cedis. In every session, the choice of the task relevant for payment was determined by one participant who selected randomly from a bowl a numbered and folded piece of paper.To ensure a good understanding the tasks were explained very carefully, and therefore the experiment was quite long (3 and half hours on average), but was adequately rewarded. In fact, subjects earned on average 21.23 Ghana cedis, equivalent to $4.78 and about two and a half times the daily minimum wage at the time (8.80)[44].

43 The experimental protocol involved then the elicitation of loss aversion and time preferences. These tasks, however, are not analysed in what follows. The reason is that the choices in the loss aversion task turn out to be highly collinear with those in the risk elicitation task. Given that risk aversion also affects the choices in the lotteries with negative payoffs, we find no evidence of an additional role played by loss aversion. As far as time preferences is concerned, impatience does not significantly correlate with the inclination to cooperate.

44 http://www.myjoyonline.com/news/2017/july-11th/daily-minimum-wage-goes-up-by-10.php

RESULTS

In this section we first provide evidence supporting the goodness of the experimental design, in terms of the ex-ante socio-economic characteristics of treated and control groups as well as concerning the effectiveness of the intended treatment represented by the proximity to the White Volta river. We then present the experimental results capturing the effect of the different degree of exposure to the risk of floods on farmers' inclination to cooperate, risk attitudes, and the interaction between these behavioural traits.

Goodness of the experimental design

Crucially for a field experiment based on equality via matching, we first test whether the treated and control groups are similar ex ante, except for their exposure to the risk of floods. Table 1 includes the descriptive statistics of a wide range of socio-economic characteristics that turn out to be balanced across experimental conditions. In particular, a battery of Mann-Whitney tests shows that there is no significance difference in the average age of participants, in the household size, in the number of adults in the households, as well as in the dependency ratio (total number of household members over number of members working in the household). A non-parametric Fisher exact test of proportions shows a similar distribution of educational levels. Farmers are similar across experimental groups also in terms of crop area cultivated and in the number of years of experience. Confirming the effectiveness of the selection procedures, all the participants confirmed in the questionnaire that they have spent their entire lifetime in the current community, indicating that there was no migration issue between the two experimental groups.

Table 1: Socio-economic characteristics of treated and control groups

Variable	Control	Treated	Mann-Whitney Z	p-value
Age	44.17	43.05	1.030	0.3032
	(7.58)	(8.59)		
Household Size	5.96	6.27	-1.164	0.2443
	(1.71)	(1.84)		
Number of Adults	2.32	2.37	-0.627	0.5307
	(0.57)	(0.60)		
Dependency	2.60	2.66	-0.925	0.3549
	(0.60)	(0.55)		
Education: (Fisher Test)				
No Education	58%	66%		
Basic Education	19%	16%		0.530
Secondary Education	23%	18%		
Farm Size	5.07	4.82	1.273	0.2031
	(1.44)	(1.33)		
Farming Years	23.52	22.44	0.991	0.3219
	(8.14)	(8.31)		
Migrant	0	0		
	(0)	(0)		

Note: Standard deviation in parenthesis. Source: Author's survey, 2017.

The following question to answer is whether the choice of the communities based on their proximity to the White Volta river effectively captures a different exposure to the risk of the natural disaster represented by floods. The experiment took place in September 2017 at the end of a harvest season in which severe floods occurred (see above Footnote 3).

Participants are asked to report in the questionnaire the amount of crop losses suffered. Table 2 shows that farmers in the treated group lost about 5.19 bags of maize in the last growing season on average, more than twice the amount of the controls (2.39 bags). A Mann-Whitney test shows that the difference is highly significant ($p < 0.001$ $p < 0.001$). The results also show a significant difference in the amount of cassava output lost, with the treated group losing about 1.7 bags more (Mann-Whitney test $p < 0.001p < 0.001$).

Using the price at which the respondents report to have sold their maize and cassava output in the market we compute the total monetary value of the losses. This value ranges from a minimum of $68.06 to a maximum of $322.88 in the whole sample, with an average of about $169.4. The treated group lost about $218.44 on average, significantly more than the $120.36 of the controls (Mann-Whitney test $p < 0.001$ $p < 0.001$).Farmers are also asked to indicate how the losses. In 2017 compare with the average in the previous five years. 91% and 85% of the respondents in the treated and the control group, respectively, report a similar pattern. Floods are not a one-off occurrence as they represent an impending risk borne by treated and control communities to a different degree on a regular basis. As such, the identification of the communities in the experimental design seems to properly represent the intended treatment, i.e. a different exposure to the risk of natural disasters.

Table 2: Analysis of the outcome of the exposure to risk ex-ante

Variable	Control	Treated	Mann-Whitney Z	p-value
Maize Loss (Bags)	2.39	5.19	-12.11	< 0.001
	(0.88)	(0.87)		
Cassava Loss (Bags)	3.51	5.16	-10.15	< 0.001
	(0.70)	(1.05)		
Value of Crop Loss ($)	120.34	218.44	-12.07	< 0.001
	(26.46)	(34.35)		
Losses: (2017 vs 2012-16)				
Different	15%	9%	Fisher	0.276
Similar	85%	91%		
Maize Output (Bags)	23.25	22.71	1.229	0.2192
	(3.15)	(3.16)		
Cassava Output (Bags)	18.45	17.8	1.578	0.1146
	(2.67)	(2.00)		
Maize Productivity	5.32	6.06	-5.061	< 0.001
	(1.03)	(1.05)		
Cassava Productivity	4.58	5.05	-3.004	0.0027
	(1.05)	(1.13)		
WTP for Drainage System	5.57	13.60	-11.225	< 0.001

	(2.38)	(3.92)		
WTP for Fertilizer	6.72	5.31	4.735	< 0.001
	(2.35)	(1.84)		

Note: Standard deviation in parenthesis. Source: Author's survey, 2017.

Two things deserve to be stressed. First, the controls also face some risk of natural disaster, although with significantly less severe consequences. Hence, the results in Section 3 should not be interpreted quantitatively as the absolute effect of exposure to background risk, but rather in relative terms as the effect of a higher exposure. Second, Table 2 also shows that summing up the output brought to the market and the amount lost, we find that the productivity per acre is significantly higher in the treated communities for both crops. Hence, living closer to the river represents a lottery with a potentially higher reward but also a higher risk. The combined effect using the 2017 data displays that the output brought to the market is not significantly different.

Additional evidence supporting the effectiveness of the treatment comes from the elicitation of the farmers' Willingness to Pay (WTP) for different goods. In particular, respondents were asked to indicate the maximum amount they are willing to paya) in building a drainage system around farmlands; b) to buy a bag of fertilizer[45].Farmers in the treated group are willing to pay \$13.60 per year on average for a drainage system, while this amount drops to \$5.57 on among the controls. The difference is highly significant (Mann-Whitney test $p < 0.001p < 0.001$) indicating that the farmers in the communities close to the river attach a higher value to the protection against the impact of floods. The WTP for a bag of fertilizer is instead significantly lower for the treated, confirming that the soil is more fertile close to the river.

In all, the evidence in this section shows that the two experimental groups are comparable in terms of their ex ante socio-economic and cultural characteristics. At the same time, they differ significantly in terms of exposure to flood risk and of the consequent impact on their activity. Given that we can exclude self-selection into the treatment, this setting allows us to identify the causal effect of a higher exposure to the risk of floods on the behavioural traits under investigation.

Experimental results

This section analyses the participants' risk attitudes and inclination to cooperate, as well as the interaction between these preferences for different levels of exposure to the risk of natural disaster.

Risk Preferences

The effect of the environment on individual risk preferences is in line with the literature stating that background risk makes individuals less tolerant to other avoidable risks

45 These amounts are elicited using a dichotomous Contingent Valuation Method (CVM) on hypothetical scenarios. Respondents are first asked whether they are willing to pay more or less than an initial value. According to their answer, a second (higher or lower) value is proposed, and finally the respondents report (see Table 3, top panel). Subjects in the treated group chose on average \$18.3\$ boxes, against 30.5 of the controls (Mann-Whitney test $p < 0.001p < 0.001$) displaying a significantly higher degree of risk aversion. A Fisher exact test confirms that there is a significantly higher fraction of risk averse subjects among the treated (92% Vs. 80%, $p = 0.024p = 0.024$). This finding is consistent withCameron & Shah (2015), who report that respondents exposed to flood and earthquake in Indonesia exhibit higher levels of risk aversion compared to unexposed respondents.

The respondents from both groups display a remarkably strong degree of risk aversion, a result that at first glance is at odds with the finding that subjects in developing countries are generally risk tolerant (l'Haridon & Vieider, 2019).This purported contradiction can be rationalized by the fact that respondents in both groups face a high (though different) risk of natural disasters, which makes the whole sample more risk averse.

A regression of the choice in the BRET controlling for the socio-economic characteristics of the subjects confirms the robustness of the effect of exposure to risk (see Table 4, Column 1). Results display decreasing absolute risk aversion, something typically observed also in the literature concerning developing countries, both in Asia (Liu, 2013; Tanaka, Camerer, & Nguyen, 2010) and in Africa (Yesuf & Bluffstone, 2009; Liebenehm & Waibel, 2014). The higher risk aversion of poorer farmers suggests that they are even less willing to undertake risky endeavours such as investments and therefore could be trapped in poverty. Education also makes subjects less risk averse, similarly to what found by Liebenehm & Waibel (2014) among cattle farmers in West Africa[46].

Table 3: Descriptive statistics of experimental tasks results

Variable	Control	Treated	Mann-Whitney Z	p-value
Risk Tolerance (Number of Steps)	30.47	18.26	5.764	< 0.001
	(20.46)	(18.42)		
Risk Attitudes:				
Risk Averse	80%	92%	Fisher	0.024
Risk Loving	20%	8%		
Average Contribution	3.38	5.16	-6.026	< 0.001
	(0.36)	(0.52)		

Notes: Standard deviation in parenthesis.

The test of the average contribution is based on the average group choices, i.e. 25 independent observations per treatment

Source: Author's survey, 2017.

the exact amount they attach to the good. Five different initial values are proposed, in order to minimize possible anchoring effects. Indeed, there is no correlation between the initial value and the final WTP for the two goods ($\rho = -0.0174; p - value = 0.8065\rho = -0.0174; p - value = 0.8065$), which implies that there is no starting point biases in the CVM. A correlation between the initial bid and the final WTP would have mean the respondents' final WTP was influenced by the initial bid.

46 Tanaka, et al. (2010) and Nguyen (2011) find instead the opposite relationship in Asia.

The positive relationship between education and risk tolerance suggests a channel that policies may exploit to foster the adoption of more rewarding methods of production that require investments perceived as risky. Finally, the classic positive correlation between age and risk aversion also emerges. These significant correlations also corroborate the goodness of the elicitation of risk preferences with experimental tasks, something not obvious in general and even less so in developing countries (Charness & Viceisza, Three Risk-elicitation Methods in the Field-Evidence from Rural Senegal, 2016).

Cooperation

The results clearly show that exposure to flood risk increases cooperation substantially (see Table 3, bottom panel).The average contribution to the public good is 51.6% of the endowment in the treated group and 33.8% among the controls.Using the average contribution of each group across the ten period as an independent observation, a Mann-Whitney test detects that differences are highly significant despite the low number of observations ($p < 0.001p < 0.001$). The same pattern emerge analysing the contributions period by period (see Figure 3). In both groups we observe the classic decay in the contributions over time (Isaac, McCue, & Plott, Public goods provision in an experimental environment, 1985; Andreoni, 1988; Ledyard, 1994), but the treated contribute steadily and significantly more. This result seems to extend the findings of Afzal, et al. (2015) also to the case of devastating floods.

Column 2 of Table 4 reports the analysis of the degree of cooperation controlling for the main socio-economic characteristics of individuals in a standard linear regression. The treatment dummy display a very strong and significant effect, while only age displays a weakly significant correlation with the average individual level of the contributions. Poorer subjects are also those who display a higher risk aversion, thereby suggesting that the correlation of age with cooperation is likely spurious. In fact, the significance of this correlation disappears when individuals' risk preferences are controlled for.

Table 4: Factors influencing farmers' economic preferences.

Variables	(1)	(2)	(3)
	Risk (Steps)	Cooperation	Cooperation
Treated	-10.875***	1.7674***	1.6528***
	(2.028)	(0.1215)	(0.1268)
Risk Tolerance			-0.0105***
			(0.0033)
Income	0.094***	-0.0011*	-0.0001
	(0.015)	(0.0007)	(0.0007)
Age	-0.517***	0.0109	0.0054
	(0.126)	(0.0084)	(0.0081)
Education			

No Education	Reference	Reference	Reference
Basic Education	9.677***	-0.0641	0.0379
	(2.714)	(0.1340)	(0.1336)
Secondary	17.346***	-0.0434	0.1393
	(3.361)	(0.1430)	(0.1365)
Farm Size	0.951	-0.0345	-0.0245
	(0.770)	(0.0388)	(0.0378)
Dependency	2.614	0.0319	0.0595
	(1.587)	(0.0773)	(0.0815)
Constant	-29.770***	3.7923***	3.4789***
	(8.959)	(0.4697)	(0.4804)
R-squared	0.6711	0.7316	0.7449

Standard errors in parentheses() are clustered at the group level

$*p < 0.1, **p < 0.05, ***p < 0.01$

Risk tolerance turns out to be negatively and strongly correlated with cooperation (Table 4, Column 3), showing that the interplay between these two behavioural traits needs to be analysed carefully. The fact that risk aversion increases cooperation suggests that cooperation may indeed work as a form of self-insurance. This result is in line with Lohse, et al. (2012), who report that a highly risk averse person will demand more self-insurance to reduce the size of a loss. If cooperation was only driven by self-insurance purposes the change in cooperation should be entirely linked to the change in risk aversion. However, greater exposure to natural risk likely has a direct effect, too. The interesting question is therefore to disentangle how much of the stronger inclination to cooperate is directly driven by exposure to risk from what is due to higher risk aversion, which is in turn affected by the treatment.

Cooperation as self-insurance ?

In general terms, risk aversion plays the role of an intermediate variable that lies in the causal path between the treatment (exposure to risk of disaster) and the outcome (inclination to cooperate). In our data we observe the level of cooperation and risk aversion under the two separate conditions (treated vs. control). What cannot be observed is the counterfactual level of cooperation for the controls when the level of risk aversion is equal to that of the treated. This measure would represent the indirect effect of exposure to flood on cooperation, i.e. the fraction of the total effect that can be attributed to the increase in risk aversion. In what follows we identify this indirect effect using the Average Causal Mediation Effect (ACME) proposed byImai, et al., 2010a,b; Hicks & Tingley, 2011). The ACME estimator applies to continuous mediation and outcome variables, as in our experiment, and requires less parametric assumptions than the linear structural equation model. Once the mediation effect is inferred, we can then identify how much of the total effect is driven by the so-called natural direct effect of the treatment on cooperation and how much by the mediating

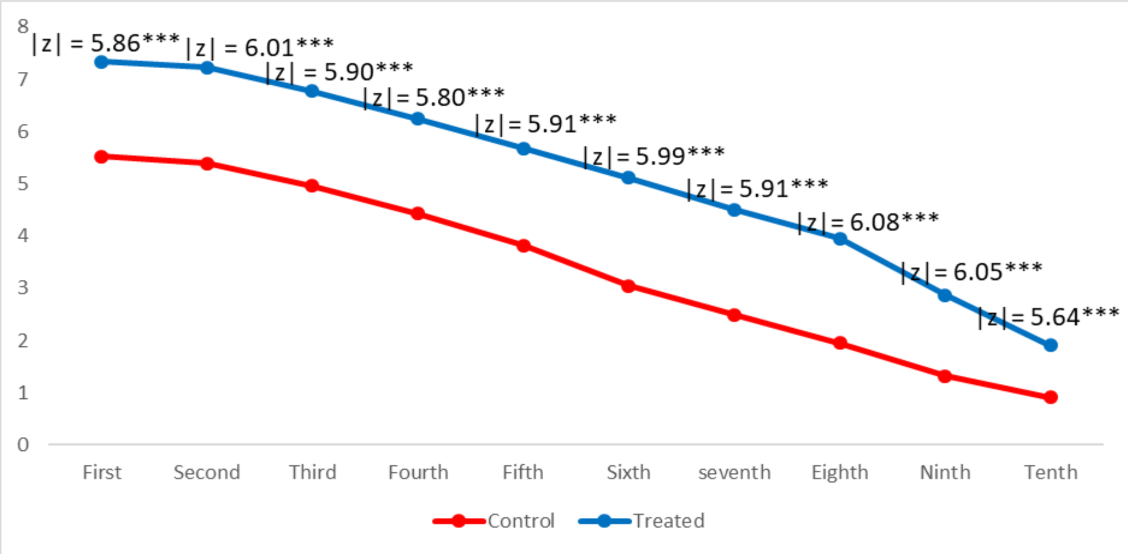

Figure 3: Average group contributions by location

Source: Author's survey, 2017.

The mediation effect turns out to be only 6.3% of the overall impact of the treatment, showing that the bulk of the effect of exposure to the risk of flood on cooperation is direct. The identification of ACME relies upon the sequential ignorability assumption. In particular, while the two groups display similar observable characteristics, we cannot exclude that there may exist unmeasured covariates that confound the relationship between the mediator and the outcome. For example, the sequential ignorability assumption would be violated if cooperation responded to risk aversion differently depending on whether it was directly assigned occurred as a natural response to the treatment. Sensitivity analysis show that the mediation effect remains of a small order of magnitude for reasonable departures from the identification assumption (see Figure 4).

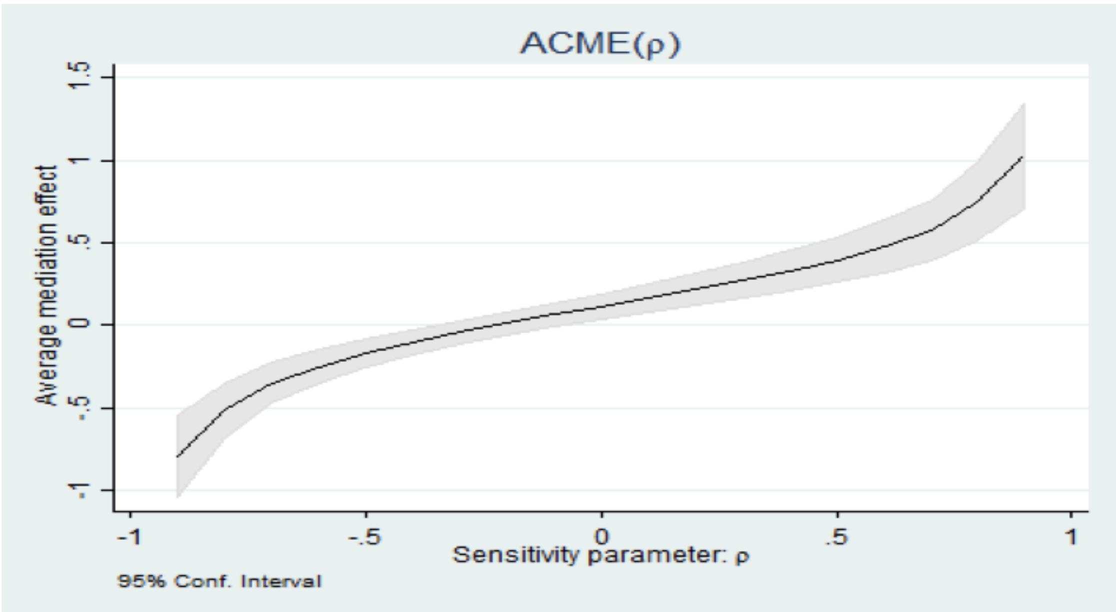

Figure 4: Sensitivity analysis of causal mediation analysis around the identification assumption $\rho = 0\rho = 0$

CONCLUSION

The growing risk of natural disasters has a profound impact especially in developing countries, where rural livelihoods are inextricably linked with the environment. The difficulty to insure this type of risk magnifies the role played by individual behavioural traits when dealing with the severe consequences of these unfavourable events as well as in shaping appropriate adaptation strategies. This paper studies the causal effect of a different exposure to flood risk on the inclination to cooperate, on risk aversion, and their interplay. While the role of risk aversion is intuitive, we also investigate the effect of background risk on cooperation, something not established in the literature. The idea is that the collective effort of the members of a community constitute a major strength of rural households in reducing the impact of natural shocks on their livelihood. In particular, given that cooperation may be seen as a form of self-insurance at the local level, the goal is to assess how much of the change in pro-social behaviour is a direct effect of exposure to risk, and how much is instead mediated by the effect on risk preferences.

Our experiment confirms that preferences are significantly affected by the environment. As regards risk aversion, we find that highly exposed individuals exhibit a significantly higher level of risk aversion, an effect of background risk that is well-known in the literature. The average degree of risk aversion is higher than what commonly found in developing countries, possibly because respondents in both the treated and the control group face a significant (though different) risk of natural disaster. This treatment effect is robust to the inclusion of socio-economic characteristics in a multivariate analysis. Besides the classic positive correlation with age, we find evidence of decreasing absolute risk aversion, suggesting that poorer farmer may be less willing to adopt more rewarding methods of production involving risky investments and therefore be trapped in poverty. However, risk aversion decreases with education suggesting a channel that policies may exploit to foster the adoption of rewarding but risky innovations.

Our results show that a higher exposure to the risk of natural disaster significantly increases the inclination to cooperate. The results also reveal a strong and positive correlation between cooperation and risk aversion. At first glance, the fact that more risk averse individuals contribute more to the public good lends support to the interpretation of cooperation as a form of self-insurance in an environment where classic forms of insurance are not available. We therefore perform a causal mediation analysis to test whether risk aversion acts as an intermediate variable in the causal path between background risk and individuals' inclination to cooperate. We find that risk aversion does play a role, but that only a small proportion (6.3%) of the change in cooperation may be ascribed to the increase in the level of risk aversion, with the bulk of the effect being direct. In other words, the increase in the farmers' inclination to cooperate is to a great extent directly driven by the higher exposure to natural disaster.

While cooperation seems to emerge as a spontaneous and relevant adaptation strategy, the results of our experiment also provide suggestive evidence for policy implications. The take-up of innovative but risky methods of production could be fostered by policies aimed at increasing farmers' income and education, given their negative relationship with risk aversion. The results of our paper also provide interesting insight for future research. Understanding the exact shape of the relationship between different levels of exposure to risk of natural disaster and cooperation, as well as discovering other and more relevant mediating variables (e.g. altruism, trust and trustworthiness) looks like two promising endeavours in our opinion.

REFERENCES

Afzal, U., Turner, G., & Said, F. (2015). The Voluntary Provision of Public Goods after a Natural Disaster: A Field Experiment from Pakistan. https://editorialexpress.com/cgi-bin/conference/download.cgi?db_name=CSAE2015&paper_id=772

Andreoni, J. (1988). Why free ride?: Strategies and learning in public goods experiments. Journal of Public Economics , Vol.37, Issue 3, pages 291-204.

Armah, F. A., Odoi, J. O., Yengoh, G. T., Obiri, S., Yawson, D. O., & Afrifa, E. K. (2011). Food security and climate change in drought-sensitive savanna zones of Ghana. Mitigation and adaptation strategies for global change , Vol. 16, Issue 3, pages 291-306.

Bchir, M. A., & Willinger, M. (2014). Does the exposure to natural hazards affect risk and time preferences? Some insights from a field experiment in Perú. Working Papers 13-04, LAMETA, University of Montpellier.

Belfor, H. (2014). Impact of Natural Disaster Exposure on Prosocial Preferences and Public Goods Provision: Evidence from the Solomon Islands.Master's Thesis 8, https://repository.usfca.edu/thes/83.

Bohnet, I., & Zeckhauser, R. (2004). Trust, risk and betrayal. Journal of Economic Behavior & Organization , Vol. 55, Issue 4, pages 467-484.

Boucher, S. R., Carter, M. R., & Guirkinger, C. (2008). Risk rationing and wealth effects in credit markets: Theory and implications for agricultural development. American Journal of Agricultural Economics , Vol. 90, Isssue 2, pages 409-423.

Callen, M. (2015). Catastrophes and time preference: Evidence from the indian ocean earthquake. Journal of Economic Behavior & Organization , Vol. 118, pages 199-214.

Cameron, L., & Shah, M. (2015). Risk-taking behavior in the wake of natural disasters. Journal of Human Resources, Vol. 50,Issue 2, pages 484-515.

Carter, M. R., & Barrett, C. B. (2006). The economics of poverty traps and persistent poverty: An asset-based approach. The Journal of Development Studies , Vol. 42, Issue 2, pages 178-199.

Carter, M., De Janvry, A., Sadoulet, E., & Sarris, A. (2014). Index-based weather insurance for developing countries: A review of evidence and a set of propositions for up-scaling. Development Policies working paper , 111. https://econpapers.repec.org/paper/fdiwpaper/1800.htm

Charness, G., & Viceisza, A. (2016). Three Risk-elicitation Methods in the Field-Evidence from Rural Senegal. Review of Behavioral Economics , Vol. 3, Isssue 2, pages 145-171.

Charness, G., & Villeval, M.-C. (2009). Cooperation and competition in intergenerational experiments in the field and the laboratory. American Economic Review , Vol. 99, Issue 3, pages 956-978.

Charness, G., Garcia, T., Offerman, T., & Villeval, M. C. (2019). Do measures of risk attitude in the laboratory predict behavior under risk in and outside of the laboratory? IZA Discussion Paper (12395).

Cherry, T. L., Howe, E. L., & Murphy, J. J. (2015). Sharing as risk pooling in a social dilemma experiment. Ecology and Society , Vol. 20, Issue 1, pages 68.

Crosetto, P., & Filippin, A. (2016). A theoretical and experimental appraisal of four risk elicitation methods. Experimental Economics , Vol. 19, Issue 3, pages 613-641.

Crosetto, P., & Filippin, A. (2013). The 'Bomb' Risk Elicitation Task. Journal of Risk and Uncertainty , Vol. 47 , Issue 1, pages 31-65.

Dave, C., Eckel, C. C., Johnson, C. A., & Rojas, C. (2010). Eliciting risk preferences: When is simple better? Journal of Risk and Uncertainty , Vol. 41, Issue 3, pages 219-243.

Dercon, S., & Christiaensen, L. (2011). Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia. Journal of development economics , Vol. 96, Issue 2, pages 159-173.

Eckel, C. C., El-Gamal, M. A., & Wilson, R. K. (2009). Risk loving after the storm: A Bayesian-Network study of Hurricane Katrina evacuees. Journal of Economic Behavior & Organization , Vol. 69, Issue 2, pages 110-124.

Eeckhoudt, L., Gollier, C., & Schlesinger, H. (1993). Changes in background risk and risk taking behavior. Econometrica: Journal of the Econometric Society , Vol. 64, Issue 3, 683-689, https://doi.org/10.2307/2171866

Fafchamps, M. (2003). Rural poverty, risk and development. Edward Elgar Publishing, Cheltenham: Edward, 2003, pp.272. Journal of International Development , Vol. 18, Issues 2, pages 293-294.

Friedl, A., De Miranda, K. L., & Schmidt, U. (2014). Insurance demand and social comparison: An experimental analysis. Journal of Risk and Uncertainty , Vol. 48, Issue 2, pages 97-109.

GSS. (2012). 2010 Population and Housing Census: District Analytical Report (Tolon-Kumbungu Districts). Ghana Statistical Service.

Guala, F. (2005). The methodology of experimental economics. Cambridge University Press.

Heinemann, F., Nagel, R., & Ockenfels, P. (2009). Measuring strategic uncertainty in coordination games. The Review of Economic Studies ,Vol. 76, Issue 1, pages 181-221.

Hicks, R., & Tingley, D. (2011). Causal mediation analysis. The Stata Journal , 11 (4), 605-619.

Imai, K., Keele, L., & Tingley, D. (2010). A general approach to causal mediation analysis. Psychological methods , Vol.15, Issue 4, pages 309-334.

Imai, K., Keele, L., & Yamamoto, T. (2010). Identification, inference and sensitivity analysis for causal mediation effects. Statistical science , Vol. 25, Issue 1, pages 51-71.

IPCC. (2014). Climate Change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.). IPCC, Geneva, Switzerland, 155 pp.

Isaac, M. R., & James, D. (2000). Just who are you calling risk averse? Journal of Risk and Uncertainty , Vol. 20, Issue 2, pages 177-187.

Isaac, M. R., McCue, K. F., & Plott, C. R. (1985). Public goods provision in an experimental environment. Journal of Public Economics , Vol. 26, Issue 1, pages 51-74.

Jakpa, J. T. (2015, July). Smallholder Farmers' Vulnerability to Floods in The Tolon District, Ghana. University of Ghana, http://197.255.68.203/handle/123456789/8499

Kahsay, G. A., & Osberghaus, D. (2018). Storm Damage and Risk Preferences: Panel Evidence from Germany. Environmental and Resource Economics , Vol. 71, Issue 1, pages 301-318.

Kimball, M. S. (1993). Standard risk aversion. Econometrica: Journal of the Econometric Society , Vol. 61, Issue 3, 589-611.

Konrad, K. A., & Skaperdas, S. (1993). Self-insurance and self-protection: a nonexpected utility analysis. The GENEVA Papers on Risk and Insurance-Theory , Vol. 18, Issue 2, pages 131-146.

Ledyard, J. O. (1994). Public goods: A survey of experimental research. Public Economics, (9405003), University Library of Munich, Germany, revised 22 May, 1994.

l'Haridon, O., & Vieider, F. M. (2019). All over the map: A worldwide comparison of risk preferences. Quantitative Economics , Vol. 10, Issue 1, pages 185-221.

Liebenehm, S., & Waibel, H. (2014). Simultaneous estimation of risk and time preferences among small-scale cattle farmers in West Africa. American Journal of Agricultural Economics , Vol. 96, Issue 5, pages 1420-1438.

Liu, E. M. (2013). Time to change what to sow: Risk preferences and technology adoption decisions of cotton farmers in China. Review of Economics and Statistics , Vol. 95, Issue 4, pages 1386-1403.

Lohse, T., Robledo, J. R., & Schmidt, U. (2012). Self-insurance and self-protection as public goods. Journal of Risk and Insurance , Vol. 79, Issue 1, pages 57-76.

Mensah, J. T., & Adu, G. (2015). An empirical analysis of household energy choice in Ghana. Renewable and Sustainable Energy Reviews , Vol. 51, Issue C, pages 1402-1411.

Musah, B. A., & Oloruntoba, A. (2013). Effects of Seasonal Floods on Households? Livelihoods and Food Security in Tolon/Kumbumgu District of the Northern Region, Ghana. American Journal of Research Communication , Vol. 1, Issue 8, pages 160-171.

Nguyen, Q. (2011). Does nurture matter: Theory and experimental investigation on the effect of working environment on risk and time preferences. Journal of Risk and Uncertainty , Vol. 43 Issue 3, pages 245-270.

Norton, M., Osgood, D., Madajewicz, M., Holthaus, E., Peterson, N., Diro, R., et al. (2014). Evidence of demand for index insurance: Experimental games and commercial transactions in Ethiopia. Journal of Development Studies , Vol. 50, Issue 5, pages 630-648.

Olbrich, R., Quaas, M. F., Haensler, A., & Baumgärtner, S. (2012, May 15). Risk preferences under heterogeneous environmental risk. Available at SSRN 1904315 .

Ostrom, E. (1998). A behavioral approach to the rational choice theory of collective action: Presidential address, American Political Science Association, 1997. American Political Science Review , Vol. 92, Isssue 1, pages 1-22.

Pratt, J. W., & Zeckhauser, R. J. (1987). Proper risk aversion. Econometrica: Journal of the Econometric Society , Vol. 55, Issue 1, pages 143-154.

Sabater-Grande, G., & Georgantzis, N. (2002). Accounting for risk aversion in repeated prisonersí dilemma games: An experimental test. Journal of Economic Behavior & Organization , Vol. 48, Issue 1, pages 37-50.

Schechter, L. (2007). Traditional trust measurement and the risk of confound: an experiment in rural Paraguay. Journal of Economic Behavior & Organization , vol. 62, Issue 2, pages 272-292.

Tanaka, T., Camerer, C. F., & Nguyen, Q. (2010). Risk and time preferences: Linking experimental and household survey data from Vietnam. American Economic Review , Vol. 100 Issue 1,pages 557-571.

Teyssier, S. (2012). Inequity and risk aversion in sequential public good games. Public Choice , Vol. 151 Issue 1-2, pages 91-119.

Voors, M. J., Nillesen, E. E., Verwimp, P., Bulte, E. H., Lensink, R., & Van Soest, D. P. (2012). Violent conflict and behavior: a field experiment in Burundi. American Economic Review , Vol. 102, Issue 2, pages 941-964.

Wunsch, C., & Strobl, R. (2018). Risky Choices and Solidarity: Why Experimental Design Matters. CESifo Working Paper Series (7125).

Yesuf, M., & Bluffstone, R. A. (2009). Poverty, risk aversion, and path dependence in low-income countries: Experimental evidence from Ethiopia. American Journal of Agricultural Economics , Vol. 91, Issue 4, pages 1022-1037.

Climate change, agricultural output, household income and policies in Senegal

Khady Yama Sarr

ABSTRACT

The Senegalese agricultural sector shows low production level over the last decades. This study assesses the impact of climate change on crop production, household income, and also tests policies instruments through a national static computable general equilibrium model. The model has four agents (government, firms, households and the rest of the world), two factors of production (labor and capital) and fourteen branches. The model structure is based on five blocks of equations describing the production, income and savings, demand, prices and trade with the outside; the balance is achieved in factor markets and commodity markets. Equality between savings and investment is realized. The main results show that the local impacts of climate change (through declining yields) are likely to affect Senegal beyond the agricultural sector and farmers. The results show also after testing different policies instruments in the worst climate scenario for Senegal that decreasing the rice import tariff by 20% and subsidizing fertilizers is the most suitable policy instrument that can help to mitigate the negative effects that climate change has on agricultural sector in Senegal.

Keywords: Computable General Equilibrium, Climate Change, Policy instruments, Senegal

RÉSUMÉ

Le secteur agricole sénégalais présente un faible niveau de production au cours des dernières décennies. Cette étude évalue l'impact du changement climatique sur la production agricole, le revenu des ménages, et teste également les instruments de politiques à travers un modèle d'équilibre général calculable statique national. Le modèle comporte quatre agents (gouvernement, entreprises, ménages et le reste du monde), deux facteurs de production (travail et capital) et quatorze branches. La structure du modèle est basée sur cinq blocs d'équations décrivant la production, le revenu et l'épargne, la demande, les prix et le commerce avec l'extérieur ; l'équilibre est réalisé sur les marchés des facteurs et des marchandises. L'égalité entre l'épargne et l'investissement est réalisée. Les principaux résultats montrent que les impacts locaux du changement climatique (par la baisse des rendements) sont susceptibles d'affecter le Sénégal au-delà du secteur agricole et des agriculteurs. Les résultats montrent également, après avoir testé différents instruments politiques dans le pire scénario climatique pour le Sénégal, que la diminution de 20% des droits d'importation de riz et la subvention des engrais sont les instruments politiques les plus appropriés pour

aider à atténuer les effets négatifs du changement climatique sur le secteur agricole au Sénégal.

Mots-clés: Équilibre général calculable, changement climatique, instruments de politique, Sénégal.

INTRODUCTION

Senegalese agriculture is mainly rain-fed for more than 94% of the area planted. It is one of the main economic activities and the engine of growth in the framework of the implementation of the Senegal Emergent Plan (PSE) (Rapport revue conjointe agriculture, MAER, 2016). Agriculture is a key sector in Senegal economy and it is mainly the backbone of rural economy. Wherein, 55% of the population lives in rural areas, 49.5% have farming as main activity while 60% engage on rain fed agriculture (MEDD, 2016). Agriculture employs more than 70% of the Senegalese workforce. Most household cultivate on plots of 1 to 5 ha. Cereals like rice, millet and sorghum are key subsistence crops, while groundnuts, a main cash crop, are grown on 40% of cultivated land and employ up to 1 million people (U.S. Agency for International Development-USAID, 2017).

However, it is clear that climate change such as extreme weather events, increased incidence of droughts and floods. Variability in rainfall and degradation of marginal lands affects the agricultural sector. Climatic projections of average (RCP 4.5) and extreme (RCP 8.5) scenarios indicate a general downward trend in rainfall by 2035 throughout the country. As for temperatures, for both scenarios (RCP 4.5 and RCP 8.5), there is a general upward trend. Temperatures have been predicted to increase on average between 1.17 and 1.41 degrees Celsius by 2035 (NDC, 2017). This increase in temperature combined with a rainfall deficit could lead to a deterioration of the agricultural productive base resulting in: the reduction of the vegetation cover; a process of water and wind erosion leading to encrusting and degradation of soils; salinization related to saltwater invasion and poor drainage of land; loss of soil fertility and more specifically nutrient loss (Crasswell et al., 2004 in Edward R. et al, 2004). All these forms of land degradation will result in a reduction of cultivated areas. The reduction in farmland could reduce cereal production by 20% in 2025 (Funk et al., 2012 in Edward R. et al, 2004).

Smallholder agriculture, which is predominantly rainfed, is already stressed by overexploitation of land, soil degradation, conflicts between herders and farmers, and limited access to extension services. Climate change is expected to amplify most of these challenges. Without coordinated and appropriate policy measures shares, these challenges could jeopardize the prospects of the country achieving the Sustainable Development Goals. Not acting quickly can lead to a significant increase in the number of people needing assistance.

The objective of this paper is to assess the impact of climate change on the production volume of some crops (maize, millet/sorghum, groundnut) in Senegal, household income and to test alternative policies instrument that can help to mitigate fluctuations of quantities through a national static computable general equilibrium (CGE) model. The rest of the paper is organized as follow: section 1 presents the literature related to climate change and the general equilibrium model, section 2 described the model, the data and calibration issues; the climate scenarios and the different simulations are dealt with in section 3 and finally, the results are presented and discussed in section 4.

As climate change affects various sectors of the economy directly or indirectly, interactions between different sectors must be studied to assess the impacts of climate change on agriculture and productivity. CGE models are well suited to depict interactions between agriculture and other sectors in the economy.

Two broad approaches have been used to assess the impact of climate change on agriculture within the CGE framework. The first approach is to develop an integrated assessment model, which couples a CGE model with a partial equilibrium agricultural land use model. The second approach is to develop climate scenarios to determine the different changes in yields and introduce these changes to the production function of the CGE model. There has been much development in "macro-micro CGE models" during the last decade. There has been an explosive growth in analyses of developing countries' vulnerability to climate change, including its economy-wide impacts.

Breinsinger and Diao (2008) used the Dynamic Computable General Equilibrium (DCGE) model to capture the growth and poverty linkages of the agricultural sector in Ghana. This model explicitly captures the following: agricultural production technology at the sub-sector level across agro-ecological zones; agricultural input demand, including demand for factors and intermediates; output distribution, i.e. for exports and domestic markets; and incomes from agricultural production. They found that agriculture accounted for about 39 percent of national GDP in Ghana in 2005. Although the 4.2 percent average agricultural annual growth is lower than those of the two nonagricultural sectors in the base-run, the size of agriculture in the economy only falls slightly to 38 percent by 2015. In the face of slightly slower agricultural growth, agricultural prices rise for some products produced for domestic markets, especially those that are income elastic, such as rice, high-value products and poultry.

Pauw, Thurlow and Van Seventer (2011) use stochastic hydro-meteorological crop-loss models with a regionalized CGE model to estimate losses for the full distribution of possible weather events (drought and floods) in Malawi. Results for Malawi indicate that, on average, droughts and floods together reduce total GDP by about 1.7 percent per year. However, damages vary considerably across weather events, with total GDP declining by at least 9 percent during a severe 1-in-20-year drought. Smaller-scale farmers in the southern regions of the country are especially vulnerable to declining agricultural revenues and increasing poverty during drought and flood years.

Zhai et al. (2009) examined the potential long-term impacts of global climate change on agricultural production and trade in the People's Republic of China, using an economy-wide, global CGE model, as well as simulation scenarios of how global agricultural productivity may be affected by climate change up to 2080. This study suggested that, with a declining share of agriculture in GDP, the impact of climate change on the overall macro economy may be moderate. Food processing sectors carry the burden of some crop sectors (wheat, in particular) that are likely to expand due to increased demand.

Octaviani et al., (2011) measured the impact of climate change on the Indonesian economy using a combination of the partial equilibrium model and the CGE model as the main analytical tool. To analyze in detail, the impact on the agricultural sector and macroeconomic conditions in Indonesia, they link IMPACT with the national Indonesian general equilibrium model (Indonesian CGE Model for Climate Change), which has different agricultural product aggregations and also includes labor aggregations. They discovered that the impact on domestic prices, measured by the consumer price index (CPI), is expected to increase from −2.37 percent change in the baseline to −2.08 and −2.17 percent change in Sims 2a and 2b, respectively, worsening the deflation of the baseline scenario. Prices increase particularly for paddies and rice under the MIROC A1B scenario, which shows higher impacts for Indonesia. Real household consumption is expected to slightly decrease because of climate change due to the decrease in average real wages in most labor classifications. Furthermore, operator and professional labor will suffer from the highest negative impact under the climate change scenario. They also found that there is a reduction in capital rental. Net export performance worsens because Indonesia has to focus on allocating resources to provide adequate supply in response to domestic demand of strategic food commodities (rice and maize).

METHODS

Description of the model, data and calibration

To highlight the effects of climate change on the volume of production and household income in Senegal and to test alternative policies instruments, the methodology used in this study is based on a static computable general equilibrium (CGE) because it has the ability to analyze the interactions among different sectors. In this study, the model has four agents (government, firms, households and the rest of the world), two factors of production (labor and capital) and fourteen branches. The model structure is based on five blocks of equations describing the production, income and savings, demand, prices and trade with the outside; the balance is achieved in factor markets and commodity markets. Equality between savings and investment is realized.

The Representative Household

Households aim to maximize their utility function under the constraint of their budget. Their income consists of the remuneration received from their supply of production factors namely labor and capital. In addition, households receive transfers from the Government and the rest of the world. Household preferences regarding their demand for consumer goods are represented using a linear expenditure system from the maximization of a Stone-Geary (SG) utility function.

The maximization program of the household h utility is as follows :

Max ℗ (Ci,h,t – CMINi,h,t)yi,h (1)

$$\sum_i Pci,h,t\ Ci,h,t = Rht \sum_i Pci,h,t\ Ci,h,t = Rht \qquad (2)$$

With the following restrictions :

CMINi,h,t < Ci,h,t and $\sum_i Pmci,h,t = 1 \sum_i Pmci,h,t = 1$ (3)

Pmci,h,t is the marginal consumption of good I; CMINi,h,t is the minimal consumption (in volume) of good i by the household h at time t.

The production process

Production activities are represented by branches of the national accounts system whose

organization is based on the NAEMAS nomenclature. In the basic model, each activity j (j =1, .., J) is the production of a single good noted i (i = 1, .., I).

In general, each producer aims to minimize costs, with a constraint production technology available according to the structure described in Annex. The technology is such that the production is a Leontief function of value added and a composite measure of inputs. Value added is, in turn, specified as a Cobb-Douglas function of labor and capital in non-agricultural sectors, while in the agricultural sector, it aggregates a composite of the primary factors that are labor and capital.

As for the composite measure of inputs, it includes disaggregated intermediate consumption of the activity, according to a Leontief function. The factors of production are labor and capital. It is assumed that there is a perfect segmentation of the labor market. In this market the supply of labor will be assumed exogenous while the wage rate will adjust to clear the market in response to changes in the demand for labor.

The supply of capital is supposed to be specific to sectors. The annual change in the capital stock is endogenous and determined by the following equation :

$$KDjt= (1- d(j))\ KDjt-1 + INVjt-1 \quad (4)$$

KDjt is the capital stock of the sector j at time t ; d(j) is the depreciation rate of capital of the sector j and INVjt represents the investment volume of sector j at period t.

The Final Demand

Final demand for each commodity i is formed by the sum of domestic and import demand of his commodity. Once incorporated, the final demand for any good i is the sum of final onsumption, government consumption, investment and intermediate goods industries, ollowing the traditional script of the equilibrium equation on goods and services.

Trade

The foreign trade block comes from export activities and the import of goods from the Senegalese economy. World prices of imports and exports will be assumed exogenous in that the analysis is conducted in the context of a small open economy. In general, for each product, export supply will be determined by arbitration between exports and supply on the domestic market, through a constant elasticity of transformation function (CET). In contrast, imports will come from the arbitration between the demand for locally produced goods and those addressed to the "rest of the world," according to a constant elasticity of substitution function (CES) or Armington function.

Government

The function of government is to collect indirect taxes on production, the components of final demand, direct taxes on incomes of households and enterprises and, finally customs duties and taxes on exports. It receives transfers from the "rest of world" and conducts itself in transfers to households, as well as subsidies to enterprises. Moreover, the government has resources in respect of capital remuneration. Its income thus formed is then used for its spending. Public resources are intended, first, for the consumption of goods (public consumption) and, on the other hand for investment (public investment). The difference between the state resources and its expenditures (current and investment) constitute the budgetary balance.

The market equilibrium, the model assumptions and mechanisms of closure

In terms of macroeconomic closure of the model, foreign savings will be assumed to be exogenous. The balance of the external account will be realized on the basis of the assumption of exogeneity of the trade balance and therefore, the adjustment process will be achieved through the real exchange rate. The meaning of this assumption is that the Senegalese economy cannot adjust to the external debt to cover internal imbalances, but should generate sufficient export earnings to proceed to the purchase of imported goods and services. In other words, any increase in imports of certain goods will be systematically offset by lower imports of other goods or by an equivalent increase in exports, to meet the constraint. In general, the prices of different goods adjust to balance the relevant markets. (Equations are in annexes)

Data and Calibration

The model is calibrated using the 2010 agricultural accounting matrix for Senegal (DPEE, 2010). DPEE is one component of the Senegalese ministry of economy. The social accounting matrix (SAM) is a summary table that outlines the structure of production in an economy through the use of production and operating accounts and the interactions between the economic agents.

Brief description of the Climate Scenarios

To assess the impacts of climate change on agricultural output and household income, we used the results of the study of Dering (2015) on the impacts of climate change on crop productivity in semi-arid economies (Senegal, Burkina Faso, and Kenya).

In the study, the author presents a comprehensive assessment of climate change impacts on crop productivity in semi-arid croplands in the world for the 2030s relative to the 2000s under a business-as- usual greenhouse gases (GHGs) emissions scenario (all results are shown for the emission rates associated with Radiative Concentration Pathway (RCP 8.5). Simulated changes in the extent of semi-arid areas and impacts on crop yield are presented. The geographical focus of the analysis is global, with a particular emphasis on six Pathways to Resilience in Semi-Arid Economies (PRISE) countries: Senegal, Burkina Faso, Kenya and Tanzania in Africa and Pakistan and Tajikistan in Central Asia. Results are shown with changes in climate (temperature, precipitation and radiation) from five different global climate models (GCMs) and crop yield impacts simulated by six different global gridded crop models (GGCMs) (an ensemble of 30 simulations). The results are sourced from a global climate impact assessment programme (Inter-Sectoral Impact Modelling Inter-comparison Project (ISI-MIP)).

The study focuses also on 13 crops including maize, wheat for the full ensemble of

GGCMs, as well as millet, groundnut, sorghum and peanuts for a subset of two GGCMs. Results take into account effects of elevated atmospheric CO_2 concentrations under a business-as-usual GHGs emissions scenario (i.e. RCP 8.5). According to the study, In Senegal three climate models (HadGEM2-ES, IPSL-CM5A-LR and GFDL-ESM2M) project a drier climate, and two climate models (MIROC-ESM-CHEM and NorESM1-M) simulate a wetter climate.

The results show that in Senegal average crop yield by the 2030s decreases by 7.5 to 16.7% under Climate Change: yields of groundnut, millet, sorghum and maize decrease between 5.4% and 12.3% in the ensemble median. Under RCP 8.5 scenario with positive effects of CO_2 concentration on crops, average crop yield decreases by 8.5 to 9.9%, groundnut, millet/sorghum fall respectively by 8.5% and 6% with maize experiencing the largest decrease (-8.8 to 14.7%)

Table 1: Climate change induced yield effects by crop, % change from yield with 2000 climate to yield with 2030 climate

Crops	Scenario without CO_2 effects on crops	RCP 8.5 scenario (with CO_2 effects on crops)
Maize	Fall of 5.4% to 12.3%	Fall of 8.8% to 14.7%
Groundnut	Fall of 5.4% to 12.3%	Fall of 8.5% to 9.9%
Millet	Fall of 5.4% to 12.3%	Fall of 8.5% to 9.9%
Sorghum	Fall of 5.4% to 12.3%	Fall of 8.5% to 9.9%

Source: Deryng, (2015)

The RCP 8.5 scenario (2006–2300) assumes high population growth and high energy demand without climate change policies.

We introduce the different changes of yields in the production function of the CGE model by using minimum, mean and maximum of the ranges. The production volume is in tons.

RESULTS AND DISCUSSION

The results of the CGE model show that under climate change scenario without the positive effects of CO_2 on crops, the production of all the crops (maize, millet/sorghum and groundnut) falls: 30.7% for maize, 29% for groundnut and 11.5% for millet/sorghum. The impact of climate change on the production volume is different between crops. The decline is much less important for millet / sorghum. The household demand decreases due to higher prices resulting from the lower level of crop production. This is also explained by the reduction of the household income by 26%. This reduction of household income is due to the drop of salary rate in the agricultural activities sectors and also in the others economic sectors. The results of the CGE model show also that the climate projected in 2030 will lead to a decrease in agricultural value added by 11.5%. Under RCP 8.5 scenario including the positive effects of CO_2 on crops, we noted a drop of the production volume of all the crops: 21% for maize, 17.5% for groundnut and 8.5% for millet/sorghum. The negative effects of climate change on crops are less important under RCP 8.5 scenario including the positive effects of CO_2 than under climate change scenario without the positive effects of CO_2. The household demand for millet and sorghum and maize decreases respectively by 12% and 16.5% due to the increase in their prices. The household income falls by 17% and the agricultural value added also decreases by 8%.

The projected climate in 2030s in Senegal will lead to a decrease in the production of the top four most produced crops (groundnut, millet, sorghum and maize), even when including positive effects of CO_2. As a result, the productivity of the agricultural sector and the workforce will decrease. The fall in the household income due to the reduction of salary rate will lead to a deterioration of household welfare because of the increase in prices. Therefore, a decrease in agricultural value added is noted that will slow down the sector's activities.

The agricultural policy of Senegal is defined in many strategies formulated at regional, sub-regional and national levels. Given the multiplicity of the agricultural policy documents, it is convenient to focus on the projects and agricultural programs which are in the National Agricultural Investment Program (PNIA). Then, for this study we focus on some policy types which are in this program namely: the adjustment of import taxes for agricultural products, an increase in investment in capital and subsidy fertilizers.

Decrease in the rice import tariff by 20%

In the worst climate scenario for Senegal, a decrease in rice import tariff by 20% leads to an increase in agricultural value added by 0.21%. Productions of maize, millet and sorghum are intensified and this leads to prices lowering. Groundnut production decreases. More value added can allow more workers to be employed in the agricultural sector. This can be helpful for rural households who rely on agriculture as their main source of food and income. But we remarked that the household income falls by 0.2% which can be compensated by lower prices. Senegal is a country already open to imports, especially to rice imports. The country imports a lot of rice and has opened his frontier for the rice imports. Although this reduction of rice imports tariff does not help local producers, but it can help to reduce the negative effects of climate change on production and prices. According to Fall (2005), we import much quantities of rice than we produce cereals. Rice imports positively affect the production volume and prices of millet, maize and sorghum. So, the decrease in the price of imported rice is spread on the prices of other agricultural products namely millet, maize and sorghum.

Increase in the capital stock (10%)

An increase in the capital stock by 10%, boosts the value added of the agricultural sector by 8%. This jump is more significant than the changes that occur when the import tariff for rice is decreased. The production volume of maize, millet, sorghum and groundnut rises. This leads to a loss of profit for farmers, except for groundnut which is compensated by its good domestic price. The greater capital stock contributes to alleviating the food expenses of the urban household who also benefit from the increase in income. The downside of an increase in capital stock is that it simultaneously leads to lower labor volume. In fact, the increase in these stocks results in higher prices relative to labor, which in turn leads to lower demand for labor. This substitution effect reduces the expected benefits of the increase in capital stocks.

Subsidize fertilizers by reducing tax on fertilizers by 50%

When the tax on fertilizers is reduced by 50%, we notice a notable increase in the production of millet (21%), sorghum (21%), maize (45%) and groundnut (27%). The household income drops overall by 0.1%. The value added of the agricultural sector increases by 0.22%. This growth in the agricultural sector is a direct result of the lower tax rate for fertilizers.

The decline in soil fertility today prompted the Senegalese government to resume its fertilizer subsidy policy from 2003/2004. After several years of modest subsidies, GOANA was introduced in 2008 to subsidy chemical fertilizers and equipment. The return of the subsidy on fertilizers may help to fight against the impacts of climate change on crop production.

Increasing the maize import tariff by 50%

Not promoting the maize importation leads to an increase in the productions of maize (49%), millet and sorghum (21%), whereas the production of groundnut decreases by 27%. We notice a higher value added for the agricultural sector by 0.20%. The labor demand increases for all the crops (maize, millet and sorghum) due to the effect that hiking the maize import tariff by 50% has on the value added for the agricultural sector. A negative consequence of this policy is that the household income is reduced by 0.18%, which is not good for the household, but this can be compensated by the lower prices. This policy also developed the Senegalese farming system by creating more jobs, as in Senegal the agricultural sector is the most important source of revenue and food for poor people.

All these policies bring positive value added for the country except for an increase in maize import tariff for which value added is negative. This positive impact on the economy is much more important for policies about the increase in capital stock (11.081% million F. CFA) and subsidizing fertilizers by decreasing fertilizers taxes by 50% (-0.39% million F. CFA). So, the financial implications of the increase in maize import tariffs are not good for the state revenues because this shock leads to a loss of value added which is not favorable for the economy. The increase in capital stock increases the value added but the problem is that it leads to decrease the labor demand.

Finally, it appears that cutting the rice import tariff by 20% and subsidizing fertilizers by slashing taxes by 50% are the most suitable policies instruments that can help to mitigate the negative effects that climate change has on agricultural sector in Senegal. Cutting rice import tariff by 20% generates agricultural value added (0.21%). Subsiding fertilizers by halving fertilizer taxes increases agricultural value added by 0.22% which is still an improvement even with an agricultural value-added loss of 0.08%. These two policies, modeled in the worst climate scenarios for Senegal can generate agricultural value added that can compensate for the losses that we have in the RCP8.5 scenario.

As in Senegal the agricultural sector employs 70% of the working population, the greater value added can provide more jobs in agricultural sector. This growth of the labor force can lead to an increase in the volume of production in the agricultural sector, which is shown by the positive results that we have for the production volume of maize, millet and sorghum. If the government applies these two policy instruments, the Senegalese farming system will be strengthened because farmers will benefit in comparison to the RCP 8.5 scenario. Even if we notice small decline in the household income, the better prices can compensate for this loss.

So, these two policies contribute to alleviating the food expenses of the urban household with cheaper food and also, they can be helpful for rural households who rely on agriculture as their main source of food and income.

CONCLUSION

This study assessed the impact of climate change on production volume and household income and to test alternative policies instruments that can help to mitigate fluctuations of quantities. Particularly it focused on some policies that are in the Senegalese National Agricultural Investment Program (PNIA). The level of production decreased in these last years and this is particularly due to climate change. The difficulties of the agricultural sector are mainly due to low levels of rainfall, degradation of soils, degradation of the agricultural infrastructure, seed quality etc. Consequently, the production deficit is still critical leading to higher levels of imports for agricultural products. A static computable general equilibrium model oriented on the agricultural sector has been used to assess the impact of climate change on the level of production and to test alternative policies instrument that can help to reduce the fluctuation of quantities.

The results show that the projected climate in 2030s in Senegal will lead to a decrease in the production of the top four most produced crops (groundnut, millet, sorghum and maize), even when including positive effects of CO_2. As a result, the productivity of the agricultural sector and the workforce will decrease. The fall in the household income due to the reduction of salary rate will lead to a deterioration of household welfare because of the increase in prices. The results show also after testing different policies instrument in the worst climate scenario for Senegal that cutting the rice import tariff by 20% and subsidizing fertilizers are the most suitable policies instruments that can help to mitigate the negative effects that climate change has on agricultural sector in Senegal. With these two policies the level of production rises as well as the agricultural value added. These two policies generate agricultural value added that can compensate for the losses that we have in the RCP 8.5 scenario.

Also, the improvement of agricultural performance can significantly reduces the poverty in urban and rural areas. This requires seed quantity and of good quality, modernization of technical production, in particular through the training of rural stakeholders, encouraging innovation and research development; strengthening production diversification policies (especially in areas where traditional farming is experiencing a decrease in production and yield) and improved access to credit for farmers. Emphasis should also be placed on policies that enable the poorest people to carry out and go beyond subsistence agriculture, especially in areas where the severity of poverty is the most significant.

REFERENCES

Breinsinger, C. and X. Diao. (2008). Economic transformation in theory and practice : What Are the messages for Africa? IFPRI Discussion Paper 797. Washington, D.C: International Food Policy Research Institute, pages 50, https://www.ifpri.org/publication/economic-transformation-theory-and-practice

Crasswell, E.T., Grote, U., Henao, J. and Vlek, P.L.G. (2004) Nutrient Flows in Agricultural Production and International Trade: Ecological Policy Issues. Discussion Paper No. 78, Bonn, Germany: ZEF Center for Development Research, University of Bonn.

Dering, D. (2015). Climate change impacts on crop productivity in global semi-arid areas and selected semi-arid economies. Small Grant Programme Working Paper, Overseas Development Institute (ODI), London. Available online at http://prise.odi.org/research/small-grant-programme-climatechange-impacts-on-crop-productivity-in-global-semi-arid-areas-andselected-semi-arid-economies

Fall, A.A. (2005). Impact économique de la recherche sur le riz au Sénégal et en Mauritanie. In : Revue Agronomie Africaine, CORAF, Numéro Spécial (5), ISSN n°1015-2288, pages 53-6, décembre. https://www.bameinfopol.info/IMG/pdf/securite_alimentaire1.pdf

Funk, C., J. Michaelsen, and M. Marshall. (2012). Mapping recent decadal climate variations in precipitation and temperature across Eastern Africa and the Sahel. In: Remote Sensing of Drought: Innovative Monitoring Approaches [Wardlow, B.D., M.C.Anderson, and J.P.Verdin (eds.)]. CRC Press, Boca Raton, FL, USA, pp. 331-358.

MAER. (2016). Rapport sur la revue conjointe du secteur agricole, pages 140, https://www.mediaterre.org/

MEDD (2016). Contributions Déterminées au niveau National (CDN)- volet adaptation secteur de l'agriculture. Organisation des Nations Unies pour l'alimentation et l'agriculture Rome, 2017, http://www.fao.org/3/b-i6400f.pdf

Oktaviani, R., E. Puspitawati, and Haryadi. (2008). Impacts of ASEAN Agricultural Trade Liberalization on ASEAN-6 Economies and Income Distribution in Indonesia. Working Paper series no. 51 Bangkok: .Asia-Pacific Research and Training Network on Trade, United Nations of Economic and Social Commission for Asia and the Pacific (UNESCAP). Working Paper 5100.

Pauw, K., J. Thurlow, M. Bachu, and D.E. Van Seventer. (2011). The Economic Costs of Extreme Weather Events: A Hydro-Meteorological CGE Analysis for Malawi. Environment and Development Economics, Vol.16, Issue 2, pages 177-98.

USEPA. (2009). Opportunities to Reduce Greenhouse Gas Emissions through Materials and Land Management Practices, September 2009. Pages 98, https://archive.epa.gov/epa/climatechange/opportunities-reduce-greenhouse-gas-emissions-through-materials-and-land-management.html

USAID (2017). Finding the best fit: Naatal Mbay case study, Christina Manfre, https://www.usaid.gov/digitalag/naata-mbay-case-study

Zhai, F., and J. Zhuang, (2009), 'Agriculture impact of climate change: A general equilibrium analysis with special reference to Southeast Asia', ADBI Working Paper Series 131. DOI: 10.4135/9788132114000.n3

Adhésion au groupe et adoption de stratégies d'adaptation aux changements climatiques : cas des producteurs de céréales sèches dans le bassin arachidier du Sénégal

Pape Bilal Diakhaté, Birahim Bouna Niang, Mbaye Diop et Malick Sané

RÉSUMÉ

Le bassin arachidier est l'une des six zones agro-écologiques du Sénégal où les exploitants agricoles sont particulièrement menacés par l'incertitude climatique en saison d'hivernage. Ce travail examine les conditions dans lesquelles l'adhésion à un groupe influence l'adoption de stratégies d'adaptation au changement climatique. Une enquête a été effectuée de façon aléatoire auprès de 545 exploitants agricoles répartis dans les régions de Louga, Kaolack et Fatick. Les estimations effectuées avec le modèle de Heckman probit ont montré que la prise de risque financier et l'utilisation d'informations climatiques augmentent le niveau d'adoption. Ainsi, il est nécessaire de faciliter l'accès des producteurs aux informations climatiques et de développer un système d'assurance-crédit.

Mots-clés. Stratégies d'adaptation, groupe, modèle heckman probit

ABSTRACT

The Groundnut Basin is one of the six Senegalese agro-ecological zones where farmers are particularly threatened by climate uncertainty in the rainy season. This work examines the conditions which group membership influences the adoption of climate change adaptation strategies. A random survey was conducted with 545 farmers in the regions of Louga, Kaolack and Fatick. The estimations by heckman probit model have shown that financial risk-taking and the use of climate information increase the level of adoption. Thus, it is necessary to facilitate producers' access to climate information and to develop a credit insurance system

Keywords: Adaptation strategies, group, Heckman model probit

INTRODUCTION

Selon les néoclassiques, le marché constitue le meilleur système de coordination des échanges entre acteurs. Ces derniers sont supposés égoïstes car ils accordent une priorité à leurs intérêts personnels. Aussi, le choix effectué par chacun est-il considéré comme rationnel. Cependant, les expériences comme la crise des années 30 et l'échec des programmes d'ajustement structurel en Afrique constituent des raisons qui justifient l'inefficacité du libre marché. En effet, les agents ont des intérêts différents et parfois divergents. Le cadre dans lequel ils effectuent leur choix est caractérisé par une asymétrie d'information. À ce titre, il est peu probable que les décisions décentralisées de tous les agents soient cohérentes. D'autres dispositifs essaient de donner une réponse au problème de l'harmonisation des intérêts individuels. Ces démarches instituent des règles de comportements à chaque agent à travers des contrats, des conventions ou des organisations. Pour ces dernières, la coordination est assurée par des individus ayant des centres d'intérêt spécifiques et fonctionnant de façon continue en vue d'atteindre des objectifs partagés par les membres.

Au Sénégal, les associations formées en milieu rural ont un rôle important dans les activités agricoles. En effet, les groupements de producteurs constituent, pour l'Etat et les autres acteurs de développement, un canal de diffusion et de distribution de biens et de services agricoles (distribution d'intrants, adoption de bonnes pratiques agricoles, etc.). À ce titre, les groupements villageois se présentent comme un support de diffusion d'innovations agricoles notamment la promotion des stratégies de gestion du risque climatique. L'Agence Nationale de l'Aviation Civile et de la Météorologie (ANACIM) travaille avec les organisations de producteurs pour la diffusion d'informations climatiques. De même, la Compagnie Nationale de l'Assurance Agricole du Sénégal (CNAAS) œuvre avec « Planet garantee » pour promouvoir l'assurance agricole auprès des associations paysannes. Aussi, les nouvelles variétés de semences découvertes par la recherche sont-elles distribuées aux organisations de producteurs qui assurent la multiplication et la vente auprès des membres.

Malgré les stratégies d'extension des services agricoles, la mise à l'échelle est insuffisante au Sénégal. Le taux d'utilisation des informations climatiques par les producteurs reste faible ainsi que le niveau de souscription à l'assurance agricole. En effet, seulement 100 000 producteurs ont souscrit à l'assurance agricole en 2016 sur 755 532 ménages pratiquant l'agriculture (ANSD, 2014). Ces faibles taux d'adoption sont imputables aux comportements des agriculteurs vis-à-vis du risque mais aussi à l'organisation et au fonctionnement des associations qui constituent un blocage à la diffusion à grande échelle.

Ainsi, la question de l'efficacité de passer par les groupements de producteurs pour la diffusion des stratégies d'adaptation au changement climatique se pose avec acuité. Ce travail essaie de montrer dans quelle condition l'appartenance à un groupe permet l'adoption des stratégies d'adaptation. Il s'agit donc d'analyser les déterminants de la gestion du risque climatique dans un groupe.

De façon spécifique, cette étude cherche à : (i) déterminer les facteurs explicatifs de l'adhésion des membres dans un groupe et (ii) analyser les déterminants du niveau d'adoption des stratégies d'adaptation dans un groupe.

Il s'agit entre autres de tester l'hypothèse selon laquelle l'utilisation d'informations climatiques et la propension du producteur à prendre des risques financiers augmentent le niveau d'adoption des stratégies d'adaptation des membres du groupe. Ces deux facteurs sont généralement abordés de façon exclusive (Bocqueho et al., 2014 ; Diarra, 2014 ; Charness et Gneezy, 2012 et Brick et al., 2012). Ainsi, il est nécessaire de combiner ces deux facteurs pour mieux appréhender la décision d'adaptation aux changements climatiques des exploitants agricoles dans un groupe

Cette étude prolonge les nombreux travaux de recherche déjà menés sur les déterminants de l'adhésion au groupe et l'adoption des stratégies d'adaptation. Ofuoko et Agbamu (2012) ont montré que les agriculteurs adhèrent au groupe non pour accroître leur capacité d'adaptation au changement climatique mais plutôt pour élargir leur accès aux services agricoles et disposer des facilités de crédit (Ofuoku et Agbamu, 2012). De même, Ofuoko et al. (2008) considèrent que la relation entre l'adhésion au groupe et l'adoption de stratégies d'adaptation n'est pas directe, elle résulte des contacts entre les agriculteurs et les appuis des services extérieurs (Ofuoku et Urang, 2009). Pour Ofuoku et Agbamu (2012), la cohésion au sein du groupe joue un rôle déterminant dans la gestion du risque climatique (Ofuoku et Agbamu, 2012). Selon Ofuoku et Urang (2009), cette cohésion est perçue du point de vue affectif à travers l'attraction interpersonnelle entre les membres et l'efficacité du leadership démocratique (Ofuoku et Urang, 2009).

La suite de l'article présente la méthodologie puis les résultats et enfin la discussion et la conclusion.

MÉTHODOLOGIE

Modélisation théorique : modèle de Heckman probit

La décision d'adopter des stratégies de gestion du risque dans un groupe est un processus à deux étapes. Dans un premier temps, l'individu déclare s'il est membre ou non d'un groupe ; ensuite, le cas échéant, il décide de l'adoption. Ainsi, c'est quand l'exploitant agricole a une propension à être membre d'un groupe qu'il est possible d'étudier les facteurs l'ayant poussé à adopter les stratégies d'adaptation retenues, ce qui implique l'utilisation du modèle de sélection « heckman probit » (Maddison, 2006). Cette approche est semblable à celle des « two-parts models » dont un aperçu peut être obtenu dans Manning (1997).

Les modèles d'adoption se présentent sous la forme générale :

$$A_i = f(Z_i) \qquad [1]$$

Où A_i et Z_i représentent respectivement la décision d'adoption du producteur i et un ensemble de caractéristiques démographiques et socioéconomiques du même producteur i. En analysant la relation adhésion au groupe-adaptation, la plus simple manière d'intégrer l'adhésion au groupe dans le mode d'adoption précédent est de l'exprimer sous la forme :

$$A_i = f(Z_i, Ag_i) \qquad [2]$$

Cependant, à la lumière de la revue, l'adhésion à un groupe elle-même apparait comme une variable endogène (fonction d'un certain nombre de caractéristiques propres à l'individu). Dès lors, l'estimation de l'équation [2] est frappée de biais d'endogénéité. Dans ces conditions, la spécification de deux modèles séparés : un modèle d'adaptation (équation [3]) et un modèle d'adhésion à un groupe (équation [4]), se présente comme une alternative qui limiterait les biais d'estimations, soit :

$$A_i = f(Z_i) \qquad [3]$$

$$Ag_i = f(Y_i) \qquad [4]$$

Où Y_i représente un ensemble de caractéristiques démographiques et socioéconomiques du même producteur i ; qui pourraient être identiques ou différentes de Z_i.

De cette formulation, bien qu'elle élimine le biais d'endogénéité, se pose un problème de sélection. Ainsi, comme l'ont proposé Maddison (2006) et Gbetibouo (2009), un modèle de sélection tel que le modèle probit de Heckman permet de mieux explorer la décision d'adaptation des producteurs en relation avec l'adhésion au groupe. Ce faisant, le modèle général devient :

$$A_i = f(Z_i)$$

$$si\ et\ seulement\ si \qquad [5]$$

$$Ag_i = f(Y_i) > 0$$

La forme ainsi définie est basée sur deux modèles : l'output modèle ou modèle d'adaptation dont la variable dépendante est l'adaptation (A) et le modèle de sélection dont la variable est l'adhésion au groupe (Ag). Considérant j caractéristiques démographiques et socioéconomiques liées au producteur i et capable de déterminer sa décision d'adaptation (caractéristiques notées Z_{ij}) d'une part, puis j' caractéristiques démographiques et socioéconomiques liées au même producteur i et susceptible de déterminer son adhésion au groupe (caractéristiques Y_{ij}) d'autre part, le modèle économétrique qui en ressort est :

$$a_i = \alpha_0 + \sum_j \alpha_j Z_{ij} + \mu_i$$

$$ag_i = \beta_0 + \sum_{j'} \beta_{j'} Y_{ij'} + v_i > 0$$

Dans ce modèle, a_i est le degré d'adaptation (1= degré d'adaptation observé ; 0= sinon) du producteur i et ag_i son adhésion au groupe (1=adhésion ; 0=pas d'adhésion). Les paramètres α et β sont des paramètres à estimer ; enfin μ et v sont les termes d'erreurs (μ et v suivent une loi normale $N(0;1)N(0;1)$).
Cependant, il existe un coefficient de corrélation $\rho\rho$ des termes d'erreur :

$$(\rho\colon \mathrm{corr}(\mu_i, v_i) \neq 0)\rho\colon \mathrm{corr}(\mu_i, v_i) \neq 0).$$

Dans le cas où le coefficient $\rho\rho$ est égal à 0, les termes d'erreur des deux équations ne sont pas corrélés entre eux. Ainsi, l'équation de sélection n'a plus de raison d'être car les deux décisions sont indépendantes.

La méthode de Heckman probit donne une approximation des résultats trouvés par la méthode du maximum de vraisemblance (Yirga, 2007). De même, Heckman probit (Heckprob) offre une estimation consistante et asymptotiquement efficiente pour tous les paramètres d'un tel modèle (Statacorp, 2003)[47].

Zone d'étude

L'étude a été réalisée dans le Bassin arachidier du Sénégal. Cette zone représente la partie semi-aride du pays avec des isohyètes variant entre 200 à 600 mm par an. À l'image des autres parties du pays, le Bassin arachidier est caractérisé par une variabilité pluviométrique due à l'incertitude sur le démarrage effectif des pluies (Diop, 1996). Trois régions ont été choisies en fonction de leur niveau d'aridité : la région de Louga (nord-aride)[48], Kaolack (semi-aride)[49] et Kaffrine (proche de Tambacounda[50] où les pluies enregistrées par an dépassent 600 mm), représentant la zone Est (figure 1).

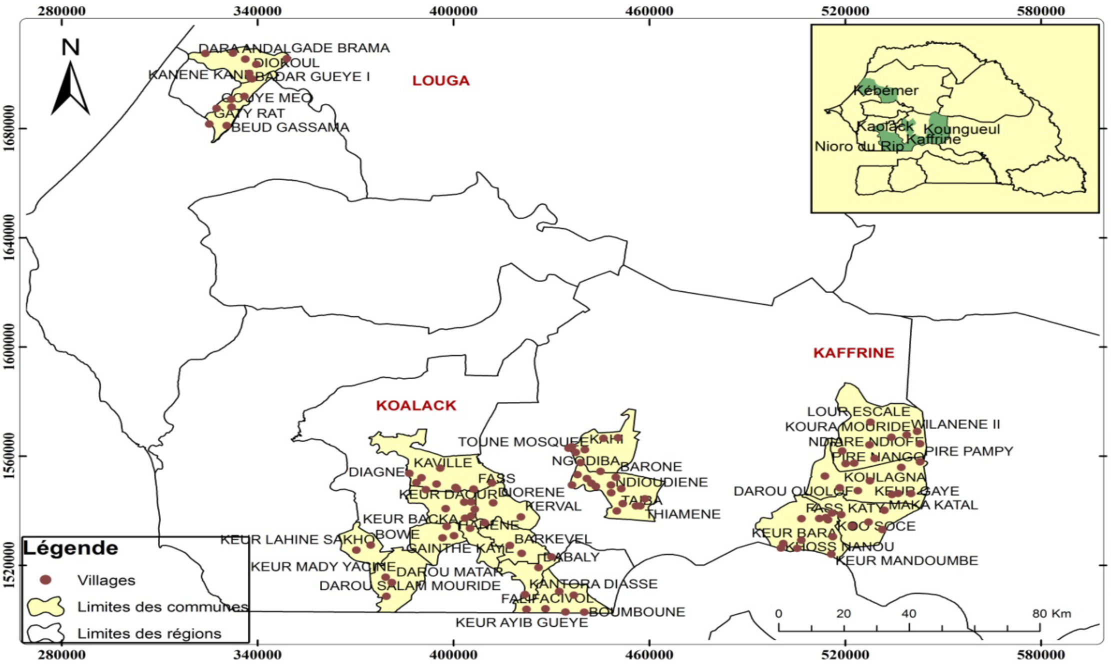

Figure 1 : Cartographie des régions, des départements et les villages choisis

Source : ISRA-BAME, zone d'enquête, 2015

Données

La base de sondage provient de l'ASPRODEB[51] et du RESOPP[52]. Ces deux organisations travaillent avec des associations de producteurs, des coopératives, des organisations non gouvernementales (ONG), des groupements d'intérêt économique et des

47 *StataCorp, 2003, Stata base reference manual,Volume 4, Stata Corporation.*

48 *Les niveaux de pluviométrie moyens par an sont environ 200 mm.*

49 *Les niveaux de pluie compris entre 400 et 600 mm par an*

50 *C'est une région située au Sud-est du pays. La région appartient à la zone agro-écologique appelée Sénégal oriental.*

51 *L'Association Sénégalaise pour la Promotion du Développement par la Base est créée en 1995.*

52 *Le Réseau des Organisations Paysannes et Pastorales du Sénégal est créé en 2002.*

fédérations de producteurs afin d'améliorer les conditions de vie des ruraux à travers l'agriculture et l'élevage principalement. Ainsi, les données contenues dans les bases ont permis de choisir les villages. Ce choix est fait pour tester l'hypothèse définie dans cette étude. Pour maximiser la taille de l'échantillon, une proportion de 15% de producteurs est retenu dans chaque village Ce taux de référence est choisi pour maximiser le niveau de ménages agricoles affiliés à une organisation de producteurs estimée à 11,4% au niveau national (ANSD, 2013). Ainsi, avec un niveau de confiance de 95% et une marge d'erreur de 3%, la taille obtenue est de 545 exploitants pour un modèle d'enquête probabiliste (Tableau 1). La collecte des données est faite en juillet 2015 sur une durée d'un mois. Les exploitants agricoles sont choisis de façon aléatoire.

RÉSULTATS

Analyses descriptives

- La variable de sélection : adhésion au groupe

La première étape du modèle Heckman probit est l'adhésion à un groupe. Ainsi, 259 producteurs disent appartenir à un groupe, soit environ 48,05% des répondants. Les groupes les plus représentatifs concernent les coopératives (28,48%), les associations religieuses (21,82%) et les GIE (21,21%). Cependant, les tontines (épargnes collectives), les organisations de producteurs, les associations culturelles ou politiques et les ONG sont moins fréquentées par ces exploitants agricoles (figure 2).

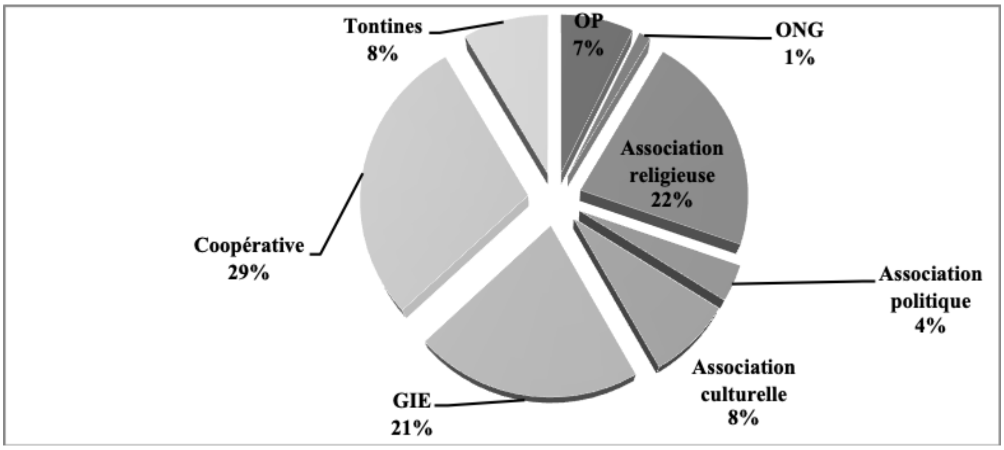

Figure 2: Taux d'adhésion des producteurs aux groupes

Source : les auteurs à partir des données d'enquête d'ISRA/BAME, 2015

- Variables substantielles : Adoption des stratégies d'adaptation

Trois stratégies d'adaptation ont été prises en compte : la rotation culturale, le changement de la date de semis et l'utilisation de variétés à cycle court. Les agriculteurs ont été classés en quatre groupes : ceux qui n'ont pas adopté de stratégie d'adaptation (1) ; ceux qui ont un niveau d'adaptation faible (2) ; ceux qui ont un niveau moyen (3) ; et ceux qui ont un niveau élevé d'adoption (4). Le deuxième groupe correspond aux agriculteurs n'ayant adopté qu'une seule stratégie, le troisième est constitué par ceux qui ont adopté deux stratégies et le dernier groupe constitue les exploitants qui ont adopté les trois stratégies retenues (figure 3).

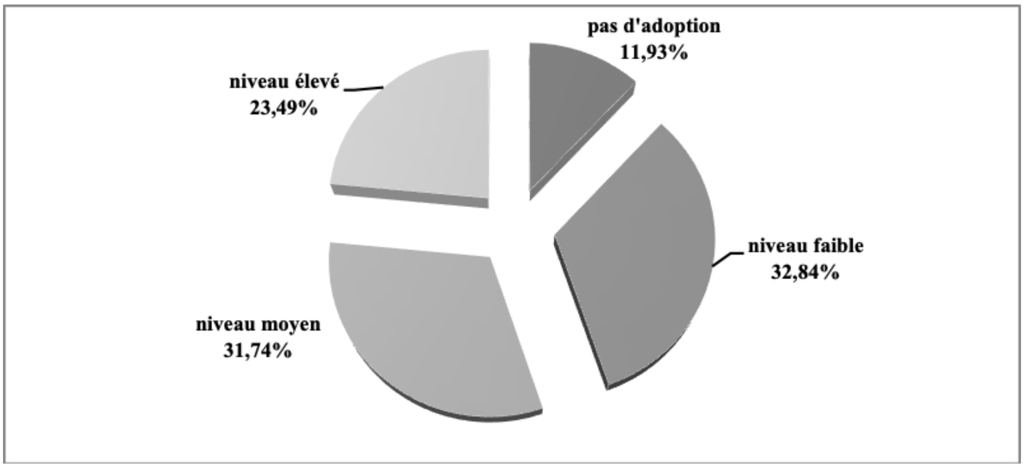

Figure 3 : Degré d'adoption des stratégies d'adaptation

Source : les auteurs à partir des données d'enquête, ISRA/BAME, 2015

- Variables descriptives du modèle

Pour estimer l'équation substantielle ou les degrés d'adaptation, les variables : aversion pour le risque financier, utilisation d'informations climatiques, niveau de perte supportable par l'exploitant et refus de payer pour se couvrir contre un niveau de perte tolérable (CAP nul), sont utilisées. Le rôle de l'utilisation d'informations climatiques sur la décision d'adoption a été cité dans la littérature (Vernier, 2009). En revanche, les autres variables ont été introduites pour justifier l'hypothèse de départ. Ces variables semblent avoir un effet positif sur le degré d'adoption.

Concernant l'équation de sélection, huit variables exogènes ont été retenues dans l'estimation. La plupart découlent de la littérature (Ogionwo Eke, 1999 ; Ofuoku et Agbamu, 2012 ; Ofuoku et Urang 2009). En effet, l'âge de l'exploitant est pris en compte pour comprendre l'effet d'exclusion lié à ce facteur. De plus, le besoin de formation, l'accès au crédit et aux services extérieurs peuvent influencer la décision d'adhésion au groupe. Le désenclavement, le fait d'être victime d'un événement climatique et de ne pas payer pour s'assurer au-delà d'un niveau de risque tolérable, conditionnent aussi l'appartenance au groupe. Également, le désir de vouloir discuter sur les changements climatiques est pris en compte pour comprendre s'il est un réel motif d'adhésion. Le tableau 2 donne une description des variables dépendantes et explicatives des équations à estimer.

Estimations économétriques

Pour chaque niveau d'adaptation, une estimation du modèle de heckman probit a été effectuée. Les statistiques de Wald sont respectivement 28,18 ; 22,24 et 14,34. Les modèles estimés paraissent bien spécifiés : l'hypothèse H0 qui dit que tous les coefficients de corrélation sont égaux à zéro est rejetée.

Pour chaque niveau d'adaptation, la décision d'adoption est justifiée. En effet, les p values du test de significativité de rho (p_c) dans le tableau 3 sont partout inférieures à 5%.

Tableau 2 : Description des variables du modèle

Équation de sélection			Équations substantielles				
Variable dépendante			Variables dépendantes				
Description	Pourcentage des exploitants agricoles membres d'un groupe	Pourcentage des exploitants agricoles non membres d'un groupe	Description	Pourcentage des exploitants ayant un niveau faible d'adaptation	Pourcentage des exploitants ayant un niveau moyen d'adaptation	Pourcentage des exploitants ayant un niveau élevé d'adaptation	Pourcentage des exploitants n'ayant pas adopté les stratégies retenues
Adhésion au groupe	48,05%	51,95%	Degré d'adaptation aux changements climatiques	32,84%	31,74%	23,49%	11,93%
Variables indépendantes	Variables indépendantes						
Description (nomenclature)	Moyenne	Écart-type	Description (nomenclature)	Moyenne	Écart-type		
Age (âge)	51,86	12,56	Aversion au risque financier (Aversion rf)	0,75	0,42		
Besoin de formation (BF)	0,84	0,36	Utilisation d'informations climatiques (Info climat)	0,64	0,48		
Crédit (Credit)	0,49	0,5	Niveau de perte tolérable (niveau de perte)	2,42	1,43		
Services extérieurs reçus (SER)	0,44	0,49	CAP nul (CAP nul)	0,39	0,49		
Présence de village à moins d'1 km (Désenclavement)	0,59	0,49					
Victime du changement climatique (victime du CC)	0,71	0,45					
CAP nul	0,39	0,49					
Discussions sur le changement climatique (Discuss sur CC)	0,38	0,49					

Source : les auteurs à partir des données d'enquête d'ISRA/BAME, 2015

Tableau 3 : Présentation synthétique des coefficients estimés par type d'adoption

Variable	Niveau faible	Niveau moyen	Niveau élevé
Niveau faible			
Aversion au risque financier	.44517087**		
Utilisation informations climatique	-.86792064***		
Niveau de perte de production tolérable en kg	-.25418918***		
constante	.02084755		
Adhésion			
Age	-.01098706**	-.01165231**	
Besoin de financement	.5341668***	.48193172***	.51902924***
Accès au crédit	.32950859***	.38123483***	.60696794***
Accès aux services extérieurs	.93002401***	.89644897***	
Victime du changement climatique	.19179286	.23590752	.27779754**
CAP nul	-.47623573***	-.40236415***	-.30666929***
Désenclavement		.29943715**	.28843497**
Discussions sur le changement climatique			.33685769***
constante	-.69122223**	-.85132437**	-1.201742***
athrho			
constante	1.1072674***	-.70031826**	-.85154998**
Niveau moyen			
Aversion financier pour le risque		-.3227835	
Utilisation informations climatiques		.93141244***	
constante		.42002154	
Niveau élevé			
Aversion financier pour le risque			-.41245589***
Utilisation informations climatiques			.32942258**
CAP nul			-.40099279**
constante			.72953725***
Statistiques			
N	474	474	545
N censuré	284	284	286
rho	.80309434	-.60456975	-.69187835
p_c	.00002651	.03178222	.03268751

*Notes: * définit la probabilité associée aux variables expliquées. Il est noté * si $p<0.1$; ** si $p<0.05$ et *** si $p<0.01$*

Source : les auteurs à partir des données d'enquête d'ISRA/BAME, 2015

DISCUSSION

- **La propension à prendre un risque financier augmente le degré d'adoption**

Les estimations montrent que l'aversion pour le risque financier diminue avec le degré d'adoption. En effet, les agents prenant des risques financiers sont plus susceptibles d'adopter des stratégies d'adaptation afin de limiter les pertes de récolte.

- **L'utilisation d'informations climatiques impacte positivement le degré d'adoption**

L'utilisation d'informations climatiques augmente le degré d'adoption des stratégies d'adaptation. En effet, les informations climatiques constituent un support pour l'exploitant agricole car lui permettant de combiner des stratégies afin de limiter les pertes liées au climat. Ainsi, elle est négativement significative lorsque le producteur n'utilise qu'une seule stratégie.

- **La hausse du niveau de perte tolérable ne favorise pas l'adoption de stratégie d'adaptation**

L'augmentation du niveau de perte tolérable diminue la probabilité d'adopter une seule stratégie d'adaptation. Cette variable n'est pas significative pour les autres modèles. Ainsi, un niveau de perte de production tolérable élevé peut entrainer un comportement « oisif » de la part du producteur.

- **La disposition à payer a une influence positive sur le degré d'adoption le plus élevé**

Un consentement à payer nul diminue la probabilité d'adopter les trois stratégies retenues. En d'autres termes, pour une adoption élevée, il faut que l'exploitant agricole manifeste la volonté de payer pour se protéger contre une perte éventuelle.

- **Les conditions d'adhésion pour une adoption de stratégies d'adaptation**

Dans l'équation de sélection, il apparaît que l'âge et la non disposition à payer pour s'assurer d'un niveau de perte tolérable diminuent la probabilité d'être membre d'un groupe. Ces deux variables sont significativement négatives pour les trois niveaux d'adoption. Par contre, le besoin de formation, l'accès au crédit et aux services extérieurs, le fait d'être victime d'un événement climatique, le désenclavement et le désir de discuter sur le changement climatique ont un effet positif sur l'adhésion à un groupe. Ces résultats sont conformes à la littérature (Blanchet et Trognon, 1994 ; Featherstone et Goodwin, 1993 ; Soule et al., 2000 ; Isham, 2002)

Pour accroître l'impact des groupes dans la promotion de stratégies d'adaptation au changement climatique, quelques implications politiques peuvent être formulées. Il s'agit de :

- Élargir la production de données climatiques en multipliant les stations météorologiques sur tout le territoire avec des niveaux élevés de précision sur les caractéristiques climatiques locales. Il est aussi recommandé de mener des activités d'animation dans les villages enclavés pour essayer de sensibiliser davantage la population sur l'importance de l'utilisation des informations climatiques.
- Développer un système de crédit-assurance pour accroître le niveau d'adoption

des membres dans un groupe. Dans un tel contexte, il est nécessaire de proposer un système de crédit-assurance mutualisé car l'assurance a un coût plus élevé selon qu'il est supporté individuellement que collectivement.

Ce travail présente des limites car ne mettant pas l'accent sur les coûts d'adaptation. En effet, l'exploitant agricole n'adoptera une stratégie d'adaptation que lorsque le coût de l'adoption est inférieur à la perte supportable.

RÉFÉRENCES BIBLIOGRAPHIQUES

ANSD, (2014). Recensement Général de la Population, de l'Habitat, de l'Agriculture et de l'Elevage. (2013), 19 p.

Bocqueho G., F. Jacquet and A. Reynaud. (2014), Expected utility or prospect theory maximizers? Assessing farmer' risk behaviour from field-experiment data, Oxford academic: European review of agricultural Economics, 41 (1), pp. 135-172.

Blanchet A. et A. Trogo, (1994) la phychologie des groupes, Paris : Natan, 1vol. 127 p.

BrIck, K., M. VIsseR et J. BuRns(2012). Risk Aversion: Experimental Evidence from South African Fishing Communities, American Journal of Agricultural Economics, 94(1) : 133-152.

Charness, G. et U. Gneezy (2012) Strong Evidence for Gender Differences in Risk Taking, Journal of Economic Behavior & Organization, 83(1): 50-58.

Diarra A. (2014). Adaptation de l'agriculture sahélienne aux changements climatiques : une approche par la modélisation stochastique, Institut International d'Ingénierie de l'Eau et de l'Environnement, 17p.

Diop M.. (1996). A propos de la durée de la saison des pluies au Sénégal, Sciences et changements planétaires/Sécheresse, volume 1, pp. 7-15.

Featherstone A. M. and B. K. Goodwin. (1993). Factors Influencing a Farmer's Decision to Invest in Long-Term Conservation Improvements, Land Economics 69 (1), pp. 67-81.

Gbetibouo G.A. (2009). Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa, Environment and Production Technology Division, IFPRI Discussion Paper 00849, Washington (DC): IFPRI. www.ifpri.org/sites

Isham J. (2002). The effect of social capital on fertilizer adoption: evidence from rural Tanzania. Journal of African Economies 11(1), pp. 39–60.

Maddison, D. (2006). The perception of and adaptation to climate change in Africa, CEEPA, Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa, University of Pretoria, Pretoria, South Africa.

Manning W. G. (1997). Alternative Econometric Models of Alcohol Demand, The Science of Prevention: Methodological advances from alcohol and substance abuse research, pp.101-121), Washington, DC: American Psychological Association.

Ofuoku A.U. et Agbamu J.U, (2012). Influence of Farmers' Group Cohesion on Adoption Of Climate Change Adaptation Strategies In Delat State, Nigeria, Global Journal of Science Frontier Research, Vol 12, n°6.

Ofuoku A. U., Egho E. O. and Enujeike E. O, (2008). Integrated Pest Management (IPM) adoption among farmers in Central Agro-ecological Zone of Delta State, Nigeria, African Journal of Agricultural Research, 3(12), pp. 852 –856.

Ofuoku, A. U. and Urang. (2009). Effect of cohesion on loan repayment in farmers' cooperative societies in Delta State, Nigeria. International Journal of Sociology and Anthropology, 1(4), pp. 070 – 076

Ogionwo W. and Eke, P. (1999.). An introduction to social psychology. Owerri, Nigeria: Springfield Publishers.

Soule M. J., A. Tegene and K. D. Wiebe. (2000). Land Tenure and the Adoption of Conservation Practices, American Journal of Agricultural Economics 82(4), pp.993-1005.

Vernier M., Monceaux I., Daille B. (2009). Détection de la subjectivité et catégorisation de textes subjectifs par une approche mixte symbolique et statistique, Actes de l'atelier de clôture de la 5ème édition du Défi Fouille de Textes, 2009.

Yirga C. T. (2007). The dynamics of soil degradation and incentives for optimal management in Central Highlands of Ethiopia, Department of Agricultural Economics, Extension, and Rural Development, University of Pretoria, South Africa.

Impacts of Adaptation to Climate Change on farmers' income in the Savana Region of Togo

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ABSTRACT

Do farm households that take steps to adapt to climate change experience a higher income than those who do not? This paper proffers answer this question in the context of crop and livestock income in the Savannah region of Togo. Bio-economic model based on farm households' model theory, and survey data collected from a representative sample of 450 farm households in the agricultural year 2013/2014 were used. Farm-household types were identified through cluster analysis and application of simulation model. From the simulation results, it was established that current costs, soil and water conservation techniques and irrigation can on average provide higher income even under climate change, since they are able to mitigate the impacts of climate change on crop and livestock income. By contrast, reducing the quantity of applied fertilizer, mentioned as an adaptation option by farmers, increased the farm households' vulnerability to climate change. Therefore, there is the need to encourage soil and water conservation techniques and sustainable irrigation as sound strategies for higher income under climate change in the Savannah region of Togo. These are "no regret options" with a positive impact on livelihoods while preserving the resource base.

Keywords: Adaptation, Bio-economic model, Climate change, Savannah region, Togo

RÉSUMÉ

Les ménages agricoles qui prennent des mesures pour s'adapter au changement climatique ont-ils un revenu plus élevé que ceux qui ne le font pas ? Cet article propose de répondre à cette question dans le contexte des revenus des cultures et du bétail dans la région des Savanes au Togo. Un modèle bio-économique basé sur la théorie du modèle des ménages agricoles, et des données d'enquête recueillies auprès d'un échantillon représentatif de 450 ménages agricoles au cours de l'année agricole 2013/2014 ont été utilisés. Les types de ménages agricoles ont été identifiés par l'analyse des clusters et l'application du modèle de simulation. Les résultats de la simulation ont permis d'établir que les coûts actuels, les techniques de conservation du sol et de l'eau et l'irrigation peuvent en moyenne fournir un revenu plus élevé même en cas de changement climatique, car ils sont capables d'atténuer les impacts du changement climatique sur les revenus des cultures et du bétail. En revanche, la réduction de la quantité d'engrais appliquée, mentionnée comme une option d'adaptation par les agriculteurs, a augmenté la vulnérabilité des ménages agricoles au

changement climatique. Par conséquent, il est nécessaire d'encourager les techniques de conservation des sols et de l'eau et l'irrigation durable en tant que stratégies solides pour augmenter les revenus dans le cadre du changement climatique dans la région des Savanes au Togo. Ce sont des « options sans regret « qui ont un impact positif sur les moyens de subsistance tout en préservant la base de ressources.

Mots-clés: Adaptation, Modèle bio-économique, Changement climatique, Région des savanes, Togo.

INTRODUCTION

The agricultural sector still plays a central role in Sub-Saharan African (SSA) countries' economic development. It supports the welfare of most of the residents directly or indirectly. However, recent agricultural performance trends of the region are discouraging. Indeed, the agricultural productivity growth in SSA region has been lower compared to the rest of the world (Willy and Holm-Müller, 2013) and there is the perception that the region is falling further away from the agricultural productivity frontier, thus contradicting the convergence hypothesis (Wurlod and Eaton, 2015). This situation may, among other things, be a signal of low land productivity in agriculture. The latter can be partly attributed to the low investment in agricultural sector, high rates of land fragmentation, intensive tillage of land, nutrient mining and extraction of crop residues to feed livestock, and climate variability and change[53]which characterized agricultural activities of the region (DiFalco et al., 2011; Willy and Holm-Müller, 2013). Climate change and variability are major challenges to SSA agriculture today because they not only increase production costs and the risk of crop failure, but also put at risk the stability of the whole agricultural production chain (Wheeler and von Braun, 2013). Scientific evidence on climate change suggests that even with a strong mitigation policy the observed lower and stagnant agricultural performance of the SSA region will persist or even get worse if the sector does not find ways to adapt to climate change under a business-as-usual scenario for agricultural sector.

Farmers have always and will continue to adapt to the changing climate. However, it is unclear whether they are able to identify practices and options that are appropriate to respond to climate change as the required adjustments may fall beyond their range of experience (Seo et al., 2010). The implication of this is the possibility of mal-adaptation resulting in transitional losses of unknown duration (Di Falco et al, 2011). By mal-adaptation we mean any practice which is more harmful than helpful, by contrast to an adaptation, which is more helpful than harmful. That is, adaptation practices, if not appropriately implemented, can increase vulnerability to climate change.

Determining the productive implications of adaptation to climate change is therefore crucial. It helps understand how the set of strategies implemented by the farmers (e.g., irrigation, low fertilizer use, soil conservation techniques, etc.) in response to

53(e.g., high average temperature, scarce and erratic rainfall) changes in environmental conditions affect farm income from cropping and livestock. More specifically, it is necessary to assess whether the farm households that actually did implement adaptation strategies are getting benefits in terms of an increase in farm income. Thus, the aim of this paper is to assess the impact of private adaptation to climate change on households' income from farming and livestock. This is central if adaptation strategies need to be put in place. Although there are overwhelming numbers of studies dealing with adaptation, quantitative estimates of adaptation and its impact sare only starting to emerge (Rosenzweig, 2005; Seo et al., 2008; Calzadilla, 2013; Lobell, 2014; Shah and Dulal, 2015).

The impacts of adaptation to climate change are traditionally estimated using agronomic models or Ricardian analysis (Di Falco et al., 2011). Agronomic models first estimate climate change impact and then feed the results into behavioural models that assess the impact of different agricultural system on farm income. The Ricardian approach isolates the impact of climate change by implicitly incorporating the potential of adaptation since it assumes that farm households have been adapting optimally, an assumption that is not necessarily verified for the reasons mentioned above. In our study we use a bio-economic model for empirical estimates. This type of model has been used because of its capability to handle economic and agricultural interactions that prevail within a given farm system.

METHODS

Data

The data used in this study come mainly from a cross-sectional, representative farm household survey in the Savannah region of Togo during the agricultural year 2013/2014on 450 households (Pilo, 2015). The survey is representative of the four zones of the Savannah region which were identified as most vulnerable to food insecurity and income shocks by the PADAT project. The survey collected information on farmers' perception of current and future states of rainfall, adaptation strategies developed by farmers, household assets and livestock. Additional data were gathered from literature and interviews with extension service managers that operate in the region.

Materials

We employ a bio-economic model based on risk-averse, constrained profit maximizing behaviour and apply it to the Savannah region of Togo. Characterized by high climate variability and frequent climatic shocks, the Savannah region of Togo has soils of average productivity (relative to other regions in Togo) and a landscape which ranges from flat to gently rolling hills. The region activities are dominated by rain-fed agriculture associated with livestock raising (crop-livestock farming). Its climate varies from tropical to Savannah with the main climatic risks, according to the National Adaptation Programme of Action (NAPA carried out in 2011), being poor distribution of rainfall, flood and drought.

Crop-livestock farming is the main farming system of the region. In this system many adaptation strategies are adopted by farmers in their attempts to withstand climatic shocks that the region is experiencing. To simulate the impact of these strategies in this farming system we link a model of constrained profit maximization for risk adverse farmers (allowing for alternative adaptation options) to a biophysical model. 2.2.1 Biophysical inputs of the bio-economic model

A typical bio-economic model includes a biophysical model which simulates plant growth, development and yield, along with nutrient cycling and nonpoint source water pollution, hydrology, and greenhouse gas emissions, for example. A commonly used biophysical model in bio-economic simulations is the Environmental Policy Integrated Climate model (EPIC) (Egbendewe-Mondzozo et al, 2015; Belhouchette et al. 2011; Barbier and Bergeron, 2001). We could not run the EPIC model because of considerable missing data constraints. Instead, the biophysical components of our model comprises of data characterizing the biophysical context of the study site (type of soil, states of rainfall). In particular, we retained five types of rainfall states for the survey.

Specification of the crops yield

For the sake of analysis we distinguish two type of crops: i) the traditional crops and ii) the cash crops. The traditional crops include millet, groundnut, and beans while the cash crops include rice, maize and cotton. The traditional crops are assumed to depend on rudimentary technologies as is the case for most of the SSA countries where it can be assumed that inputs are used in fixed proportion. Consequently, the two most important factors determining the yield level of traditional crops are the prevailing rainfall condition and the adaptation practice used. Thus the yield level which accounts for adaptation strategy implemented and the state of rainfall is therefore specified as :

$$y_{jqs} = min\{\alpha_{jqs} X_i\} \qquad (1)$$

y_{jqs}represents yield level of crop j cultivated under the adaptation strategy q and the rainfall condition s.$X_i$is the level of ith input and α_{jqs} are constant production coefficients, representing the necessary input per unit of output. The yield level of cash crops was specified as follow :

$$y_{kqs} = \beta_0 * L_k^{\beta_1} * F_{1k}^{\beta 2} * F_{2k}^{(1-\beta_1-\beta_2)} \qquad (2)$$

y_{kqs}stands for the yield level of the cash crop k practiced under the adaptation strategy q and the rainfall condition s. β_0, β_1 and $\beta_2$are parameters while L_k,F_{1k} and F_{2k} are production factors representing labour, urea and NPK respectively.

Specification of the livestock yield

Grazing is the dominant livestock farming system in the Savannah region of Togo. To capture how a given adaptation strategy influences the size of livestock heads on the one hand, and on the other, how rainfall patterns could affect it in the other, we specify the yield of livestock as follow :

$$y_{mqs} = max\{aX_{mqs}\} \qquad (3)$$

y_{mqs}Stands for the yield level of livestock m (beef, sheep, etc.), depending on forage X devoted to livestock m, practiced under the adaptation strategy q and the rainfall condition s.

The regional Mathematical Programming Model to simulating adaptation

Most agricultural producers in Africa are risk averse, particularly smallholders (Antle, 1987). They face a variety of yield, price and resource risks that make incomes unstable. All these risks can be classified into production and price risks. To account for risk in the programming model, our analysis is based on Telser's safety first (SF) approach, a downside risk approach. The general structure of Telser's SF model is the following:

Max: $E(Z) = E_Y'X$

S.t:AX<b

Prob(Z <g) <α (4)

In the above specification, $E(Z)$ represents the total expected gross margin, AX a set of resource constraints, b resource endowments, (Z) is income level, (g) is exogenously determined minimum level of income a household must earn to meet obligations of high priority, and (α) is the acceptable limit on the probability of failing to meet that minimum level of income.Telser's SF approach accounting for the rainfall risk, adaptation to climate change and the subsistence level of farming in the Savannah region of Togo isempirically specified as follows.

Specification of the objective function

$$E(Z) = \left(\sum_j \overline{C_j} X_j^P - iX^J\right) + \left(\sum_k \overline{C_k} X_k^P - iX^K\right) - \sum_{l=1}^{12} P_w' X_l^F - \sum_{i=1}^{12} (1+i) P_w X_t^l + \sum_{t=1}^{12} P_w X_t^o + \sum_{liv=1}^{4} \sum_{l=1}^{12} P_{liv} X^L - \sum_{liv=1}^{4} \sum_{l=1}^{12} P_W X_l^{liv} \quad (5)$$

Where $\overline{C_j}$= expected gross margin of traditional crop production activity j,

$\overline{C_k}$= expected gross margin of cash crop production activity k,

X_j^P = j[th] traditional crop production activity measured in hectare,

X_k^P = k[th] cash crop production activity measured in hectare,

X^{liv}= liv[th]l ivestock production activity. liv= {chicken, goats, sheep and caws}

P_w = Wage rate in franc CFA per Man-Day (MD),

P_w' = reservation wage rate which accounts for household leisure demand. It has been set in the range of 50% of P_w for wealthier farmers and 0% of P_w for poor farmers in the study of Dessalegn (2005) in the Upper East Region of Ghana. This means that poor farmers' leisure time is negligible. Given the similarities between our study area and that region, we used the same reservation wage rate.

X_t^o= t[th] month off-farm activity in Man-Days (MD),

i = interest rate, a rate which accounts for the cost of capital and the transaction costs in the credit market. It usually differs between farmers depending on the farmer's wealth. For instance, in the case of Dessalegn (2005) study in Ghana, it was set in the range of 50% for poor farmers and 25% for wealthier farmers,

X_t^l = t[th] month hired labour hiring activity (in MD),

X_t^F = t[th] month family labour used for crop farming (in MD),

X_t^L = t[th] month labour used forlivestock farming (in MD),

X^J = borrowing activity related to traditional crop production in Franc CFA,

X^K = borrowing activity related to cash crop production in Franc CFA,

$\overline{C_j} = E(gm_j), \overline{C_k} = E(gm_k)$

$gm_j = Y_{jqs} * P_j - X^J, \ gm_k = Y_{kqs} * P_k - X^K$

$$E(gm_j) = \sum_{s=G,N,B,F,D} P_s Y_{js} * P_j - X^J, \ E(gm_k) = \sum_{s=G,N,B,F,D} P_s Y_{js} * P_j - X^K \qquad (6)$$

Where $gm_j, gm_k$are gross margin per hectare of traditional crop j and cash crop k respectively, which are gross return in rainfall state, less capital cost per hectare. The capital cost includes cash cost on fertilizer, seed, tractor/bullock. And $Y_{js}$and$Y_{ks}$is the yield level of traditional crop j and cash crop k respectively in state of rainfall s. The rainfall conditions are grouped into five states namely: G=good, B=bad, N= normal, F= disastrous due to floods and D=disastrous due to droughts.

Specification of the set of constraints

In the following sections, the various constraints of the programming model are discussed.

Land constraint

The sum of crop allocated surface under each typeof land (compound land, irrigated land, bush land, water and soil conservation area) cannot exceed total available surface for the given type. For the sake of analysis, this study identifies four land types that are compound land, non-irrigated bush land, irrigated land, water and soil conservation area. For each of these land type we implement a corresponding constraint. For compound land it is specified as:

$$\sum_{j=1} X_{jc}^P \leq L_c \qquad (7)$$

WhereX_{jc}^P is production activity of crop j (measured in hectares) on compound plots and Lc is total compound land available. The superscript p indicates that the activity is a production activity on the other hand the suffix c indicates that the production activity is on compound land. The remaining constraints relative to land are presented below.

$\sum_{j=1} X_{jB}^P \leq L_B \sum_{j=1} X_{jB}^P \leq L_B$ Bush land constraint,

$\sum_{j=1} X_{jI}^P \leq L_I \sum_{j=1} X_{jI}^P \leq L_I$ Irrigated land constraint

$\sum_{j=1} X_{js}^P \leq L_s \sum_{j=1} X_{js}^P \leq L_s$ Water and soil conservation constraint

Labour constraint

Labour is the most important factor of production constraining agricultural and livestock production in the study area. There is a relatively working labour market so the model assumes that farm households can both hire-in and hire-out labour. Households make labour allocation decision both during the rainy and dry seasons mainly between crop and livestock farming. Traditionally, during the rainy season labour is allocated between rain fed agriculture production and livestock rearing, while during the dry season the allocation is made across livestock rearing, temporary irrigation, leisure, and off-farm activities. Thus the labour constraint can be represented as :

$L_R^F + L_D^F + L^o - L_R^H - L_D^H - L_R^L - L_D^L \le \bar{L}$ Household annual labour constraint,

$L_R^F - L_R^H - L_R^L \le L_1 L_R^F - L_R^H - L_R^L \le L_1$ Rainy season labour constraint,

$L_D^F + L_D^o + l - L_D^H + L_D^L \le L_2 L_D^F + L_D^o + l - L_D^H + L_D^L \le L_2$ Dry season labour constraint,

Where the super- and subscripts R stands for rainy season and D for dry season, F for farm labour, H for hired labour, O for off farm labour and L for livestock labour, while l is leisure and $\bar{L}$ total household labour endowments over the year respectively.L_1,L_2 represent rainy season and dry season specific labour endowments. Because of the seasonality of most farming activities, supply of labour may be more critical at some time of the year than others. Thus, we disaggregated annual labour into monthly labour.

Fertilizer and credit constraints

The fertilizer type commonly used in the study area is a combination of Nitrogen, Phosphorus and Potassium nutrients (NPK) and Urea. Due to the risk associated with rainfall variability farmers apply fertilizer mainly on cash crops. All fertilizer used is purchased from the market. The fertilizer constraints on these fields can be specified as :

$\sum_{j=1} a_{fj} X_j^P - X_f \le 0 \sum_{j=1} a_{fj} X_j^P - X_f \le 0$ Fertilizer balance, (8)

Where a_{fj}= Kg of fertilizer required to produce a hectare of jth crop activity and X_f= Amount of fertilizer purchased in Kgs.

$\sum_{j=1} a_{jk} X_j^P + \sum_{t=1} P_w X_t^j - X^k - \sum_{t=1} P_w X^o \le K$
$\sum_{j=1} a_{jk} X_j^P + \sum_{t=1} P_w X_t^j - X^k - \sum_{t=1} P_w X^o \le K$ Credit constraint, (9)

$X^k \le \bar{K} X^k \le \bar{K}$ Credit market constraint,

Where :

a_{jk}= the amount of direct cash cost required to produce a hectare of the jth crop activity, X^k= the amount of borrowed fund, K = total available own fund in CFA and $\bar{K}$= amount of cash available from credit market (rationing in the credit market). The rationing constraint accounts for the fact that under the existing market condition, households can access to only limited amount of cash. The rationing system in the credit market can be clearly observed in agricultural input markets where farmers get fixed amount of in kind input credit.

Consumption constraint (captured through Engel curves)

Households in the study area consume a whole set of food and non-food items. The major consumables are cereals such as Millet, Groundnut, beans and Rice. On the other hand households solely depend on the market for the purchase of some consumable items such as sugar, salt, root and tuber crops and non-food items such as kerosene.

Consumption estimates usually use Calories to measure the quantity of food consumed, this approach has advantage in aggregating different food types and also when there is policy interest to know the nutritional implication of the consumption decisions. In our case the main modelling interest is to incorporate the impact of consumption decision on overall household resource allocation decision, for which units like Kg are more useful than Calorie units, since farmers think in terms of Kg, not in Mega joules. Therefore, in order to keep consistency and ease of integration into the matrix the quantitative terms (in Kg) of consumption are retained. The empirical specification of the Engel curves is specified by the below equation.

$KG_p = b_0 + b_1 TOTINC + b_2 HHSIZE + e_p$

KG_p= is Kg of crop P consumed, which includes Maize, Soya, Beans and Rice, TOTINC = is total household expenditure in CFA, HHSIZE= is household size measured in the number of household members (not weighted by age or gender, for lack of data), and b's are parameters to be estimated while e is the error term.

Imposing Probabilistic Constraints

The probabilistic constraint in a Telser's SF model is specified as: pr(Z<g)< α Where (Z) is income level, (g) is exogenously determined minimum level of income a household must earn to meet obligations of high priority, pr(.) is the probability of event and (α) is an acceptable limit on the probability of goal failure.

In order to incorporate the probabilistic constraint into a linear programming model one needs to either make assumption on the distribution of income or use distribution free methods. Here, we implemented Atwood (1988) where a Lower Partial Moment (LPM) based constraint allows optimization algorithms to endogenously select the appropriate and least constraining level of (t) given statistical data set. Indeed, Atwood (1988; Buschena and Zilberman, 1994) demonstrated that the sufficiency constraint necessary to impose the probabilistic constraint, $(\Pr(Z < g) \leq \alpha) \Pr(Z < g) \leq \alpha)$ is: $t - L^* Q(t) \geq gt - L^* Q(t) \geq g$. Where t is a reference level below which deviations are measured, Q (t) is the LPM.

Simulation of the impact of adaptation

Farm Household Classification

One approach is to aggregate all households into a mega household (Gameiro et al., 2016). This approach ignores the heterogeneity among farm households which prevails even within a very small area. To avoid this paramount drawback, a second approach assumes that farm households' land use and technology choice decisions are governed by their objectives and constraints. The major limitation of this second approach is that it ignores the interactions among farm household groups. Because interactions among farmers are most likely not truly significant, we follow this approach in this study.

To classify farm households, we first select clustering variables using factor analysis. Seventeen variables representing the households' technology use, resource endowments and adaptation strategies were used for factor analysis. We hypothesize that these choices implicitly incorporate the objectives of the farmers. The Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity indicated that all the variables included were relevant. Six factors which cumulatively explain about 65.21percent of the total variance of the seventeen variables were identified. These factors have been retained according to Kaiser's criterion.

From the factor analysis results, the following variables had the largest factor loading on the first factor: operated land, quantity of fertilizer bought (NPK and Urea), farm equipment value, available own funds, credit obtained, number of household members. Since these variables measure household resources status the factor is referred to as Resources Endowment. The second factor has more factor loadings from the variables assets value and livestock value, thus it is referred to here as Wealth. The third factor has more factors loading from household irrigation practice and from the access to water for irrigation; therefore it is referred to here as Irrigation development capacity. The fourth has the largest loadings from crop diversification and plant different varieties (of the same crop); we refer to it as on farm diversification. The fifth factor has the largest loadings from farm size reduction and change from crop to livestock so we refer to it as livestock development. The last factor has the largest loadings from the variables measuring off farm activities and stone bunds development; this last factor is named Soil and Water Conservation techniques development capacity. It is worth justifying the name given to this last factor. Off-farm activities are not soil and water conservation (SWC) technique but we posit that because off-farm activities development provides resources necessary for SWC practices, it can be consider as contributing to SWC capacity building. The results of Factor Analysis (FA) are presented in Table 1.

Table 1: Results of Factor Analysis

Variables	Components						Total
	1	2	3	4	5	6	
Operated land	0.823	-0.163	0.062	-0.071	-0.016	-0.089	
Urea bought in 50 kg-bag	0.801	0.322	0.092	0.008	0.108	0.008	
NPK bought in 50 kg-bags	0.798	0.372	0.138	0.001	0.046	-0.009	
Farm equipment value	0.756	0.378	-0.079	-0.053	-0.113	0.102	
Available own fund	0.629	0.374	-0.037	-0.165	-0.036	-0.133	
Credit obtained	0.489	-0.168	-0.280	0.180	-0.121	0.022	
HH members	0.339	-0.10	-0.154	-0.163	-0.127	0.028	
Assets value	0.286	0.854	0.034	-0.020	-0.080	0.040	
Livestock value	0.142	0.851	0.015	-0.041	-0.006	0.056	
Access to water for irrigation	-0.077	0.053	0.815	0.015	0.034	0.038	
Irrigation dummy	0.051	-0.033	0.809	0.166	-0.104	0.056	
Has developed crop diversification	-0.225	0.082	0.011	0.707	0.074	0.132	
Has developed plant different varieties	0.047	-0.146	0.154	0.575	0.019	-0.113	

Has developed reduce farm size	-0.104	-0.329	-0.090	-0.011	0.808	0.233	
Has developed change from crop to livestock	0.018	0.119	0.041	0.136	0.701	-0.255	
Off activities	0.05	-0.169	-0.045	-0.102	-0.157	0.753	
Has developed Stone bunds	-0.131	0.084	0.68	0.131	0.238	0.696	
Summary							
Sum of squares (Eigenvalues)	4.18	1.77	1.56	1.35	1.16	1.06	11.08
Percentage of trace	24.64	10.41	9.17	7.96	6.83	6.21	65.21

Source: Authors 2017 from survey data

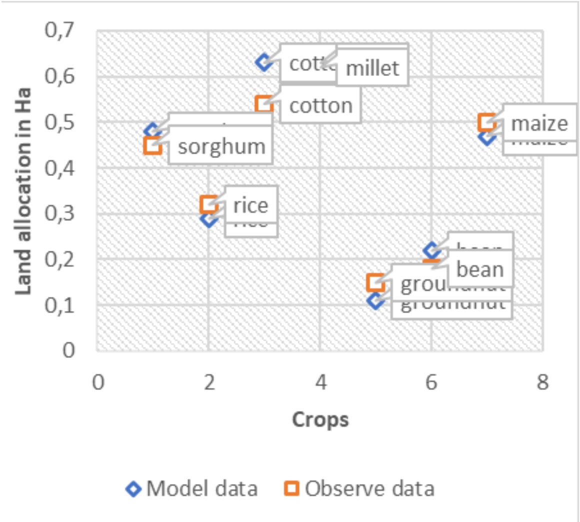
Based on the identified factors, we select representative farm households using cluster analysis. There are several clustering techniques; here we used a Ward hierarchical method in combination with a non-hierarchical method. By doing this the advantage of the hierarchical method is complemented by the ability of the non-hierarchical approach to "fine-tune" the results by allowing the switching of cluster membership. Thus, the 444 farm households in the data set were grouped into 6 clusters, one of thema single cluster (consisting of one farm only) and another one a pair cluster (consisting of two farms only). The single cluster and the pair-cluster are discarded since we conclude that they are too different from the rest of the sample. Finally, four clusters with the size of 90, 8, 40 and 303 are retained. The analysis of the characteristics of the clusters reveals that the cluster 2 (with 8 observations) has the highest level of asset value, farm equipment, own fund and operated land; so we refer to it as wealthier farmers group. By contrast, the cluster 4 (with303 observations) has the lowest level of asset value, farm equipment, own fund and operated land; we refer to it as poorer farmers group. These two clusters represent the "extreme cases" in our dataset. We undertake simulation analysis first for these two clusters and complement our analysis with simulations for the remaining two "middle" clusters, in order not to lose any information these two groups can provide.

RESULTS AND DISCUSSION

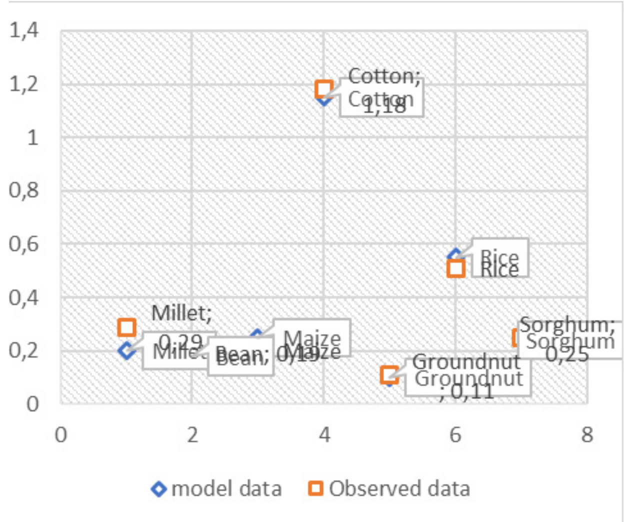
Farmers' perceptions of rainfall risks, reflected in their evaluation of rainfall conditions in the area, were used as a reference to elicit their subjective probabilities. The most important consideration in eliciting subjective probabilities is to organize the questions so as to help the respondents to make judgments that are consistent with their real feelings of uncertainty and as well as with the rules of probability (Dessalegn, 2005). In our survey farmers were asked to evaluate the rainfall conditions of their community for the period from 2003 to 2012 as good, normal, bad, disastrous due to floods or disastrous due to droughts. Some of the questions employed in the elicitation exercise were: "Following your characterization of the rainfall conditions in this locality, how many of the years between 2003 and 2012 had good, normal, bad, disastrous due to floods or disastrous due to droughts?". In addition, farmers were asked to name a representative year for each rainfall condition between 2003 and 2012 so as to help them have a good focus on the past rainfall events. The results of the elicitation process, indicate that on average good, normal, bad, disastrous due to floods, disastrous due to droughts conditions have a probability of 0.29, 0.34 and 0.24, 0.04 and 0.09 respectively.

Base run scenario

This section tests how well the previous constructed model serves its intended purpose. Naturally, the model cannot replicate each and every empirical observation. However, this is rarely realised because of information gap between the modeller and the decision maker. Thus, the realisable approach consists to value the extent to which certain model outputs, which are of policy and research interests, are depicted. For example, Dessalegn (2005) used land use as an indicator variable to validate their model. Land allocation across different land use types is of much importance in this study, therefore we retain it as our indicator variable. Figure 2 shows how correctly the model predicts the observed data.



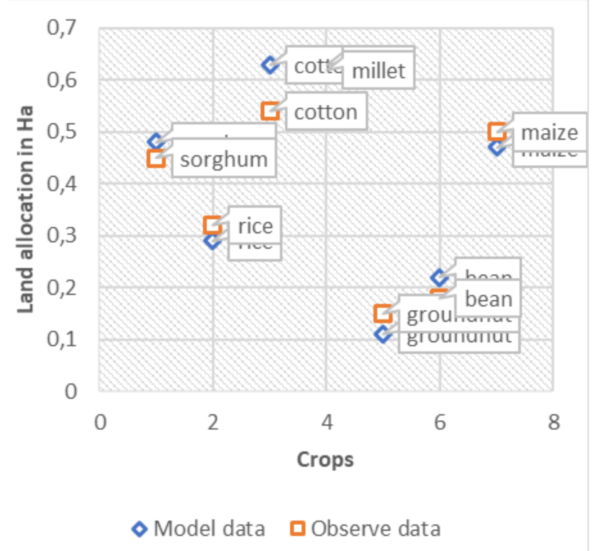
Calibration of the bio-economic model for cluster 1



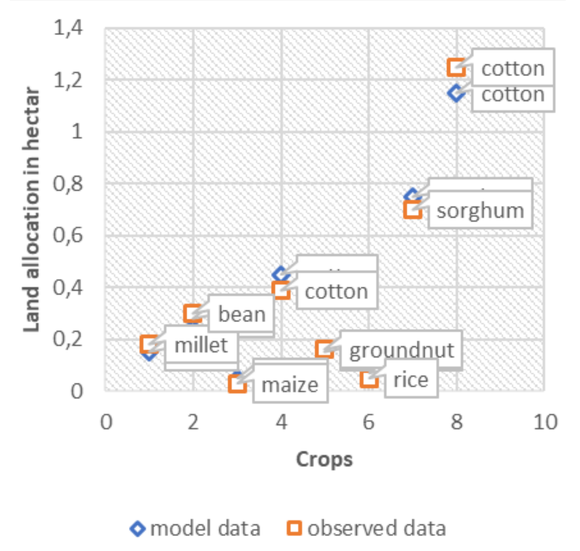
Calibration of the bio-economic model for cluster 2

Source: Authors, 2017 from simulations in GAMS

The calibration of the bio-economic model



Calibration of the bio-economic model for cluster 3



Calibration of the bio-economic model for cluster 4

Figure 2: The calibration of the bio-economic model

Source: Authors, 2017 from simulations in GAMS

We used in addition to the plotted figures above, the regression technique to assess the association of the model values with observed values. This is captured as bellow :

$$X^M = \beta_0 + \beta_1 X^o X^M = \beta_0 + \beta_1 X^o \qquad (9)$$

X° is observed land use type, X^M is modelled land use while $\beta_i's$ are parameters. For a valid model there is a high association between the model results and observed values and the intercept tends to be zero while the slope is one. The table 1 below gives the results of the regression.

	β_0	β_1
Values	-0.009827	1.047698
P-Values	0.545	0.000

R-squared = 0.9770

The value of the slope is 1.048 and significant at 1% level while the constant was not significantly different from zero. In addition, the R-square of 0.9770 implies that there is a very good association between modelled and observed land use. Thus, the constructed model can be used for simulation purpose.

Simulation experiment

A climate change scenario is implemented in the model through the creation of an additional climate file representing possible future climate. This scenario is based on farmers' subjective perception of future climate given the absence of scientific forecast of future climate for the study area. The new climate is an average weather condition of the five states of nature prevailing in Togo, namely: good rainfall condition, normal rainfall condition, bad rainfall condition, disastrous due to floods and disastrous due to droughts. This new climate is obtained by asking farmers to state their subjective perception of future rainfall conditions based on their past experience. The exact question was: "Based on your experience, in the ten coming years (2013 to 2023), how many years are you expecting to be Good, Normal and Bad in terms of rainfall, disastrous due flood and disastrous due to drought? The new climate file is substituted to the baseline[54] climate file (S0) to simulate the climate change scenarios (S1). The outcomes of the scenario S1 are then compared to the outcomes from the scenario S0 for the four farmers' groups retained. To assess the impact of adaptation strategies, we introduce successively the retained strategies in the scenario S1. Thus, we first introduce irrigation by converting 25% of the operating area into irrigated area, this scenario is referred to as S2.For soil and Water conservation (SWC) techniques, we supposed these techniques are implemented on 25% of the operated land, this scenario is named scenario S3. For fertilizer reduction, we reduce applied fertilizer quantity by 25%, this is the scenario S4.These figures are guided by the on-going country' policy debates regarding adaptation. The results are presented in the table 2 below.

The overall research question of this study is: to which extent do private adaptation strategies mitigate climate change impacts on farm income from crops and livestock? To answer this question, the bio-economic model is solved introducing sequentially the retained strategies. From the results one can note that adaptation strategies in terms of irrigation and SWC techniques do mitigate climate change impact for all the four identified groups although the impacts vary from one group to another. Specifically, if a representative wealthier farm group household converts 25% of its operated land into irrigated area, this will mitigate on average96.43%of the climate change impacts. However, this will reduce climate change impact by only 83.24%, 92.36% and 87.10% on average if the representative household was from cluster 4 (the poor group), or from clusters 1 or 3 (the middle groups), respectively. These performances fall to 75.81%, 75.46%, 77.25% and 63.81%for cluster 2 (wealthier), cluster 4(poor), cluster 1 and cluster 3(middle groups), respectively, if the converted area was devoted to SWC techniques. As one could have predicted, the reduction of applied fertilizer quantity by 25% increases the four groups' vulnerability to climate change (by 10.53% for the wealthier farm group and 12.31% for the poor farm group, for instance). The variation of impacts observedbetween groups is more likely the result of differences in households' managerial skills and farms' specific characteristics, though specific categories of technologies might be of various quality and efficiency across income groups (e.g. both apply water conservation, for instance rain water tanks, but not of the same quality).Clearly, irrigation practice appears to be the superior strategy for the four groups. It should be the first target for any policy aiming to reduce climate change adverse impacts on farm households' income. SWC techniques should not be ignored in the pursuit of this aim since irrigation practices could merely be impossible for some farms.

54 The baseline scenario in this study represents simulation outcomes from the calibration procedure

Table 2: Annual average operating profit per hectare

Scenarios (Sn)	Profits/Benefits (US$)		Percentage of variation		Residual Impacts	
	Wealthier farmers (cluster 2), n=8	Poor farmers (cluster 4), n=303	Wealthier farmers (cluster 2)	Poor farmers (cluster 4)	Wealthier farmers (cluster 2)	Poor farmers (cluster 4)
S0	710.54	582.34	-	-	-	-
S1	451.45	335.23	-36.46%	-42.47%	-36.46%	-42.47%
S2	693.82	487.45	+32.89%	+27.43%	-3.57%	-16.76%
S3	549.08	397.00	+ 12.94%	+ 18.34%	-24.19%	-24.54%
S4	379.86	268.16	-10.78%	12.09%	-46.99%	-54.78
	Cluster 1 (n=90)	Cluster 3 (n=40)	Cluster 1	Cluster 3	Cluster 1	Cluster 3
S0	630.32	588.90	-	-	-	-
S1	355.00	340.23	-43.67%	- 42.22%	-43.67%-	-42.22%
S2	582.17	517.67	+36.04%	+30.13%	-07.64%	-12.09%
S3	486.95	375.76	+20.93%	+06.03%	-22.75%	-36.19%
S4	289.43	269.00	-10.40%	-12.09%	-54.08%	-54.32%

Source: Authors, 2017 from simulations in GAMS

CONCLUSION

Achieving food security under the climate change context is a crucial challenge especially for countries relying heavily on rain-fed agriculture like in Togo. For these countries, it is crucial for agriculture to adapt to the changing climate. However, quantitative analysis of the impacts of adaptation strategies is only starting to emerge since most studies have been focusing on the impacts of climate change and adaptation adoption rather than its implications on welfare. We contribute to filling this research gap by simulating climate change adaptation options and assessing their impact on farm income from crops and livestock in the Savannah region of Togo. Contrary to the existing studies on the topic, a farm modelling approach is used. The approach represents the integration of the economic decision making environment with the spatial and temporally biophysical conditions. The findings reveal that irrigation and soil and water conservation techniques can be used to deal with the adverse impacts of climate change on farm households' income. These are of course win-win strategies with adaptation and conservation pay-offs coupled with productivity impacts. However, fertilizer reduction, an adaptation strategy used by farmers in the study area, decreases income forall farm types covered in our model; wealthier farm group, poorer farm group and the middle farm groups. Given the social benefits and private costs nature of water and soil conservation techniques, policy makers should consider their promotion to stimulate farmers' adaptation to climate change. Irrigation is also shown to have strong adaptation benefits in our model. Yet, given its high costs, there are definite financial barriers to its adoption at individual level. Support to institutional arrangements, such as community-based irrigation schemes based on local water user associations, could pay high dividends by allowing farm households to benefit from economies of scale in irrigation infrastructure. The community-based irrigation developed in the Sidiki village of the Savana region could serve as an example in the move towards such a system. The Sidiki village-based irrigation system is co-managed by the village development committee (CVD), one of the village coordination mechanisms, and the ministry of agriculture.

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REFERENCES

Antle J. M., (1987). Econometric Estimation of Producers' Risk Attitudes. American Journal of Agricultural Economics. Vol. 69, Issue 3, pages 509-522.

Atwood, J.A., Watts, M. J., & Helmers, G. A. (1988). Chance-Constrained Financing as a Response to Financial Risk. Vol. 70, pages 79-89.

Barbier, B. & Bergeron, G. (2001). Impact of policy interventions on land management in Honduras: results of a bioeconomic model. Agricultural Systems, Vol. 60, Issue 1, pages 1-16.

Belhouchette H., Louhichi K., Therond O., Mouratiadou I.,Wery J., Ittersum M. V, & Flichman G. (2011). Assessing the impact of the Nitrate Directive on farming systems using a bio-economic modelling chain. Agricultural Systems. Vol. 104, Issue 2, pages 135–145.

Buschena, D. & Zilberman, D. (1994). What do we know about decision making under risk and where do we go from here? Journal of Agricultural Resource Economics. Vol. 19, Issue 2, pages 425-445.

Dessalegn, T.Y. (2005). Modeling Farm Irrigation Decisions under Rainfall Risk in the white-volta basin of Ghana: A tool for policy analysis at the farm-household level. Center for Development Research (ZEF), PhD thesis.

Di Falco, S., Veronesi, M., & Yesuf, M. (2011). Does Adaptation to Climate Change Provide food Security? A Micro-Perspective from Ethiopia. American Journal of Agricultural Economics, Vol. 93, Issue 3, pages 825-842.

Egbendewe-Mondzozo, A.., Swinton S. M., Wilfred S. K., Post W. M., Binfield J.C., & Wyatt Thompson W. (2015). Bioenergy Supply and Environmental Impacts on Cropland : Insights from Multi-market Forecasts in a Great Lakes Sub regional Bioeconomic Model. Applied Economic Perspectives and Policy, Vol. 37, Issue 4 pages 603-618.

Gameiro, H. A. G, Rocco, D. R., Filho J. V. C., (2016). Linear Programming in the economic estimate of livestock-crop integration: application to a Brazilian dairy farm.

Revista Brasileira de Zootecnia, Vol. 45, Issue 4, pages 181-189.

Lobell, D. B. (2014), Climate change adaptation in crop production: Beware of Illusion. Global Food Security. Vol. 3, pages 72-76. http://doi.org/10.1016/j.gfs.2014.05.002. Accessed 2016/07/11Parry, M., Rosenzweig, C., Livermore M., (2005), Climate Change, Global Food Supply and Risk of Hunger. Phil.Trans. Royal. Soc. B Vol. 360, pages 2125–2138.

Seo, S. N., Bruce, McCarl, B. A., Mendelsohn, R. (2010). From beef cattle to sheep under global warming? An analysis of adaptation by livestock species choices in South America. Ecological Economics, Vol. 69, Issue 12, pages. 2486-2494.

Seo, S. N., Mendelsohn, R. (2008). Measuring Impacts and Adaptations to ClimateChange: A Structural Ricardian Model of African Livestock Management. Agricultural Economics, Vol. 38, pages 151–165. https://doi.org/10.1111/j.1574-0862.2008.00289.x

Shah, K. U., Dulal, B. (2015). Household capacity to adapt to climate change and implications to food security in Trinidad and Tobago. Regional Environmental Change, Vol. 15, Issue 5.

Wheeler T, von Braun, J. (2013). Climate change impacts on global food security. Science, Vol. 341, pages 508–513.

Willy and Holm-Müller, (2013), Social influence and collective action effects on farm level soil conservation effort in rural Kenya. Ecological Economics. Vol. 90, pages 94–103.

World Bank.(2007). Frome Agriculture to Nutrition, pathways, Synergies and Options. Report 40196-GLB, World Bank, Washington, DC. www.worldbank.org.

Wurlod, J.-D. and Eaton, D. (2015). Chasing after the frontier in agricultural productivity. Food Secure Working Paper No 36. http://www3.lei.wur.nl/FoodSecurePublications/WP_36_productivity.pdf. Accessed 2017/02/02.

Analyse de la performance d'une filière d'exportation et impact dans l'atténuation des effets des changements climatiques : Cas de l'anacarde au Sénégal

Ibra Sounkarou Ndiaye et Malick Sané

ABSTRACT

Export value chains such as cashew nut are important levers for socioeconomic added value and climate change resilience in Senegal despite their low levels of financing, organization and strategies. The Leontief model and the Intergovernmental Panel on Climate Change Guidelines were used to determine the performances. This study shows an added value amont of 32.6 billion F CFA, or approximately 31% of the environmental sector Gross Domestic Product. Furthermore, Semi-industrial processing is most strongly linked to production, followed by the primary branch and artisanal processing. The potential of carbon sequestration has also been estimated about 177408 tons of carbon per year which could be valorized in carbon market.

Keywords : Value chains analysis, environment, steering strategy, Cashew nut value chain, commercial exports.

RÉSUMÉ

Les filières d'exportation comme celle de l'anacarde constituent d'importants leviers de création de valeur ajoutée et de résilience aux changements climatiques au Sénégal malgré les faibles niveaux de financement, d'organisation et de stratégies. Le modèle de Leontief et les Lignes directrices 2006 du Groupe d'Experts Intergouvernemental sur le Climat ont été utilisés pour déterminer la performance de la filière. La valeur ajoutée de la filière s'élève à 32,6 milliards F CFA, soit 31% de celle du secteur de l'environnement[55]. La transformation semi-industrielle est fortement liée à la production suivie de la branche primaire et de la transformation artisanale. Le potentiel de séquestration a été estimé à 177408 tonnes de carbone par an susceptibles d'être valorisées dans le marché du carbone.

Mots-clefs: Analyse filière, Environnement, stratégie de pilotage de la performance, chaine de valeur anacarde, exportations commerciales.

55 La valeur ajoutée totale du secteur de l'environnement est de : 104 842 milliards (DPVE : Rapport sur la contribution du secteur au PIB, 2016)

INTRODUCTION

Dans la plupart des pays en développement les opportunités économiques reposent sur les potentialités agro-sylvo-pastorales. Certaines cultures sont incluses dans des filières ou des chaînes de valeurs globalisées dans lesquelles plusieurs acteurs sont souvent en interrelation. Ce commerce soulève de nombreuses préoccupations du fait de ses effets sur l'environnement, en termes de dégradation des sols, de déforestation et de perte de la biodiversité dans un contexte de changement climatique.

L'anacardier (Anacardium occidentale L.), introduit à partir du XV^{ième} siècle en Afrique de l'Ouest par des navigateurs portugais, engendre une filière émergente et est en passe de devenir au Sénégal comme ailleurs en Afrique de l'Ouest (Côte d'Ivoire, Guinée Bissau, etc.), l'une des premières cultures d'exportation et de sources de revenus pour les populations. La croissance de la production mondiale de noix de cajou a été très rapide au cours des cinquante dernières années. Elle a été multipliée par 10 et est passée de 288.000 tonnes en 1961 à 2,5 millions de tonnes en 2015 (Réseau d'ONG Européenne pour l'Agriculture et le Développement, 2015). Avec une production moyenne annuelle entre 15 000 et 20 000 tonnes exportées essentiellement vers l'Inde (PADEC : Programme d'Appui au Développement Economique de la Casamance, 2016), pour approximativement 64 000 hectares de plantation, le Sénégal fait partie des plus importants producteurs de noix de cajou en Afrique.

Le développement de filières d'exportation performantes comme la filière anacarde considérée parmi les plus prometteuses en Afrique constitue un important levier en termes d'amélioration du commerce international, de création de valeur ajoutée, d'emplois et de lutte contre la pauvreté. Cette filière concentre près de 22 551 ménages soit 1,4% des ménages du pays pour 351 991 personnes (PADEC, 2016). La « filière anacarde » constitue ainsi un moyen de développement socioéconomique (Samb et al., 2018). La filière contribue à la lutte contre la pauvreté car étant à la portée des catégories sociales les plus démunies. En effet, l'exploitation telle que pratiquée ne nécessite pas forcément d'investissements structurants ni trop d'intrants de production. Cependant, elle est confrontée à plusieurs difficultés liées à des modes de production non durables tels que la non utilisation de variétés non adaptées, le vieillissement des plantations, l'absence de protection et d'entretien, mais également le faible accès au crédit des producteurs (Touré et al., 2017). À cela s'ajoute le nombre limité d'unités de transformation installées à proximité des zones de production, le manque d'organisation de la filière, le manque de formation des producteurs et la faiblesse de la pénétration du marché international par les acteurs sénégalais. En outre, les exportations se font presque exclusivement pour la noix brute (seul 3% de la production est transformée). Par ailleurs, le rendement dans le processus de transformation de l'anacarde est encore faible et de l'ordre de 18 pour cent. 5 kg de noix brut sont nécessaires pour 1 kg d'amandes blanches dans le processus de transformation semi-industrielle ; alors qu'en transformation artisanale 5,5 kg de noix brutes environ seront utilisés pour le même résultat (Tinlot M. et Al., 2009).

Dans la filière anacarde peu de stratégies sont développées et les projections dans la prise de décision souffrent d'un manque de connaissance des interrelations entre les différents segments de l'activité. La vulnérabilité ainsi notée dans le secteur, se révèle comme le résultat d'une équation complexe entre la gestion de l'environnement et les stratégies de pilotage de la filière d'exportation. Dès lors, il importe de se poser la question suivante : quels sont les déterminants de la performance de la filière anacarde dans le contexte actuel de changement climatique ?

Notre hypothèse est que « la performance dans la chaîne de valeur s'explique par l'efficacité, l'efficience et la durabilité du pilotage pour la valorisation des potentialités et la résilience ».

À ce sujet, l'économiste américano-russe Wassily Léontief (1930) a mis au point une méthode d'analyse intersectorielle avec des tableaux d'échanges pour mieux comprendre le fonctionnement d'une économie et faciliter la planification et la fixation d'objectifs quantitatifs.

L'objectif général de cette recherche est de dégager des éléments de planification stratégique pour le développement de la filière anacarde, du commerce compatible avec la gestion durable de l'environnement et de prise de décisions politiques pour une meilleure compréhension des interrelations entre branches et des impacts potentiels des stratégies définies.

REVUE DE LITTÉRATURE

Revue théorique

Une filière est un ensemble ou une gamme d'activités nécessaires pour un produit ou un service depuis sa conception, en passant par ses différentes phases de production intégrant la transformation physique et l'apport de services aux producteurs, la livraison aux consommateurs finaux et l'élimination finale après usage (Kaplinsky et Morris, 2000).

Elle part d'un produit de base et aboutit à des produits finis alors que la chaîne de valeur part d'un produit particulier ou spécifique pour un marché précis (local, sous-régional, international).

Les effets des échanges commerciaux sur l'environnement ont été pris en considération dès 1970 dans le sillage de la préparation du premier sommet sur l'Environnement et le développement de 1972 à Stockholm en Suède.

Plus tard, Grossman and Krueger (1995) ont montré que les effets du commerce sur l'environnement seraient de trois ordres par rapport à sa composition, à l'échelle et aux aspects techniques. Pour Brander and Taylor (1998), l'ouverture au commerce pourrait conduire à une surexploitation des ressources naturelles.

Sur la base de la « courbe environnementale de Kuznets » (figure 1) et ses hypothèses, certains économistes comme Grossman and Krueger (1995) avancent que la croissance est nuisible à l'environnement jusqu'à ce que soit atteint un certain niveau de revenu par habitant, et qu'au-delà les effets favorables à l'environnement deviennent dominants.

Les études microéconomiques donnent à penser que la demande de qualité de l'environnement augmente avec le revenu. Les gains de revenu qui résulteraient du commerce ou du progrès technique font baisser la pollution, tandis que le revenu résultant de l'accumulation du capital augmente la pollution. En effet, l'accumulation du capital favorise nécessairement la production de biens polluants, contrairement au progrès technologique.

Andreoni et Levinson (1998) trouvent que la technologie de la lutte antipollution est un autre facteur qui influe sur la forme de la CEK (Courbe Environnementale de Kuznets) et postulent que la demande de qualité environnementale est indépendante du revenu.

Pour parvenir à un effet globalement positif du libéralisme sur l'environnement, il faudrait que l'effet technique (amélioration des technologies) soit supérieur à l'effet d'échelle (croissance de la production).

Revue empirique

Les études effectuées au Mexique et rapportées par Kevin Gallagher (2004), infirment également l'hypothèse selon laquelle la dégradation de l'environnement évolue de la même façon en fonction du niveau de revenu. En effet, le revenu-seuil au-delà duquel la pollution tend à diminuer est estimé à environ 5 000 dollars, et le Mexique avait déjà atteint ce seuil en 1985.

Pour Chichilnisky (1994), l'avantage comparatif serait déterminé par les différences de normes environnementales et de régimes de gestion des ressources naturelles. Brander et Taylor (1997) nuancent les résultats de Chichilnisky en faisant constater que les pays dans lesquels les ressources naturelles sont considérées comme des ressources communautaires en libre accès auront tendance à les épuiser même s'il n'y a pas de commerce international.

S'agissant des changements climatiques, le phénomène affecte indirectement les rendements des cultures en augmentant le stress hydrique sur les cultures irriguées (Nelson et al., 2009). L'Institut international de recherche sur les politiques alimentaires pour l'analyse des politiques de produits agricoles et le commerce établit qu'en Afrique subsaharienne les récoltes en cultures pluviales et irriguées, vont diminuer respectivement de 0,6 pour cent et 3,5 pour cent.

La lutte contre les changements climatiques est un domaine ou un exemple de « systèmes socio-climatiques » dans lesquels des facteurs de différents domaines interagissent à différentes échelles spatiales et temporelles (Holling, 2001).

Pour apprécier les impacts environnementaux d'une filière, l'Analyse du cycle de vie (ACV) basée sur les tableaux entrées-sorties (Jolliet et al., 2005) a été utilisée dans la filière anacarde pour son intégration dans la mitigation au changement climatique (Tinlot, 2009).

Dans une filière de rente comme celle de l'anacarde, il existe de nombreux marchés de consommation (figure 1). Les échanges se font souvent entre pays développés, émergents et pays en développement, ceci avec des stratégies, des approches, des mécanismes et des technologies différentes (Tinlot, 2009).

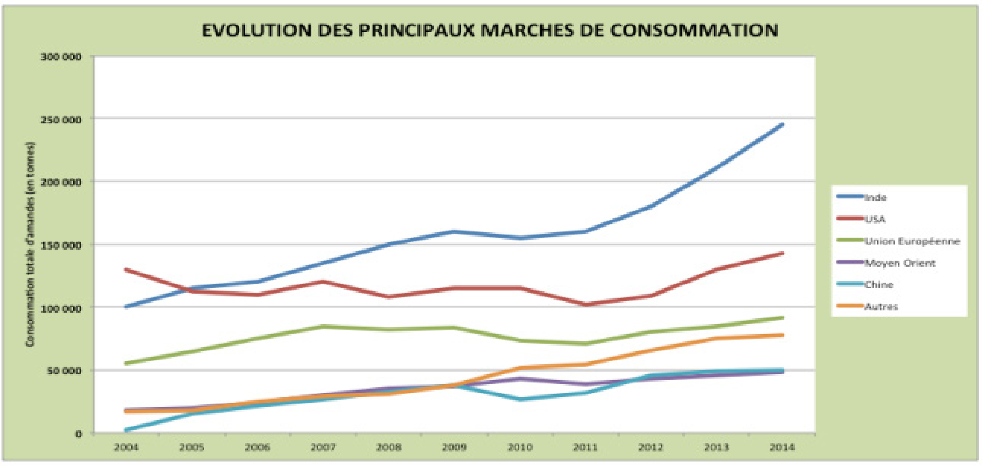

Figure 1 : Évolution de la consommation d'anacarde dans les principaux pays consommateurs
Source : Étude ISRA, PADEC 2016

L'analyse de filières a été systématisée à travers l'ouvrage de Golberg R.A and Davis intitulé « A concept of agribussiness » publié en 1957 qui l'a ensuite appliquée aux filières blé, Soja et agrumes en 1968. Ce travail fait apparaître les valeurs ajoutées en termes de séquences ainsi que les flux entre le « cœur de métier » qu'est l'agroforesterie et les marchés finaux.

Le système de gouvernance conduit à distinguer des filières pilotées par l'aval (Buyer-driven chains, ce qui est le cas de l'agroalimentaire) et des filières pilotées par l'amont (Producer-driven chains, par exemple l'automobile ou l'informatique). D'après Koné (2011), quatre mécanismes de gouvernance, à savoir le partenariat, la confiance, le contrat et le pouvoir sont supposés influencer les deux dimensions de la performance (performance financière et performance non financière).

Ce travail vise à analyser la performance dans la filière anacarde et à dégager des axes de pilotage.

MÉTHODOLOGIE

Ce travail de recherche s'est appuyé pour l'essentiel sur trois techniques : la recherche documentaire, l'entretien et l'observation directe.

Zone d'étude

L'étude porte sur les régions de Fatick (Sokone, Toubacouta, Passy), Kolda, Sédhiou et Ziguinchor qui sont de grandes régions de production agricole et d'exploitation de l'anacarde.

Approche méthodologique

Enquêtes et documentation

Les données utilisées proviennent d'enquêtes que nous avons menées et de la documentation. Ainsi, pour le nombre d'emplois utilisé dans l'étude, les données proviennent directement du rapport d'enquête sur le sous-secteur de l'anacarde au Sénégal de 2016 de l'Institut Sénégalais de Recherche Agricole (ISRA) en collaboration avec le Projet d'Appui au Développement économique de la Casamance (PADEC) couvrant 22 551 ménages.

Modèle utilisé

Nous nous appuierons sur le modèle de Léontief pour analyser la stratégie de pilotage de la filière anacarde ainsi que ses impacts sur l'environnement dans la perspective d'un développement durable.

Le modèle de Léontief est basé sur l'analyse du Tableau Entrée-Sortie (TES) ou tableau output-input. Les tableaux entrées-sorties sont des outils uniques d'analyse des relations entre les différentes branches d'activité d'une économie. Ils sont souvent utilisés en combinaison avec des modèles macro-économiques, qui permettent d'introduire des éléments structurels. Ils fournissent ainsi rapidement différentes mesures synthétiques d'analyse. L'essentiel du matériau analytique de cette approche est la combinaison d'un tableau de comptabilité nationale et d'un modèle mathématique utilisant le calcul matriciel.

Dans ce modèle le point de départ est d'une part l'écriture des égalités emplois-ressources pour chaque secteur et d'autre part des égalités entre les valeurs ajoutées additionnées aux coûts de production et aux prix. Ceci forme deux systèmes d'équations autonomes. Des coefficients techniques apparaissent dans le système des quantités donnant ainsi une écriture matricielle.

Ceci permet de calculer la quantité de bien d'une branche (j) nécessaire à la production d'une unité de bien de chaque branche (i) : ce ratio est un coefficient technique.
En général, on a le système suivant :

$$\begin{cases} q_1 = a_{11}q_1 + a_{12}q_2 + \cdots + a_{1n}q_n + y_1 \\ q_2 = a_{21}q_1 + a_{22}q_2 + \cdots + a_{2n}q_n + y_2 \\ \cdots \\ q_n = a_{n1}q_1 + a_{n2}q_2 + \cdots + a_{nn}q_n + y_n \end{cases}$$

Où n est le nombre de secteurs et le coefficient technique aij donne la quantité de l'input i nécessaire pour produire une unité de l'output j.
On peut aussi écrire :

$$\begin{cases} (1-a_{11})q_1 - a_{12}q_2 - \cdots - a_{1n}q_n = y_1 \\ -a_{21}q_1 + (1-a_{22})q_2 - \cdots - a_{2n}q_n = y_2 \\ \cdots \\ -a_{n1}q_1 - a_{n2}q_2 - \cdots + (1-a_{nn})q_n = y_n \end{cases}$$

Et, sous forme matricielle :

$$[I - A]q = y$$

Où A est la matrice des coefficients techniques (A= $[a_{ij}]$), q et y sont des vecteurs (q= $[q_i]$, y= $[y_i]$) et I est la matrice unitaire.

Il convient de noter que la matrice A ne contient pas les coefficients techniques du facteur primaire (services).

On détermine l'output nécessaire pour satisfaire un niveau donné de demande finale en résolvant ce système par rapport à q :
Pourvu que [I – A] soit une matrice non singulière.
Soit b_{ij} les éléments de la matrice $[I - A]^{-1}$.
On peut écrire :

$$\begin{cases} q_1 = b_{11}y_1 + b_{12}y_2 + \cdots + b_{1n}y_n \\ q_2 = b_{21}y_1 + b_{22}y_2 + \cdots + b_{2n}y_n \\ \cdots \\ q_n = b_{n1}y_1 + b_{n2}y_2 + \cdots + b_{nn}y_n \end{cases}$$

Comme les q_i sont des outputs, il faut que tous les coefficients b_{ij} soient non négatifs. En effet, si un coefficient est négatif, on peut trouver une valeur suffisamment élevée de la consommation finale, associée à ce coefficient, qui conduit à une production négative et ceci n'est pas possible du point de vue économique. Par conséquent, la matrice [I – A] doit satisfaire des conditions spéciales, appelées conditions de Hawkins-Simon (1949) :

$$1 - a_{11} > 0 \quad ; \quad \begin{vmatrix} 1 - a_{11} & -a_{12} \\ -a_{21} & 1 - a_{22} \end{vmatrix} > 0 \ldots \begin{vmatrix} 1 - a_{11} & \ldots & -a_{1n} \\ \ldots & & \\ -a_{n1} & \ldots & 1 - a_{nn} \end{vmatrix} > 0$$

Tous ces déterminants doivent être positifs. Si ces conditions ne sont pas satisfaites, l'économie n'est pas productive.

Après avoir déterminé l'output nécessaire pour obtenir une consommation finale donnée, il faut encore vérifier si l'input primaire est disponible en quantité suffisante. Soit a_{ij} les coefficients techniques de l'input primaire et L_0 la quantité disponible. Il faut alors satisfaire l'inégalité suivante :

$$a_{o1}q_1 + a_{o2}q_2 + +a_{on}q_n \leq L_o$$

Limites de la méthode

La principale faiblesse du modèle input-output réside dans la supposition de coefficients de production fixes. À court terme, cette hypothèse peut être valable et les projections du modèle input-output ne devraient pas être trop éloignées de la réalité.
À long terme, une substitution pourrait être opérée entre les procédés et les facteurs de production car si les prix des facteurs augmentent fortement, d'autres techniques seront utilisées. Enfin, l'utilisation du modèle nécessite des données nombreuses et affinées Kaplinski, 2004).

Traitement des données

L'évaluation de la performance prend en compte i) la contribution à la lutte contre la pauvreté et la sécurité alimentaire, ii) la durabilité environnementale et iii) la compétitivité commerciale.

Dans le cas de notre étude on a trois secteurs : i) Le secteur primaire (Y1) ; ii) Le secteur de la transformation artisanale (Y2) ; iii) Le secteur de la transformation semi-industrielle (Y3). Pour aboutir au modèle de Leontief, nous partons de la matrice ci-dessous extraite du tableau 1 et générée à partir des données recueillies avant le calcul des coefficients techniques.

Tableau 1 : Extrait du tableau entrée-sortie pour application du modèle

Utilisateurs	Secteur primaire	Transformation artisanale avec les GIE du PADEC et autres Points de transformation primaire au niveau national	Transformation semi industrielle (ACASEN, SENAR, autres PME .....)
Producteurs	(Champs du PADEC, autres producteurs)		
Secteur primaire	1320	357	143
Transformation artisanale	0	0	100
Transformation semi-industrielle	0	0	500
Services (en millions d'heures)	60	2	1

Source : Etude ISRA, PADEC 2016

Tableau 2 : Méthode de calcul des coefficients techniques

Utilisateurs	Secteur primaire	Transformation artisanale avec les GIE du PADEC et autres Points de transformation primaire au niveau national	Transformation semi industrielle (ACASEN, SENAR, autres PME .....)
Producteurs	(Champs du PADEC, autres producteurs)		
Secteur primaire	1320/17552	357/15165	143/2370
Transformation artisanale	0/17552	0/15165	100/2370
Transformation semi-industrielle	0/17552	0/15165	500/2370
Services (en millions d'heures)	60/17552	2/15165	1/2370

Source : Calculs de l'auteur

Étant donné l'hypothèse de rendement d'échelle constant, on peut calculer la quantité d'input nécessaire pour une unité d'output. Il suffit de diviser les inputs de la branche par la production totale. On obtient ainsi la matrice des coefficients techniques suivante (tableau3). Ces valeurs sont appelées les coefficients techniques de production.

Tableau 3 : matrice des coefficients techniques

Utilisateurs	Secteur primaire	Transformation artisanale avec les GIE du PADEC et autres Points de transformation primaire au niveau national	Transformation semi industrielle (ACASEN, SENAR, autres PME .....)
Producteurs	(Champs du PADEC, autres producteurs)		
Secteur primaire	0,08	0,02	0,06

Transformation artisanale	0,00	0,00	0,04
Transformation semi-industrielle	0,00	0,00	0,21
Services (en millions d'heures)	0,08	0,02	0,06

Source : Calculs de l'auteur

En se basant sur le tableau 3 (matrice des coefficients techniques nommée A), on calcule la matrice [I – A].

$$A = \begin{pmatrix} 0{,}08 & 0{,}02 & 0{,}06 \\ 0{,}00 & 0{,}00 & 0{,}04 \\ 0{,}00 & 0{,}00 & 0{,}21 \end{pmatrix} \quad I = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$I - A = \begin{vmatrix} 0{,}92 & -0{,}02 & -0{,}06 \\ 0{,}00 & 1 & -0{,}04 \\ 0{,}00 & 0{,}00 & 0{,}79 \end{vmatrix}$$

On a donc :
1 - 0,08 >0 ; $\begin{matrix} 0{,}92 & -0{,}02 \\ 0{,}00 & 1 \end{matrix} = 0{,}92x1 + 0{,}02x0 = 0{,}92$ >0; et le déterminant de la matrice

[I – A] est égal à 0,73 > 0 cela satisfait la condition de Hawkins-Simon.
La fonction de production obtenue après inversion de la matrice (I-A) est donnée par le système d'équation linéaire suivant :

P1 =0,08Y1 + 0.03Y2 + 0,08Y3

P2 = Y2 + 0,05Y3

P3 = 1,27Y3

Où P1, P2 et P3 représentent les productions des branches et Yi les demandes finales (la consommation finale des ménages, des administrations publiques et des institutions sans but lucratif au service des ménages, la formation brute de capital fixe, les exportations et la variation des stocks).

Détermination du potentiel de séquestration du carbone

La méthodologie de calcul se base sur l'approche préconisée par les Lignes directrices 2006 et 2013 du Groupe Intergouvernemental d'Experts sur le Climat (GIEC) pour les inventaires nationaux de gaz à effet de serre qui distingue deux catégories i) les terres forestières restant terres forestières et ii) les terres converties en terres forestières.

Compte tenu de l'adoption de technologies agro-forestières dans la filière anacarde au Sénégal, c'est la deuxième catégorie qui a été retenue. En effet, ces terres sont converties en terres forestières par reboisement donc par régénération artificielle

Étant donné la non disponibilité des données relatives aux affectations des terres, la méthode d'estimation, de la biomasse et du calcul des absorptions de carbone dues aux variations de biomasses aérienne et souterraine, a été faite sur la base du niveau 1 avec l'utilisation de paramètres par défaut.

Gains annuels moyens de biomasse

Cce_{Totale} = $\sum$ {Cce(1 + Tx)} : les données de l'augmentation de la biomasse (matière

sèche) sont utilisées directement.
Avec : CceTotale = Croissance moyenne de la biomasse souterraine et aérienne en tonnes m.s. ha^{-1} an^{-1} ;

Cce = Croissance annuelle moyenne de la biomasse aérienne pour un type spécifique de végétation ligneuse, tonnes m.s. ha^{-1} an^{-1} ;

Tx = taux de biomasse souterraine par rapport à la biomasse aérienne pour un type spécifique de végétation, en tonne m.s. de biomasse souterraine (tonne m.s biomasse aérienne)$^{-1}$. Tx doit être fixé à zéro si l'on estime qu'il n'y a pas eu de modifications des schémas d'allocation de biomasse souterraine (niveau 1).
En se basant sur les travaux de Mokany et al., (2006) : Tx = 0.32 pour la steppe subtropicale.

RÉSULTATS

Effets directs des activités économiques des branches de la filière

D'après le Tableau Entrée Sortie (TES) la valeur ajoutée sur toute la filière anacarde est de 32,6 milliards F CFA (tableau 5). Ainsi, un ha de plantation d'anacardiers a une valeur de 509 375 FCFA (1018.75 USD). Le nombre d'emplois créés est de : 26 093 dont 98,1% pour le secteur primaire, 1,7% pour la transformation artisanale et 0,2% pour la transformation semi-industrielle. Le niveau d'exportation est de 5%.

Tableau 4 : contribution des branches à la richesse du pays

Branches	Valeur ajoutée brute (VAB)	Contribution à la richesse du secteur de l'environnement	Emplois	Taux d'exportation
Agriculture (secteur primaire)	16232	15%	25593	5%
Transformation artisanale	14808	14%	450	0%
Transformation semi-industrielle	1627	2%	50	0%
Total	32667	31%	26093	5%

Source : Etude ISRA, PADEC 2016

Interdépendance des différents secteurs ou branches économiques intervenant dans la filière anacarde du Sénégal

L'analyse en amont de la filière anacarde montre que la transformation semi-industrielle a de fortes liaisons avec la production nationale, ainsi qu'avec le secteur primaire et de la transformation artisanale. Ces résultats sont confirmés par le modèle prévisionnel de Léontief.

Tableau 5 : degré de liaison de la branche de transformation artisanale avec la production nationale

Branches	Données		Prévisions	
	Demande finale	Production	Demande finale projetée	Production calculée
Secteur primaire	15732	17552	15752	17574
Transformation artisanale	15065	15165	15065	15165
Transformation semi-industrielle	1870	2370	1870	2370
Total		35087		35109

Source : Calculs de l'auteur

Une même augmentation de la demande finale du secteur de la transformation artisanale entraîne une augmentation de 21 unités de la production nationale ;

Tableau 6 : Degré de LIAISON DE la branche transformation semi-industrielle avec la production nationale

Branches	Données		Prévisions	
	Demande finale	Production	Demande finale projetée	Production calculée
Secteur primaire	15732	17552	15732	17553
Transformation artisanale	15065	15165	15085	15185
Transformation				
semi-industrielle	1870	2370	1870	2370
Total		35087		35108

Source : Calculs de l'auteur

Une même augmentation de la demande finale du secteur de la transformation semi-industrielle entraîne une augmentation de 28 unités de la production nationale.

Tableau 7 : Degré de liaison du secteur primaire avec la production nationale

Branches	Données		Prévisions	
	Demande finale	Production	Demande finale projetée	Production calculée
Secteur primaire	15732	17552	15732	17554
Transformation artisanale	15065	15165	15065	15166
Transformation				
semi-industrielle	1870	2370	1890	2395
Total		35087		35115

Source : Calculs de l'auteur

Potentiel de séquestration du carbone

Les plantations sont d'environ 64 000 ha. En considérant qu'une plantation est proche d'une Forêt sèche subtropical Afrique (≤ 20 ans) :

- La biomasse aérienne de telles plantations est de 30 tonnes de matière sèche/ha/an
- La croissance annuelle moyenne de la biomasse aérienne est de 5 tonnes de matière sèche/ha/an (GIEC, 2013).

Sur toute la superficie, elle est de 422 400 tms/an
La croissance moyenne annuelle de la biomasse aérienne est de 64 000 ha * 5tms/ha/an = 320 000 tms/an. Pour obtenir la biomasse souterraine, on applique un taux de 0.32. La biomasse totale est de 320 000 + (320 000 * 0.32) = 422 400 tms/an qui représente la biomasse totale. Pour passer de la quantité de biomasse à la quantité de carbone, le taux de conversion de la biomasse en carbone de Feldpausch et al., 2004 qui est appliqué, est de 0.42. En appliquant le coefficient de Feldpausch de 0.42, nous avons un gain total 177 408 tonnes de carbone/an, soit 2,77 t C/ha par an.

DISCUSSION

À partir des résultats nous pouvons déduire que partant de la demande finale connue ou attendue, il est possible de définir la production nécessaire. Cela permettra de satisfaire les besoins et d'identifier les branches dans lesquelles l'accent sera mis. Cette démarche pourra engendrer davantage de bénéfices et d'effets d'entraînement en fonction des consommations intermédiaires utilisées et des impacts socio-économiques et environnementaux potentiels. La valeur ajoutée sur toute la filière anacarde est de 32,6 milliards F CFA, soit 31% de la valeur ajoutée totale du secteur de l'environnement[56], ce qui montre l'importance de cette filière pour ce secteur. Cette valeur ajoutée rapportée à l'hectare représente 509 375 FCFA (1018.75 USD).

La filière anacarde emploie près de 26 093 dont 98,1% pour le secteur primaire, 1,7% pour la transformation artisanale et 0,2% pour la transformation semi-industrielle. Malgré ce faible taux de création d'emplois du sous-secteur de la transformation semi-industrielle, il a de fortes liaisons avec la production nationale suivie du secteur primaire et de la transformation artisanale. Ainsi, la performance du secteur repose sur le sous-secteur de la transformation semi-industrielle.

Les analyses relatives aux chaînes de valeur ne traitent que très partiellement les impacts des activités sur la pauvreté, les inégalités, la sécurité alimentaire et surtout sur l'environnement (Bolwig et al., 2010) et en particulier les changements climatiques ; elles se limitent généralement aux opportunités de revenu sans prendre en considération les externalités.

L'intérêt particulier de la méthode du GIEC de même que celui de la méthode Léontief réside surtout dans leur potentiel d'analyse et de prise de décision.

Les plantations d'anacardiers participent à la lutte contre les changements climatiques à travers la séquestration du carbone. Notre étude montre que les quantités de carbone

56 La valeur ajoutée totale du secteur de l'environnement est de : 104 842 milliards (DPVE : Rapport sur la contribution du secteur au PIB) séquestrées par an sont de l'ordre 177 000 tonnes de matière sèche /ha/an en termes de biomasse totale soit 2, 77 tonnes de Carbone par ha.

Les résultats en matière de séquestration de carbone peuvent varier en raison des méthodologies et modèles mais aussi des pratiques culturales, des conditions pédoclimatiques (Noelli O., 2009). Au Burkina Faso, la biomasse totale moyenne (aérienne et souterraine) estimée en appliquant le modèle à deux variables sur un échantillon de 52 arbres était 22,40 ± 2,67 t matière sèche par ha (Biah et al., 2018). Le potentiel de séquestration de la forêt classée de Bellefoungou et la savane cultivée de Nalohou ont été estimés respectivement en moyenne à 640 ± 50 g C /m2 (soit environ 7 tonnes de Carbone par hectare et par an) et 232 ± 27 g C /m2 et la forêt cultivée de Nangatchori en équilibre à 29 ± 16 g C /m2 (Expédit Evariste AGO, 2006). Ce qui est proche de nos résultats. En effet, les plantations d'anacardiers au Sénégal sont surtout intégrées dans les systèmes agroforestiers. Ces quantités de carbone sont susceptibles d'être valorisées dans le marché dans le cadre du Mécanisme de Développement Propre (MDP) ou de la Réduction des Émissions dues à la Dégradation et la Déforestation (REDD).

CONCLUSION

Le développement des filières d'exportation nécessite la mise en œuvre de politiques et de stratégies reposant sur les mécanismes de pilotage cohérent et rigoureux. Pour ce faire, la base de connaissance des différents maillons de production de transformation et de commercialisation mais aussi du niveau de l'organisation des filières devrait être davantage maîtrisée. La filière anacarde constitue un exemple typique dans ce cadre au Sénégal car étant en passe de devenir l'un des plus importants créneaux de développement socioéconomique au niveau local. Notre étude nous a permis de démontrer que l'analyse intersectorielle et l'utilisation du modèle de Léontief pourraient constituer un outil efficace de planification des interventions des différents acteurs à court terme, en particulier celles de l'État. L'impact de la filière sur l'environnement est positif surtout en matière de lutte contre le changement climatique et la désertification, cela en raison de la plasticité de l'espèce, de son potentiel comme pare-feu vert, et sa capacité à améliorer et la couverture végétale et à séquestrer du carbone. Ainsi, le développement des plantations permettrait une valorisation des services éco-systémiques (production, régulation, soutien, culturel, etc.) et à travers le marché du carbone. Cela contribuerait également à la création d'activités génératrices de revenus, d'emplois verts et donc au développement durable. Il serait nécessaire de sécuriser davantage l'approvisionnement en noix brutes des unités locales pour parvenir à une capacité de transformation locale optimale ; mais également d'encourager le développement de petites unités de transformation semi-industrielles au niveau des zones de production afin de minimiser l'impact du transport. Le modèle de pilotage utilisé peut-être étendu à d'autres filières ou pour mieux comprendre les interrelations avec d'autres secteurs ou branches de l'économie du pays.

RÉFÉRENCES BIBLIOGRAPHIQUES

Bencharif A., Rastoin J. L. (2007). Concepts et Méthodes de l'Analyse de Filières Agroalimentaires : Application par la Chaîne Globale de Valeur au cas des Blés en Algérie - Montpellier SupAgro, France.

Biah I., Guendehou S., Goussanou C., Kaire M.and Sinsin B.A. (2018). Modèles allométriques pour l'estimation de stocks de biomasse dans une plantation d'anacardiers (Anacardium occidentale L.) au Bénin.

Bolwig, S., Ponte, S., Toit, A.D., Riisgaard, L., Halberg, N. (2010). Integrating Poverty and Environmental Concerns into Value-Chain Analysis: A Conceptual Framework. Development Policy Review 28 (p. 173–194).

Bourque José. (1999). L'impact de la libéralisation des échanges commerciaux sur l'environnement (Mémoire de maîtrise es sciences). Ecole des Hautes Etudes Commerciales affiliée à l'Université de Montréal.

Brander, J.A., Taylor, M.S. (1998). The Simple Economics of Easter Island: A Ricardo-Malthus Model of Renewable Resource Use. The American Economic Review (Vol. 88). (p. 119–138).

Expédit Evariste AGO. (2006). Dynamique des flux de carbone entre l'atmosphere et des écosystèmes ouest-africains : cas des forêts et savanes sous climat soudanien au Bénin, (Thèse de Doctorat). Université de Liège Gembloux Agro-Bio-Tech (ULg) Belgique. (p. 3 -14).

Gallagher, Kevin P. (2004). Free Trade and the Environment. Mexico, NAFTA and Beyond. Palo Alto, CA: Stanford University Press.

Grossman, G.M., Krueger, A.B. (1995). Economic Growth and the Environment. Q J Econ (Vol. 110). (p. 353–377).

Koné, A. (2011). Mécanismes de gouvernance et performance de la filière coton du Mali (phdthesis). Université d'Angers.

Mokany, K., Raison, R.J., Prokushkin, A.S. (2006). Critical analysis of root : shoot ratios in terrestrial biomes. Global Change Biology (Vol. 12). (p. 84–96).

Noumi, V.N., Zapfack, L., Djongmo, V.A., Witanou, N., Nyeck, B., Ngossomo, J.D., Hamadou, M.R., Chimi, C.D., Mbobda, R.B.T. (2017). Floristic structure and sequestration potential of cashew agroecosystems in Africa: A case study from Cameroon. Journal of Sustainable Forestry (Vol. 36). (p. 277–288).

Noëllie Oudet .(2009). Impacts environnementaux de la filière fruits et légumes – analyse de cycle de vie. Journées Techniques Fruits et Légumes Biologiques.

PADEC (Programme d'Appui au Développement Economique de la Casamance). (2016). Enquêtes sur le sous-secteur de l'anacarde au Sénégal.

Tinlot Marianne. (2010). Intégration des filières dans la mitigation au changement climatique : Cas de la filière anacarde au Burkina Faso. FAO, Rome, Italy.

Samb, C.O., Touré, M.A., Faye, E. (2018). Caractéristiques sociodémographique, structurale et agronomique des plantations d'anacardier (Anacardium occidentale L.) du Bassin arachidier et de la Casamance/Sénégal. Journal of Animal & Plant Sciences (Vol. 38). (p. 6307–6325).

Touré, M.A., FAYE, E., Goudiaby, R. (2017). Réponse de quatre variétés de Anacardium occidentale L. aux techniques de greffage horticole en pépinière. VertigO - la revue électronique en sciences de l'environnement. https://doi.org/10.4000/vertigo.18861.

The Bouaflé Protected Forest conservation, in Côte d'Ivoire : Estimating the Total Economic Value

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ABSTRACT

The important role of forests in ecosystem balance, hydrological cycle, carbon cycle and biodiversity conservation cannot be overemphasized. Hence, the need to estimate the value of forests. Contingent valuation method was used to estimate the willingness to pay. A structured questionnaire was addressed to 159 households within and around the Bouaflé protected forest. The median and mean WTP estimated to 1000 CFA FRANCS (~ 1.5 Euros ~ 2$) and 1658.491 CFA FRANCS (~2.53 Euros~ 3$), respectively. The non-use value was approximated using estimates of tropical forests-related benefits per hectare provided in the literature. The indirect benefits encompassing climate regulation; disturbance regulation and water regulation; erosion control and sediment retention; soil formation; nutrient cycling; waste treatment; and genetic resources as well as carbon sequestration and water supply. The research outcomes underscore the importance of participation in forest conservation, and promotion best practices like the use of cook stoves, intensive agriculture, and ecological tourism for a sustainable management of forests.

Key words : Protected forest, Total economic value, Willingness-to-pay, Climate change mitigation

RÉSUMÉ

On ne saurait trop insister sur le rôle important des forêts dans l'équilibre des écosystèmes, le cycle hydrologique, le cycle du carbone et la conservation de la biodiversité. D'où la nécessité d'estimer la valeur des forêts. La méthode d'évaluation contingente a été utilisée pour estimer la volonté de payer. Un questionnaire structuré a été adressé à 159 ménages au sein et autour de la forêt protégée de Bouaflé. La médiane et la moyenne du consentement à payer ont été estimées à 1000 francs CFA (~ 1,5 euros ~ 2$) et 1658,491 francs CFA (~ 2,53 euros ~ 3$), respectivement. La valeur de non-usage a été approximée en utilisant les estimations des avantages liés aux forêts tropicales par hectare fournies dans la littérature. Les bénéfices indirects englobent la régulation du climat, la régulation des perturbations et la régulation de l'eau, le contrôle de l'érosion et la rétention des sédiments, la formation des sols, le cycle des nutriments, le traitement des déchets, les ressources génétiques ainsi que la séquestration du carbone et l'approvisionnement en eau. Les résultats de la recherche

soulignent l'importance de la participation à la conservation des forêts, et de la promotion des meilleures pratiques telles que l'utilisation de fourneaux, l'agriculture intensive et le tourisme écologique pour une gestion durable des forêts.

Mots clés : Forêt protégée, valeur économique totale, volonté de payer, atténuation du changement climatique.

INTRODUCTION

Forest means different things to people depending on concerns. The Food and Agriculture Organization of the United Nations (FAO) considers forest to be "land with a tree canopy cover of more than 10%, which has a larger area than 0.5 ha and is not specifically under a non-forest land use" (Food and Agriculture Organization-FAO, 2010). Clear-felled land that can be used for re-planting are considered as forest land. Forest classification includes also higher canopy cover extending from 10% to 30% as "sparse trees and parkland" (UNEP-WCMC, 2000). According to FAO (2010), deforestation is responsible for the loss of 13 million hectares of the world's forests. Africa is the most affected continent. Data covering the period 1990-2000 shows that the highest rate of deforestation is in Africa 0.8%, before Latin America with 0.4%, and Asia with 0.1% (Naoto, 2006). South America and Africa are still ranked first in deforestation rates today, with 4 million hectares and 3.4 million hectares respectively recorded per year between 2000 and 2010.

As is the case of other countries in West Africa, Côte d'Ivoire has suffered severe deforestation.

Since the 1960s, Côte d'Ivoire's total forest area has fallen from around 16 million hectares to 4 million hectares. Moron (1994) estimated that this rate of forest reduction is close to 90%. Côte d'Ivoire is ranked at the top of the most deforested tropical African countries. In 2005, the primary forest represented less than 2 % of the country's land area, while less than a third of Côte d'Ivoire was forested at all. In the years 1990 to 2007, the annual rate of depletion was estimated at 3.1%, confirming that Côte d'Ivoire has one of the highest rates of deforestation in West Africa. If nothing is done to regulate forest loss, the state of forest in Côte d'Ivoire will worsen.

Forest conservation is an important issue worldwide. The Food and Agricultural Organisation (FAO) reports that the most diverse terrestrial ecosystems are located in primary forests, especially tropical moist forests (FAO 2010). Since forests store carbon, their destruction releases greenhouse gases (GHGs) into the atmosphere, at the rate of one fifth of the global anthropogenic GHGs emissions and so contribute to global warming. Deforestation is classified second for carbon emissions after fossil-fuel combustion. It contributes to between 12 and 20% of global carbon dioxide into the atmosphere. Forest conservation should be included in mitigation of global warming schemes at an international level (Van der Werf, 2009).

In order to address the issue of deforestation, many actions are taken globally and locally, one of which is the implementation of protected areas within countries. Forest conservation measures put restrictions on the access of local communities to forest services. However, local communities supplement their daily livelihood from forests resources, especially from timber and non-timber forest products. Tropical forests are a major income source for these communities and they contribute between 20% and 40% of total household income for people living in forest areas. The dependence on forest-related services is higher for the poor population, especially on fuel wood and fodder. The current study estimates the benefits of the Bouaflé protected forest conservation. It focuses on the Bouaflé protected forest (forêt classée de Bouaflé) located in the western part of Côte d'Ivoire. The forest is 20350 ha and was made a protected forest in 1974. It is one of the most deforested protected areas in the country. The methodology applied was the Total Economic Value developed by Pearce and Turner (1990). The forest direct benefits were evaluated using a contingent valuation approach, particularly the Willingness to Pay (WTP) methodology added to data on timber production and the indirect benefits were computed. We evaluate the non-use value, using estimates provided in the literature.

CONTEXT

Côte d'Ivoire with a surface area of 322,463 km^2, is in Sub-Saharan Africa precisely in West Africa. Geographically, Côte d'Ivoire is between the 4°30' and 10°30' N latitude and between 2°30' and 8°30' W Longitude.

The state of the forest in the country

The country is shared in two parts by the 8th Parallel. The Northern part from the 8th parallel is the savannah area. The Southern part of the country up to the 8th parallel constitutes the forest area. This part is covered by wet forest (forêt dense humide sempervirente et forêt mésophile). Some specific types of the Ivorian forests are the mountain forests at the border with Guinea and the mangroves at the coastal areas. It encompasses guinea savannah which has been replaced mostly by export plantations such as palm trees, coconut trees, and rubber trees. The forest area covered by primary forests has been converted to secondary forests mostly, many fallow and savannah lands. Little primary forest remains. The forest land area has collapsed since the 19s. In fact, from 16 million ha of forests in 1900, the primary forest has shifted to 12 million ha in 1960, down to not more than 4 million ha today. The remaining natural forest is around 10 % of the country land surface.

The Ivorian protected areas: institutional framework

In Côte d'Ivoire, two types of protected areas exist. On one hand, there are national parks and reserves. On the other hand, there are "protected forest" (called in French, "forêts classées"). Each category has a specific aim assigned by the State of Côte d'Ivoire. The first category is implemented for biological diversity conservation. The second category is created for forest conservation and sustainable management.

The national parks and reserves are under the responsibility of the ministry of environment. They are managed by a state-owned company named OIPR (Office Ivoirien des Parcs et Réserves). National parks and reserves are either for the conservation of the fauna, either for the conservation of the flora. They could be located in forest areas or savannah regions. National parks could be subject to tourism activities, but reserves cannot. The protected forests are under the responsibility of the ministry of Water and Forests and managed by another state-owned company named SODEFOR (Société de dévéloppement des forêts).

The main difference between these two types of protected areas is related to the nature of the protection. The national parks and reserve benefit from strict protection. The rising of an area to the status of national park or reserve is definitive, irreversible whereas the implementation of a "protected forest" is more flexible and could change over time. The government could decide to "declassify" all or one part of the protected forest for some reasons such as exponential demographic growth for example. Protected forests are subject to wood trade regulated by the government through SODEFOR to ensure a sustainable management of the forest.

The permanent forest area of Côte d'Ivoire represents approximatively 8% of the country land area, which is estimated to be 6,267,730 ha. It encompasses protected forests, National parks, reserves and perimeters for protection. The permanent forest area is broken down as follow, 231 protected forests covering 4,196,000 ha; eight (8) national parks and five (5) reserves covering a total of 2,071,730 ha. The protected forests are affected by degradation and exposed to anthropological activities like plantations and illegal settlements of rural population.

On the opposite side, there is the rural domain which represents 70% of the national territory. The rural domain is the most affected forest part, now evaluated between 2 and 3 million ha of forests. The rural domain is the supplier for agriculture and wood exploitation. It provides 90% of total wood manufactured. In this area, there is no need for certification in order to proceed to reclamation for new agricultural land. Agriculture has the priority of the land disposal.

Forests play an important role in the hydrological process and Carbone cycle. Hetherington (1987) supports the effects of forests in the water cycle through evaporation, transpiration, soil freezing and the stock of snow. In fact, the reducing forest cover leads to an increasing amount of solar radiation that reaches the ground, since forest that could act as an intercept is lacking. The declining forest cover decreases soil moisture and reduces soil storage capacity. So, water availability for stream flow is increased.

Moreover, protected areas are recognised for their role in providing good quantity and quality of water. There is an attempt to monetize these water-related benefits of forests. For instance in China, the role of forests in storing water was valuated to be 7.5 trillion yuan at the country level. This estimate is three times the value of the timber of the Chinese forests. Emerton L. (2001) estimated to more than $US 20 million the water related benefits of the Mount Kenya forest which covers 130,559 ha. This forest protects the catchment of two of the main rivers of the country (Tana and Ewaso Ngiro) and so, contributes to their recharge.

Hein (2011) working on the benefits provided by Hoge Veluwe forest in Netherlands valuates the benefits in term of water provided by that forest. By using the replacement costs method, the author measures the avoided costs of maintaining the forest for groundwater supply. In fact, application of the replacement cost approach was based on 3 assumptions described. First, an alternative does exist that supply a similar service. Second, drinking water users would opt for that alternative in case the forest does not provide this service. Third, this alternative service is the most cost-effective one. The study reveals that the alternative to infiltration service provided by the forest is using water from the closest river and purifies it to get drinking water. Data justify the average incremental cost of 0.41 Euros per m^3. This price was applied to the total amount of groundwater supply by the forest of 16.8 million m^3/year among them 29% is used for producing drinking water. The economic value of the infiltration service of the Hoge Veluwe forest was evaluated to be 1.95 million Euros per year.

Among other valuation technics used to valuate environmental benefits, Contingent Valuation Method (CVM) is widely used. In fact, when we are evaluating directly the total economic value of an ecosystem, CVM is the appropriate method (Lescuyer, 1998). The popularity of CVM is related to some of its advantages. First, CVM provides directly a monetary valuation of the environmental commodity. Second, CVM gives the monetary valuation of non-use values. Since it is difficult to capture the non-use values of the environmental good based on the market which does not exist sometime, CVM helps capture these components. Third, CVM is a flexible technique. It allows an ex-ante valuation. CVM valuates the benefits related to the environmental good according to some scenarios. These states of nature do not need to occur before the valuation is possible. CVM can also help in policy decision-making.

Forests are widely recognized for their role in the Carbon cycle. This role is revealed in climate change mitigation processes occurring through carbon emission reduction by preventing deforestation and forest degradation on one hand; and through carbon capture by mechanisms such as afforestation and sustainable forest management on the other hand. (FAO 2010). Forests contribute to climate change mitigation by absorbing carbon emitted by anthropogenic activities. This ability of forests to store Carbon will lead to the reduction of the stock of Carbon into the atmosphere. Climate change is less likely to occur in such conditions. Conversely, deforestation releases Greenhouse gases into the atmosphere and so contributes to climate change.

METHODS

Theoretical model

In order to access the benefits, we will follow the Total Economic Value (TEV) approach developed by Pearce (1990). This approach tries to attribute economic values for both present and future uses of the protected areas. Generally, TEV is split up as follow :

$$TEV = UV + NUV \quad (1)$$

such as $UV = DUV + IUV + OV$ (2)

$$NUV = EV + BV + QOV \quad (3)$$

where

TEV: Total Economic Value

UV: Use Value

NUV: Non-Use Value

DUV: Direct Use Value

IUV: Indirect Use Value

OV: option value

EV: Existence Value

BV: Bequest value
QOV: Quasi-Option Values

Approaches Used for Valuing Benefits

Three main approaches were used for benefits valuation. First the contingent valuation method, especially the willingness to pay was applied for direct use value estimation, to which we add data on timber production. Second, we use some computation to determine the indirect use value (Carbone sequestration and water supply). Third, the estimates per ha provided in the literature were used as a proxy to valuate non-use value of the protected forest.

We applied the following steps for the contingent valuation method which are justification of the method; method implementation; description of the environmental quality; contingent market description; Willingness to pay question and socio-demographic characteristics of the respondents. The method implementation has followed three steps. First, we described the environmental quality. Second, we asked for the willingness to pay of the respondents. Third, we asked for the socio-demographic characteristics of the respondents. In order to capture the environmental quality in our case study we asked some questions to the respondents related to the importance of the Bouaflé protected forest. These questions reveal the perception of the population of the forest-related benefits to them. The current state of the conservation is that local people supplement their daily livelihoods with forest-based products. Forest provides them food, fuelwood and medicines. Forest provides rainfall and reduces the local heat. Forest provides fertile soil. Bush meat is not more consumed because the Government made a law to forbid all the activities related to bush meat as a measure to prevent the Ebola disease. As a contingent market, we design a hypothetical market such that the answers of the respondents could be the same as if they were on the real market. The payment mean they will use to express their WTP is the local currency CFA Franc (CFA F). It is a lump sum payment that would be used by the protected forest authorities to finance that forest conservation. For the willingness to pay question, we asked each household head of our sample population which amount he is willing to pay at most for the conservation of the Bouaflé protected forest so that it could still provide them the resources they mentioned. The WTP question was a discrete choice question. The socio-demographic characteristics of the respondents were addressed by collecting the following information on the respondents related to their social status: Marital status; age; sex; level of education (ability to read, to write, level at school); permanent residency; ethnic, origin, religion, household size, number of active persons per household. The economic information collected on the households were: current economic activities, main activity, second activity, source of financing of economic activities.

RESULTS AND DISCUSSION

Benefits estimation

This section includes the estimation of the forest benefits that include direct-use value, indirect-use value and non-use values. The direct benefits of the Bouaflé protected forest was estimated using the Willingness to pay approach. For our sample size, the estimated values for the median WTP and mean WTP are 1000 CFA FRANCS (~ 1.5 euros ~ 2$) and 1658.491 CFA FRANCS (~2.53 euros~ 3$) respectively. Fifty percent of the households of the sample are able to pay the amount of 1000 CFA Francs. Our sample size of 5 localities represents 7516 inhabitants. On average, they are 6 individuals per slot. And we assume each slot to be a household for our computation. So, the number of households of our sample size is 1253 (in fact, 7516/6= 1252.66). Assuming this sample size represent 10% of the entire population of households around and inside of the Bouaflé protected forest, we deduce the entire population to be 12 530 households. The application of the median WTP amount of 1000 CFA Francs to the 12 530 households will result in a benefit of 12.53 million CFA Francs which corresponds to the benefit perceived by the population living around and inside the Bouaflé protected forest. To these benefits, we add the annual estimation of timber production provided in SODEFOR plans for the decade 2014-2023.

The direct benefits are evaluated by summing up the food production and timber production estimates. The food production was evaluated using the results of the contingent valuation study. So, the household Willingness to pay (1000 CFA FRANCS) times the number of households estimated (1250 households). The raw material was evaluated using the estimations of timber production of SODEFOR for the period 2014-2023.

Estimation of indirect benefits provided by the Bouaflé protected forest

The indirect benefits of the Bouaflé protected forest are the water supply; the carbon sequestration; the regulation services (climate regulation, disturbance regulation and water regulation); erosion control and sediment retention; soil formation; nutrient cycling; the waste treatment and genetic resources preservation.

The Bouaflé protected forest contributes to the groundwater replenishment. We will estimate in monetary term the benefits related to this ecosystem service. BGR/UNESCO (2008) provides an estimation of groundwater recharge of more than 100 mm for the region which encompasses our study area. The Bouaflé protected forest belongs to the category of forests which recharge is between 100 and 300 mm. For the purpose of our study, we consider the mean value of the groundwater replenishment. We do the computation as follow: (100+300)/2=200. The amount of groundwater refilled (Q) is determined as follow :

$$Q = S*R \qquad (4)$$

Where :
S refers to the surface of the forest (in m^2)
R refers to the recharge or refill of the groundwater (in m)

In this case study the surface of the forest land is 20,350 ha so 203,500,000 m^2 by conversion (1ha equals 10,000 m^2). The refill of the groundwater is 200 mm so 0.2 m by conversion (ie. 1 mm= 0.001 m). Finally Q= 203,500,000*0.2= 40,700,000 m^3. For the monetary valuation, we used a shadow price which is the market price of the company in charge of the treatment and distribution of water in the country named SODECI (Société de dévelopement de l'eau en Côte d'Ivoire). The price is 403.3 CFA

FRANCS per m³. The amount of groundwater recharge times the shadow price of 403.3 CFA FRANCS provide the value of the water related benefits of the Bouaflé protected forest which is 461,800 billion CFA FRANCS.

Protected forests are also recognised for their role in Carbon emission reduction and sequestration. The increase in Carbon emission is regarded as the main cause of Global warming, the current manifestation of Climate Change. The negative impact of Climate Change and the increase of Carbon stock into the atmosphere is matter of international concern. Strategies to reduce Carbon emission or to increase Carbon sequestration into biomass and soils should be considered. This idea is referred to by "Land use and land use change and forestry" by the articles 3.3 and 3.4 of the Kyoto Protocol (IPCC, 2000).

Forests sequester Carbon through five compartments which are the aboveground biomass (trunks; branches; leaves; climbers; lianas and shrubs); the underground biomass (in the roots); dead organic matter; litter and soils (IPCC, 2006). Soils capture more Carbon than vegetation (650 Pg) and the atmosphere (750 Pg). There are two types of Carbon flows between the soils and the atmosphere which are positive flow (sequestration) or negative flow (emission). Sequestration refers to Carbon captured or kept in the soil, whereas emission refers to Carbon released or rejected into the atmosphere. Methods for Carbon sequestration valuation include the terrestrial ones (survey, allomeric equation) and the aerial ones (GIS, satellite images)

Zian G.A. (2012) used an allometric model to estimate the stock of Carbon in the Tai National Park in Côte d'Ivoire. He used three ecosystems samples (Eco 1, Eco 2 and Eco 3). Eco 1 represents an old secondary forest and Eco 2 is a primary forest while Eco 3 is an agricultural ecosystem which encompasses dominantly cocoa trees. All the species with a DBH (Diameter at Breast Height) higher than 10 cm in the forests placettes and higher than 5 cm in the cocoa farms were used for the analysis. These species were identified and measured. It results that the estimated carbon stock was on average 134,9±18,3; 174,7±26,3; 41,3±1,4 (ton C/ha) for the ecosystems Eco 1; Eco 2 and Eco 3 respectively.

FAO (2010) in its inventory of forest Carbon stock of countries worldwide estimated for Côte d'Ivoire 177-ton C/ha. So, the country had the highest Carbon stock in Africa. Depending on the method of Carbon stock measurement applied, the result could be different. In fact, according to PNUE/ WCMC (2010) Ivorian forests and protected forests have less Carbon sequestration capacity. The reason is the methodology applied based on GIS which under-valuates the stock of Carbon and biomass. Satellite images do not capture biomass under the canopy level. It results a minimal estimation of the Carbon stock by GIS method.

Hein (2011) trying to evaluate the Carbon related benefits of the Hoge Veluwe forest in Netherland, proceeds by the avoided costs approach. The author estimates to 0.31-ton C/ha/year so 900-ton C/year. This total amount of Carbon stored above-ground in the biomass is equivalent to 3280 ton CO_2 /year. For the appropriate price of CO_2 to consider, the author referred to the review of studies of Tol (2005) aimed to analyse the marginal costs related to Carbon dioxide emissions. The latter deduces a marginal damage costs likely to be lower than US$14/ton CO_2 (or $50/ ton C). The author assumed a social discount rate of around 4% to 5% referring to government discount rates applied to long term investments. Stern (2008) was in favour of a lower discount rate. He suggests prices amounting to US$ 30/ton CO_2. Hein (2011) made the assumption of a marginal damage cost per ton of CO_2 of 10 Euros. Based on this unit value estimate of Carbon sequestration, the total Carbon sequestration estimated in above-ground biomass in that forest is evaluated to 32,800 Euros. The issue is that this value does not include the Carbon sequestered in soils and wood.

For our study area, we used the estimate of Carbon sequestration provided by FAO (2010) which is 177-ton C/ha. This estimate is converted into CO_2 equivalent by applying the factor 3.67. Then we apply the average price per ton of Carbone equivalent for Certified Emission Reductions (CERs) which equals $7.51 per ton. The per hectare resulting estimate of Carbon sequestration comes to $4878. This value times the total area of the protected forest is 56.425 billion CFA FRANCS.

The regulation service encompasses Climate regulation, disturbance regulation and water regulation. The climate regulation refers to the regulation of precipitation and temperature and also some climatic processes occurring at global and local scales. Disturbance regulation refers to the capacity of the vegetation cover to control the habitat in the ecosystem through flood prevention or drought recovery. The water regulation refers to the regulation of the flows of water for human activity (agriculture or industry). The water supply refers to the ability of forests to absorb and maintain water underground. Erosion control and sediment retention is the ability of the forest to lay as a barrier to wind and runoff, then avoiding erosion. Soil formation encompasses the process of decomposition of rocks and the gathering of organic matter which result in new layers of soil. Nutrient cycling refers to all the process including nutrients, their uptake and release allowed by the vegetation structure. Waste treatment refers to the capacity of the forest to capture waste particles and contribute to purify the air and the soil. Genetic resources refer to the capacity of the forest to provide genes that could be used in medicine or science development.

The regulation services were estimated by using the estimates described in the study of Costanza et al (1997). This study provides the estimates per hectare for tropical forest- related benefits. Each estimate times the surface of the Bouaflé protected forest results in the monetary value of that related benefits. These estimates are for climate regulation, disturbance regulation and water regulation $223: $5 and $6 respectively. For erosion control and sediment retention; soil formation; nutrient cycling; waste treatment; genetic resources, the monetary estimates are $245; $10; $922; $87 and $41 respectively (See Table 1).

Table 4. benefits of the Bouaflé protected forest

Ecosystem good or service	Values for tropical forests ($/ha)	Values for tropical forests (CFA FRANCS/ha)	Total value (billion CFA FRANCS)
Climate regulation (**)	223	126746,51	2.57
Disturbance regulation (**)	5	2841,85	0.057
water regulation (**)	6	3410,22	0.069
Water supply (***)		22692898516	4.618E+5
erosion control and sediment retention (**)	245	139250,65	2.833
Soil formation (**)	10	5683,7	0.115
Nutrient cycling (**)	922	524037,14	10.664
Waste treatment (**)	87	49448,19	1.006
genetic resources (**)	41	23303,17	0.474
Carbon sequestration (****)	4878,4209	2772748,087	56.425
IUV+ NUV			461800
DUV			608.59
TEV			462408.59

Source : Constanza et al (1997) ; Krieger. D.J. (2001) (**);

P. D¨oll, K. Fiedler (2007); BGR/UNESCO (2008) (***); FAO(2011); Capoor, K., and P. Ambrosi (2006) (****)

DISCUSSION

The estimated TEV reveals that Forest conservation contribute to huge benefits; locally and globally. The WTP was estimated to 1000 CFA FRANCS (~ 1.5 euros ~ 2$) and 1658.491 CFA FRANCS (~2.53 euros~ 3$) for median and mean values respectively. We used the median value for aggregating the direct benefit in term of food production provided by the protected forest. The median amount has the advantage of being less influenced by extreme values (high bids). In fact, 50% of the household of our sample are willing to pay 1000 CFA Francs for the conservation. If we want to apply the WTP value for policy purposes, the median amount is expected to be approved by at least 50 % of our sample individuals. The current study suggests some policy implications that the government should also invest in ecological civism. A positive change in behaviors could occur by sensitizing local people on the consequences of their actions on the environmental services provided by forest to them. There should be promotion of ecological tourism. Ecological tourism activities will develop new type of returns for local people, by increasing their revenue due to the existence of the forests, the local people interest in the forest conservation will increase.

Famers should practice intensive agriculture, which consists in producing more by using less land. In fact, local people look for new lands for agriculture activities extension. These anthropogenic actions contribute to reduce the forest area and threaten forests-related services to the population. Promoting intensive agriculture will reduce the pressure on forests land for agricultural activities.

Another approach could be a participatory conservation where local people could act for forest conservation. The government should encourage local population participation in conservation measures design and implementation. There are several available measures of forests conservation adapted to poor people and that have shown their efficiency in forest conservation (Cookstoves, NTFP, Biofuel production using cow dungs). Local people should appropriate conservation measures. They need to be sensitized and trained to some good practices, so that they could adopt them easily. This could lead to a sustainable management of the forest.

CONCLUSION

Protected forests are widely spread and recognised for their multiple functions related to climate, ecology and people. They intervene in climate change mitigation through carbon sequestration and also aim to conserve biodiversity. When it comes to their benefits to local population, empirical studies are scarce. We estimated the direct benefits of forest conservation using the contingent valuation approach, particularly the Willingness to Pay (WTP) methodology. It results that on average; people are willing to pay 1658.491F CFA (2.53 Euros). However, for the aggregation purposes of the benefits of the conservation to local people, we used the median WTP which is 1000CFA Francs (1.526 Euro). The aggregated direct benefit of the forest to local people estimated was then 12,53 million CFA Francs. We added the direct benefits related to the timber production provided by the management company (SODEFOR) data. Then, the indirect benefits related to regulation services, water supply, carbon sequestration and biodiversity conservation were added.

In this part, the sum of the Direct Use-Value (DUV), the Indirect Use-Value (IUV) and the Non-Use Value (NUV) will determine the total Economic Value (TEV). The TEV of the Bouaflé protected forest is estimated to 462408.59 billion CFA Francs. Further studies could investigate other methods in order to estimate the indirect benefits of the Bouaflé protected forest. For the current study, we evaluate the benefits related to carbon sequestration based on the Bouaflé protected forest entire surface regardless to the vegetation cover. Further studies should consider the differences in vegetation cover distribution in order to compute more accurate estimates of the value related to such ecosystem services. However surrounding population are aware of forest-related benefits to them, their monetary potential contribution to the conservation of that forest is low. So, we could capture their participation to the conservation through non-monetary means (i.e. adoption of ecological friendly innovative strategies like cookstoves, biofuel).

REFERENCES

Costanza R,, d'Arge R., de Groot R., Farberk S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R. V., Paruelo J., Raskin R. G., Sutton P. & van den Belt M. (1997), The value of the world's ecosystem services and natural capital: State and trends of the carbon market, Washington, DC: World Bank and International Emissions Trading Association, Nature Vol. 387, Issue (6630) DOI; 1038/387253a0.

Emerton, L. (2001). Why forest values are important to East Africa, ACTS Innovation, Vol. 8 Issue 2: pages 1–5. Environmental Policy Working Paper Series #2001-006

FAO. (2010). Global Forest Resources Assessment 2010. Main report. Food and Agriculture Organization of the United Nations,.Rome, Italy. FAO Forestry Paper 163, ISBN 978-92-5-106654-6. 378 pages.

Hein L. (2011). Economic benefits generated by protected areas: the case of the Hoge Veluwe forest, the Netherlands. Ecology and Society Vol. 16 Issue 2 page 13, Research Gate.

Lescuyer, G. (1998). Globalization of environmental monetary valuation and sustainable development. An Experience in the tropical forest of Cameroon, International Journal of Sustainable Development, pages 115-133

Naoto, J. (2006). International trade and terrestrial open-access renewable resources in a small open economy. Canadian Journal of Economics. Vol. 39, No.3, pages 790-808, Canada.

Pearce, David W & Turner, R. K.erry (1990), Economics of natural resources and the environment 1990, page. 13, 378, Baltimore: Johns Hopkins University Press, Maryland, United States.

UICN/BRAO (Union Internationale pour la Conservation de la Nature/Bureau Régional pour l'Afrique de l'Ouest). (2008). Evaluation de l'efficacité de la gestion des aires protégées : Parcs et réserves de Côte d'Ivoire. Programme Aires protégées. Ouagadougou, Burkina Faso

Van der Werf, G.R., D.C. Morton, R.S. DeFries, J.G.J. Olivier, P.S. Kasibhatia, R.B. Jacson, G.J. Collatz and J.T. Randerson (2009), CO_2 emissions from forest loss. Nature Geosciences, 2009. Vol. 2: pages. 737-738.

Tarification en assurance agricole au Sénégal : cas de l'assurance récolte

Allé Nar DIOP

ABSTRACT

The objective of this article is to determine the pure premium to be paid by the Senegalese farmer who is insured but exposed to different types of risks. The use of the General Linear Model (GLM) has made it possible to determine the frequency and severity of claims according to the different types of risks to which farmers are exposed. Two main results were obtained: the number of claims follows a Poisson's law and the cost of the claim follows a Gamma law. The pure premium depends positively on the type of risk and the parameters of the estimated models are all significant. We have shown that health risks, locust (desert locust), animal and wild duck invasions have a higher loss experience than climatic phenomena (rainfall deficit, floods). The insurance company will have to take into account the type of risk to which each insured is most exposed when determining the corresponding premium.

Key words : Risk, Claims, Pricing, Pure Premium

RÉSUMÉ

L'objectif de cet article est de déterminer la prime pure à payer par l'agriculteur sénégalais assuré mais exposé à différents types de risques. L'utilisation du modèle linéaire général (GLM) a permis de déterminer la fréquence et la sévérité des sinistres en fonction des différents types de risques auxquels sont exposés les agriculteurs. Deux principaux résultats sont obtenus : le nombre de sinistres suit une loi de Poisson et le coût du sinistre suit une loi Gamma. La prime pure dépend positivement du type de risques et les paramètres des modèles estimés sont tous significatifs. Nous avons montré que les risques sanitaires, les invasions acridiennes (criquets pèlerins), d'animaux et de canards sauvages ont une sinistralité plus élevée que les phénomènes climatiques (déficit pluviométriques, inondations). La compagnie d'assurance devra tenir compte du type de risque auquel chaque assuré est le plus exposé pour déterminer la prime correspondante.

Mots clés : Risque, Sinistre, Tarification, Prime pure

INTRODUCTION

Au Sénégal, le secteur agricole est confronté à une multitude de risques, parmi lesquels ceux liés aux aléas climatiques, aux maladies sanitaires, phytosanitaires et aux fluctuations des marchés. Dans ce contexte, l'enjeu est la mise en œuvre de stratégies en matière de protection notamment : la maîtrise des risques , la gestion préventive des ressources en eau, la vulgarisation de bonnes pratiques agricoles, l'intégration des mesures d'adaptation au changement climatique dans les projets agricoles, la poursuite de la mise en place d'un système d'assurance agricole, et ce en adoptant une approche différenciée, adaptée à chaque filière de production et visant autant l'agriculture performante et productiviste que l'agriculture solidaire (CIARRA, 2014). Ainsi, la gestion des risques agricoles et l'éventuelle multiplication de désordres climatiques d'ampleur inhabituelle, renforcent la nécessité d'améliorer les mécanismes de protection des exploitations contre les aléas par la mise en place d'une assurance agricole.

L'assurance agricole est l'assurance contre la perte de production de produits agricoles ; la perte subie lorsque l'ensemencement ou la plantation est empêchée par l'un des risques ; la perte de produits agricoles désignés résultant de l'un des risques désignés, la perte de revenus tirés de produits agricoles désignés résultant de l'un des risques désignés ; et toute autre perte réglementaire.

Il existe essentiellement deux systèmes de couverture : la couverture individuelle de rendement et l'assurance indicielle régionale basée sur une ou plusieurs conditions météorologiques paramétré(e)s. Les différentes manières de travailler des deux systèmes de couverture peuvent être démontrées sur la base des niveaux de couverture, de la modélisation des prix et du calcul des pertes. L'assurance indicielle est facturée selon un modèle de rendement météorologique. Qu'elle soit basée sur un facteur de rendement régional ou un facteur météorologique, le paiement des prestations est déclenché en fonction d'un indice prédéterminé plutôt que sur la base de l'évaluation des pertes.

Miranda (1991) a analysé théoriquement et empiriquement l'assurance-récolte avec les rendements à l'hectare à l'aide du modèle additif linéaire des producteurs de soja du Kentucky occidental. Dans le modèle additif linéaire, il montre la relation entre le rendement moyen du producteur individuel (variable dépendante) et le rendement moyen d'une zone géographique environnante (variable indépendante) et un terme d'erreur aléatoire non corrélé au rendement en surface agrégé. Alba et al., (2017) analysent les écarts de rendement dans le contexte d'assurance-récolte. Ils établissent un indicateur d'information asymétrique et évaluent l'influence éventuelle d'informations asymétriques sur la décision des producteurs de blé de souscrire une police d'assurance. L'analyse comprend le rendement simulé à l'aide d'un modèle de culture validé. Les résultats suggèrent que la précision dans la détermination du rendement assuré est déterminante dans la décision des agriculteurs de souscrire à une assurance-récolte dans le cadre d'une couverture plus large. Le constat est que la tarification en assurance agricole se base essentiellement sur l'assurance indicielle ou sur les écarts de rendement d'une culture donnée. L'analyse des déterminants du coût et de la fréquence des sinistres ainsi que les lois de probabilité suivies par ces derniers sont une voie de recherche intéressante pour améliorer les méthodes de tarification en assurance agricole.

L'objectif de cette étude est de déterminer la prime pure à payer par l'agriculteur sénégalais assuré à des risques classiques. Spécifiquement, nous déterminerons la fréquence et le coût des différents risques auxquels les agriculteurs sont confrontés. Le choix du Sénégal s'explique par la récurrence des sinistres dans le secteur agricole et leurs sévérités. En effet, l'agriculture sénégalaise se caractérise par des invasions acridiennes, des attaques d'oiseaux, la variabilité des prix aux producteurs, la prévalence de risques climatiques importants (variabilité importante des pluies dans le temps et dans l'espace). Ces risques pèsent sur le secteur agricole et entraînent des menaces qui impactent négativement les performances des filières agricoles (baisse des rendements, baisse des productions, baisse des revenus des producteurs).

Le présent article est composé comme suit : la première section est consacrée à la revue de littérature, la seconde à la méthodologie, la troisième à la présentation et à l'interprétation des résultats et la quatrième à la conclusion.

REVUE DE LA LITTÉRATURE

Williams et al., (1993) ont étudié la « conception de l'assurance-récolte et de l'aide en cas de catastrophe pour le sorgho et le blé ». Dans cette étude, ils ont comparé l'efficacité de deux modèles d'assurance-récolte, deux modèles d'aide aux sinistrés, une assurance-récolte et un produit du gouvernement programmé pour réduire le risque de rendement net des exploitations de sorgho. Ils utilisent l'analyse de la dominance stochastique de la distribution des revenus nets pour identifier là où sont les préférences sur plusieurs intervalles de risque. L'analyse empirique montre que les producteurs de blé et de sorgho préféreraient un programme d'assurance-récolte ou d'aide en cas de catastrophe en plus du programme de produits de base du gouvernement. Ils ont également mentionné que l'assistance, en cas de catastrophe, est préférable à la souscription à une police d'assurance récolte.

Aranee (2011) examine l'impact des cultures sur la consommation d'assurance non-vie. Il utilise des variables économiques, institutionnelles et culturelles de 82 pays sur une période de 10 ans. En utilisant les techniques de bootstrap, il montre que les nations les plus faibles, avec un niveau élevé d'individualisme et un degré élevé d'évitement de l'incertitude, ont tendance à avoir un niveau élevé de consommation d'assurance non-vie. Les résultats empiriques suggèrent que les consommateurs peuvent répondre aux sollicitations d'assurance en fonction de leur croyance culturelle, et non et leur seule rationalité économique.

Fazelbeigi et Yavari (2010) constatent que les obstacles à l'assurance sont le manque de respect des cadres économiques, les problèmes dans le système statistique, le manque de concurrence dans le secteur des services et le manque de suivi et d'évaluation. En outre, ils ont trouvé les menaces auxquelles les assureurs sont confrontés : il s'agit d'entités de production inappropriées, de terres dégradées, d'absence de normes de production et d'existence de systèmes d'exploitation médiocres.

Claassen et al., (2011) et Miao et al., (2011) ont fait les études les plus complètes et les plus récentes sur les questions d'assurance-récolte et d'utilisation des terres aux Etats-Unis. Ils utilisent une combinaison de techniques économétriques et de simulation et améliorent la littérature antérieure en se concentrant sur les terres marginales (une partie critique des plaines septentrionales qui comprennent une grande partie de la région des cuvettes des Prairies), en distinguant les types de prairies convertis et en utilisant des données sur le terrain plutôt que des données au niveau du comité. Leurs conclusions sont conformes à la littérature antérieure, à savoir que l'effet de l'assurance-récolte subventionnée dans la mise en culture des terres marginales est statistiquement significatif mais faible, car inférieur à 1 pour cent.

En particulier, Miao, Feng et Hennessy (2011) estiment que l'effet des prix des cultures est beaucoup plus important que les subventions à l'assurance-récolte sur la conversion des terres marginales. Ils constatent qu'une diminution de 5% du taux de subvention des primes d'assurance-récolte fait en sorte que 0,6% des terres cultivées assurées sont converties en terres non cultivées. Alors qu'une baisse de 5% des prix des cultures entraîne la conversion de 1,01% des terres cultivées assurées en terres non cultivées.

Au-delà du faible effet expansionniste sur la conversion des prairies en terres cultivées, l'assurance culture a des effets compensateurs sur les terres cultivées sous la forme d'une utilisation moindre d'autres stratégies de réduction des risques, telles que l'utilisation intensive de produits chimiques. Les résultats empiriques des grandes plaines suggèrent que les agriculteurs qui achètent une assurance-récolte utilisent moins d'intrants chimiques (Smith et Goodwin, 1996). Des résultats similaires ont été obtenus dans Babcock et Hennessy (1996) pour le maïs. Iowa, Smith et Goodwin (1996) et Babcock et Hennessy (1996) ont réfuté les résultats contradictoires de l'étude antérieure de Horowitz et Lichtenberg (1993). Smith et Goodwin (1996) ont conclu que les conséquences environnementales ne devraient pas être à la base des efforts visant à persuader les législateurs de mettre fin au programme d'assurance culture.

Nwosu et al., (2012) dans leur étude sur « La performance des producteurs de cultures vivrières nigérians dans l'État d'Imo, au sud-est du Nigéria », évaluent les performances de production de cultures vivrières des agriculteurs qui ont adopté le régime d'assurance agricole mis en place en 1984 et l'influence des caractéristiques socioéconomiques sur la production des agriculteurs. Des données primaires et secondaires ont été utilisées dans l'étude. Les données primaires ont été obtenues à partir de 77 producteurs de cultures vivrières sélectionnés par sondage aléatoire simple parmi une liste de 145 agriculteurs dans le cadre du régime d'assurance de l'État d'Imo. Le Z-test et le modèle de régression multiple ont été utilisés pour déterminer l'impact et l'influence des caractéristiques socioéconomiques telles que l'âge, l'expérience agricole, l'éducation, etc., sur la production des agriculteurs. Le Z-test de l'impact du programme sur la production des agriculteurs a montré qu'il y avait un changement significatif de la production des agriculteurs après l'assurance.

L'analyse de la régression multiple sur l'influence des caractéristiques socioéconomiques de la production agricole après l'assurance a montré que le niveau d'éducation, l'expérience agricole, la taille de la ferme et le nombre de technologies utilisées dans la ferme sont des variables significatives alors que l'âge, le sexe et la taille du ménage sont non significatifs. L'étude recommande donc de redoubler d'efforts pour sensibiliser les producteurs sur les objectifs louables du régime d'assurance de cultures vivrières, en particulier dans la recherche de la sécurité alimentaire par la nation.

Adisak et al., (2010) dans leur étude intitulée « Modélisation mathématique pour l'estimation de la prime d'assurance culture : Etude de cas de la compensation totale de primes égaux » construisent un modèle mathématique pour estimer la prime d'assurance-récolte pour le cas de l'indemnisation totale des dommages-intérêts. Ils étudient également les secours accordés par le gouvernement thaïlandais aux agriculteurs qui ont connu des inondations. La portée de cette recherche est une assurance-récolte couvrant les dommages causés par les inondations. Le résultat montre que le coût d'assurance prévu (prime) pour chaque ménage d'agriculteur pourrait être calculé par le produit d'une valeur de compensation attendue pour chaque inondation et d'un nombre prévu de demandes d'indemnisation.

Gideon et al., (2014) analysent la disposition de payer pour l'assurance du prix du cacao au Ghana dans l'industrie cacaoyère en utilisant la méthode de l'évaluation contingente sur des données collectées auprès de 201 producteurs de cacao dans le district de Bibiani-Anhiawso-Bekwai au Ghana. Un modèle sous contrainte est utilisé pour déterminer les facteurs influençant l'adoption par les agriculteurs de l'assurance prix du cacao et les primes que les agriculteurs sont prêts à payer. Les résultats empiriques de l'étude révèlent que l'intérêt des agriculteurs pour l'assurance prix du cacao était affecté par la diversité des variables explicatives telles que l'état matrimonial, le nombre d'années de culture de cacao, le niveau d'éducation, la taille du ménage, la taille de l'exploitation, la propriété des terres agricoles, l'âge de la plantation de cacao, l'âge au carré de la plantation de cacao.

D'autre part, la prime que les agriculteurs étaient disposés à payer est fortement influencée par l'état matrimonial, les réalisations, l'utilisation des terres arables à des fins agricoles et la sensibilisation des agriculteurs au régime d'assurance. Les producteurs de cacao sont en moyenne disposés à payer entre 9,3% et 10,5% de la valeur de l'option qu'ils ont l'intention de recevoir en prime, en fonction de la valeur. L'étude recommande de porter une attention particulière à l'éducation à l'assurance des agriculteurs.

Zelda et al., (2018) ont examiné les effets des conditions météorologiques et de l'assurance sur les revenus nets des cultures en utilisant l'approche de régression variable instrumentale sur un modèle ricardien. L'étude identifie les facteurs influençant l'achat d'une assurance chez les agriculteurs en utilisant un modèle probit. Les résultats ont indiqué que la possession d'une assurance, le nombre de travailleurs employés, la taille des terres agricoles irriguées et les précipitations avaient des effets importants sur le revenu net. Il a également été révélé que l'expérience, illustrée par des années d'exploitation et de revenus, avait influencé l'adoption de l'assurance par les agriculteurs. En conséquence, ils préconisent la mise en place d'installations d'irrigation efficaces et la promotion de l'assurance auprès des agriculteurs.

La revue de littérature illustre la difficulté liée à l'évaluation de la perte subie par l'agriculteur et de la prime payée par ce dernier.

L'apport de cette étude est de proposer un modèle de tarification en estimant la prime pure facturée aux agriculteurs exposés à un risque donné.

MÉTHODOLOGIE

Dans cette section, nous exposerons le modèle linéaire général qui est utilisé pour l'estimation de la fréquence et des coûts des sinistres. Les modèles linéaires généralisés (GLM) sont conventionnellement les méthodes principales pour l'analyse des données de comptage et de sévérité des sinistres, les éléments clés de leur spécification étant un énoncé de la façon dont la réponse moyenne est liée à un ensemble de prédicteurs et de comment la variance est supposée changer à mesure que la moyenne varie. Elles sont préconisées du fait de leur plus grande efficacité lors de l'estimation des paramètres et évitent les problèmes de biais de transformation et d'interprétabilité lors de l'analyse des données transformées.

Modèle de poisson

La loi de poisson est une loi qui s'applique à la modélisation des phénomènes dont la survenance n'est pas très fréquente ou est rare par rapport à la taille de population concernée. Les évènements au sein de la population étudiée doivent être indépendants. La loi de Poisson est fondamentale dans la modélisation du nombre de sinistres pour les risques en assurance IARD. Elle constitue en quelque sorte la loi de base.

$N \sim \mathrm{Pois}(\lambda)$

$$\mathrm{P[N = k]} = \frac{\lambda^k e^{-\lambda}}{k!} \qquad (1)$$

où

$$k! = \mathrm{k.(k-1)(k-2).2.1}$$

Et

$$k = 0,1,2,3,4, \ldots ..$$

Pour la loi de Poisson $E(N) = V(N) E(N) = V(N)$. Cette propriété est appelée l'équidispersion. Quand l'équidispersion n'est pas respectée, c'est-à-dire quand on a une surdispersion, on considère une loi quasi-poisson, telle que $Var((\mathrm{N|X}) = \varphi \mathrm{E(N|X)})$ $Var((\mathrm{N|X}) = \varphi \mathrm{E(N|X)})$, où φ paramètre de dispersion. C'est un paramètre à estimer.

Modélisation du coût moyen des sinistres

La loi log normale

La loi log normale est une loi qui permet la modélisation de données à peu près symétriques ou asymétriques vers la droite. Une variable aléatoire X suit une loi log normale lorsque son logarithme suit une loi normale. La densité de probabilité de

$$f(x) = \frac{1}{x} \frac{1}{\beta\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{ln(x)-\alpha}{\beta})^2}, x > 0 \qquad (2)$$

Avec

$\alpha = E(ln(X)) \alpha = E(ln(X))$ Espérance mathématique de ln(X) (3)

Et

$\beta = \sigma_{ln(X)} \beta = \sigma_{ln(X)}$ Ecart type de ln(X)

$$\mu_x = E(X) = e^{(\mu_{ln(X)} + \frac{\sigma_{ln(X)}}{2})} \qquad (4)$$

La variance est :

$$\sigma_x^2 = V(X) = e^{2(\mu_{ln(X)} + \sigma_{ln(X)}{}^2)} \left(\frac{e^{\sigma_{ln(X)}{}^2} - 1}{e^{\sigma_{ln(X)}{}^2}} \right) \qquad (5)$$

La loi Gamma

Une variable aléatoire réelle suit une loi gamma de paramètres $\gamma\gamma$ et a, si et seulement si sa densité de probabilité est donnée par la formule suivante :

$$f(x) = \frac{\gamma^a}{\Gamma(\mathrm{a})} x^{a-1} e^{-\gamma x}, x \geq 0 \qquad (6)$$

D'où les moments de la variable aléatoire réelle X sont :

$$\mu_x = E(X) = \frac{a}{\gamma} \qquad (7)$$

$$\sigma_x = V(X) = \frac{a}{\gamma^2} \qquad (8)$$

Données utilisées

L'application de cette méthode de tarification nécessite une expérience de sinistres. Nous avons à notre disposition des données provenant du portefeuille de la CNAAS de 2009 à 2015.

Les données proviennent de trois sources : les statistiques sur la production et les sinistres de la CNAAS et les données de production agricole de l'Agence Nationale de la Statistique et de la Démographie (ANSD), et celles de la Direction de l'Analyse de la Prévision et des Statistiques Agricoles (DAPSA).

La source première de données dont dispose l'actuaire pour modéliser les risques, et construire un tarif segmenté est la base constituée à partir des informations collectées dans les formulaires de souscription. Les données sur les assurés proviennent de la Compagnie Nationales d'Assurance Agricole, elles sont stockées dans une base appelée « Bordereau des sinistres ». Elles sont observées sur sept ans (2009 à 2015) et la base de données contient dix-huit variables.

Les variables retenues sont au nombre de neuf dont deux endogènes (le nombre de sinistres et le coût moyen d'un sinistre) et sept variables exogènes dont cinq sont dichotomiques (1 : si le risque s'est réalisé sur l'assuré et 0 : sinon) et une quantitative en l'occurrence la superficie. Les types de risques sont : Animaux sauvages (AS) ; Canards sauvages (CS) ; Déficits pluviométriques (DP) ; Inondation (INOND) ; Risques Sanitaires (RS) ; Criquets Pèlerins (CP), Invasions de Pucerons (IP) ; Superficie (SUP). Les variables endogènes sont le nombre de sinistres et le coût moyen d'un sinistre.

PRÉSENTATION ET INTERPRÉTATION DES RÉSULTATS

Trois modèles sont estimés : un modèle de poisson pour la fréquence des sinistres, un modèle log-normal et un modèle gamma pour le coût moyen d'un sinistre. Nous avons pris comme référence le risque « accident ». Les paramètres des trois modèles sont estimés par l'estimateur du maximum de vraisemblance et l'estimation de la matrice de variance-covariance des paramètres conduit à la pseudo-vraisemblance. Les vraisemblances des trois modèles sont obtenues respectivement au bout de trois, quatre et six itérations et sont égales à -1471,38 ; -7351,83 ; -6714,70.

Pour le modèle de poisson, la statistique de Wald chi-carré avec sept degrés de liberté pour le modèle complet, permet de tester si tous les coefficients estimés sont égaux à zéro. À partir de la valeur p, nous pouvons voir que le modèle est statistiquement significatif. Les coefficients du modèle sont tous significatif à 1%. Le pseudo-R2 est égal à 0,18.

Les coefficients de la régression de Poisson pour chacune des variables, ainsi que des erreurs types robustes sont consignés dans le tableau ci-dessous. Le coefficient pour la superficie est 0,34. Cela signifie que l'augmentation de la superficie cultivée de 10% entraîne une hausse du nombre de sinistre de 3,4%. Le coefficient de la variable « animaux sauvages » est la différence attendue de ce risque avec le risque de référence (Invasions de Pucerons). Comparé aux invasions de pucerons, le log du nombre de sinistres attendus avec les animaux sauvages augmente d'environ 0,401. Le nombre de sinistres augmente de exp (0,401) = 1,493. Pour les canards sauvages, le log nombre de sinistres augmente de 1,425, soit une hausse de 4,15 sinistres. Pour les criquets pèlerins, nous notons une augmentation de 0,848 du log du nombre de sinistres soit 2,33 sinistres. Le log du déficit pluviométrique quant à lui enregistre une augmentation de 1,648, soit 5,196 sinistres. La sinistralité est très élevée avec les inondations, En effet, une hausse du log du nombre de sinistres de 2,585 par rapport aux accidents est enregistrée soit 13,26 sinistres. En ce qui concerne les maladies, le logarithme du nombre de sinistres augmente de 1,872, traduisant ainsi une augmentation du nombre de sinistres par rapport aux accidents de exp (1,872) =6,50.

Tableau 1 : Estimations économétriques

Variables	(M1) Nombre sinistre	(M2) Coût Moyen	(M3) Coût Moyen
Log superficie	0,340***	0,579***	0,682***
	(0,0745)	(0,0518)	(0,0323)
Animaux sauvage	0,401***	1,645***	1,275***
	(0,108)	(0,441)	(0,118)
Canards Sauvages	1,425***	0,863***	1,104***
	(0,306)	(0,135)	(0,131)
Criquet pèlerins	0,848***	1,921***	2,255***
	(0,199)	(0,175)	(0,177)
Déficit pluviométrique	1,648***	0,520**	0,803***
	(0,455)	(0,202)	(0,260)
Inondations	2,585***	1,323***	1,268***
	(0,366)	(0,388)	(0,239)
Risques sanitaires	1,872***	1,862***	3,260***
	(0,561)	(0,547)	(0,288)
Oiseaux carnivores	1,094***	1,974***	1,898***
	(0,114)	(0,0993)	(0,0599)
Constant	-0,872***	10,11***	9,842***
	(0,191)	(0,133)	(0,0829)
Observations	491	491	491
Family	poisson	lognorm	Gamma

Link	log	gaussian	Log
Deviance	1770,61	2,911e+14	401,51
Pearson	2997,77	2,911e+14	407,75
Loglik	-1471,38	-7351,83	-6714,70
AIC	6,02	29,97	27,38
BIC	-1222,27	2,91e+14	-2591,36

*** p<0,01, ** p<0,05, * p<0,1

Pour choisir entre deux modèles (gamma et log-normale), nous utiliserons les statistiques de la déviance, la statistique de Pearson et les critères AIC et BIC des deux modèles. La déviance et la statistique de Pearson sont des mesures de la qualité de l'ajustement d'un modèle linéaire généralisé, ou plutôt, ce sont des mesures du mauvais ajustement. En utilisant la statistique de la déviance, le modèle estimé est comparé au modèle dit saturé, c'est-à-dire le modèle possédant autant de paramètres que d'observations et estimant donc exactement les données. Cette comparaison est basée sur l'expression de la déviance D des log-vraisemblances L et Lsat : D = -2(L - Lsat) qui est le logarithme du carré du rapport des vraisemblances. Ce rapport remplace ou "généralise" l'usage des sommes de carrés propres au cas gaussien et donc à l'estimation par moindres carrés. On montre qu'asymptotiquement, D suit une loi du χ 2 à n − p degrés de liberté, ce qui permet de construire un test de rejet ou d'acceptation du modèle, selon que la déviance est jugée significative ou non importante. Pour la statistique de Pearson, un test du χ 2 est également utilisé pour comparer les valeurs observées yi à leur prévision par le modèle. En pratique, ces deux approches conduisent à des résultats peu différents. On remarque que la déviance et la statistique de Pearson de la loi log-normale sont plus élevées que celles de la loi gamma. De plus, les valeurs des critères AIC et BIC pour la loi gamma sont plus faibles que celles de la loi log-normal. Par conséquent, nous avons opté pour le modèle de la loi gamma présenté par le tableau ci-dessus.

Sachant que le coût moyen des sinistres suit une distribution Gamma, notre modèle s'écrit sous la forme :

$$E[\log CM] = 9{,}842 + 1{,}104 \times CS + 1{,}275 \times AS + 0{,}803 \times DP + 1{,}268 \times INOND + 3{,}260 \times RS + 2{,}255 \times CP + 0{,}682 \times SUP \quad (8)$$

De l'équation précédente, on déduit que les agriculteurs exposés aux risques sanitaires, aux criquets pèlerins et aux oiseaux granivores ont un risque de sinistralité supérieur aux autres. Par conséquent, si un assuré subit un risque sanitaire, l'espérance de son log coût augmente de 3,26 par rapport à une invasion de pucerons, donc son coût est multiplié par exp (3,26) =26,049. A l'inverse, si un assuré s'expose à des criquets pèlerins, l'espérance du logarithme de son coût augmente de 2,25, donc son coût est multiplié par exp (2,25) =9,48 par rapport à une invasion de pucerons. Pour les assurés subissant une invasion des oiseaux granivores, le logarithme du coût augmente de 1,898, soit une multiplication du coût de exp (1,898) =6,72 par rapport à un accident. L'exposition aux animaux sauvages augmente le logarithme du coût de 1,275 soit une multiplication du coût de 3,578. Les inondations entraînent une multiplication du coût de 3,553, les canards sauvages de 3,016 ; le déficit pluviométrique de 2,232. En ce qui concerne la superficie, une hausse de 10% de la superficie entraîne une augmentation du coût de 6,82%.

En somme, nous constatons que les risques sanitaires, les invasions acridiennes (criquets pèlerins), d'animaux et de canards sauvages ont une sinistralité plus élevée que les phénomènes climatiques (déficits pluviométriques, inondations).

Le tableau 2 donne la prime pure dans le cas où le nombre de sinistres enregistrés est égal à 1 ou 2. La prime pure est déterminée en multipliant la probabilité de sinistres par le coût du sinistres (tableau 2). Si la prime est subventionnée à hauteur de 50%, la prime nette à payer par l'assuré est donnée par la dernière colonne du tableau. Nous constatons que les invasions de criquets pèlerins, d'oiseaux granivores, d'animaux et de canards sauvages sont les plus fréquentes. La prime pure varie en fonction du risque auquel l'assuré est exposé. En effet, pour ces quatre risques les plus fréquents, la prime pure la plus élevée est celle liée aux oiseaux granivores (68773 f CFA), suivie par de celles liée aux animaux sauvages (57103 f CFA), aux criquets pèlerins (34822 f CFA) et aux canards sauvages (20239 f CFA).

Les risques sanitaires, les inondations et déficits pluviométriques sont des phénomènes extrêmes dont les probabilités de réalisation sont faibles. Ce qui explique la faiblesse des primes pures de ces risques.

Tableau 2 : Prime pure

Risques	**CM**	**Prob(n=2)**	**Espérance**	**Sub 50%**	**Prime à payer**
Animaux sauvages	348 947	0,192	67 141	33 570	33 570
canards sauvages	252 567	0,191	48 157	24 079	24 079
Criquets pèlerins	190 409	0,183	34 824	17 412	17 412
Déficit pluviométrique	100 430	0,197	19 817	9 909	9 909
Inondations	225 490	0,033	7 500	3 750	3 750
Invasions pucerons	108 000	0,184	19 865	9 933	9 933
Maladie	3 416 935	0,020	67 919	33 960	33 960
oiseaux granivores	614 873	0,224	137 425	68 712	68 712
Pourriture de collet	260 549	0,242	63 105	31 552	31 552
Risques	**CM**	**Prob (n=1)**	**Espérance**	**Sub 50%**	**Prime à payer**
Animaux sauvages	348 947	0,327	114 206	57 103	57 103
canards sauvages	252 567	0,160	40 478	20 239	20 239
Criquets pèlerins	190 409	0,366	69 644	34 822	34 822
Déficit pluviométrique	100 430	0,123	12 359	6 179	6 179
Inondations	225 490	0,014	3 215	1 607	1 607
Invasions pucerons	108 000	0,368	39 731	19 865	19 865
Maladie	3 416 935	0,006	18 964	9 482	9 482
oiseaux granivores	614 873	0,224	137 746	68 873	68 873
Pourriture de collet	260 549	0,281	73 327	36 664	36 664

Source : Base CNAAS/calcul auteur

La plupart des études sur la tarification en assurance agricole se basent sur la construction d'indices (pluviométrique, satellitaire, etc.) ou sur l'écart de rendement de la culture considérée. L'utilisation des types de risques auxquels les agriculteurs sont exposés améliore la précision dans le calcul de la prime pure par rapport à l'assurance indicielle.

CONCLUSION

Le but de cet article était de déterminer la prime pure à payer par l'agriculteur sénégalais assuré aux risques classiques. À l'aide du modèle linéaire général (GLM), la fréquence et la gravité des différents types de risques pour les agriculteurs ont été déterminées. La fréquence des sinistres suit une loi de poisson et le coût moyen suit une loi gamma. Ils dépendent positivement du type de risque et les paramètres des modèles estimés sont tous significatifs. Il ressort des résultats que les risques pour la santé, les criquets pèlerins, les animaux sauvages et les canards ont des sinistres plus importants que les événements climatiques (déficit pluviométrique, inondations).

Les risques pour la santé, les inondations et les précipitations insuffisantes sont des phénomènes extrêmes dont la probabilité de réalisation est faible. Ceci explique les faibles primes de ces risques. Pour obtenir de meilleurs prix, la compagnie d'assurance devra considérer le type de risque auquel chaque assuré est le plus exposé et déterminer le montant correspondant. Cette segmentation déterminera la prime correcte.

Une autre perspective d'amélioration proposée consiste à combiner plusieurs algorithmes d'analyse prédictive pour effectuer les prédictions et à ne pas s'appuyer uniquement sur la régression linéaire généralisée.

RÉFÉRENCES BIBLIOGRAPHIQUES

Adisak P., Sukuman S., Thiradet J.(2010). Mathematical modelling for the estimation of crop insurance premium: a case study of total premium equal damage compensation. King Mongkut's University of Technology Thonburi

Alba C., Antonio S., Inés M., Alberto G. (2017). Crop insurance demand in wheat production: focusing on yield gaps and asymmetric information. Spanish Journal of Agriculture research Vol 15, N°4.

Aranee Treerattanapun. (2011). The Impact of Culture on Non-Life Insurance Consumption. University of Pennsylvania

Babcock, B.A. and D.A. Hennessy. (1996). Input Demand under Yield and Revenue Insurance. American Journal of Agricultural Economics 78(2): 416-427.

Claassen, R., F. Carriazo, J.C. Cooper, D. Hellerstein, and K. Ueda. (2011). Grassland to Cropland Conversion in the Northern Plains: The Role of Crop Insurance, Commodity, and Disaster Programs. USDA, Economic Research Service, Economic Research Report 120, June. Available online at: www.ers.usda.gov/publications/err120/.

Fazelbeigi, M.M; Yavari, G.R. (2010). An analysis of challenges faced by crop insurance fund in Iran, Rural Areas & Development. 13 (1): 21-41.

Gideon D., Kwabena N., Dennis E. (2014). Willingness to Pay for Farm Insurance by Smallholder Cocoa Farmers in Ghana. Journal of Social Science for Policy Implications, Vol. 2, No. 1, pp. 163-183

Horowitz, J.K. and E. Lichtenberg. (1993). Insurance, Moral Hazard, and Chemical Use in Agriculture. American Journal of Agricultural Economics 75(4): 926-935.

Miao, R., H. Feng, D.A. Hennessy. (2011). Land Use Consequences of Crop Insurance Subsidies. Paper Presented at the Annual Meeting of the Agricultural and Applied Economics Association, Pittsburgh, PA, July 24-26.

Miranda Mario J. (1991). Area-Yield Crop Insurance Reconsidered American Journal of Agricultural Economics, Vol. 73, No. 2. pp. 233-242.

Nwosu, F. O., Oguoma, N. N. O., Lemchi, J. I., Ben–Chendo, G. O., Henri-Ukoha, A., Onyeagocha, S. U. O., and Ibeawuchi, I. I. (2012). Output Performance of Food-Crop Farmers Under. The Nigerian Agricultural Insurance Scheme In Imo State, South East, Nigeria. Academia Arena, 2(6): 43-47.

Smith, V.H., B.K. Goodwin. (1996). Crop Insurance, Moral Hazard, and Agricultural Chemical Use. American Journal of Agricultural Economics 78(2): 428-438, May.

Williams .J, Gordon L. Carriker, G. Art Barnaby and Jayson K. Harper. (1993). Crop Insurance and Disaster Assistance Designs for Wheat and Grain Sorghum. American Journal of Agricultural Economics, vol. 75, issue 2, 435-447.

Zelda A. , Godwell N., Michael A. . (2018). Effects of climate variability and insurance adoption on crop production in select provinces of South Africa. Journal of Water and Climate Change. Vol 9, Issue 3

Socio-economic and environmental triggers of agricultural actors' conflict and building peace in Niger

Mamane Bello Garba Hima, Ahmadou Aly Mbaye and Akoété Ega Agbodji

ABSTRACT

Conflicts between agricultural actors (farmers and herders) have existed for decades, and fundamentally involves disputes over land and water access. In Niger, as in the wider parts of the Sahel, these conflicts have grown more violent in recent time. The objective of this paper is to determine triggers of farmer-herder conflict escalation in Niger and ways to build peace. The paper adopts the Heckman's sample selectivity Probit with two stages models by assuming that the resource conflict nexus has two steps. The conflict problem becomes: a farmer or herder first has to judge (subjective measurement) that the resource (his interest) is tied and not sufficient to share and at the second step he/she decides to attack (conflict escalation) or not. This gives rise to a sample selectivity problem since only those who perceive resource to be scarce will fight. The paper used both primary and secondary data. On the process to build peace, the paper exposes traditional tools and administrative mechanisms to deal with conflict between local actors. Interview results showed that the inability of government to secure the peace together with the breakdown of traditional conflict resolution mechanisms have compelled local communities to form tribal militias which have further reinforced cleavages along ethnic line. Policy in Niger should be informed by both regional dynamics and local particularities. The regression results have shown that variables such as extensions (electricity, TV, Radio, Health centre, access to credits etc.), household size, household head's age, and resources (land mass, income from farming and herding) affect positively and significantly the perception of resource scarcity. And the conflict escalation between farmers and herders is significantly and positively affected by the household size, the household's age and the scarcity perception. While the household education level and the per capita agricultural incomes are negatively and significantly affected by conflict escalation between actors. These findings confirm the theory of environmental resource constraints leading to violence in areas where people lack education, and households with large size.

Keywords : Climate change, Resource scarcity, Farmer-herder conflict, Niger

RÉSUMÉ

Les conflits entre les acteurs agricoles (agriculteurs et éleveurs) existent depuis des décennies et portent essentiellement sur des différends concernant l'accès à la terre et à l'eau. Au Niger, comme dans les autres régions du Sahel, ces conflits sont devenus plus violents ces derniers temps. L'objectif de ce document est de déterminer les éléments déclencheurs de l'escalade du conflit entre agriculteurs et éleveurs au Niger et les moyens de construire la paix. L'article adopte le modèle Probit à deux étapes de Heckman, basé sur la sélectivité de l'échantillon, en supposant que le lien entre le conflit et les ressources comporte deux étapes. Le problème du conflit devient : un agriculteur ou un éleveur doit d'abord juger (mesure subjective) que la ressource (son intérêt) est liée et qu'elle n'est pas suffisante pour être partagée et, à la deuxième étape, il/elle décide d'attaquer (escalade du conflit) ou non. Cela donne lieu à un problème de sélectivité de l'échantillon puisque seuls ceux qui perçoivent la ressource comme étant rare se battront. L'article a utilisé des données primaires et secondaires. En ce qui concerne le processus de construction de la paix, l'article expose les outils traditionnels et les mécanismes administratifs permettant de gérer les conflits entre les acteurs locaux. Les résultats des entretiens ont montré que l'incapacité du gouvernement à garantir la paix et l'effondrement des mécanismes traditionnels de résolution des conflits ont contraint les communautés locales à former des milices tribales qui ont renforcé les clivages ethniques. La politique au Niger devrait être informée par la dynamique régionale et les particularités locales. Les résultats de la régression ont montré que des variables telles que les extensions (électricité, télévision, radio, centre de santé, accès aux crédits, etc.), la taille du ménage, l'âge du chef de ménage et les ressources (superficie, revenus de l'agriculture et de l'élevage) affectent positivement et significativement la perception de la rareté des ressources. Et l'escalade des conflits entre agriculteurs et éleveurs est significativement et positivement affectée par la taille du ménage, l'âge du chef de ménage et la perception de la rareté des ressources. Alors que le niveau d'éducation du ménage et le revenu agricole par habitant sont négativement et significativement affectés par l'escalade des conflits entre les acteurs. Ces résultats confirment la théorie selon laquelle les contraintes liées aux ressources environnementales conduisent à la violence dans les zones où les gens manquent d'éducation et où les ménages sont de grande taille.

Mots clés : Changement climatique, Rareté des ressources, Conflit entre agriculteurs et éleveurs, Niger.

INTRODUCTION

In this paper, we first aimed at understanding triggers of conflict between agricultural actors (farmers and herders) in Niger. Secondly, we aimed at understanding the legitimate and functioning conflict resolution tools and mechanisms of conflict resolution. It is important to understand and gain knowledge about the resolution of conflicts within states because of their frequency, and because of their negative consequences, including human starvation and death, refugee and displacement flows, and economic and ecological devastation. In this paper, conflict is defined as the manifestation of a difference, an antagonism, an opposition between people or groups of people on a specific object or interest. Any conflict involves three key elements that are: the actors, the object, and its manifestation. The rapid population growth (Niger is the World record) combined to the needs of new arable lands to develop irrigation and the adverse effects of climate change reduce considerably grazing land for animals. So, the mobility of the animals in the search of pastures, salted cures and water points is not done without difficulties.

Recent studies have shown that, in West Africa, farmer-herder conflicts are not only a common phenomenon over the years but also a common characteristic of their economic livelihood (Moritz 2012; Tonah 2006; Turner, et al. 2011). In many countries of the Sub-Saharan Africa, farmer-herder conflicts have escalated into widespread violence leading to economic damages (crop destruction and loss of animals), loss of human lives and displacement of people (Dary, et al. 2017; Hussein, et al. 1999). For instance, in November 2016 in Tahoua region of Niger twenty (20) people were killed and forty-three (43) got injured after conflict escalate between farmers and herders. In the same line, 10 people were killed and thirteen (13) injured in November 2014 in Konni (Tahoua region). In Tillabery region during 2010 more than fifty (50) herders were killed when conflict escalated between herders from Mali and Niger herders. In 1991, more than one hundred (100) people passed because of violence escalation between farmers and herders in Maradi region of Niger (Boureima, 2000). On the 20th November 2017, about thirty-four (34) people were killed including the head of Maijirigui village in Maradi region.

Another conflict between farmers and herders occur in June 2012 at Zouzou Sané Peulh in the department of Boboye (Dosso)[57]. In this latter conflict it is registerd more than six people killed and an economic damage estimated to more than five million (CFA).

Farmer-herder conflicts is reported to have many causes. However, the central argument is about the issue of access to and use of land and freshwater resources. According to Moritz (2012), the likelihood of conflict between these actors increases, whenever a given factor increases the competition to access the land or the freshwater. Climate change is a key factor that may accentuate the scarcity (Abbass, 2014 Mwiturubani and Wyk, 2010; Okoli and Atelhe 2014) of those resources used by the groups simultaneously or mutually exclusive depending to the season. According to Dary, et al. (2017), climate change also causes conflicts due to pastoralists migration from drought prone areas into favourable grazing areas.

The existing literature defines intergroup conflicts to be conflicts between collections of individuals, such as organized political violence, civil conflicts, riots, wars, and land invasions. In trying to study farmer-herder conflict, we believe that from a climate-and-security perspective it is most likely that small-scale violence is more affected by resource scarcity. However, some studies argued that pastoralist violence seems to be more driven by tactical concerns than by resource-based grievances. For instance, Adano, et al. (2012), argue from two case studies in Kenya that weather tensions are high in both resource scarce area and in abundant resource area. A theoretically work by Butler and Gates (2012), using a contest success function model, deduced the presence of biased property rights institutions in periods of relative rainfall abundance to be crucial in determining whether pastoralists engage in inter-ethnic violence or focus on production. The majority of the research on pastoralist societies were conducted in

57 *https://goo.gl/dkRvSM*

drylands and it is reasonable to assume that the mechanisms at play are different from those driving civil wars (Theisen, Gleditsch, and Buhaug, 2013). Indeed, Raleigh and Kniveton (2012), found that communal violence takes place in less-populated areas, in contrast to what is found for civil war literature (Theisen, et al. 2012). Barron, et al. (2009), used survey material on Indonesia and conclude that violent conflict is more likely in villages that had suffered a natural disaster during the last 3 years. According to Benjaminsen, et al. (2012), there is no relationship between climatic conditions and land-use disputes in the Mopti region of Mali. Rather than natural resource scarcity, they find, political negligence, restricted mobility for pastoralists, and rent seeking and corruption to be at the heart of conflict in the region. Many scholars have found that high temperatures elevate the risk of many forms of intergroup conflict, both political violence and other forms of collective violence (e.g. Burke, et al. 2009; Hsiang,et al. 2011; Hsiang, et al. 2013; Dell, et al. 2012; O'Loughlin et al. 2012; Baysan, et al. 2014; Caruso, et al. 2016; Maystadt and Ecker 2014; Maystadt, et al. 2015). Importantly, for all these cases, the finding is primarily in low and middle-income settings in which populations are exposed to, on average, warm or hot temperatures.

Other important factors leading to conflict through resource scarcity are the population growth and the expansion of agricultural land. Indeed, rapid population growth increases competition over available resources by increasing migration of many pastoralists (Moritz, 2012; Adebayo, 1997; Mwiturubani and van Wyk, 2010). Population growth is also reported to raise the demand of food, thus the demand of cropland which in turn shrinks the reserved area for pasturing. Importantly, in trying to adapt to climate change adverse effect, communities encroach pasture land to practice commercial crop production. Therefore, pastoralists are left with insufficient passage for livestock to reach water points, causing conflicts (WANEP, 2010). Turner et al. (2011) have shown that this closeness of livestock to the farm land creates more crop damages. The livestock-induced crop damage, either on the field or in storage on farms, has been argued to be the most important trigger of farmer-herder conflicts in most parts of West Africa (Abubakari, Yakubu, and Longi, 2014; Ofuoku and Isife 2009; Turner, et al. 2007).

However, resource scarcity is not the only path through which conflicts occur. Indeed, evidences show that farmer-herder conflicts can occur in the abundance of resources and low human population densities. For instance, in studying Ghana's case, Tonah (2002; 2006) found that conflict arose between farmers and herders over access to the best agricultural lands and water sources.

According to (Ahmadu, 2011) and Moritz (2012), cultural, religious and ethnic differences between herders and farmers are also triggers of conflicts by creating misunderstandings, suspicion, hostility and prejudices. In some communities, herders are considered or felt to be strangers or alienated (Yembilah and Grant, 2014). Such consideration leads to conflicts as soon as the herders started demanding for equal or acceptable right in the usage of land. Mwamfupe (2015) argues that it is the non-functioning of government institutions and the breakdown of traditional rules are recent key elements explaining the increase of farmer-herder conflicts. Other authors found that cattle rustling, theft, highway robbery, female harassment and rape, corruption of local authorities, and deliberate bush burning are some other factors causing farmer-herder conflicts (e.g. Abubakari, Yakubu and Longi, 2014; Ahmadu, 2011; Ofuoku and

Isife, 2009). Distinguishing between long term and short-term causes of farmer-herder conflict is very important for policy implementations. Indeed, resource related conflicts do not simply escalate because of an increase of the competition over the scarce resource but that triggering factors are often involved (Turner, 2011).

Dary, et al. (2017) specified climate change, rapid population growth, expansion of agricultural land, cultural and religious differences, and changes in policies as factors considered as remote causes of farmer-herder conflicts. While destruction of crops, pollution of water bodies, engagement in social vices and the inability of institutions (local and national) to deal with grievances are considered to be triggers of such conflicts. This work is interested in analysing both remote causes and triggers of the farmer-herder conflict in Niger and how actors resolve conflict.

2. METHODS

Study area

Conflict related to natural resources (except mining) in Niger is across the whole country. However, they are more frequent in areas where population density is higher (UNDP

[United Nations Development Programme], 2014) such as Maradi region and the southern part of Dosso, Tahoua and Zinder regions. Some factors such as bad governance and injustice, rapid population growth, climate change, political instability, and segregationist practices are reported by the UNDP to accentuate such conflicts in the country.

Seven over the eight administrative regions (Agadez, Diffa, Dosso, Maradi, Tahoua, Tillabery and Zinder)[58] were considered to perform the regression part of this study. The capital city (Niamey) is not considered in this study because with the bad and unorganized urbanization, there is almost no land for farming or herding for the region. Farmer-Herder conflict is then difficult to analyse in such place. Even among these seven regions, the UNDP conducted a field work at national level and classified the risk of conflict related to resources (farmer-herder) escalation to be very high in some regions (Dosso, Maradi and Diffa) and moderate in the remaining regions of the country. Indeed, some ethnic groups (practicing almost the same activity like farming) developed an unpleasant behaviour to see another group (like group almost practicing herding) as an eternal enemy. Resource scarcity combined with some cyclical tension between communities make these three regions predominant in conflict escalation between farmers and herders. Therefore, for the general analysis we consider the seven regions and for the focus group discussions and resource persons interview we purposively (financial resource availability and predominance of conflict) chose the three regions (Diffa, Dosso and Maradi).

Importantly, the three regions are key in the national economy as represented in the Table 1 bellow. Indeed, Maradi and Dosso are respectively first and second producer of cereals (millet, sorghum, beans etc.) in the country. Given their weight in crop production (farmers) and the relatively good animal production (herders) and the high

58 See Figure 15

population pressure on such resources, they are potential for conflict escalation. The region of Diffa is the main (about 50%) producer of fish at national level because of Lake Chad and the Komadougou river. Diffa is also a zone of transhumance of herders (nomadism) and an important area for irrigation of leguminous such as sweet pepper (called the Red Gold).

Table 1: Agriculture statistics of the interview areas from (2000-2009)

Region	Animal Production (in 1000 of heads)			Cereals Production (in 1000 of tons)			Fishing (in tons)	Conflict prone (UNDP)
	Cattle	Caprine + Ovine	Dromedary	Millet	Sorghum	Bean		
Diffa	8,246.5	17,248	3,644.5	431.1	30.9	709.9	141,885	Very High
Dosso	7,260	15,000.3	276	5,162.7	519.3	1,369.5	19,492	Very High
Maradi	11,680.9	35,104.8	2,479.6	5,602.3	2469.7	1,474.9	1,145	Very High
Niger	75,639	204,255.3	15,532.9	26,012.4	6620.5	3,551.5	243,016	

Source: Summations from INS, 2010

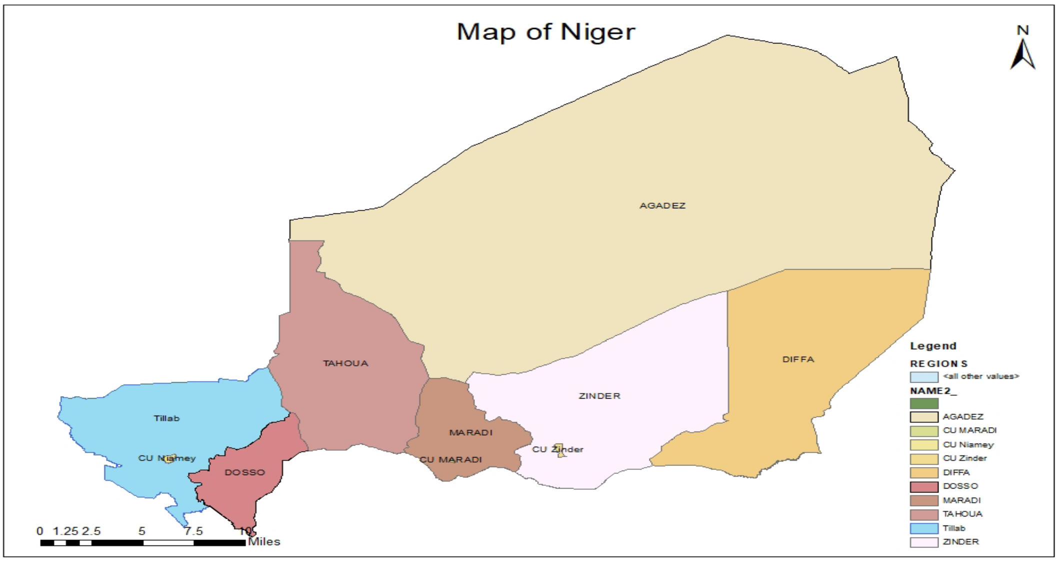


Figure 1: Map of Niger showing its 8 regions

Data and sampling

Data

To conduct this study and achieve the stated objectives, we used primary data from field work conducted in October 2017 and household survey secondary data from the INS. The following data collection methods are used: Focus Group Discussions (FGDs) with farmers and herders to capture what causes their conflicts and how they are being resolved. There were interviews of key resource persons, NGOs, and local authorities on conflict management. A questionnaire was implemented on four hundred farmers and herders in the three (Diffa, Dosso and Maradi) regions. The secondary data are from INS for the year 2015 on about 2,500 farmer/herder households throughout the seven regions.

Data Collection

The primary data is collected from farmers, herders, local government officials, community leaders, representatives of farmers and herders' associations, and non-governmental organizations (NGOs) directly related to farmer-herder cohabitation. Two research instruments for data collection are used: The first one is a questionnaire survey which was used to elicit information on socio-economic characteristics of actors (farmers and herders), incidences of conflict, causes, consequences and strategies adopted to resolve conflicts. A total of four hundred (400) copies of questionnaire were administered to farmers and herders. Each of the tree regions received proportionally to its population size (2016 national estimation) the number of respondents. Thus, in Diffa we administered 50 questionnaires, 130 for Dosso and 220 for Maradi region. The second instrument is an interview guide containing open-ended questions for local government officials and community leaders and resource persons, to understand how resource scarcity affects farmers and herders, and policies that regulate the use of land and water sources by these actors. In total we worked with 87 respondents in October 2017.

Sampling Design

For the primary data, respondents for the study are selected through multi-stage sampling procedure. We select purposively at the first stage three regions (Diffa, Dosso, and Maradi) of the country where conflict between farmers and herders is more frequent. At the second stage we selected purposively one (1) department from each region. For Diffa region, the reason for a purposive randomisation to choose the department of Mainé Soroa is due to security issue. But for the department of Boboye (Dosso) and department of Madarounfa (Maradi) the selection purpose is simply due to the frequency of conflict escalation in these departments. From each of the selected department we randomly select one (1) district. At the third stage, we randomly selected and respectively one (1), two (2) and four (4) villages in Mainé Soroa, Boboye and Madarounfa, giving a total of 7 villages for the sample. At the fourth stage, a combination of respectively 50 (Mainé Soroa); 130 (Birni N'Gaoure) and 220 (Madarunfa) actors are randomly selected from the selected villages (see Table 2).

Table 2 : Selected communities for primary data

Region	Department	District	Village	Sample COORDINATES		
					LAT.	LOG.
Diffa	Mainé Soroa	Mainé	Alaouri	50	L:011°59',409	l:13°11',376
			Batama Beri	65	L:002°53',952	l:13°07',459
Dosso	Birni N'gaoure	Bimi	Kofo	65	L:002°44',113	l:13°09',311

			Gangaré	55	L:007°11',958	l:13°17',053
Maradi	Madarounfa	Madarounfa	Jambali	55	L:007°11',936	l:13°15',983
			Angoual Mata	55	L:007°11',752	l:13°19',996
			Kountoumi	55	L:007°11',892	l:13°10',606

Source: Garba, 2018

The sample repartition is based on the proportion of the region population in the national total. The selection is on adults as respondents, yielding to four hundred (400) total respondents for this purpose.

Key informants provide information and opinions on the causes and factors that lead to conflicts between the farmers and herders in their various communities and the possible solutions to such problems. For instance, issues between these actors can be where and what size the corridor for herders should be? What is the right time to release animals for free grazing? How much should be paid per hectare to compensate a farmer in case a given herder damages his crop, and vice versa? As one can see these are just some issues on which the parties are surely going to have differences of preferences.

As with most of economic problems, studying the climate change and conflict nexus is not straightforward. The ideal situation would be to observe two identical populations or societies, change the climate of one, and observe whether this treatment will lead to more or less conflict relative to the control group. Given that climate cannot be experimentally manipulated, researchers have relied on natural experiments in which plausibly exogenous variation in climatic variables generates changes in conflict risk that can be measured by an econometrician (Burke, et al., 2015).

We adopt the Heckman two stages models in this work. We conceive the resource conflict nexus to have two steps as many scholars did in studying climate change adaptation at farmers' level. Indeed, they assume that farmers perceive climate change, and then decide whether or not to adopt a particular measure. In accordance to that logic, our conflict problem becomes: a farmer or herder first has to judge (subjective measurement) that the resource (his interest) is tied and not sufficient to share and at the second step he/she decides to attack (conflict escalation) or not. This gives rise to a sample selectivity problem since only those who perceive resource to be scarce will fight. Since the objective is to determine triggers of farmer-herder conflict escalation in general, we applied the Heckman's sample selectivity Probit model. We assumed the farmer herder conflict to be resource (access to land, access to water points, crop damage, animal theft etc.) based conflict. We also made the assumption that retaliation is also due to prior perception of the resource scarcity. However, the retaliation decision may not be motivated by the same perception of the resource scarcity. Indeed, he/she may retaliate to protect his life or "dignity" and not necessarily to overtake his opponent's goods.

In climate change studies this method is applied to generally explore farmers' climate change perceptions and adaptation decisions (e.g. Maddison 2007; Deressa, et al. 2009; Mandleni and Anim 2011). Authors argued in applying the Heckman sample selectivity Probit model to have: two-steps of adaptation to climate change. The first requires that farmers perceive climate change then secondly decide to respond to changes through adaptation or not.

Theoretical model

Heckman (1974) considered a model of labour supply in which wages and hours worked are the two endogenous variables. Based on his assumption of equating wage equation to market's one, the problem became a decision problem in which the person is whether in the labour force or he is not. Individuals choose to belonging to one group or another and this is based on the individual's assessment of the choices. Individual will opt to belonging to a group whenever the expected gains are greater than not belonging to a group and will not adhere otherwise. Therefore, the problem becomes a utility maximization problem. Lewis (1974) and Heckman (1974) noted that, modelling these kinds of relationship on the outcome from the decision would lead to over prediction of the gains in econometrics. This possibility to over predict the gains creates a selectivity bias problem. This means that there may be some inert characteristics of say the contributors that are related to their contribution level other than the explicitly measured factors. In our study, the objective was to estimate triggers influencing agricultural practitioners' decision to fight upon scarce resources. This suggested that, we are interested in i) the determinants of resource scarcity and ii) the determinants of conflicts escalation between farmers and herders. To handle this objective, conventionally, the approach would have been to estimate a Probit/ Logit function for the first part of the objective and an ordinary least square (OLS) function for the second part. But according to Heckman (1974) this is fraud and would lead to inconsistent estimates. To overcome this inconsistency, and following Greene (2003) we adopted the Heckman (1976) two-stage approach. Thus, a new variable is generated through an iteration procedure after estimating the Probit model (the perception of resource scarcity). In the second stage, this new variable is used as an additional variable (the determinants of actors' decision to fight or not).
Mathematically, the model is presented as :

$$\Pi^*_{ij} = \beta'_3 X_{ij} + \varepsilon_{ij} \quad \text{.......} \quad (1)$$

With β'_3 is a vector of coefficients and ε_{ij} is the disturbance term in the size of the issue equation. The sample selection problem arises in the size of issue equation because the sample contains farmers and herders who perceive resource to be scarce and those who do not. Those who perceived the scarcity choose between fighting or bargaining (peace).

The farmers/herders who chose to fight $(\Pi^*_{ij}, j = A)$ are observed only if they perceived both scarcity and chose to fight. The peaceful farmers/herders $(\Pi^*_{ij}, j = N)$ are observed only if they perceived scarcity and chose not to fight but to bargain. These two selection processes can be considered as non-random, and the model should explicitly consider this selection problem in order to produce unbiased estimates (Mandleni and Anim, 2011). Therefore, addressing the multiple sample selection problems inherent in the size of the conflict equation, consider the following model specification :

Let represent the propensity of a farmer/herder being convince on scarcity rather than not. Then the relationship between the observed outcome y_{i1} and the response propensity can be written as :

$$y_{i1} = \begin{Bmatrix} 0 & if & Y_{i1}^{*} & \leq 0 \\ 1 & if & Y_{i1}^{*} & \geq 0 \end{Bmatrix} \qquad \text{Resource Scarcity selection} \ldots\ldots\ldots\ldots (2)$$

Let be the corresponding propensity to choose fighting versus peace as a result of scarcity perception. This variable is only observed when $y_{i1} = 1$, i.e. y_{i2} is a choice between fighting and peace if the farmer/herder judged resource to be scarce and takes the value of 1 for fighting and 0 for peace.

$$y_{i2} = \begin{Bmatrix} 0 & if & Y_{i2}^{*} & \leq 0 \\ 1 & if & Y_{i2}^{*} & \geq 0 \end{Bmatrix} \qquad \text{Conflict selection} \ldots\ldots\ldots\ldots (3)$$

The variable Π_{iA} is only observed when $y_{i1} = 1$ and $y_{i2} = 1$ (scarcity and fighting), while Π_{iN} is only observed when $y_{i1} = 1$ and $y_{i2} = 0$ (scarcity but peace).
If we consider a random sample of N observations, the selectivity model with bivariate Probit selection equations for the farmer/herder i is as follow :

$$y_{i1} = \beta_1^{'} X_{i1} + \mu_{i1}, \quad y_{i1} = \begin{cases} 1 \ldots\ldots\ldots\ldots if \quad Y_{i1}^{*} & > 0 \\ 0 \ldots\ldots\ldots\ldots otherwise \end{cases} \qquad \text{Perceived scarcity equation} \ldots\ldots\ldots\ldots (4)$$

$$y_{i1} = \beta_1^{'} X_{i1} + \mu_{i2}, \quad y_{i1} = \begin{cases} 1 \ldots\ldots\ldots\ldots if \quad Y_{i1}^{*} & > 0 \\ 0 \ldots\ldots\ldots\ldots otherwise \end{cases} \qquad \text{Conflict equation} \ldots\ldots\ldots\ldots (5)$$

$$\Pi_{ij} = \beta_3^{'} X_{ij} + \varepsilon_{ij} = \begin{cases} E(\Pi_{iA} \mid \mathrm{X}_{iD}, \mathrm{y}_2 = 1, \mathrm{y}_1 = 1) \\ E(\Pi_{iN} \mid \mathrm{X}_{iA}, \mathrm{y}_2 = 0, \mathrm{y}_1 = 1) \end{cases} \qquad \ldots\ldots\ldots\ldots (6)$$

Equation (4) summarizes the first situation stage function between scarcity and non-scarcity (abundance) of resources and equation (5) represents situation between fighting and peace (no fight). Both equations represent a partially observed bivariate Probit model. The partially observed situation in the model is due to the unobserved cases of the decision (judgement) of some farmers/herders between fight and peace in cases where farmers/herders were not observing the scarcity of resource due to climate change during the study period.

Empirical models

To handle this objective, two stages are needed: in the first stage, we examined the probability that a farmer or herder with particular characteristic perceives environmental resource to be scarce or not.

Heckman's sample selectivity Probit model is based on the following two latent variables :

$$y_{1i}^{*} = X_{1i}^{'}\beta_1 + u_{1i}$$
$$y_{2i}^{*} = X_{2i}^{'}\beta_1 + u_{2i}$$

$$y_{1i} = \begin{cases} y_{1i}^{*} & if \quad y_{2i}^{*} > 0 \\ 0 & if \quad y_{2i}^{*} \leq 0 \end{cases} \tag{7}$$

With X_1 a k-vector of regressors, X_2 is an m vector of repressors, u_{1i} and u_{2i} are error terms.

The sample rule is that y_{1i} is observed only when y_{2i}^{*} is greater than zero. Suppose as well that u_{1i} and u_{2i} have a bivariate normal distribution with zero means and correlation ρ.

$$\begin{aligned} E[y_{1i} \mid y_{1i}\ is\ observed] &= E[y_{1i} \mid y_{2i}^{*} > 0] \\ &= E[y_{1i} \mid u_{2i} > -X_{2i}^{'}\beta_2] \\ &= x_i^{'}\beta + E[u_{1i} \mid u_{2i} > -X_{2i}^{'}\beta_2] \\ &= X_{1i}^{'}\beta_1 + \rho\sigma_{u_{1i}}\phi(X_{2i}^{'}\beta_2 / \sigma_{u_{1i}}) / \Phi\lambda_i(X_{2i}^{'}\beta_2 / \sigma_{u_{1i}}) \end{aligned} \tag{8}$$

Where Φ is the cumulative distribution function of the standard normal distribution; ϕ is the corresponding density; $\sigma_{u_{1i}}^2$, $\sigma_{u_{2i}}^2$ are the variances of u_{1i} and u_{2i} respectively; and ρ is the correlation between u_{1i} and u_{2i}.

The latter term in the last line of equation (8) causes sample selection bias if $\rho \neq 0$. In order to avoid the sample selection problem, and to get asymptotically efficient estimators, we followed Maddison, (2007) and Deressa et al. (2008) in applying the Heckman Probit selection model but for different purposes.
This is specified as :

$$\begin{aligned} Scarcity_i = \alpha_0 + \alpha_1 Hhsize + \alpha_2 Resource + \alpha_5 Hheduc + \\ \alpha_6 Hhage + \alpha_8 Extension + \mu_1 \end{aligned} \quad \ldots (9)$$

In the second stage, we sought the probability to fight instead of bargaining (negotiating) a situation. The model specification here is :

$$\begin{aligned} Conflict_i = \beta_0 + \beta_1 Gender + \beta_2 Hheduc + \beta_3 Hhage + \beta_4 Perc\exp + \\ \beta_5 hhsize + \beta_6 Accesscredit + \beta_7 Disauth + \beta_8 Corptauth + \mu_2 \end{aligned} \tag{10}$$

Where; Gender is a dummy variable taking 1 if the actor (farmer or herder) is male and 0 if females; Heduc is the number of years a household head has been to formal school; Hhage is the number of years of the household head; Percexp is an estimation of the total riches from herding or farming; hhsize is the number of persons that depend on the household head; Extension (Access to Credit, Heath services, Good roads....) represents the facilities a farmer or a herder have access to, given his location; the degree of corruption of traditional and modern authorities (Corptauth) is a binary variable taking one (1) if a farmer/herder thinks that authorities in his area are corrupted in managing conflict issues and takes zero (0) otherwise.

Model variables

Dependents variables for both models

The dependent variable for the selection equation is binary and indicates whether or not a farmer/herder perceives resource scarcity due to climate change. The dependent variable for the outcome equation is also binary and indicates whether or not a farmer/herder responded to the perceived scarcity by fighting. Farmers/Herder are asked to indicate whether they had been in conflict and if this is motivated by scarcity or other reasons (envy, ethnic tension, seek for revenge etc.). A dummy variable was then created taking the value of one (1) if the farmer had been in conflict because of the observed scarcity, and zero (0) if he/she had not.

Explanatory variables for the selection equation

Variables are chosen base on the hypothesis that they influence a farmer/herder to judge whether he/she observes a scarcity and its origin. The household head's socio-economic conditions[59] have an impact on their judgement of resource scarcity.

The household size (Housesize) is expected to be positively correlated to farmer/herder's capacity to observe the resource scarcity. The per capita needs in the household is supposing to decrease given the decrease of resources associated to climate change. The resources (Land size, water access, agricultural gain…) is supposed to be negatively correlated to the scarcity judgement. Everything being equal, big land for farming or herding gives more opportunities to produce or to get more pasture. Education[60] (Hheduc) is more likely to expand farmers' sources of information through various media, such as newspapers, TV and/or radio. The more education a farmer/herder has, the greater his ability to perceive resource scarcity is. Therefore, higher education is likely to expose farmers to more information on climate change and to the associated scarcity. Previous studies (Maddison 2007; Nhemachena and Hassan 2007; Ndambiri, et al. 2013) have indeed found that education influenced the ability of a farmer to perceive climate change and its effect. The farmer/herder's age (Age) is used as a proxy of his/her experience and is assumed to be positively correlated to his/her perception of scarcity causes by climate change and other source of scarcity. Access to credit (Accesscredit) and off-farm (Offfarm) activity participation are binaries and are assumed to be positively correlated to the scarcity observation. Indeed, a farmer/herder who leaves his own activity to look for minimal survival means or who has to borrow informally (high interest rate) is more positioned to observe resource scarcity link to climate change. Importantly, the income (percexp) is critical in drawing the attention of a farmer/herder that resources available are scarce. Their (farmers and herders) income is estimated base on what they produce during the 2015 harvest

59 Age of the head of household, Educational level, Information on climate change, access to credit, and off-farm participation, household size, land size, farmer/herder's Income.

60 This variable is supposing to contribute positively in observing scarcity and in deciding not to fight but seek for negotiations (peace).

season. Environmental stresses such as drought and flood increase the farmer/herder judgement on scarcity of resources. Drought hits both farmers and herders because they all lose their production, while flood is more likely to be more dangerous for farmers.

Explanatory variables for the outcome equation

The variables hypothesized to influence conflict escalation between farmers and herders include the level of education of the head of household, the size of the household, the sex of the head of household, conflict precedent, access to credit, the household's income, land size, the distance to the administrative authority, degree of corruption of traditional and modern authorities, crop damage, animal theft, and ethnicity.

The education (Hheduc) level is believed to be negatively corelated to conflict escalation. The more the farmer/herder is educated, the more he chooses to resolve issues through negotiation rather than violence. The sex (Gender) of the household head is hypothesized to influence the decision to fight over negotiation. Probably[61] men are more violent than women when facing a scarcity in resource. The income (percexp) and age (Hhage) are continuous variables and are expected to be negatively correlated to conflict escalation. The more endowed a farmer/herder is, the less he/she is interested in fighting over scarce resource. Also, we assumed that elders are characterised with wisdom and less motivated to get involved their families in a deadly battle. The household size (Hhsize) is expected to offer more fighting power and increases the likely preference of conflict over peace. Extension services such as access to Credit is expected to decrease the probability to fight. Indeed, credit may increase the coping strategies of a farmer/herder when scarcity due to climate change is crucial. It also allows to diversify activities, which impose to the actor to consider others as customers not as opponents. Another explanation of our assumption is that, researchers (Katungi and Akankwasa, 2010) found that availability of credit relaxes the financial constraints and allows farmers to afford the cost of adaptation (use of improved crop varieties and irrigation facilities) to cope with climate change adverse effects, thus to help not to fight.

Also, researchers have shown that variables such as conflict precedent, distance to the administrative authority, degree of corruption of traditional and modern authorities, crop damage, animal theft, are all to contributing positively to conflict escalation. However, in this work we dealt with time constraints therefore such variables were not used in the regression but analyse in the interview results.

RESULTS AND DISCUSSION

Farmer-Herder's perceptions of change and how they cope with

This section analyses actors' perceptions of climate change and how it affects their resources availability. We present the outcome of the survey of farmers-herders 'constraints in their activities practices in response to climate changes. The survey

61 According to Bello and Maman (2015) the majority of households are headed by men (99% of their sample) in Niger.

instruments were designed to capture farmer-herder's perceptions and understanding of climate change as well as channels through which their activities are affected and how they cope with. The respondents were asked whether they have noticed changes in mean temperature and rainfall. Results show that 92% of the selected households have perceived changes in the mean temperature while the corresponding response to rainfall accounts for 94.5% in the last two decades.

Regarding the direction of the change in temperature, 86.5% of the sample households perceive an increase in mean temperature and 5.5% a decrease. The rest (8%) do think that direction of the mean temperature remained the same. With regard to the rainfall, 3.5% of the sample households observed an increase and 78% a decrease while 18.5% of them do not observe any change. Table 3 depicts respondents' perceptions of climate changes. In general, increased temperature and declined precipitation are the predominant perceptions in the study sites.

Table 3 : Farmers' perception of changes in the climate

ID	Directions	Precipitation	Temperature
1	increase %	3.5	86.5
2	decrease %	78	5.5
3	same%	18.5	8
Total		100	100

Source: Garba, July 2018

Coping strategies with limited resource

In general, Niger Republic farmer-herder's ability to adapt is limited by their lack of economic and technical resources, and their vulnerability is accentuated by heavy dependence on the climate, because of the rain fed system, diseases/pests and their high poverty rate. Given the diversity of the constraints they have to face, the aggregate capacity to cope with changes is currently very low. The prolonged and increasing temperature, combined with the declining of the rainfall and the frequency of the drought, as well as the marked degradation of the soils, have resulted in a succession of bad years. Many studies such as Deressa et al. (2008) indicated that crop yield declined by 32.8% as result of shocks such as drought, hailstorm, and flood etc. Farmers and herders therefore try to develop their own strategies to mitigate or adapt to climate adverse impacts.

The adaptation methods most commonly cited in the literature include the use of new crop varieties and livestock species that are more suited to drier conditions, irrigation, crop diversification, mixed crop livestock farming systems, changes of planting dates, diversification from farm to nonfarm activities, increased use of water and soil conservation techniques, and trees planted for shade and shelter (Nhemachena and Hassan, 2007). In the case of this study, farmers and herders were asked about their perceptions of climate change and their actions to counteract the negative impact of climate change. As shown in Table 4, about 85% of the respondents did at least something in response to climate changes. This shows that they are aware of the changing climatic conditions. About (15%) of the sample did not use any adaptation option for many reasons. The adaptation strategy most commonly used (about 17%) is irrigation especially in Dosso region. Other adaptation strategies farmers used are soil conservation (8%), using different crop varieties (12%), trade (10%), planting trees (12%), fighting (11) and livestock (14%).

Table 4 : Coping strategies to climate change

Number	Adaptation methods	Percentage
1	No Adaptations	16
2	Soil conservations	8
3	Planting trees	12
4	Different crop varieties	12
5	Irrigations	17
6	Trade Fight	10
7		11
8	Livestock	14
Total		100

Source: Garba, July 2018

The use of planting trees is mainly ascribed to provide natural shades for their livestock or as a wind or hail storm break when the temperature is hot. Soil conservation techniques may be attributed to avoid the risk of flooding. The use of different crop varieties as an adaptation method could be associated with the lower expense and ease of access by farmers. The greater use of irrigation could be attributed to the closeness of some villages in our sample to Lake Madarunfa and the Boboye (zone of the country, Dosso, where even at one-meter depth well is operational). But take as the whole Niger Republic this cannot be the case because of lack of more capital and low potential for irrigation over the country. However, 16% of the farmers do not have any of these adaptation strategies mainly because of lack of necessary funds, information and government support. To our point of view, this group could easily join the group of those who chose to fight over resources as an adaptation strategy.

Farmer-herder scarcity perception and conflict decision

To be able to check the appropriateness of the proposed model, we tested the dependence of the error terms in the outcome and selection equations. We found that the error terms from the outcome and selection models were dependent, therefore there is a sample selection problem. The coefficient "rho" was significantly different from zero (Wald test for independent equations = 61.99, with P = 0.0000), giving room for the use of the Heckman model. The Wald X_2 statistics, which hypothesize that the estimated coefficients are equal to zero and that significantly, thus the null hypotheses (Wald for zero slopes = 10313.58, with P = 0.0000). The model is globally suitable and the independents variables have a strong explanatory power.

As expected, the age of the household head, which represents experience in herding or farming, is positively and significantly related to the scarcity perception but negatively and significantly related to the conflict escalation. This means that older households are more likely to perceive the dwindling of agricultural resources and less willing to fight. This finding is intuitive, when we assumed that elders are more tolerant than young men in retaliation for any damage. The household size is positively and significantly related to both the scarcity perception and to the conflict escalation variables. Farmers and herders feel more the scarcity based on the number of people they are feeding. This is expected because the per capita land to farm or the per capita livestock are decreasing given the negative effect of climate variability. So, from our sample, we can assume that the size of a household is not synonymous of having labour for production but people to feed. Importantly, the size of a household increases the potential for conflict escalation. Big households tend to fight more probably because they have more to feed and expect a victory from any conflict outbreak. The arms used in farmer-herder conflict are mainly traditional and does not require any skill so sized household can easily retaliate. Beyond the household, groups (farmers or herders) decides to retaliate base on the opponent soldiers. Extensions availability and their access allow a farmer or a herder to perceive at which extent resources are scarce. Indeed, whenever extension increases, a given actor perception of scarcity decreases.

The level of education is negatively and significantly correlated to the likelihood of farmer-herder conflict. Educated people are more willing to resolve differences through negotiation instead of fighting. This result is important in terms of policy recommendation. Indeed, to build a peaceful society, the work has to be done from the bottom through educating young people from rural to urban area. As many scholars have shown, the per capita income is significantly and negatively correlated to conflict potential. This finding confirms the theory of environmental resource constraints leading to violence in areas where people lack education and households' size bigger.

REGRESSION RESULTS

Table 12: Results of the Heckman's Model of Farmer-Herder Scarcity Perception and Conflict decision

	Scarcity Perception model				Conflict model			
	Regression model		Marginal effects		Regression model		Marginal effects	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Household Head Age	0.013691***	0.000	0.013691***	0.000	-0.0420264***	0.003	0.013691***	0.000
Gender					0.3851825	0.439		
Household Head Education level					-0.969638*	0.062		
Household size	0.0270679***	0.000	0.0270679***	0.000	0.325733***	0.002	0.0270679***	0.000
Extension services	0.1467351***	0.003	0.1467351***	0.003			0.1467351***	0.003
Resources	-2.05e-06***	0.000	-2.05e-06***	0.000			-2.05e-06***	0.000
Per capita income					-0.0000281***	0.000		
Scarcity					7.56046***	0.000		
Constant								
Wald test for zero slopes	10,313.58, Prob > chi2 (4) =0.000							
Wald test for independent equations	61.99 Prob > chi2(1) = 0.0000							
Total observations	2,333							
Censored	1,703							
Uncensored	630							

Notes: ***, **, * = 1%, 5%, and 10% significance level, respectively
Source: Regression from INS dataset

The more an actor has resourced the less he considers the scarcity not to be crucial. Everything being equal, it shows that big farming or herding households will automatically have less per capita resources compare to small households. One of our variables of interest, scarcity, is positively and significantly correlated to conflict escalation. This is fundamental because scarcity perception is linked in our sample to frustration. It means people when they lack basic needs, they become frustrated and are willing to fight in order to redress their grievances. Climate change hampered the agricultural resources and lead people to fight over the remaining resources instead of cooperating. Though the variable gender is not significant, the coefficient is showing that males are more likely to fight each other compare to female, probably because males are more involved in farming and herding activities.

Building peace

In this section, we assessed method and points of view to overcome conflict in general. We first present technics used in Niger to deal with farmer-herder conflict and then we present some ways to handle conflict as terrorism.

Dealing with farmer-herder conflict : Farmer-herder conflict is the more frequent as conflict type in Niger and results in many deaths and economic damages. To resolve such conflict, many actors are involved.

Village or tribal leaders : They are competent to reconcile parties in conflict in the population of a village or a tribe. Village or tribal leaders are most often assisted by religious authority during the conciliation. If conciliation is accepted by the parties, the conflict is considered settled. Otherwise, it is referred to the head of canton or group.

Head of canton or group : These authorities are competent to deal with cases falling within their jurisdiction conflicts related to the exploitation of natural resources when the head of village or trial fails in their attempt at conciliation.

If the various attempts at conciliation have failed, the head of the canton or group or parties go to the common law judge.

Administrative authorities : Some conflict actors make use this category of authorities because on the grounds there is no physical presence or remoteness of jurisdictions in their localities.

Judicial authority

District Court and District High Court

The district and high courts have jurisdiction over conciliation and adjudication of disputes in accordance with the applicable provisions. They interpret the laws and customs and are responsible for their application. These two levels of jurisdiction judged in customary matters (rural disputes, succession ...) in a collegiate formation composed of a professional judge and two customary assessors of the custom of the parties to the dispute.

Supreme Court

This is the judicial chamber of the Supreme judge. The litigant who is not satisfied with the decision of the appeal judge may challenge it before this chamber by an appeal in cassation.

Customary conciliation procedures

Whether it is land conflicts following the damage to the fields, claims of property rights or boundaries of fields or inheritance, four (4) main phases are considered in the normal course of a process of conciliation: initiation, preparation, negotiation and application.

Initiation phase

It is during this phase that the victim in our case the owner or the usufruct field initiates the process of conflict resolution by posing the problem of compensation for the damage suffered as a result of damage to his crops.

In the absence of an amicable solution, the victim may demand compensation, thus dedicating the beginning of the procedure whose first step is the information of the customary authority of the locality where the damaged field is located. Once complaint received, then the verification of facts starts.

Preparation phase

Immediately after the registration of the complaint, the customary authority invites the author of the damage. When the chief himself is not present at the site of the damage, the commission reports back to him the accused party’s answer.

Negotiation phase

In the presence of concordant testimony or in case of flagrante delicto, the defendant, generally acknowledges the facts against him and the proceedings are concluded by accepting the compensation of the victim by the latter.

Application phase

Once the negotiation is conclusive, the guilty remains indebted for the negotiated amount that he will have to pay as soon as possible.

It should be noted that the procedures described above are only applicable when the herder acknowledges the facts alleged against him. It happens sometimes that one party rejects the accusations of damage. In this case, the search for evidence is done either through the Koranic oath or by the possible identification of animal traces.

Local tools for conflict management

In the area of conflict management (prevention, conciliation or settlement), it is recourse to tools which are the gentleman’s agreement of conciliation or non-conciliation, Koranic oaths and traditionally specific tools to certain areas.

Denominational oaths

In Niger, it is especially the Koranic oath, of course the other forms of oath (biblical and civil) are legally enshrined in the Civil Code and other texts in force. With regard to the Koranic oath which is most frequently used in the conflict resolution, it should be noted that it is only used when all other conciliation attempts will have been unproductive, when one of the parties made the request expressly or when the judge deems it ex officio. This is the last resort.

GON (in Zarma) or Kara (in Hausa)

This is a customary practice quite common in some parts of Niger. The master of ceremonies secures two (2) twigs of ground grasses with an interval of a few inches between them. The parties to the dispute, having made their ablutions are invited to take turns in their right forearm between the two twigs. The part around the forearm from which the twigs are narrowed to the image of the handcuffs is found guilty.

Toungouma

It is a magic stone that would have the singularity to move towards the guilty when the latter stands before it at a public sitting of conflict resolution. The crowning of the punishment inflicted by this stone magic can be death, as a result of a hit on the culprit by the stone under the impulse of an invisible force. It's a practice that's going on in the centre-west of Niger in the Arewa in particular.

Head of Dog (Tête de chien)

It is a practice used in the regions of Maradi and Zinder. The procedure used consists of install a dog's head on a tabernacle and have it carried by two (2) men.

Under the effect of the incantations of the master of ceremonies, the dog's head goes into move and indicates the home of the culprit who committed the wrongdoing decried by the victim or even the community.

International tools for conflict management and resolution

They are part of conflict management at the Sub-regional institutional level and community-based organizations such as WAEMU, ECOWAS, the African Union, the CEN-SAD, etc. As such, we can mention among others:

- The International Court of Justice of ECOWAS and the African Union;
- The WAEMU court of justice;
- treaties and agreements ratified between states

CONCLUSION

In general, the current situation of the Sahel region and Niger in particular is characterized by violence, high population growth and dwindling natural resources, increased competition for the exploitation of natural resources generating conflicts between rural actors.

Farmer-herder conflict is the more frequent as conflict type in Niger and results in many deaths and economic damages. Through our interview results, we understand that it has many causes such as: Resource access (well, pasture, water points...), sinking of private wells, introducing of animal diseases in a common grazing area, grazing area cultivation by sedentary herders, refuse to obey to usages and customs, animal theft and robbery, Bad interpretation of land tenure system, refusal to obey to court decision, and empoisoning of water points and so on. The regression result from the Heckman two stage model shows that the extensions (electricity, TV, Radio, Health centre, access to credits etc.), household size, household head's age, and resources (land mass, income from farming and herding) significantly affect the perception of resource scarcity. The conflict escalation between farmers and herders is significantly affected by the household size, household education level, the per capita agricultural income, the household's age and the scarcity perception.

Given this situation and with the aim of boosting local development, in the peace and social tranquillity, favourable behavioural changes for a better use of available natural resources is needed. The paper also argued that to build peace at global scale in the country, there is need to involve of the population in making decisions before their implementation. It is also important to deal with conflict as a problem of lack of social justice, lack of good education system for all and a problem of jobless in the country.

REFERENCES

Abbass, I. M. (2014). No Retreat no Surrender Conflict for Survival between Fulani *Pastoralists and Farmers in Northern Nigeria. European Scientific Journal, Vol. 8, Issue 1,pages 331–346.*

Abubakari, A., Yakubu, F., & Longi, T. (2014). Pastoralism and Violence in Northern Ghana : Socialization and Professional Requirement. International Journal of Research In Social Sciences, Vol.4, Issue 5, Corpus ID: 130035654

Adano, W. R., Dietz, T., Witsenburg, K., & Zaal, F. (2012). Climate change, violent conflict and local institutions in Kenya's drylands. Journal of Peace Research, Vol. 49, Issue 1, pages 65–80. https://doi.org/10.1177/0022343311427344

Adebayo, A. G. (1997). Contemporary dimensions of migration among historically migrant Nigerians - Fulani pastoralists in southwestern Nigeria. Journal of Asian and African Studies, Vol 32, Issues 1–2, pages 93–109. https://doi.org/10.1177/002190969703200108

Ahmadu, H. J. (2011). Farmer-herder Conflict: Exploring the Causes and Management Approaches in the Lake Chad Region Nigeria. UTARA MALAYSIA. Retrieved from http://etd.uum.edu.my/3399/2/1.HAMMAN_JUMBA_AHMADU.pdf

Barron, P., Kaiser, K., & Pradhan, M. (2009). Understanding Variations in Local Conflict: Evidence and Implications from Indonesia. World Development, Vol. 37, Issue 3, pages 698–713. https://doi.org/10.1016/j.worlddev.2008.08.007

Baysan C, Gonzalez F, Burke M, Hsiang S, M. E. (2014). Economic and non-economic factors in violence: evidence from drug cartels, suicides, and climate in Mexico. Berkeley.NBER Working Paper Series, Working Paper, 24897, DOI 10.3386/w24897

http://www.nber.org/papers/w24897.

Bello, G. H. M., & Maman, M. N. M. (2015). A Ricardian Analysis of the Impact of Temperature and Rainfall Variability on Agriculture in Dosso and Maradi Regions of Niger Republic. Agricultural Sciences, Vol. 6, Issue 1, pages 724–733. https://doi.org/10.4236/as.2015.67070

Benjaminsen, T. a., Alinon, K., Buhaug, H., & Buseth, J. T. (2012). Does climate change *drive land-use conflicts in the Sahel? Journal of Peace Research, Vol. 49, Issue 1, pages 97–111. https://doi.org/10.1177/0022343311427343*

Boureima, A. G. (2000). Instances d ' arbitrage et itinéraires de résolution des conflits fonciers dans le Boboye (Niger). Le Griot, Vol. 8, pages 1–18.

Burke, M. B., Miguel, E., Satyanath, S., Dykema, J. a, & Lobell, D. B. (2009). Warming increases the risk of civil war in Africa. Proceedings of the National Academy of Sciences of the United States of America, Vol.106, Issue 49, pages 20670–20674. https://doi.org/10.1073/pnas.0907998106

Burke, M., Hsiang, S. M., & Miguel, E. (2015). Climate and Conflict, Annual Review of Economics, Vol. 7, pages 577-617 (May). https://doi.org/10.1146/annurev-economics-080614-115430

Butler, C. K., & Gates, S. (2012). African range wars: Climate, conflict, and property rights. Journal of Peace Research, Vol. 49, Issue 1, pages 23–34. https://doi.org/10.1177/0022343311426166

Caruso, R., Petrarca, I., & Ricciuti, R. (2016). Climate change, rice crops, and violence: Evidence from Indonesia . Journal of Peace Research, Vol 53, Issue 1, pages 66–83. https://doi.org/10.1177/0022343315616061

Dary, S. K., James, H. S., & Mohammed, A. S. (2017). Triggers of Farmer-Herder Conflicts in Ghana: A Non-Parametric Analysis of Stakeholders' Perspectives. Sustainable Agriculture Research, Vol. 6, Issue 2, pages 141–151. https://doi.org/10.5539/sar.v6n2p141

Dell, M., Jones, B. F., & Olken, B. A. (2012). Temperature shocks and economic growth: Evidence from the last half century. American Economic Journal: Macroeconomics, ol. 4, Issue 3, pages 66–95. https://doi.org/10.1257/mac.4.3.66

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change, Vol. 19, Issue 2, pages 248–255. https://doi.org/10.1016/j.gloenvcha.2009.01.002

Greene, W. H. (2003). Econometric Analysis (7th Ed.). Upper Saddle River, Prentice Hall. American Journal of Aplied Mathematics and Statistics, Vol. 6, Issue 6, pages 262-265. DOI: 10.12691/ajams-6-6-7.

Heckman, J. J. (1974). Shadow Prices, Market Wages, and Labor Supply. Econometrica, Vol. 42, Issue 4, pages 679–694. https://doi.org/10.2307/1913937

Heckman, J. J. (1976). The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimator for Such Models. Annals of Economic and Social Measurement, Vol.5, Issue 4, pages 475–492. Retrieved from http://ideas.repec.org/h/nbr/nberch/10491.html

Hsiang, S. M., Burke, M., & Miguel, E. (2013). Quantifying the influence of climate on human conflict. Science (New York, N.Y.), Vol. 341, Issue 6151, pages 1-16. https://doi.org/10.1126/science.1235367

Hussein, K., Sumberg, J., & Seddon, D. (1999). Increasing Violent Conflict between

Herders and Farmers in Africa : Claims and Evidence. Development Policy Review, Vol. 17, Issue 4, pages 397–418. https://doi.org/https://doi.org/10.1111/1467-7679.00094

Katungi, E., & Akankwasa, K. (2010). Community-based organizations and their effect on the adoption of agricultural technologies in Uganda: A study of banana (Musa spp.) pest management technology. Acta Horticulturae.879 https://doi.org/10.17660/ActaHortic.2010.879.77

Lewis, H. G. (1974). Comments on Selectivity Biases in Wage Comparisons. Journal of Political Economy, Vol. 82, Issue 6, pages 1145–1155. https://doi.org/10.1086/260268

Maddison, D. (2007). The Perception of and Adaptation To Climate Change in Africa. World Bank Policy Research Working Paper, 4308. https://doi.org/10.1596/1813-9450-4308

Mandleni, B., & Anim, F. D. K. (2011). Climate Change Awareness and Decision on Adaptation Measures by Livestock Farmers in South Africa. Journal of Agricultural Science, Vol. 3, Issue 3, pages 258–268. https://doi.org/10.5539/jas.v3n3p258

Maystadt, J. F., Calderone, M., & You, L. (2015). Local warming and violent conflict in North and South Sudan. Journal of Economic Geography, Vol.15, Issue 3, pages 649–671. https://doi.org/10.1093/jeg/lbu033

Maystadt, J. F., & Ecker, O. (2014). Extreme weather and civil war: Does drought fuel conflict in Somalia through livestock price shocks? American Journal of Agricultural Economics, Vol. 96, Issue 4, pages 1157–1182. https://doi.org/10.1093/ajae/aau010

Moritz, M. (2012). Farmer-herder conflicts in Sub-Saharan Africa. Retrieved from http://editors.eol.org/eoearth/wiki/Farmer-herder_conflicts_in_Sub-Saharan_Africa

Mwamfupe, D. (2015). Persistence of Farmer-Herder Conflicts in Tanzania. International Journal of Scientific and Research Publications, Vol. 5, Issue 2, page 8. Retrieved from http://www.ijsrp.org/research-paper-0215/ijsrp-p3862.pdf

Mwiturubani D.A. and van Wyk. (2010). Climate Change and Natural Resources Confl icts in Africa. Monogragh 170, pages 1-272. https://issafrica.s3.amazonaws.com/site/uploads/Mono170.pdf

Ndambiri, H. K., Ritho, C. N., & Mbogoh, S. G. (2013). An Evaluation of Farmers ' Perceptions of and Adaptation To the Effects of Climate Change in Kenya. International Journal of Food and Agricultural Economics.Vol. 1, Issue 1, pages 1-22.

Nhemachena, C., & Hassan, R. (2007). Micro-Level Analysis of Farmers ' Adaptation to Climate Change in Southern Africa. IFPRI Discussion Paper 714. Washington, DC.

O'Loughlin, J., Witmer, F. D. W., Linke, A. M., Laing, A., Gettelman, A., & Dudhia, J. (2012). Climate variability and conflict risk in East Africa, 1990-2009. Proceedings of the National Academy of Sciences of the United States of America, Vol. 109, Issue 45, pages 18344–9. https://doi.org/10.1073/pnas.1205130109

Ofuoku, A. U., & Isife, B. I. (2009). Causes , effects and resolution of farmers-nomadic cattle herders conflict in Delta state , Nigeria. International Journal of Sociology and Anthropology, Vol.1, Issue 2, pages 47–54. Retrieved from http://www.academicjournals.org/ijsa

Okoli Al Chukwumaa & A. George Atelhe. (2014). Nomads against Natives : A Political Ecology of Herder / Farmer Conflicts in Nasarawa State , Nigeria. American International Journal of Contemporary Research, Vol. 4, Issue 2, pages 76–88.

Raleigh, C., & Kniveton, D. (2012). Come rain or shine: An analysis of conflict and climate variability in East Africa, SAGE Journals. https://doi.org/10.1177/0022343311427754

Solomon M. Hsiang, Kyle C. Meng, & Mark A. Cane. (2011). Civil conflicts are associated with the global climate. Nature, Vol. 476, Issue 7361, pages 438–441. https://doi.org/10.1038/nature10311

Theisen, O. M., Gleditsch, N. P., & Buhaug, H. (2013). Is climate change a driver of armed conflict? Climatic Change, Vol. 117, Issue 3, pages 613–625. https://doi.org/10.1007/s10584-012-0649-4

Theisen, O. M., Holtermann, H., & Buhaug, H. (2012). Climate Wars? Assessing the Claim That Drought Breeds Conflict. International Security, Vol. 36, Issue 3, pages 79–106. https://doi.org/10.1162/ISEC_a_00065

Tonah, S. (2002). Fulani Herdsmen, Indigenous Farmers and the Contest for Land in Northern Ghana. Africa Spectrum, Vol. 37, Issue 1, pages 43–59.

Tonah, S. (2006). Migration and Farmer-Herder Conflicts in Ghana ' s Volta Basin. Canadian Journal of African Studies, (December 2014), pages 37–41. https://doi.org/10.1080/00083968.2006.10751339

Turner, M. D.; Ayantunde, A. A.; Kristen, P. P.; Patterson III, E. D. (2011). Livelihood Transitions and the Changing Nature of Farmer – Herder Conflict in Sahelian West Africa. The Journal of Development Studies, Vol. 42, Issue 2, pages 183–206. https://doi.org/10.1080/00220381003599352

Turner, M., Ayantunde, A. A., Patterson, E. D., & Patterson, K. P. (2007). Conflict management for improved livestock productivity and sustainable natural resource use in Niger. Retrieved from http://hdl.handle.net/10568/1304

UNDP [United Nations Development Programme]. (2014). Analyse des Facteurs de Conflits au Niger. Bureau D'Etude Niger Horizons, Niamey. www.undp.org/publications.

WANEP (West African Network for Peacebuilding). (2010). Concept Paper on Agriculture and Pastoralist. https://doi.org/10.3734/isj.2008.1205

Yembilah, R., & Grant, M. (2014). The political ecology of territoriality: Territorialities in farmer-herder relationships in Northern Ghana. GeoJournal, Vol.79, Issue 3, pages 385–400. https://doi.org/10.1007/s10708-013-9509-7

Dégradation des rizières par salinisation à l'heure du changement climatique : une menace à la sécurité alimentaire à Baïla

Dramane Cissokho, Jean Philippe Coly et Ibrahima Diombaty

ABSTRACT

This paper focuses on the salinization of rice fields in the village of Baïla from the perspective of the threat to food security. The methodology is based on documentary research and a field survey, supplemented by participatory observation and mapping of rice land. The results show that rice remains the staple food in Baïla. In addition, they reveal that 75% of rice fields are abandoned as a result of salinization in relation to climate change. The land shortage and the fragmentation of rice plots that result from this abandonment result in insufficient rice production, which leads to food insecurity

Keywords: Salinization, Food insecurity, Baïla, Rice growing, Climate change.

RÉSUMÉ

Cet article s'intéresse à la salinisation des rizières du village de Baïla sous l'angle de la menace à la sécurité alimentaire. La méthodologie repose sur une recherche documentaire et une enquête de terrain, complétées par une observation participative et une cartographie du foncier rizicole. Les résultats montrent que le riz demeure l'aliment de base à Baïla. En outre, ils révèlent que 75 % des rizières sont abandonnées sous l'effet de la salinisation en rapport avec le changement climatique. La pénurie foncière et le morcellement des parcelles rizicoles qui découlent de cet abandon ont comme corollaire une production insuffisante de riz qui occasionne une insécurité alimentaire.

Mots clés: Salinisation, Insécurité alimentaire, Baïla, Riziculture, changement climatique.

INTRODUCTION

Au cours de ces dernières décennies, la salinisation des terres se pose avec acuité. En effet, elle affecte au moins 400 millions d'ha et menace gravement une surface équivalente (FAO, 2005). Une bonne partie des espaces concernés par le phénomène de salinisation se trouve localisée dans les terres arides et semi-arides, du fait que le processus de salinisation est plus marqué par des températures élevées durant presque toute l'année, du drainage restreint et des précipitations insuffisantes pour lessiver les sels solubles du sol (FAO, 2005).

Des études (Poitevin, 1993 ; CSE, 2005) ont montré que le Sénégal est touché par la salinisation des sols. L'estimation des superficies des terres sous l'emprise du processus de salinisation donne plusieurs résultats selon les auteurs. Elle varie de 925 000 ha, dont 625 000 sévèrement affectés (Fall, 2006), à 1 700 000 ha (CSE, 2003). Les études menées par INP en 2008 avancent 996 950 ha. Tous ces travaux soulignent l'importance dudit phénomène.

Le village de Baïla fait partie de ces espaces où s'observe la salinisation des terres. D'ailleurs, selon INP (2014), il est l'un des terroirs qui en souffrent énormément. De ce fait, par quel mécanisme les terres de ce village se salinisent ? Quelles en sont les conséquences ?

La présente étude a pour objectif principal de faire ressortir les effets de l'envahissement des rizières par le sel sur la sécurité alimentaire.

Après la présentation de la méthodologie, l'accent sera mis sur les résultats structurés autour de cinq points. Le premier traite la fonction nutritionnelle, sociale et religieuse du riz. La deuxième porte sur la salinisation des rizières en rapport avec la baisse de la pluviométrie. Le troisième met l'accent sur les tentatives infructueuses de lutte contre la salinisation des rizières. Le quatrième aborde la pénurie foncière pour la culture du riz et le morcellement des parcelles. Le cinquième et dernier point a trait à la menace sur la sécurité alimentaire.

Le village de Baïla, cadre de cette étude est situé à 12°53′ 39″Nord et 16° 21′ 08″ Ouest. Il fait partie de la commune rurale de Suel ; elle-même rattachée au département de Bignona. Ce dernier, est une partie intégrante de la région administrative de Ziguinchor, localisée au sud du Sénégal (figure 1).

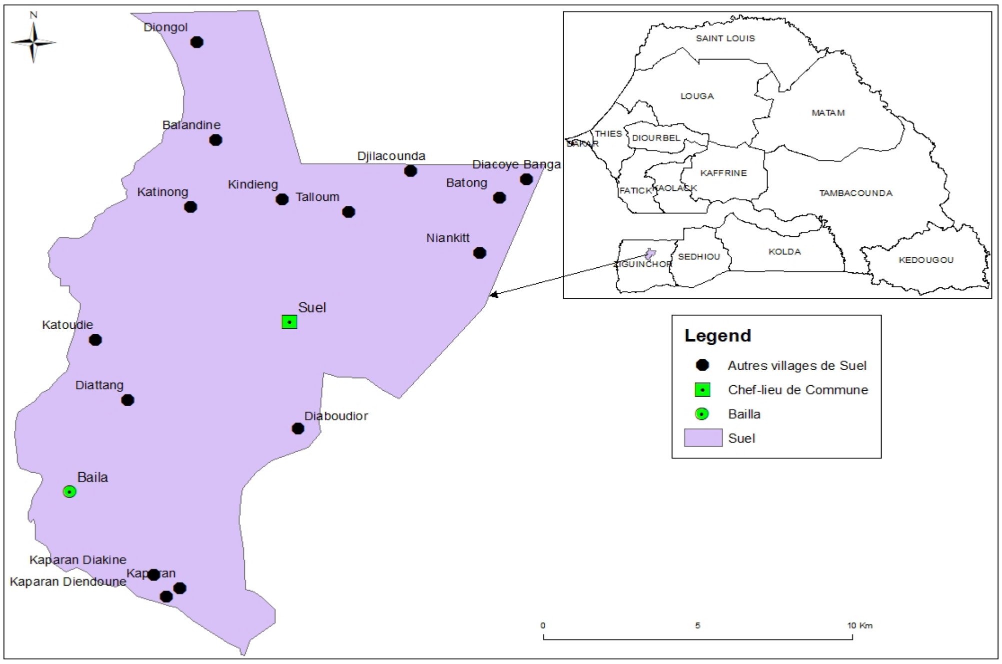


Figure 1 : Situation géographique de Baïla

MÉTHODOLOGIE

Au niveau méthodologique, une recherche documentaire, une enquête, des relevés de points GPS et l'observation sur le terrain ont été faits entre janvier et mars 2019. La recherche documentaire a porté sur des travaux relatifs à la thématique de salinisation des terres et sur la zone d'étude. Cette revue de littérature a été faite au niveau de la bibliothèque de l'université Assane Seck de Ziguinchor et sur l'internet. L'enquête par questionnaire est menée auprès de 60 ménages sur les 180 que compte le village soit 25 %, choisis de façon aléatoire simple (sans remise). Le but de l'enquête est à collecter des données entre autres, sur les pratiques alimentaires, la taille des exploitations, la riziculture, les quantités de riz récoltées et les pratiques locales mises en œuvre pour lutter contre la salinisation des sols.

L'observation a consisté en une prise de contact direct avec l'espace d'étude. Elle a permis d'apprécier l'état de la salinisation et la réalité du terrain et de procéder à des prises de vue. Lors de la descente sur le terrain des points GPS ont été relevés. La finalité recherchée est de réaliser une cartographie qui mettra en lumière les parcelles rizicoles abandonnées. L'analyse de l'ensemble des informations obtenues permet d'aboutir aux résultats suivants.

RÉSULTATS

Le riz : une céréale avec une fonction nutritionnelle, sociale et religieuse

Baïla est un village diola et de notre enquête, il ressort que 95 % des ménages déclarent qu'ils sont de cette ethnie (figure 2). On note toutefois une cohabitation avec quelques groupes minoritaires.

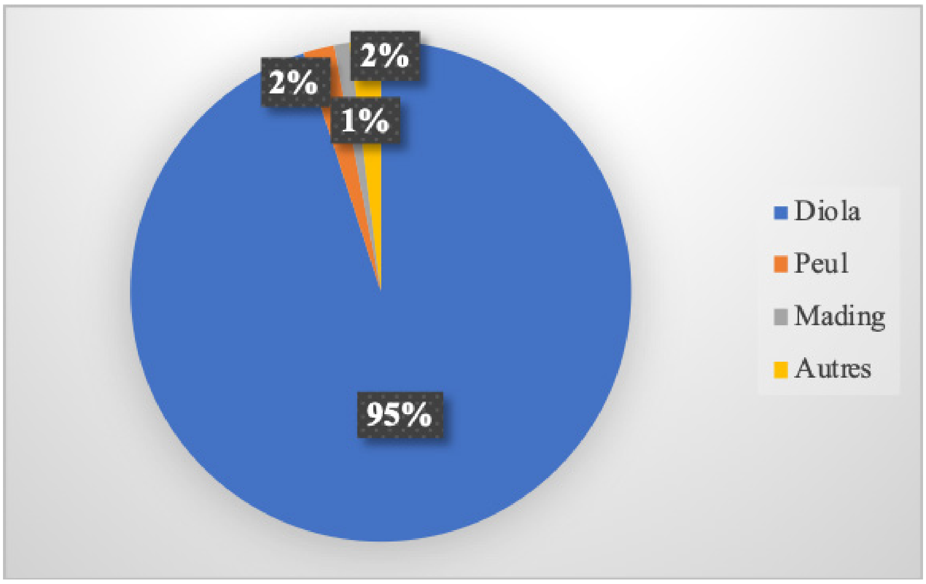


Figure 2 : Composition ethnique de Baïla

De toute façon, le riz constitue l'aliment de base de l'ensemble de la population de Baïla. Notre enquête laisse apparaître que plus 98 % des ménages le consomment tant au petit déjeuner qu'au déjeuner et au dîner. A l'instar d'autres contrées de la Basse Casamance, cette céréale joue un rôle économique en ce sens que, traditionnellement, la richesse d'une personne se mesure au stock de son grenier en riz (Diédhiou, 2004 ; Séne et Diémé, 2018). En outre, elle a une importance religieuse car la population y recourt lors des rituels et cérémonies traditionnelles. De ce fait, sa consommation se révèle comme l'expression d'une identité et d'une fidélité aux valeurs ancestrales. Elle explique l'attachement de la population à la riziculture qui demeure l'activité principale et essentiellement familiale et qui est toujours pratiquée de manière traditionnelle et en saison pluvieuse.

Salinisation des rizières, un phénomène en rapport avec la baisse de la pluviométrie

D'emblée, il importe de souligner que les rizières du village de Baïla jouxtent le marigot qui porte le même nom et qui est un affluent du fleuve Casamance. Jusqu'à l'avènement de la dégradation des conditions pluviométriques qui a débuté en Basse Casamance à partir de 1968, personne ne parlait de la salinisation des terres. Les quantités de pluies reçues étaient suffisantes pour soutenir l'écoulement du fleuve sur une longue période et assurer la dilution de l'eau marine qui remontait le fleuve jusqu'au marigot par le biais des marées. Cependant, cet équilibre s'est rompu avec la baisse prononcée de la pluviométrie. Les moyennes décennales permettent d'avoir une idée de la dynamique pluviométrique (figure 3).

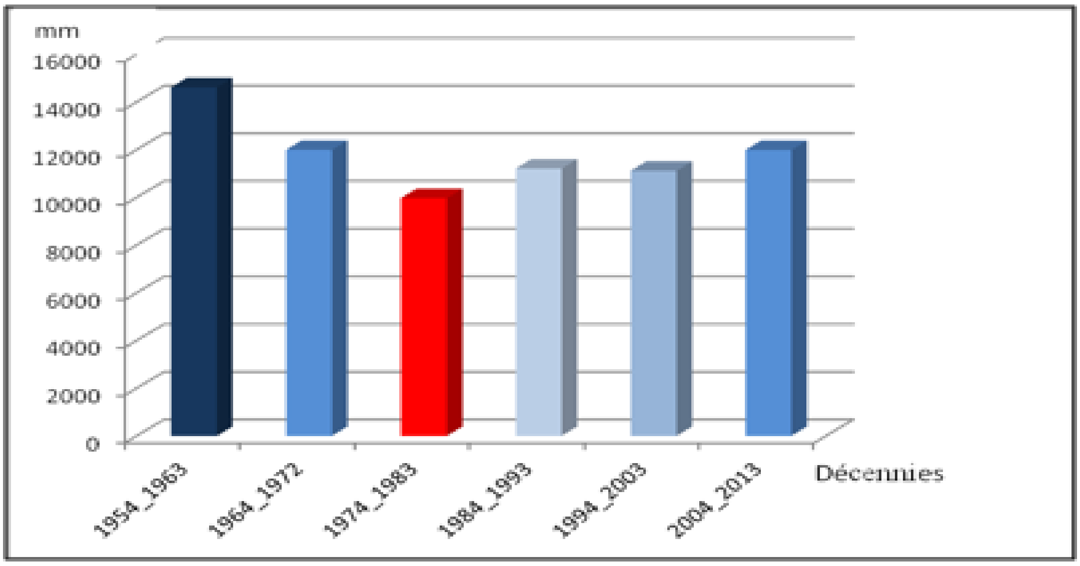


Figure 3 : Evolution décennale de la pluviométrie à la station de Bignona
Source de données : Station pluviométrique de Bignona

Compte tenu de la faiblesse de la pente et de la baisse de la pluviométrie, le fleuve Casamance fonctionne actuellement de manière inverse. Autrement dit, les eaux marines remontent vers l'amont pour compenser les pertes par évaporation en y apportant le sel qui s'y concentre. Le marigot de Baïla et les rizières qui l'environnent, qui sont sous l'influence du fleuve, lui-même alimenté par les eaux marines, sont affectés par la salinisation. Les investigations de Coly (2016) font état d'une concentration en sel des eaux du marigot de l'ordre de 154 g/l. Cette teneur en sel est trois à cinq fois plus élevée que celle de l'eau de mer estimée à 35g/l. Le dépôt et l'accumulation du sel suite à la submersion des terres par les eaux salées, au fil du temps, ont fini par générer la salinisation des rizières. L'un des paramètres physico-chimiques souvent utilisé pour déterminer la salinité du sol est la Conductivité Electrique. La Conductivité Electrique moyenne des rizières de Baïla est de 85,424 mS/cm (Coly, 2016), elle est donc très élevée. Une observation dans les rizières permettra de constater aisément la présence de sel (photo 1).

Photo 1 : Images (1 et 2) illustrant la présence du sel dans les rizières

Tentatives infructueuses de lutte contre la salinisation des rizières

Dans l'esprit de protéger les terres destinées à la culture du riz contre la salinisation, il a été décidé en 2009, sous l'initiative du PAM (Programme Alimentaire Mondial), la construction d'une digue anti-sel d'une dimension d'un mètre de hauteur avec une longueur de 2,654 km. La digue doit être construite par la population locale par le système « Work for Food » autrement dit, « travail contre vivre » et a pour mission de limiter le contact direct entre les eaux salées venant du marigot et les rizières environnantes d'une superficie de 61,550 ha. Même si la population a accepté de commencer les travaux de construction, l'ouvrage n'a pas été achevé pour défaut d'appui en vivre du PAM. Ce qui fait que les eaux salées du marigot n'ont pas pu être endiguées. L'approche mise en œuvre par le PAM dans la réalisation de cette digue comportait beaucoup d'enjeux. Tout au début, la population était motivée par la disponibilité des vivres mais après le retrait du PAM, le projet a connu un arrêt. La participation de la population moyennant une quantité de vivres met cette dernière dans une position attentiste, ce qui ne favorisait pas la continuité de l'action et ne permettait pas l'appropriation du projet par la population locale.

Face à l'échec de l'endiguement des eaux salées, la population se contente d'épandre dans les rizières en proie au sel des matières comme les gousses de Parkia biglobosa ou « néré » dépourvues de leurs graines, les coques d'arachide, les feuilles de manguier (photo 2) et de la cendre. Ces éléments sont perçus localement comme de véritables absorbants de sel. Force est de reconnaître que ces pratiques locales sont loin de donner les résultats escomptés.

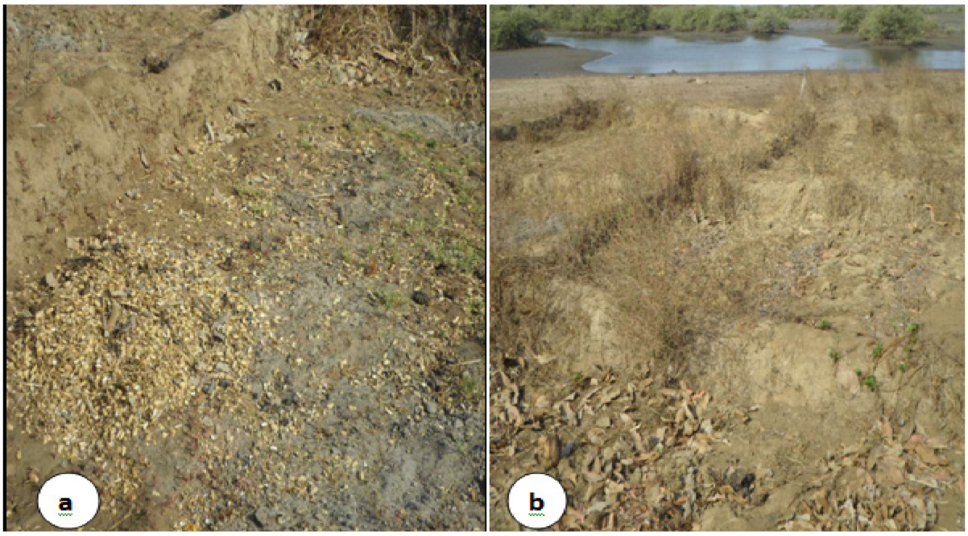


Photo 2 : Coques d'arachide (a) et feuilles de manguier(b) répandues dans les rizières

L'échec de l'ensemble des tentatives de lutte contre la salinisation de terres à vocation rizicole est mis en évidence par l'importance des rizières abandonnées (figure 4) et il importe de souligner que ces dernières représentent à elles seules 75 % des surfaces inondables de Baïla, destinées à la production du riz.

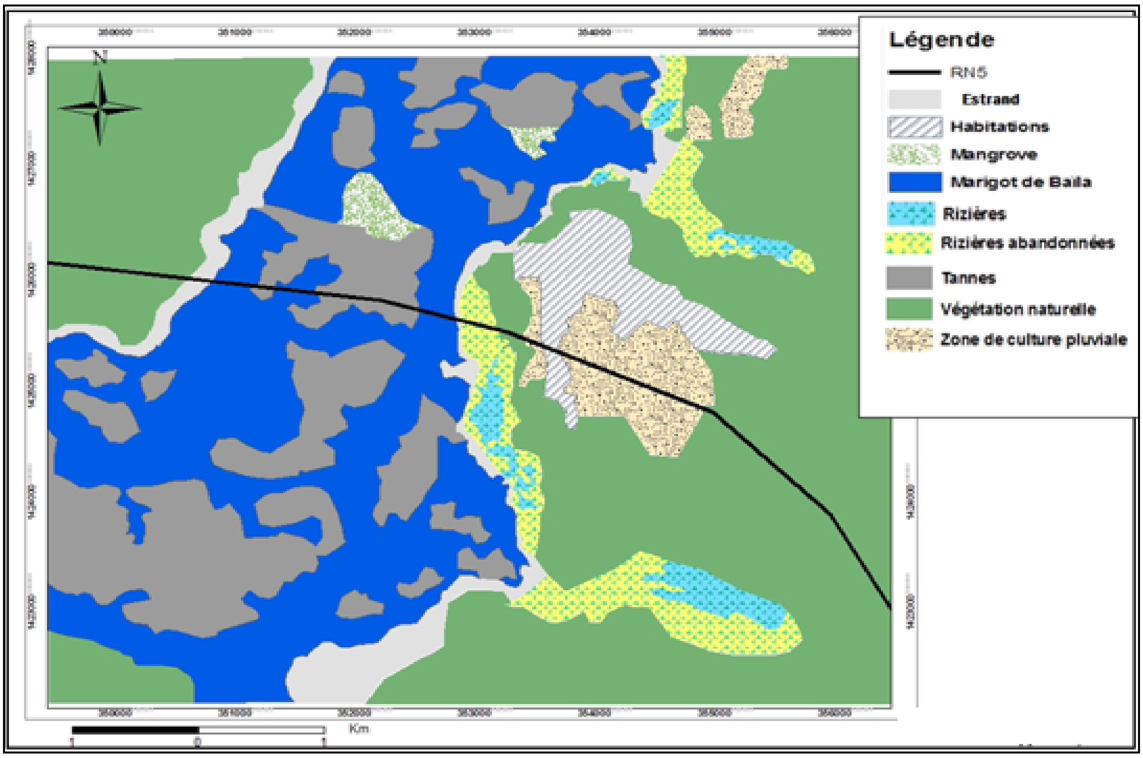


Figure 4 : Carte de l'occupation du sol de Baïla

La multiplication des surfaces rizicoles incultes en quelques décennies, entraîne une pénurie foncière prononcée et le morcellement des parcelles.

Pénurie foncière actuelle pour la culture du riz et morcellement des parcelles

Depuis quelques années le village de Baïla connaît une dynamique démographique. D'après les données du recensement de la population et de l'habitat de 2002, il comptait 1623 habitants. En 2013, on y dénombrait environ 2045 personnes, soit une croissance de 11 % (ANSD, 2013). Les données villageoises avancent le chiffre de 3884 habitants en 2019. Cette croissance de la population et le processus d'individualisation progressif qui s'est mis en place ont eu comme conséquence le morcellement des terres. En effet, les vieux pères ont partagé leurs rizières entre leurs fils, devenus chefs de ménages suite à leur union conjugale. Comme résultat, on assiste à une démultiplication de petites exploitations rizicoles. Notre enquête montre que les exploitations de 79 % des unités domestiques (ménages) ne dépassent guère un demi-hectare (figure 5).

En outre, avec la contraction des rizières sous l'effet de la salinisation, ceux qui avaient prêté certaines de leurs parcelles à leurs voisins ou proches afin qu'ils en tirent le riz nécessaire à leur subsistance, les ont récupérées faute d'avoir assez de terres. Cette situation s'accompagne inéluctablement d'une altération du tissu social voire de tensions latentes. En effet, certains ménages ont difficilement accepté de rendre les terres qu'ils avaient empruntées. L'insuffisance et l'émiettement du foncier pour la production du riz laissent planer une insécurité alimentaire.

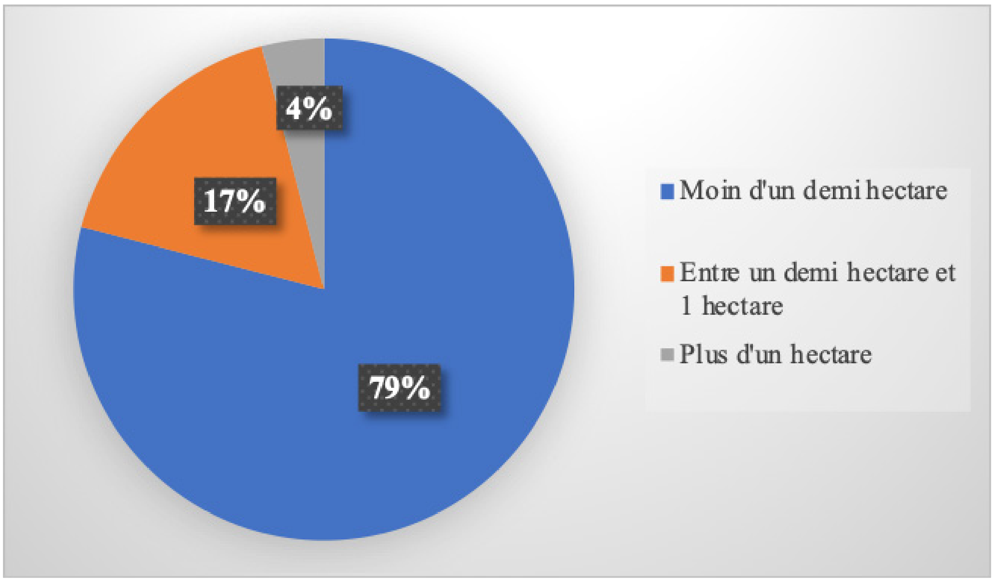


Figure 5 : Répartition de la taille des exploitations rizicoles

La sécurité alimentaire menacée

Pélissier (1966) écrivait « labour, fumure, contrôle de l'eau, telles sont les techniques d'aménagement et d'entretien du sol qui permettent, en Basse Casamance, une riziculture perfectionnée, capable d'utiliser en permanence les différentes surfaces inondables, de tirer parti de la riche gamme de variétés cultivées, d'assurer la sécurité alimentaire ». Ce constat n'est plus d'actualité à Baïla. Certes la riziculture est toujours pratiquée mais elle ne couvre plus les besoins alimentaires. Les quantités récoltées (après décorticage) par les ménages varient entre 14 kg et 975 kg. Cette production est largement décriée par les chefs des ménages qui la jugent très faible par rapport aux besoins. Si jusqu'à la fin des années 1990, la salinisation progressive des rizières n'a pas induit une crise de subsistance, elle constitue, au cours de ces dernières années, une sérieuse menace à la sécurité alimentaire. Ceci s'explique par deux facteurs : d'une part, l'insuffisance de la production liée à l'effet combiné de l'exacerbation de la contraction des surfaces aptes à la culture du riz, l'émiettement des parcelles en activité et la baisse actuelle des rendements et d'autre part l'augmentation des besoins consécutive à la poussée démographique.

Face au déséquilibre entre la production et les besoins et pour assurer leur subsistance, les ménages disposant de moyens financiers recourent à l'achat du riz importé d'Asie. Par contre ceux qui sont dans l'incapacité de se procurer ce riz ont dû sauter un, voire deux des trois repas conventionnels (petit déjeuner, déjeuner et dîner). Actuellement, Baïla fait partie des zones les plus touchées par l'insécurité alimentaire au Sénégal. Cette situation justifie ces dernières années, les interventions sporadiques du PAM à Baïla à travers l'appui en vivres.

CONCLUSION

En somme, la salinisation progressive des terres rizicoles consécutive à la baisse de la pluviométrie, elle-même corollaire au changement climatique, induit dans un contexte de croissance démographique, une insécurité alimentaire à Baïla. Face à cette menace dont les conséquences sont dramatiques, la relance de la riziculture s'impose. Elle passera par la construction d'une véritable digue anti-sel capable de contenir les eaux salées du marigot et de retenir les eaux de ruissèlement dans les rizières pour la dilution du sel. Le financement de cette digue peut provenir des pouvoirs publics sénégalais ou d'une coopération décentralisée que les élus locaux se doivent de nouer ou par des partenaires sensibles à l'amélioration des conditions de vie des ruraux.

RÉFÉRENCES BIBLIOGRAPHIQUES

ANSD (2013). Rapport définitif RGPHAE, 416 p.

Coly J. P. (2016). Salinisation et conséquences dans le terroir de Baïla. Mémoire de Master, université Assane Seck de Ziguinchor, 123 p.

CSE (2003). Évaluation de la dégradation des terres au Sénégal. LADA, Rapport, 59 p.

CSE (2005). Rapport sur l'Etat de l'Environnement. Edition 2005. 204 p.

CSE (2010). Rapport sur l'Etat de l'Environnement. Edition 2010, 266 p.

Diédhiou L. (2004). Riz, symboles et développement chez les Diola de Basse-Casamance. Presse de l'Université Laval 368 p.

Fall R. D. (2006). Les processus de dégradation des terres au Sénégal. Rapport, 12 p.

FAO (2005). World reference base for soil resources. World Soils Resources. Reports Food and Agricultural Organization, Rome, Italy 98 p.

INP (2008). Estimation des superficies affectées par le sel à partir de la carte morphopédologique au 1/500 000 du Sénégal.

INP (2014). Cartographie des sols dominants de 11 vallées du PADERCA (Bona,Briou, Niorory, Madina EIH, Souané, Suelle, Séléky, Tengory, Karthiack, Médiana Boudialabou, Etama, Bandial), Rapport, 58 p.

PELISSIER P. (1966). Les paysans du Sénégal : les civilisations agraires du Cayor à la Casamance. Saint- Yriex, Haute- Vienne : Imprimerie Fabrègue, 941 p.

Poitevin F. (1993). Etude d'impact des techniques culturales sur les aménagements hydro-agricoles dans la région de Podor (Sénégal). Mémoire de Master de l'ESAP, multigr. ORSTOM, Dakar, 53 p.

Sène A. M., Diémé I. L. (2018). Entre développement touristique et recul des espaces rizicoles dans la commune de Diembéring (région de Ziguinchor, Sénégal) : quelle alternative pour un développement local durable ? Belgeo [En ligne], 2 | 2018, mis en ligne le 08 juillet 2018, consulté le 8 mars 2019. URL : http://journals.openedition.org/belgeo/23362.

PART IV :

INNOVATION AND CLIMATE CHANGE

The potential for success in climate change mitigation requires the mobilisation of knowledge and innovative practices in all economic sectors and in particular the agricultural sector. This is confirmed by experiences in the sub-region, particularly in the Sudano-Sahelian zone of Nigeria. Currently, insurance in agriculture is needed to develop and strengthen farmers' resilience to climate change. However, quality and reliable climate predictions must accompany strategies and innovations to enable the implementation of an intelligent agricultural calendar and the selection of suitable agricultural varieties. In the Sahel, these innovations will be highly relevant because food agriculture is highly dependent on rainfall. In these countries where the staple food is millet, maize and sorghum, the promotion of innovative strategies in agriculture can help mitigate the effects of climate change.

This fourth section consists of a set of seven (07) articles that focus mainly on innovations as strategies to respond to the effects of the changing climate cycle:

1. Multi-Crop Supply Response in a Risky Production Environment: Evidence from the Sudano-Sahelian Zone of Nigeria
2. Explaining farmers' willingness-to-insure farms and resilience to climate change in Ghana
3. Is Weather Index Insurance Sufficient for Smallholder Protection? Emerging Insights from Rainfall-Index Calibration of Maize Crop Losses in Central-West Nigeria
4. what drives the adoption of Climate Smart Agricultural Practices? Evidences from Maize Farmers in Northern Nigeria.
5. Factors influencing the adoption of Climate Smart Agriculture by farmers in Segou region in Mali
6. Impact of Climate Change on cereal yield and production in the Sahel: Case of Burkina Faso
7. Impact of Climate-Smart Innovations on food security farming household in Benin: A case study of Drought Tolerant Maize (DTM) varieties

Multi-Crop Supply Response in a Risky Production Environment : Evidence from the Sudano-Sahelian Zone of Nigeria

Yusuf Isah Maikudi

ABSTRACT

This paper is based on the premise that the impact of climate variability and change on crop production decision can either be positive or negative depending on the crop, cropping system and variation in weather patterns. Using time series data (1994-2009) pooled across the sub-regional (states) level in the Sudano-Sahelian zone of Nigeria, two systems of regional multi-crop supply equations represented by a normalized quadratic indirect utility function, assuming linear mean-variance risk preferences were estimated. Parameter estimates with seemingly unrelated regression estimation technique indicate that expected weather and climate risk have impacted negatively on the expected supply of millet and sorghum in spite of risk hedging opportunities provided by a multiple cropping system. Thus, government should increase investment in weather forecast infrastructure are necessary to reduce the mismatch between expected and actual weather realisation, and institutions that will support the introduction of crop weather index insurance should be established in the Sudano-Sahelian zone of Nigeria.

Keywords : Climate variability, Multi-crops supply, Sudano-sahelian zone, Nigeria

RÉSUMÉ

Cet article part du principe que l'impact de la variabilité et du changement climatique sur les décisions de production agricole peut être positif ou négatif selon la culture, le système de culture et la variation des régimes climatiques. À l'aide de données chronologiques (1994-2009) regroupées au niveau sous-régional (États) dans la zone soudano-sahélienne du Nigeria, deux systèmes d'équations régionales d'approvisionnement en cultures multiples représentées par une fonction d'utilité indirecte quadratique normalisée, supposant des préférences linéaires en matière de risque de moyenne-variance, ont été estimés. Les estimations des paramètres avec la technique d'estimation de régression apparemment non liée indiquent que les risques météorologiques et climatiques prévus ont eu un impact négatif sur l'offre prévue de millet et de sorgho malgré les possibilités de couverture des risques offertes par

un système de cultures multiples. Ainsi, le gouvernement devrait augmenter les investissements dans l'infrastructure de prévision météorologique sont nécessaires pour réduire le décalage entre la réalisation météorologique prévue et réelle, et les institutions qui soutiendront l'introduction de l'assurance de l'indice météorologique des cultures devraient être établies dans la zone soudano-sahélienne du Nigeria.

Mots clés : Variabilité climatique, offre de cultures multiples, zone soudano-sahélienne, Nigeria.

INTRODUCTION

Unpredictable and extreme weather induced by climate change and variability have led to land degradation, threatening about 35% of Nigeria's land mass mainly in the Sudano-Sahelian Zone (Nigerian Institute of Social and Economic Research-(NISER, 2010). Several studies show that the climate of Sudano-Sahelian Zone of Nigeria have fluctuated substantially, affecting both intra-annual and inter-annual rainfall patterns (Abaje, Ati, & Iguisi, 2012; Ifabiyi & Ojoye, 2013) as well as key precipitation effectiveness indices (Sawa & Adebayo, 2011). This have impacted on crop yield and yield variability (Akinseye, Ajayi, & Oladitan, 2013; Omotosho, Agele, Balogun, & Adefisan, 2013) creating imbalances in local and regional food markets. These imbalances could worsen the already high level of vulnerability and low adaptive capacity faced by the rural populace (Adesina & Odekunle, 2011; Madu, 2012) due to rapid growth in population as well as high unemployment and poverty rates (Olojo, 2013). Findings from an anthropometric and retrospective mortality survey across the Sudano-Sahelian Zone show also that over 40% of children less than 5 years are suffering from stunting (UNICEF, 2012), highlighting the level of poverty and food insecurity in the study region.

Like in other parts of the country, rural livelihoods in the Sudano-Sahelian Zone of Nigeria are largely based on subsistence rain-fed mixed crop and livestock farming system (Ati, Stigter, Iguisi, & Afolayan, 2009). The cropping system[62] include mono crops, permanent intercrops and mixed farming as well as lands under temporary intercrops in rotation with fallows, all largely on a small scale (Bationo et al., 2012). However, intercropping is the most common cropping system in the Sudano-Sahelian zone (Bationo et al., 2012) and involves the growing of two or more crops in proximity to promote interaction between them (Ibeawuchi, 2007). The intercropping system provides the farmer with several options for returns from land and labor, often increasing efficiency with which scarce resources are used (Norman, 1974). It also reduces dependence upon a single crop that is susceptible to environmental and economic fluctuations (Bationo et al., 2012). This is largely because different crops or

62 A cropping system is an aspect of agricultural production system which consists of one or more crops in which sets of resources and inputs are uniquely managed by the farmer in the production process to satisfy human needs for food, fibre, other products, monetary income and other objectives (Okigbo, 1984) crop varieties have different water demands and phenology, especially in the event of adverse weather patterns (Callo-Concha et al., 2013).

Given that climate change is unlikely to confront a static world, farmers are likely to respond to changes and variation in their natural and economic environment with the aim of making themselves better off (Burke & Lobell, 2010). The extent to which crop producers can adapt clearly raises empirical questions on their supply response to changing climatic conditions. Hence, this paper estimates the impact of climate variability on the supply of two most extensively grown crops (Millet and Sorghum) in the Sudano-Sahelian zone from 1994-2009. This paper fills an important gap in the body of relevant empirical literature (Blanc, 2013; Boussios & Barkley, 2012; Huang & Khanna, 2012; Traboulsi, 2013) because these studies have not taken into account the possibilities of farmers' adaptive response to climate variability and change. Adams et al. (2009) argued that there are several ways that farmers may be able to respond to adverse climatic conditions (for example, by changing crop mixes, cultivars and using fertilizer) to maintain or offset reductions in output levels. In general, studies that ignore these adjustment possibilities are likely to overstate the cost of climate variability and change[63].

METHODS

Data Structure

The annual time series data sets on crop output quantities (millet and sorghum), variable inputs quantities (fertilizer and seeds) and their respective prices and quasi-fixed inputs (area harvested for each crop and family farm labour)[64] from 1994-2009 was collected from the National Bureau of Statistics (NBS) and the National Program on Food Security (NPFS). The aggregate seeds price and quantity variables are indexes for the four crops used in estimating the econometric model. A pooled time-series, cross-sectional (TSCS) panel data structure which generated 128 observations (that is $t = 128$ and $i = 8$).

Weather and technological change are assumed to be exogenous. It is widely accepted that the distribution of rain within the rainy season as well as the utilization of fixed and variable farm inputs has a significant impact on crop yields and output supply. This informed the use of average monthly rainfall data from April to October from Nigerian Meteorological Agency (NIMET)[65] as a measure of climate variability. The mean and variance of rainfall for each of the eight stations at time t was calculated using weights of past realizations. The formula is specified as follows :

$$\bar{\varepsilon}_t = 0.5\varepsilon_{t-1} + 0.33\varepsilon_{t-2} + 0.17\varepsilon_{t-3} \quad (1)$$

$$\sigma^2_{\varepsilon_t} = 0.5(\varepsilon_{t-1} - \bar{\varepsilon}_{t-1})^2 + 0.33(\varepsilon_{t-2} - \bar{\varepsilon}_{t-2})^2 + 0.17(\varepsilon_{t-3} - \bar{\varepsilon}_{t-3})^2 \quad (2)$$

63Solomon, S. et al. (2007) defines climate change as "a change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean and/or the variability of its properties and which persists for an extended period typically decades or longer"

64 Due to the imperfect substitutability between family and hired labour, family farm labour is considered as a quasi-fixed allocable input in the short-run.

65 The ground level rainfall data for Jigawa state was not available. Since Yobe state is close to Jigawa state and has two weather stations (in Potiskum and Nguru) whose data is available, the data for the weather station closer to Jigawa state (that is, Nguru) was used for Jigawa state.

The mean rainfall expression in equation 16 fits adaptive expectation where belief at time t is a weighted average of past realizations. In equation 17, the current variance equals the sum of squares of prediction errors of the three previous years, with declining weights similar to other studies (Coyle, 1999). Also, means $\overline{y}$ and variances Ω_y of crop quantities are defined similar to equation 16 and 17 above respectively. Crop quantities' co-variances Ω_{ik} are defined as follows :

$$\begin{aligned}\Omega_{ik_t} &= 0.5(y_{it-1} - \overline{y}_{it-1})(y_{kt-1} - \overline{y}_{kt-1}) \\ &+0.33(y_{it-2} - \overline{y}_{it-2})(y_{kt-2} - \overline{y}_{kt-2}) \\ &+0.17(y_{it-3} - \overline{y}_{it-3})(y_{kt-3} - \overline{y}_{kt-3})\end{aligned} \tag{3}$$

Trends, other descriptive summary statistics of crop output, monthly rainfall and other variables used are presented in the appendix below. Also in the appendix are the definition and lables of the variables used.

Analytical Framework

The profit function approach to supply analysis provides a conceptual framework for evaluating interdependencies and trade-offs in the production decisions of farmers in mixed cropping system (Wall & Fisher, 1988). Therefore, following the Neumann & Morgenstern (1944) utility theory, the famer maximizes his expected utility of profits $E\left[U\left(\pi\right)\right]$. Thus, a duality model is developed under the following assumptions: (a) linear mean-variance risk preferences (which imply constant absolute risk aversion (CARA)), (b) quadratic indirect utility function and (c) price certainty. Although these assumptions are restrictive, they have been used in several empirical studies on agricultural producer behavior (Coyle, 1999). More importantly, these assumptions imply that the farmer's objective function is almost linear in parameters, which simplifies empirical application. Consequently, the certainty equivalence of a production technology with multiple stochastic outputs based on the foregoing assumptions is specified as follows :

$$EU\left(\pi\right) = \overline{\pi} - \frac{\alpha}{2}\sigma_{\pi}^{2} \tag{4}$$

Where $\overline{\pi}$ and σ_{π}^{2} are the mean and variance of profit which is a random variable. Also, $\alpha > 0$ and measures the coefficient of absolute risk aversion. The randomness in profit is attributed to the revenue component of the profit function because input prices and quantities are assumed to be fixed. Therefore, given a multi-crop production system, the production technology can be specified generally as follows :

$$y = g\left(x, \mathrm{z}, \varepsilon\right) + u \tag{5}$$

Where y is an (m rows) crop output vector, g represents a vector with terms $g_i\left(x, \mathrm{z}, \varepsilon\right)$ which are "well behaved" crop production functions, x is the ($n-m$ rows) variable input vector, z is the ($q-n$ rows) quasi-fixed input vector, ε is a stochastic weather variable with mean $\overline{\varepsilon}$ and variance σ_{ε}^{2} . Note that the weather variable is assumed to be exogenous and random. u is a vector of other random component of crop output with mean 0 and covariance matrix Ω . Taking the mathematical expectation of the second order Taylor Series expansion around $\overline{\varepsilon}$, the expected crop output level can be specified as :

$$\bar{y} = f\left(x, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right) \tag{6}$$

Where $f\left(x, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right)$ is a vector with terms $f_i\left(x, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right)$. Here, it is assumed that ε is unobservable and a producer makes his production plan conditional on mean and variance of past weather variables. The output covariance matrix is defined generally as :

$$\Omega_y = \Omega \tag{7}$$

Recall that the profit function which is stochastic can be fully specified as follows:

$$\pi = \sum_{i=1}^{m} p_i y_i - \sum_{j=1}^{n} w_j x_j \tag{8}$$

Hence, the mean and variance of profit can be expressed as:

$$\bar{\pi} = \sum_{i=1}^{m} p_i \bar{y}_i - \sum_{j=1}^{n} w_j x_j \tag{9}$$

$$\sigma_\pi^2 = p^{'}\Omega p = \sum_{i=1}^{m}\sum_{k=1}^{m} p_i p_k \sigma_{ik} \tag{10}$$

Where p stands for output price vector, w for input price vector and σ_{ik} stands for the covariance between i^{th} and the k^{th} output. By substituting equations 3 in 6, we have

$$\bar{\pi} = \sum_{i=1}^{m} p_i f\left(x, z, \bar{\varepsilon}, \sigma_\varepsilon^2\right) - \sum_{j=1}^{n} w_j x_j$$

If equation 7 and 8 are substituted in equation 1, the certainty equivalent of the profit function can be expressed as follows :

$$EU(\pi) = \sum_{i=1}^{m} p_i f_i\left(x, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right) - \sum_{j=1}^{n} w_j x_j - \frac{\alpha}{2} p^{'}\Omega p \tag{11}$$

From equation 9 above, the first order condition for certainty equivalent profit maximization will yield :

$$\frac{\partial EU(\pi)}{\partial x_j} = \sum_{i=1}^{m} p_i \frac{\partial f_i\left(x, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right)}{\partial x_j} - w_j = 0 \qquad \text{For all} \qquad j = 1....\mathrm{n} \tag{12}$$

Equations 10 provide the necessary condition to reach the optimal expected output and input levels : $\bar{y}_i\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right)$ and $x_j\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right)$. Substituting them into equation 7 and 9 will yield the dual indirect utility function of profit, that is, the relation between maximum feasible utility U and exogenous variables :

$$V\left(p, w, z, \bar{\varepsilon}, \sigma_\varepsilon^2, \Omega\right) = \max_{x_j \geq 0} EU(\pi)$$

$$= EU(\pi)^* = \sum_{i=1}^{m} p_i \bar{y}_i\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right) - \sum_{j=1}^{n} w_j x_j\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right) - \frac{\alpha}{2} p^{'}\Omega p \tag{13}$$

Where $(\pi)^*$ is the maxim making use of the envelop theorem. The partial derivative of equation 11 with respect to input and output prices yields :

$$\frac{\partial V(.)}{\partial p_i} = \bar{y}\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right) + \sum_{k=1}^{m} p_k \frac{\partial \bar{y}_k\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right)}{\partial p_i} - \sum_{j=1}^{n} w_j \frac{\partial x_j\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right)}{\partial p_i} - \frac{1}{2}\alpha \frac{\partial\left(p^{'}\Omega p\right)}{\partial p_i}$$

$$= \bar{y}\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right) + \sum_{j=1}^{m}\left[\left(\sum_{k=1}^{n} p_k \frac{\partial \bar{y}_k\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right)}{\partial x_j} - w_j\right)\frac{\partial x_j}{\partial p_i}\right] - \alpha \sum_{k=1}^{m} p_k \sigma_{ik} \tag{14}$$

$$\frac{\partial V(.)}{\partial w_j} = -x_j\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right) + \sum_{k=1}^{m} p_k \frac{\partial \bar{y}_k\left(\mathrm{p}, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right)}{\partial w_j} - \sum_{j=1}^{n} w_j \frac{\partial x_j\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right)}{\partial w_j}$$

$$= -x_j\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right) + \sum_{j=1}^{n}\left[\left(\sum_{k=1}^{m} p_k \frac{\partial \bar{y}_k\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right)}{\partial x_j} - w_j\right)\frac{\partial x_j}{\partial w_j}\right] \tag{15}$$

By re-arranging, the expected output and input equations can be re-presented thus :

$$\bar{y}_i\left(p, w, \mathrm{z}, \bar{\varepsilon}, \sigma_\varepsilon^2\right) = \frac{\partial V(.)}{p_i} + \alpha \sum_{k=1}^{m} p_k \sigma_{ik} \quad \text{For all} \quad i = 1, \ldots., m \tag{16}$$

$$x_j\left(p, w, z, \bar{\varepsilon}, \sigma_\varepsilon^2\right) = -\frac{\partial V(.)}{\partial w_j} \quad \text{For all} \quad j = 1, \ldots, n \tag{17}$$

The system of expected crop(s) output supply equations (14) and input demand equations (15) are major derivations when uncertainty is accommodated in the production decision of risk non-neutral agricultural producers based on duality theory. All input quantity and prices as well as output prices are fixed, hence there is no effect of risk averseness behavior on the demand system. The proposition that establishes the properties of the system as obtained and its extensive proof can be found in the appendix of Coyle (1999).

Econometric Model

To apply econometrics methods in estimating the indirect utility function, it needs to take a specific functional form. The normalized quadratic specification has been used by several studies due to its appealing theoretical and empirical properties (Shumway, 1983). In addition, the normalized quadratic is attractive and unique for use in empirical applications as correct curvature can be imposed in a parsimonious way without losing the desirable property of flexibility (Diewert & Fox, 2009). Therefore, assuming a normalized quadratic function and using the price of cowpea as numeraire, the following equations reflecting the panel data structure of the system of expected crop(s) supply equations is specified :

$$\bar{y}_{1t} = a_1 + a_{11,t}\frac{p_{1t}}{p_{kt}} + a_{12,t}\frac{p_{2t}}{p_{kt}} + a_{13,t}\frac{w_{1t}}{p_{kt}} + a_{14,t}\frac{w_{2t}}{p_{kt}} + b_{11,t}z_{1t}$$

$$+b_{12,t}z_{2t} + c_{11,t}\sigma^2_{\varepsilon_t}p_{kt} + c_{12,t}\bar{\varepsilon}_t + c_{13,t}p_{kt} + c_{14,t}tt_t + \alpha\left(p_{1t}\Omega_{11} + p_{2t}\Omega_{12}\right.$$

$$\bar{y}_{2t} = a_2 + a_{21,t}\frac{p_{1t}}{p_{kt}} + a_{22,t}\frac{p_{2t}}{p_{kt}} + a_{23,t}\frac{w_{1t}}{p_{kt}} + a_{24,t}\frac{w_{2t}}{p_{kt}} + b_{21,t}z_{1t}$$

$$+b_{22,t}z_{1t} + c_{21,t}\sigma^2_{\varepsilon_t}p_{kt} + c_{22,t}\bar{\varepsilon}_t + c_{23,t}p_{kt} + c_{24,t}tt_t + \alpha\left(p_{2t}\Omega_{22} + p_{1t}\Omega_{12}\right.$$

$$x_{1t} = -\left(a_3 + a_{31,t}\frac{p_{1t}}{p_{kt}} + a_{32,t}\frac{p_{2t}}{p_{kt}} + a_{33,t}\frac{w_{1t}}{p_{kt}} + a_{34,t}\frac{w_{2t}}{p_{kt}} + b_{31,t}z_{1t} + b_{32,t}z_{2t}\right.$$

$$\left.+c_{31,t}\sigma^2_{\varepsilon_t}p_{kt} + c_{32,t}\bar{\varepsilon}_t + c_{33,t}p_{kt} + c_{34,t}tt_t\right)$$

$$x_{2t} = -\left(a_4 + a_{41,t}\frac{p_{1t}}{p_{kt}} + a_{42,t}\frac{p_{2t}}{p_{kt}} + a_{43,t}\frac{w_{1t}}{p_{kt}} + a_{44,t}\frac{w_{2t}}{p_{kt}} + b_{41,t}z_{1t} + b_{42,t}z_{2t}\right.$$

$$\left.+c_{41,t}\sigma^2_{\varepsilon_t}p_{kt} + c_{42,t}\bar{\varepsilon}_t + c_{43,t}p_{kt} + c_{44,t}tt_t\right)$$

$$\Omega_{11t} = -\left(\frac{2}{\alpha}\right)\frac{\sigma^2_{\varepsilon_t}}{\left(p_1/p_{kt}\right)^2}\times\left(a_5 + a_{51,t}\frac{p_{1t}}{p_{kt}} + a_{52,t}\frac{p_{2t}}{p_{kt}} + a_{53,t}\frac{w_{1t}}{p_{kt}} + a_{54,t}\frac{w_{2t}}{p_{kt}}\right.$$

$$\left.+b_{51,t}z_{1t} + b_{52,t}z_{2t} + c_{51,t}\sigma^2_{\varepsilon_t}p_{kt} + c_{52,t}\bar{\varepsilon}_t + c_{53,t}p_{kt} + c_{54,t}tt_t\right)$$

$$\Omega_{22t} = -\left(\frac{2}{\alpha}\right)\frac{\sigma^2_{\varepsilon_t}}{\left(p_2/p_{kt}\right)^2}\times\left(a_6 + a_{61,t}\frac{p_{1t}}{p_{kt}} + a_{62,t}\frac{p_{2t}}{p_{kt}} + a_{63,t}\frac{w_{1t}}{p_{kt}} + a_{64,t}\frac{w_{2t}}{p_{kt}}\right.$$

$$\left.+b_{61,t}z_{1t} + b_{62,t}z_{2t} + c_{61,t}\sigma^2_{\varepsilon_t}p_{kt} + c_{62,t}\bar{\varepsilon}_t + c_{63,t}p_{kt} + c_{64,t}tt_t\right)$$

$$\Omega_{12} = -\frac{1}{\alpha}\frac{\sigma^2_{\varepsilon}}{p_1p_2/p^2_{kt}}\times\left(a_7 + a_{71,t}\frac{p_{1t}}{p_{kt}} + a_{72,t}\frac{p_{2t}}{p_{kt}} + a_{73,t}\frac{w_{1t}}{p_{kt}} + a_{74,t}\frac{w_{2t}}{p_{kt}}\right.$$

To achieve stochasticity in the equation, error terms which presumably represent errors in optimization were added to them. The added error terms were assumed to be inter temporarily independent and symmetrically distributed around zero with non-zero contemporaneous co-variances which satisfy the requirement for the Zellner's (1962) Seemingly Unrelated Regression (SUR) model. t is the time indicator in the panel data structure while k is the parameter indicator. In addition, tt is included as an explanatory variable to captures the effects of technological change over time. A system of two regional expected output supply and input demand equations are estimated.

RESULTS AND DISCUSSION

Due to shared parameters, and because production decisions on one crop is likely to be associated with decisions on another crop, contemporaneous correlation among crop supply equation is likely. Zellner (1962) demonstrated that the Seemingly Unrelated Regression (SUR) method can be used to account for this correlation and give more efficient parameter estimates. In order to account for this correlation, the expected crop(s) supply equations in this study were estimated as a system of seemingly unrelated regression (SUR). The price of cowpea as the least important crop was used as numeric. All the estimates were done using STATA statistical software. Lastly, the logged variables enable the interpretation of the regression coefficients as marginal estimates measuring elasticity.

The results (Tables 1 and 2) show that expected millet supply is decreasing in its own price which negates theoretical expectation, and the coefficient is statistically insignificant. Cross price effect between millet and sorghum indicates that the expected millet supply is increasing in the price sorghum and statistically insignificant. Although price responsiveness of crops is not the focus of this study, it was expected that cross price effect should be negative, therefore giving an indication of substitutability of these crops in face of climate risk. However, the cross-price effect between millet and cowpea is positive and significant at 5% level. In general, a mismatch between actual and expected rainfall over the cropping season impacts negatively on the expected supply of millet. In particular however, regression estimates show that expected millet supply is increasing in the expected rainfall of May and August, with the coefficients statistically significant at 10% and 5% respectively.

The R-square of measure indicates that 79% of the observed variation in expected millets supply is explained by the variables in the model. Similarly, regression results for the expected supply of sorghum equation shows that sorghum supply is increasing and statistically insignificant in its own price which conforms to expectation based on economic theory. The cross-price effects coefficient with respect to millet is negative indicating that an increase in the price of millet impacts negatively on expected sorghum supply. Given that there is some measure of correlation between weather and price changes, the negative cross price effect could also indicate substitution effect in response to rainfall risk which is in conformity with expectation. In general, measures of monthly rainfall expectation are statistically insignificant but increasing in the supply of sorghum. Likewise, about 60% of the measures of seasonal rainfall risk impacts negatively on the supply of sorghum but most of the coefficients are statistically insignificant. The R-square measure suggests that 86% of the changes observed changes in expected sorghum supply is explained by the variables in the regression model.

Table 1: SUR Estimates of Expected Crop Outputs Supply and Inputs Demand Functions in the Sudano-Sahelian Zone of Nigeria

Variable	Millet	Sorghum	Fertilizer	Seed
constant	Na	Na	-70.77 (-0.72)	-241.79 (-2.35)**
lnpmi	-0.02 (-0.06)	-0.66 (-1.74)*	0.33 (0.96)	-0.24 (-0.67)
lnpso	0.26 (0.96)	0.38 (1.27)	-0.29 (-.05)	0.88 (3.06)
lpco	0.86 (2.37)**	0.67 (1.84)*	-0.25 (-0.78)	-0.85 (-2.58)**
lnpfe	0.19 (0.43)	0.52 (1.13)	-0.40 (-0.98)	-0.81 (-1.88)*
lnspi	0.13 (1.20)	0.07 (0.58)	-0.07 (-0.62)	-0.01 (-0.07)
lahm	0.94 (14.98)***	1.17 (15.32)***	0.73 (9.23)***	0.37 (4.87)***
lmfem	-0.09 (-1.16)	0.06 (0.07)	0.23 (3.14)***	0.18 (2.26)**
lffem	0.01 (0.52)	-7.80 (-0.31)	-0.02 (-0.93)	0.04 (1.62)
legrap	-2.81 (-0.13)	0.02 (0.46)	0.08 (2.00)**	-0.02 (-0.63)

legrma	0.09 (1.69)*	0.07 (1.24)	-0.05 (-0.84)	0.11 (1.95)*
legrju	-0.07 (-0.77)	-0.13 (-1.34)	-0.02 (-0.21)	-0.11 (-1.24)
legrjl	0.06 (0.66)	0.08 (0.73)	0.17 (1.80)*	0.26 (2.51)**
legrau	0.35 (2.54)**	0.06 (0.37)	0.26 (2.12)**	0.22 (1.55)
legrse	-0.12 (-1.54)	7.10 (0.08)	-0.20 (2.53)**	-0.34 (-4.20)***

Note: ***P<0.01, **P<0.05, P<0.10. Values in bracket are t statistics
Source: Author's estimation

Table 2: SUR Estimates of Expected Crop Outputs Supply and Inputs Demand Functions in the Sudano-Sahelian Zone of Nigeria (cont.)

Variables	Millet	Sorghum	Fertilizer	Seed
legroc	-8.50 (-0.13)	0.01 (0.19)	0.03 (0.49)	-0.02 (-0.28)
lnvgrap	-0.12 (-0.62)	-0.03 (-0.25)	-0.02 (-0.85)	6.67 (0.23)
lnvgrma	-0.07 (-1.89)*	-0.05 (-1.19)	0.09 (2.25)**	5.63 (0.14)
lnvgrju	0.02 (0.84)	0.01 (0.48)	-0.03 (0.96)	-2.34 (-0.08)
lnvgrjl	-0.05 (-1.98)**	-0.04 (-1.49)	-0.06 (-2.56)**	-0.01 (-0.47)
lnvgrau	-0.03 (-0.89)	0.05 (1.40)	-0.01 (-0.40)	-0.09 (-2.59)**
lnvgrse	-0.04 (-1.62)	-0.03 (-1.00)	-0.05 (-2.27)**	0.03 (1.02)
lnvgroc	8.00 (0.23)	0.07 (1.84)*	-0.01 (-0.34)	0.02 (0.57)
Year	-0.06 (-1.01)	-0.07 (-1.17)	0.04 (0.75)	0.12 (2.34)**
	0.01 (0.86)	-9.17 (-0.66)		
R2	0.79	0.86	0.76	0.72
X2	441.55***	611.77***	266.25***	226.45***
Breusch-Pagan test	51.06***			
Number of Observations	117	117	117	117

Note: ***P<0.01, **P<0.05, P<0.10. Values in bracket are t statistics
Source: Author's estimation

CONCLUSION

Accurate weather forecasts on the start of the rainy season when sowing is done will impact positively on the supply of these crops. As results also indicate that supply of all the crops considered are decreasing in measures of monthly rainfall risks, agricultural insurance programs will provide a hedge against weather risks that farmers face, therefore enabling farmers to be less risk averse. This will impact positively of the supply of these crops as well as the demand for farm inputs, including the utilization of family labour on family farms. Adaptation measures that involve the adjustment of crop calendars could also be useful in addition to providing farmers with climate related information that could help to ensure rational and time-efficient management of the agricultural calendar. Climate index crop insurance also presents opportunities to manage weather risk caused by variation in climatic conditions in a manner that addresses some short comings of the traditional crop insurance.

REFERENCES

Abaje, I. B., Ati, O. F., & Iguisi, E. O. (2012). Recent Trends and Fluctuations of Annual Rainfall in the Sudano-Sahelian Ecological Zone of Nigeria : Risks and Opportunities. Journal of Sustainable Society, Vol. 1, Issue 2, pages 44–51.

Adams, R. M., McCarl, B. A., Segerson, K., Rosenzweig, C., Bryant, K. J., Dixon, B. L., ... Ojima, D. (2009). Economic effects of climate change on US agriculture. In TheImpact of Climate Change on the United States Economy (pages. 18–54). Cambridge University Press. https://doi.org/10.1017/cbo9780511573149.002

Adesina, F. A., & Odekunle, T. O. (2011). Climate Change and Adaptation in Nigeria:Some Background to Nigeria's Response - III. International Conference on Environmental and Agriculture Engineering IPCBEE, Vol. 15, pages 146–154. http://www.ipcbee.com/vol15/26-U30024.pdf

Akinseye, F., Ajayi, V., & Oladitan, T. (2013). Assessing the impacts of climate variability on crop yield over Sudano- Sahelian zone in Nigeria. Access International Journal of Agricultural Sciences, Vol. 1, Issue 7, pages 91–98.

Ati, O. F., Stigter, C. J., Iguisi, E. O., & Afolayan, J. O. (2009). Profile of Rainfall Change and Variability in the Northern Nigeria, 1953-2002. Research Journal of Environmental and Earth Sciences, Vol.1, Issue 2, pages 58–63.

Bationo, A., Kimetu, J., Kihara, J., Traore, Z., Bagayoko, M., Bado, V. B., ... Koala, S. (2012). Cropping systems in the sudano-sahelian zone: Implications on soil fertility management over varied seasons. In Lessons learned from Long-term Soil Fertility Management Experiments in Africa, Springer, Vol. 9789400729, pages. 137–158).

Springer Dordrecht Heidelberg. https://doi.org/10.1007/978-94-007-2938-4_8

Blanc, E. (2013). Food crop supply in sub-Saharan Africa and climate change. Journal of Development and Agricultural Economics, Vol.5, Issue 9, pages 337–350. https://doi.org/10.5897/jdae12.145

Boussios, D., & Barkley, A. (2012). Kansas Grain Supply Response to Economic and Biophysical Factors, period 1977-2007. Ideas.repec.org. Vol 81, Issue 1, pages 180-194

Burke, M., & Lobell, D. (2010). Food Security and Adaptation to Climate Change: What Do We Know? In Book: Climate Change and Food Security, pages. 133–153. https://doi.org/10.1007/978-90-481-2953-9_8

Callo-Concha, D., Gaiser, T., Webber, H., Tischbein, B., Müller, M., & Ewert, F. (2013). Farming in the West African Sudan Savanna: Insights in the context of climate change. African Journal of Agricultural Research, Vol. 8, Issue 38, pages 4693–4705. https://doi.org/10.5897/ajar2013.7153

Coyle, B. T. (1999). Risk Aversion and Yield Uncertainty in Duality Models of Production: A Mean-Variance Approach. American Journal of Agricultural Economics, Vol. 81, Issue 3, pages 553–567.

Diewert, E., & Fox, K. J. . (2009). The Normalized Quadratic Expenditure Function. Economics Working Papers. pages 36, https://EconPapers.repec.org/RePEc:ubc:bricol:erwin_diewert-2009-3

Huang, H., & Khanna, M. (2012). An Econometric Analysis of U.S. Crop Yield and Cropland Acreage: Implications for the Impact of Climate Change..Annual Meeting, July 25-

27, 2010, Denver, Colorado 61527, Agricultural and Applied Economics Association. In SSRN Electronic Journal, pages 0–33 https://doi.org/10.2139/ssrn.1700707

Ibeawuchi, I. I. (2007). Intercropping-A Food Production Strategy for Resource Poor Farmers. Nature and Science, Vol.5, Issue 1, pages 171–174. https://doiorg/10.2320/materia.46.171

Ifabiyi, I. P., & Ojoye, S. (2013). Rainfall Trends in the Sudano-Sahelian Ecological Zone of Nigeria. Earth Science Research, Vol. 2, Issue 2, pages 194–202. https://doi.org/10.5539/esr.v2n2p194

Madu, I. (2012). Spatial Vulnerability of Rural Nigeria to Climate Change. The International Journal of Climate Change: Impacts and Responses, Vol. 3, Issue 4, pages 79–98. https://doi.org/10.18848/1835-7156/cgp/v03i04/37134

Neumann, J. Von, & Morgenstern, O. (1944). Theory of Games and Economic Behavior (Commemorative Edition). American Journal of Agricultural Economics, Vol. 27, Issue 3, https://doi.org/10.2307/j.ctt1r2gkx

NISER. (2010). Socio-Economic Impact of Climate Change in Nigeria (NRND, 2010). Ibadan: New World Press, Ibadan. Retrieved from https://niser.gov.ng/

Norman, D. W. (1974). Rationalising Mixed Cropping under Indigenous Conditions: The Example of Northern Nigeria. The Journal of Development Studies, Vol. 11, Issue 1, pages 3–21. https://doi.org/10.1080/00220387408421509

Okigbo, B. N. (1984). Shifting cultivation in tropical Africa: definition and description. (International Institute of Tropical Agriculture, Ibadan, Nigeria. FAO Accession No:XF8551655.

Olojo, A. (2013). Nigeria's Troubled North: Interrogating the Drivers of Public Support for Boko Haram. Terrorism and Counter-Terrorism Studies, Vol. 4, Issue 7. https://doi.org/10.19165/2013.1.07

Omotosho, J. B., Agele, S. O., Balogun, I. A., & Adefisan, E. A. (2013). Climate variability, crop-climate modeling and water ecophysiology research: implications for plant's capacities for stress acclimation, yield production and food security, Vol. 3, Issue 2, pages 56–69.

Sawa, B. A., & Adebayo, A. A. (2011). The Impact of Climate Change on Precipitation Effectiveness Indices in Northern Nigeria. Research Journal of Environmental and Earth Sciences, Vol. 3, Issue 5, pages 481–486.

Shumway, C. R. (1983). Supply, Demand, and Technology in a Multiproduct Industry: Texas Field Crops. American Journal of Agricultural Economics, Vol. 65, Issue 4, pages 748. https://doi.org/10.2307/1240463

Solomon, S., D., Qin, M., Manning, Z., Chen, M., Marquis, K. B., Averyt, M. T., … Miller, H. L. (2007). Summary for Policymakers. In: Climate Change 2007: The Physical Science

Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. D Qin M Manning Z Chen M Marquis KAveryt M Tignor and HL Miller New York Cambridge University Press Pp, Geneva, 996. https://doi.org/10.1038/446727a

Traboulsi, M. R. (2013). Effect of Climate Change on Supply Response of Florida Citrus Crops EconPapers, No. 143063, pages. 1–13.

UNICEF. (2012). Summary Findings of Cross-Sectional Nutrition Survey Northern Nigeria, Food Security Cluster, pages 1–4. https://fscluster.org/nigeria/document/summary-findings-unicef-cross-sectional

Wall, C. A., & Fisher, B. S. (1988). Supply Rsponse and the Theory of Profit and Production Functions. Review of Marketing and Agricultural Economics. Corpus ID: 153907679

Zellner, A. (1962). An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias Author. Journal of the American Statistical Association, Vol. 57, Issue 298, pages 348–368. https://doi.org/10.1080/01621459.1962.10480664

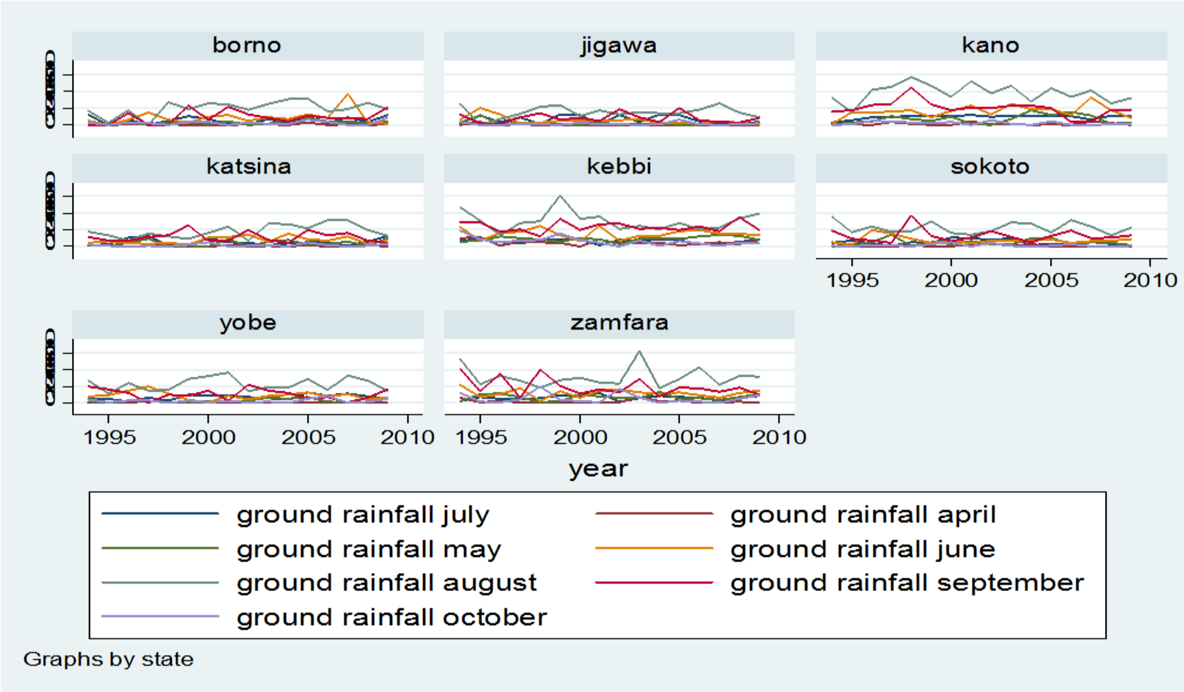
Zheng, Q. (2010). Production, Consumption and Risk in Agricultural Economics. School of Economic Sciences.

APPENDIX

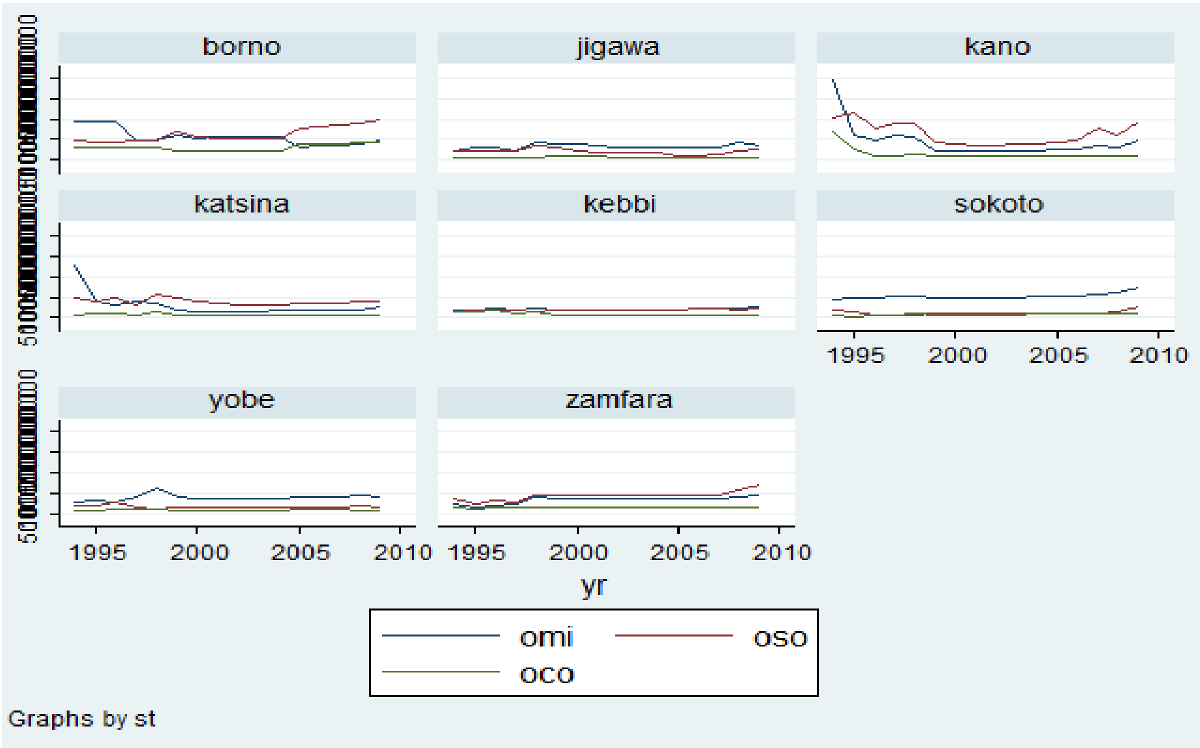
Description of Variables and Labels Continued

S/N0.	Variables	Measurement	Labels
1	pmi	Naira/kg	farm gate price millet
2	pso	Naira/kg	farm gate price sorghum
3	pco	Naira/kg	farm gate price cowpea
4	pfe	Naira/kg	average cost of fertilizer
5	qfe	Kilograms	quantity fertilizer
6	spi	Naira/kg	seed price index
7	sqi	Kilograms	seed quantity index
8	omi	Kilograms	output millet
9	oso	Kilograms	output sorghum
11	ahm	'000 Hectares	area harvested millet
12	ahs	'000 Hectares	area harvested sorghum
14	tfem	'000 Workers	total family employment
15	mfem	'000 Workers	male family employment
16	ffem	'000 Workers	female family employment
24	grap	Millimeters	ground rainfall April
25	grma	Millimeters	ground rainfall May
26	grju	Millimeters	ground rainfall June
27	grjl	Millimeters	ground rainfall July
28	grau	Millimeters	ground rainfall August
29	grse	Millimeters	ground rainfall September
30	groc	Millimeters	ground rainfall October
31	tt		technological change

Trends in Monthly Seasonal Rainfall (NIMET) 1994-2009



Trend in Crop Output Quantity (millet, sorghum and cowpea) 1994-2009



Summary Statistics for pooled TSCS panel data

Variable	Mean	Std. Dev.	Min	Max	Observations
pmi overall	18.64977	5.715762	6.62	33.67	N =128
between		1.27865	17.05937	20.37437	n = 8
within		5.58821	5.425391	31.94539	T=16
pso overall	17.39789	5.547285	5.76	39.73	N =128
between		1.540539	15.66813	20.5775	n = 8
within		5.355317	4.25039	36.55039	T=16
pco overall	19.62094	5.593341	7.68	29.12	N =128
between		1.103276	18.555	22.035	n = 8
within		5.496545	5.395937	29.49219	T=16
pfe overall	34.48047	20.33977	8	78.75	N = 128
between		0.960496	34.24625	34.52063	n = 8
within		20.33779	7.959844	78.98422	T = 16
spi overall	502.5833	251.0674	99.89	1438.6	N = 128
between		181.0055	223.0987	783.4231	n = 8
within		184.7741	-31.03233	1238.548	T = 16
omi overall	379.0005	226.4111	145.7	1967.13	N = 128
between		116.1583	202.685	549.585	n = 8
within		198.4007	129.4155	1908.367	T = 16
oso overall	336.7488	230.8605	55.05	1153.08	N = 128
between		205.5531	105.7094	631.3787	n = 8
within		126.6291	65.37008	858.45	T = 16
ahm overall	368413.3	231997.2	126700	1747350	N = 128
between		115238.4	188560.6	557858.1	n = 8
within		205210.4	139185.2	1731802	T = 16
ahs overall	321308.4	192024.3	126750	1033490	N = 128
between		155393.5	158193.1	573016.9	n = 8
within		124812.8	30851.52	851262.8	T = 16
qfe overall	3976483	2308965	1455360	2188500	N = 128
between		1420.216	2100.375	6044462	n = 8
within		1884.817	1216.020	1981702	T = 16
sqi overall	510.0591	303.468	100	2225.9	N = 128
between		188.3996	212.8519	800.7719	n = 8
within		246.5577	105.3472	1935.187	T = 16
tfem overall	713521.9	292656.7	215300	1710000	N = 128
between		294.0192	291.8313	1245.381	n = 8
within		97.0101	477.1406	1178.141	T = 16
mfem overall	456953.1	331053.6	118000	1249000	N = 128
between		349660.1	144875	1107438	n = 8
within		42128.02	284515.6	598515.6	T = 16
ffem overall	256568.8	187963.1	1000	689000	N = 128
between		185850.2	75687.5	626937.5	n = 8
within		69781.04	119625	626625	T = 16
grap overall	12.30313	21.27368	0	114.6	N = 128
between		15.28268	2.16875	48.30625	n = 8
within		15.70335	-33.40313	78.59687	T = 16
grma overall	47.25156	41.08203	0	175.74	N = 128
between		24.65053	18.5375	89.41875	n = 8
within		33.93897	-17.21094	157.4891	T = 16

grju overall between within	100.8621	67.21369 39.43674 56.09025	0 51.93125 -53.49414	371.6 160.8562 386.1434	N = 128 n = 8 T = 16
grjl overall between within	62.92969	36.65785 14.61406 33.99194	1 49.0625 -5.945313	126 93.875 137.1172	N = 128 n = 8 T = 16
grau overall between within	246.7705	116.9154 77.9385 91.17155	0 150.25 9.583048	625 150.25 9.583048	N = 128 n = 8 T = 16
grse overall between within	142.3105	92.88192 57.59607 75.50863	0 78.9625 -22.58945	441.1 233.5187 389.423	N = 128 n = 8 T = 16
groc overall between within	27.51523	36.23253 19.64035 31.18674	0 10.63125 -34.93477	194.2 62.45 167.7902	N = 128 n = 8 T = 16
tt overall between within	8.5	4.627885 0 4.627885	1 8.5 1	16 8.5 16	N = 128 n = 8 T = 16

Explaining farmers' willingness-to-insure farms and resilience to climate change in Ghana

William Adzawla, Nicaise J. Aman and Moussa Diallo

ABSTRACT

This study analysed farmers' willingness-to-insure their farms and their recovery from climate shocks. Primary data from 209 farmers were collected through multi-stage sampling procedure and analysed using double hurdle and ordered probit regressions. The findings showed that farmers were willing-to-insure their farms and also pay insurance premiums. Farmers' decision to insure their farms was significantly influenced by their membership in a farmer's group, producing beyond subsistence, flood, drought, windstorm, shock awareness and use of drought resistant variety. The level of premiums they are willing to pay was also influenced by education, extension, remitters, prior awareness of shocks and climate perception. Farmers in northern region were generally more willing to insure their farms. Nearly all the farmers indicated ability to recover from climate shocks with varying times and this was influenced by socioeconomic factors such as age, sex, education, adults, extension, credit access, welfare, perception and willing-to-insure farm. Therefore, farm-insurance is an important strategy of making farming households recover faster from climate shocks. Hence, farm insurance policies must be provided to crop farmers in Ghana at an agreed price between farmers and insurance providers.

Keywords: Climate resilience, Double-hurdle model, Farm insurance, Willingness-to-insure, Ghana

RÉSUME

Cette étude a analysé la volonté des agriculteurs d'assurer leurs exploitations et leur rétablissement après des chocs climatiques. Les données primaires de 209 agriculteurs ont été collectées par le biais d'une procédure d'échantillonnage à plusieurs degrés et analysées à l'aide de régressions à double haie et de probits ordonnés. Les résultats montrent que les agriculteurs sont disposés à assurer leurs exploitations et à payer des primes d'assurance. La décision des agriculteurs d'assurer leurs exploitations a été significativement influencée par leur appartenance à un groupe d'agriculteurs, la production au-delà de la subsistance, les inondations, la sécheresse, les tempêtes de vent, la sensibilisation aux chocs et l'utilisation de variétés résistantes à la sécheresse. Le niveau des primes qu'ils sont prêts à payer a également été influencé par l'éducation, la vulgarisation, les remettants, la connaissance préalable des chocs et la perception du climat. Les agriculteurs de la région nord étaient généralement plus disposés à assurer leurs exploitations. Presque tous les agriculteurs ont indiqué leur capacité à se remettre des chocs climatiques dans des délais variables, ce qui a été influencé par des facteurs socio-économiques tels que l'âge, le sexe, l'éducation, les adultes, la vulgarisation, l'accès au crédit, le bien-être, la perception et la volonté d'assurer l'exploitation. Par conséquent, l'assurance agricole est une stratégie importante pour permettre aux ménages agricoles de se remettre plus rapidement des chocs climatiques. Par conséquent, les polices d'assurance agricole doivent être fournies aux agriculteurs au Ghana à un prix convenu entre les agriculteurs et les fournisseurs d'assurance.

Mots-clés : Résilience climatique ; Modèle à double obstacle ; Assurance agricole ; Volonté de s'assurer, Ghana.

INTRODUCTION

A major threat to global development and a concern for both policy makers and researchers is climate change. Scientific predictions and analysis shows that climate change is non-contestable andif nothing is done, its future impacts are high than currently observed. This is likely to constrain the achievement of sustainable development across the world. In a research carried out by Filho et al., (2018), it was established that there is a strong relationship between climate change and development. Africa is particularly projected to experience different and more severe impacts of climate change (Filho et al., 2018; Adenle et al., 2017). The major effect of climate change on Africa isthe impact it has on food security, depletion of natural food sources and habitats (Abrams et al., 2018). Similarly, climate change and variability would decrease crop productivity and resource use efficiency in Africa (Amouzou et al., 2019). Arndt et al. (2015) revealed that climate change could lead to as high as 1.9% reduction of agriculture's share of Ghana's GDP by 2050. Although agriculture is a high climate risk economic activity, it still remains a significant sector of Ghana's economy; contributing 18.9 percent to Gross Domestic Product (GDP) in 2016, 36 percent of employment in 2015 and the primary source of employment for new workers entering the labour force of the country (World Bank, 2018).

It is noted also according to the World Bank (2018) report that growth in the agricultural sector is at least twice more effective in benefiting the poor than growth in the non-agricultural sector of Ghana. Ghana's climate has become drier in recent times and this has major negative implications on all sectors of the country (Ankrah, 2018). Farmers have observed changes in both rainfall and temperatures (Apuri et al., 2018). This has raised concerns for climate adaptation in the country in order to build the resilience of the households. Thus, in order to minimize the agricultural losses and take advantage of existing emerging potentials provided by climate change, there is the need to enhance the resilience of households through climate adaptation (Holzkämper, 2017). Building climate resilience is therefore an essential objective for improving the adaptive capacities of farming households. However, a number of climate adaptation strategies are available to farmers, of which this research focused on one which is farm insurance. This is one of the means to ensure that there is no loss of livelihoods under worse climate conditions ; hence, farmers must start to insure their farms.

Falco et al. (2014) noted that financial insurance against extreme climate events is an important strategy for prevarication of the impacts of climate change, and further argued that crop insurance is likely to increase under climate change. Although risks and shocks are common feature of crop production, farmers can rely on insurance and other financial mechanisms to protect their livelihoods against these shocks (Jensen and Barrett, 2017). Unfortunately for most rural parts of developing countries where agriculture is their mainstay, there is nearly nonexistence of insurance opportunities (Jensen and Barrett, 2017). Müller et al. (2017) described farm insurance as largely a 'developed country businesses. Jensen and Barrett (2017) observed that, the absence of agricultural insurance opportunities have forced rural farm households to adopt strategies that are detrimental to their wellbeing. This for instance involves engaging in low risk and low yielding production practices, skipping of meals, selling of capital assets and withdrawal of children from school. Müller et al. (2017) also explained that if adaptation is not carefully developed with local-specificity, it would lead to mal-adaptation which would have negative consequences on the households. Because climate shocks are covariate in nature (affects several people within an area), it can be concluded that exposure to uninsured climate risks is a major reason for low yields, persistent poverty and slow growth in most rural agrarian economies. The severity of climate shocks means that farming households are unable to offset the impacts from self-finance mechanisms such as using savings or credit facilities. Jensen and Barrett (2017) concluded that although index insurance does not remedy all the impacts of climate shocks or risks, it is a cost-effective approach of providing social support and improving the lives of rural agrarian households.

Although studies on the impacts of market systems such as insurance on poverty reduction have been given a considerable study, the impacts on climate resilience of farm household is less studied (Kuhl, 2018). Like most developing countries, farm insurance is less developed and promoted among farming households in Ghana. Therefore, there is the need to first examine the existence of or otherwise, a potential market for farm insurance in the Northern region of Ghana. Also, this study analysed the effects of climate shocks on the farmers' decision to insure their farms and the impact of farm insurance on climate resilience of the farm households.

METHODS

Study area

The study was conducted in the Northern Region of Ghana. As at the time of the study design and data collection, this wasa single region but now divided into three (Northern region, North East and Savannah region) by constitutional instrument in 2019.The then Northern region occupied 70,384 square kilometres of Ghana's landmass. Due to its geographical location, temperatures are higher than the southern parts of the country and also have only one cropping season due to a uni-modal rainfall pattern; a mean annual rainfall of 740mm minimum and 1230mm maximum. Associated with these climatic conditions are shocks such as floods, droughts, bush fires and diseases. The region is widely seen as one of the most vulnerable regions to climate change in the country. Majority, 69.72%, of the residents are located in rural areas and engages primarilyin agriculture (GSS, 2012; 2015).

Sampling procedureand data collection

The research employed a multi-stage technique in the selection of the respondents. In the first stage, stratified sampling was used to put the various districts of Northern region into three strata. In the second stage, one district from each stratum was selected using simple random sampling procedure. In the third stage, simple random was used to select three communities from each selected district. Again, simple random sampling was used to select a total of 23 farmers from each community; given a total of 209 farmers.

The study used a primary data that was collected in 2017. The primary data was obtained through the administration of pre-tested questionnaires.The data collected includes information on the socioeconomic characteristics of the farmers, climate shocks experienced by farmers within the past ten years, farmers perceptions on climate change, farm characteristics and farmers willing-to-insure their farms.

Analytical framework and empirical model

Theoretically, farmers make rational decisions based on expected benefits from farm insurance. Therefore, the theory of utility maximisation was used as the theoretical explanation of the study. Empirically, a double hurdle model as proposed by Craig (1971) was used to analyse both the decision and amount farmers are willing-to-pay as an insurance premium while an ordered probit was fitted to estimate the effect of insurance decision on climate resilience of farmers.

From the utility maximization theory, a farmer takes a decision on whether or not to insure his farm, and the amount to pay based on the expected satisfaction or benefits from each decision. The farmer does not only consider how to maximize profit from a decision but considers how to attain the highest level of utility, otherwise referred to as utility maximization (McConnell and Leibold, 2009). This means that the utility levels for farmers differ from one another. Ultimately, a farmer takes a decision that would give the maximum expected benefit. In this study for instance, a farmer is faced with two discrete choices, either to insure farm or not to insure farm. These types of discrete choices are modelled using the random utility theory. Choices made between alternatives will be a function of the probability that the utility associated with a particular optionis higher than those for the other alternative(Hensher et al., 2005). However, there is no market incentive for farm insurance in the study area. Therefore, economic analysis of these types of relationship follows the stated preference approach. In this study, the contingent valuation (CV) method was used to provide a further theoretical diagnosis of the empirical work.

Contingent Evaluation (CV) is a widely used technique for estimating non-market benefits of environmental goods and services (Vossler and Kerkvliet, 2003; Venkatachalam, 2004). The efficiency can be improved by asking a follow-up question relative to a single dichotomous choice question when there is inconsistency in responses. Hanemann et al., (1991) have argued that the double bounded model and its variations provide efficient estimates beyond the single bounded models. Therefore, the double bound approach was used to ellicit information from the farmers. The empirical models to estimate the decision and amount willing-to-pay for farm insurance is given as :

$$Y = b_0 + b_1 Farmer\ group + b_2 Extension + b_3 Commercial\ production + b_4 Education + b_5 C\lim ate\ perception$$
$$+ b_6 prioaware + b_7 emigremit + b_8 Off - farm + b_9 drought + b_0\ flood + b_1\ Windstorm$$
$$+ b_2\ Drought\ \ resis\tan t\ \ \mathrm{var}\, iety + \varepsilon_i \qquad (1)$$

Where Y is defined the decision and premium.The definition of the independent variables and their mean statistics are provided in Table 1.
In addition to the farm insurance, an ordered probit was estimated to determine the effects of farm-insurance on the recovery period of the farmers from climate shocks. This is given as :

$$\begin{aligned} recovery\ period &= \gamma_0 + \gamma_1 Age + \gamma_2 Sex + \gamma_3 Education + \gamma_4 Adults + \gamma_5 Children \\ &+ \gamma_6 Extension + \gamma_7 Contract\ farming + \gamma_8 Farmer\ group \\ &+ \gamma_9 Credit\ access + \gamma_{10} Farm\ size + \gamma_{11} Climate\ perception \\ &+ \gamma_{12} Farm\ insurance + u_i \qquad (2) \end{aligned}$$

Table 1: Definition of variables

Variable	Definition
Age	The number of years from birth
Sex	Dummy: 1 for males, 0 for females
Adults	Number of household members with 18 years and above
Children	Number of household members with ages less than 18 years
Education	Total number of years of formal education
Experience	Total number of years into farming
Extension	Dummy: 1 if a farmer had access to extension service and 0 if not.
Farmer group	Dummy: 1 if a farmer belonged to a farmer group and 0 if not.
Remitters	Total number of family members outside the community who sends money home.
Contract farming	Dummy: 1 for contract farmers, 0 otherwise
Farm size	Total acreage cultivated by a farmer
Credit	Dummy: 1 for farmers who accessed credit,0 if otherwise
Commercial production	Dummy: 1 if farmer produce for sale or partly for sale and 0 for sole subsistence
Flood	Total number of times in 5 years a farmer experienced floods on farm.
Drought	Total number of times in 5 years a farmer experienced droughts on farm.
Windstorm	Total number of times in 5 years where windstorm destroyed farmer's farm.
Shock awareness	1 if a farmer was aware of a climate shock prior to its occurrence, 0 otherwise.

Climate perception	Dummy: 1 if farmer perceived rainfall as decreasing and temperature increasing, 0 if otherwise.
Drought resistant varieties	Dummy: 1 if a farmer planted drought resistant maize variety and 0 otherwise.
WTP-decision	Dummy: 1 if a farmer is willing-to-insure farm, 0 if otherwise.
WTP-Amount	The premium (in Ghana cedis) a farmer is willing-to-pay to insure farm.

RESULTS AND DISCUSSION

Factors explaining farmers' decision to insure farms and the premiums willing to pay

The outcome from Table 1 shows willingness-to-insure decisions and amount willing-to-pay as an annual insurance premium. From the result, farmer groups, commercial production, flood, drought, windstorm, shock awareness and drought resistant variety had significant effect on the decision to insure farms. Also, education, extension, remitters, awareness of shocks and climate perception had significant effect on the premium farmers were willing-to-pay for farm insurance.

The effect of education on willingness-to-pay is positive in both the decision and the amount. Thus, farmers with higher formal education have higher probabilities of insuring their farms and were willing-to-pay higher insurance premiums. This is consistent with Ali (2013), Falola et at., (2013) andEllis, (2016)who also found a positive relationship between education and willingness-to-pay. Farmer groups have a mixed effect on willingness-to-insure farms. While it had a negative effect on insurance decision, it had a positive effect on insurance premium. However, the effect is statistically significant only at the decision stage. This means that farmers who belonged to a farmer group were less likely to insure their farms. Nonetheless, Elum et al. (2018) also found a negative insignificant effect of farmer group on crop insurance decision. Extension access had a positive effect on both the decision and amount farmers were willing-to-pay for farm insurance. This is significant for the amount but insignificant for the decision. This means that farmers who had access to extension services have higher probabilities of engaging in farm insurance and were willing-to-pay higher amounts for insurance. This is contrary to the findings in Ellis, (2016).

Commercial production had a positive significant effect on farmers' decision to insure their farms. This means that farmers who produced solely or partly for sale were more willing-to-insure their farms than those who produce solely for domestic consumption. This is because the commercial producers see their farms as a business venture that needs to be insured.The number of remitters in a household increases the decision of farmers to declare higher willingness-to-pay amount for farm insurance. This is because the extra incomes received from remitters can cushion the ability of the farmers to pay for farm insurance.

All climate variables had significant effect on the willingness-to-insure decisions of the farmers except climate perception. For the amount farmers were willing-to-pay, only climate perception and shock awareness were statistically significant. Thus, climate shocks have no significant effect on the amount farmers were willing-to-pay for farm insurance but only on the decision to insure. The positive significant effect of drought and floods means that farmers who experienced these climate shocks were more willing-to-insure their farms than those who did not experience these shocks. This is because the farmers become risk averse after experiencing climate shocks and would be willing to engage in strategies that would spread risks and reduce their exposure and vulnerability to climate shocks. Jones and Tanner (2017) observed that experiencing shocks positively and significantly affects the amount farmers are willing-to-pay for insurance. Elum et al. (2018) found that there is a positive relationship between crop insurance and rainfall level.It is not clear the mechanisms through which the experience of windstorms would reduce the willingness-to-insure decision of the farmers. It was evident from the result that, farmers who were aware of climate shocks prior to their occurrences had less probabilities of declaring a positive willingness-to-insure their farms. This is because, as the farmers become aware of these shocks, they adopt coping strategies to minimise the impacts from the shocks (Jiri et al., 2017). For instance, prior to floods, the farmers could have constructed bunds around their farms or harvest their cropsthat were almost matured. Contrarily,Ellis, (2016) estimated a positive relationship between awareness and ability to buy and pay for insurance.

Table 1: Determinants of farmers' willingness-to-insure and premium for insurance

Variable	Decision			Amount		
	Coeff.	Std. error	P value	Coeff.	Std. error	P-value
Education	0.142	0.004	0.998	0.073***	0.024	0.003
Farmer groups	-0.135***	0.044	0.002	0.026	0.203	0.897
Extension	0.057	0.039	0.140	0.463**	0.195	0.018
Commercial production	0.049**	0.021	0.017	0.142	0.105	0.177
Remitters	-0.026	0.018	0.141	-0.117*	0.064	0.066
Flood	0.034*	0.019	0.072	0.131	0.105	0.213
Drought	0.028**	0.013	0.038	0.059	0.696	0.393
Windstorm	-0.040**	0.019	0.036	-0.098	0.100	0.33
Shock awareness	-0.077**	0.038	0.041	0.361*	0.192	0.061
Climate perception	-0.035	0.045	0.429	-0.549**	0.232	0.018
Drought resistant	0.095*	0.050	0.056	-0.191	0.242	0.431
Log likelihood (-178.86)Pseudo R2 =0.1674						

Note: ***, ** and * indicates significance at 1%, 5% and 10%, respectively.
Source: Field Survey, 2017

Factors explaining households' recovery period from climate shocks

Factors explaining the recovery period from climate shocks by the farmers can be seen in Table 2. This self-reported recovery periods are a measure of the resilience of the farming households. Therefore, these results are interpreted as the determinants of households' resilience. Thus, the faster the household recover from climate shock, the higher the resilience to climate shocks. From the result, age, sex, education, adults, extension, credit access, welfare, perception and willing-to-insure farm had significant effect on the recovery period of farming households. The dependent variable in the model ranged from 1 (bounce back same season), 2 (bounce back after one season), 3 (bounce back after two seasons), 4 (bounce back after three seasons) to 5 (never bounce back after climate shock). Therefore, the negative coefficients means that farmers recovered faster from climate shocks if the variable is positive or increased.

The effect of age on recovery period is negative. This means that age decreases the probability of recovering back faster and increase the probability of bouncing back faster from climate shocks. Hence, the elderly farmers recovered faster than the younger farmers. Consistently, Jiri et al. (2017) argued that younger farmers are more likely to adapt to climate change because of their flexibility in adopting new or modern technologies as well as their access and use of modern information.The result shows that the male farmers have higher chance of recoveringlately from climate shocks than female farmers. Although this is contrary to expectations, this justified that there is a quick positive response in investment programs that seeks to reduce the climate vulnerability of female farmers. Although not significant, Tesso et al. (2012) estimated a positive effect of sex on the recovery period of farming households. Similarly, existing biases against women increases their challenge in adapting their farming practices against climate risks, thereby, reducing women's resilience (Perez et al., 2015). Consistent with the expectations of the research, education had a negative significant effect on recovery period. Thus, an increase in the educational level of the farmer decrease the probability of recovering back lately from climate shocks. Consistently, Tesso et al. (2012) found that education is an essential factor in building households' resilience to climate change. Similarly, Kassem et al. (2019) also estimated that education improves climate adaptation abilities of farmers.

Access to extension services had a negative significant effect on recovery period. Thus, farmers who had access to extension services had lesser probabilities of recovering lately. In order words, access to extension service reduces the recovery period of the farmers. Consistent with this finding, Jiri et al. (2017) found that access to climate information through extension services improve the adaptive capacities of households. Kassem et al. (2019) recommended for extension to improve awareness on anticipated effects of climate change. Access to credit had a positive significant effect on recovery period from climate shocks. Thus, farmers who had access to credit had a higher probability of recovering lately from climate shocks. The implication is that in the midst of climate shocks, the provision of credit to farmers may not be an ideal situation unless well regulated. This does not invalidate the positive role of credit in improving adaptive capacities of households. For instance, in Jiri et al. (2017),it was evident that farmers with access to credit are more likely to adapt to climate change. The effect of farmers' perceptions on climate change is positive. This implied that farmers who correctly predicted changes in temperature and rainfall have higher probabilities of recovering lately from climate shocks. This is contrary to the expectations of the research since it was expected that farmers who have an understanding of climate change would be able to take necessary steps to improve their resilience.

Consistently, farm insurance (proxied by the farmers willingness-to-insure) had a negative effect on the recovery period of farmers. Thus, farmers who insured their farms have higher probability of recovering faster from climate shocks. This is due to the fact that the farm insurance provides the opportunity for the farmers to gain the losses they incurred on their farms. Hence, the impacts of climate shocks are negated by farm insurance, hence, shortening the recovery period of the farmers. This justified the need for providing farm insurance opportunities to farmers to avert the impact of climate shocks. It was clear in article 8 of the Paris agreement that there is the need for risk insurance facilities, climate risk pooling and other insurance solutions in the midst of climate change (United Nations, 2015). Falco et al. (2014) also noted that financial insurance is an important tool for hedging the impacts of climate change, especially on welfare losses. For Elum et al. (2018), agricultural insurance is being promoted to improve adaptation to climate change and improve farm production and farmers' livelihoods, as a result, estimated a positive impact of crop insurance on net farm income.

Table 2: Determinants of recovery period from climate shocks by farmers

				Marginal effects of recovery periods (Seasons)				
Variable	Coef.	Std. Err.	P>z	Same season	After one season	After two season	After three season	Never recovered
Age	-0.012*	0.006	0.053	0.002	0.002	-0.002	-0.002	0.0003
Sex	0.306*	0.180	0.089	-0.060	-0.061	0.050	0.062	0.009
Education	-0.016	0.019	0.387	0.003	0.003	-0.003	-0.003	0.0005
Adults	0.047**	0.022	0.038	-0.009	-0.009	0.008	0.009	0.001
Children	-0.009	0.024	0.709	0.002	0.002	-0.001	-0.002	0.0003
Extension	-0.278*	0.163	0.089	0.054	0.055	-0.045	-0.056	-0.008
Contract farming	-0.349	0.217	0.108	0.068	0.070	-0.057	-0.070	-0.010
Farmer groups	-0.211	0.158	0.180	0.041	0.042	-0.035	-0.043	-0.006
Credit access	0.540***	0.170	0.002	-0.105	-0.108	0.088	0.109	0.016
Farm size	-0.018	0.013	0.160	0.004	0.004	-0.003	-0.004	-0.001
Perception	0.333**	0.159	0.037	-0.065	-0.066	0.054	0.067	0.010
Willingness-to-insured	-0.521***	0.159	0.001	0.102	0.104	-0.085	-0.105	-0.015
Pseudo R square		0.859						

Note: ***, ** and * indicates significance at 1%, 5% and 10%, respectively.
Source: Field Survey, 2017

CONCLUSION

In this study, we examined the farmers' perceptions on climate change, their willingness-to-insure their farms and their resilience to climate shocks. Generally, it is concluded that most of the farmers were willing-to-insure their farms as well as willing-to-pay a positive premium for farm insurance. From the result, farmer groups, commercial production, flood, drought, windstorm, shock awareness and drought resistant variety had significant effect on the decision to insure farms. On the other hand, education, extension, remitters, prior awareness of shocks and climate perception had significant effect on the premium farmers were willing-to-pay for farm insurance.Evident from the study, climate shocks positively influenced farmers' willingness-to-insure their farms.

It is concluded from the findings that the farmers are generally able to recover from climate shocks after one season but not more than two seasons. Nearly all the farmers indicated the ability to recover from climate shocks with varying time periods. Generally, the factors that had significant effect on the recovery period of the farmers were age, sex, education, adults, extension, credit access, welfare, perception and willing-to-insure farm. It is concluded therefore that farm-insurance is an important strategy of making farming households more resilient to climate shocks. As such, there is the need to introduce farm insurance policies to crop farmers in the region. In order to ensure that the farmers remain loyal to the insurance policies, an appropriate premium should be determined based on the farmers declared premiums and not solely determined by the insurance providers. Also, in order to ensure that farmersrecover faster from climate shocks, there is the need to improve extension service delivery and education of farmers on climate change.

REFERENCES

Abrams R. W, Abrams J. F & Abrams A. L. (2018). Climate change challenges for Africa. Encyclopedia of the Anthropocene, Vol. 2, pages 177-194. Reference Module in Earth Systems and Environmental Sciences . Elsevier, Amsterdam, Netherlands, ISBN 978-0-12-813576-1 DOI https://doi.org/10.1016/B978-0-12-809665-9.09754-8.

Adenle A. A., Ford J D., Morton J, Twomlow S. Alverson K., Cattaneo A. Cervigni R., Kurukulasuriya P. Huq S., Helfgott A. & Ebinger J. O (2017). Managing climate change risks in Africa - A Global Perspective. Ecological Economics, ELSEVIER, Vol.141, Issue C, pages 190–201.

Ali A (2013). Farmers' willingness to pay for index based crop insurance in Pakistan: A case study on food and cash crops of rain-fed areas. Agricultural Economics Research Review, Vol. 26, Issue 2, pages 241-248.

Amouzou, K. A., Lamers, J.P.A., Naab, J.B., Borgemeister,C., Vlek, P.L.G., & Becker. M. Climate change impact on water- and nitrogen-use efficiencies and yields of maize and sorghum in the northern Benin dry savannah, West Africa, Field Crop. Res., Vol. 235, pages 104-117.

Ankrah J. (2018). Climate change impacts and coastal livelihoods; an analysis of fishers of coastal Winneba, Ghana.Ocean and Coastal Management, Vol. 161, pages 141–146.

Apuri I., Peprah K. & Achana G.T.W (2018). Climate change adaptation through agroforestry: The case of KassenaNankana West District, Ghana. Environmental Development, Vol. 28, pages 32–41.

Arndt, C., Asante, F., & Thurlow, J. (2015). Implications of climate change for Ghana's economy. Sustainability, Vol. 7, Issue 6, pages 7214–7231.

Cragg J. G (1971). Some statistical models for limited dependent variables with application to the demand for durable goods. Econometrica, Vol. 39, Issue 5, pages 829–844.

Ellis E. (2016). Farmers Willingness to pay for crop insurance: Evidence from Eastern Ghana. MPHIL thesis. McGill University, Montréal; Quebec: Canada. International Journal of Agricultural Management and Development (IJAMAD). Vol. 7, Issue 4, pages 447-463.

Elum Z. A., Nhamo G. & Antwi M. A. Effects of climate variability and insurance adoption on crop production in select provinces of South Africa. Journal of Water and Climate Change, Vol. 9, Issue 3, pages 500-511.

Falco S. D., Adinolfi F., Bozzola M. & Capitanio F. (2014).Crop Insurance as a Strategy for Adapting to Climate Change. Journal of Agricultural Economics, Vol. 65, Issue 2, pages 485–504.

Falola, A., Ayinde, A.E. & Agboola, B.O. (2013).Willingness to take agricultural insurance by cocoa farmers in Nigeria. International Journal of Food and Agricultural Economics Vol. 1, Issue 1, pages 97-107.

Filho W.L., Balogun A., Ayal D. Y., Bethurem E. M., Murambadoro M., Mambo J., Taddese H., Tefera G. W., Nagy G.J., Fudjumdjum H., & Mugabe P. (2018). Strengthening climate change adaptation capacity in Africa- case studies from six major African cities and policy implications. Environmental Science and Policy, Vol.86, pages 29–37.

GSS. (2015). Ghana poverty mapping report. Accra, Ghana. https://www2.statsghana.gov.gh/docfiles/publications/POVERTY%20MAP%20FOR%20GHANA-05102015.pdf.

GSS. (2012). Ghana Statistical Service. 2010 population and housing census summary report of final results May, 2012. https://www.statsghana.gov.gh/gssmain/storage/img/marqueeupdater/Census2010_Summary_report_of_final_results.pdf

Hanemann W. M., Loomis J. & Kanninen B. J. (1991).Statistical efficiency of double bounded dichotomous choice contingent valuation.American Journal of Agricultural Economics, Vol. 73, Issue 4, pages 1255-1263.

Hensher D. A., Rose J. M and Greene W. H. (2005). Applied choice analysis: A primer. Cambridge: Cambridge University Press.

Holzkämper A. (2017). Adapting agricultural production systems to climate change : What's the use of models? Agriculture, Vol. 7, Issue 10, pages 86.

Jensen N. & Barrett C. (2017). Agricultural Index Insurance for Development. Applied Economic Perspectives and Policy, Vol. 39, Issue 2, pages 199–219.

Jiri O., Mafongoya P. L. & Chivenge P. (2017).Building climate change resilience through adaptation in smallholder farming systems in semi-arid Zimbabwe.International Journal of Climate Change Strategies and Management, Vol. 9, Issue 2, pages 151-165.

Jones L. & Tannner T. (2017). 'Subjective resilience': using perceptions to quantify household resilience to climate extremes and disasters. Regional Environmental Change, Vol. 17, Issue 1, pages 229–243.

Kassem H. S., Bello A. R. S., Alotaibi B. M., Aldosri F. O. & Straquadine G. S. (2019). Climate Change Adaptation in the Delta Nile Region of Egypt: Implications for Agricultural Extension. Sustainability Vol. 11, Issue 3, pages 1-22.

Kuhl L. (2018). Potential contributions of market-systems development initiatives for building climate resilience. World Development, Vol. 108, Issue C, pages 131–144.

McConnell A. R. & Leibold J. M. (2009). Weak criticisms and selective evidence: Reply to Blanton et al. (2009). Journal of Applied Psychology, Vol. 94, Issue 3, pages 583-589.

Müller B., Johnson L. & Kreuer D. (2017).Maladaptive outcomes of climate insurance in agriculture. Global Environmental Change. Vol. 46, pages 23–33.

Perez C., Jones E. M., Kristjanson P., Cramer L., Thornton P.K., Förch W. & Barahona C. (2015). How resilient are farming households and communities to a changing climate in Africa? A gender-based perspective. Global Environmental Change, Vol. 34, pages 95-107.

Tesso G., Emana B. & Ketema M. (2012). Analysis of vulnerability and resilience to climate change induced shocks in North Shewa, Ethiopia. Agricultural Sciences, Vol. 3, Issue 6, pages 871-888. United Nations (2015). Paris agreement. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

Velandia M., Rejesus R. M., Knight T. O. & Sherrick B. J. (2009). Factors affecting farmers' utilization of agricultural risk management tools: The case of crop insurance, forward contracting, and spreading sales. Journal of Agricultural and Applied Economics, Vol. 41, Issue 1, pages 107–123.

Venkatachalam, L (2004). The contingent valuation method: a review. Environmental impact Assessment Review, Vol. 24, Issue 1, pages 89-124.

Vossler C.A. & Kerkvliet J. (2003). A criterion validity test of the contingent valuation method: comparing hypothetical and actual voting behaviour for a publicreferendum. Journal of Environmental Economics and Management, Vol. 45, Issue 3, pages 631-649.

World Bank (2018). 3rd Ghana economic update- agriculture as an engine of growthand jobs creation. World Bank Group. https://www.worldbank.org/en/country/ghana/publication/ghana-economic-update-agriculture-ghana-s-engine-of-growth-for-jobs-creation.

Is Weather Index Insurance Sufficient for Smallholder Protection ? Emerging Insights from Rainfall-Index Calibration of Maize Crop Losses in Central-West Nigeria

David Olufemi Awolala

ABSTRACT

Residual impacts from rainfall deficit and failures of traditional crop insurance to protect smallholders are resulting in economic losses threatening Post-Paris adaptation target in Nigeria. Weather index insurance is being considered as a possible pathway towards sharing farmers' risks. This paper analysed reliability of rainfall indexes as proxy for calibrating grain crop losses in designing index-based insurance product for farmers in South West and North Central Nigeria. Results reveal that two strongest correlated rainfall indexes in the development phase of maize are the second dekad cumulative rainfall climatology and cumulative rainfall below the pre-set 440mm threshold. However, it was the third dekad cumulative rainfall climatology and consecutive dry days of total rainfall less than daily 2.5 mm threshold in the reproductive stage. There is an overall weak statistical relationship between maize yield and rainfall indexes calibrated in middle savannah belt of Nigeria. This study provides a first-hand empirical validation that rainfall-based indexes are though fairly promising but does not sufficiently measure actual farmers' income losses, hence should not be regarded as a standalone safety-net for protecting smallholders. Careful consideration is required in developing appropriate weather indexes for designing index-based insurance product that will fully captured food crop losses significantly attributed to rainfall deficits, thus facilitate uptake in the South West and North Central zones of Nigeria.

Key words : Rainfall deficit, Agricultural losses, Weather-index insurance, Correlation indexes, Nigeria

RÉSUMÉ

Les impacts résiduels du déficit pluviométrique et l'incapacité de l'assurance récolte traditionnelle à protéger les petits exploitants entraînent des pertes économiques qui menacent l'objectif d'adaptation post-Paris au Nigeria. L'assurance indexée sur les conditions météorologiques est considérée comme une voie possible vers le partage des risques des agriculteurs. Cet article a analysé la fiabilité des indices pluviométriques en tant que proxy pour calibrer les pertes de récoltes céréalières dans la conception d'un produit d'assurance basé sur un indice pour les agriculteurs du sud-ouest et du centre-nord du Nigeria. Les résultats révèlent que les deux indices pluviométriques les plus fortement corrélés dans la phase de développement du maïs sont la climatologie des précipitations cumulées de la deuxième décade et les précipitations cumulées inférieures au seuil préétabli de 440 mm. Cependant, ce sont la climatologie des précipitations cumulées de la troisième décade et les jours secs consécutifs de précipitations totales inférieures au seuil journalier de 2,5 mm dans la phase de reproduction. Il existe une relation statistique globalement faible entre le rendement du maïs et les indices pluviométriques calibrés dans la ceinture de savane moyenne du Nigeria. Cette étude fournit une validation empirique de première main selon laquelle les indices pluviométriques sont certes assez prometteurs mais ne mesurent pas suffisamment les pertes de revenus réelles des agriculteurs, et ne doivent donc pas être considérés comme un filet de sécurité autonome pour protéger les petits exploitants. Il convient d'accorder une attention particulière au développement d'indices météorologiques appropriés pour concevoir un produit d'assurance basé sur l'indice qui rendra pleinement compte des pertes de cultures vivrières attribuées de manière significative aux déficits pluviométriques, facilitant ainsi l'adoption dans les zones du sud-ouest et du centre-nord du Nigeria.

Mots clés : Déficit pluviométrique, pertes agricoles, assurance basée sur l'indice météorologique, indices de corrélation, Nigéria.

INTRODUCTION

The Fifth Assessment Report (AR5) stated that climate change is expected to have social, economic and political impacts on African society especially the Sub-Sahara, arising from the increasing harsh tropical environment. Drought is the most impactful hazard which had affected 80% uninsured African smallholders and 40% of total economic damages which illustrates the need to identify processes, methods and tools which may assist African economies to adapt on local scale (Intergovernmental Panel on Climate Change [IPCC] 2014). Of particular concern are the income and livelihoods of low-income farmers in areas where long dry spells and rainfall uncertainties are primary sources of risk. A central problem is the huge possibility of droughts and dry spells trapping smallholders in poverty. To escape from the poverty traps, smallholders need financial cover, driven by risk assessment and local needs (International Institute for Applied Systems Analysis [IIASA] 2015). Given that global food stability may be at risk because of short-term variability in supply, evidence concludes for the need for considerable investment in adaptation actions toward a "climate-smart food system", more resilient to climate change influences on food security (Wheeler and Braun, 2013).

As stated in the National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN), current and future climate changes will interfere with its ability to achieve the Vision 20: 2020 in longer term (Federal Government of Nigeria [FGN], 2010). Converging results from climate model simulations projected that temperature will rise with an average of 1–2°C by 2050, water stress will increase by 10% and water availability will be uncertain over one-third of Nigeria's surface with consequences for food security (Building Nigeria's Response to Climate Change [BNRCC] 2011).

In 2010, an estimated 46.3% of the adult Nigerians were financially excluded. Of this estimate, 80.4% of the excluded populations live in rural areas, thus expensive to access financial services and limiting potential profits of financial institutions (Central Bank of Nigeria [CBN], 2014a). Despite that the agriculture determines over 70% of income employments and rural livelihoods and responsible for 42% share of the nation's GDP, yet the banking sector provides only 2% of its total lending to the Sector. Absence of insurance deters smallholder farmers from seeking loans for fear of default and losing productive assets secured as collateral (CBN 2014a; 2014b). In order to break this cycle, risk transfer tools such as agricultural insurance are been considered. Several studies have been conducted to evaluate effectiveness of weather index insurance as a risk management tool. In countries where uptake has occurred, impacts have been positive but there has been a very low uptake. As a strategy of sustainable scaling-up uptake, the first-order importance of reducing basis risk, and further insights on the determinants of behaviour toward risk and insurance become more necessary.

In Nigeria, it is a challenge for the climate adaptation community to find risk-financing instruments to correct the failures of existing in traditional crop insurance systems. The development of reliable future scenarios and appropriate adaptation constitute an eminent task for science, policy, and stakeholders to develop tools that minimize losses and maximize rural resilience in Nigeria (Awolala 2016). There is no known empirical study which has analysed the extent of reliability of weather indexes as proxy in estimating actual crop losses in Nigeria.

Few policy research questions thus remain that do dry spells justify weather index-based insurance design in the middle belt ? Could basis risk be possibly minimized through correlated indexes for insurance contracts ? The focus of this paper is to fill this research gap. This study analyzed patterns of rainfall distribution and determining extent of correlations with agricultural income losses as a critical starting point for rainfall-index insurance for drought risk-transfer in Nigeria. The study further tested if there is significant trend pattern in annual cumulative rainfall over the study area; if no statistical pattern with theoretical probability distributions, and if no positive serial correlation in the residual errors of yield and indexes, that is, *ei* have mean zero and constant variance [E(*ei*) = 0, Var(ei) = $\sigma 2$, and E(*ei, ej*) = 0], (H_0 : ρ = 0 but H_a : ρ > 0).

METHODS

Study area, data and data collection

The study was carried out in the savannah middle-belt of Central-West Nigeria. The middle-belt of Nigeria is the most extensive agro-ecological zone, covering nearly 50% of the country's land surface area. Guinea savannah is the most luxuriant of the savannah vegetation belts in Nigeria. The dataset used was a cross-sectional data collected from 264 peasant farmers in 2014 household surveyed across 12 different villages known for heavy concentration of maize production and within 20 km distance from nearest weather stations in the savannah belt. The 30-year decadal daily weather data (1981-2013) on rainfall were obtained from the Nigerian Meteorological Agency (NIMET), Abuja, Nigeria. Figure 1 presents the map showing the study area covering about 40,000 km^2 in Central-West Nigeria.

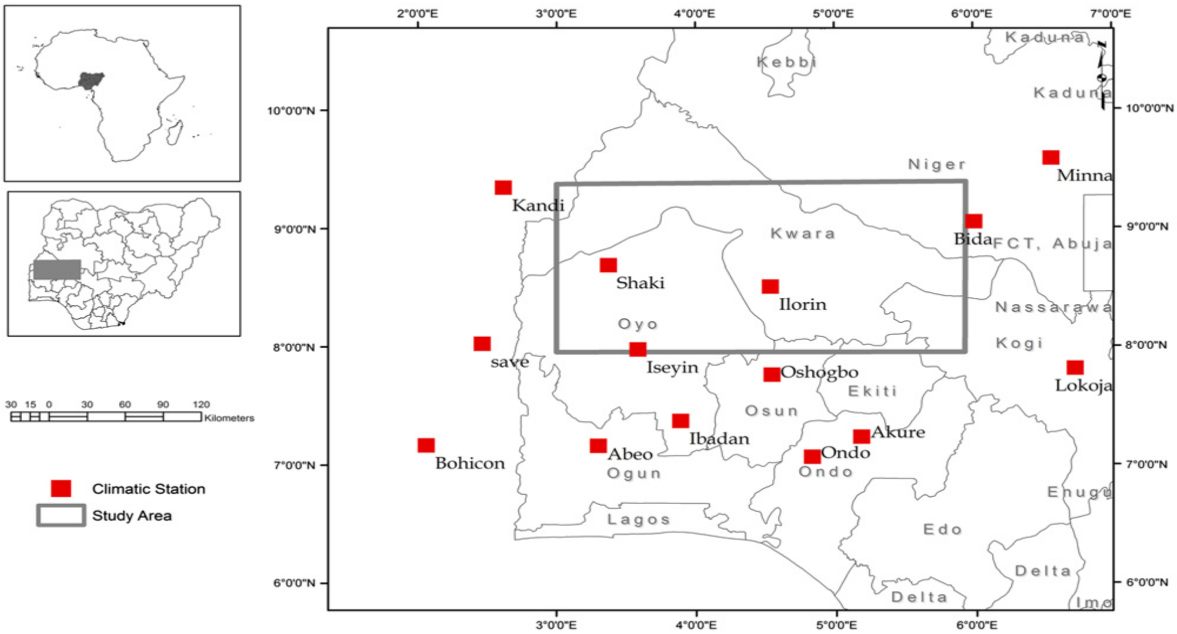


Figure 1. Map of Nigeria showing the study area
Source : Authors (2016)

Determination of rainfall regime from probabilistic models

The pattern of rainfall regime that best describes the decadal rainfall distribution (1984 and 2013) was determined based on theoretical distributions. Eight probabilistic functions were fitted for annual and seasonal rainfall data using Maximum Likelihood Method (MLE) to evaluate the best fit probability distribution. The description of various probabilistic models and density function, range and the parameter involved are presented in Table 1.

Construction of weather indexes

The reliability of rainfall data for the savannah AEZ for weather index insurance was obtained through a set of weather indexes tested for their correlations with maize yield to determine the most accurate indexes that best predicts yield losses at different times of the season. The causal-effect relationship between historical maize yield and selected rainfall indexes were fitted from 15 selected rainfall indexes using linear equation as shown in Table 2. Pearson correlation coefficient was used as basis for index selection at 5% level of statistical significance. The linear regression function is expressed as :

$$y \sim \alpha + \beta X_i + \in_i \quad .... (1)$$

where,

Y_i = Annual maize yield (kg/ha); X_i = weather index in a year, i; α = intercept (Y value when X=0)

β = the gradient of the regression line; ε_i = stochastic error

Table 1. Description of rainfall probabilistic model functions

Distribution	Probability distribution function	Range	Parameters
Erlang	$f(x;k,\lambda) = \frac{\lambda^k x^{k-1} e^{-\lambda x}}{(k-1)!}$ for x, $\lambda \geq 0$	$0 \leq x < +\infty$	k = shape parameter (k >0) μ = scale parameter (μ = $\frac{1}{\lambda}$ > 0)

Exponential	$f(x;\lambda)=\begin{cases}\lambda e^{-\lambda x} & x\geq 0,\\ 0 & x<0.\end{cases}$	$0 > x < +\infty$	λ = shape parameter (λ > 0)
Frechet	$\Pr(X \leq x)=e^{-x^{-\alpha}}$ if $x>0$	$0 < x < +\infty$	α = shape parameter (α > 0) β = scale parameter (β > 0)
Gamma	$f(x)=\dfrac{(x)^{\alpha-1}}{\beta^{\alpha}\Gamma(\alpha)}\exp\left(-{(x)}/{\beta}\right)$	$\gamma \leq x < +\infty$	σ = shape parameter (σ > 0) β = scale parameter (β > 0) γ = location parameter (γ = 0) becomes the two parameter weibull distribution
Inverse Gauss-ian	$f(x;\mu,\lambda)=\left[\dfrac{\lambda}{2\pi x^{3}}\right]^{1/2}\exp\dfrac{-\lambda(x-\mu)^{2}}{2\mu^{2}x}$	$\lambda \geq x < +\infty$	μ = scale parameter (μ > 0) γ = location parameter (γ > 0)
Log-Gamma (2P)	$f(x)=\dfrac{(In(x))^{\alpha-1}}{x\beta^{\alpha}\Gamma(\alpha)}\exp\left(-{In(x)}/{\beta}\right)$	$0 < x < +\infty$	α = shape parameter (α > 0) β = scale parameter (β> 0)
Lognormal (2P)	$f(x)=\dfrac{\exp\left[\dfrac{-1}{2}\left(\dfrac{In(x-\gamma)}{\alpha}\right)^{2}\right]}{(x)\alpha\sqrt{2\pi}}$	$\gamma < x < +\infty$	σ = scale parameter (σ > 0) μ = shape parameter (μ > 0) γ = location parameter (γ = 0) becomes the two parameter Lognormal distribution
Weibull (2P)	$P(x)=\dfrac{\alpha}{\beta}\left(\dfrac{x}{\beta}\right)^{\alpha-1}\exp\left[-\left(\dfrac{x}{\beta}\right)^{\alpha}\right]$	$\gamma \leq x < +\infty$	α = shape parameter (α > 0) β = scale parameter (β > 0) γ = location parameter (γ = 0) becomes the two parameter weibull distribution

Source: Authors (2016)

Table 2. Potential rainfall indexes to capture maize yield-drought losses

Critical weather index at phenological phase	Description of index
Cumulative annual rainfall 1st Wet season cumulative rainfall (April – June)	Total 12-month cumulative annual rainfall First 3-month cumulative rainfall (April-June)
Full wet season cumulative rainfall (April – Oct)	Full 8-month cumulative rainfall (April-Oct)

10-day cumulative rainfall from April 11 to 20	10-day cumulative rainfall during phenological phase (development)
10-day cumulative rainfall from April 21 to 30	10-day cumulative rainfall during phenological phase (development)
10-day cumulative rainfall from May 1 to 10	10-day cumulative rainfall during phenological phase (development)
Cumulative rainfall total < 440 mm from April 14 to May 13	Cumulative rainfall that below pre-set 420mm threshold during (development)
10-day cumulative rainfall from May 11 to 20	10-day cumulative rainfall during phonological phase (tarselling)
Minimum raindays not < 4 within 1st dekad (May 18-27)	Number of raindays must not be less than 4 times during the first 10 days (cob formation + grain filling)
10-day cumulative rainfall from May 21 to 31	10-day cumulative rainfall during phonological phase (cob formation + grain filling)
10-day cumulative rainfall from June 1 to 10	10-day cumulative rainfall during phonological phase (cob formation + grain filling)
Cumulative rainfall total < 125mm from May 18 to June 8	Cumulative rainfall that below pre-set 125mm threshold during (cob formation + grain filling)
Consecutive dry spells (deficit rainfall) from May 21-June 10	Number of consecutive of dry days (CDDs), during (cob formation + grain filling), (a dry day is with total rainfall < daily 2.5 mm threshold)
Total Rainfall deficit in Development Phase	The sum of the water deficits recorded during the 10-day periods in each phase. Total deficit for "Development" is the sum of the deficits during three 10-day periods in April and May.
Total Rainfall deficit in Flowering/Reproductive Phase	
Total Deficits	Sum of "Development" and "Flowering/Reproductive" Phase deficits

Source: Authors (2016)

Minimizing basis risk

Detecting time trend in crop yield

Linear and quadratic regression functions were fitted using Maximum Likelihood Estimate (MLE) method to estimate time trend of the 30-year cumulative rainfall to observe any trend pattern. The gradient of the equations described the trend whether positive or negative. The regression functions estimated for the rainfall data are given by the expressions :

Linear equation: $y \sim \alpha + \beta X_i + \in_i$ .... (2)

Quadratic regression: $y \sim \alpha + \beta X_i + \gamma X_i^2 + \in_i$ ....(3)

where, Y_i = Annual cumulative rainfall (mm); X_i = Year (year) for time, I; α = intercept (Y value when X=0); β = the gradient of the regression line; ε_i = stochastic error term, $i = 1984, 1985, 1986, \ldots\ldots, 2010$

The null hypothesis was tested that the gradient of the regression line is zero, that is, there is no trend in the cumulative rainfall data. The coefficient of R-square (R^2) was used to explain the strength of the correlation between the variables X and Y.

Constructing multiple phase weather indexes

To minimize basis risk of payouts for not adequately reflecting a strong correlation with yield losses, rainfall indexes were developed in multiple phases. The growing season was divided into sequential phases of crop-growth stages as defined by maize crop phenology and cropping calendars. Maize growth stages are divided Sowing and Emergence (Establishment), Vegetative Growth (Crop Development), Flowering and Reproductive (Tasselling, Cob Formation and Grain Filling) phases. The schedule of payments for drought risk event was taken as piecewise linear of total 10-day climatology (dekad) rainfall deficits in each of the phases. Payment is due only if the total rainfall deficits in a phase is sufficiently below maize crop water requirements in a phase.

Test of Hypothesis

Regression equations were fitted to capture the hypothesis that there is no time trend in annual cumulative rainfall hypothesis. The Kolmogorov-Smirnov, Anderson-Darling and Chi-square goodness of fit tests were used to test the null hypothesis that cumulative 3-dacadal rainfall data have no statistical pattern in a specified probability distribution. The Kolmogorov-Smirnov statistic (KS) is defined as the largest vertical difference between the theoretical and the empirical cumulative distribution function (ECDF) :

$$KS = \max_{1\le i\le n}\left(F\left(X_i\right)-\frac{i-1}{n},\frac{i}{n}-F\left(X_i\right)\right) \qquad \text{..................} (4)$$

where, X_i is a random variable, i =1, 2,....., n, CDF = $F_n\left(X\right)=\frac{1}{n}$. [Number of observations ≤ x]

This test is used to decide if a sample comes from a hypothesized continuous distribution. Anderson-Darling statistic $\left(A^2\right)$ is expressed as :

$$A^2 = -n-\frac{1}{n}\sum_{i-1}^{n}(2i-1).\left[InF\left(X_i\right)+In\left(1-F\left(X_{n-i+1}\right)\right)\right] \qquad \text{..............} (5)$$

It is a test to compare the fit of an observed cumulative distribution function (CDF) to an expected cumulative distribution function. This test gives more weight to the tails than the Kolmogorov-Smirnov test. Chi-square is a statistical test commonly used to compare observed data with data we would expect to obtain according to a specific hypothesis. The chi-square test is always testing what researchers referred to as the null hypothesis, which states that there is no significant difference between the expected and observed result.

The Chi-Squared statistic is defined as :

$$X^2 = \sum_{i-1}^{k}\left(\frac{(O_i-e_i)^2}{e_i}\right) \qquad \text{..............}(6)$$

Where O_i = observed frequency, e_i = expected frequency, 'i' = number of observations (1, 2, ...k), estimated by: $e_i = F\left(X_2\right)-F\left(X_1\right)$, F = the CDF of the probability distribution that was tested. The observed number of observation (k) in interval 'i' was computed from equation given as :

$$k = 1 + \log_2 n \qquad \text{............... (7)}$$

n = sample size

These goodness of fit tests were fitted to the annual rainfall of 30 year period, 1st wet season, and the 2nd wet season rainfall data. These tests were performed to measure the compatibility of the random cumulative 3-dacadal rainfall data with eight theoretical probability distributions. The test statistic of each test was computed and tested at α =0.01 level of significance. The Durbin-Watson test states that: Ho: $\rho = 0$ and $H_1 : \rho > 0$. The test statistic states that:

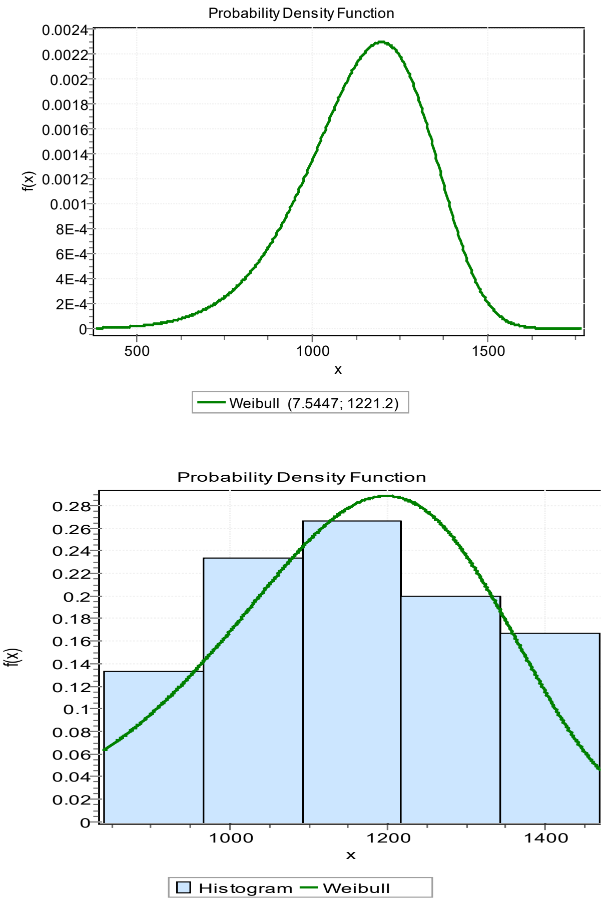
$$d = \frac{\sum_{i=2}^{n} (e_i - e_{i-1})^2}{\sum_{i=1}^{n} e_i^2} \qquad \text{............................. (8)}$$

where, $e_i = y_i - \hat{y}_i$ and y_i and $\hat{y}_i$ are, respectively, the observed and predicted values of the response variable for individual i. d becomes smaller as the serial correlations increase. Upper and lower critical values, dU and dL have been tabulated for different values of k (the number of explanatory variables) and n. Decision rules: If d < dL reject H_o: $\rho = 0$; If d > dU do not reject H_o: $\rho = 0$; If dL < d < dU test is inconclusive.

RESULTS AND DISCUSSION

Predicting drought risk from probabilistic forecasting

Given that rainfall is the most critical element that determines rain-fed agriculture, quantifying seasonal rainfall variability is a first step of developing adaptation interventions. Figure 3 presents fitted Weibull probability density function for the 3-decadal rainfall data for Central-West Nigeria. It is observed that the distribution fitting on the histogram bar modeled a Weibull distribution. The Weibull function has a skewness value of -0.50 which serves as a pointer that distribution of the 3-decadal rainfall is negatively skewed (not symmetric), since the left tail of the distribution longer than the right tail. This is a further indication that most of the rainfall values are concentrated on the right of the mean with extreme values to the left, hence Central-West Nigeria is experiencing significant very low rainfall than normal over the past 3 decades. It is evident that the region is exposed to drought risk with implication for food crop production arising from deficit-rainfall.



(a) (b)

Figure 3. Fitted Weibull distributions for the 3-decadal rainfall
Source: Field data (2016)

The Cumulative Distribution Function (CDF) is presented in Figure 4 indicating that the Weibull probability distribution was well fitted to the 30-year rainfall data in the study area.

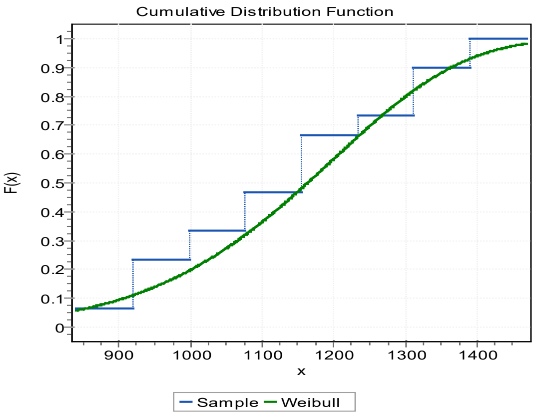


Figure 4. Weibull cumulative distribution of decadal rainfall
Source: Field data (2016)

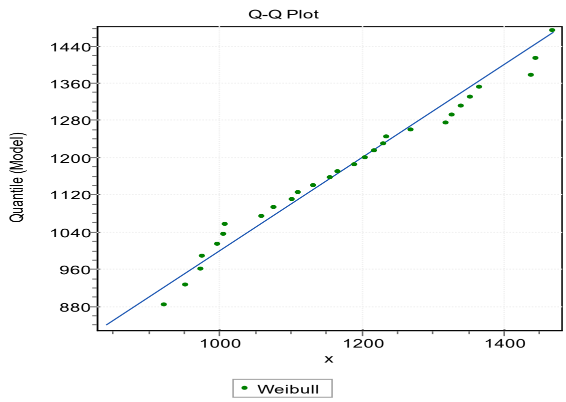


Figure 5. Weibull quantile-quantile plot for decadal rainfall
Source: Field data (2016)

The Quantile-Quantile plot presented on Figure 5 provided a useful diagnostics of how well the specified theoretical Weibull distribution fits the quantiles of the 30-year daily rainfall for the study area. The reference line corresponds to the estimated values for the threshold and scale parameters of α =7.5447, β=1221.2. The Normal Q-Q plot indicates that the Weibull distribution well corresponds, hence the correct model for the 30-year rainfall data.

Time trend analysis of maize yield (wet season) and rainfall

Linear and quadratic regression functions were fitted to capture time trend that maize yield per unit land is constantly increasing due to technological improvements. Figure 6 presents that yield losses/ha were observed in maize production in 1996, 2002, sharply declining after 2008 in both regression models. Yield losses are expected at every 6-year interval.

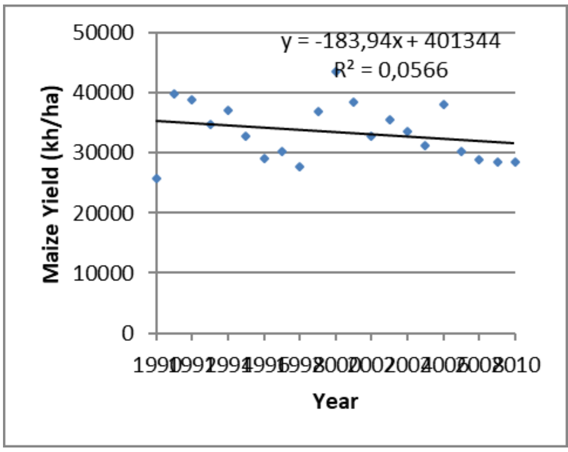


Fig.6. Maize yield linear regression with time trend Source: Field data (2016)

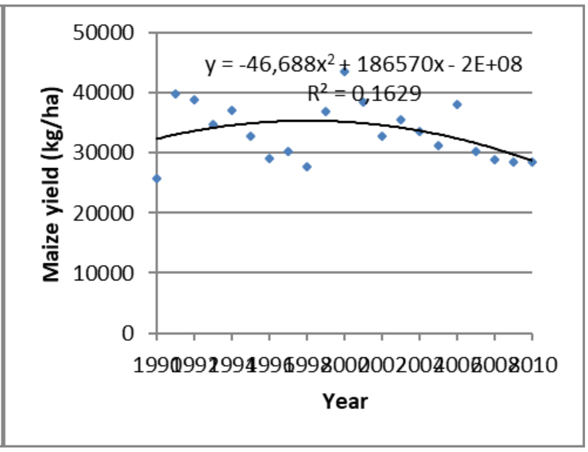


Fig. 7. Quadratic regression of maize yield with time trend Source: Field data (2016)

When expand the observed data range, a non-linear function seems a much more realistic approximation of the yield-time relationship as indicated in Figure 7, quadratic function has a better R^2 of 21.1% than linear function, estimate of intercept of linear time trend suggests no significant time trend in yield variations, hence was used to predict yield losses to rainfall indexes in this study.

Calibrating optimal deficit-rainfall indexes

The statistical relationships were obtained for maize development stage between April 14 and May 13 and the reproductive phase (cob formation + grain filling) between May 18 and June 8 adequately explained the causal-effect relationship between historical maize yield data and the selected rainfall indexes based on deficit rainfall risk periods for maize in the study area. The correlation results between maize yields and weather indexes are shown in Table 4.

Table 4. Regression statistics and correlations of rainfall indexes and maize yield

Rainfall Index	Regression Equation	Correlation Co-efficient, r	R^2	D-Watson Statistic
Cumulative annual rainfall Full wet season cumulative rainfall (April – October)	y = 31042.73 + 2.06X y = 29304.30 + 3.806X	0.07 0.13	0.005 0.017	1.195 1.183
10-day cumulative rainfall deficit April 11-20	y = 35001.39 – 33.77X	0.18	0.031	1.428
10-day cumulative rainfall deficit April 21- 30	y = 36492.16 – 63.01X	0.33	0.106	1.297
10-day cumulative rainfall deficit May 1-10	y = 37227.57 – 28.22X	0.27	0.072	1.363
Cumulative rainfall total < 440 mm from April 14 to May 13	y = 31765.72 + 37.31X	0.32	0.105	0.911
Minimum rain days not < 4 within 1st dekad (May 18-27)	y = 32028.32 + 28.61X	0.20	0.039	1.189
10-day cumulative rainfall deficit May 21- 31	y = 33014.37 + 7.40X	0.05	0.003	1.277
10-day cumulative rainfall deficit June 1- 10	y = 28709.77 + 39.64X	0.32	0.104	1.249
Cumulative rainfall total < 125mm from May 18 to June 8	y = 36666.90 –221.31X	0.12	0.014	1.225
Consecutive dry spells (deficit rains) from May 21-June 10	y = 24952.71 – 28.22X	0.27	0.072	1.363
Total deficit in development phase	y = 24952.71 – 28.22X	0.27	0.072	1.363
Total deficit in flowering/reproductive	y = 37297.82 + 23.79X	0.24	0.058	1.071
Total Rainfall deficits	y = 33215.68 – 0.558X	0.01	0.000	1.268

Source: Field data (2016)

There is an overall weak statistical relationship between maize yield and all the rainfall indexes constructed. It is evident that stronger rainfall indexes would be very difficult to be established for the region given the inability of yield data to be disaggregated at district-level. However, based on the most critical rainfall risk period, highest correlation coefficients were obtained for a possible prototype rainfall index insurance design.

Table 5 presents the correlation analysis of two strongest correlated rainfall indexes in the development phase namely the 2nd dekad cumulative rainfall climatology and 3rd dekad cumulative rainfall climatology. The 2nd dekad cumulative rainfall climatology during maize vegetative growth period is positively correlated with yield (r=0.33) per unit of cultivated land while 3rd dekad cumulative rainfall climatology during maize vegetative growth period is also positively correlated with yield (r=0.27) per unit of cultivated land. This suggests that based on the crop water requirement of maize, water is scarce during both the second and third dekads of development and reproduction stages in study area. These two rainfall indexes are critical for maize phenological growth, hence affecting crop yield levels. However, the indexes fairly predict maize yield losses in the study area.

Table 5. Correlation of weather indexes and maize yield (development stage)

Maize Growth Stage	Development Phase	
	2nd dekad cumulative rainfall	3rd dekad cumulative rainfall
Start and end date	April 21-30	May 1-10
Correlation	0.33	0.27
Durbin -Watson statistic	1.297	1.363

Source. Computed from data analysis, 2015

The Durbin-Watson (D-W) statistic was used to test for autocorrelation in the residuals from the statistical regression analysis performed between the 20-year time series maize yield and rainfall indexes that well predict yield losses. The DW (1.297) < dL of 1.5 obtained for the 2nd dekad cumulative rainfall and DW (1.363) < dL recorded for the 3rd dekad cumulative rainfall indicate positive autocorrelation at 5% level of significance. Therefore, we reject Ho and accept Ha that there is positive serial correlation of the residual errors between rainfall indexes and maize yield.

The correlation analysis on Table 6 presents two strongest correlated rainfall indexes in the reproductive stage (cob formation + grain filling) namely the Consecutive dry spells (deficit rains) from May 21-June 10. During maize reproductive stage, this index is positively correlated with yield (r=0.27) which suggests rainfall deficits for maize cob formation and grain filling given the crop water requirement of maize in the study area. This index is critical for maize cob formation and grain filling, hence affecting crop yield levels. The index also fairly predicts maize yield losses in the study area.

Table 6. Correlation of weather indexes and maize yield (reproductive stage)

Maize Growth Stage	Reproductive Phase
	Consecutive dry spells (deficit rains) from May 21-June 10
Start and end date	June 1-10
Correlation	0.27
Durbin -Watson statistic	1.249

Source. Computed from data analysis, 2015

The hypothesis was tested that residual errors between rainfall indexes and maize yield are independents. The DW (1.249) < dL of 1.5 obtained for the 3rd dekad cumulative rainfall climatology and DW (1.363) < dL recorded for the consecutive dry days of total rainfall < daily 2.5 mm threshold show that errors are positively autocorrelated at 5% level of significance. We therefore reject H_o and accept H_a that residual errors of rainfall indexes and maize yield exhibit positive serial correlation. The tested H_o that there is no positive serial correlation in the residual errors of yield and indexes is rejected while the alternate hypothesis that there is no positive serial correlation in the residual errors of yield and indexes is therefore accepted at 5% level of significance. Therefore attempt to design possible rainfall insurance contract as adaptation instrument against yield losses from drought risk event is fairly reasonable.

CONCLUSION

The study found that quadratic function was a more realistic approximation of the yield-time relationship than linear function. Estimate of intercept of linear time trend suggests no significant time trend in yield variations, hence better able to predict yield losses to rainfall indexes. Hence, there is an overall weak statistical relationship between maize yield and all the rainfall indexes constructed in middle belt of Nigeria. It is evident that based on the most critical rainfall risk period, highest correlation coefficients were obtained for a possible prototype parametric rainfall insurance design.

The two strongest correlated rainfall indexes in the development phase of maize crop are the 2nd dekad cumulative rainfall climatology and cumulative rainfall below pre-set 440mm threshold. The 2nd dekad cumulative rainfall climatology during maize vegetative growth period is positively correlated with yield (0.33) per unit of cultivated land which suggests that water is scarce during the second dekad of growth and development stage. The cumulative rainfall below a pre-set 440mm threshold during maize vegetative growth period is positively correlated with yield (0.32) per unit of land cultivated. These two rainfall indexes are critical for maize phenological growth, hence affecting crop yield levels.

The two strongest correlated rainfall indexes in the reproductive stage (cob formation + grain filling) are the 3rd dekad cumulative rainfall climatology and consecutive dry days of total rainfall < daily 2.5 mm threshold. The 3rd dekad cumulative rainfall climatology during maize reproductive stage is positively correlated with yield (0.32) which suggests rainfall deficits for maize cob formation and grain filling. The consecutive dry days < daily 2.5 mm threshold during maize reproductive stage is positively correlated with yield (0.27). These 4 indexes are critical for maize cob formation and grain filling, hence affecting crop yield levels. The indexes weakly predicted maize losses in the savannah agro-ecological zone of Nigeria.

This paper therefore concludes that the rainfall pattern and distributions in the savannah region of Nigeria fairly predict maize crop yield, hence do not fully capture maize crop losses. It should not be completely rely on to serve as prozy for measuring income losses in the agro-ecological zone. Rainfall-index insurance possibly can be a promising risk-transfer instrument but only shows weak signals of its capability of providing index-based insurance protection against farmers' losses. Serious caution should be exercised at the initial stage of rainfall-index construction for designing maize insurance contract given that the success of any weather insurance product heavily lies on a very strong correlation between crop yield and weather indexes constructed. Other safety nets should be added to complement this risk sharing management tool in Central-West Nigeria.

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REFERENCES

Awolala, D.O. (2016). Modelling Future Demand for Weather Index Insurance asAdaptation Instrument to Drought Risk Event in Central-West Nigeria. Ph.D Thesis, Department of Economics, Universite Cheikh Anta Diop Dakar, Senegal.

Building Nigeria's Response to Climate Change [BNRCC]. (2011). National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN). Ibadan, Nigeria: BNRCC. http://nigeriaclimatechange.org/naspa.pdf.

Central Bank of Nigeria [CBN]. (2014a). "Capturing the 'unbanked' in Nigeria: Frontiering the Financial Inclusion Strategy". Available at http://dailyindependentnig.com/2014/01/capturing-unbanked-nigeria/

CBN (2014b). Promoting Global Financial Inclusion in Africa, Forum for Discussion at a Conference organized by the Central bank of Nigeria, Abuja, Nigeria. www.cbn.gov.ng

Federal Government of Nigeria [FGN]. (2010). Nigeria Vision 20: 2020: The First NV20: 2020 Medium-Term Implementation Plan (2010–2013). Vol.1. The Vision and Development Priorities, Lagos, Nigeria. https://www.preventionweb.net/files/14632_1stnipeditedversionvol1.pdf

International Institute for Applied Systems Analysis [IIASA]. (2015). Risk Policy and Vulnerability. https://iiasa.ac.at/web/scientificUpdate/2015/program/rpv/risk-policy-and-vulnerability.html

Intergovernmental Panel on Climate Change [IPCC]. (2014). "Climate Change 2014: Impacts, Adaptation, and Vulnerability". Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

Wheeler and Braun, J. (2013). Climate Change Impacts on Global Food Security. Science.2:Vol. 341, Issue 6145: pages 508-13. doi: 10.1126/science.1239402

What Drives the Adoption of Climate Smart Agricultural Practices ? Evidence from Maize Farmers in Northern Nigeria

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ABSTRACT

The adoption of Climate Smart Agriculture (CSA) remains low in sub-Saharan Africa, despite its promotion as a sustainable production system for mitigating agriculture's contribution to climate change, as well as for helping farmers adapt to the adverse effects of climate change. This necessitates continuing research on its determinants, in order to identify appropriate mechanisms to encourage adoption. This paper investigates the factors that drive CSA practices' adoption using recent plot-level survey data from Northern Nigeria. A Multivariate Probit Model was used to analyse the adoption of six CSA practices and control for the influence of socioeconomic, plot and institutional factors. Our study finds that the likelihood of CSA practices' adoption is influenced by land ownership, social capital, gender, off-farm work participation and plot distance from homestead. However, these factors do not unanimously influence the six CSA practices considered and vary significantly among them. Therefore, the factors that drive CSA should be considered when designing policies to promote CSA towards the achievement of sustainable livelihoods among farm households in Nigeria. Farmers should be encouraged to join groups (farmer groups, cooperatives), in order to build their social capital, which could expose them to better practices, obtain informal training from those who have adopted them, and obtain help for implementation.

Keywords: Climate Smart Agriculture, Multivariate Probit model, Sustainable Agriculture, Nigeria

RÉSUMÉ

L'adoption de l'agriculture intelligente climatique (ASC) reste faible en Afrique subsaharienne, malgré sa promotion en tant que système de production durable pour atténuer la contribution de l'agriculture au changement climatique, ainsi que pour aider les agriculteurs à s'adapter aux effets changement climatique. Cela nécessite la poursuite des recherches sur ses déterminants, afin d'identifier les mécanismes appropriés pour encourager l'adoption. Cet article examine les facteurs qui ont conduit l'adoption des pratiques de l'ASC à l'aide de données récentes sur les enquêtes au niveau de l'intrigue dans le nord du Nigéria. Un modèle Multivariate Probit a été utilisé pour analyser l'adoption de six pratiques de l'ASC et le contrôle de l'influence de facteurs socio-économiques, de complot et institutionnels. Notre étude révèle que la probabilité de l'adoption des pratiques de l'ASC est influencée par la propriété foncière, le capital social, le sexe, la participation au travail à l'extérieur de la ferme et la distance de parcelle de terrain de la ferme. Toutefois, ces facteurs n'influencent pas unanimement les six pratiques de l'ASC examinées et varient considérablement d'entre elles. Il a été conclu que ces facteurs doivent être pris en considération lors de l'conception de politiques visant à promouvoir l'ASC en vue de la réalisation de moyens de subsistance durables parmi les ménages agricoles au Nigéria. Nous recommandons que les agriculteurs soient encouragés à se joindre à des groupes (groupes d'agriculteurs, coopératives), afin de construire leur capital social, ce qui pourrait les exposer à de meilleures pratiques, obtenir une formation informelle de ceux qui les ont adoptés et obtenus de l'aide pour la mise en œuvre.

Mots-clés : Climate Smart Agriculture, Probit multivariable, Agriculture durable, Nigéria

INTRODUCTION

Climate change is a major global challenge as it affects the availability of critical resources like water, energy and land (Beddington et al., 2012). As such, the issue of climate change mitigation forms a major focus of the Sustainable Development Goals (1, 2 and 13) (UNDP, 2016). The most direct impact of climate change is on agriculture and food systems, and its adverse effects (such as erratic and unpredictable rainfall, marginal soil fertility, increasing loss of land to aridity and desertification, shorter growing seasons among others) are felt more by smallholder farmers in developing countries (Brown and Funk, 2008). This is especially true in Africa, where about 85% of the population depend on rain-fed agriculture and agriculture-based activities for their livelihood (Moyo, 2016). Furthermore, about 96% of the total crop production in Sub-Saharan Africa (SSA) is based on rain-fed systems, which leave agricultural production, and the livelihood of the people highly exposed to changes and fluctuations in climatic conditions (Srivastava et al., 2017). This has important implications for Nigeria's poverty alleviation efforts, as it is estimated that 69% of the poor in the country derive their livelihood from agriculture (NBS, 2012).

Already, Lobell et al. (2011) estimated that climate change has reduced global yields of maize and wheat by 3.8% and 5.5% between 1980 and 2008 respectively, while estimated impacts of future climate change on cereal crop yields in different regions indicate that the yield loss can be up to 60% for maize, 35% for rice, 20% for wheat and 50% for sorghum depending on the location (Khatri-Chhetri et al., 2017). However, agricultural production is one of the major drivers of climate change, implying that farmers are both victims and drivers of climate change. It is estimated that agriculture is responsible for about 60% of tropical deforestation and accounts for as much as 13.5% of Greenhouse Gases (GHGs) emissions per year (IPCC, 2007; Chakravarty et al., 2012). Smallholder farmers in developing countries (including Nigeria) employ unsustainable practices such as excessive reliance on slash and burn agriculture, cropping on marginal lands, and over-exploitation of forest, grassland and wetland ecosystem services, which emit GHGs, predispose the soil to erosion, land degradation and desertification, with an attendant decline in soil productivity and crop yield, increased poverty and food insecurity (Garibaldi et al., 2017). Yet, an additional 2.4 billion people are expected to be living in developing countries by 2050, with 1.3 billion more people in Africa. In particular, Nigeria has the highest population growth among the ten largest countries in the world, and is expected to become the third largest in the world by 2050 (UNDESA, 2015). Thus, agricultural production systems require adaptation to climate change in order to ensure the achievement of national sustainable development goals (SDGs) of reduction in poverty and food insecurity, as the livelihood of majority of the poor hinge on it (Khatri-Chhetri et al., 2017).

In response to these challenges, Climate Smart Agriculture (CSA) was introduced, and is promoted by the Food and Agriculture Organization (FAO) as an alternative sustainable approach to agricultural production (FAO, 2010). CSA practices are defined as those activities that sustainably increase agricultural productivity and incomes, build resilience and capacity of agricultural and food systems to adapt to climate change, and reduce or remove greenhouse gases while enhancing national food security (Neufeldt et al., 2013). Although several farm level studies suggest that adoption of CSA technologies can improve crop yields, increase input use efficiency, increase net income and reduce GHG emissions (Gathala et al., 2011; Sapkota et al., 2014; Khatri-Chhetri et al., 2016), the adoption of such practices remains generally low, particularly in sub-Saharan Africa (Arslan et al., 2013; McCarthy and Brubaker, 2014). This has led to a growing body of literature on its determinants, with a view to identifying appropriate mechanisms by which wide-spread adoption of CSA practices may be promoted to ensure improved livelihood in the region.

This study contributes to the on-going discussion about what drives CSA practices' adoption at the plot level. Understanding the drivers of CSA adoption will enable policy-makers and development practitioners to better target policies and interventions to aid the diffusion of these practices, towards the achievement of improved and sustainable livelihoods. Specifically, we analysed the adoption of a range of CSA practices (green manure, agroforestry, organic manure, crop rotation, refuse retention and zero/minimum tillage) among maize farmers using the Multivariate Probit model to determine the influence of socioeconomic, plot and institutional factors. This study focuses on maize, as it is one of the most important staple food crops in Nigeria, with far reaching implications on the food security and livelihood of smallholder farmers. In particular, maize cultivation occupies the largest arable land area in Nigeria, as over fifty million farmers grow maize every year, while over ninety million people are employed in its processing and usage daily (Onyibe et al., 2014). In addition, it is cheaper than the other cereals (such as rice and wheat) and is thus more accessible to the poor, and the average person in Nigeria consumes 60g of it daily in both fresh and processed forms (Ranum, Peña-Rosas and Garcia-Casal, 2014). This is in addition to the fact that many agro-allied industries depend on it as raw material, and it contributes about 80 percent of poultry and other livestock feed in the country, thus having a great implication on protein intake. Also, with a national supply deficit of about 5.7 million tonnes in 2013 (Onyibe et al., 2014), there is the need for maize production to increase, in the face of constraints imposed by climate change, in order to ensure food security for the growing population. Although the literature shows a growing number of recent studies which have attempted to investigate the determinants of

CSA practices adoption in Africa using plot-level data (Asfaw et al., 2016; Theriault et al., 2017), literature on this in Nigeria is still observed to be very scanty. Thus, this study fills a gap in existing literature by using a plot-level dataset to examine the adoption of CSA practices in Nigeria.

METHODS

Study area

The study was conducted in northern Nigeria. Northern Nigeria consists of three geopolitical zones; the Northwest (which consists of 7 states), North-central (which consists of 6 states and the Federal Capital Territory) and Northeast (which consists of 6 states) geopolitical zones. Northern Nigeria lies between latitude 9^0 – 14^0N and longitude 3^0 – 15^0E, and is bounded in the North by Niger republic, Chad and Cameroon in the East, and in the West by Republic of Benin (AbdulKadir et al., 2013). Northern Nigeria is dominated by the Guinea, Sudan and Sahel savannahs, and the vegetation density decreases northwards in response to climatic conditions. Although the region is geographically prone to drought, desertification, wind and water erosion, agriculture remains the most dominant economic activity in the region. Dominant crops grown in the region include maize, rice, sorghum, millet, cotton and groundnut, among others (Ugwu and Kanu, 2012).

Data and sampling procedure

This data used in this study was collected by FUNAAB-RAAF-PASANAO project, titled "Incentivizing Adoption of Climate Smart Practices in Cereals Production in Nigeria: Sociocultural and Economic Diagnosis" which was funded by ECOWAS - Regional Agency for Agriculture and Food (RAAF) under its Support Programme for Food and Nutrition Security in West Africa (PASANAO). The respondents for this study were drawn in a multi-stage sampling process. The first stage entailed the purposive selection of two states reputed for maize production from each of the three (3) geopolitical zones of northern Nigeria. Kaduna and Kebbi States were selected from the Northwest, while Niger and Nasarawa were selected from the North-central. However, only Taraba State was selected from the Northeast because of the religious unrest in the zone. At the second stage, three (3) blocks reputed for maize production were purposively chosen from each of the five (5) states that had been selected. In stage three, two (2) cells were randomly selected from each block, while the last stage was a random selection of 10 maize farmers from each of the selected cells. After dropping households with incomplete information, this process yielded a total of 238 maize farming households and 410 plots that were used for the study. Data collected include farmers' social, economic and institutional variables, their perception of climate change, adoption of CSA practices as well as their livelihood characteristics.

Analytical framework

Modelling the adoption decision: Utility maximization theory

Following Afolami et al. (2015), a farmer was considered to be an adopter of a CSA practice if he/she has used the practice at least one planting season before the interview, and is still utilizing such practice at the time of interview. In this study, we assume that each plot manager compares the CSA practice with the traditional technology and adopts it if he/she perceives that the expected utility from adoption exceeds the utility of the traditional technology (Awotide et al., 2016). Furthermore, we assume that farmers make multiple adoption decisions at the same time, and attempting to model adoption of single technologies separately using a Probit or Logit model ignores the potential correlation among the unobserved disturbances in the adoption equations, thus leading to inefficient estimates and thereby wrong inference (Theriault et al., 2017). Thus, this study utilized the Multivariate Probit model (MVP), which simultaneously models the influence of the set of explanatory variables on each of the different CSA practices by estimating a set of binary probit models simultaneously, while allowing the error terms in those models to be correlated (Greene, 2008). Consider the ith farmer (i=1,...N) facing a decision on whether or not to adopt a CSA practice on plot p. Let U_0 represent the benefits to the farmer from traditional management practices, and let U_k represent the benefit of adopting the kth CSA practice, where k denotes choice of CSA practice. The farmer decides to adopt the kth CSA practice on plot p if :

$$Y_{ipk}^{*} = U_{k}^{*} - U_{0} > 0 \qquad Y_{ipk}^{*} = U_{k}^{*} - U_{0} > 0 \qquad (1)$$

However, the net benefit (Y_{ipk}^{*}) that the farmer derives from the adoption of the kth CSA practice (G = Green manure, A = Agroforestry, M = Organic manure, C = Crop rotation, R = Refuse retention, T = Zero/Minimum tillage) is a latent variable determined by observed personal, household, plot and location characteristics (X_i) and the error term (ε_i) :

$$Y_{ipk}^{*} = X_{i}\beta_{k} + \varepsilon_{i} \qquad (k = G, A, M, C, R, T) \qquad (2)$$

The unobserved preferences in equation (2) above translate into the observed binary outcome equation for each choice as follows:

$$Y_{ipk} = \begin{cases} 1 & if\ Y_{ipk}^{*} > 0 \\ 0 & otherwise \end{cases} \qquad (k = 1, 2, \ldots k) \qquad (3)$$

Where Y_{ipk} is the adoption of the kth CSA practice by the ith farmer on plot p.

RESULTS AND DISCUSSION

Description of dependent variables

The adoption of the climate smart practices was generally low; Green manure, agroforestry, crop rotation, organic manure, zero tillage and refuse retention were adopted on 18%, 40%, 27%, 45%, 38% and 44% of the sample plots used in this study, which corroborates other findings in SSA (Arslan et al., 2013; McCarthy and Brubaker, 2014).

Description of explanatory variables

The explanatory variables in the empirical model are based on a review of theoretical work and empirical literature on adoption of sustainable agricultural practices (Teklewold, Kassie and Shiferaw, 2013). Table 1 presents the description and summary statistics of these variables. The results show that most (90.0%) of the maize plots are managed by male farmers. The average age of a maize farmer was 44 years, having a mean household size of nine (9) persons. Over half (56.3%) of the respondents had at least primary education, although the average years of formal education obtained was about 7 years. Most (74.0%) of them had access to extension services in the previous season, indicating a robust presence of agricultural extension services in the study area, while only 40% received credit in the same period. The mean farm size of the maize farmers was 3.17 hectares, which indicates that the average farmer is a smallholder according to Nigeria's official definition of smallholders (<5 hectares) (Anderson et al., 2017). With respect to plot-specific characteristics included in the model, we found that on the average, plot managers had to trek for almost an hour (51.4 minutes) to get to their plots. According to Menale et al. (2012), adoption of sustainable practices that involve transporting bulky inputs is likely to be low for the farthest plots, compared to those closer to the homestead. We also found that about 67.0% of the maize plots were owned by the farmers. This is quite important in the adoption process as farmers are more likely to invest in and improve lands which they own (Oladele et al., 2011).

Table 1: Definition and summary statistics of variables used in the analysis

Variable	Description	Mean (SD)
Climate Smart Agricultural Practices' Adoption		
Green Manure	If plot manager adopts green manure = 1, otherwise 0	0.18 (0.39)
Agroforestry	If plot manager adopts agroforestry = 1, otherwise 0	0.40 (0.49)
Organic Manure	If plot manager adopts organic manure = 1, otherwise 0	0.45 (0.50)
Refuse retention	If plot manager adopts refuse retention = 1, otherwise 0	0.44 (0.50)
Crop rotation	If plot manager adopts crop rotation = 1, otherwise 0	0.27 (0.44)
Zero/Minimum tillage	If plot manager adopts zero/minimum tillage = 1, otherwise 0	0.38 (0.49)
Socioeconomic characteristics		
Age	Age of the plot manager	43.89 (12.67)
Female plot manager	If plot manager is female = 1, otherwise = 0	0.10 (0.31)
Marital Status	If the plot manager is married = 0; Otherwise = 1	0.07 (0.25)
Years of Schooling	Years of formal education of the plot manager	6.74 (6.29)
Household size	Number of household members	9.48 (6.67)
Off farm Income	Plot manager's total off farm income in the last year (in Naira)	45,608.79 (143,214.40)
Asset ownership	1 if plot manager owns a major asset – (such as land, buildings, machinery) - 0 otherwise	0.86 (0.35)

Farmers' Group membership	1 if plot manager is a member, 0 otherwise	0.86 (0.35)
Institutional characteristics		
Extension Contact	1 if plot manager was visited by an agricultural extension agent or if plot manager visited extension service office during last 1 year, 0 otherwise	0.74 (0.44)
Access to credit	1 if plot manager received credit, 0 otherwise	0.40 (0.49)
Plot characteristics		
Farm Size (Ha)	Size of the plot being cultivated by plot manager in hectares	3.17 (4.00)
Lowland	If plot is lowland = 1; Otherwise = 0	0.35 (0.48)
Land Ownership Status	If plot manager owns the plot = 1; Otherwise = 0	0.67 (0.47)
Plot Trekking distance from home	Number of minutes used in trekking to the plot	51.36 (53.41)
Land dispute	1 if plot manager ever experienced dispute, 0 otherwise	0.04 (0.19)
Fertilizer Use	If plot manager used inorganic fertilizer on the plot = 1; Otherwise = 0	0.69 (0.46)
Plot Observations		410

Source: Field survey, 2017. Figures in parentheses are standard deviations.

Adoption of CSA practices

Table 2 shows the results of the Multivariate Probit regression which was used to analyse the factors influencing farmers' adoption of CSA practices on the plots which they manage. The Wald chi-square test statistics [$\mathcal{X}^2$ (120) = 486.53] shows that the hypothesis that all regression coefficients in each equation are jointly equal to zero is rejected at 1% (Prob > $\mathcal{X}^2$ = 0.00), thus indicating the fitness of the model with the data, and the relevance of the chosen explanatory variables in explaining the model. Furthermore, the likelihood ratio test [$\mathcal{X}^2$ (15) = 75.25], which tests the hypothesis that the correlations between the error terms of the equations are all zero is also rejected at 1% (Prob > $\mathcal{X}^2$ = 0.00), thus confirming the appropriateness of the MVP model over six (6) distinct univariate Probit models which ignore the potential correlation between the adoption decision of the different CSA practices by a plot manager. The correlation between error terms of the adoption equations are reported (see appendix). The estimated correlation coefficients are statistically significant in ten of the fifteen pair cases indicating that the decision to adopt CSA practices are often jointly determined.

The results reveal that farmers are more likely to adopt agroforestry and zero/minimum tillage on plots which they own. In line with earlier work on technology adoption (Kassie, 2017), this could be because they are reasonably assured of future access to return of their investment, unlike tenants who have access to the land for the duration of their tenure, and can only plan for the short term. However, plot owners are less likely to adopt green manure against a priori expectation. This could be a reflection of the very low acceptance of the practice in Northern Nigeria, due to two major reasons; the tedium of incorporating the green manure with native hoes, and the unwillingness of farmers to allow an economically unproductive fallow period (Yusuf and Yusuf, 2008).

The results also show that social capital positively influences the likelihood of adopting some CSA practices; particularly green manure and organic manure. This could be particularly helpful in the selection of appropriate green manure species, as well as sourcing of organic manure, which may not be readily available in required quantity (Ukoje and Yusuf, 2013). Farmers' group membership is an important component of their social capital, as it enables them to interact with other farmers, share their experiences, learn new techniques, obtain informal training from others who have already adopted better practices, and even obtain help implementing them (Akinbode and Bamire, 2015).

We also found that female farmers are less likely to adopt crop rotation and refuse retention, relative to their male counterparts. This may be because male farmers have access to more land due to gender norms which govern its ownership in the study area, and can afford to rotate crops among their multiple plots, compared to female farmers who have limited land access (Quisumbing and Pandolfelli, 2010). Furthermore, female farmers may consider bush burning over refuse retention, since it is a faster method of land clearing, given that they have to allocate their time between home management and farming (SOFA and Doss, 2011). Also, farmers who engage in off-farm activities have a greater likelihood of adopting agroforestry and green manure. This is expected, since both agroforestry and green manuring require considerable financial commitment from adopters. For example, agroforestry necessitates a reduction in effective crop area available for cultivation which may lead to a decrease in crop output initially, while adopters of green manuring have to be willing to allow an economically unproductive fallow period. Thus, farmers engaged in other income generating activities are more likely to adopt these practices, given that they have other income sources to augment household consumption (Kassie, 2017).

With respect to other plot characteristics, the likelihood of adopting organic and green manure reduced with walking distance. According to Ndiritu et al. (2014) who reported a similar result in Kenya, distance can be a significant cost for the adoption of certain labour-intensive technologies, especially those involving heavy and bulky inputs. Also, farmers who cultivate lowland plots are more likely to adopt crop rotation. Farmers use lowlands as an adaptation strategy, and plant different crops on them in line with the soil water content, which is dependent on the season they are in (rainy or dry). As expected, crop rotation and refuse retention are substitutes for inorganic fertilizer. Since their main benefit is to avoid draining the soil of the same nutrients continuously (Muhammad-Lawal et al., 2014), farmers who use fertilizer may feel that such practices are not necessary, given that they augment soil nutrient with fertilizers. The results further show that maize farmers in the Sudan savannah are more likely to adopt green manure, agroforestry and organic compost relative to other agro-ecological zones as expected, since they are affected more by the adverse effects of climate change, particularly desertification.

CONCLUSION

A shift to sustainable agriculture, which mitigates agriculture's contribution to climate change and helps farmers adapt to the conditions imposed by climate change is necessary in order to achieve the SDGs in Nigeria. In this study, we analysed the probability of adoption of six CSA practices by maize farmers in northern Nigeria, using plot-level data. We found that the adoption of these practices was generally low among the respondents. The econometric results showed that factors that influence adoption of CSA practices are not unanimous and vary significantly with the practices. In summary, plot owners are more likely to adopt agroforestry and zero/minimum tillage, while farmers engaged in off-farm income generating activities have a greater likelihood of adopting green manure and agroforestry. Social capital seems to positively influence organic manure and green manuring, and female farmers are less likely to adopt practices that require more time and more land (crop rotation and refuse retention). Practices that involve heavy and bulky inputs (organic manure and green manure) are less likely to be adopted by farmers whose plots are far from home, while farmers in the Sudan savannah are more likely to adopt practices that combat desertification. Based on these results, it is recommended that farmers be encouraged to join groups (farmer groups, cooperatives) as it provides an avenue for awareness, informal education and technical assistance in applying a new agricultural practice. Furthermore, local institutions (local government areas, village councils etc.) should be strengthened to improve rural roads, as this will considerably ease the transportation of farm inputs, especially organic manure, and thus encourage its adoption. It is recommended that government provides a policy strategy to promote the off-farm sector through investment in farmers' human capital. The income stream off-farm activities generate helps to ease the liquidity constraint often faced by smallholder farmers, which causes them to be risk averse to new technology, especially those that have significant financial implications. We conclude that these factors have to be accounted for when designing policies to promote CSA towards the achievement of sustainable livelihoods among farm households in Nigeria.

REFERENCES

AbdulKadir, A., Usman, M. T., Shaba, A. H. & Saidu, S. (2013) An appraisal of the eco-climatic characteristics in Northern Nigeria. African Journal of Environmental Science and Technology Vol. 7, Issue 8, pages 748-757

Afolami, C.A., Obayelu, A.E. & Vaughan, I.I. (2015) Welfare impact of adoption of improved cassava varieties by rural households in South Western Nigeria. Agricultural and Food Economics Vol. 3, Issue 1, pages 1-17. DOI 10.1186/s40100-015-0037-2

Akinbode, W.O. & Bamire, A.S. (2015) Determinants of adoption of improved maize varieties in Osun state, Nigeria. Journal of Agricultural Extension and Rural Development Vol. 7. Issue 3, pages 65-72

Anderson, J., Marita, C., Musiime, D. & Thiam, M. (2017). National Survey and Segmentation of Smallholder Households in Nigeria: Understanding Their Demand for Financial, Agricultural, and Digital Solutions. Consultative Group to Assist the Poor Working Paper. https://www.cgap.org/sites/default/files/Working-Paper-Survey%2BSegmentation-of-Smallholders-Nigeria-Oct-2017.pdf.

Arslan, A., McCarthy, N., Lipper, L., Asfaw, S. & Cattaneo, A. (2013) Adoption and intensity of adoption of conservation farming practices in Zambia. Agriculture, Ecosystems and Environment Vol. 187, pages 72–86.

Asfaw, S., Battista, F. & Lipper, L. (2016). Agricultural Technology Adoption under Climate Change in the Sahel: Micro-evidence from Niger Journal of African Economies, Vol. 25, Issue 5, pages 637-669 doi: 10.1093/jae/ejw005

Awotide, B.A., Karimov, A.A. & Diagne, A. (2016) Agricultural technology adoption, commercialization and smallholder rice farmers' welfare in rural Nigeria. Agricultural and Food Economics Vol. 4, Issue 1, pages 1-24

Beddington J., Asaduzzaman, M., Clark, M., Fernández, A., Guillou, M., Jahn, M., ... Wakhungu, J. (2012) Achieving food security in the face of climate change: Final report from the Commission on Sustainable Agriculture and Climate Change. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org/commission

Brown, M.E. & Funk, C.C. (2008) Food security under climate change. Science Vol. 319, Issue 5863, pages 580-581

Chakravarty, S.K., Ghosh, C.P., Suresh, A.N. Dey & Shukla, G. (2012) Deforestation: Causes, Effects and Control Strategies. In: Dr.Clement A. Okia (Ed.) Global Perspectives on Sustainable Forest Management. InTech, DOI: 10.5772/33342. Available from: http://www.intechopen.com/books/global-perspectives-on-sustainable-forest-management/deforestation-causes-effects-and-control-strategies

FAO (2010) Climate Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Garibaldi, L.A., Gemmill-Herren, B., D'Annolfo, R., Graeub, B.E., Cunningham, S.A. & Breeze, T.D. (2017) Farming Approaches for Greater Biodiversity, Livelihoods, and Food Security. Trends in Ecology and Evolution Vol. 32, Issue 1, pages 68–80

Gathala, M.K., Ladha, J.K., Kumar, V., Saharawat, Y.S., Kumar, V., Sharma, P.K., ... Pathak, H. (2011) Tillage and crop establishment affects sustainability of South Asia Rice–Wheat system. Agronomy Journal Vol. 103, Issue 4, pages 961–971.

Greene, W. H. (2008) Econometric Analysis (7th edition). New Jersey: Prentice Hall).

IPCC (2007) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp

Kassie, G.W. (2017) Agroforestry and farm income diversification: synergy or trade-off? The case of Ethiopia. Environmental Systems Research Vol. 6, Issue 1, page 8. Available at DOI 10.1186/s40068-017-0085-6

Khatri-Chhetri, A., Aggarwal, P.K., Joshi, P.K. & Vyas, S. (2017). Farmers' prioritization of climate-smart agriculture (CSA) technologies. Agricultural Systems Vol. 151, pages 184–191

Khatri-Chhetri, A., Aryal, J.P., Sapkota, T.B. & Khurana, R. (2016) Economic benefits of climate-smart agricultural practices to smallholders' farmers in the Indo-Gangetic Plains of India. Current Science Vol. 110, Issue 7, pages 1251–1256.

Lobell, D.B., Schlenker, W. & Costa-Roberts, J. (2011) Climate trends and global crop production since 1980. Science Vol. 333, Issue 6042, pages 616–620

McCarthy, N. & Brubaker, J. (2014) Climate-Smart Agriculture and resource tenure in Sub-Saharan Africa: A conceptual framework. Food and Agriculture Organization, Rome. www.fao.org.

Menale, K., Moti, J., Bekele, S., Mmbando, F. & Muricho, G. (2012) Plot and Household Level Determinants of Sustainable Agricultural Practices in Rural Tanzania. Environment for Development Discussion Paper Series EfD DP 12-02

Moyo, S. (2016) Family farming in sub-Saharan Africa: its contribution to agriculture, food security and rural development. International Policy Centre for Inclusive Growth (IPC-IG) Working Paper No. 150

Muhammad-Lawal, A., Omotesho, K.F., Adekola, O.F. & Adekunle, D. (2014) Assessment of Land Management Practices in Food Crops Production among Small Scale Farmers in Kwara State, Nigeria. International Journal of Agricultural Management and Development Vol. 4, Issue 2, pages 105-116

NBS (2012) Annual Abstract of Statistics. Nigerian Bureau of Statistics. Federal Republic of Nigeria, https://www.nigerianstat.gov.ng/pdfuploads/annual_abstract_2012.pdf.

Neufeldt, H.M., Jahn, B., Campbell, J., Beddington, F., DeClerck, A., De Pinto, J., Zougmore. R. (2013) Beyond climate-smart agriculture: toward safe operating spaces for global food systems. Agricultural Food Security Vol. 2, Issue 12, pages 1-6.

Onyibe, J.E., Sani, B.M., Baba, D., Chindo, H., Ibrahim, I.K. and Malumfashi, M. 2014. Maize: Production, Marketing, Processing and Utilization in Nigeria. National Agricultural Extension Research Liaison Services Extension Bulletin No. 217

Oladele O. I., Kolawole A. & Wakatsuki, T. (2011) Land tenure, investment and adoption of Sawah rice production technology in Nigeria and Ghana: A qualitative approach. African Journal of Agricultural Research Vol. 6, Issue 6, pages 1519-1524

Quisumbing, A.R. & Pandolfelli, L. (2010) Promising approaches to address the needs of poor female farmers: resources, constraints and interventions. World Development, Vol. 38, Issue 4, pages 581–592

Ranum, P., Peña-Rosas, J.P. and Garcia-Casal, M.N. (2014). Global maize production, utilization, and consumption Annals of the New York Academy of Sciences Vol. 1312, Issue 1, pages 105-112, Ann. N.Y. Acad. Sci. ISSN 0077-8923.

S.O.F.A. & Doss, C. (2011). The role of women in agriculture. Agricultural development economics division. Food and Agricultural Organisation of the United Nations. Working paper 11: 02

Sapkota, T.B., Majumdar, K., Jat, M.L., Kumar, A., Bishnoi, D.K., McDonald, A.J. & Pampolino, M. (2014). Precision nutrient management in conservation agriculture *based wheat production of Northwest India: profitability, nutrient use efficiency and environmental footprint. Field Crop Research Vol. 155, pages 233–244.*

Srivastava, A.K., Mboh, C.M., Gaiser, T. & Ewert, F. (2017) Impact of climatic variables on the spatial and temporal variability of crop yield and biomass gap in Sub-Saharan Africa- a case study in Central Ghana. Field Crops Research. Vol. 203, pages 33–46

Ugwu, D.S. & Kanu, I.O. (2012) Effects of agricultural reforms on the agricultural sector in Nigeria. Journal of African Studies and Development, Vol. 4, Issue 2, pages 51-59

Ukoje, J.A. & Yusuf, R.O. 2013. Organic Fertilizer: The Underestimated Component in Agricultural Transformation Initiatives for Sustainable Small Holder Farming in Nigeria. Ethiopian Journal of Environmental Studies and Management, Vol. 6, Issue 1, pages 794-801

UNDESA (2015). World Population Prospects The 2015 Revision Key Findings and Advance Tables. ESA/P/WP.241 Department of Economic and Social Affairs Population Division. United Nations, New York. https://esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf

UNDP (2016). Sustainable Development Goals http://www.undp.org/content/dam/undp/library/corporate/brochure/SDGs_Booklet_Web_En.pdf

Yusuf, A. A. and Yusuf, H.A. (2008). Evaluation of Strategies for Soil Fertility Improvement in Northern Nigeria and the Way Forward

Factors influencing the adoption of climate smart agriculture by farmers in Ségou region in Mali

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ABSTRACT

Climate change and its impacts on agriculture are major concerns for a food secured economy especially for developing countries like Mali. The carbon footprints of agriculture also a concern for future climate. These make sustainable agricultural practices a prerequisite for crop production today. This study analysed the adoption of Climate Smart Agriculture (CSA) by farmers in Ségou region in Mali. Data was collected on 432 households covered by climate smart villages using multivariate probit and poisson regressions. The result showed that, out of five CSA practices, row planting was the main practice adopted by the farmers. The adoption of various CSA strategies was significantly influenced by socioeconomic, institutional and climate related factors. The study concluded that CSA adoption is low among the farmers. Nonetheless, policy factors such as extension service delivery can be triggered to enhance CSA adoption.

Key words: Climate change, climate smart agriculture, multivariate probit, poisson regression, Ségou region, Mali,

RÉSUMÉ :

Le changement climatique et ses impacts sur l'agriculture sont des préoccupations majeures pour une économie sans sécurité alimentaire comme le Mali. L'empreinte carbone de l'agriculture est également une préoccupation pour le climat futur. Les pratiques agricoles durables sont donc une condition préalable à la production agricole actuelle. Cette étude a analysé l'adoption de l'agriculture intelligente face au climat (CSA) par les agriculteurs de la région de Ségou au Mali. Les données ont été recueillies auprès de 432 ménages couverts par des villages intelligents sur le plan climatique. Des régressions probit et poisson multivariées ont été utilisées pour l'analyse des données. Les pratiques CSA étaient les suivantes : variétés résistantes à la sécheresse, agriculture de conservation, gestion intégrée et durable des forêts, plantation en ligne et lutte intégrée contre les parasites. Le résultat a montré que, sur les cinq pratiques CSA, la plantation en ligne était la principale pratique adoptée par les agriculteurs. L'adoption des différentes stratégies CSA a été significativement influencée par des facteurs socio-économiques, institutionnels et climatiques. L'étude a conclu que l'adoption de la CSA est faible parmi les agriculteurs. Néanmoins, des facteurs politiques tels que la prestation de services de vulgarisation peuvent être déclenchés pour améliorer l'adoption de la CSA.

Mots clés : Changement climatique, Agriculture intelligente face au climat, Probit multivarié, Régression de Poisson, région de Ségou, Mali.

INTRODUCTION

Climate change has become a global threat as its impacts are noticeable in all sectors and all regions. Its impact is also high on agrarian communities that formed a large portion of developing countries such as Mali. The scientific evidence of the impacts of climate change is in no doubt established. This recognition led to the adoption of the Sustainable Development Goal (SDG) 13 that seeks to take urgent action to combat climate change and all its impacts. One of the major impacts of climate change is on food security. This is obvious from the current levels of food insecurity in the world that has been on the increase despite the commitment in SDG 2 that seeks to achieve zero hunger by 2030. Globally, one out of every nine person (10.9 percent, representing 821 million people) were undernourished in 2017 and this is higher than 804 million people in 2016 (FAO, IFAD, UNICEF, WFP, & WHO, 2018), and in sub-Saharan African (SSA), 23.2 percent of the population is undernourished in 2017. The food insecurity situation is more prevalent in SSA as there is an increasing level of undernourishment in all of its regions except Eastern Africa. For instance, the prevalence of undernourishment in Western Africa (where Mali is located) increase from 10.4 percent in 2010 to 10.7 percent in 2014, 12.8 percent in 2016 and 15.1 percent in 2017 (FAO, IFAD, UNICEF, WFP, & WHO, 2018)[66]. These observed trends of undernourishment are similar to the observed levels of food insecurity measured through food insecurity experience scale that shows that food insecurity is worsening and requires more attention than before.

Climate variability are key contributing factors to the increasing food insecurity levels whose impacts are noticeable on all the dimensions of food security (FSIN, 2018; FAO, IFAD, UNICEF, WFP, & WHO, 2018; Tripathi et al., 2016). Therefore, not only is climate change leading to low food production or availability but also, a decline in the quality of foods (Tripathi et al., 2016). Smallholder farmers are one of the most vulnerable groups to climate change and variability. Climate change leads to wearing out of all efforts made by farmers in savings and resource accumulation. Mutabazi et al. (2015) explained that households that lack effective safeguards to risks are likely to be more prone to poverty and other vulnerability traps. Food production is expected to increase by 60 percent in order to meet the increasing food demands, and this objective is unattainable under business-as-usual response to climate change (FAO, 2013). Farmers, therefore, need to take adaptive measures that would minimize the impacts of climate change. These adaptation strategies must lead to higher food production without depletion of natural resources. For sustainable food production, one of the important strategies is Climate Smart Agriculture (CSA). This is defined as

66FAO-Food and Agriculture organization, IFAD-International Fund For Agriculture Development, UNICEF-United Nations International Children Emergency Fund, WFP- World Food Programme, WHO-World Health Organization 'agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances the achievement of national food security and development goals' (FAO, 2013). The objective of CSA is not to introduce new sustainability principles, but to integrate specificities of adaptation and mitigation into sustainable agricultural policies, programs and investments (Lipper & Zilberman, 2017). The emergence of CSA is due to different opinions on the concepts and approaches to sustainable agriculture and the lack of integrating climate change into agriculture policies and their role in ensuring food security (Lipper & Zilberman, 2017). Unlike conventional food production, CSA integrates climate change and agricultural development planning efforts (Sain et al., 2016). This implies that CSA has become a necessary condition to sustainable agriculture due to three major factors. These include increase climate change and events that worsens rainfed agriculture, permanent changes in weather patterns which led to non-productivity at certain locations, and the need to reduce agriculture's contribution to greenhouse gas concentration in the atmosphere (Lipper & Zilberman, 2017).

CSA has become an important adaptation and mitigation strategy to climate change (Partey et al., 2018) and to provide food for the increasing population (Totin et al., 2018). Maguza-Tembo et al. (2016) estimated that the adoption of CSA leads to an increase in maize yield between 9-37 percent and an increase in crop revenue between 36-60 percent; depending on the CSA strategy. These are indications of positive gains from the adoption of CSA. Considering the significant roles of CSA, there is the need to engage in its promotion. Unfortunately, it appears the adoption of CSA is low among farmers in arable land zone in Mali. Therefore, the main question this study seeks to answer is what factors influence or limits the adoption of CSA by farming households in the climate smart village in Ségou region. This is aimed to provide policy indicators that must be considered and promoted to enhance the adoption of CSA in the region. The findings of this study are particularly useful for the Government of Mali on its planting for food and jobs policy. Other non-governmental organizations working with farmers such as IFDC and CCAFS can rely on the recommendations in this research to promote CSA in Mali. Maize farmers are considered in this study because maize is the number one food security crop in Mali, where almost every farmer cultivates maize and almost every household consumes food from maize. However, among the major food grains (maize, rice, sorghum and millet), maize is the most affected by climate change (Tripathi et al., 2016). These therefore means that sustainable maize production amidst climate change is a necessary condition for sustainable food security in Mali.

METHODOLOGY

Study location

The study was conducted in Ségou region in Mali. This area covers 64,821 km^2 (5%) of Mali's land area and located in the middle part of the country. Agriculture (crop, fishing and animal husbandry) is the main stay for the majority of households in the region. Due to its location Segou is characterized by a semi-arid climate, close to Tombouctou region that is dessert or semi-dessert, it is naturally warm and also experiences an average rainfall 513 mm. This make households in the region more vulnerable to climate change and climate shocks such as drought. However, agriculture is the main economic activity of the economically employed in this region. The major grain crops cultivated include maize, rice, sorghum and millet. For sustainable food production and reduced poverty among households in the region, it is appropriate that farmers in the region adopt CSA technologies.

Sampling and data collection

The target population of the study is the maize farming households. The study collected data on all farmers covered by the project of climate smart agriculture. In the first stage, purposive sampling was used in the choice of Ségou region in Mali for the study. The choice is based on the researcher's in-depth knowledge in this region and the high vulnerability of farming households to climate change in this part of Mali. In the second stage, all the farmers covered by the project smart climate village in Cinzana in Ségou region. In all, a total of 300 households were interviewed for the study.

The data was collected using questionnaire administering. Trained research assistants who can speak both French and the community dialect (Bambara) helped in the data collection. This helped in minimizing possible errors in translating the various questions. The data was entered into and analysed by STATA 14 software package.

Data analysis

The study analysed the determinants of the adoption of CSA technologies among farming households (see definition of variable in Table 1). This was analysed using multivariate probit regression for the specific strategies and a poisson regression for the count of the technologies. In this study, five climate smart technologies were considered, and this suggests that the individual adoption equations are five. Theoretically, the multivariate probit model is an extension of the probit and bivariate probit models. Its applicability differs from multinomial probit where the individual observations (farmers in this case) are fixed to choose only a single option from more than two options. For the multivariate probit model, the options are independent, therefore, the farmers are allowed to choose more than one options simultaneously. In this study, a household is free to adopt more than one of the five technologies simultaneously. The MVP result was complemented with a Poisson regression that uses the count of CSA adopted by the farmers. Empirically, the model estimated is :

$$\begin{aligned} CSA = {} & \beta_1 Sex + \beta_2 Adults + \beta_3 Farm\,hours + \beta_4 Land\ source + \beta_5 Experience + \beta_6 Education \\ & + \beta_7 Farming\ system + \beta_8 Commercial\ production + \beta_9 Extension + \beta_{10}\ FBO + \beta_{11}\ Credit\ access + \\ & \beta_{12}\ Drought + \beta_{13}\ Flood + \beta_{14}\ Pest\,infestation + \beta_{15}\ Climate\ perception \end{aligned}$$

Table 1: Definition and descriptive statistics of respondents

Variable	Definition
Sex	Dummy: 1 if farmer is a male and 0 if a female
Adults	The total number of household members with age 18 and above
Farm hours	The average number of hours a farmer spends on farm daily
Land source	Dummy: 1 if farmer own the land used for cultivation, 0 otherwise
Experience	Total number of years of maize cultivation
Education	Total number of years of formal education.
Farming system	Dummy: 1 if monocropping and 0 if mixed cropping.

Commercial production	Dummy: 1 if farmer produce beyond subsistence motive and 0 solely for subsistence
Extension	Dummy: 1 if a farmer had access to extension service, 0 if not.
FBO	Dummy: 1 if farmer belonged to an FBO, 0 if not.
Credit access	Dummy: 1 if farmer had access to credit for crop production and 0 if not.
Farm size	Total number of acres of maize cultivated by a farmer.
Drought	Number of times a farmer experience drought within the past ten years
Flood	Number of times a farmer experience flood within the past ten years
Pests infestation	Dummy: 1 if farmer perceived that pest infestation is increasing, 0 if decreasing.
Climate perception	Dummy: 1 if farmer perceived precipitation as increasing and temperature as decreasing, 0 if otherwise.

Source: Authors, (2019)

RESULTS AND DISCUSSIONS

Level of adoption of climate smart technologies

Climate smart technologies used in the study and the adoption level by farmers were shown in table 2; the first section of the table shows the adoption level of each of the technologies while the second section shows the combination or rate of adoption of the five technologies. Among the five technologies, only row planting recorded an adoption level beyond 50.0%. This implies that the level of adoption of the climate smart technologies is low among the farmers. Specifically, only 29.9%, 31.5%, 23.6% and 30.1% of the household heads adopted drought resistant varieties, CA, ISFM and IPM, respectively. In terms of adoption rate, as high as 22.5% of the farmers adopted none of the five CSA technologies while only 1.4% adopted all five technologies. The highest percentage (26.4%) of the household heads adopted only one of the technologies. It can be concluded from this result that the adoption of CSA is low among the household heads. Considering the changing climatic conditions and the need for climate adaptation to ensure sustainable food production, the result of this study is rather revealing, therefore, the need for policy makers to redirect their efforts in promoting these technologies among farming communities of Ségou region in Mali.

Table 2 : Level of adoption of climate smart technologies

CSA technology	Adopters		Non-adopters	
	Freq.	%	Freq.	%
Drought resistant	129	29.9	303	70.1
CA	136	31.5	296	68.5
ISFM	102	23.6	330	76.4
Row planting	218	50.5	214	49.5
IPM	130	30.1	302	69.9
Adoption level				

None of the technologies	97	22.5
Only one technology	114	26.4
Any two technologies	110	25.5
Any three technologies	69	16.0
Any four technologies	36	8.3
All five technologies	6	1.4
Total	432	100

Source: Authors, (2019)

Factors influencing the adoption of climate smart technologies

The outcome in Table 3 shows the factors influencing the adoption of each CSA technology (multivariate probit estimates) and the adoption intensity of farmers (poisson estimates). The result shows that a number of socioeconomic, institutional and climate related factors had significant influence on the adoption decision and/or intensity of the farmers. These factors are discussed in this section.

The sex of the household head had a positive significant effect on the adoption of row planting but a negative significant effect on the adoption of IPM. This means that while the male heads have a higher probability of adopting row planting, the female heads on the other hand have a higher probability of adopting IPM. The estimated positive effect of sex on row planting is consistent with the findings of Mentire & Gecho (2017). Contrary to this finding, Donkor et al. (2016) estimated that female farmers have a higher probability of adopting row planting of rice in northern Ghana. The number of adults in a household is used as a proxy for labour availability for farm activities. The result shows that higher number of adults in a household significantly decreases the probability of adopting drought resistant varieties, ISFM and IPM. This finding discounted studies such as Lunduka et al. (2017) and Idrisa et al. (2014). Education plays a crucial role in improving the human capital and the understanding of climate change and the need for adaptation. The result shows that although education leads to a reduction in the probability of adopting ISFM, higher education leads to the adoption of more CSA technologies. Consistently, Mutua-Mutuku et al. (2017) also estimated a negative effect of education on the adoption of ISFM. Aura (2016) on the contrary estimated that education enhances the adoption of ISFM.

The source of land had a mixed effect on the adoption of CSA. While it had positive significant effects on the adoption of drought tolerant varieties and row planting, it had negative significant effect on the adoption of CA and adoption intensity of the farmers. Empirically, Donkor et al. (2016) also estimated a positive effect of land source on the adoption of row planting, although insignificant. The number of years a farmer had in maize production decreases the probability of adopting drought resistant varieties but increases the adoption intensity of the farmers. Generally, the experienced farmers are conversant with the production process and are able to adjust their production activities other than just the adoption of CSA. While farming system had significant effect on the adoption of individual strategies such as drought tolerant varieties and IPM, it had a positive significant effect on the adoption intensity of the farmers. Commercial production had a negative significant effect on the adoption of CA but positive significant effects on the adoption of ISFM, row planting and IPM technologies. Deressa et al., (2011) also estimated a negative effect of farm size on climate adaptation.

The effect of access to extension services is positive and significant in explaining ISFM and IPM adoption decision by farmers. Thus, farmers who had access to extension services in the cropping season had higher probability of adopting these technologies than those who did not access extension services. Extension officers are generally responsible for transferring technologies to the farmers. Therefore, it is expected that the farmers become more aware of these technologies and their importance, hence the high adoption probability. This justified the need for enhancing the provision of extension service to farmers, especially, in the era of climate change and the rapid technological advancement. Mutua-Mutuku et al. (2017) also estimated a positive effect of extension access on ISFM adoption.

FBO membership had positive significant effects on the adoption of drought resistant varieties and IPM technologies. These are justifiable findings. In addition to the provision of labour assistance to each other and sharing knowledge among groups, the groups also serve as a contact for most climate intervention programs. Because the groups offer the opportunity to contact large number of farmers at a time, programs that aim at promoting CSA are done through the groups. Thus, groups have become a conveying belt for CSA in most farming communities. Consistently Mwungu et al. (2018) estimated that FBO members have higher probability of adopting improved varieties.

Access to credit leads to a higher probability of adopting row planting but leads to the adoption of lesser number of CSA technologies. Since row planting are done using human labour, it implies that the demand for labour would increase and this would mean that more capital is required for farming. It is therefore consistent that farmers who had access to credit would adopt row planting. However, credits may come with some terms and conditions that may favour the adoption of specific technologies other than several technologies. Consistently, Imran et al. (2018) explained that adoption of CSA is limited by low access to farm services such as credit. Also, Deressa et al., (2011) found a positive effect on the adaptation to climate change by farmers.

Climate perception and pest infestation had significant effects on the adoption of IPM technologies. These are all positive, implying that, farmers who perceives the direction of change in temperature and precipitation appropriately as well as perceived an increasing level of pest infestation have higher probabilities of adopting IPM. This justify the need for improving the understanding of farmers on climate change and enhancing their local knowledge in predicting the patterns of most climatic variables, particularly, precipitation.

Table 3 : Factors influencing the adoption of climate smart technologies

Variable	Drought resistant		CA		ISFM		Row planting		IPM		Count (Poisson model)	
	Coef. (Std. err.)	Z-value [P-value]	Coef. (Std. err.)	Z-value [P-value]	Coef. (Std. err.)	Z-value [P-value]	Coef. (Std. err.)	Z-value [P-value]	Coef. (Std. err.)	Z-value [P-value]	Coef. (Std. err.)	Z-value [P-value]
Sex	-0.128 (0.179)	-0.71 [0.475]	-0.050 (0.164)	-0.3 [0.762]	-0.270 (0.175)	-1.54 [0.123]	0.292* (0.161)	1.81 [0.071]	-0.537*** (0.169)	-3.18 [0.001]	-0.100 (0.092)	-1.09 [0.275]
Household adults	-0.070*** (0.024)	-2.96 [0.003]	0.017 (0.020)	0.83 [0.409]	-0.069*** (0.023)	-3.05 [0.002]	-0.031 (0.020)	-1.57 [0.117]	-0.055** (0.022)	-2.49 [0.013]	-0.034 (0.022)	-1.57 [0.117]
Education	0.007 (0.014)	0.50 [0.618]	0.021 (0.013)	1.63 [0.103]	-0.036** (0.015)	-2.37 [0.018]	0.006 (0.013)	0.41 [0.680]	0.017 (0.014)	1.21 [0.225]	0.210*** (0.079)	2.66 [0.008]
Farm hours	0.022 (0.040)	0.56 [0.575]	0.127*** (0.038)	3.32 [0.001]	-0.035 (0.042)	-0.84 [0.398]	-0.050 (0.037)	-1.34 [0.180]	0.016 (0.040)	0.41 [0.684]	-0.002 (0.003)	-0.64 [0.524]
Land source	0.728*** (0.157)	4.63 [0.000]	-0.304** (0.139)	-2.20 [0.028]	0.055 (0.152)	0.36 [0.718]	0.739*** (0.137)	5.40 [0.000]	-0.159 (0.145)	-1.09 [0.274]	-0.222*** (0.077)	-2.87 [0.004]
Experience	-0.030*** (0.007)	-4.37 [0.000]	0.000 (0.005)	0.02 [0.982]	0.005 (0.005)	1.01 [0.313]	0.001 (0.005)	0.28 [0.778]	0.008 (0.005)	1.50 [0.134]	0.242*** (0.085)	2.85 [0.004]
Farming system	-0.631*** (0.149)	-4.23 [0.000]	-0.101 (0.138)	-0.74 [0.461]	0.064 (0.150)	0.43 [0.670]	-0.197 (0.136)	-1.44 [0.149]	-0.515*** (0.142)	-3.61 [0.000]	0.155* (0.080)	1.94 [0.053]
Commercial production	0.196 (0.165)	1.18 [0.236]	-0.347** (0.164)	-2.11 [0.035]	0.337** (0.167)	2.02 [0.044]	1.037*** (0.162)	6.39 [0.000]	0.341** (0.159)	2.14 [0.032]	0.126 (0.080)	1.56 [0.118]
Extension	0.199 (0.158)	1.26 [0.207]	-0.074 (0.142)	-0.52 [0.604]	0.259* (0.154)	1.68 [0.093]	-0.181 (0.141)	-1.28 [0.200]	0.717*** (0.147)	4.88 [0.000]	0.075 (0.087)	0.87 [0.386]
FBO	0.285* (0.152)	1.88 [0.060]	-0.052 (0.139)	-0.37 [0.710]	0.175 (0.156)	1.12 [0.262]	-0.160 (0.139)	-1.15 [0.248]	0.426*** (0.149)	2.85 [0.004]	0.001 (0.007)	0.14 [0.889]
Credit access	0.078 (0.177)	0.44 [0.658]	0.021 (0.154)	0.14 [0.891]	0.165 (0.165)	1.00 [0.317]	0.442*** (0.158)	2.80 [0.005]	-0.268 (0.165)	-1.63 [0.104]	-0.125*** (0.032)	-3.93 [0.000]
Farm size	0.010 (0.012)	0.79 [0.427]	-0.019 (0.020)	-0.95 [0.342]	0.009 (0.012)	0.76 [0.447]	0.006 (0.015)	0.44 [0.656]	0.003 (0.012)	0.26 [0.791]	-0.105** (0.042)	-2.48 [0.013]
Climate perception	0.335 (0.214)	1.56 [0.118]	0.285 (0.188)	1.51 [0.130]	0.096 (0.207)	0.47 [0.642]	-0.100 (0.184)	-0.55 [0.584]	0.344* (0.203)	1.69 [0.091]	0.085 (0.123)	0.69 [0.488]
Drought times	0.011 (0.053)	0.20 [0.840]	-0.088* (0.049)	-1.79 [0.074]	-0.352*** (0.072)	-4.89 [0.000]	-0.091* (0.051)	-1.78 [0.076]	-0.232*** (0.066)	-3.52 [0.000]	-0.036*** (0.012)	-2.98 [0.003]
Flood times	-0.227*** (0.083)	-2.72 [0.007]	-0.005 (0.063)	-0.08 [0.937]	-0.163** (0.079)	-2.06 [0.039]	-0.067 (0.066)	-1.02 [0.308]	-0.005 (0.072)	-0.06 [0.949]	0.148 (0.111)	1.34 [0.181]
Pests infestation	0.301 (0.231)	1.30 [0.193]	0.043 (0.204)	0.21 [0.832]	-0.124 (0.235)	-0.53 [0.596]	-0.100 (0.200)	-0.50 [0.617]	0.510** (0.233)	2.19 [0.029]	0.004 (0.008)	0.51 [0.612]
_cons	-0.583 (0.431)	-1.35 [0.176]	0.343 (0.385)	0.89 [0.373]	0.368 (0.421)	0.88 [0.381]	0.135 (0.376)	0.36 [0.720]	-0.709 (0.412)	-1.72 [0.085]	0.852 (0.223)	3.82 [0.000]

Unexpectedly, farmers who experienced drought within the past ten years have lesser probabilities of adopting CA, ISFM, row planting and IPM. Again, farmers who experienced floods in the last ten years have lower probability of adopting IPM technology. Although the mechanisms through which farmers that experienced floods and droughts may resist the adoption of CSA technologies is not clear in this study, it is possible that these farmers are laggards and may not adopt these technologies despite the impacts of drought or flood. Contrary to the findings of this research, Mwungu et al. (2018) estimated that farmers who have experienced any climate shock have higher probability of adopting minimum tillage. Also, Deressa et al. (2011) estimated that an increase in observed precipitation leads to a decrease in climate adaptation by farmers.

CONCLUSION

The negative impacts of climate change on the performance of agriculture as well as the potential role of CSA to ensure sustainable food production has become increasingly evident. Within this framework, it is crucial that research efforts are intensified to promote and analyses the adoption of various CSA technologies, especially in areas of Ségou region in Mali, where climate change impacts are more noticeable and experienced. The descriptive statistics and marginal success prediction show that the adoption of row planting is higher than that of the other technologies. The factors that influenced the adoption of each CSA vary in terms of magnitude, direction and significance. For the adoption level, education, land source, experience, farming system, credit access, farm size and drought had significant effect on adoption. These clearly indicates that for the promotion of adoption of various climate smart technologies, specific factors must be considered, although targeting some variables for the adoption of one technology may have a replication effect on the adoption of another technology. Considering the low level of adoption and the positive effect of education on adoption of more technologies, there is the need to improve farmers' knowledge on the need for CSA. This also justifies the need for intensifying the delivery of extension services by the Ministry of Agriculture and Rural development to promote the adoption of climate smart agriculture. However, considering the low extension to farmer ratio in Mali, and the positive effect of FBO membership on the adoption of CSA technologies, farmers are encouraged to join community farmer groups to enhance extension services' provision through these groups.

REFERENCES

Aura, S. (2016). Determinants of the adoption of integrated soil fertility management technologies in Mbale division, Kenya. African Journal of Food, Agriculture, Nutrition and Development, Vol. 16, Issue 1, 10697–10710. https://doi.org/10.18697/ajfand.73.15735

Deressa, T. T., Hassan, R. M., & Ringler, C. (2011). Perception and adaptation to climate change by farmers in the Nile basin of Ethiopia. Journal of Agricultural Science, Vol. 149, pages 23–31. https://doi.org/10.1017/S0021859610000687

Donkor, E., Owusu-Sekyere, E., Owusu, V., & Jordaan, H. (2016). Impact of row-planting adoption on productivity of rice farming in northern Ghana. Review of

Agricultural and Applied Economics, Vol 2, pages 19–28. https://doi.org/10.15414/raae/2016.19.02.19-28

FAO. (2013). Climate-smart agriculture: Sourcebook. FAO, Rome. ISBN 978-92-5-107720-7 (print) E-ISBN 978-92-5-107721-4 (PDF), http://www.fao.org/3/a-i3325e.pdf

FAO, IFAD, UNICEF, WFP, & WHO. (2018). The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition. Rome, FAO. ISBN 978-92-5-131570-5 © FAO 2019, http://www.fao.org/3/ca5162en/ca5162en.pdf

FSIN. (2018). Global report on food crises 2018. Rome. Retrieved from http://www.fsincop.net/fileadmin/user_upload/fsin/docs/global_report/2018/GRFC_2018_Full_report_EN_Low_resolution.pdf

Guteta, D., & Abegaz, A. (2015). Determinants of Integrated Soil Fertility Management adoption under annual cropping system in Arsamma watershed , southwestern Ethiopian Highlands. African Geographical Review. https://doi.org/10.1080/19376812.2015.1088390

Gwandu, T., Mtambanengwe, F., Mapfumo, P., Mashavave, T. C., Chikowo, R., & Nezomba, H. (2014). Factors Influencing Access to Integrated Soil Fertility Management Information and Knowledge and its Uptake among Smallholder Farmers in Zimbabwe. The Journal of Agricultural Education and Extension, Vol. 20, Issue 1, pages 79–93. https://doi.org/10.1080/1389224X.2012.757245

Idrisa, Y. L., Abdoulaye, T., Mohammed, S. T., & Ibrahim, A. A. (2014). Analysis of Drought-Tolerant Maize Adoption and its Effect on Food Security among Farmers in the Sudan Savanna of Northeastern Nigeria. Asian Journal of Agricultural Extension, Economics & Sociology, Vol. 3, Issue 6, pages 496–504.

Imran, M. A., Ali, A., Ashfaq, M., Hassan, S., Culas, R., & Ma, C. (2018). Impact of Climate Smart Agriculture (CSA) Practices on Cotton Production and Livelihood of Farmers in Punjab , Pakistan. Sustainability, Vol.10, pages 1–20. https://doi.org/10.3390/su10062101

Kirinya, J., Taylor, D., Kyamanywa, S., & Karungi, J. (2013). Adoption of integrated pest management (IPM) technologies in Uganda: review of economic studies. International Journal of Advanced Research, Vol. 1, Issue 6, pages 401–420.

Lipper, L., & Zilberman, D. (2017). A short history of the evolution of the climate smart agriculture approach and its links to climate change and sustainable agriculture debates. Climate Smart Agriculture, pages 13–30. https://doi.org/10.1007/978-3-319-61194-5

Lunduka, R. W., Mateva, K. I., Magorokosho, C., & Manjeru, P. (2017). Impact of adoption of drought-tolerant maize varieties on total maize production in south Eastern Zimbabwe. Climate and Development, Vol. 11, Issue 1, pages 35-46. https://doi.org/10.1080/17565529.2017.1372269.

Maguza-Tembo, F., Abdi-Khalil, E., Mangisoni, J., & Mkwambisi, D. (2016). Does Adoption of Climate Smart Agriculture (CSA) Technologies Reduce Household Vulnerability to Poverty ? Journal of Economics and Sustainable Development, Vol. 7, Issue 21, pages 125–130.

Matthews, G. (2017). Integrated Pest Management : Principles. Encyclopedia of Applied Plant Sciences (Second Edi, Vol. 2). Elsevier. https://doi.org/10.1016/B978-0-12-394807-6.00060-5

Mentire, W., & Gecho, Y. (2017). Factors Affecting Adoption of Wheat Row Planting Technology : The Case of Sodo Zuriya Woreda , Wolaita Zone , Southern. Innovative Systems Design and Engineering, Vol. 8, Issue 1, pages 1–8.

Mutabazi, K. D., Sieber, S., Maeda, C., & Tscherning, K. (2015). Assessing the determinants of poverty and vulnerability of smallholder farmers in a changing climate : the case of Morogoro region , Tanzania. Regional Environmental Change. Vol. 15, No. 7, pages 1243-1258, https://doi.org/10.1007/s10113-015-0772-7

Mutua-Mutuku, M., Nguluu, S. N., Akuja, T., Lutta, M., & Bernard, P. (2017). Factors that influence adoption of integrated soil fertility and water management practices by smallholder farmers in the semi-arid areas of Eastern Kenya. Tropical and Subtropical Agroecosystems, Vol. 20, Issue 1, pages 141–153.

Mwungu, C. M., Mwongera, C., Shikuku, K. M., Acosta, M., & Läderach, P. (2018). Determinants of Adoption of Climate-Smart Agriculture Technologies at Farm Plot Level : An Assessment from Southern Tanzania. In W. L. Filho (Ed.), Handbook of Climate Change Resilience (pp. 1–15).

Palm, C., Blanco-canqui, H., Declerck, F., Gatere, L., & Grace, P. (2014). Conservation agriculture and ecosystem services: An overview. Agriculture, Ecosystems and Environment, Vol. 187, pages 87–105. https://doi.org/10.1016/j.agee.2013.10.010

Partey, S. T., Zougmor, R. B., Ouedraogo, M., & Campbell, B. M. (2018). Developing climate-smart agriculture to face climate variability in West Africa : Challenges and lessons learnt. Journal of Cleaner Production Journal, Vol. 187, pages 285–295. https://doi.org/10.1016/j.jclepro.2018.03.199

Powlson, D. S., Stirling, C. M., Thierfelder, C., White, R. P., & Jat, M. L. (2016). Does conservation agriculture deliver climate change mitigation through soil carbon sequestration in tropical agro-ecosystems? Agriculture, Ecosystems and Environment, Vol. 220, pages 164–174. https://doi.org/10.1016/j.agee.2016.01.005

Rahman, S., Norton, G. W., & Rashid, M. H. (2018). Economic impacts of integrated pest management on vegetables production in Bangladesh. Crop Protection, Vol. 113, pages 6–14. https://doi.org/10.1016/j.cropro.2018.07.004

Sain, G., María, A., Corner-dolloff, C., Lizarazo, M., Nowak, A., Martínez-barón, D., & Andrieu, N. (2016). Costs and bene fi ts of climate-smart agriculture: The case of the Dry Corridor in Guatemala. Agricultural Systems, Vol. 151, pages 163–173. https://doi.org/10.1016/j.agsy.2016.05.004

Totin, E., Segnon, A. C., Schut, M., & Affognon, H. (2018). Institutional Perspectives of Climate-Smart Agriculture : A Systematic Literature Review. Sustainability, Vol.10, pages 1–20. https://doi.org/10.3390/su10061990

Tripathi, A., Kumar, D., Chauhan, D. K., Kumar, N., & Singh, G. S. (2016). Agriculture, ecosystems and environment paradigms of climate change impacts on some major food sources of the world: A review on current knowledge and future *prospects. Agriculture, Ecosystems and Environment, Vol. 216, pages 356–373. https://doi.org/10.1016/j.agee.2015.09.034*

Vandercasteelen, J., Dereje, M., Minten, B., & Taffesse, A. S. (2013). Scaling-up adoption of improved technologies: The impact of the promotion of row planting on farmers' teff yields in Ethiopia. LISCO Discussion papers 34413, LICOS-Centre for Institution Economic Performance, KU Leuven.

Witkowska, E., Moorhouse, E. R., Jukes, A., Elliott, M. S., & Collier, R. H. (2018). Implementing Integrated Pest Management in commercial crops of radish (Raphanus sativus). Crop Protection, Vol.114, pages 148–154. https://doi.org/10.1016/j.cropro.2018.08.008

Wolde, E. Y. (2016). Effect of wheat row planting technology adoption on small farms yield in Ofla Woreda, Ethiopia. International Journal of Agricultural Extension and Rural Development, Vol. 3, Issue 5, pages 184–196.

Wossen, T., Abdoulaye, T., Alene, A., Feleke, S., Menkir, A., & Manyong, V. (2017). Measuring the impacts of adaptation strategies to drought stress : The case of drought

tolerant maize varieties. Journal of Environmental Management, Vol. 203, pages 106–

113. https://doi.org/10.1016/j.jenvman.2017.06.058

Impact of Climate Change on cereal yield and production in the Sahel: case of Burkina Faso

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ABSTRACT

Climate change is one of the biggest challenges of the 21st century. It affects all countries in the world, especially Sahelian countries in Africa. This paper evaluated the impact of climate change on cereal yield in Burkina Faso. The ordinary least squares (OLS) regression model was applied to time-series data from 1991 to 2016 extracted from the World Bank databases. The results show that temperature adversely affects yield and cereal production, while precipitation has positive effect. An increase in rainfall of 1 millimetre would increase cereal production by 385 tons in the long term and 252 tons in the short term. In the same vein, an increase in rainfall of 1 millimetre would increase agricultural yield by 9 kg per hectare in the long term. However, in the short term, an increase in temperatures of 1°C would result in a decrease in cereal production and agricultural yield of 134,748 tons and 72 kg per hectare, respectively. However, in the long term, a rise in temperatures of 1°C would result in a decrease in cereal production and cereal yield of 154,634 tons and 1,074 kg per hectare, respectively. Besides, the results indicate that the emission of carbon dioxide has no significant effect on yield and cereal production. Implementing effective adaptation strategies, such as access to improved seed, smart agriculture practice, and irrigation infrastructure could reduce vulnerability to climate shocks.

Keywords : Climate change, Cereal production, Vulnerability, Burkina Faso

RÉSUMÉ

Le changement climatique est l'un des plus grands défis du 21ème siècle. Il affecte tous les pays du monde, en particulier les pays sahéliens d'Afrique. Cet article a évalué l'impact du changement climatique sur le rendement des céréales au Burkina Faso. Le modèle de régression des moindres carrés ordinaires (MCO) a été appliqué aux données chronologiques de 1991 à 2016 extraites des bases de données de la Banque mondiale. Les résultats montrent que la température affecte négativement le rendement et la production céréalière, tandis que les précipitations ont un effet positif. Une augmentation des précipitations de 1 millimètre augmenterait la production céréalière de 385 tonnes à long terme et de 252 tonnes à court terme. Dans le même ordre d'idées, une augmentation des précipitations de 1 millimètre augmenterait le rendement agricole de 9 kg par hectare à long terme. Cependant, à court terme, une augmentation des températures de 1°C entraînerait une diminution de la production céréalière et du rendement agricole de 134 748 tonnes et 72 kg par hectare, respectivement. Cependant, à long terme, une augmentation des températures de 1°C entraînerait une diminution de la production céréalière et du rendement agricole de 154 634 tonnes et de 1 074 kg par hectare, respectivement. En outre, les résultats indiquent que l'émission de dioxyde de carbone n'a pas d'effet significatif sur le rendement et la production céréalière. La mise en œuvre de stratégies d'adaptation efficaces, telles que l'accès à des semences améliorées, des pratiques agricoles intelligentes et des infrastructures d'irrigation, pourrait réduire la vulnérabilité aux chocs climatiques.

Mots clés : Changement climatique, Production céréalière, Vulnérabilité, Burkina Faso

INTRODUCTION

One of the biggest challenges of this century is climate change, which affects almost every country in the world with disastrous consequences for livelihoods (Erenstein and Ali, 2017, Xie and al, 2018). Mainly is due to human activities, particularly industrial activities that lead to a high rate of emission of greenhouse gases into the atmosphere (Shi and al, 2018). This causes global warming and frequents extremes climate such as drought and the flood.

Although Africa contributes only marginally to global pollution (10%), it is most affected by climate change (Sarker and al, 2014; IPCC, 2014). The Intergovernmental Panel on Climate Change forecasts a decline in agricultural productivity from 21 to 9 per cent in sub-Saharan Africa by 2080 (IPCC, 2007). Climate change effects are particularly severe in Sahelian countries. Roudier and al (2011) indicate that the Sudano-Sahelian countries (located in the North of West Africa) could experience a loss of agricultural yields higher (18%) compared to the countries located in South-West Africa (11%). Mendelsohn and al (2000) and Maddison (2007), argued that Burkina Faso and Niger could experience a loss in agricultural production of 19.9% and 30.5% respectively by 2050.

Also, the agricultural system that prevails in most African countries remains rain-fed, therefore highly depend on climatic conditions (Sultan and al., 2012). It explains the relatively high sensitivity of the agricultural sector to climate change (Sultan, 2017). The vulnerability of this sector is linked to the increase of temperature and the decrease in rainfall. Between 1991 and 2016, the temperature increased from 23.16°C in January 2008 to 33.83°C in April 2016 and rainfall dropped from 290.26 mm in August 1994 to 144.11 mm in September 2016 in Burkina Faso (World Development Indicator (WDI), 2019).

Empirical studies are almost agreed on the sensitivity of agriculture to climate change. Mohamed and al. (2002) analysed climate variability on millet production in Niger and found that this issue can cause a decline in millet production of 13% by 2025. Wossen and al (2018) showed that climate and price variability negatively affect household income and food security in Ethiopia and Ghana. Similarly, in Malawi, the work of Warnatzsch and Reay (2019) indicated that changes in temperature and precipitation are not favorable for agricultural activities.

In a recent study, Houngbedji and Diaw (2018) showed that the concentration of CO_2 negatively influences agricultural production in Benin. In Burkina Faso, Ouedraogo (2012) showed that climate change has a negative impact on the agricultural sector. The author concludes that the impact of temperature on-farm income is -19.9 $ USD per hectare, while that of rainfall is + 2.7 $ USD per hectare. Besides, the author reveals that when rainfall increases by 1%, farm income increases by 14.7% while an increase in temperature of 1% leads to a decrease in agricultural income of 3.6%.

Agricultural sector sensitivity to climate change has been widely discussed in West Africa, but there are still few studies on the vulnerability of agriculture in Burkina Faso. This paper assessed the impact of climate change on cereal yield and cereal production in Burkina Faso. The ordinary least squares (OLS) was applied to time-series data from 1991 to 2016 collected on the World Bank website. The results show that climatic variables such as temperature and precipitation significantly affect cereal yield and cereal production in Burkina Faso. Precipitation positively effects while temperature negatively effects. Results also indicate that the emission of CO_2 has no significant effect on cereal yield and cereal production.

The next step of the paper presents an empirical literature review, followed by research method. Results and discussion come after, and the conclusion ends the paper.

EMPIRICAL REVIEW

Climate change has been a frequent subject in several fields of research. Economics researchers have analyzed the impact of climate change on agricultural incomes through production or agricultural output.

Concerning the impact on farm incomes, most authors conclude that climate change tends to reduce agricultural incomes, particularly in Africa, where dependence on agriculture is relatively high. Wossen and al (2018) conducted a study in Ethiopia and Ghana and argue that climate and price variability would negatively affect income and food security. They propose several adaptation strategies such as improving the supply of credit to production, access to improved seeds and increasing irrigation infrastructure. Similarly, Ouédraogo (2012) in Burkina Faso indicated that climate change is having a negative impact on the agricultural sector. According to him, the country's agricultural sector is susceptible to rainfall variations. The impact of temperature on-farm income is -19.9 $ USD per hectare, while rainfall is about + 2.7 $ USD per hectare. In addition, a 1% increase in rainfall leads to an increase in agricultural income of 14.7% while a 1% rise in temperatures leads to a decrease in agricultural income of 3.6%. The author finally reports that an increase in temperature of 5 ° C could cause to farmers losing 93% of their income, while a decrease in rainfall of 14%, farmers risk losing all their income.

Most studies established a relatively negative link between climate change and agriculture at the global level, in Asia as well as in Africa. These studies confirmed the vulnerability of the agricultural sector to climate change. Ding and al (2017) used data from 109 countries to assess the impact of climate change on fisheries and food security. They indicated that developing countries in Africa, in Asia, in Oceania and Latin America are the most vulnerable to climate change. Raymundo and al (2018) also analysed the impact of climate change on global potato production. Their results indicate that a high concentration of CO_2 in the atmosphere and an increase in temperature would cause a downward trend in tuber production. Also, forecasts of global tuber production are worrying, ranging from a 6% drop by 2055 to a 26% decrease by 2085.

Intergovernmental Panel on Climate Change points out that the impact of climate change on agriculture varies from place to place. In temperate regions, moderate global warming (temperature increase of 1 to 3°C) would positively affect agricultural yield while in tropical regions, it would negatively affect cereal production (IPCC, 2007). However, warming above 3°C would have negative effects on agricultural production. Sarker and al (2014) show that the average maximum temperature has a negative impact on rice production while the average minimum temperature is favorable for rice production Bangladesh.

In Asia, Shi and al (2018) showed that food production and consumption lead to significant greenhouse gas emissions that affect the environment, which in turn affects agricultural yields. Similarly, Ruszkiewicz and al (2019) reported that climate change disturbs the quantity and quality of water, which affects food production. Xie and al (2018) found that climate change would cause a drop in wheat yield of 9.4% by 2050 in China. In the same way, Lu and al (2019) confirmed the persistent effects of climate change in China. Using a Cobb-Douglas production function, the authors concluded that climate change is having an increasingly severe impact on China's water resources and grain production.

In Africa case, Knox and al (2012) showed that by 2050, agricultural yields would fall by 8% on average due to climate change. According to these authors, cereals like wheat, maize, sorghum and millet will decline by 17%, 5%, 15% and 10% respectively. Schlenker and Lobell (2010) analysed the impacts of climate change on agriculture and found that climate change has contributed to lower production of maize, sorghum, groundnut, millet and cassava, respectively. 22%, 17%, 18%, 17% and 8% in SSA. Warnatzsch and Reay (2019) showed that changes in temperature and precipitation are not favorable for agricultural activities in Malawi.

Most studies in West Africa indicate that climate change does affect countries in the same way. Indeed, the Sahelian countries are more vulnerable to the phenomenon. Roudier and al (2011) indicated that the Sudano-Sahelian countries (located in the North of West Africa) could experience a loss of agricultural yield (18%) higher compared to the countries located in South-West Africa (11%). Moreover, according to the work of Mendelsohn and al (2000) & Maddison (2007), Burkina Faso and Niger are likely to experience a loss of agricultural production of 19.9% and 30.5% respectively on the horizon. 2050. Similarly, by studying the impact of climate variability on millet production in three major producing regions of Niger, Mohamed and al. (2002) showed that climate change would lead to a 13% decline in millet production by 2025.

In conclusion, this empirical work highlights the vulnerability of agriculture to climate change, particularly in Africa. The impacts of climate change on cereal production would be particularly pronounced in Sahelian countries (Zhu and al., 2018).

METHODOLOGY

Framework of study

Burkina Faso is a landlocked country in West Africa, bordered on the North by Mali, on the South by Ghana and Togo, on the East by Niger, on the South-East by Benin, and the South. West by Ivory Coast. Covering an area of 274,200 km2, this country has a total inhabitant of 19,751,535 in 2018 (WDI, 2019). Three climatic zones characterise this country (see Figure 1) namely (i) the Sudanian zone to the South, (ii) the Sudano-Sahelian zone going from East to West and (iii) the Sahelian zone to the North. The Sudano-Sahelian zone is much larger than the other two climatic zones.

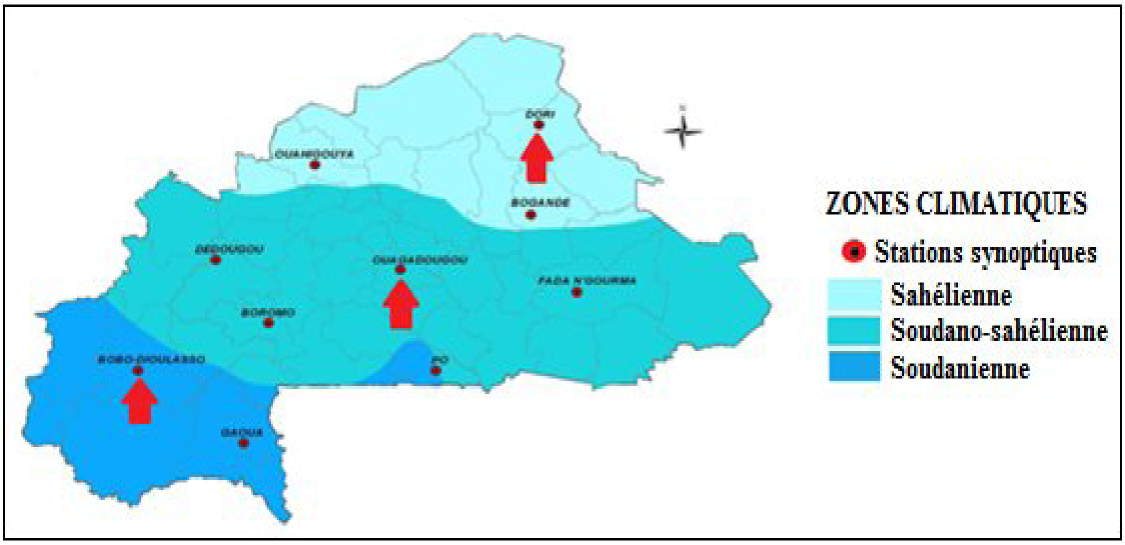

Figure 1: Map of climatic zones in Burkina Faso

Source: Kaboré and al (2017)

Data

Our data was the time series from 1991 to 2016 collected on the World Bank website.

Methodological approach

Following Lu and al., (2019), they used a Cobb-Douglas production function to show that climate change is having an increasing impact on forest resources, water and grain production. They also used a production function to assess the impact of climate change (temperature, precipitation and carbon dioxide (CO_2) emissions) on cereal yield and cereal production in Burkina Faso. The mathematical form of this function is as follows :

$$Y = \lambda_0 + \lambda_1 F + \lambda_2 Z + \mu \quad (1)$$

Where Y captures cereal production or agricultural yield, F captures the linear relationship between production and climate, Z represents control variables such as rainfall squared, temperature squared and factors of production, are parameters to estimate then u represents the error term of the model. The quadratic terms of the model capture the non-linear relationship between production and climate.

The empirical models that will be tested in this research are as follows :

Model 1: Agricultural Performance Model

$$CY_t = \alpha_0 + \alpha_1 RF_t + \alpha_2 TEM_t + \alpha_3 CO2_t + \alpha_4 (RF_t)^2 + \alpha_5 (TEM_t)^2 + \alpha_6 RPG_t + \alpha_7 GRCL_t \varepsilon_t \qquad (2)$$

Model 2: Cereal Production Model

$$PROD_t = \alpha_0 + \alpha_1 RF_t + \alpha_2 TEM_t + \alpha_3 CO2_t + \alpha_4 (RF_t)^2 + \alpha_5 (TEM_t)^2 + \alpha_6 RPG_t + \alpha_7 GRCL_t \varepsilon_t \, (\qquad (3)$$

Where CY (Cereal Yield): is the cereal yield expressed in kilograms (kg) per hectare (ha). It is calculated based on dry grain harvests only like rice, maize, sorghum and millet. This variable represents the dependent variable of the first model.

PROD is the cereal production of Burkina Faso expressed in metric tons. This variable represents the second model dependent variable and refers to dry grain crops only.

RF is the average annual rainfall expressed in millimetre (mm). This variable measures the amount of precipitation recorded annually in Burkina Faso.

TEM is the average annual temperature expressed in degrees Celsius. This variable represents the average of the minimum and maximum temperatures recorded annually in Burkina Faso.

CO_2 is the average amount of carbon dioxide emitted annually in Burkina Faso. It is expressed in kiloton (kt). It takes into account carbon dioxide emissions from the use of fossil fuels or cement manufacturing. It also includes carbon dioxide produced during the consumption of solid, liquid or gaseous fuels.

RF2 is the square of the rainfall. This variable makes it possible to test the non-linear relationship that could exist between production and climate.

TEM2 is the square of the temperature. This variable also makes it possible to test the non-linear relationship that could exist between production and climate.

RPG (rural population growth): is the growth rate of the rural population expressed as a percentage. The rural population represents people living in rural areas. It is calculated by subtracting the total population from the urban population.

GRCL (growth rate of cereal land): is the area of land devoted to cereal production. It is expressed in hectare and refers to dry grain crops only such as rice, maize, sorghum and millet.

The estimation strategy consists, firstly, in the application of standard unit root and cointegration tests, and then in estimating the empirical models using ordinary least squares (OLS).

RESULTS AND DISCUSSIONS

Descriptive analysis

Table 1: Descriptive statistics

Variables	Years	Number of Observations	Min	Max	Mean
RF	1991-2016	26	676.83	941.86	798.97
TEM	1991-2016	26	28	29.13	28.70
PROD	1991-2016	26	2013552	4898544	3325844
CY	1991-2016	26	704.5	1225.8	988.77
CO□	1991-2012	22	11859.68	50062.48	34280.9
RPG	1991-2016	26	1.96	2.44	2.18
GRCL	1991-2016	26	2661349	4291496	3314568

Source: Authors, from WDI data (2019)

Table 1 presents the descriptive statistics of the variables used in the two models to estimate the impact of climate change on cereal production in Burkina Faso The data are annual and cover the period from 1991 to 2016 except the data on the emission of carbon dioxide (CO_2), which lasts in 2012. In Burkina Faso, the average CO_2 emissions are about 34 280.9 kilotons per year, and the cereal yield produced remained low 989 kilograms (kg) per hectare (ha). Cereal production varies between 2 and 4 million of tones with an annual average of 3,325,844 tones. The rural population is 2.18% of the total population. The cultivated area of cereal crops is 3,314,568 hectares. In this country, on average, rainfall and temperature are respectively 798.97 millimetre (mm) and 28.69 degrees Celsius (°C) with a respective maximum value of 941.86 mm and 29.13 °C.

Referring to Figure 1, the country has two (02) seasons (rainy season and dry season). The rainy season lasts about 4 months, from May-June to the end of September or beginning of October and the dry season lasts about 8 months, between October and the end of April, or even May in the North region (totally desert region). Overall, the country is characterized by a relatively high atmospheric temperature throughout the year. It is often warmer in the North than in the South.

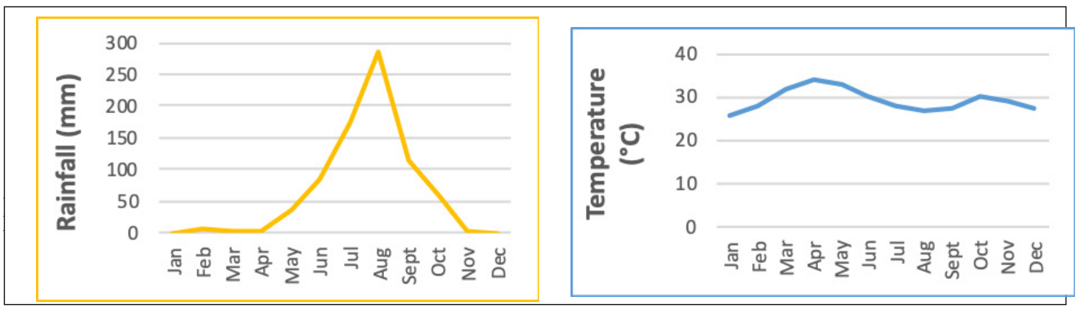

Figure 1: Evolution of rainfall and temperature in Burkina Faso in 2015

Source: WDI, 2019

Figure 2 reports the evolution of rainfall and temperature. Rainfall highly varies over time. When we take a look at the figure reporting the temperature, we can acknowledge that there is an increase in temperature over the period.

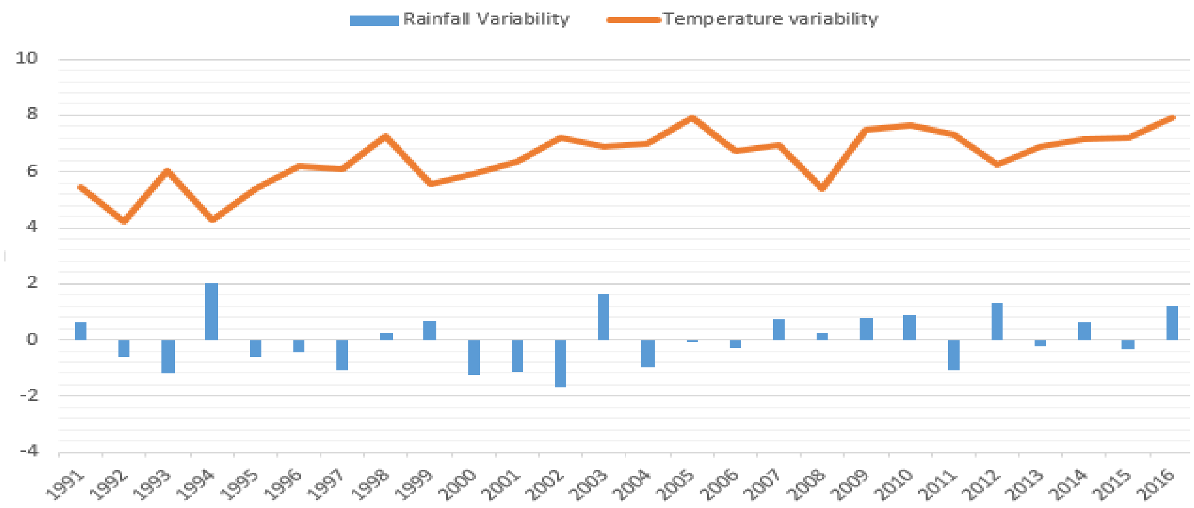

Figure 2 : Evolution of rainfall variability and temperature in Burkina Faso

Source: WDI, 2019

Results of the unit root test

Table 2 contains the test of stationarity. To avoid fallacious regressions, it is necessary to check the property of stationarity or not of the variables. To do this, several unit root tests can be used, such as the Phillips-Perron test (PP, 1988), the Augmented Dickey-Fuller test (ADF, 1981) and the Kwiatkowski, Philips, Schmidt and Shin test (KPSS), 1992). In this study, we use the Augmented Dickey-Fuller (ADF) to test stationarity of the variables. Overall all variables are stationary in level except the emission of carbon dioxide (CO_2) and the growth of the rural population, which are stationary in first difference.

Table 2: Increased Dickey-Fuller Unit Root Test Results

Variables	Level		First difference		Decision
	ADF	PROB	ADF	PROB	
PROD	-5.75 [3]	0.0004			I(0)
RF	-6.98 [3]	0.0000			I(0)
TEM	-4.72 [3]	0.0047			I(0)
CO□	0.24 [1]	0.746	-5.90 [3]	0.0006	I(1)
RPG	-0.68 [1]	0.411	-2.76 [2]	0.0779	I(1)
GRCL	-4.41 [3]	0.0093			I(0)

Note: ADF: Augmented Dickey-Fuller, [1]: Model without constant or deterministic trend; [2]: Constant model with no deterministic trend; [3]: Model with the constant and deterministic trend.

Source: Authors, from WDI data (2019)

Johansen cointegration test results

Since not all our variables are integrated in the same order, we use the Johansen cointegration test, which has the merit of applying to all cases. Indeed, Johansen (1988) proposes maximum likelihood estimators to test the cointegration of series. It performs a cointegration rank test. As shown in Table 3, the RF variable is cointegrated to the PROD variable at 5% threshold. Then, we can deduce that climatic variables are cointegrated at cereal production at the 5% threshold.

Table 3 : Johansen cointegration test

Variables	Hypothesis	Eigen-value	Statistic	Critical value	Prob
PROD RF	None	0.53	18.56**	15.49	0.016
	At most 1	0.02	0.40	3.84	0.527
PROD TEM	None	0.31	9.16	15.49	0.35
	At most 1	0.02	0.38	3.84	0.53
PROD CO□	None	0.26	6.57	15.49	0.63
	At most 1	0.03	0.53	3.84	0.47
PROD RPG	None	0.24	6.89	15.49	0.59
	At most 1	0.02	0.46	3.84	0.50
PROD GRCL	None	0.40	12.66	15.49	0.13
	At most 1	0.01	0.31	3.84	0.57

** indicates significance at the 10% threshold, ** significance at the 5% threshold and *** significance at the 1% level*

Source: Authors, from WDI data (2019)

Empirical results

The empirical results present both long-term and short-term results.

Long-term dynamics

Table 4 presents the long-term dynamics of the impact of climate change on both cereal yield and cereal production in Burkina Faso. Columns (1) and (2) present the results for cereal yield (model 1) and columns (3) and (4) present the results for cereal production (model 2). Columns (2) and (4) contain the results of the quadratic variables introduced in the models in order to test the non-linearity of the relationship between climate and production. The Fisher test analysis indicates that the model is globally significant at 5% level. The R squared is about 0.33 in the first two columns and 0.84 in the last two columns. The grain production model shows a better quality of fit with the agricultural yield model. The quadratic variables are not significant, and one can thus deduce that in the long term, the relation between the climate and the production is linear in Burkina Faso.

Climate variables (precipitation and temperature) are significant at 10% level. Precipitation positively affects production and yield with coefficients of 384.70 and 9.17, respectively. Thus, an increase (or decrease) in rainfall of 1 millimetre would result in an increase (or decrease) in cereal production and cereal yield of 385 tons and

9 kg per hectare, respectively. Temperatures negatively affect production and yield with coefficients of -154,634.2 and -1073.74 respectively. It can, be concluded that an increase (or decrease) in temperatures of 1°C would result in a decrease (or increase) in cereal production and agricultural yield of 154 634 tons and 1074 kg per hectare, respectively.

Besides, the emission of carbon dioxide (CO_2) has a negative sign but not significant. On the other hand, the area planted affects positively and significantly the cereal production. Indeed, since most African households practice extensive agriculture, the more the area planted increases, the more production increases.

Table 4: Long-term dynamics

	Model 1 Cereal Yield (CY)		Model 2 Cereal production (PROD)	
	(1)	(2)	(3)	(4)
Rainfall (RF)	0.108	9.17*	384.70*	27316.58
Temperature (TEM)	64.88	-1073.74*	-154634.2*	8854889
CO_2	0.00003	-0.0004	-0.4227	-1.64
GRCL	0.00013	0.0001	1.437***	1.46***
RPG	-132.12	-192.38	-389242	-553166.8
RF^2		-0.005		-16.70
TEM^2		-18.08		-153452.7
Cons	-1111.68	-18682.82	-5380150	-1.39E+08
R^2 ajusté	0.33	0.32	0.84	0.83
Obs	22	22	22	22

** indicates significance at the 10% threshold, ** significance at the 5% threshold and *** significance at the 1% level*

Source: Authors, from WDI data (2019)

Short-term dynamics

Table 5 below presents the short-term dynamics of the impact of climate change on the agricultural sector in Burkina Faso. Indeed, the coefficients associated with the standard error of the yield and output models are significantly negative and less than unity in absolute value. This justifies the validity of an error correction model.

In the short term, the relationship between climate change and production is linear in Burkina Faso because the quadratic variables are not significant. However, temperatures and precipitation are significant at the 10% threshold in the production model (model 2), but only the temperatures are significant in the model for yield (model 1). In the short term, rainfall positively affects production with a coefficient of 251.70. It can, therefore, be concluded that an increase (or a decrease) in rainfall of 1 millimetre would increase (or decrease) cereal production by 252 tons. Temperatures negatively affect production and yield with coefficients of -134748.3 and -72.39 respectively.

Thus, an increase (or decrease) in temperatures of 1°C would result in a decrease (or increase) in cereal production and agricultural yield of 134748 tons and 72 kg per hectare, respectively.

Also, the emission of carbon dioxide (CO_2) and the growth of the rural population do not have any significant effect on either production or yield. However, the area planted affects positively and significantly the cereal production in Burkina Faso.

Table 5: Short-term dynamics

	Model 1 Cereal Yield D(CY)		Model 2 Cereal production D(PROD)	
	(1)	(2)	(3)	(4)
D(RF)	0.2016	9.17	251.70*	29454.14
D(TEM)	-72.39*	1073.74	-134748.3*	8777553
D(CO_2)	-0.0029	-0.0004	-9.0231	-1.24
D(GRCL)	7.93E-05	0.0001	1.3086***	1.47***
D(RPG)	143.44	-192.38	216850	-559677.6
D(RF^2)		-0.005		-18.05
D(TEM^2)		-18.08		-152298.8
Erreur (-1)	-0.1115***		-0.083***	
Cons	7.69	-18682.82	20751.97	-1.39E+08
R^2 ajusté	0.37	0.32	0.75	0.81
Obs	21	21	21	21

** indicates significance at the 10% threshold, ** significance at the 5% threshold and *** significance at the 1% level*

Source: Authors, from WDI data (2019)

DISCUSSION OF RESULTS

Burkina Faso's cereal cultivation is highly sensitive to climate change. Rainfall positively affects agriculture. An increase in rainfall of 1 millimetre would increase cereal production by 385 tons in the long term and 252 tons in the short term. Similarly, an increase in rainfall of 1 millimetre would increase agricultural yield by 9 kg per hectare in the long term. Our results are contrary to those of Xie and al (2018) who indicated that climate change strongly affects agricultural production. Similarly, our results are contrary to those of Lu and al (2019) who used a Cobb-Douglas production function to show that climate change is having an increasingly severe impact on water resources and cereal production in China. In addition, our results show that rainfall does not significantly affect crop yield in the short term. These results confirm those of Houngbedji and Diaw (2018) who indicated that rainfall has no significant effect on cereal production in Benin.

Our results indicate that temperature adversely affects yield and cereal production in both the long term and the short term. In the short term, a rise in temperatures of 1°C would result in a decrease in cereal production and agricultural yield of 134748 tons and 72 kg per hectare, respectively. However, in the long term, a rise in temperatures of 1°C would result in a decrease in cereal production and agricultural yield of 154 634 tons and 1074 kg per hectare, respectively. Our results are consistent with those of Knox et al. (2012) who indicate that by 2050, the increase in temperatures would lead to a decline in agricultural yields of 8% in both Africa and South Asia. In Africa, decreases would be in the order of 17%, 5%, 15% and 10% respectively for wheat, maize, sorghum and millet. Similarly, our results confirm those of Nonvidé and Porgo (2014) who indicated that cereal yield is sensitive to temperature in Benin. However, our results are contrary to those of Sarker and al (2014) who indicated that the minimum average temperature is favorable for rice production in Bangladesh.

Carbon dioxide (CO_2) emissions have a negative but not significant in both situation the long term and the short term. These results go against Houngbedji and Diaw (2018) result, they argued that the concentration of carbon dioxide (CO_2) significantly affects agricultural production in Benin. However, our results are in line with Raymundo and al (2018) results. They concluded that a high concentration of carbon dioxide (CO_2) in the atmosphere and an increase in temperature would cause a drop in world production of tubers of 26 %.

CONCLUSION

This paper assessed the impact of climate change on cereal yield and cereal production in Burkina Faso. Sahelian countries are the most vulnerable countries to the effects of climate change in Africa. The ordinary least squares (OLS) was applied to time-series data from 1991 to 2016 collected on the World Bank website. The results show that climatic variables such as temperature and precipitation significantly affect cereal yield and cereal production in Burkina Faso. Precipitation positively effects while temperature negatively effects. The long-term effects are higher than those in the short term. An increase in rainfall of 1 millimetre would increase cereal production by 385 tons in the long term and 252 tons in the short term. However, in the long term, a rise in temperatures of 1°C would result in a decrease in cereal production and cereal yield of 154 634 tons and 1074 kg per hectare, respectively. Results also indicate that the emission of CO_2 has no significant effect on cereal yield and cereal production. Implementing effective adaptation strategies, such as access to improved seed, introduce smart agriculture in the system of cereal in Burkina Faso and increasing irrigation infrastructure could reduce the cereal production's vulnerability to climate shocks.

REFERENCES

Badolo F. (2013), « Chocs de prix, vulnérabilité climatique et sécurité alimentaire dans les pays en développement. Economies et finances. Université d'Auvergne - Clermont-Ferrand I, Thèse de doctorat.

Boko M, Kosmowski F, Vissin WE (2012). Les enjeux du changement climatique au Bénin. Rapport du Programme pour le dialogue politique en Afrique de l'Ouest Konrad Adenauer Stiftung; 2012. French.

Ding Qi, Xinjun Chen, Ray Hilborn, Yong Chen (2017), Vulnerability to impacts of climate change on marine fisheries and food security, Marine Policy, Vol.83, PP55-61

Erenstein O. and Ali A. (2017), "Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan", Climate Risk Management, Vol 16, PP 183-194

Houngbedji B.C., Diaw A. (2018), Analysis on climate change effect on agricultural production in Benin, Asian Journal of Agricultural Extension, Economics, Sociology, 24(4):1-12, Article n°AJAEES.40522

IPCC, (2014). Climate change impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. (Eds.), Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC, (2007). Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press. 2007;976.

Johansen S (1988). Statistical analysis of cointegrating vectors. Journal of Economie Dynamics and Control. 1988 ; 12:231-254.

Kabore B., S. KAM, G. W. P. Ouedraogo & D. J. Bathiebo (2017), « Étude de l'évolution climatique au Burkina Faso de 1983 à 2012 : cas des villes de bobo Dioulasso, Ouagadougou et Dori », Arabian Journal of Earth Sciences, Vol. 4, Issue 2: 50□59

Knox Jerry, Tim Hess, Andre Daccache and Tim Wheeler (2012), Climate change impacts on crop productivity in Africa and South Asia, Environmental Research Letters.

Lu Shibao, Xiao Bai, Wei Li, Ning Wang (2019), "Impacts of climate change on water resources and grain production", Technological Forecasting and Social Change, Vol. 143, pp 76-84.

Maddison D (2007). The perception and adaptation to climate change in Africa. The World Bank development research group, sustainable Rural and Urban development team; 2007.

Mendany M, Niang-Diop I, Nyong T, Tabo R, Vogel C. (2006). Background paper on impacts, vulnerability and adaptation to climate change in Africa. For the African Workshop on Adaptation Implementation of Decision 1/CP.10 of the UNFCCC Convention. Accra, Ghana, 2006;21-23. United Nations Framework Convention on Climate Change.

Mendelsohn R, Dinar A et Dalfelt A. Climate change impacts on African agriculture; (2000). Available: http://www.ceepa.co.za/Climate_Change/pdf/(5-22-01) afrbckgrndimpact.Pdf

Mohamed AB, Van Duivenbooden N, Abdoussallam S. Impact of climate change on agricultural production in the Sahel – Part 1. Methodological approach and case study for millet in Niger. Climate change. 2002;54(3):327–48.

Nonvide GM, Armel, Porgo M. (2014). Effect of climate change on cereal yield: Evidence from Benin and Burkina Faso. Mimeo..

Ouedraogo Mathieu. (2012). Impact des changements climatiques sur les revenus agricoles au Burkina Faso. Journal of Agriculture and Environment for International Development – JAEID.;106(1):3-21.

Raymundo Rubí, Senthold Asseng, Richard Robertson, Athanasios Petsakos, Joost Wolf (2018). Climate change impact on global potato production, European Journal of Agronomy, Vol. 100, pp 87-98

Roudier Philippe, Benjamin Sultan, Philippe Quirion and Alexis Berg (2011). The impact of future climate change on West African crop yields : What does the recent literature say?, Global Environmental Change, Vol 21, Issue 3, PP 1073-1083.

Ruszkiewicz Joanna A., Alexey A. Tinkov, Anatoly V. Skalny, Vasileios Siokas, Efthimios Dardiotis, Aristidis Tsatsakis, Aaron B. Bowman, Joao B. T. da Rocha, Michael Aschner (2019), « Brain diseases in changing climate », Enviromental Research, Vol. 177, N°108637.

Sarker M. R. A., Khorshed A., Jeff G., (2014), "Assessing the effects of climate change on rice yields: An econometric investigation using Bangladeshi panel data", Economic Analysis and Policy, Vol.44, Issue 4, pp 405-416

Schlenker Wolfram and David B. Lobell (2010), Robust negative impacts of climate change on African agriculture, Environmental Research Letters.

Shi Jing, Vivianne H. M. Visschers, Noemi Bumann, Michael Siegrist. (2018), Consumers' climate-impact estimations of different food products, Journal of Cleaner Production, Vol.172, pp1646-1453.

Sultan B, Barbier B., Baron C., Tsogo M. B. M., Berg A., Dingkuhn M., Fortilus J., Kouressy M., Leblois A., Marteau R., Muller B., Oettli P., Quirion P., Roudier P., Traoré S., etVaksmann M. (2012) «La question de la vulnérabilité et de l'adaptation de l'agriculture sahélienne au climat au sein du programme AMMA», la météorologie- Spécial AMMA, pp. 5-6.

Sultan, Benjamin (2017) «Les impacts du changement climatique sur l'agriculture en Afrique de l'Ouest», IRD-LOCEAN, Université Pierre et Marie Curie, Paris, disponible à http://otmed.osupytheas.fr/sites/default/files/ancien_site/IMG/pdf/Les_impacts_du_changement_climatique_sur_l_agriculture_en_Afrique_de_l_Ouest_Sultan.pdf.

Warnatzsch Erika A. and David S. Reay. (2019), Temperature and precipitation change in Malawi: Evaluation of CORDEX-Africa climate simulations for climate change impact assessments and adaptation planning, Science of The Total Environment, Vol.654, pp 378-392.

World Development Indicators (2019), World Bank data, available on https://data.worldbank.org/ accessed on 19/ 08/ 2019.

Wossen Tesfamicheal, Thomas Berger, Mekbib G. Haile, Christian Troost (2018), Impacts of climate variability and food price volatility on household income and food security of farm households in East and West Africa, Agricultural Systems, Vol 163, PP 7-15.

Xie Wei, Jikun Huang, Jinxia Wang, Qi Cui, Ricky Robertson, Kevin Chen (2018), « Climate change impacts on China's agriculture: The responses from market and trade», China Economic review, in press.

Zhu Lv, Z., Y., Liu, X., Ye, H., Tian, Y., & Li, F. (2018). Climate change impacts on regional rice production in China. Climatic change, 147(3-4), 523-537.

Impact of climate-smart innovations on food security of farming household in Benin : A Case study of Drought tolerant maize (DTM) varieties

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ABSTRACT

This paper assessed the impact of drought tolerant maize (DTM) varieties as climate-smart innovation on food security, using country-wide cross-sectional data of about 518 maize farming households from 48 villages in Benin. Household food expenditure per capita, household food consumption scales (HFCS), household diet diversity score (HDDS) and household food insecurity experienced score (HFIES) were used as outcome indicators of food security of maize farming households. A mixed methods approach involved the use of qualitative techniques for the data collection and quantitative techniques (Endogenous Switching Regression) for identification of the causal effects of adopting drought-tolerant maize varieties on the productivity and food security of maize farming households. The Average Treatment Effect (ATE) was estimated with controlled variables and allow for causal interpretation of the real effect of drought tolerant maize varieties adoption. Drought tolerant maize varieties adoption significantly increased household food expenditure per capita, household food consumption scales (HFCS), household diet Diversity Score (HDDS), and decreased the household food insecurity experienced score (HFIES). The findings underscore the importance of adoption of drought tolerant maize varieties for the improvement of food security in Benin.

Keywords : Climate-smart innovations, Drought tolerant maize, Food security, Benin

RÉSUMÉ

Cet article évalue l'impact des variétés de maïs tolérantes à la sécheresse (DTM) en tant qu'innovation intelligente du point de vue climatique sur la sécurité alimentaire, en utilisant des données transversales à l'échelle du pays d'environ 518 ménages cultivant du maïs dans 48 villages du Bénin. Les dépenses alimentaires des ménages par habitant, les échelles de consommation alimentaire des ménages (HFCS), le score de diversité alimentaire des ménages (HDDS) et le score d'insécurité alimentaire des ménages (HFIES) ont été utilisés comme indicateurs de résultats de la sécurité alimentaire des ménages cultivant le maïs. Une approche de méthodes mixtes a impliqué l'utilisation de techniques qualitatives pour la collecte de données et de techniques quantitatives (régression à commutation endogène) pour l'identification des effets causaux de l'adoption de variétés de maïs tolérantes à la sécheresse sur la productivité et la sécurité alimentaire des ménages de producteurs de maïs. L'effet de traitement moyen (ATE) a été estimé avec des variables contrôlées et permet une interprétation causale de l'effet réel de l'adoption de variétés de maïs tolérantes à la sécheresse. L'adoption de variétés de maïs tolérantes à la sécheresse a augmenté de manière significative les dépenses alimentaires des ménages par habitant, les échelles de consommation alimentaire des ménages (HFCS), le score de diversité alimentaire des ménages (HDDS), et a diminué le score d'insécurité alimentaire des ménages (HFIES). Ces résultats soulignent l'importance de l'adoption de variétés de maïs tolérantes à la sécheresse pour l'amélioration de la sécurité alimentaire au Bénin.

Mots-clés : Innovations intelligentes face au climat, maïs tolérant à la sécheresse, sécurité alimentaire, Bénin

INTRODUCTION

With the existence of very critical areas where hunger is rife, the food security status in the world is very worrying (FAO and PAM, 2009). Indeed, over 39 countries surveyed in 2006 with a high level of food insecurity in the world 25 of them come from Africa. According to Horton et al., (2009), the undertaking of micronutrient in consumption food than the required is one of the most significant health and socio-economic issues, but the treatment of which is underestimated. Rising food prices have severe consequences for inflation and the well-being of people around the world (Golay, 2010) and especially in developing countries. The strong disturbances in agricultural production due to climate change are the leading causes contributing to food insecurity (Kurukulasuriya and Mendelsohn, 2008). Furthermore, Hubert and Caron, (2009), through the EICASTD report, states that the impacts of climate change associated with growing demand for food and energy products can have serious consequences for the natural resources on which agriculture depends, security food will take a hit.

West Africa is identified as one of the most vulnerable regions to climate change (Yegbemey et al., 2013). Benin, like other Sub-Saharan countries, is vulnerable to climate change. Climate risks mainly identified on the territory of the Republic of Benin are drought, floods, sea level rise and coastal erosion. Also, it is noted that the rainfall decline, the reduction in the length of the agricultural season, the persistence of negative anomalies, the rise in minimum and maximum temperatures, now characterize the climates of Benin and modify rainfall patterns and agricultural production systems (Ogouwalé 2006, Tidjani and Akponikpè, 2012).

The impacts of climate change are significant and are characterised by a degradation of natural resources, the displacement of populations, disruption of economic activities, mainly agricultural. In fact, agriculture is the primary activity with a contribution of 35% to the gross domestic product (GDP) and 75% of export revenue, the agriculture's sector in Benin which employs 70% of the active population (Bini, 2016). Agricultural products accounted for about 20.50 % of total export earnings between 2015 and

2016[67]. However, the IPCC, (2014) predicts a decrease in agricultural yields in West Africa of around 20 to 50% in semi-arid sub-Saharan Africa by 2050, which could be between 5 and 20% Benign. This decline would not be uniform across the territory. The climatic variability and in particular the decrease of the precipitations from March to May poses a significant risk on the food security of the country. For Agbossou et al., (2012) and Gbêtondji and Porgo, (2014), cereal yield is sensitive to temperature in Benin. Thus, climate change is degrading the food and nutritional situation of the population in the face of food insecurity, particularly that of rural households.

In Benin, according to the AGVSA, (2014)[68], 1.1 million people were food insecure in 2013, coming from 11% of households with less than 1% severe food insecurity and 11% moderate food insecurity. These households have inadequate food consumption or cannot meet their minimum food needs without resorting to irreversible adaptation strategies (ACF (Action Contre la Faim), 2012; OECD, 2008; Paunov, 2013). Thus, the proposals for action related to the reduction of impacts and the adoption of pre-adoption strategies (Füssel and Klein, 2006). ACF, (2012) points out that these populations, already threatened by food insecurity, do not have much choice to cope with and adapt to climate change. They use negative coping strategies, further exacerbating their vulnerability, or weakening their resilience. For Burton, (1997), the consequences are mostly for the reduction of agricultural and economic risks through the diversification of activities. As for the ACF, (2012), adaptation approaches must take into account three levels of simultaneous intervention: the ex-ante approach, the ex-post approach and the mitigation measures. Indeed, it is commonly accepted that climate-smart innovations are crucial to meeting the challenges of adaptation to climate change to ensure food security and increase farmer's income (Campbell et al., 2014; Long et al., 2016).

The paper examines the adoption DTM varieties as climate-smart innovations and evaluate its impact of on food security and nutritional status of maize farming households in Benin. Indeed, according to Cooper et al., (2013) and Fisher et al., (2015) the drought-tolerant maize varieties are climate-smart innovations firstly because they are increasing yields even under moderate drought conditions, thus raising income for farmers. Secondly, the new varieties are enabled farmers to cope with more frequent droughts projected as a result of climate change.

In the literature, there are several studies related to climate change adaptation in agriculture, at the micro-level (i.e. farm level) and an impressive number of empirical studies[69] (e.g. Campbell et al., 2014; Deressa et al., 2009; FAO, 2013; Gnangle et al., 2012; Long et al., 2016) identified and reported that the development, the promotion and the adoption of new crop varieties appropriate to our socio-economic realities would help not only to adapt to climate change but also to improve economics performances, food (and nutritional) security and reduce poverty (Fisher et al., 2015; Shiferaw et al., 2014; Tambo and Abdoulaye, 2012; Wossen et al., 2017). Some research has done on climate change adaptation strategies on the level of food security and nutritional status of rural populations. But most of these are broad (i.e. not on a specific case of

67 Retrieved from http://perspective.usherbrooke.ca/bilan/servlet/BMImportExportPays?codePays=BEN
68 Global Vulnerability and Food Security Report
69 For more reading, check the review of (John K. M. Kuwornu, Al-Hassan, Etwire, & Osei-Owusu, 2013)

climate change adaptation strategy such as drought-tolerant varieties) on adoption of climate change strategies Di Falco et al., (2011) but also more focused on Africa or in the best case on eastern Africa. Furthermore, the existing studies on DTM mostly focus on adoption and impacts on yield (Holden and Fisher, 2015; Kassie et al., 2017; Tambo and Abdoulaye, 2012; Wossen et al., 2017) and our paper adds to these studies by focusing on food and nutrition security.

With the aim of reducing poverty and ensure food security by increasing agriculture productivity while adapting to climate change since 2006, some research institutions like International Center for the Improvement of Maize and Wheat (CIMMYT) and the International Institute of Tropical Agriculture (IITA) with the collaboration of the National Research Institute of Agriculture of Benin (INRAB) and West Africa Agricultural Productivity Project in Benin (WAAPP) have developed and disseminated or promoted seven varieties[70] of Drought Tolerant Maize in Benin. However, thing surprising despite these multiple efforts is that not only generally empirical data on adoption of rates, on productivity and outcome indicators related to well-being are few in the literature, but there are practically no studies on the adoption of DTM varieties and better on their impact in Benin. Indeed, for this Drought Tolerant Maize for Africa (DTM) varieties developed and disseminated from 2006 to 2016, simultaneously in 13 countries including Angola, Benin, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Nigeria, Tanzania, Uganda, Zambia and Zimbabwe, showed high adoption rate (85 percent of farmers that adopt DTM varieties) in Kenya and Zambia, but only 20 percent in Benin, 30 percent in Mali and 27 percent in Mozambique (CIMMYT-IITA, 2015). In the context of Benin, understanding the primary determinants of DTM varieties adoption, in addition to the expected returns from adoption, so as to design policies that could address the supply side constraints in West Africa is consequently essential.

With the aim to bring out the probable impacts of adoption of DT maize varieties at the household level in Benin this paper offers a comprehensive ex-post assessment. Especially, it seeks to address the following relevant questions: What is the impact of adoption of DT maize varieties on food security? Furthermore, this study empirically contributes to the current adoption literature by examining the food security effects using a rigorous approach accounting for both unobserved and observed variables of heterogeneity between non-adopters and adopters. The rest of this paper is structured as following sections: section 2: data sources, section 3: the empirical framework, section 4: the results and discussion and section 5: Conclusion.

METHODS

Data sources

The data used come from household survey data collected from the rural zone in Benin. From November 2017 to January 2018, the survey was carried out. The study adopted a multi-stage sampling procedure selecting the respondents. First, municipalities were randomly selected within each AEZ based on their number of agricultural households. Second, villages were randomly selected within selected municipalities. Finally,

70 For the name of the varieties disseminated see: http://dtma.cimmyt.org/index.php/varieties/dt-maize-varieties random farm households were selected within selected villages. Therefore, the municipalities were randomly selected within each AEZ (AEZ I: one municipality, AEZ II: one municipality, AEZ III: one municipality, AEZ IV: one municipality and AEZ V: two municipalities). The choice of municipalities and there the number per AEZ is linked to the high number of producers of maize and food and cash crops, and the predominant agricultural production systems are cash-based and food-based crops with maize, cotton, yam, sorghum, millet, ...etc. First of all, where the agro-ecological zone has more than three municipalities, the first three having the highest maize production in relation to the total area cropped. Above all, the municipalities were selected within each AEZ by means of Primary Sampling Units (PSUs).

In each selected municipality, villages were also randomly selected in the exploratory survey according to the level of drought or the rainfall perturbations they experienced, the diversification of the drought tolerant maize disseminated and adopted, the access to the village, and their response to climate change, especially in dry season. Also, the villages are villages where WAAPP has introduced the DTM varieties - IITA-INRAB. Indeed, the selection of these villages is justified by the fact that they were the villages in which the spread of improved and tolerant varieties of maize was made. This information was obtained from exploratory surveys conducted with some resource persons such as extension agents, seed production managers such as APRODIS (Association of Producers and Seeds Distributors) of each municipality. These officials and extension agents have seed distribution centres for drought-tolerant maize varieties in their respective municipalities. As a result, they have a wide range of village information on the adoption of improved and tolerant maize varieties. This is the reason why they have been associated with the study with the objective smooth out the possible varietal confusions, all the more so as producers re-label varieties in their own language. I each selected village, ten farming household's in an average of eight villages were surveyed in each municipality, it except Kétou (five villages), Kandi (nine villages) and Savè (nine villages) due to logistical and accessibility constraints. This sampling framework overall generated a total of 518 farming households.

Analytical methods

The information collected in the survey were on the households socioeconomic characteristics , household income, expenditure of household on food and non-food items, information on adoption of improved maize varieties, outputs of maize, food security indicators (like households Dietary Diversity (HDD), Household Food Consumption Score (SCA), and Household Food Insecurity Access Scale (HFIAS)) and anthropometric measure (for children under five years old and the women between fifteen and forty five years old). Indeed, in additional to the anthropometric measurement's materials (personal scale, height gauge, tricolour strip), it is important to note that each enumerator kept along the survey the seven specimens of DT maize cob disseminated in Benin[71]. Adoption of DTM varieties as treatment variable, was created using the following survey two questions: 1) During the last cropping season (2015/16), what is the name (in local or French language) of the maize seed or how

71 *The name of the DTM varieties are available here: http://dtma.cimmyt.org/index.php/varieties*

can you describe the seed package, seed size and seed colour of the variety, does your household have to grow? And 2) During the last agricultural season (2015/16), give the code of the varieties of maize that your household has grown? At the first question, enumerators were asked to see the seed bag, if available, or ask a more educated household member for the name of the variety with the goal to fill the second question. Based on the second question, we extracted a dummy variable that took one as value if the farmer had grown one of the DT maize varieties, and zero otherwise. About 60 % of farm households had used DT maize varieties in the survey season according to our survey. TZE Comp 3DT, EV DT 97, STR W; 2000 Syn EEW; Across 97 TZL Comp 1 were the most common DTM varieties identified in our survey. Across the different municipality of Benin, there was also significant variation in the use of DTM varieties.

In the literature, some authors have used as an indicator for the assessment of household food security to different shocks, per capita consumption or per capita income of the household (Abdoulaye and Wossen, 2018; Boarini and Johansson, 2006; Dercon, 2006; Droy et al., 2004; Wossen et al., 2017). According to Kakwani and Son, (2016) compared to per capita income, per capita consumption is more directly related to people's level of food security and more accurately reflects a household's actual standard of living. In fact, the use of per capita consumption, rather than income per capita, makes it possible to understand the response of rural households to climate hazards better. Based on this background and according to Bickel et al., (2000); Coates and Bilinsky, (2007); Hoddinott and Yohannes, (2002); Parry et al., (1999) and Yohannes, (2002), in our research, the main proxy used for household food security and nutritional status outcome indicators were per capita expenditure, food per capita expenditure, households Dietary Diversity score (HDDS), Household Food Consumption Score (SCA), Household Food Insecurity Access Scale (HFIAS) and our main productivity outcome indicator included grain yield of maize.

In fact, the SCA, the HDDs indicators capture quality and diversity (Ndiaye, 2014) and that HFIAS measures access (Bickel et al., 2000; Coates et al., 2007; FAO, 2016). These consumption scores are indicators of food accessibility and the quality of food consumption (FAO & PAM, 2009; INSAE, 2015). They are calculated from: a) the diversity of the diet (number of food groups consumed by a household during the seven days preceding the survey); b) the frequency of consumption (number of days during which a food group was consumed during the seven days preceding the survey); c) The relative nutritional importance of different food groups. That is why, as part of our research, we used the three scores.

Firstly, following Bickel et al., (2000) and Coates et al., (2007), the score of food consumption that reported the level of household food security was computed. It is a dietary diversity score weighted (wi) by frequency. The calculation is based on the frequency of consumption of the different food groups (grouped in 8) consumed by a household during the seven days preceding the research (FAO, 2016). According to N'diaye, (2014) that score is an acceptable proxy for measuring calorie intake and diet quality at the household level, indicating household safety status combined with other indicators of household food access. Given that, SCA is the sum of the Weighting of each food group multiple by the number of days of consumption in the last seven days (Coates et al., 2007; FAO and PAM, 2009)

Also, a second HDDS score has been calculated; it represents the dietary diversity of the number of foods or food groups consumed during a given reference period. This similar SCA score does not provide information on the frequency but a proxy for household access to a varied diet (N'diaye, 2014). Following (Bilinsky and Paula, (2006), for the HDDs calculation, the food groups used for the SCA were grouped into seven groups by summing the frequencies. Thus, we have group 1: cereals and tubers; group 2: legumes; group3: vegetables; group 4: fruits; group 5: meat and fish; group 6: milk and group 7: oil. For each group, a binomial variable is created that takes two values: 1- yes: the household consumed food of this group; 0- no: he did not eat this food. Subsequently, all binomial variables are summed to create a new HDD variable; this new variable has a value between 0 and 7 (the number of food groups collected).

Finally, regarding, the HFIAS score computed, provides information on food insecurity (access) at the household level. Four types of indicators can be calculated to help understand the characteristics and changes in household food insecurity (access) in the surveyed population. These indicators provide summary information on the following: a) Conditions related to food insecurity (access) of the household; b) Areas related to household food insecurity (access); c) Scale score related to household food insecurity (access); d) Prevalence related to household food insecurity (access). The condition of household food insecurity (access) is an indicator that provides specific and disaggregated information on the behaviours and opinions of the households in the survey. Indeed, the HFIAS score is a continuous measure of the level of food insecurity (access) in the household in the last four weeks (last 30 days). First, the HFIAS score variable is calculated for each household by summing the codes for each question on the frequency of occurrence. The maximum score for the household is 27 (the household's response to all nine frequency of occurrence questions was "often," coded as 3); the minimum score is 0. The higher the score, the higher the household's food insecurity (access). The lower the score, the less the household experiences food insecurity (access).

The descriptive statistics of the main outcome indicators, variables of inputs used (soil fertility status, the use of chemical fertilizer, pesticides, and herbicides) and of some specific characteristics (gender, membership of different social groups, household size, age, education, land size...etc.) of household of maize producer based on adoption status is presented in the table 1 as control variables. The risk-taking the behaviour of farmers for new improved maize varieties was also used as an additional control. This variable measured as a dummy variable (one if the respondent is willing to try any type of new variety, and zero otherwise), is linked to farmer's willingness to take the risk to adopt new varieties. In the same table 1, we presented the difference of the main control variables means between adopters and non-adopters. The Instruments variables used are the distance from home to the shop where they sell seeds to households and distance from home to the demonstration field. For our instrument variables, they were the statistically significant difference between the two groups (adopters and non-adopters). All of our instrument's variables were continuous variables.

We supposed that variables used in the regression model could affect farmer's decisions to adopt, their productivity and as well as their household's food security and nutritional status. For example, maize income has a positive and significant effect that influences food security. According to Sib et al., (2013), income stability and the reliability of income sources are positively influence food security. Similarly, age is a factor that influences adoption and household food security. The head of household whose age is very advanced may not reach food security. On the other hand, a young producer can better achieve this food security with other contributing factors. The influence of age remains significant but mitigated. Contact with an extension service and belonging to an organisation enhances adoption (Wossen et al. 2017) and contribute to the food security of a rural household. The size of the farm is a factor that influences a producer's decision to adopt and food security. The larger the size of the farm, the more income the farmer will have and meet the food needs of his household. It is, therefore, a significant but mitigating factor, as the case may be. Kassie et al. (2014) documented that there is a positive effect of a more abundant supply of family labour on adoption decisions. Education has a significant influence on household food security. Educational attainment can be an essential constraint to human capital development. The level of household food insecurity is related to the level of education of the household head. However, rural producers, given their ancestral know-how and other enabling factors such as extension services and membership in an organisation, can improve adoption decision and their food security without any formal education. In sum, education has a positive influence on food security and adoption decision in our research area.

Base on the producer theory, we assumed that maize producer adopts DT varieties based on expected benefits. Indeed, the rational producer always seeks to maximise his profit by reducing the costs of the inputs. In this particular case, a producer adopts DTM varieties if the output (gain) from adoption is superior to non-adoption.

Assuming that the cropping of DTM varieties net gain (compared with non-cropping) for a given producer is Y^*, then $Y^* > 0$ implicates that the benefit from adoption is superior to non-adoption. Evidently, it is not possible to observe Y^*. However, the gain from adoption (Y^*) can be stated as a function of an observable vector of covariates in a latent model presented further down :

$$Y^* = \alpha X_i + \omega_i \begin{pmatrix} A_i & if \;\; Y^* > 0 \\ 0, & otherwise \end{pmatrix} Y^* = \alpha X_i + \omega_i \begin{pmatrix} A_i & if \;\; Y^* > 0 \\ 0, & otherwise \end{pmatrix} \qquad (1)$$

Where A_i is a binary variable that equals 1 if a producer adopts the DTM varieties and zero otherwise; X_i is a vector of socio-economic and demographic characteristics as well as control and institutional variables at the farm level, and α is a vector of parameters to estimate in the equation; w_i is the error term of a specific household, assumed to be normally distributed. Isolating the causal effect of DTM varieties adoption on productivity and hence on household food security and nutritional status, in the above framework, is difficult due to endogeneity bias. According to Alene and Manyong, (2007) and Wooldridge, (2010, 2011) cited by (Abdoulaye et al., 2018), Audu and Aye, (2014); Bratti and Alfonso, (2009); Kassie et al., (2014); Manda et al., (2016), the causal effects of adoption on productivity requires controlling for both observable and unobservable sources of heterogeneity between adopters and non-adopters. To solve this issue, a model that accounts for both unobserved and observed sources of bias like ESR (Endogenous switching regression) has usually been employed (Lokshin and Sajaia, 2004, 2011; Malikov & Kumbhakar, 2014). This model required instrumental variables, and most of existing literature use awareness to innovation or technology and distance is quietly use. Following Shiferaw et al., (2014); Kassie et al., (2014); Alene and Manyong, (2007), access to information about DT maize varieties was used as an instrument. While following Asfaw et al., (2012); Di Falco et al., (2011) and Tambo and Wünscher, (2017) the distance from home to the shop where they sell seeds to households and distance from home to the demonstration field was used as an instrument. Indeed, we assume that distance variables and access to information on DTM varieties can affect adoption decision, but it cannot affect the welfare outcomes of non-adopter households.

Finally, following Woolbridge, (2011), the ESR approach was used to address the problem of endogeneity, we have simultaneously estimated the selection model (first stage) and then secondly the outcome model (second stage), using the full information maximum likelihood (FIML).

Based on the above conceptual framework, the outcome function conditional on adoption can be stated as an ESR model in the following way :

$$\textit{Regime 1}: Y_{1i} = f(H\,;Z\,;X\,;\,\alpha_1) + \varepsilon_{1i} \quad \textit{if } A_i = 1 \qquad (2)$$

$$\textit{Regime 2}: Y_{2i} = f(H\,;Z\,;X\,;\,\alpha_2) + \varepsilon_{2i} \quad \textit{if } A_i = 0 \qquad (3)$$

Where Y_{1i} and Y_{2i} represent the outcome indicators for adopters (maize yield and welfare indicators) and for non-adopters respectively; ε represents the error term of the outcome variable. The variables H, Z and X capture respectively the grown of DT maize varieties, the farm inputs and characteristics socio-economic/demographics with all others variables presented in Table 1. Finally, the variable A_i measures adoption status ($A_i = 1$, implies the producer is an adopter and $A_i = 0$ implies the producer is non-adopter). The error terms in the selection and the outcome equation (1), (2) and (3) are assumed to have a tri-variate normal distribution with mean zero and covariance matrix (Φ) in the following way :

$$\Phi = \begin{bmatrix} \sigma_\omega^2 & \sigma_{1\omega} & \sigma_{2\omega} \\ \sigma_{\omega 1} & \sigma_1^2 & . \\ \sigma_{\omega 2} & . & \sigma_2^2 \end{bmatrix} \qquad (4)$$

Di Falco et al., (2011) and Tesfaye and Tirivayi, (2018), documented that, since the error terms in the selection equation are correlated with those in the outcome equations, the means of the error terms in the outcome equations conditional on the sample selection are non-zero. For instance, if the estimated covariance turns to be significant, DTM varieties adoption outcome are correlated proving evidence of endogenous switching.

Table 1: Definition of the variable used in the model and descriptive statistics of maize farmers in Benin by DTM varieties adoption status

Variable Name and description	full sample	Adopters	non-Adopters	Mean Diff
Household Per capita Food Expenditure (in thousands of Euro)	72.72	73.26	71.88	1.37
Household food consumption scores (1 "Poor" 2 "Limite" 3 "Acceptable")	2.67	2.75	2.55	0,20*

Household Dietary Diversity Score	6.23	6.27	5.70	0,57***
Food insecurity severity experienced by households	1.99	2.23	1.62	0,61***
Holding of any personal capital before started maize farming (1=Yes and 0 otherwise)	0.81	0.85	0.76	0.088***
Number of members of your household	11,19	11,31	11	0,31
Total area planted (in ha)	8,16	7,83	8,67	-0,84*
Household farm income in Euro	2231.68	2520.163	1787.645	732.51***
Ownership of land where maize is produced (1 = yes and 0 = no)	0.93243	0.96492	0.8823	0.08***
Experience in agriculture (in years)	24.22	24.14	24.35	-0.21
Emigration for agricultural purposes (0 = No, 1 = Yes)	0,05	0,04	0,05	-0,00
Experience of growing maize (years)	22,67	22,83	22,42	0,41
Average total area planted in all for your maize crop	4,16	3,87	4,62	-0,75*
Use fertilizers (0=No,1=Yes)	0,75	0,73	0,79	0,06**
Distance from the closest formal magazine where farm input is stored	7,72	8,48	6,55	1,93***
Membership in an association or producer's cooperative (0 = No, 1 = Yes)	0,39	0,36	0,43	-0,06*
Easy access to agricultural credits (0 = No, 1 = Yes)	0,43	0,35	0,33	0,02
Status of Ownership of livestock (0 = No, 1 = Yes)	0,87	0,84	0,91	-0,06**
Total farm member participating farm activities in the household	9,20	8,87	9,70	¬-0,84*

*** p<0.01, ** p<0.05, * p<0.1 and Standard errors in parentheses

Source: author's computation, result from survey

We estimated the endogenous switching regression models using the full information maximum likelihood estimation (Wooldridge, 2011). Afterward estimating the model's parameters, the conditional expectations or expected outcomes and the Average treatment effect on treated households (ATT) are computed as follows :

$$E\ (\mathrm{Y}_{1i} \mid \mathrm{A}_i = 1 = \mathrm{f}\,(\mathrm{H};\ \mathrm{Z};\ \mathrm{X};\ \alpha_1) + \lambda_{1i}\sigma_{1\omega} \tag{5}$$

$$E\ (\mathrm{Y}_{2i} \mid \mathrm{A}_i = 0 = \mathrm{f}\,(\mathrm{H};\ \mathrm{Z};\ \mathrm{X};\ \alpha_2) + \lambda_{2i}\sigma_{2\omega} \tag{6}$$

$$E\ (\mathrm{Y}_{2i} \mid \mathrm{A}_i = 1 = \mathrm{f}\,(\mathrm{H};\ \mathrm{Z};\ \mathrm{X};\ \alpha_2) + \lambda_{1i}\sigma_{2\omega} \tag{7}$$

$$E\ (\mathrm{Y}_{1i} \mid \mathrm{A}_i = 0 = \mathrm{f}\,(\mathrm{H};\ \mathrm{Z};\ \mathrm{X};\ \alpha_1) + \lambda_{2i}\sigma_{1\omega} \tag{8}$$

$$ATT = E\ (\mathrm{Y}_{1i} \mid \mathrm{A}_i = 1)\ -\ E\ (\mathrm{Y}_{2i} \mid \mathrm{A}_i = 1) \tag{9}$$

RESULTS AND DISCUSSION

Our main results are presented in this section (Table 2 and Table 3). In table 2 the second-stage estimations of the Endogenous Switching Regression (ESR) model by full information maximum likelihood (FIML) for household food consumption expenditure per capita and Household food consumption score (HFCS) are presented. The table 3 presented the second-stage estimations of the Endogenous Switching Regression (ESR) model by full information maximum likelihood (FIML) for Household Food insecurity severity experienced (HFIES) and Household food consumption score (HFCS) and Household Dietary Diversity Score (HDDS). For each outcome, the third column represents the selection equation which reports the determinants of adoption. In the first two rows of each outcome, the determinants of the concern outcome by adoption status (respectively for non-adopters and adopters) are shown.

Determinants of impacts on household food consumption expenditure per capita

The results (table 2) show that the household size, experience in agriculture, the quantity of maize consumed in the household, holding a bank account, amount of own financial capital, use fertilizers significantly affect food consumption expenditure per capita of both adopter and non-adopters always in the same direction either positively or negatively. In fact, that means, an increase or decline in one of this variable implies an increase or a decline in food consumption expenditure per capita. Some differences between what determines expenditure per capita and food consumption expenditure per capita among adopter and non-adopters were remarked, and this explains the use of the ESR model. For example, the access to agricultural credits, the experience in agriculture and the total maize farm size are significantly and positively correlated with food consumption expenditure per capita of DTM farmer's non-adopters, but the impacts are insignificant among adopters. In opposition, the total amount of the household assets, the gender and the awareness of climate change are significantly and positively correlated food consumption expenditure per capita of only DTM farmer's adopters.

Table 2: Endogenous switching regression result of DTM adoption and food consumption expenditure per capita of households and Household food consumption score (HFCS).

VARIABLES	household Per capita Food consumption expenditure per year in (US Dollars)	Household food consumption score (HFCS)				
	Non-adopter	Adopter	selection	Non-adopter	Adopter	selection
Household's total assets amount	-0.00 (0.00)	0.00** (0.00)	-0.00 (0.00)	0.00*** (0.00)	0.00 (0.00)	-0.00 (0.00)
Gender	0.03 (0.16)	0.26** (0.11)	0.18 (0.33)	-0.19 (0.26)	-0.08 (0.13)	0.07 (0.34)
Access to agricultural credits	0.20* (0.11)	0.03 (0.05)	0.30 (0.19)	-0.18 (0.18)	-0.04 (0.07)	0.29 (0.20)
Awareness of climate change	-0.20 (0.15)	0.13*(0.07)	0.83*** (0.26)	-0.51** (0.23)	-0.19** (0.08)	0.83*** (0.26)
Participation in Migration	-0.21 (0.20)	-0.03 (0.13)	-0.33 (0.44)	-0.40 (0.32)	0.29* (0.16)	-0.12 (0.44)
Size of the household	-0.05*** (0.01)	-0.06*** (0.01)	0.04** (0.02)	0.04* (0.02)	-0.00 (0.01)	0.05** (0.02)
Number of children under 5 years old	-0.03 (0.05)	-0.03 (0.03)	0.07 (0.10)	0.02 (0.08)	0.05 (0.03)	0.09 (0.10)
Number of children dropped from school	-0.00 (0.02)	0.01 (0.01)	-0.04 (0.03)	-0.11*** (0.03)	-0.02** (0.01)	-0.04 (0.03)
Experience in agriculture	0.01** (0.01)	-0.00 (0.00)	-0.02 (0.01)	0.03*** (0.01)	-0.01* (0.00)	-0.02* (0.01)
Contact with extension services	-0.10 (0.10)	-0.06 (0.06)	-0.38** (0.19)	0.50*** (0.16)	0.08 (0.07)	-0.38* (0.20)
Quantity of maize consumed in the household	0.00*** (0.00)	0.00** (0.00)	0.00*** (0.00)	-0.00*** (0.00)	-0.00 (0.00)	0.00** (0.00)
Holding of a bank account	0.28** (0.12)	0.25*** (0.06)	0.26 (0.21)	-0.58*** (0.19)	-0.00 (0.07)	0.39* (0.21)
Amount of Own financial capital	0.00*** (0.00)	0.00*** (0.00)	0.00 (0.00)	-0.00*** (0.00)	-0.00 (0.00)	0.00 (0.00)
Use fertilizers	0.28** (0.12)	0.19*** (0.07)	-0.58** (0.24)	0.03 (0.19)	-0.03 (0.08)	-0.66*** (0.25)
Total maize farm size	0.03*** (0.01)	0.00 (0.01)	-0.09*** (0.02)	-0.02 (0.02)	-0.00 (0.01)	-0.10*** (0.03)

Possession of a side activity	0.11 (0.10)	0.01 (0.06)	0.02 (0.19)	0.32** (0.16)	0.01 (0.07)	-0.16 (0.19)
Existence of Health centre	-0.20 (0.13)	-0.12* (0.07)	-0.01 (0.26)	0.34* (0.20)	0.10 (0.08)	0.01 (0.27)
Year of Education	0.00 (0.01)	0.00 (0.01)	0.03* (0.02)	0.03* (0.02)	0.00 (0.01)	0.03 (0.02)
Participation in an informal education	0.07 (0.05)	0.03 (0.03)	0.05 (0.10)	0.07 (0.08)	-0.10*** (0.04)	0.03 (0.11)
Awareness of DTM varieties	0.24 (0.15)	0.01 (0.07)	0.86*** (0.24)	-0.05 (0.22)	0.15* (0.09)	0.78*** (0.24)
The distance of home to Demonstration fields			-0.43*** (0.06)			-0.47*** (0.05)
The distance of home to Farm inputs shop			0.07*** (0.01)			0.08*** (0.01)
Constant	11.08*** (0.32)	11.85*** (0.21)	0.08 (0.74)	4.01*** (0.51)	3.84*** (0.26)	0.53 (0.74)
Wald chi2	143.83***			92.52***		
Log-likelihood	-427.10008			-581.65748		
lns0, lns1	-0.636***, -0.878***			-0.151**, -0.690***		
r0, r1	0.004, 0.811**			-0.331**,0.147		
p0, p1	0.529, 0.415			0.859, .501		
p0, p1	0.004, 0.670***			0-.319**,0.146		
LR test of indep. eqns.	chi2(2) = 8.83 Prob > chi2 = 0.0121			chi2(2) = 4.37 Prob > chi2 = 0.1127		

Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$
Source: author's estimations

The selection bias is provided by the correlation coefficients between the error terms of the selection and outcome equations (ρ0 and ρ1) at the bottom part of the table of equation outcomes result. In the food consumption expenditure per capita where (ρ0) and (ρ1) represent respectively, the correlation coefficients of non-adopter and adopters, only ρ1 is positive and statistically significant, telling that there is self-selection among adopters. So, farm households with higher than average household food consumption expenditure per capita for adopter are more likely to adopt DTM varieties. Finally, the significance of the likelihood ratio tests for independence of equations indicates that there is joint dependence between the selection and food consumption expenditure per capita equations for non-adopter and adopter.

Determinants of impact on Household food consumption score (HFCS)

The household food consumption score (HFCS) estimations result (table 2) from the Endogenous Switching Regression (ESR) model by full information maximum likelihood (FIML) shows that the awareness of climate change, the number of children, dropped from school, and the experience in agriculture are statistically significant and affect HFCS of both adopter and non-adopters from the results HFCS equations (Table 31). Indeed, the positive or negative correlation with one of the variable means respectively implies an increase or a decline in HFCS.

This results also, shows that the total amount of the household assets, the household size, the contact with extension services, the possession of a side activity, the existence of health centre, the year of education are statistically significant and positively affect only the DTM non-adopters' farmers, but the impacts are insignificant among adopter (Table 1). In the other hand, only the participation in migration for agriculture purposes and awareness of DTM varieties are statistically significant and positively affect only the DTM adopter's farmers while insignificant for the DTM non-adopters' farmers. At the bottom part of table 31 of the equation of the outcome result, the correlation coefficients between the error terms of the selection and HFCS outcome equations (ρ0 and ρ1) are provided and represent respectively, the correlation coefficients of non-adopter and adopters. Only ρ0 is negative and statistically significant, telling that there is self-selection among non-adopters. So, farm households with lower than average household food consumption score for non-adopters are less likely to adopt DTM varieties. Also, the non significance of the likelihood ratio tests for independence of equations indicates that there is not joint dependence between the selection and household food consumption score equations for non-adopter and adopter.

Table 3: Endogenous switching regression result of DTM adoption and Household Food insecurity severity experienced (HFIES) and Household Dietary Diversity Score (HDDS).

VARIABLES	Household Food insecurity severity experienced (HFIES)			Household Dietary Diversity Score (HDDS)		
	Non-adopter	Adopter	selection	Non-adopter	Adopter	selection
Household's total assets amount	-0.00 (0.00)	-0.00 (0.00)	-0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-0.00 (0.00)
Gender	-0.19 (0.40)	-0.61* (0.34)	0.11 (0.34)	-0.10 (0.07)	-0.13** (0.06)	0.11 (0.31)
Access to agricultural credits	0.27 (0.28)	0.19 (0.17)	0.26 (0.21)	-0.01 (0.05)	-0.10*** (0.03)	0.31*(0.18)
Awareness of climate change	-0.31 (0.36)	-0.03 (0.21)	0.80*** (0.26)	0.07 (0.06)	0.02 (0.04)	0.60** (0.26)
Participation in Migration	-0.34 (0.49)	-0.05 (0.41)	-0.09 (0.46)	0.12 (0.09)	-0.03 (0.07)	0.04 (0.39)
Size of the household	0.02 (0.03)	0.01 (0.02)	0.04** (0.02)	-0.00 (0.01)	-0.01** (0.00)	0.03** (0.02)
Number of children under 5 years old	0.08 (0.12)	-0.01 (0.09)	0.12 (0.10)	0.03 (0.02)	0.03** (0.02)	0.10 (0.09)
Number of children dropped from school	0.02 (0.04)	-0.01 (0.03)	-0.04 (0.03)	-0.01 (0.01)	-0.01 (0.00)	-0.02 (0.02)
Experience in agriculture	0.01 (0.02)	0.00 (0.01)	-0.02 (0.01)	0.00 (0.00)	0.01** (0.00)	-0.02** (0.01)
Contact with extension services	-0.27 (0.25)	-0.33* (0.18)	-0.39** (0.20)	-0.03 (0.04)	0.11*** (0.03)	-0.38** (0.18)
Quantity of maize consumed in the household	0.00 (0.00)	0.00 (0.00)	0.00** (0.00)	0.00 (0.00)	-0.00 (0.00)	0.00** (0.00)
Holding of a bank account	0.15 (0.29)	0.02 (0.18)	0.37* (0.21)	0.10* (0.05)	0.07** (0.03)	0.27 (0.19)
Amount of Own financial capital	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-0.00 (0.00)	0.00 (0.00)
Use fertilizers	-0.28 (0.29)	0.15 (0.20)	-0.63** (0.26)	0.24*** (0.05)	0.06 (0.04)	-0.72*** (0.24)
Total maize farm size	0.01 (0.03)	0.00 (0.02)	-0.09*** (0.03)	0.00 (0.01)	0.01 (0.00)	-0.09*** (0.02)
Possession of a side activity	0.37 (0.25)	0.30* (0.18)	-0.07 (0.19)	-0.05 (0.04)	-0.08** (0.03)	-0.14 (0.17)
Existence of Health centre	0.07 (0.31)	0.12 (0.20)	0.01 (0.27)	0.13** (0.06)	0.01 (0.04)	-0.31 (0.25)
Year of Education	-0.07*** (0.03)	0.02 (0.02)	0.03 (0.02)	0.01* (0.00)	0.00 (0.00)	0.04** (0.02)
Participation in an informal education	0.32** (0.13)	0.03 (0.10)	0.02 (0.11)	0.05** (0.02)	-0.03* (0.02)	0.03 (0.10)
Awareness of DTM varieties	-0.14 (0.35)	0.26 (0.23)	0.80*** (0.24)	0.12* (0.06)	-0.12*** (0.04)	0.68*** (0.21)

The distance of home to Demonstration fields			-0.47*** (0.05)			-0.33*** (0.09)
The distance of home to Farm inputs shop			0.08*** (0.01)			0.07*** (0.01)
Constant	2.15*** (0.80)	2.24*** (0.68)	0.28 (0.75)	1.57*** (0.14)	2.16*** (0.12)	-0.00 (0.72)
Wald chi2	21.78			179.88***		
Log-likelihood	-921.12135			-96.468296		
lns0, lns1	0.288***,0.228***			-1.470***, -1.458***		
r0, r1	-0.397**, -0.186			0.114, -1.425**		
p0, p1	1.334, 1.256			0.229, .232		
p0, p1	-0.377**, -0.184			0.113, -0.890***		
LR test of indep. eqns.	chi2(2) = 4.86 Prob > chi2 = 0.0879			chi2(2) = 3.91 Prob > chi2 = 0.1416		

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Source: author's estimations

Determinants of the impact on Household Food insecurity severity experienced (HFIES)

In Table 3, the result from the Endogenous Switching Regression (ESR) model by full information maximum likelihood (FIML) of Household Food insecurity severity experienced (HFIES) shows that none of the variables introduces in the model has a simultaneous significantly impact on the household experience of food insecurity of both adopter and non-adopters. But, variables like gender, the contact with extension services, the possession of side activity, the year of education, the Participation in an informal education somehow impact the household Food insecurity severity experienced (HFIES) whether negatively or positively. Indeed, the positive or negative correlation or impact with one of the variable means respectively implies an increase or a decline in HFIES.

In addition, it has also shown some differences between what impact HFIES among adopter and non-adopters in table 32. For instance, the possession of a side activity and only that is significantly and positively correlated with household experience of food insecurity of DTM farmer's adopters, while the impacts are insignificant among non-adopters.

On the contrary, participation in an informal education is significantly and positively correlated household experience of food insecurity of only DTM farmer's adopters.

In the result of HFIES, $\rho 0$ and $\rho 1$ are negative, but only $\rho 0$ is statistically significant and negative, telling that there is self-selection among non-adopters. The same result in the table 32 states a significant correlation coefficient and also the significance of the likelihood ratio tests for independence of equations indicates that there is joint dependence between the selection and HFIES outcome for non-adopter and adopter.

Determinant of impact of Household Dietary Diversity Score (HDDS)

On the other hand, table 3 presented the second-stage estimations of the Endogenous Switching Regression (ESR) model by full information maximum likelihood (FIML) for household Dietary Diversity Score (HDDS). Generally, the results show that the gender, the access to agricultural credits, the household size, the number of children under 5 years old in the household, the experience in agriculture, the contact with extension services, the holding of a bank account, the use or application of fertilizers, the possession of a side activity, the

existence of Health centre, the number of year of Education, the participation in informal education and the awareness of DTM varieties are significantly correlated (or impacted) with household Dietary Diversity Score (HDDS) whether specially positively or negatively on adopter and non-adopters. In fact, the positive or negative correlation (or impact) with one of the variable means respectively implies an increase or a decline in household Dietary Diversity Score (HDDS).

A deep analysis of the results in table 33 show that the holding of bank account and the Participation in an informal education significantly affect household Dietary Diversity Score (HDDS) of both adopter and non-adopters always in the same direction either positively or negatively. But, the awareness of DTM varieties which also significantly affect household Dietary Diversity Score (HDDS) of both adopter and non-adopters is impacted in a different direction (positively for non-adopters and negatively for adopters). The HDDS model estimations provides also that the number of children under 5 years' old in the household, the experience in agriculture and the contact with extension services are only statistically significant and positive impacted the HDDS of adopters while the use of fertilizers, the existence of health centre and the number of year of Education are only statistically significant and positive impact on the HDDS of non-adopters.

In the result of HDDS, $\rho 0$ and $\rho 1$ are negative, but the only $\rho 1$ is negative and statistically significant, telling that there is self-selection among adopters. So, farm households with lower than average household Dietary Diversity Score (HDDS) for adopters are less likely to adopt DTM varieties. The same result in table 33 states a non-significance of the likelihood ratio tests for independence of equations indicates that there is independence between the selection and HDDS outcome for non-adopter and adopter.

Impact of Adoption of DTM varieties on household food security in Benin

An essential component of the objective of this thesis is to estimate the impact of DTM adoption on the food security status of the households. This involved the counterfactual analysis and the estimation of the average treatment effect on the impact of adoption of DTM varieties food security and the result shown in table 4. Indeed, the table 4 presents the average or mean of the impact of DTM adoption. This table shows that the DTM varieties adoption significantly increase food expenditure and food security while reducing food insecurity of the DTM adopters' households.

Indeed, that DTM varieties adoption significantly increased the household food consumption expenditure per capita of the DTM adopters' households base on the ATT by 11.68 compared to 11.51 for non-adopter's households representing about 1.44% increase in household food consumption expenditure per capita of the adopter's households. This positive impact on total household expenditure may come from DTM productivity or from the potential reduction of DTM production costs. This result are consistent with Shiferaw et al., (2014) and Kassie et al., (2014), who respectively found at the household level, that adoption of improved varieties increases food consumption expenditure up to 2.7% and 14, 44% points in Ethiopia and Tanzania. In fact, this result is consistent with Awotide et al., (2016b) finding which concludes that DTMVs adoption increase per capita consumption expenditure significantly in Nigeria using a propensity score matching approach.

Similarly, the result of the ATT shows that adopting households significantly increased their household food consumption score (HFCS) by about 17.58%. Indeed, that DTM varieties adoption significantly increased the household food consumption score (HFCS) of the DTM adopters' households base on the ATT by 3.84 compared to 2.91 for non-adopter's households. This result is not consistent with Tambo and Wünscher, (2017) funding in Ghana, the adoption of innovations contribute significantly to increase of household income but not significantly translate into the nutritious diet, measured by household dietary diversity. But, this result is consistent with Mathenge et al., (2014) and Smale, Moursi, and Birol, (2015) findings.

In addition, from the estimations of ATT for the HDDS, it was suggested that adoption of DTM varieties increase household dietary diversity. Specifically, a significant increase of 1.86 index points (about 2.34% of increasing of household dietary diversity) for adopters of the DTM adoption compares to 1.82 for non-adopter's households. This result is not consistent with Tambo and Wünscher, (2017) funding in Ghana which found that innovations contribute significantly to increase of household food security. Indeed, their study finds that positive impact of innovations on household income do not significantly translate into a nutritious diet, measured by household dietary diversity. But, this result is consistent with Mathenge et al., (2014) and Smale, Moursi, and Birol, (2015) findings. In fact, according to that study, there is a powerful effect on the numbers of food groups consumed by household members and the adoption of hydride varieties of maize.

Table 4: Impact of DTM adoption on the food security in farming household in Benin

Outcomes	Adoption of DTM varieties		ATT	ATT in %	T-test
	Non-adopters	Adopters			
Household food consumption expenditure per capita	11.51	11.68	0.166	1.449	5.63***
Household food consumption score (HFCS)	2.91	3.848	0.929	31.83	17.58***
Household Food Insecurity Access Scale (HFIES)	4.14	2.26	-1.88	-45.46	18.06***
Household diet Diversity Score (HDDS)	1.82	1.86	0.042	2.34	3.47***

*** p<0.01, ** p<0.05, * p<0.1

Source: author's computation, estimations results

Finally, the same of ATT in table 34 shows that DTM varieties adoption significantly reduced Household Food Insecurity experience score of the DTM adopters' households base on the ATT by 2.260285 compared to 4.144288 for non-adopter's households representing about 25.32% reduction in Household Food Insecurity experience of the adopter's households. This suggests that the harvested quantity of maize does indeed convert into nutritious diets.

CONCLUSION

By conducting our study on the impact of Drought tolerant maize (DTM) varieties adoption on household productivity, food security and Nutritional status in Benin, we contribute to the existing literature on smart climate innovations.

For this purpose, we have based our analysis on estimations of the Treatment Effect (ATT) method for adoption DTM varieties on productivity and household welfare indicators measured by total expenditure, consumption expenditure and food security and nutritional status. To control selection bias, we have applied econometric techniques on our data from a field survey of rural farm households in Benin.

We have, in this study, grouped the different varieties of DTM adopted by the producers into one and also, we have only adopters and non-adopters according to which one of the varieties was cultivated the past agricultural campaign. However, it will be interesting to assess the gap between the different categories of adoptive parents based on the experience in adoption (the number of years since the household began cultivating incessantly) adopting DTM varieties and better to estimate how the different specific varieties of DTM contribute to household welfare. We also have a relatively small sample size, so we recommend that future searches with a large sample size allow such an analysis.

As a result of our study, using both subjective and objective indicators of food security and nutritional status, we have been able to confirm many other studies, written or oral reports (farmers' perceptions), on the important role of smart climate innovations such as DTM varieties on the livelihoods of rural farm households. As a first result, we found that the adoption of DTM varieties not significantly improves the productivity of adopter households' but increases total household spending and their level of dietary diversity in general food and nutritional security. Furthermore, one of the exciting results of our study is that because of the adoption of DTM varieties, households reduce expenditures on food purchases and also that these households are the most likely to be food secure.

Overall, it is clear that our findings highlight that adoption potentially contributes, despite this current climate change context, to improve the livelihoods of rural households. Consequently, it would be beneficial to support existing adaptation strategies and to intensify the dissemination of DTM varieties to all AEZs in Benin. Indeed, information is crucial in the adoption of agricultural technologies and more particularly improved varieties of maize including DTM where the risk perceived by maize growers can be very high. Thus, a lack of information or under-reporting could lead to an undervaluation of expected earnings and downgrade potentially profitable technology. For this reason, public and / or private bodies involved in the extension of these varieties should be encouraged and supported.

Omitted the indicator of Household Food Insecurity Access, the significant contribution to all the other indicators of food security and household nutritional status in Benin of the adoption of DTM varieties, suggests the need to undertake additional actions to ensure that the positive effects on productivity translate into an increase in the share of maize harvests reserved for consumption likely to undergo agri-food processing for better household nutrition in the area of our study. Thus, it would be beneficial that beyond the availability dimension of food security, in our study area that policies to reduce food insecurity also focus on nutritional security.

Even though our study has shown that poor rural farmers with limited resources through the adoption of DTM varieties that generate benefits on household welfare, the adoption of innovation being a dynamic process, we envision that future research involving panel data to study the long-term effects of innovations led by farmers. Finally, it would also be interesting to extend this research on the impact of DTM varieties on the schooling of children in the same study area also on the nutritional status of children and women in the same household in Benin using anthropometric measurement.

REFERENCES

Abdoulaye, T., Wossen, T., & Awotide, B. (2018). Impacts of improved maize varieties in

Nigeria: ex-post assessment of productivity and welfare outcomes. Food Security, 10(2), 369–379. https://doi.org/10.1007/s12571-018-0772-9

ACF (Action Contre la Faim). (2012). Enhancing Climate Resilience and Food & Nutrition Security.

Agbossou, E., Toukon, C., Akponikpe, P. B. I., & Afouda, A. (2012). Climate Variability and Implications for Maize Production in Benin : a Stochastic Rainfall Analysis. African Crop Science Journal, 20(s2), 493–503.

Alene, A. D., & Manyong, V. M. (2007). The effects of education on agricultural productivity under traditional and improved technology in northern Nigeria: An endogenous switching regression analysis. Empirical Economics, 32(1), 141–159. https://doi.org/10.1007/s00181-006-0076-3

Asfaw, S., Shiferaw, B., Simtowe, F., & Lipper, L. (2012). Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. Food Policy, 37(3), 283–295. https://doi.org/10.1016/j.foodpol.2012.02.013

Audu, V. I., & Aye, G. C. (2014). The effects of improved maize technology on household welfare in Buruku, Benue State, Nigeria. Cogent Economics and Finance, 2(1), 1–10. https://doi.org/10.1080/23322039.2014.960592

Awotide, B. A., Awoyemi, T. T., Omonona, B. T., & Diagne, A. (2016). Impact of improved agricultural technology adoption on sustainable rice productivity and rural farmers' welfare in Nigeria. Inclusive Growth in Africa: Policies, Practice, and Lessons Learnt, 216–237. https://doi.org/10.4324/9781315562179

Below, T. B., Mutabazi, K. D., Kirschke, D., Franke, C., Sieber, S., Siebert, R., & Tscherning, K. (2012). Can farmers' adaptation to climate change be explained by socio-economic household-level variables? Global Environmental Change, 22(1), 223–235. https://doi.org/10.1016/j.gloenvcha.2011.11.012

Bickel, G., Nord, M., Price, C., Hamilton, W., & Cook, J. (2000). Guide to Measuring Household Food Security Revised 2000. Agriculture, 1–76.

Bilinsky, A., & Paula, S. (2006). Score de Diversité alimentaire des Ménages (SDAM) pour la mesure de l'accès alimentaire des ménages : Guide d'indicateurs VERSION 2. 14.

Bini, V. (2016). Food security and food sovereignty in West Africa. African Geographical Review, 6812(May), 1–15. https://doi.org/10.1080/19376812.2016.1140586

Boarini, P. R., & Johansson, Å. (2006). Les indicateurs alternatifs du bien-être. Cahiers Statistiques de l'OCDE, 1(Septembre), 8.

Boko, M., Kosmowski, F., & Vissin, E. (2012). Les Enjeux du Changement Climatique au Bénin. Chemistry &, (December 2015), 76. https://doi.org/10.13140/RG.2.1.2825.4808

Brandt, P., Kvakic, M., Butterbach-Bahl, K., & Rufino, M. C. (2017). How to target climate-

smart agriculture? Concept and application of the consensus-driven decision support framework "targetCSA." Agricultural Systems, 151, 234–245. https://doi.org/10.1016/j.agsy.2015.12.011

Bratti, M. (2009). Selection endogenous dummy ordered probit, and selection endogenous dummy dynamic ordered probit models.

Burton, I. (1997). Vulnerability and adaptive response in the context of climate and climate change. Climatic Change, 36(1–2), 185–196. https://doi.org/10.1023/a:1005334926618

Campbell, B. M., Thornton, P., Zougmoré, R., van Asten, P., & Lipper, L. (2014). Sustainable intensification: What is its role in climate smart agriculture? Current Opinion in Environmental Sustainability, 8, 39–43. https://doi.org/10.1016/j.cosust.2014.07.002

CIMMYT-IITA. (2015). Maïs résistant à la sécheresse. 4(1), 1–4.

Coates, J., & Bilinsky, P. (2007). Echelle de l ' Accès déterminant l ' Insécurité alimentaire des Ménages (HFIAS) pour la Mesure de l ' Accès alimentaire des Ménages : Guide d ' Indicateurs VERSION 3. 1–17.

Cooper, P., Cappiello, S., Vermeulen, S., & Campbell, B. (2013). Large-scale implementation of adaptation and mitigation actions in agriculture.

Dembélé, N. N. (2001). Sécurité alimentaire en Afrique Sub-saharienne: Quelle Stratégie de Réalisation? In Ageconsearch.Umn.Edu.

Dercon, S. (2006). La vulnérabilité: une perspective microéconomique. Revue d'économie Du Développement.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change, 19(2), 248–255. https://doi.org/10.1016/j.gloenvcha.2009.01.002

Di Falco, S., Veronesi, M., & Yesuf, M. (2011). Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. American Journal of Agricultural Economics, 93(3), 825–842. https://doi.org/10.1093/ajae/aar006

Droy, I., Ced, I. R. D., & Bordeaux, U. De. (2004). ENTRE CYCLONES ET MARCHES MONDIAUX : LA VULNERABILITE DES MENAGES RURAUX DE LA COTE EST DE La problématique de la Côte Est de Madagascar Les données disponibles : des enquêtes ménages en panel. Ged.U-Bordeaux4.Fr, 1–18.

DTMA, P. (2009). Definitions of common terms used in the DTMA Project.

Everts, E. (2003). Identifying a particular family humor style: A sociolinguistic discourse analysis. Humor, 16(4), 369–412. https://doi.org/10.1515/humr.2003.021

FAO. (2013). Evaluation de la Sécurité Alimentaire des ménages ruraux dans les zones Sahélienne et soudaniene du Tchad.

FAO, & PAM. (2009). Etat de l'insécurité alimentaire dans le monde 2009 : Crises économiques, répercussions et enseignement.

Fieldsend, A. (2013). Facilitating Innovation In Agriculture: Lessons From A European Perspective. Agricultural Economics and Rural Development, (2), 177–190.

Fisher, M., Abate, T., Lunduka, R. W., Asnake, W., Alemayehu, Y., & Madulu, R. B. (2015). Drought tolerant maize for farmer adaptation to drought in sub-Saharan Africa: Determinants of adoption in eastern and southern Africa. Climatic Change, 133(2), 283–299. https://doi.org/10.1007/s10584-015-1459-2

Food and Agriculture Organisation. (2016). Voices of the Hungry Technical Report (Vol. 2016).

Füssel, H. M., & Klein, R. J. T. (2006, April). Climate change vulnerability assessments: An evolution of conceptual thinking. Climatic Change, Vol. 75, pp. 301–329. https://doi.org/10.1007/s10584-006-0329-3

Gbêtondji, M. A. N., & Porgo, M. (2014). Effect of climate change on cereal yield: evidence from Benin and Burkina Faso. 1–16.

Gnangle, P., Egah, J., Baco, M., Gbemavo, C., Kakaï, R., & Sokpon, N. (2012). Perceptions locales du changement climatique et mesures d'adaptation dans la gestion des parcs à karité au Nord-Bénin. International Journal of Biological and Chemical Sciences, 6(1), 136–149. https://doi.org/10.4314/ijbcs.v6i1.13

Golay, C. (2010). Crise et sécurité alimentaires : vers un nouvel ordre alimentaire mondial ? Revue Annuelle de Politique de Développement – Genève, (1), 229–248. https://doi.org/10.4000/poldev.133

Gonfa, L. (2015). Farmers' willingness to pay for improved forage seed in LIVES Districts of west Shewa Zone, Ethiopia.

Halpin, B. (2017). SADI: Sequence analysis tools for stata. Stata Journal, 17(3), 546–572. https://doi.org/The Stata Journal

Hoddinott, J., & Yohannes, Y. (2002). Dietary Diversity as a Household Food Security Indicator. 136(May), 4.

Holden, S. T., & Fisher, M. (2015). Subsidies promote use of drought tolerant maize varieties despite variable yield performance under smallholder environments in Malawi. Food Security, 7(6), 1225–1238. https://doi.org/10.1007/s12571-015-0511-4

Hu, M., Fu, X., Cui, Y., Xu, S., Xu, Y., Dong, Q., & Sun, L. (2015). Expression of KAP1 in epithelial ovarian cancer and its correlation with drug-resistance. In International Journal of Clinical and Experimental Medicine (Vol. 8). https://doi.org/10.1596/978-0-8213-8077-2

Hubert, B., & Caron, P. (2009). Imaginer l'avenir pour agir aujourd'hui, en alliant prospective et recherche : l'exemple de la prospective Agrimonde. Natures Sciences Sociétés, 17(4), 417–423. https://doi.org/10.1051/nss/2009060

INSAE. (2015). Enquête Modulaire Intégrée sur les Conditions de Vie des ménages 2ème Edition (EMICoV-Suivi 2015): Note sur la pauvreté au Bénin en 2015.

IPCC. (2014). Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

John K. M. Kuwornu, Al-Hassan, R. M., Etwire, P. M., & Osei-Owusu, Y. (2013). Adaptation Strategies of Smallholder Farmers to Climate Change and Variability : Evidence from Northern Ghana. Information Management and Business Review, 5(5), 233–239.

Kakwani, N., & Son, H. H. (2016). Measuring Food Insecurity: Global Estimates. Social Welfare Functions and Development, 253–294. https://doi.org/10.1057/978-1-137-58325-3_9

Kassie, G. T., Abdulai, A., Greene, W. H., Shiferaw, B., Abate, T., Tarekegne, A., & Sutcliffe, C. (2017). Modeling Preference and Willingness to Pay for Drought Tolerance (DT) in Maize in Rural Zimbabwe. World Development, 94, 465–477. https://doi.org/10.1016/j.worlddev.2017.02.008

Kassie, M., Jaleta, M., & Mattei, A. (2014). Evaluating the impact of improved maize varieties on food security in Rural Tanzania: Evidence from a continuous treatment\rapproachh . Food Security, 6(2), 217–230. https://doi.org/10.1007/s12571-014-0332-x

Kurukulasuriya, P., & Mendelsohn, R. (2008). How Will Climate Change Shift Agro-Ecological Zones and Impact African Agriculture? Policy Research Working Paper 4717, (September).

Lokonon, B. O. K., Savadogo, K., Mbaye, A. A., & others. (2015). Assessing the impacts of climate shocks on farm performance and adaptation responses in the Niger basin of Benin. African Journal of Agricultural and Resource Economics Volume, 10(3), 234–249.

Long, T. B., Blok, V., & Coninx, I. (2016). Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: Evidence from the Netherlands, France, Switzerland and Italy. Journal of Cleaner Production, 112, 9–21. https://doi.org/10.1016/j.jclepro.2015.06.044

Malikov, E., & Kumbhakar, S. C. (2014). A generalized panel data switching regression model. Economics Letters, 124(3), 353–357. https://doi.org/10.1016/j.econlet.2014.06.022

Manda, J., Gardebroek, C., Khonje, M. G., Alene, A. D., Mutenje, M., & Kassie, M. (2016). Determinants of child nutritional status in the eastern province of Zambia: the role of improved maize varieties. Food Security, 8(1), 239–253. https://doi.org/10.1007/s12571-015-0541-y

Mathenge, M. K., Smale, M., & Olwande, J. (2014). The impacts of hybrid maize seed on the welfare of farming households in Kenya. Food Policy, 44, 262–271. https://doi.org/10.1016/j.foodpol.2013.09.013

Munz, E. D. (2017). Psychotherapie in der Psychiatrie. In Nervenheilkunde (No. 10). https://doi.org/10.1007/s13398-014-0173-7.2Ndiaye, M. (2014). Indicateurs de la sécurité alimentaire. In Programme Alimentaire Mondial , Bureau Régional pour l'Afrique de l'Ouest, Dakar: Intégrer les programmes de nutrition et de sécurité alimentaire en situation d'urgence et pour le renforcement de la résilience, Atelier Régional de Formation: 10-12 Juin 20.

Nyasimi, M., Kimeli, P., Sayula, G., Radeny, M., Kinyangi, J., & Mungai, C. (2017).

Adoption and Dissemination Pathways for Climate-Smart Agriculture Technologies and Practices for Climate-Resilient Livelihoods in Lushoto, Northeast Tanzania. Climate, 5(3), 63. https://doi.org/10.3390/cli5030063

OECD. (2008). OECD Reviews of Innovation Policy: China 2008. OECD Reviews of Innovation Policy, (June), 395–423. https://doi.org/10.1787/9789264039827-en

Ofuoku, A. U. (2011). Rural Farmers' Perception of Climate Change in Central Agricultural Zone of Delta State, Nigeria. Indonesian Journal of Agricultural Science, 12(2), 63. https://doi.org/10.21082/ijas.v12n2.2011.63-69

Parry, M., Rosenzweig, C., Iglesias, A., Fischer, G., & Livermore, M. (1999). Climate change and world food security: A new assessment. Global Environmental Change, 9(SUPPL.), S51–S67. https://doi.org/10.1016/S0959-3780(99)00018-7

Paunov, C. (2013). Innovation and Inclusive Development. OECD Publishing, 67. https://doi.org/10.1787/5k4dd1rvsnjj-en

Peterson, J. E. (2014). Christopher M. Davidson. After the Sheikhs: The Coming Collapse of the Gulf Monarchies. In Asian Affairs (Vol. 45). https://doi.org/10.1080/03068374.2014.874687

Shiferaw, B, Kassie, M., Jaleta, M., & Yirga, C. (2014). Adoption of improved wheat varieties and impacts on household food security in Ethiopia Bekele Shiferawa, , Menale Kassie b , Moti Jaleta c , Chilot Yirga d - Tìm vòi Google. Elsevier, 44, 272–284.

Shiferaw, Bekele, Kassie, M., Jaleta, M., & Yirga, C. (2014). Adoption of improved wheat varieties and impacts on household food security in Ethiopia. Food Policy, 44, 272–284. https://doi.org/10.1016/j.foodpol.2013.09.012

Shiferaw, Bekele, Tesfaye, K., Kassie, M., Abate, T., Prasanna, B. M., & Menkir, A. (2014). Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. Weather and Climate Extremes, 3, 67–79. https://doi.org/10.1016/j.wace.2014.04.004

Smale, M., Moursi, M., & Birol, E. (2015). How does adopting hybrid maize affect dietary diversity on family farms? Micro-evidence from Zambia. Food Policy, 52, 44–53. https://doi.org/10.1016/j.foodpol.2015.03.001

Smit, B., McNabb, D., & Smithers, J. (1996). Agricultural adaptation to climatic variation. Climatic Change, 33(1), 7–29. https://doi.org/10.1007/BF00140511

Smithers, J., & Blay-Palmer, A. (2001). Technology innovation as a strategy for climate adaptation in agriculture. Applied Geography, 21(2), 175–197. https://doi.org/10.1016/S0143-6228(01)00004-2

Tambo, Justice A., & Wünscher, T. (2017). Farmer-led innovations and rural household welfare: Evidence from Ghana. Journal of Rural Studies, 55, 263–274. https://doi.org/10.1016/j.jrurstud.2017.08.018

Tambo, Justice Akpene, & Abdoulaye, T. (2012). Climate change and agricultural technology adoption: The case of drought tolerant maize in rural Nigeria. Mitigation and Adaptation Strategies for Global Change, 17(3), 277–292. https://doi.org/10.1007/s11027-011-9325-7

Technical, N., Project, A., Development, E., Ave, C., & Washington, N. W. (2005). Measuring Household Food Insecurity Workshop II Report October 19, 2005.

Tesfaye, W., & Tirivayi, N. (2018). The impacts of postharvest storage innovations on food security and welfare in Ethiopia. In Food Policy (Vol. 75). https://doi.org/10.1016/j.foodpol.2018.01.004

Tidjani, M. A., & Akponikpè, P. B. I. (2012). Evaluation des stratégies paysannes d'adaptation aux changements climatiques : cas de la production du maïs au nord-Bénin. African Crop Science Journal, 20(Suppl. 2), 425–441.

Wooldridge, J. M. J. (2011). Front matter. In Neurology Secrets (2nd ed.). https://doi.org/10.1016/B978-0-323-05712-7.00031-3

Wossen, T., Abdoulaye, T., Alene, A., Feleke, S., Menkir, A., & Manyong, V. (2017). Measuring the impacts of adaptation strategies to drought stress: The case of drought tolerant maize varieties. Journal of Environmental Management, 203, 106–113. https://doi.org/10.1016/j.jenvman.2017.06.058

Yegbemey, R. N., Yabi, J. A., Tovignan, S. D., Gantoli, G., & Haroll Kokoye, S. E. (2013). Farmers' decisions to adapt to climate change under various property rights: A case study of maize farming in northern Benin (West Africa). Land Use Policy, 34, 168–175. https://doi.org/10.1016/j.landusepol.2013.03.001

Yohannes, Y. (2002). NUTRITION TECHNICAL Dietary Diversity as a Household Food Security Indicator John Hoddinott.

Zeng, D., Alwang, J., Norton, G. W., Shiferaw, B., Jaleta, M., & Yirga, C. (2017). Agricultural technology adoption and child nutrition enhancement: improved maize varieties in rural Ethiopia. Agricultural Economics (United Kingdom), 48(5), 573–586. https://doi.org/10.1111/agec.12358

Zongo, B., Diarra, A., Barbier, B., Zorom, M., Yacouba, H., & Dogot, T. (2015). Farmers ' Practices and Willingness To Adopt Supplemental Irrigation in Burkina Faso. International Journal of Food and Agricultural Economics, 3(1), 101–117.

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Abstract

This volume is a compendium of papers on climate change and food security in West Africa. Findings presented in the book are innovative and cutting-edge solutions and insights related to climate-related food insecurity in the Western Africa region. They reflect a diversity of background among authors from different horizons, using different approaches to analysing various aspects of the complex nexus between climate change and food security.

About the Editors

Ahmadou Aly Mbaye is professor of Economics and public policies at Cheikh Anta Diop University, in Senegal, where he is currently serving as Vice-Chancellor. Until recently, he was the Director of the West African regional graduate program in climate change economics, covering West-African countries. Previously, he had also served as the dean of the School of Economics and Management at Cheikh Anta Diop University and Chair of the francophone research network. He has been a consultant for many regional and international organizations. He has numerous publications on development economics and Africa. He is Non-Resident Senior Research Fellow at the Brookings Institution in Washington DC, and Senior Research fellow at the Center for Development Research (ZEF), University of Bonn (Germany).

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