Volume 1 No: 7 (2017)

Impact of Climate Change Adaptation Strategies on Farm Yields and Income in Benin

ADEGBOLA Ygué Patrice, AHOYO ADJOVI Nestor René, Hessavi Pélagie
KOUTON-BOGNON Baudelaire, Montcho Dorian and Mensah Serge E.

October 2017

PARI
FARA
Forum for Agricultural Research in Africa
Zentrum für Entwicklungsforschung
Center for Development Research
University of Bonn
ZEF Bonn
ISSN 2550-3359
9 772550 335000

Citation

Adegbola, Y P, Ahoyo-Adjovi, N R, Hessavi P, Kouton-Bognon B, Montcho D and Mensah SE, (2017). Impact of Climate Change Adaptation Strategies on Farm Yields and Income in Benin. FARA Research Results Vol 1(7) PP 58.

.

Corresponding Author

Dr. ADEGBOLA Ygué Patrice (patrice.adegbola@yahoo.fr)

Forum for Agricultural Research in Africa (FARA)
12 Anmeda Street, Roman Ridge PMB CT 173, Accra, Ghana Tel: +233 302 772823 / 302 779421 Fax: +233 302 773676 Email: info@faraafrica.org Website: www.faraafrica.org

Editorials

Dr. Fatunbi A.O (ofatunbi@faraafrica.org); Dr. Abdulrazak Ibrahim (aibrahim@faraafrica.org), Dr. Augustin Kouevi(akouevi@faraafrica.org) and Mr. Benjamin Abugri(babugri@faraafrica.org)

ISSN: 2550-3359

About FARA

The Forum for Agricultural Research in Africa (FARA) is the apex continental organisation responsible for coordinating and advocating for agricultural research-for-development. (AR4D). It serves as the entry point for agricultural research initiatives designed to have a continental reach or a sub-continental reach spanning more than one sub-region.
FARA serves as the technical arm of the African Union Commission (AUC) on matters concerning agricultural science, technology and innovation. FARA has provided a continental forum for stakeholders in AR4D to shape the vision and agenda for the sub-sector and to mobilise themselves to respond to key continent-wide development frameworks, notably the Comprehensive Africa Agriculture Development Programme (CAADP).
FARA's vision is; "Reduced poverty in Africa as a result of sustainable broad-based agricultural growth and improved livelihoods, particularly of smallholder and pastoral enterprises" its **mission is the** "Creation of broad-based improvements in agricultural productivity, competitiveness and markets by strengthening the capacity for agricultural innovation at the continental-level"; its **Value Proposition is the** "Strengthening Africa's capacity for innovation and transformation by visioning its strategic direction, integrating its capacities for change and creating an enabling policy environment for implementation". FARA's strategic direction is derived from and aligned to the Science Agenda for Agriculture in Africa (S3A), which is in turn designed to support the realization of the CAADP vision.

About FARA Research Result (FRR)

FARA Research Report (FRR) is an online organ of the Forum for Agricultural Research in Africa (FARA). It aims to promote access to information generated from research activities, commissioned studies or other intellectual inquiry that are not structured to yield journal articles. The outputs could be preliminary in most cases and in other instances final. The papers are only published after FARA secretariat internal review and adjudgment as suitable for the intellectual community consumption.

Disclaimer

Acknowledgements

This impact evaluation study of climate change adaptation strategies on farm management in Benin was conducted with funding granted to the Program of Accompanying Research for Agricultural Research (PARI) by the German Federal Ministry of Economic Cooperation and Development (BMZ), and managed by the Forum for Agricultural Research in Africa (FARA) for African countries. We express our deep gratitude to the managers of this programme. We also thank the authorities of the National Institute of Agricultural Research of Benin (INRAB) at the various levels for their useful scientific and administrative support.

Thanks, are also due to the data collection agents who have contributed to the success of this study. Finally, we thank the various people we interviewed, who sacrificed their precious time to give us the information we required in the study.

Our sincere thanks to all those who have contributed, directly or indirectly, through their actions, their availability and their edifying advice, towards implementing this study.

Abstract

The objective of this study was to analyse the economic and environmental impacts of the adoption of climate change adaptation strategies on farm management in Benin. The data were collected from 371 producers. Descriptive statistics, pie charts and histograms were used to represent and characterise the different adaptation strategies depending on the climatic risks experienced on the farms surveyed. The flora analysis tool EX-ACT developed by FAO allowed us to evaluate greenhouse gas at farm level depending on the adaptation strategies used. The econometric approach based on the calculation of the Marginal Treatment Effect (MTE) and the Ricardian approach were used to quantify the impact of using adaptation strategies on the revenues and the yields of the farms. The study revealed that the endogenous strategies used relied on rain makers and sacrifices. The main exogenous strategies used were short-cycle varieties of rice and maize, and mulching using plant residues. Estimation of the MTE indicated that the utilisation of short-cycle maize varieties increased yield by 490.43 kg/ha. Mulching using plant residues increased maize yield by 404.29 kg/ha in the sub-population of potential users. Regarding utilisation of short-cycle rice varieties for adaptation to climate change, the impact was 1432.22 kg/ha in the sub-population of the potential users. The results also revealed that utilisation of short-cycle maize varieties increased the maize net revenue by FCFA 138,480 per hectare. In the sub-population of the real users of short-cycle maize varieties, the impact was FCFA 153,930 per hectare and significant at the threshold of 5 percent. The impact of using short-cycle rice varieties on the net revenue was FCFA 351,940 per hectare in the sub-population of the potential users. Elsewhere, the results of the Ricardian model showed that an increase of 1°C in the average temperature during the rainy season decreases the maize revenues by FCFA 4,760.29 per hectare on average for all the farmers in the sample. Likewise, a decrease of 1 mm of water in the average yearly rainfall of the dry season generates an increase in the revenue of the farm holding for the farmers of the sample by FCFA 500.17 per ha for those who already practise climate change adaptation. The results of the elasticities showed that during the rainy season, an increase of 1 percent in the temperature leads to a decrease of 2.67 percent in the maize revenue. During the dry season, an increase of 1 percent in rainfall leads to a decrease of 4.26 percent in the revenues of the farm holdings of the sample. Although the adaptation strategies disseminated allowed producers to adapt to climate change and to improve their yield and revenue, they did not help them to reduce the emissions of greenhouse gases at farm level. In fact, the study observed that the use of mineral fertiliser contributed to emission of greenhouse gases, especially in rice plots. In view of this observation, we recommend that the use of chemical fertilisers be regulated. Producers must be followed up and supervised rigorously or encouraged to use minimal qualities of mineral fertilisers. The study suggests that in the frame of other projects on the adaptation to climatic risks, measures to reduce greenhouse gases be considered and disseminated.

Key Words:

Climate change adaptation strategies, crop yield, farm income, rainfall and greenhouse

Introduction

Climate change, deep modification of environmental conditions identified by changes in temperatures, rainfall, wind, and other indicators over an extended period, are a major concern for stakeholders working to meet the food demand for a net increasing population, as well as for stakeholders working to preserve natural ecosystems and the services they offer (IPCC, 2007; UNEP, 2006). Climate change is a global process largely induced by human activities. Climate evolution dynamics affect agriculture over extended periods. According to Ramirez (2010), climate change and population growth contribute to scarcity of water resources and phenomena such as floods and droughts. Disasters generated by the phenomenon of climatic modification have deep influence on agriculture in developing countries (Sperling *et al*., 2003; Agossou *et al*., 2012). According to the fourth evaluation report of GIEC (IPCC, 2007; Agossou *et al*., 2012), poor communities will be the most vulnerable because of their limited adaptation capacities and their high dependence on resources that are highly susceptible to climate change such as water resources and agricultural production systems.

The effects of climate change as diagnosed in Benin revealed that droughts, late and heavy rains and floods are the major climatic risks (Arodokoun *et al*., 2012; Agossou *et al*., 2012). The severe effects of climate change on agriculture coupled with the weak resilience and the high vulnerability of the populations to the shocks could significantly reduce their capacity to manage natural resources, and hence their livelihoods, their food security, and their well-being. According to Agossou *et al*. (2012), the populations in the most vulnerable agro-ecological zones recognise climate change and identify it based on several indicators. In fact, several concepts, sayings and proverbs are used by the local communities to characterise climate modifications observed. Based on the observations, they develop and adopt a wide range of adaptation strategies with regard to their socio-economic conditions and the vulnerability of their agricultural enterprises vis-à-vis climate change. This study aims at analysing the impact of climate change adaptation strategies on the yield and revenues of agricultural enterprises in Benin.

Problem and justification of study

Agriculture contributes more than 30 percent to the Gross Domestic Product (GDP) in the different countries of sub-Saharan Africa (SSA) and occupies more than 70 percent of the active population. Over 90 percent of the population in this region depends on rain-fed agriculture for food production (FAO, 2006). This makes agriculture in these countries highly dependent on climate change.

In Benin Republic, five of the six most vulnerable agro-ecological zones are in rural areas (MEPN, 2008) where agriculture contributes 35 percent of the GDP. However, the agricultural sector in the country is highly dependent on climate stimuli so it is seriously affected by climate change (Bokonon-Ganta *et al*., 2009). Climate change affects crop behaviour, soil modification, and yield levels.

It was observed that vegetative and flowering phases in crops are becoming shorter. Repeated dry spells and rainfall fluctuations reduce agricultural yields in the crop farming agro-ecological zones; the multiplication and spread of insect pests aggravate the risks of post-harvest losses. Indirectly, climate change affects labour used in agriculture, prices of foodstuffs, and the operation of agribusiness processing units. According to Sombroek and Gommes (1997) then WMO and UNEP (2002) cited by Ogouwalé (2006) then by Agossou (2008), to reduce the potential direct or indirect harmful effects of climate change, the populations should adapt to, and economic systems should be adapted to, future climate contexts.

Farmers have always been able to face natural climate variability, managing over the years, knowledge and know-how deemed pertinent globally (Arodokoun, 2011). The capacities of agricultural producers in the different vulnerable agroecological zones of Benin are reinforced by the components of the national agricultural research system (NARS), the NGOs and the national projects in order to develop technologies and reinforce their resilience. Moreover, Benin having benefited from the funding of the Global Environment Facility (GEF), has implemented in four agro-ecological zones vulnerable to climate change, the Integrated Adaptation Program to control the harmful effects of climate change on agricultural production and food security in the country (PANA1). The programme leads to capacity building of agricultural communities through technical, material, and other support to farmers, fishermen, cattle breeders, and processors in these zones. Generally, these measures and the adoption of technologies are expected to improve the performance of agricultural enterprises as well as reduce greenhouse gases from agricultural activities, thus considering the two components of climate change control: adaptation and reduction. Beyond evaluating adoption of adaptation technologies and evaluation of reduced losses among others, this study, in a sustainability perspective, analyses the economic and environmental advantages and inconveniences of the adoption of adaptation strategies in managing agricultural enterprises.

It aims at finding answers to the following research questions: what is the impact of adaptation strategies on the technical efficiency of farmers? What are the costs and advantages of these strategies in farm management? What are the environmental benefits linked to the adoption of these adaptation strategies by farmers?

Studies were carried out on the use of adaptation strategies (PANA, 2008; Gnanglè *et al.*, 2011; Arodokoun *et al.*, 2012; Agossou *et al.*, 2012; Tidjani *et al.*,2012 and Adégbola *et al.*, 2014) but were not able to answer these questions. Kouton-Bognon *et al.*, (2014) attempted to address the subject of impact of adaptation strategies. However, he did not consider all the vulnerable zones of Benin.

Objective of the study

The objective of this study was to analyse economic and environmental impacts of the adoption of climate change adaption strategies on managing agricultural enterprises in Benin.

Specifically, the study aimed to:

- identify adaptation strategies to climate change adopted by farmers;
- evaluate the quantities of greenhouse gases released by the strategies adopted by farmers; and
- estimate the impact of climate change adaptation strategies on the net revenue per hectare realized by adopter farmers and on the environment.

Theoretical frame

Clarification of some concepts of the study

A concept is a mental, general and abstract representation of a category of phenomena. The same concept may have several meanings depending on the contexts, hence the necessity to define well the concept used and the meaning given to it in this study (Daane *et al.*, 1992).

Climate change

Climate change designates a statistically significant variation of the mean state of the *climate* or its variability persisting for long periods (generally for decades or more). Climate change may be due to natural internal processes or to *external forcing*, or to persistent *anthropic* changes of the *atmospheric* composition or *soil utilisation*. It is noteworthy that the *United Nations Framework Convention on Climate Change* (UNFCCC), in its Article 1, defines "climate change" as being "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". UNFCCC thus makes a distinction between "climate change" that may be attributed to human activities that alter the composition of the atmosphere, and "climate variability" due to natural causes. As part of our study, climate change is perceived from the point of view of the definition of UNFCCC, which consists globally of climate change of anthropic origins. It considers climatic parameters--rainfall, temperature, and modifications in wind that become recurrent and affect agriculture.

Climate change and climate variability

Climate change refers to progressive changes in the global system that result from anthropogenic heating of the planet due to continuous increases of the emissions of greenhouse gases, and the loss of the vegetation cover and other carbon reservoirs (FAO, 2008; Mugula, 2013). It can also be defined as gradual changes in climate norms, particularly the temperature and changes in the frequency, scope and severity of climate and time extremes, explained as a persisting change on the average and variability of climate variables such as temperature, rainfall, humidity, and soil moisture (Krishna, 2011; Mugula, 2013). Climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) as the "statistically significant variation of the mean state of climate that can be detected through modifications of the mean and/or the variability of its properties and which persists over a long period, generally for decades or more" (Arouna *et al*., 2012).

The measure in which the geophysical, biological and socioeconomic systems are sensitive to the negative impact of climate change, including climatic variability and climate extremes, is defined as the state of climatic variability (IPCC, 2007; Mugula 2013). For Arouna *et* a*l*. (2012), it is the inherent characteristics to the climate that manifest themselves through changes and deviations in time. Thus, climate variability is a natural modification of the climate and therefore independent of human activities (Dimon 2008).

Climatic risk

In agro climatology, risk is characterised by the frequency of the occurrence of a climatic or biological event that can be harmful to development (Houndénou, 1999). In this case, the risk can be climatic drought, cyclones, wind blasts, excesses or deficits of temperature, and crop attacks by insect pests. Climate risk can be defined as the probability of having insufficient rains that cause partial loss of the harvest (Eldin, 1989). Thus, risk implies a notion of heavy consequences. In agriculture, Boussard (1979) defines risk as the variance of producers' revenues due to the vagaries of weather. As part of this study, we consider as climate risk, the frequency of drought occurrence, wind blasts, and excess water (floods), because these are the major factors that could affect in the current conditions the development of plants.

Vulnerability to climate change

Vulnerability is almost exclusively related to climate change (Arouna *et al.*, 2012). It is the degree according to which a system is susceptible, or becomes incapable of tolerating the adverse effects of climate change, notably climate variability and extreme climatic conditions. But Kasperson *et al*. (2001) define vulnerability as the degree to which a unit of risk undergoes damage after having been exposed to a perturbation or a constraint and the capacity of that unit to withstand it in order to recover or disappear. It can be schematised by the following functional relation: Vulnerability = Risk (danger x exposure) +/- Adaptation (Responses/ Options) (Dimon, 2008).

Agricultural innovation and vulnerability to climate change

Vulnerability of the agricultural sector to climate change is translated by a decrease in yields with the following consequences: food insecurity or famine, poverty intensification, increase in the price of agricultural products, and low contribution to the rest of the economy (IPCC, 2014). In such a context, it is commonly accepted that innovation is crucial in addressing the challenge of climate change adaptation in order to insure food security and increase farmers' revenues (Rivera *et al.,* 2005; OCDE-CRDI, 2010; Zongo, 2014).

The adverse effects of vulnerability to climate change on agricultural production stimulate not only organisational and technological innovations, but also institutional developments in agriculture (Koppel, 1995; Rodima- Taylor *et al.,* 2012; Chhetri *et al.,* 2012; Zongo 2014). The other innovations are considered as adaptation strategies developed and implemented for international institutions, regional organisations, national governments, and local stakeholders (producers; NGOs) to reduce vulnerability to climate change in order to increase agricultural production (Zongo, 2014).

Adaptation to climate change

According to Issa (1995), adaptation is defined as the whole adjustment made or self-made within natural and human systems as a curative or preventive response to current or future climate stimuli or to their effects in order to reduce harm or take advantage of it at the right time Verbeek (2004: 192). Adaptation is defined as an adjustment in ecological, social or economic systems in response to real or expected climate stimuli and to their effects or impacts. These are changes in processes, practices, and structures to reduce potential damage (or to take advantage of opportunities) associated with climate change (Ramsey *et al.*, 2008). Arouna *et al*. (2012) defined it as a change of procedures, practices and structures that aims at limiting or eliminating the potential damages or to take advantage of the opportunities created by variability and climate change.

Different types of adaptation may be distinguished; this distinction varies depending on the authors. Smit *et al*. (2000) distinguish two forms of adaptation: reactive adaptation, which involves reacting ex-post to the adverse effects of climate change when they occur; then, anticipative adaptation, which, unlike reactive adaptation, involves acting before the impacts occur to reduce the vulnerability of these impacts, thereby limiting the adverse consequences or taking advantage of the new benefits. Donahue (2014), distinguished two types of adaptation: hard adaptation and soft adaptation. The measures of the hard adaptation include physical infrastructure and changes to natural capital such as irrigation systems, earthworks, reservoirs, and dams. The measures of soft adaptation include modification of institutions, planning processes, and incentives that change conditions in which autonomous or private adaptation investments are made.

We talk of "maladaptation" when the measures developed to adapt to the effects of climate change can lead to unexpected results, and the risks of "maladaptation" should not be underestimated. Maladaptation is defined by IPCC as "a change in the natural or human systems that increases vulnerability instead of reducing it". It is important to note that adaptation will not be able to eliminate completely the impacts of climate change (Hallegatte and Perthuis, 2010).

Agricultural exploitation

According to Dufumier (1996), agricultural exploitation can be defined as a production unit within which the farm operator mobilises different natural resources (lands, labour, cattle, plants, materials, and buildings among others) and combines them in variable proportions to obtain some plant or animal productions and thus meets their needs and interests. It is therefore a form of technical, business and social organisation of agricultural production as pointed out by Adégbidi (1994).

Aho and Kossou (1997) give a much wider definition of agricultural exploitation. According to them, agricultural exploitation is the evolutionary set comprising the farmer, the agricultural perimeter, the operating staff, the crop, animals and trees exploited, the technical reference implemented, value addition and marketing strategies of the products. The concept of agricultural exploitation has led to the notion of enterprise. However, in the tropical regions, agricultural exploitation still functions traditionally, and nobody has the right to take ownership of the collective good and make it a source of personal wealth.
Operationally and in the frame of this study, agricultural exploitation is made of the set of cultivated lands, fallow lands, lands rented to other people and which are used by the farmer, animals and plantations, and the labour force working there.

Theoretical basis of the study

Several theories can be used in the frame of this study. Among the most common in the literature are: producer theory that has the costing theory and profit maximisation; the consumer theory that has the notion of utility of the goods and the revealed preferences and needs satisfaction; the distribution theory; and the adoption theory.

Most of the studies (e.g. Ouedraogo, 2012; Muhammed *et al*., 2012; Kumar *et al*., 2014) that dealt with the impact of climate change on agriculture were based on the producer theory.

According to Ouedraogo (2012), producers maximise their net revenues. But on the contrary, studies on the adoption of technologies were based on consumer theory. Olo (2013), in a study on the factors affecting the adoption of farmers' adaptation strategies, based his study on the consumer theory.

In short, there aren't many studies on the impact of climate change adaptation strategies. For this study, we have used the theories supporting the impact works of climate change on agricultural exploitations as a theoretical basis for this study.

The producer theory teaches us that the producer is supposed to be **rational** with a behaviour of **maximising under constraint** and defining his position of **equilibrium.** His objective function is the **profit** and profit maximisation is subject, among other things, to a technical constraint called **production function (**Marianne Tenand 2005). To achieve the objective of profit maximisation, the entrepreneur adopts a perfect behaviour of rationality ("The homo economicus"). This means that the producer is able to consider all possible alternatives, that he has all information allowing him to evaluate the consequences of the choice of each alternative (information free of charge), that he can classify the foreseeable alternatives according to priorities, that he chooses the alternative corresponding to the highest level of preferences.

Summary of previous works

Analytical methods of climate change impacts on agriculture

The literature on the impacts of climate change on agricultural production revealed the use of two categories of methods: the general equilibrium models and the partial equilibrium models (Deressa, 2007). The widely used partial equilibrium models are the stochastic regression of the production function and the Ricardian model (Ouédraogo, 2012; Houcine, 2013). The latter model is part of the partial equilibrium models (Deressa, 2007). One of the advantages of this model is that it makes a more reliable prediction of the way climate affects yield because the impact of climate change on agricultural yields is determined by controlled experiences.

The production function approach

The production function approach is based on the existence of a production function for any crop that links the production (or yield) of the crop to its biophysical environment. This approach estimates directly the change in yield from the response models of the crops. It measures the impact of climate change on the yield by varying the levels of climate stimuli. This approach was used by Harvey (1976), Just and Pope (1978), Reilly *et al.* (1994), Rosenzweig and Iglesias (1994), Rosenzweig and Parry (1994), Kar and Kar (2008), Kawasaki and Herath (2011), Aye and Ater (2012), Gupta *et al*. (2012), and Kumar *et al*. (2014), to estimate the impact of climate on plant production. However, the production function approach has a bias because it tends to overestimate the damage by climate change on production by omitting the various adaptation possibilities by farmers in response to socio-economic and environmental conditions (Mendelsohn *et al.,* 1994).

The Ricardian approach

This approach is used differently in the literature on the impact of climate change on agriculture. It was developed by Mendelsohn *et al.* (1994) to correct the bias of overestimation of the effects of climate change introduced by the production function approach. The *Ricardian* approach evaluates the direct impact of climate on agricultural revenues by taking into account potential adaptations to climate change (indirect substitutions of inputs, introduction of new varieties, …). It compares the sensitivity to climate change of different regions because it links the interregional differences of climate, unlike the land value. The *Ricardian* approach was used by Darwin *et al*. (1995), Cline (1996), Dinar *et al.* (1998), Gbetibouo G. and Hassan R. (2005), Kurukulasuriya *et al.* (2006), Ouédraogo *et al.* (2006), Ajetomobi *et* al. (2011); Muhammad *et al*. (2012) and Ouédraogo (2012).

The object of this study not being to measure the impact of climate change on agricultural production, the stochastic regression of the production function will not be used in this study. However, it should be pointed out that the stochastic regression of the production function and the Ricardian model can be adapted by including the adaptation strategies as variables in the models in order to measure the effect of these strategies used for production of the exploitation. Thus, these two models can be adapted to the impact analysis of adaptation strategies on the producers' revenues. In this case, the adaptation strategies are discrete or dichotomous variables.

Effect of adaptation strategies on agricultural production

Studies on the impact of climate change adaptation strategies are new. It is a new field of research in agricultural economics. Analysis of the work shows that the different stakeholders try to conceptualise the phenomenon differently. Two categories of models are used: the econometric models and the bio-economic models. The bio-economic model is a complex model that needs several types of different data under several formats. However, the econometric model is more flexible to use and requires less data.

The results obtained from the study of Pilo *et al*. (2013) "Impact of adaptation strategies on farm households' farm income: a bio-economic analysis" following the modeling of different data collected show that the increase in the intensity of all the strategies used in the study zone, except the decrease in fertiliser use, has a positive effect on farm revenue. Moreover, irrigation can more than just compensate for the negative impacts of climate change. It has a positive effect on farm households. Irrigation helps to face the adverse effects of climate change while increasing agricultural yield. On the contrary, the decrease in fertiliser use seems to increase the vulnerability of farm households.

Delaporte *et al.* (2015) studied the impact of climate change on adaptation strategies in Bangladesh. Using a regression function, they showed that some adaptation strategies to climate change cannot be used by the poorest: change of type of crop and change of culture. The revenue decreases because climate adaptation strategies are expensive. The well-to-do households invest much in irrigation. The results also show that educated producers invest more in changing varieties as an adaptation measure. Adaptation is easier for large households. Access to electricity and the number of years of experience in agriculture favour adaptation to climate change through crop varieties. The results also show that a decrease of 1 percent in agricultural revenue due to climate change pushes 3 percent of the households to adopt a strategy. However, certain strategies are too expensive and cannot be used in bad moments.

This method agrees with the objectives of this study and is based on the producer theory. Nevertheless, it does not take into account selection biases. In fact, the living conditions of some producers and their decision to use or not to use the adaptation strategy are simultaneously affected by some socioeconomic characteristics. The difference between the revenue of adapters and non-adapters, if positive, shows a priori no causal relation. Nothing shows that we should interpret as the fact that the utilisation of adaptation strategies leads to an increase in revenue or yield, or the fact that producers with high revenues and yields have used in general adaptation strategies to climate change. It is plausible that at least part of the differences in revenue and yield between users of adaptation strategies and non-users existed even before the practice of adaptation. Experimental approaches (social experience or randomisation) and non-experimental approaches were therefore developed to try and solve this problem of selection bias and to generate estimates with less biases of the impact results.

Thus, to reduce the bias induced by observable and non-observable characteristics and at the same time treat the problem of endogeneity of the treatment variable, the econometric approach based on the calculation of the Marginal Treatment Effect (MTE) was used to quantify the impact of utilisation of adaptation strategies on the revenue and yield of the farms in the frame of this study. This approach gives a consistent economic explanation of the LATE (Local Average Treatment Effect). Björklund and Moffitt (1987), by introducing this parameter in the literature, included the heterogeneity of results in the basic model of self-selection to define, identify, and estimate the MTE parameter.

Evaluation of greenhouse gases in small agricultural endeavours

Just like the studies on the impact of climate change adaptation strategies on agricultural activities, very few studies have covered the evolution of greenhouse gases in small agricultural farms. The IPCC (2006) compiled the best available scientific methods in the guidelines published to estimate the emissions of greenhouse gases and the absorptions of emissions of the sector of land utilisation. To evaluate the existing quantification tools of greenhouse gases in order to quantify all the emissions and absorption of greenhouse gases in small farms, farm scale quantification was tested using farm data from Western Kenya by Seebauer (2014). After having done a cluster analysis to identify different farm typologies, greenhouse gases were quantified using the VCS SALM methodology completed by the emissions factors of the IPCC cattle and the tool of the fresh farm. The emission profiles of four clusters of farms representing the baseline conditions in 2009 are compared with those of 2011 where farmers have adopted sustainable land management practices (SLMP). The results demonstrate the variation of the scale of estimated emissions of GHG per hectare between the different typologies of small-scale farmers and emissions estimated by using two different compatible tools. Farm scale quantification also shows that the adoption of emission-reducing measures has an important impact on the reduction and elimination of the emissions and that the advantages of the reduction are between 4 and 6: 5 tonnes CO_2 ha/year, with reduction benefits significantly different depending on the typology of systems of plant-animal associations of their different agricultural practices, as well as the adoption rates of the best practices. However, the uncertainty inherent in the emission factors applied by the accounting tools has important repercussions on agricultural emissions declared. With regard to the uncertainty linked to data on the activities, the evaluation confirms the high variability among the different types of farms as well as between the different parameters studied to quantify fully the emissions of GHG in small farms.

Methodology

Study zone

The study zone covers the nine communes of PANA1 intervention (Malanville, Matéri, Ouaké, Savalou, Aplahoué, Ouinhi, Adjohoun, Bopa and So-Ava), located in four agroecological zones particularly vulnerable to climate change. These are the agroecological Zones 1, 4, 5, and 8. The study took into account the nine villages of demonstration of PANA1 and the nine control villages of PANA1. The intervention villages of the *Projet de Renforcement des connaissances Economiques et de la Capacité d'Adaptation face aux changements climatiques au Bénin* (PRECAB) of the IDID-ONG located in Savalou and Aplahoué in the agroecological zone 4 were also retained mainly to consider other climate change adaptation strategies not promoted by the PANA1.

Sampling

The challenge to evaluate the impact of the programme, a project or an intervention, is that it is not possible to observe what would have happened to the participants in its absence. The key for the identification and measure of the impact is therefore to have a correct hypothesis, a group for comparison (control) which is similar to the intervention group (treatment) with the exception that it did not receive the intervention.

Climate change adaptation strategies considered for this study included: new maize and rice varieties promoted by the PANA1 and adaptation options (mucuna, pigeon pea, zaï) implemented in a real learning situation in the farmer field school by IDID-NGO. It should be noted that unlike new maize varieties that have been promoted in all the intervention zones of PANA1, the new rice varieties have not been promoted in the fisheries zone (agroecological zone 8). Pigeon pea in association with maize was experimented only in Southern Benin, unlike Mucuna, which was experimented in all the intervention villages of IDID-NGO. Producers surveyed during the qualitative phase were selected in the intervention villages (treatment) of PANA1 and those of IDID-NGO. To these villages were added the control villages.

For lack of the complete list of producers per targeted village, the notebook on the village of RGPH-4 of 2013 gave us the number of households at the level of these villages of PANA1 and IDID-NGO. We supposed that in each household, there was at least one producer.

$$\mathrm{N_s} = \frac{\mathrm{N_p} * \mathrm{p} * (1-\mathrm{p})}{\left(\mathrm{N_p}-1\right)(\mathrm{B}/\mathrm{C})^2 + \mathrm{p} * (1-\mathrm{p})} \qquad (1)$$

Ns: total number of producers to be surveyed
Np: total number of producers
p: estimative proportion of the population presenting the characteristic studied in the survey (50 percent or 0.5 is the most conservative)
B: acceptable error margin (1 percent)
C: confidence interval (C=2.58 for 99 percent confidence level)

Thus, 371 producers (Table 1) were chosen randomly in the frame of this study in each of the intervention zones of PANA1 and IDID-NGO.

The following formulas were used to determine the number of producers to be surveyed at the level of the intervention villages and the control villages:

$$n_1 = \frac{N_s * N_1}{N_p} \text{ and } n_2 = \frac{N_s * N_2}{N_p} \qquad (2)$$

n_1: the number of producers in the intervention villages (pilot) to be surveyed
n_2: the number of producers in the control villages to be surveyed
N_1: total number of producers in the intervention villages (pilot)
N_2: total number of producers in the control villages.

Table 1: Number of the surveyed producers in the intervention zone of PANA1 and IDID NGO in the AEZ 1, 4, 5 and 8

Agroecological zones	**Communes**	**Villages**	**Total number of producers to be surveyed in each village (ni)**		
			Pilot	**Control**	**Total**
Fisheries zone (Zone 8)	Ouinhi	ADAME	29		29
		DOLIVI		30	30
	Bopa	SEHOMI	7		7
		AGBODJI		30	30
	Adjohoun	HOUEDO-WO	5		5
		DEKANME		8	8
	So-Ava	AHOMEY	29		29
		HOUNMEY			
		AHOME LOKPO		37	37
Cotton zone of central Benin (Zone 5)	Savalou	DAME	10		10
		AOUANKANME		26	26
		AGLAMIDJODJI	17		17
		KOUTAGO		26	26
	Aplahoué	LAGBAVE	32		32
		SEHONOUHOUE		9	9
		KAITEME	22		22
		TCHIGLIHOUE		10	10
West Atacora zone (Zone 4)	Matéri	KANKINI-SIRI	34		34
		BAMPORA		4	4
	Ouaké	KADOLASSI	5		5
		ALITOKOUM		3	3
Extreme Northern zone of Benin (Zone 1)	Malanville	TOUMBOUTOU	38		38
		MOLLA CENTRE		28	28
Total			189	175	371

Source: Survey results 2017 FARA/INRAB

Data collection

Literature review

This phase consisted in reviewing various works, including study reports, theses and dissertations, scientific articles, and monographs related to the theme of our study. This phase allowed us to gather information about: (i) the adaptation techniques and technologies used, (ii) the perceptions of the people surveyed on the characteristics of these techniques and technologies used, and (iii) the perceptions on the factors limiting and favouring adoption of technologies for climate change adaptation, and (iv) the impact analysis methods of adaptation strategies. The literature review covered the entire duration of the study.

The phase of individual surveys

Data were collected in a formal survey using a questionnaire. We collected primary data with maize and rice producers retained for the study. The data were collected on: farm characteristics and the agricultural production systems; local perceptions of the people interviewed and the techniques, technologies, and any practices currently used by farmers to adapt to climate change; the costs and benefits related to adoption of these strategies; the perceptions of the people surveyed on the factors limiting and those favouring adoption of climate change adaptation technologies; and the potential impact of the different technologies among other factors. This survey was carried out with the support of interviewers recruited and trained by researchers.

Data analysis

Descriptive statistics (averaging, standard deviations, and frequencies), pie charts and histograms were used to represent and characterise the different adaptation strategies at the level of the farm surveyed. The analysis tool EX-ACT for the flora developed by FAO allowed us to evaluate greenhouse gases at farm level depending on the adaptation strategies used. The econometric approach based on the calculation of the Marginal Treatment Effect (MTE) and the Ricardian approach were used to quantify the impact of utilising adaptation strategies on the revenue and yields of farms in the frame of this study.

GHG evaluation method

GHG evaluation was done using the flora analysis tool EX-ACT. EX-ACT is an application developed by FAO; it is used to calculate and estimate the variation of the carbon pool and other greenhouse gases per unit of earth. This tool helps project developers to estimate and prioritise activities that are highly beneficial for the economy and climate change. The EX-ACT tool is developed in Microsoft Excel, on several interrelated spreadsheets in which the user inserts the data required for the evaluation. This tool is developed in several modules and each module describes a specific variant of land utilisation forms. The EX-ACT tool is equipped with several other resources (tables, maps and FAOSTAT data).

Method to evaluate the impact of utilising adaptation strategies on farm yields and revenue

Econometric approach based on the calculation of the MTE

More precisely, this is to estimate what would have been on average the situation of the beneficiaries if they had not benefited from technical support on climate change adaptation strategies from PANA1 and IDID-NGO or from any other project that had intervened on the same aspects. A simpler approach would consist of considering the difference, for example, of the mean revenues between the beneficiaries and the non-beneficiaries. However, interpreting this difference as a causal relationship between the use of the adaptation strategies by these projects and the revenues of the beneficiaries may pose many problems. The major problem lies in the existence of selectivity bias (ex. Diagne 2003). Experimental (social experience or randomisation) and non-experimental approaches were therefore developed to try to solve the problem of selection bias and to generate estimations with fewer biases in the impact results. The non-experimental approach is most preferred in economics because motivations, tastes, individual propensities, and life experience, are rarely the same for individuals, but influence the choices of each other (see for ex. Diagne, 2003; Bassolé, 2004). This approach uses economic and econometric theories in the specification of the models in order to minimise potential errors in estimating the impacts (Diagne and Demont, 2007). It is this approach that was used in the study.

Rubin (1974) remains the pioneer of this approach which, initially, was introduced as part of performance evaluation of different treatments in medicine. This modeling then developed independently from this initial context to deal in general with the selectivity bias problem when one wishes to measure the effect of dichotomous changes (here the effect of using or not using adaptation strategies). With reference to the initial context in which these models were developed, the term “treatment” has been conserved for the dichotomous change variable. In our case, the « treatment » therefore corresponds to the utilisation of one of the climate change strategies.

MTE estimation method

Programmes on impact evaluation and policy interventions are being conducted using the potential results approach more and more. Based on the potential results developed by Rubin (1974), each farm is characterised by two types of potential results: a result denoted $as\ y_1$ when it uses climate change adaptation strategies (*D*=1) and a result y_0 when it does not (*D*=0). The net revenue of the farms according to both types of results is presented as follows:

$y_1 = \mu_1\ (X, U_1)$

and

$y_0 = \mu_0\ (X, U_0)$

where X is a vector observed variable and $(U_1)\ and\ (U_0)$ are unobserved variables.

The estimation of the causal effect is confronted with the identification problem called in the econometric literature the “counterfactual” (Rubin, 1974). In fact, only the following result is observed:

$$y = y_1 D + (1 - D) y_0 \qquad (3)$$

But, the choice of a technology will depend on the unobserved characteristics and the macroeconomic factors affecting the productivity of the technology compared to traditional technologies (Suri, 2011). The rationality of the producer leads him/her to use all information relating to adaptation strategies and to do an individual evaluation that will help him/her to adopt or not to adopt the technology (Mendola, 2007; Fourgère, 2010). Therefore, the adoption of a technology is voluntary and appeals for self-selection. In such a situation (endogenous treatment) the conditional or unconditional independence is an unrealistic hypothesis and therefore, the most plausible hypothesis is the "selection on unobservable variables" (Diagne *et al.*, 2012).

The definition and identification of treatment effects and other impact parameters using the MTE requires an explicit formulation of a selection equation that determines the values taken by the treatment status variable (Diagne *et al.,* 2012).
The equation of climate change adaptation strategies utilisation is presented as follows:

$$D = 1[\mu_D(Z) - V_D \geq 0] \qquad (4)$$

Where $1[\,.\,]$ is an indicator function taking the value 1 if the quantity between brackets is true and 0 if it is not, with Z observed and V unobserved. The assumption of additive separability above therefore characterises the utilisation of adaptation strategies. $\mu_D(Z) \geq V_D$. By supposing that the random vector V is distributed continuously with a function F_V of cumulative distribution, F_V being a non-decreasing function, equation (4) equals:

$$F_V(\mu_D(Z)) \geq U_D \qquad (5)$$

Where $U_D \equiv F_V(V)$, a random variable evenly distributed over the interval $[0,1]$. By applying a monotonous transformation of the net unit of utilisation, the selection equation can also be written in terms of D, Z, U_D and of the propensity score function P:

$$D = 1[P_Z \geq U_D] \qquad (6)$$

Where P_Z, the probability to use (called the propensity score) represented by Z, is

$$P_Z \equiv Pr\{D = 1|Z\} = F_V(\mathrm{u}_D(Z) \qquad (7)$$

The parameter MTE can be defined as follows (Heckman, 2010):

$$MTE\ (\mathrm{x}, \mathrm{u}) = E(Y_1 - Y_0|X = \mathrm{x}, U_D = \mathrm{u}_D) \qquad (8)$$

The parameter MTE, defined by a conditional expectation, is obtained regardless of an instrument (Heckman and Vytlacil, 2007b). It is defined as the mean revenue of the utilisation for the individuals who have the observable characteristics X= x and unobservable characteristics $U_A = \mathrm{u}_A$. For the individuals with a value u_D close to zero, the MTE is the expected effect of the treatment on individuals who have unobservable characteristics that make them more susceptible to use climate change adaptation strategies and who would use them even if the utility $u_D(Z)$ was low.

To estimate the parameter MTE, Heckman and Vytlacil (1999, 2005) developed the method of the local instrumental variable (LIV). This method is based on an estimation of the conditional expectation function $E(Y|X = x, P_Z = p)$, where P (.) is the function of the propensity score. They show that under additive and identification hypothesis of separability, the vector Z depends on this conditional only through the propensity score that can be written as a function of x and p. More precisely, they draw the following relationship:

$$E(Y|X=\mathrm{x},\mathrm{P(Z)}=\mathrm{p})=\mathrm{E}(Y_0|\mathrm{X}=\mathrm{x})+\int_0^P MTE\ (\mathrm{u},\mathrm{x})\,\mathrm{du} \quad (9)$$

By taking at the same time the partial derivative of these two parts of equation (9) compared to p, they give the MTE parameter as a partial derivative of the conditional expectation:

$$LIV(\mathrm{x},\mathrm{P(Z)}=\mathrm{p})=\frac{\partial(Y|X=\mathrm{x},\mathrm{P(Z)}=\mathrm{p})}{\partial\mathrm{p}}=MTE(\mathrm{p}) \qquad (10)$$

From equations (9) and (10), we can find $LATE(P_1,P_2,\mathrm{x})$ after estimation of the conditional expectation $E(Y|X=\mathrm{x},\mathrm{P(Z)}=\mathrm{p})$ as follows:

$$LATE(P_1,P_2,\mathrm{x})=\frac{E(Y|X=\mathrm{x},\mathrm{P(Z)}=P_2)-E(Y|X=\mathrm{x},\mathrm{P(Z)}=P_1)}{P_2-P_1} \qquad (11)$$

The conditional expectation $E(Y|X=\mathrm{x},\mathrm{P(Z)}=\mathrm{p})$ can be estimated by using parametric or non-parametric regression methods (Heckman, 2010). This study used a two-phase method to estimate conditional expectation. It consists in estimating the function of the propensity score $\mathrm{P(Z)}$ in a first step of a regression probit and using the predicted propensity score as independent variable, with vector X to estimate the conditional expectation in a parametric regression.

Two dependent variables were used for the models: These include the utilisation of the adaptation strategies, which is the impact factor. The utilisation of this variable in the different model is either the utilisation of short-cycle varieties for maize or rice, or mulching using plant residues. The second dependent variable is the yield or the revenue which are impacted results. The dependent variables retained to turn the different models are therefore of two orders: we have those explaining the impact factor and those explaining the impacted result. Certain variables belong to both and others are specific.

Dependent variables of the impact factor (utilisation of adaptation strategies)
Age: This is found in the majority of knowledge and adoption study models. It is a continuous variable, the sign of which cannot be defined in advance because it is subject to contradictions. Adégbola and Adékambi (2008) and Sall *et al*. (2000) showed that young producers adopt technologies to a lower extent than elders. But this observation is contradicted by Arodokoun (2011); Glèlè *et al.* (2008), who state that young farmers are much more inclined to adopt innovations than older farmers. The result obtained by the first authors is justified by the facility to access land and the frequency of contact of elders with extension agents, a fact that allows them to be more informed about innovations. Regarding the last authors, elders are more averse to risk. Age can therefore have a positive or negative influence on the probability to use an adaptation strategy considered in the frame of this study as a technology. Age is therefore perceived as an indicator of tiredness of adults. The older the producer, the smaller the yield he/she will obtain. The producer's age effect on the revenue cannot therefore be a priori predetermined.

Formal education*:* It is a binary variable that takes the value 1 if the surveyed person is educated (no matter the level reached) and 0 if the person is not. Several studies have shown that producers who have received a formal education apply innovations (Arouna *et al.*, 2011) well. It is expected that formal education reduces the risk of innovation perceived and increases the degree of openness to innovations. It is supposed that education positively influences adaptation strategies.

Household size: This variable indicates the number of persons present in the household. The major concern of producers is to meet the food needs of their household and to also draw from their activity some revenue to meet other needs. Any strategy likely production and revenue will be applied (Lokossou, 2011). This variable is expected to have a positive influence on the utilisation of adaptation strategies.

Contact of the producer with agricultural extension services: It is expected that the more contact the producer has with extension agents from SCDA and NGOs of an area, the more information they will acquire about the technology and the lower the subjective perceived risk (Honlonkou, 1999). According to Adégbola and Adékambi, (2008), contact with the extension agents gives reliable information on the innovations. Thus, this variable should have a positive influence on the application.

Distance of the village to the main town: This variable translates the easiness to sell agricultural products. In fact, the closer to towns or markets the actors are the more easily they will sell their production. It is expected that this variable can allow taking the decision to apply the strategies. A positive sign is anticipated for the coefficient of this variable.

Perception of the producer on the characteristics of the adaptation strategy used: Binary variable taking the value 1 when the characteristic is very important for the producer and 0 when not. The influence of this variable on the utilisation of the adaptation strategy may be positive or negative.

Information on the adaptation strategy: very important variable in the adoption of a strategy because one needs to be informed about the existence of a technology before taking the decision to adopt it. This variable takes the value 1 when the producer is informed about an adaptation strategy and 0 when not. A positive effect of the variable is expected on the adaptation, which is in this case is the utilisation of an adaptation strategy.

Independent variables of the impacted result (yield or revenue)

Sex of the producer: It is a binary variable that takes the value 1 when the surveyed producer is a man and 0 when the producer is a woman. Gender intervenes much in the socio-economic situation of the individual. In general, women, due to their weak physical capacity compared to men, cannot carry out activities requiring much strength. Customs in the traditional society, mainly in Africa, are also often a hindrance to women blooming. Therefore, the revenue obtained by a woman will be lower than that obtained by a man.

Access to literacy: this is a binary variable that takes the value 1 if the producer is literate and 0 if not. The influence of this variable on the revenue of the producer may be positive.

Age*:* Continuous variable, the sign of which cannot be defined in advance because it is subject to contradictions. Age is perceived as an indicator of tiredness of adults. The more aged the producer is, the lower the yield they will obtain. The age effect of the producer on the revenue cannot *a priori* be predetermined.

Experience in production: continuous variable designating the number of years of experience in the production. The number of years for a given activity has a positive influence in the acquisition of experience for that activity. Thus, the most experienced producers are more likely to have higher revenues than the less experienced producers. We expect a positive sign from this continuous variable. The ability of the producer increases with the experience and can favour yield increase. Glèlè *et al*., (2008) also identified the number of years of experience as a factor affecting the revenue positively.

Formal education: It is a binary variable that takes the value 1 when the surveyed person is educated (no matter the level reached) and 0 when not. Bravo-Ureta *et al*. (2005) identified this variable as a factor affecting agricultural revenue positively. A positive sign is therefore expected.

Member of a village producers' association: It is a binary variable taking the value 1 if the producer is a member of a group of maize or rice producers and 0 if not. Mutual aid, information and know-how sharing are the advantages that a producer can draw from being a member of a village association (Hessavi, 2013). Thus, producers who are members of an association will tend to have more knowledge on the practice of adaptation and therefore will have higher revenues compared to those who are not. The influence expected from this variable is positive.

Cultivated area*:* is a continuous variable that measures the cultivated acreage of maize or rice by the surveyed person. We estimate that producers who have cultivated a large area will have higher revenue than those who have cultivated a small area. The effect of the acreage on the revenue can only be positive.

Availability of developed lowland in the village: It is a variable that takes the value 1 when there is a developed perimeter in the village of the surveyed person and 0 when there is no developed perimeter. Sites are developed to allow producers to produce throughout the year in order to diversify production and increase their annual revenue. Hence, producers occupying developed sites will have higher annual revenues than those occupying non-developed sites.

Perception on the state of the nature of the year: When the producer considers that the year has been good, the variable takes the value 1; otherwise it takes the value of 0. A positive effect is expected from this variable on the producer's yield and revenue.

Practice of animal traction: A binary variable taking the value 1 if the producer practises animal traction and 0 otherwise. Animal traction presents an advantage in terms of crop yield and ease of work (Allagbé *et al.,* 2013). Animal traction leads to an increase in revenue and gains of time on the farms (Barro *et al*., 2005). It is therefore expected that this variable will have a positive effect on the yield and consequently on the revenue.

Perception of the producer on the climatic risks experienced during the cropping campaign: Binary variable taking the value 1 if the producer has experienced a climatic risk on one of the production plots and 0 otherwise. Negative effects of these risks are expected on the yield and revenue of producers.

Ricardian method

From the results obtained by Mendelsohn *et al*. (1994) in their study that took into account the characteristics of the climate in Burkina and Ouédraogo (2012) on the impact of climate change on farmers' revenue in Burkina Faso, the Ricardian approach was used in the frame of the study to evaluate the impact of climate change on the revenue and yield of the producers surveyed. The Ricardian approach is based on land renting, which is considered as the revenue of the best- utilised land. The advantage is that it allows evaluating directly the climate impact on farm revenues by taking into account potential adaptations to climate change (indirect substitutions of inputs, introduction of new activities, …) (Ouédraogo *et al*., 2012).

The standard Ricardian model is a quadratic model on the climate and is presented as follows:

$$V= \beta_0+\beta_1F+\beta_2F^2+\beta_3Z+\beta_4G+u \qquad (12)$$

Where: **V** is the revenue, **u** is the error term, and **F** and $\mathbf{F^2}$ are the linear and quadratic terms of the temperature and rainfall values. $\beta_{1..4,}$ represent the coefficients of the variables; Z represents the socioeconomic characteristics and G represents the edaphic variables.

In the frame of this study, this general model was adapted by taking into account the characteristics of the climate in the study zone. Thus, the functional form used is presented as follows:

$$\boldsymbol{R_{ha} = \beta_1 psp + \beta_2 psp^2 + \beta_3 pss + \beta_4 pss^2 + \beta_5 tsp + \beta_6 tsp^2 + \beta_7 tss + \beta_8 tss^2 + \sum_{i=1}^{m} a_i sol_i + \sum_{j=1}^{n} \mu_j Z_j + \mu} \qquad (13)$$

With: R_{ha}= rice revenue; psp = rainy season rainfall; pss = dry season rainfall; tsp = rainy season temperature; tss = dry season temperature; sol_i = soil characteristics (type of soil, type of ecology, fertility level); Zj = socioeconomic characteristics: household size, fallow practice, utilisation of animal traction, contact with extension, access to formal education, utilisation of short-cycle variety, production cost; μ = is the error term.

Variables introduced in the model

The dependent variable is the net agricultural revenue (RN_{ha}). It is calculated for each producer and is defined as being the value of maize or rice production minus the associated production costs (costs of seeds, fertilisers, costs for using the equipment and farm implements).

Explanatory variables

Explanatory variables are climate variables, edaphic variables and socioeconomic variables. Climate variables include temperature, expressed in degrees Celsius (°C) and rainfall expressed in millimeters (mm). Two seasonal variables were defined for each of the two climate factors (temperature, rainfall), one variable for the dry season and one for the rainy season. The dry season rainfall variable (pss) corresponds to the mean of cumulative rainfalls of the dry season for the last five years (2012 à 2016), the rainy season rainfall variable (psp) corresponds to the mean of the cumulative rainfalls of the dry season of the same period. The dry season temperature variable (tss) corresponds to the mean of the temperatures of the dry season for the last five years and the rainy season temperature variable (tsp) corresponds to that of the temperatures of the rainy season (2012 to 21016).

The edaphic variables are the soil characteristics (type of soil, type of ecology, fertility level).

- Upland is a binary variable that takes the value (1) if the producer's farm is located on an upland and (0) if not.
- Irrigated lowland is a binary variable that takes the value (1) if the producer's farm is located in a developed lowland and (0) if not.
- Non-irrigated lowland is a binary variable that takes the value (1) if the producer's farm is located in a non-developed lowland and (0) if not.
- Ferralitic soil is a binary variable that takes the value (1) if the soil of the cultivated plot is ferralitic and (0) if not.
- Clayey-sandy soil is a binary variable that takes the value (1) if the soil of the cultivated plot is clayey and sandy and (0) if not.
- Soil fertility level is a binary variable that takes the value (1) if the surveyed person estimates that the soil of his/her cultivated plot is fertile and (0) if not.

The socioeconomic variables include those related to production factors (household size, use of animal traction, practice of fallow, short-cycle variety, contact with extension, access to formal education, production cost per acre, …).

- The use of animal traction is a dichotomic variable that takes the value (1) if the individual resorts to that practice and (0) if not. This variable should allow us to see if using this equipment improves the revenue in the climatic context.
- The size of the household will allow us to see the proportional evolution of the revenue depending on the number of people in the family. The expected effect of this variable is positive.
- The practice of fallow on the cultivated plot increases soil fertility. Thus, a positive effect is expected from this variable since soil fertility gives good crop yields. It is a binary variable that takes the value (1) if fallow was practised on the soil before using it and (0) if not.
- Access to formal education is a binary variable that takes the value (1) if the surveyed person attended school and (0) if the person did not. Access to education allows the producer to choose adaptation strategies available in his/her area.
- Contact with extension has a positive expected effect. It is a binary variable that takes the value (1) if the individual is in contact with an extension agent and (0) if not. Access to extension allows the producer to be better informed on exogenous adaptation strategies including short-cycle varieties available in agricultural extension centres.
- Utilisation of the short-cycle variety was considered in this case as the practice of climate change adaptation. The adaptation strategy is used to reduce the harmful effects of climatic phenomena on production. We therefore expect a very positive effect on the revenue of the people surveyed. The variable takes the value (1) if the producer uses a short-cycle variety and (0) if not.
- The production cost per acre is a continuous variable. Its introduction in the model is justified by the practice of adaptation, which has a cost. This variable

also takes into account the cultivated acreage for the production. The effect of this variable on the revenue can be positive or negative.

Marginal effect and elasticity

The marginal effect of the climate variables on the revenue is obtained by doing the first derivative of the equation (13). For example, the marginal effect of the temperature (f_1) on rice revenue (R_{ha}) can be estimated from:

$$\boldsymbol{E[dR_{ha}/\, df_1] = E[\beta_1 + 2 * \beta_2 * f_1]} \qquad (14)$$

With $\boldsymbol{\beta_1}$ and $\boldsymbol{\beta_2}$, the coefficients of the linear and quadratic terms of the rainfall ($\boldsymbol{f_1}$).
The elasticity of the revenue ($\boldsymbol{R_{ha}}$) in relation to rainfall ($\boldsymbol{f_1}$) can be estimated from:

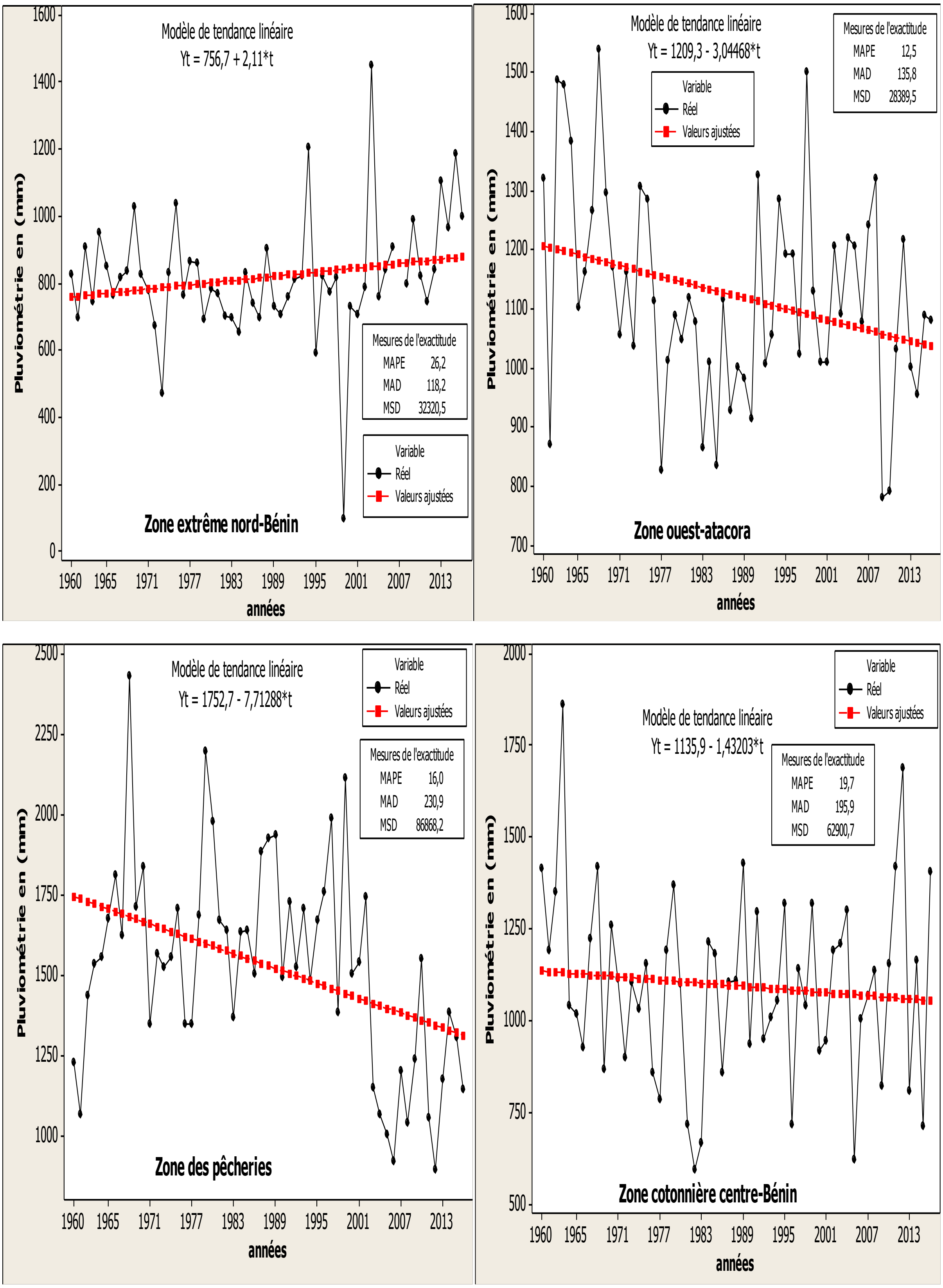
$$\boldsymbol{E = [dR_{ha}/\, df_1] * [f_1/\, R_{ha}]}. \qquad (15)$$

Climate reference situation

The three major elements that modulate climate variability in tropical regions are: rainfall, temperature, and relative humidity.

Rainfall

The evolutionary trend of the mean annual level of rainfalls between 1960 and 2016 in the agro-ecological zones of North Benin, West Atacora, Central Benin, and Fisheries generally shows a decrease, this decrease being sharper in the fisheries zones (from 1750 mm of rainfall in 1960 to 1147 mm in 2016) and in the West Atacora zone (1200 mm in 1960 to 1079 mm in 2016) with average regression ratios of 7.71 mm/year and 3.04 mm/year respectively (Figure1). In the cotton zone of Central Benin, this decrease is rather low, varying between 1412 mm in 1960 and 1407 mm in 2016 with a regression ratio of 1.43 mm/year. However, it is observed that in the extreme North of Benin, between 1960 and 2016, rainfall increased slightly (with an increase rate of 2.11 mm/year). The trends in the four zones are less linear and do not represent defined rates in terms of precision parameters MAPE, MAD and MSD, which are all relatively higher.



Source: Data, ASECNA

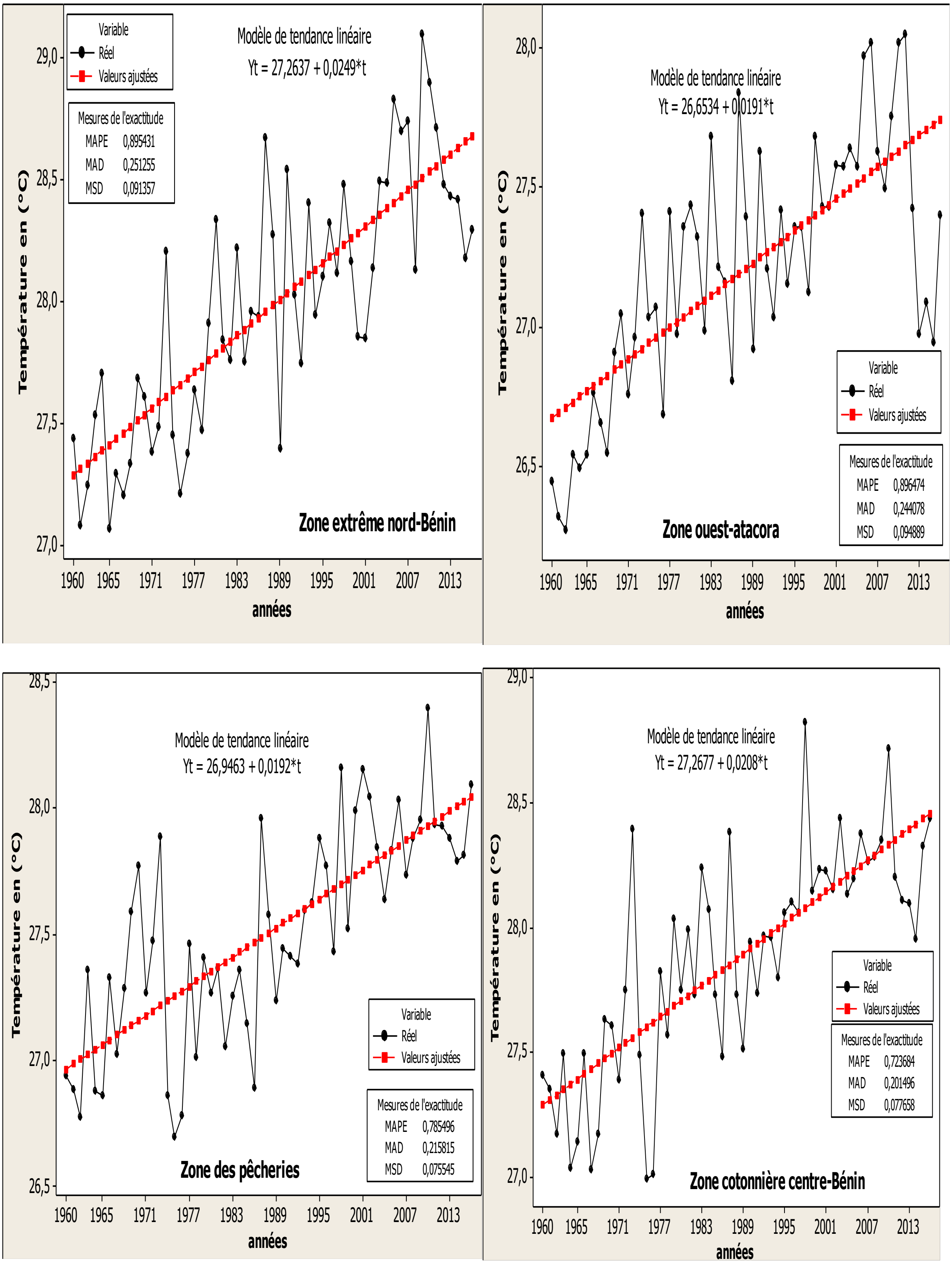
Figure 1: Curbs of the evolution trend of the average annual rainfalls of the four agro-ecological intervention zones of PANA1in Benin between 1960 and 2016

Temperature

Temporal variations from 1960 to 2016 show globally an evolutionary trend unlike that of rainfall, so a linear progression of the temperature with an increase of more than 1°C is noted for the four zones. The increase in ration in the Central-Benin, North-Benin, West-Atacora and Fisheries zones are respectively 0.020°C/year; 0.024°C/year; 0.019°C/year; 0,019°C/year (Figure2).

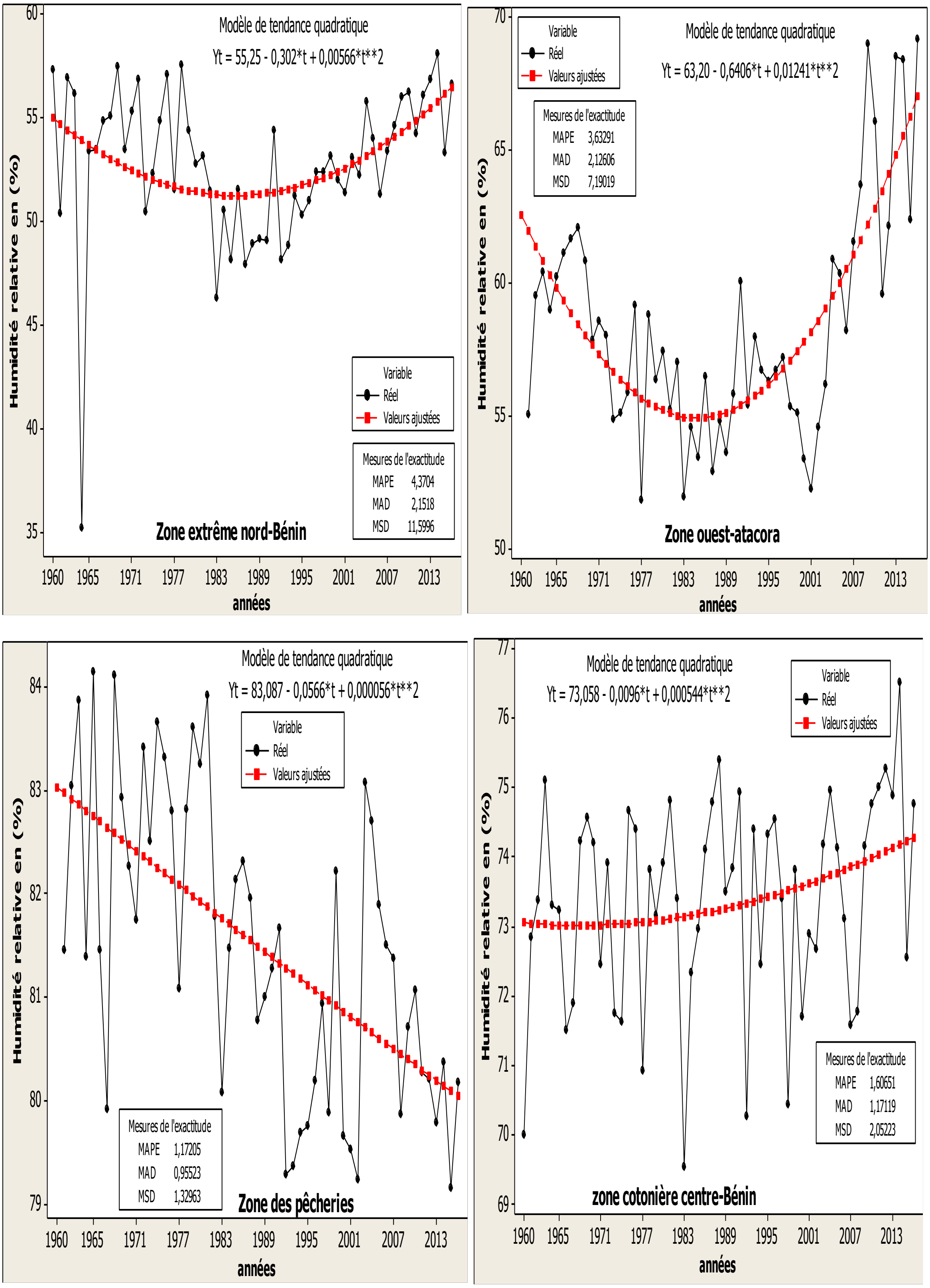
Relative humidity

The trend of the evolution of the mean annual relative humidity presents a concave quadratic shape. Figure 3 shows that apart from the fisheries zone where the relative humidity falls by about 3 percent from 1960 to 2016, it presents in the three other zones a decrease from 1960 to 1988 and an increase from 1988 to 2016.



Source: Data, ASECNA

Figure 2 ***: Curbs of the evolution trend of the average annual temperature of the four agro-ecological intervention zones of PANA1in Benin between 1960 and 2016***



Source: Data, ASECNA

*Figure 3**: Curbs of the evolution trend of the average annual relative humidity of the four agro-ecological intervention zones of PANA1in Benin between 1960 and 2016***

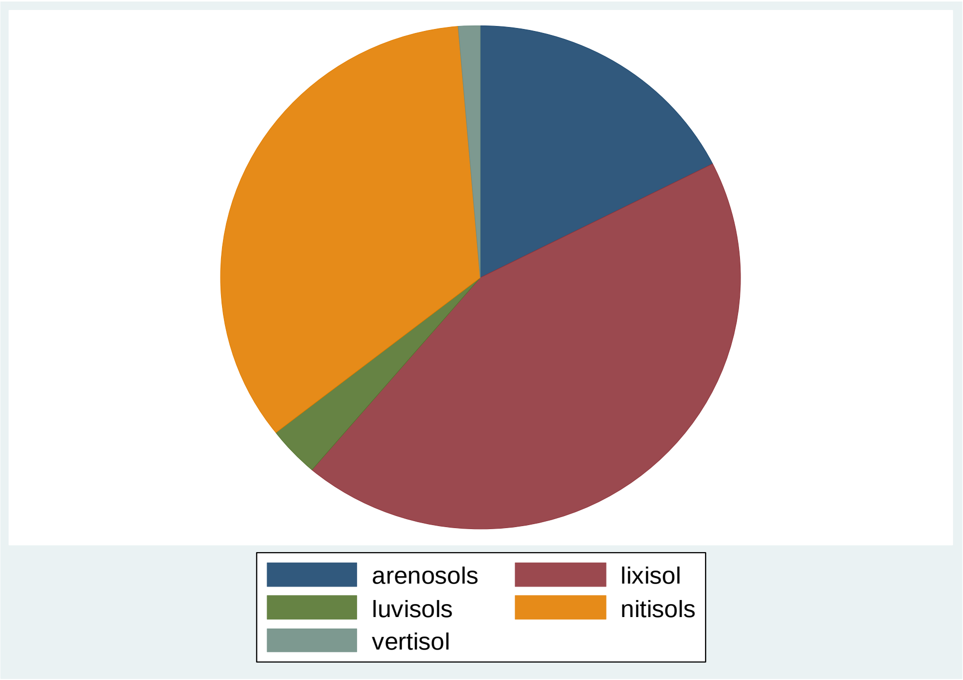
Results and Discussion

Adaptation strategies adopted by agricultural exploitations against climatic risks

The agricultural exploitations surveyed are located in the villages, which are on average between 10 and 25 km from towns. The farthest villages are located 50 km from the nearest town. The roads leading to these villages are suitable for vehicles. Markets are located on average at least 25 km from the villages. Eighty-seven percent of the producers interviewed affirmed that there was plenty of land in the villages. Developed lowlands are not available in the villages according to 66 percent of the producers. Forty-three percent of the agricultural exploitations declared that the lands were quite fertile in the production zones; 25 percent affirmed that lands in their villages were very fertile.

The farms surveyed were rice and maize farms. A total of 371 producers were surveyed in the four most vulnerable agroecological zones in Benin; the farms benefited from the adaptation strategies disseminated by PANA and IDID-NGO.

Out of the 371 produces interviewed during the study, 300 produced maize as the major crop and 71 produced rice as their major crop. This shows the importance of maize in Benin households. The farms producing rice were found mainly in Adjohoun and Malanville. Use of manure or organic fertiliser was still very rare on the farms surveyed. The most frequent soils in the zone (Figure 4) are clayey soils with 44 percent lixisols, 34 percent nitisols, and 18 percent arenosols. Vertisols and luvisols are rare, on less than 4 percent of the farms.

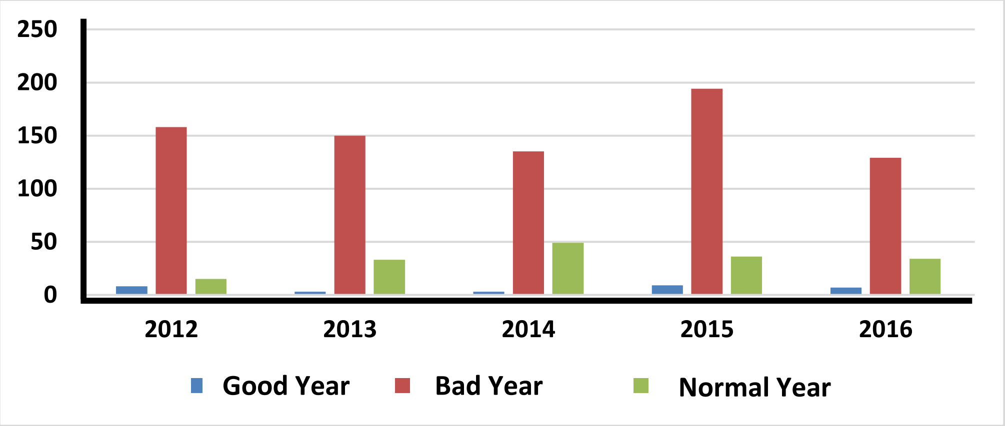


Source: Survey results 2017 FARA/INRAB

*Figure 4**: Farm distribution by type of soil***

Adaptation of farms to climatic risks experienced

According to the majority of producers, the previous five years were all bad (Figure 5). Out of 371 producers surveyed, 194 declared that the year 2015 was bad. This is due to the climatic risks experienced by the rice and maize producers surveyed. The most important risks were: late rainy seasons, drought spells, and short rainy seasons experienced by 75, 64, and 51percent respectively of the producers interviewed (Table 2). These major risks are followed by floods (29 percent), poor rain distribution (21percent) and strong winds (5 percent). The characteristic signs observed by producers were: drying out of water courses and water bodies and decreasing level of water courses. The consequences of these risks were: a decrease in yields, drying out of seedlings, and poor rate of seed germination.



Source: Survey data 2017 FARA/INRAB

Figure 5: Perception of the people surveyed on the state of the last five years of agricultural production

To confront these phenomena, several methods are used. These include endogenous as well as exogenous strategies. The study revealed that the major exogenous strategies used were introduced by CARDER, PADA, and PANA1 IDID NGO. The main exogenous strategies used were short-cycle varieties for rice and maize, mulching using crop residues, and hedgerow farming.

PANA1 favoured the utilisation of short-cycle varieties and IDID NGO mulching. All producers were convinced that short-cycle varieties limit the adverse effects of climate change.

Producers avoid agroforestry because birds perch on the trees during pre-harvest periods and eat maize and rice grains. However, the use of hedgerow farming and utilisation of mucuna is a beneficial strategy against strong winds but needs to be disseminated more; it was barely used by the people surveyed.

Table 2: Adaptation strategies used for farms depending on the climatic phenomena experienced during the bad year

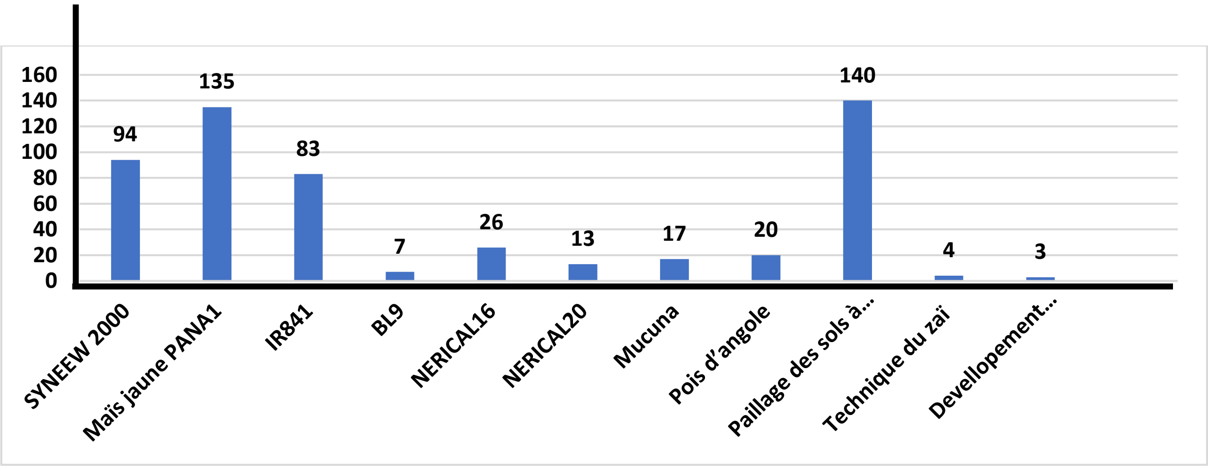
phenomena	Experience	Consequences	Indicators	Effects	Endogenous strategies	Exogenous strategies	Year
Late arrival of rains	278 (75percent)	- Yield decrease - Poor seedling emergence - Seedling drying out	- Drying out of streams and water areas - Decrease in stream levels - Sudden and unusual flooding	- Decrease in revenues - Decrease in food availability	- Sacrifice to call the rain - Change of sowing period - Call to rain makers	- Adoption of short-cycle varieties - Development of other activities - Mulching using plant residues	2013 2012 2014
Drought spells	239 (64 percent)	- Yield decrease - Seedling drying out - Poor seedling emergence	- Drying out of streams and water areas - Decrease in stream levels - Sudden and unusual flooding	- Decrease in revenues - Extension of the lean period - Decrease in food availability	- Sacrifice to call the rain - Change of sowing period - Call to rain makers	- Adoption of short-cycle varieties - Development of other activities - Mulching using plant residues	2015 2014 2012
Short rainy periods	189 (51 percent)	- Yield decrease - Poor seedling emergence - Seedling drying out	- Drying out of streams and water areas - Decrease in stream levels - Sudden and unusual flooding	- Decrease in revenues - Decrease in food availability - Extension of the lean period	- Sacrifice to call the rain - Adoption of new crops - Call to rain makers	- Adoption of short-cycle varieties - Development of other activities - Mulching using plant residues	2014 2015 2013
Poor spatial rain distribution	82 (22 percent)	- Yield decrease - Seedling drying out - Stunted plant	- Sudden and unusual flooding - Decrease in stream levels	- Decrease in revenues - Decrease in food availability - Extension of the lean period	- Sacrifice to call the rain - Change of sowing period	- Adoption of short-cycle varieties - Development of other activities - Mulching using plant residues	2015 2014 2013
Strong winds	19 (5 percent)	- Yield decrease - High post-harvest lost ratio - Stunted plant	- Sudden and unusual flooding - Decrease in stream levels - Increase in plant attacks	- Decrease in food availability - Poverty worsening - Decrease in revenues	- Sacrifice to call the rain - Adoption of new crops -	- Construction of drainage canals - Adoption of short-cycle varieties - Development of other activities	2015 2016 2014
Floods	108 (29	- Crop flooding - Total	- Sudden and unusual	- Decrease in	- Sacrifice to call the rain	- Adoption of short-cycle	2015 2016

	percent)	production lost - Yield decrease	flooding	revenues - Poverty worsening - Decrease in food availability	- Change of sowing period	varieties - Construction of drainage canals - Development of other activities

Source: Survey results 2017 FARA/INRAB

5.1.2. Adoption status of exogenous adaptation strategies most known by the people surveyed

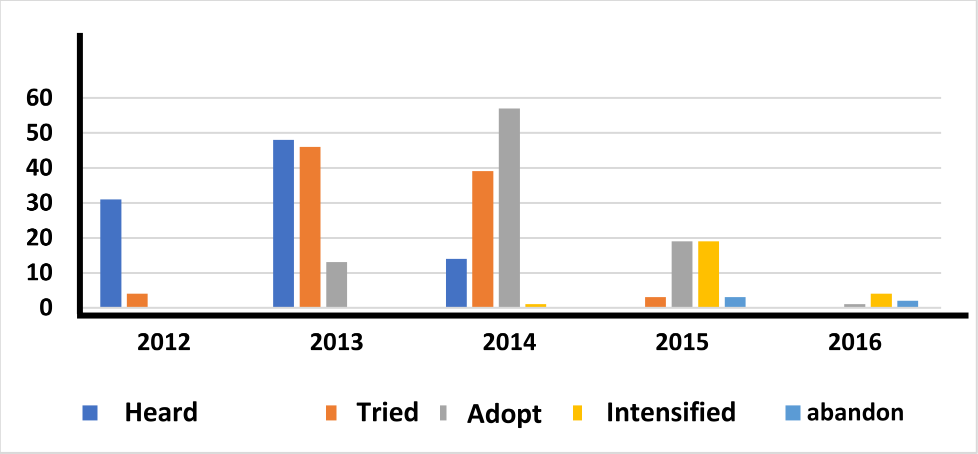
Several adaptation strategies are known and used by the people surveyed. These are short-cycle varieties; mulching, the zaï technic; pigeon pea; mucuna and the development of other revenue- generating activities. Of all these exogenous strategies, mulching using plant residues was the most known adaptation strategy by those we surveyed. It was known by 140 producers (Figure 6). Short-cycle varieties of maize (yellow maize PANA1 and SYNEEW 2000) and rice (IR841) were also well known by the producers surveyed. The other strategies were not well known, therefore they were less used by the producers surveyed to adapt to the adverse effects of the climatic risk they had experienced.



Source: Survey results 2017 FARA/INRAB

Figure 6: Exogenous adaptation strategies known by the producers surveyed

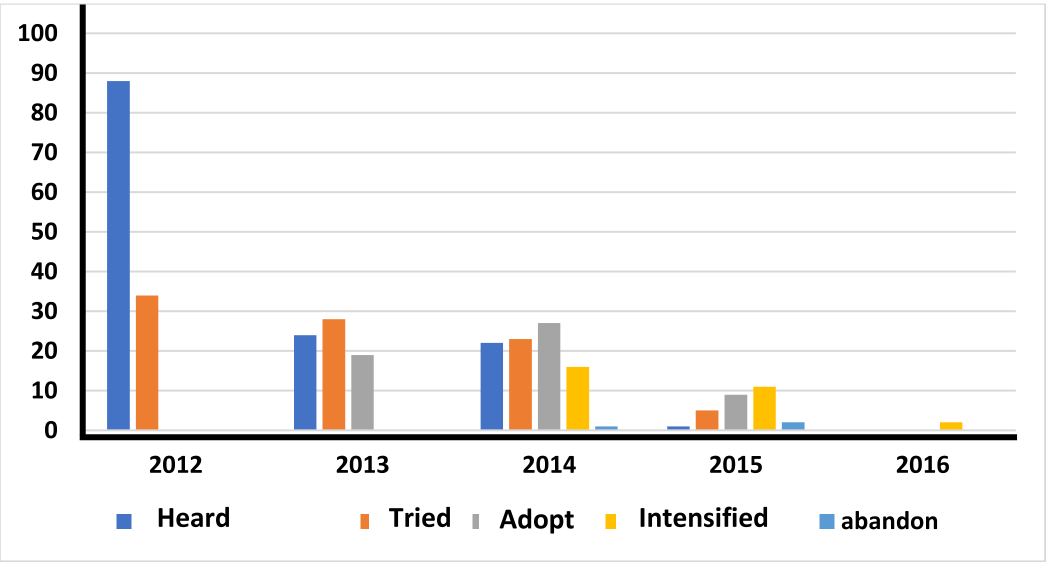
Over the previous five years, maize variety SYNEEW 2000 was best known in 2013 (Figure 7) by the majority of producers who used it. This variety was tried several times by the producers surveyed, who heard about it in 2013 and 2014. The effect of the adoption of this variety was more felt by the producers in 2014. The variety was widely adopted in 2014. However, despite the high number of producers who had tried and adopted it, only few tried to intensify its utilisation in 2016.



Source: Survey results 2017 FARA/INRAB

Figure 7: Adoption status of the rice variety SYNEEW 2000

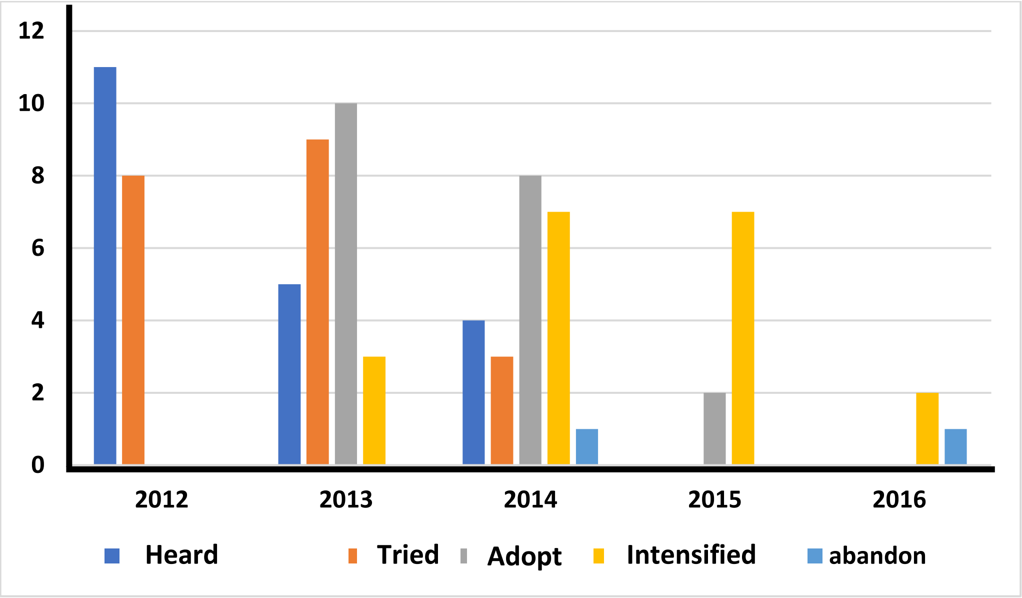
Yellow maize PANA1 was known by the majority of the producers in 2012 and 2013 (Figure 8). Producers who knew about this variety tried to use it mainly in 2013 and 2014. Most of those who tried the variety adopted it and a small number intensified its use in 2015 and 2016.



Source: Survey results 2017 FARA/INRAB

Figure 8: Adoption status of the maize variety PANA1

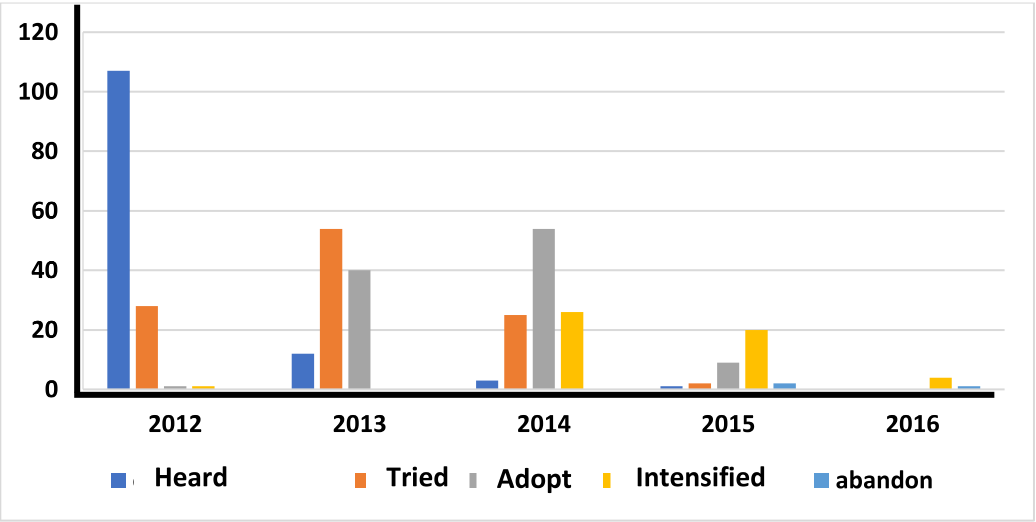
The rice variety IR841 had been known and tried by the producers surveyed since 2012 so they knew it well. Trials on the variety had been conducted in 2013 (Figure 9). The adoption peak was reached in 2013. Most of the producers who had adopted this rice variety intensified its production. Only few producers have abandoned it.



Source: Survey results 2017 FARA/INRAB

Figure 9: Adoption status of the rice variety IR841

Mulching using plant residues had been known and tried by the producers surveyed since 2012 (Figure 10). The majority of producers who had tried this technology adopted it in 2013 and 2014, with the adoption peaking in 2014. Use of the technology has intensified since 2014, with a low abandonment rate.



Source: Survey results 2017 FARA/INRAB

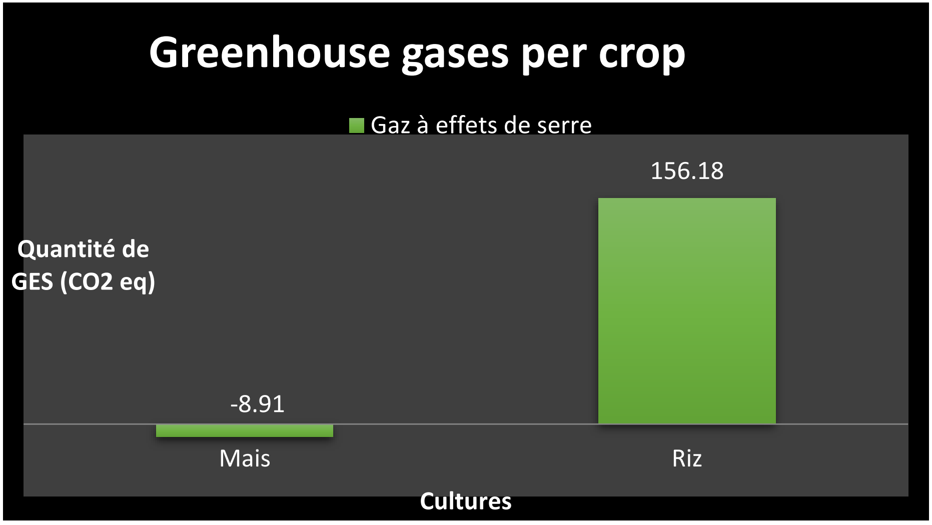
Figure 10: Adoption status of the mulching technique using plant residues

Quantities of gases emitted per adopted strategy by farm operators

Evaluation of GHG per farm

The farms surveyed emitted on average 21.74 t CO_2eq of carbon per year with their current practices. The maximal sequestrated quantity is 39.08 t CO_2eq/year while the maximal quantity emitted is 3418.75 tCO_2eq/year.

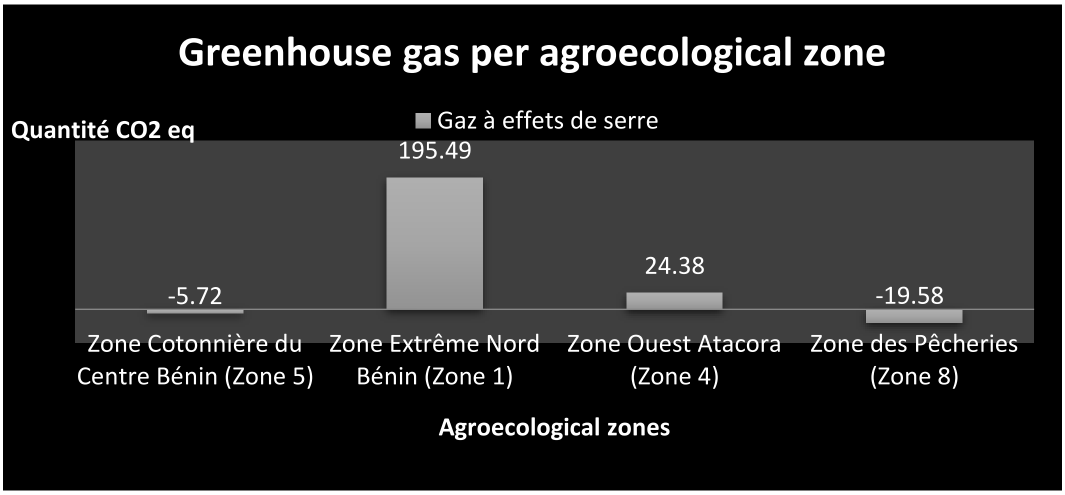
The distribution by type of main crop of the farm (Figure 11) showed that rice farms emitted 100 times more GHGs than maize farms. The results showed that farms producing maize tend to sequestrate carbon.



Source: Survey results 2017 FARA/INRAB

Figure 11: Quantities of GHG emitted by major crop and by type of farm.

The distribution of greenhouse gases per agro-ecological zone (Figure 12) showed that the crops in most AEZs sequestrate carbon. AEZ1, which is a big rice-producing zone, was the biggest zone emitting GHG while AEZ 8 was the biggest carbon-sequestrating zone.



Source: Survey results 2017 FARA/INRAB

*Figure 12: **Quantity of GHG emitted in each agro-ecological zone of intervention.***

The communes of Matéri, Ouaké and Malanville (Table 3) are the ones where the most carbon is emitted.

Table 3: ***Quantity of greenhouse gas emitted per commune***

Commune	Adjohoun	Aplahoué	Bopa	Malanville	Matérie	Ouaké	Ouinhi	Savalou	So-ava
GHG	-23.62	-4.41	-12.67	195	23.94	26.43	-19.06	-7.19	-22.83

Source: Survey results 2017 FARA/INRAB

An analysis of the emissions by type of treatment applied to the village also showed that the pilot villages emitted 40.74 while control villages emitted 1.32 GHGs.

The results in Table 4 show that there was a disparity in the application of quantities of fertilisers. This disparity partly explains the volumes of CO_2eq produced or sequestrated by the producers vis-à-vis the adaptation strategies used. The phenomenon can be explained by the lack of supervision of maize and rice producers. Control villages have less access to information than pilot villages. The latter emit relatively more GHG than the control villages. In the pilot villages, the intervention was stimulated by the availability of fertilisers. This increases the quantity of GHG emitted in the farm.

Table 4: ***Distribution of the quantities of greenhouse gases emitted by AEZ, per treatment and per crop***

AEZ	**Cotton zone of Central Benin (Zone 5)**				**Extreme North (Zone 1)**		**West Atacora (Zone 4)**		**Fisheries zone (Zone 8)**	
Crop	Maize		Rice		Rice		Maze		Maze	
Treatment	Control	Pilot	Control	Pilot	Control	Pilot	Control	Pilot	Control	Pilot
GHG	-8.04	-4.99	-3.90	18.77	84.65	275.15	14.81	32.36	-19.93	-19.19

Source: Survey results 2017 FARA/INRAB

Evaluation of GHG per exogenous adaptation strategy to climate change

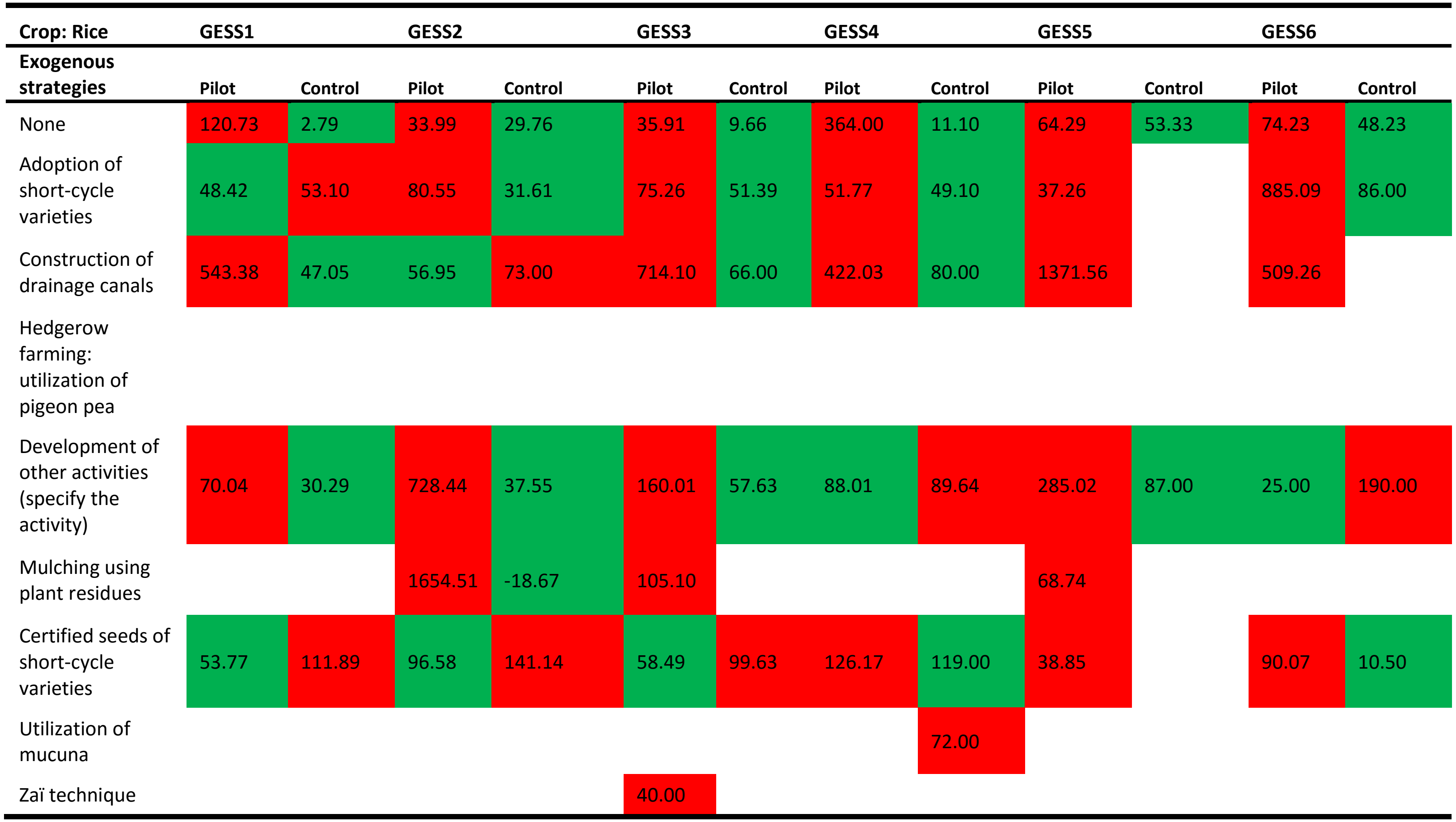
Producers who used hedgerow farming without fertiliser application emitted lower quantities of carbon (Tables 5 and 6). But those who added mineral fertilisers produced higher amounts of carbon.

Table 5: ***Quantity of greenhouse gas per exogenous strategy and per type of treatment for maize***

Crop: Maize	**GESS1**		**GESS2**		**GESS3**		**GESS4**		**GESS5**		**GESS6**	
Exogenous strategies	**Pilot**	**Control**	**Pilot**	**Control**	**Pilot**	**Control**	**Pilot**	**Control**	**Pilot**	**Control**	**Pilot**	**Control**
None	-9.76	-13.59	-7.20	-12.27	-3.08	-8.29	-5.31	-11.73	-6.28	-11.95	-1.07	-9.40
Adoption of short-cycle varieties	-5.29	-15.43	-10.19	-17.62	-14.13	-19.45	0.36	-12.24	-33.00	-3.00	-25.47	-24.50
Construction of drainage canals	-19.00		-23.00	-18.00	-5.00		-26.00		5.29		-15.38	-4.27
Hedgerow farming: utilization of pigeon pea	-11.00		-13.00	-17.00	-16.00				21.00		0.00	
Development of other activities (specify the activity)	2.88	-3.55	7.82	3.35	4.72	-5.02	-39.08	-22.00	-4.35		-18.86	-20.36
Mulching using plant residues	-15.11	-15.37	-10.90	-14.53	-11.67	-15.43	-14.12	-13.00	-2.00		-19.00	-10.25
Certified seeds of short-cycle varieties	28.17		-2.00		-2.00		0.00				-19.00	
Utilization of mucuna			21.00									

Source: Survey results 2017 FARA/INRAB

Table 6: ***Quantity of greenhouse gas by exogenous strategy and by type of treatment for rice***



Crop: Rice	**GESS1**		**GESS2**		**GESS3**		**GESS4**		**GESS5**		**GESS6**	
Exogenous strategies	**Pilot**	**Control**	**Pilot**	**Control**	**Pilot**	**Control**	**Pilot**	**Control**	**Pilot**	**Control**	**Pilot**	**Control**
None	120.73	2.79	33.99	29.76	35.91	9.66	364.00	11.10	64.29	53.33	74.23	48.23
Adoption of short-cycle varieties	48.42	53.10	80.55	31.61	75.26	51.39	51.77	49.10	37.26		885.09	86.00
Construction of drainage canals	543.38	47.05	56.95	73.00	714.10	66.00	422.03	80.00	1371.56		509.26	
Hedgerow farming: utilization of pigeon pea												
Development of other activities (specify the activity)	70.04	30.29	728.44	37.55	160.01	57.63	88.01	89.64	285.02	87.00	25.00	190.00
Mulching using plant residues			1654.51	-18.67	105.10				68.74			
Certified seeds of short-cycle varieties	53.77	111.89	96.58	141.14	58.49	99.63	126.17	119.00	38.85		90.07	10.50
Utilization of mucuna								72.00				
Zaï technique					40.00							

Source: Survey results 2017 FARA/INRAB Caption: GESSi: Greenhouse gas for Strategy i. (i=1 - 6)

Impact of climate change adaptation strategies on farmers' maize yields and revenues

Comparative description of the farms studied

The farms using short-cycle maize varieties yielded 1158.14 kg/ha compared to 667.22 kg/ha for the farms that did not use such varieties (Table 8). With a net revenue of FCFA 69245 per hectare, these farms surpass by far those that do not use this strategy by FCFA 53000 per hectare. This is the same with the utilisation of mulching using plant residues with a yield of 990.61 kg/ha and a net revenue of FCFA 57375 /ha.

Table 7: Descriptive statistics of the explained variables included in the impact models for maize

Parameters	Utilisation of short-cycle maize varieties		Utilisation of mulching using plan residues	
	Yes	No	Yes	No
Yield (kg/ha)	1158.14	667.22	990.61	768.48
Net revenue (FCFA/ha)	69245	15870	57375	36560

Source: Survey results 2017 FARA/INRAB

Table 8 presents the descriptive statistics of the explanatory variables included in the impact models for maize. The average size of the household at the level of maize producers using short-cycle varieties is four against five for non-users. The difference between producers using short-cycle maize varieties and those not using them is significant at the threshold of 1percent for the size of the household and the practice of rotation; 5 percent for the acreage planted, member of a village association, utilisation of a tractor and late rainy season; and 10 percent for the contact of the producer with a project on climate change. Regarding the practice of mulching using plant residues, the average size is 5 at the level of the users as well as at that of the non-users. Moreover, over 20 percent are in contact with a project on climate change, 28 percent have received information on the white and yellow maize varieties, 46 percent belong to a village association, 18 percent have a type of good year and 10 percent have a formal education. There is a significant difference between producers using mulching with plant residues and those not using such mulch at the threshold of 1percent for: information based on white maize variety, accessibility to the village (good road) and the availability of lowland. This difference is significant at the threshold of 5 percent at the level of formal education, accessibility to the village; tarred road, and type of ferralitic soil.

Table 8: Descriptive statistics of the variables included in the maize impact models

Variables	Unit	Utilization of maize short-cycle varieties			Practice of mulching using plant residues		
		No	Yes	Test	No	Yes	Test
Age	Year	45	43	2.17	44	43	0.18
Number of years of experience	Year	21	20	1.20	21	20	0.57
Household size		5	4	11.20 ***	5	5	2.11
Cultivated acreage for maize	Ha	1,36	1.99	4.76**	1.78	1,47	0.64
Total production cost	FCFA	118623.9	132026.1	1.57	131822.9	99536.69	5.28**
Information on white and yellow maize varieties	No (percent)	75.20	73.71	0.08	74.80	72	0.17
	Yes (percent)	24.80	26.29		25.20	28	
Information on the white maize variety	No (percent)	73.60	65.71	2.11	76.40	32	38.40***
	Yes (percent)	26.40	34.29		23.60	68	
Formal education	No (percent)	80	74.29	1.33	74	90	5.96 **
	Yes (percent)	20	25.71		26	10	
Literacy	No (percent)	80.80	87.43	2.46	85.20	82	0.32
	Yes (percent)	19.20	12.57		14.80	18	
Village association	No (percent)	65.60	53.14	4.65**	59.20	54	0.46
	Yes (percent)	34.40	46.86		40.80	46	
Contact with SCDA	No (percent)	73.60	71.43	0.17	73.60	66	1.20
	Yes (percent)	26.40	28.57		26.40	34	
Contact with a project on climate change	No (percent)	86.40	77.71	3.62*	81.60	80	0.07
	Yes (percent)	13.60	39 22.29		18.40	20	
Accessibility to the village: tarred road	No (percent)	96	89.14	4.65**	90.40	100	5.21**
	Yes (percent)	4	10.86		9.60	0	
Accessibility to the village: Practical road	No (percent)	62.40	61.14	0.04	54.80	96	29.91***
	Yes (percent)	37.60	38.86		45.20	4	
Distance of the village to the town less than or equals to 10 km	No (percent)	48.80	61.71	4.94**	51.20	82	16.06***
	Yes (percent)	51.20	38.29		48.80	18	

Availability of lowland in the village	No (percent)	77.60	76.57	0.04	73.20	96	12.23***
	Yes (percent)	22.40	23.43		26.0	4	
Sex (percent)	Woman	21.60	21.14	0.01	21.60	20	0.06
	Man	78.40	78.86		78.40	80	
Training on production	No (percent)	71.20	68.57	0.23	68.80	74	0,53
	Yes (percent)	28.80	31.43		31.20	26	
Practice of animal traction	No (percent)	99.20	97.14	1.57	97.60	100	1.22
	Yes (percent)	0.80	2.86		2.40	0	
Utilization of tractor	No (percent)	100	96.57	4.37**	97.60	100	1.22
	Yes (percent)	0	3.43		2.40	0	
Practice of rotation	No (percent)	47.20	29.14	10.23***	43.20	4	27.57***
	Yes (percent)	52.80	70.86		56.80	96	
	Yes (percent)	28.80	20.57		22.80	30	
Ferralitic soil	No (percent)	81.60	89.71	4.06**	83.60	100	9.49***
	Yes (percent)	18.40	10.29		16.40	0	
Late rainy season	No (percent)	50.40	52.57	0.13	58	20	24.09***
	Yes (percent)	49.60	47.43		42	80	
Drought spells	No (percent)	74.40	78.86	0.81	73.60	94	9,79***
	Yes (percent)	25.60	21.14		26.40	06	
Flood	No (percent)	84	89.14	1.70	85.20	96	4.29**
	Yes (percent)	16	10.86		14.80	4	
Good year	No (percent)	91.20	82.86	4.30**	87.20	82	0.95
	Yes (percent)	8.80	17.14		12.80	18	
Importance of the sensibility to pest attacks in choosing a variety	No (percent)	56	48.57	1.6113	46	80	19.28***
	Yes (percent)	44	51.43		54	20	
Importance of high yield in choosing the variety	No (percent)	34.40	44.57	3.13*	37.60	54	4.6567**
	Yes (percent)	65.60	55.43		62.40	46	
Perception of the producer on the high yield of the maize variety	No (percent)	72	65.71	1.33	68	70	0.07
	Yes	28	34.29		32	30	

(percent)

Source: Survey results 2017 FARA/INRAB

5.3.2. Impact of climate change adaptation strategies on maize yield at farm level

The impact of the utilisation of short-cycle maize varieties and mulching using plant residues are presented in Table 9. The results show that utilisation of short-cycle maize varieties increases the yield by 490.43 kg/ha. In the sub-population of the non-users of this adaptation strategy, the impact is 383.92 kg/ha and is statistically significant at the threshold of 10 percent. In the sub-population of the real users of short cycle maize varieties, the impact is 566.52 kg/ha and is significant at the threshold of 1 percent. This reveals that at the level of the farms surveyed, there are potential farms where utilisation of short-cycle maize varieties could contribute significantly to improving maize yield. The selection bias (PSB) is significant at the threshold of 1 percent. Producers who know short-cycle maize varieties therefore have the same chance to use them more than those who don’t know them. When we consider mulching using plant residues as an adaptation strategy to climate change, the results show that utilisation of this method increased maize yield by 404.29 kg/ha in the sub-population of the potential users of this adaptation strategy. In this case, the selection bias (PSB) is not significant. The hypothesis LATE1=LATE is rejected. This implies that producers exposed do not have the same chance to use mulching with plant residues than those who are not exposed. The results of the naïve method showed that the impact of using short-cycle maize varieties was an increase of maize yield by 490.90 kg/ha, significant at the threshold of 1 percent. Concerning the utilisation of mulching, the results revealed that the impact was a decrease in the maize yield by 222.13 kg/ha.

The same table shows that the yield of the farms that used the adaptation strategies: short-cycle maize varieties and mulching using plant residues is influenced positively by the practices of animal traction and crop rotation and the state of the nature of the year (producers judge the year was good). This means that the farms that use animal traction and practice crop rotation on their maize plots and which perceive the year as a good one have had increasing maize yield compared to the others. The size of the household has a negative effect, significant respectively at the threshold of 10 and 5 percent on the yield of those who have short-cycle maize varieties and the yield of those who have used mulching. Belonging to a village association had a positive effect, significant at the threshold of 10 percent on the yield of the farms that have used mulching with plant residues.

Table 9: Econometric results of determinants and the impact of short-cycle varieties and mulching on maize yield

	Utilization of short-cycle maize varieties		Mulching using plant residues	
Variable	**Coefficients**	**Standard error**	**Coefficients**	**Standard error**
Practice of animal traction	455.86**	191.51	475.37***	180.03
Ferralitic soil	127.92	92.46	--	--
Practice of rotation	231.50***	58.86	279.68***	64.10
Good year	273.78***	74.18	309.42***	75.46
Cultivated acreage	5.04	10.10	--	--

Size of the household	-14.65*	8.31	-16.31**	7.82
Drought spell	-7.92	61.54	--	--
Flood	-18.75	76.97	--	--
Experience in production	-0.02	2.95	--	--
Contact of the producer with SCDA agents	6.11	107.91	-49.03	103.78
Member of a village association	--	--	117.80*	63.54
Information on the utilization of mulching	--	--	-276.09	182.66
Age of the producer	--	--	1.32	3.11
Late	490.43**	212.91	330.37***	94.78
Late1	566.52***	218.04	404.29**	207.90
Late0	383.92*	205.72	315.59***	72.15
Psb	76.08***	7.19	73.92	143.44
Difference	490.92***	41.48	-222.13***	46.19
Adapter	1158.14***	34.60	768.48***	34.86
Non-adapter	667.22***	22.87	990.61***	30.31
Constant	819.68**	336.40	784.90***	137.16
F(14, 285) & F (13, 286)	4.48***		5.30***	
R^2	0.18		0.19	
Observations	300		300	

Source: Survey results 2017 FARA/INRAB

The econometric results of the determinants of the utilisation of short-cycle maize varieties and of mulching are indicated in Table 10. The table shows that the characteristics of the villages where the farms are located, information on the adaptation strategy, i.e., knowledge of the adaptation strategies, producers' perceptions on the adaptation strategies, and the age of the producers determined the utilisation of short-cycle maize varieties and the utilisation of mulching using plant residues. In fact, the youngest producers have the short-cycle maize varieties, unlike the elder producers. Farms with tarred roads to their village have used more short-cycle maize varieties. Producers who are informed about the existence of high-yielding short-cycle maize varieties and who think that a short-cycle maize variety is a high-yielding variety were those who had used the most this adaptation strategy to climate change. Farms located in the villages where there is no developed lowland tend to use climate change adaptation strategies more than the others. Information about mulching as an adaptation strategy has influenced farmers and positively informed their decision to use it. Table 14 shows the determinants of the utilisation of short-cycle rice varieties. From the table, it is seen that utilisation of short-cycle rice varieties was influenced by: producers' perceptions on the variety and some characteristics of the villages where the farms are located; accessibility, availability of fertile lands and developed lowland for rice cropping.

Table 10: Econometric results of the determinants of the utilization of short-cycle maize varieties and mulching using plant residues

	Utilization of short-cycle maize varieties		Mulching using plant residues	
Variables	Coefficients	Standard error	Coefficients	Standard error
Information on short-cycle maize varieties	0.13	0.18	-0.11	0.23
Age of the producer	-0.01*	0.01	0.01	0.01
Sex of the producer	-0.19	0.19	--	--
Literacy	--	--	0.24	0.27
Formal education	0.14	0.17	-0.29	0.26
Accessibility to the village: tarred road	0.97***	0.31	--	--
Distance of the village to the town less than or equal 10 km	-0.17	0.17	-0.42*	0.24
Information on the short-cycle white maize variety	0.53**	0.21	--	--
Information on the utilization of mulching	--	--	1.43***	0.24
Availability of developed lowland in the village	-0.27*	0.16	-0.56*	0.30
Importance of sensitivity to pest attacks in choosing the variety	0.50***	0.16	--	--
Importance of high yield in choosing the variety	-0.30*	0.15	--	--
Producer's perception on the high yield of the maize variety	0.50***	0.17	--	--
Member of a village association	0.20	0.16	-0.19	0.23
Contact with a project on CC	0.06	0.18	--	--
Contact of the producer with a SCDA agent	--	--	-0.38	0.24
Constant	0.31	0.39	-1.75***	
Log likelihood	-235.84		-109.21	
Chi^2	41.44***		89.43***	
Pseudo R^2	0.08		0.29	
Observations	371		371	

Source: Survey results 2017 FARA/INRAB

Impact of utilisation of short-cycle varieties on maize revenue at farm level

The impact of the utilisation of short-cycle maize varieties on the net revenue of the farms is presented in Table 11. The results show that the utilisation of short-cycle maize varieties has increased the net revenue of maize by FCFA 138,480 per hectare. In the sub-population of the non-users of short-cycle maize varieties, the impact was FCFA 116,845 per hectare and is statistically significant at the threshold of 5 percent. In the sub-population of the real users of short-cycle maize varieties, the impact was FCFA 153,930 per hectare and significant at the threshold of 5 percent. The selection bias (PSB) is not significant. Producers who know the short-cycle maize varieties do not have the same chance of using them as those who do not. From the analysis, we note that the net revenue of the farms that have used short-cycle maize varieties was positively influenced by the nature of the year and the fertility level of the farm respectively at 1 and 5 percent. The production cost has had a negative effect at the threshold of 5 percent on the net revenue of maize from the farm using this adaptation strategy.

Table 11: Econometric results of the determinants and the impact of short-cycle maize varieties on maize revenue

Variables	Coefficients	Standard error
Good year	43179.10***	15017.39
Production cost	-0.82***	0.06
Sex of the producer	19012.87	11995.74
Cultivated acreage	2888.72	2022.62
Utilization of a tractor	41525.25	35800.27
Less fertile soil	28360.77**	11860.19
Drought spells	-5728.92	13099.49
Flood	15159.05	14859.25
Late	138480**	65220
Late1	153930**	72132
Late0	116845**	55542
Psb	15450	9677
Difference	70110***	12390
Adapter	69245***	7822
Non-adapter	-868	9610
Constant	84289.05	64719.77
F (12, 287) et F (16, 52)	22.28***	
R^2	0.48	
Observations	300	

Source: Survey results 2017 FARA/INRAB

The econometric results of the determinants of utilisation of short-cycle maize varieties are indicated in Table 12. The results show that the characteristics of the villages where the farms are located, information about the adaptation strategy, producers' perceptions on the adaptation strategies, and the age of the producers are the factors that determined the utilisation of short-cycle maize varieties.

Table 4: Econometric results of the determinants of the utilisation of short-cycle maize varieties

	Coefficients	Standard error
Information on short-cycle maize varieties	-0.05	0.15
Accessibility to the village: tarred road	0.94***	0.30
Distance from the village to the town less than or equal 10 km	-0.31**	0.16
Availability of developed lowland in the village	-0.26	0.16
Importance of sensitivity to pest attacks in choosing the variety	0.46***	0.16
Importance of high yield in choosing the variety	-0.40***	0.15
Producer's perception of the high yield of the maize variety	0.50***	0.17
Age of the producer	-0.01*	0.01
Literacy	-0.25	0.18
Contact of the producer with SCDA agents	0.02	0.16
Log likelihood	-239.29	
Chi^2	34.54***	
Pseudo R^2	0.7	
Observations	371	

Source: Survey results 2017 FARA/INRAB

Impact of the utilisation of short-cycle varieties on rice farm yields and revenue (counterfactual approach)

Comparative description of the surveyed farms

Farms using adaptation strategies yielded 2657.14 kg/ha compared to 1691.19 kg/ha for non-users with a lower revenue of FCFA 80000/ha.

Table 13: **Descriptive statistics of the explanatory variables included in the impact models for rice**

Parameters	Utilization of short-cycle rice varieties	
	Yes	No
Yield (kg/ha)	2657.14	1691.19
Net revenue (FCFA/ha)	153990	76055

Source: Survey results 2017 FARA/INRAB

The average size of the household at the level of users of short-cycle rice varieties is 11 against 9 for the non-users (Table 14). Of these, 58.33 percent are in contact with SCDA agents, 33.33 percent declared that the village was accessible using a good road, and 100 percent have information about the short-cycle rice variety. There is a significant difference between users and non-users of this adaptation strategy at the threshold of 1 percent for the contact of the producer with SCDA agents. This difference is significant at the threshold of 5 percent at the level of the village accessibility (roadway) and the information on the short-cycle rice variety.

Table 14: Descriptive statistics of the variables included in the impact models for rice

Variables	Unit	Utilisation of short-cycle rice varieties		
		No	Yes	Test
Age	Year	45	44	0.06
Experience in production	Year	14	12	0.73
Household size		8.5	10.5	2.44
Cultivated acreage	Ha	1.16	1.05	0.28
Total production cost	FCFA	62705.19	198931.5	2.55
Quantity of greenhouse gases		134.2531	200.4162	0.20
Formal education	No (percent)	79.17	66.67	1.23
	Yes (percent)	20.83	33.33	
Literacy	No (percent)	68.75	71.43	0.04
	Yes (percent)	31.25	28.57	
Member of a village association	No (percent)	31.25	19.05	1.09
	Yes (percent)	68.75	80.95	
Contact of the producer with SCDA agents	No (percent)	41.67	9.52	6.95***
	Yes (percent)	58.33	90.48	
Late rainy season	No (percent)	75	90.48	2.16
	Yes (percent)	25	9.52	
Availability of developed lowland in the village	No (percent)	16.67	14.29	0.06
	Yes (percent)	83.33	85.71	
Accessibility to the village: Roadway	No (percent)	37.50	66.67	4.99**
	Yes (percent)	62.50	33.33	
Distance of the village from the town less than or equal 10 km	No (percent)	91.67	85.71	0.56
	Yes (percent)	8.33	14.29	
Sex (percent)	Woman	6.25	0	1.37
	Man	93.75	100	
Training on production	No (percent)	60.42	52.38	0.38
	Yes (percent)	39.58	47.62	
Irrigated lowland	No (percent)	37.50	57.14	2.29 (0.130)
	Yes (percent)	62.50	42.86	
Non-irrigated lowland	No (percent)	77.08	71.43	0.25 (0.616)
	Yes (percent)	22.92	28.57	
Upland	No (percent)	93.75	71.43	6.41 (0.011)
	Yes (percent)	6.25	28.57	

Contact with a project on CC	No (percent)	66.67	57.14	0.57 (0.449)
	Yes (percent)	33.33	42.86	
Accessibility to the village: tarred road	No (percent)	95.83	85.71	2.22 (0.136)
	Yes (percent)	4.17	14.29	
Information on the short-cycle rice variety	No (percent)	18.75	0	4.52 (0.033)
	Yes (percent)	81.25	100	
Good year	No (percent)	93.75	95.24	0.05 (0.808)
	Yes (percent)	6.25	4.76	
Importance of the requirement of fertilizes in choosing the variety	No (percent)	79.17	66.67	1.23 (0.268)
	Yes (percent)	20.83	33.33	
Importance of sensitivity to pest attack in choosing the variety	No (percent)	41.67	23.81	2.01 (0.156)
	Yes (percent)	58.33	76.19	
Importance of high yield in choosing the variety	No (percent)	43.75	52.38	0.44 (0.508)
	Yes (percent)	56.25	47.62	

Source: Survey results 2017 FARA/INRAB

Impact of the utilisation of short-cycle varieties on rice yield

Regarding the utilisation of a short-cycle rice variety for adaptation to climate change, the impact was 1432.22 kg/ha in the sub-population of potential users of this strategy (Table 15). The selection bias (PSB) is not significant. The hypothesis LATE1=LATE is rejected. Producers exposed to this strategy do not have the same chance to use short-cycle varieties as those who are not exposed to it. The naïve method shows that the impact of the utilisation of short-cycle rice varieties on rice yield in the farms was 461.06 kg/ha. Generally, the results showed that the utilisation of short-cycle maize and/or rice varieties and the use of mulching allowed the farms to reduce the negative effects of climatic risks on the production by increasing the yields obtained. Likewise, the results in Table 15 show that yield from the farms that used the adaptation strategy (short-cycle rice varieties) was influenced negatively by the number of years of experience in the production. Experience in rice production had a negative effect, which was significant at the threshold of 5 percent on rice yield. This implies that less- experienced producers who used the short-cycle rice variety had higher rice yields than the others.

Table 15: Econometric results of the determinants and of the impact of short-cycle variety on rice yield

Variables	Coefficients	Standard error
Experience in production	-23.95**	10.54
Sex of the producer	312.71	394.90
Household size	21.15	19.14
Age of the producer	0.27	8.65
Member of a village association	-493.60	762.36
Quantity of greenhouse gas	-0.19	0.16
Upland	148.30	230.07
Non-irrigated lowland	75.55	226.87

Formal education	-229.46	179.78
Good year	168.57	322.76
Late	857.28**	436.97
Late1	1432.42*	835.90
Late0	605.66**	262.44
Psb	575.13	301.96
Difference	461.06***	199.07
Adapter	2066.66***	171.85
Non-adapter	1605.59***	101.16
Constant	2901.09**	1255.02
F(15, 53)	4.30****	
R^2	0.54	
Observations	69	

Source: Survey results 2017 FARA/INRAB

Table 16 shows the determinants of the utilisation of short-cycle rice varieties. From the analysis, we note that the yield of the farms that used the adaptation strategies–short-cycle rice varieties–were influenced positively by importance of high yield in choosing the variety, importance of fertiliser requirements in choosing a variety, and the distance between the village and the town is less than or equal to 10 km. This means that farms using adaptation strategies and have information on the importance of the sensitivity to pest attack in choosing a variety and the availability of less fertile soil in the village gave higher rice yields than the others. The importance of high yield in choosing a variety, the importance of fertiliser requirement in choosing a variety and the distance between the village and the town being less than or equal to 10 km had a negative and significant effect at the threshold of 10, 5, and 1 percent respectively on the yields of those who used short-cycle rice varieties. It is deduced that the longer the distance from the village to the town, the less informed producers are about adaptation strategies.

Table 16: Econometric results of the determinants of the utilization of short-cycle rice varieties

Variables	Coefficients	Standard Error
Accessibility to the village: tarred road	0.46	0.31
Information on the rice variety	-0.25	0.17
Importance of the sensitivity to pest attack in choosing the variety	0.51***	0.15
Importance of high yield choosing the variety	-0.27*	0.15
Member of a village association	0.22	0.15
Importance of fertilizers requirement in choosing a variety	-0.41**	0.16
Availability of fertile soil in the village	0.89***	0.18
Sex of the producer	-0.15	0.18
Distance of the village to the town less than or equal 10 km	-0.50***	0.17

Constant	0.04	0.22
Log likelihood	-232.04	
Chi^2	49.09***	
Pseudo R^2	0.09	
Observations	371	

Source: Survey results 2017 FARA/INRAB

Impact of the utilisation of short-cycle varieties on rice yield

The results show that the impact of the utilisation of the strategy on the net revenue was FCFA 351940 per hectare in the sub-population of potential users (Table 17). In this case, the selection bias (PSB) is significant. The hypothesis LATE1=LATE is accepted. The results of the naïve method showed that the impact of the utilisation of short-cycle maize varieties was FCFA 70110 /ha, significant at the threshold of 1 percent compared to FCFA 77935/ha significant at the threshold of 5 percent for the utilisation of short-cycle rice varieties. The results showed that the utilisation of short-cycle maize varieties and/or rice allowed the farms to reduce the negative effects of climatic risks on the production by increasing the yields obtained. For the utilisation of short-cycle rice variety, the net revenue of rice from the farm was influenced negatively by the number of years of experience in rice production and the production cost at the threshold of 1 percent.

Table 17: Econometric results of the determinants and the impact of short-cycle variety on rice revenue

	Coefficients	Standard error
Good year	7666.78	58584.11
Experience in production	-4924.63***	1747.21
Irrigated lowland	-851.24	31940.70
Production cost	-0.68***	0.23
Member of a village association	-19237.66	150788.30
Training in production	-58283.64	137824.90
Sex of the producer	56197.51	72511.63
Contact of the producer with a project on CC	-32747.37	114081.20
Late	233325***	47530
Late1	351940***	29550
Late0	181430***	55400
Psb	118615*	65575
Difference	77935**	39780
Adapter	153990***	35430
Non-adapter	76055***	18084
Constant	414522.40*	218347.30
F (12, 287) et F (16, 52)	4.60***	
R^2	0.58	
Observations	69	

Source: Survey results 2017 FARA/INRAB

The econometric results of the determinants of short-cycle rice varieties are shown in Table 18. These results show that the characteristics of the villages where the farms are located, information about the adaption strategy, producers' perceptions on the adaptation strategy and the age of the producers are the factors that determined the utilisation of short-cycle rice varieties.

Table 18: Econometric results of the determinants of the utilisation of short-cycle rice varieties

	Coefficients	Standard error
Accessibility to the village: tarred road	0.61**	0.28
Availability of developed lowland in the village	-0.18	0.19
Importance of sensitivity to pest attack in choosing a variety	0.35**	0.16
Age of the producer	-0.01**	0.01
Literacy	-0.26	0.18
Information on the short-cycle rice variety	-0.04	0.21
Importance of fertiliser requirement in choosing a variety	-0.35**	0.16
Accessibility to the village: roadway	-0.07	0.16
Member of a village association	0.21	0.16
Contact of the producer with a project on CC	0.14	0.18
Constant	0.58*	0.30
Log likelihood	-242.65	
Chi^2	27.82***	
Pseudo R^2	0.05	
Observations	371	

Source: Survey results 2017 FARA/INRAB

Impact of adaptation practice on farm yield and revenue

Relationship between the maize revenue and the revenue of the farm and climate variables

The results of the regression models of maize revenue and farm revenue are presented in Tables 19 and 20. The Fisher test shows that the models are globally significant at the threshold of 1 percent. The coefficients of determination (R^2) of the models without adaptation are 0.13 and 0.18 respectively for the regression on maize revenue and that on farm revenue. Integration of the socioeconomic variables improves the quality of the coefficients of determination of the models with adaptation (R^2=0.62) and (R^2=0.51). Regardless of the regression model considered, a great part of the variation of the maize revenue and the farm revenue remains unexplained by the variables considered. Nevertheless, the models remain satisfactory in respect to the results obtained in similar studies (Kurukulasuriya *et al.,* 2006; Ouédraogo, 2012; Hessavi, 2013; Kouton-Bognon *et al*., 2015).

The temperature and the rainy season and its quadratic term are significant at 10 percent (Table 19). The rainfall during the dry season and its quadratic term are also significant at 1 percent for the model without adaptation and the model with adaptation (Table 20). Likewise, the quadratic term of the rainfall of the rainy season is significant at the threshold of 10 percent for the model without adaptation but the rainfall is not. All or nearly all the signs of the linear and quadratic terms are opposed. This tallies with the results of Kouton-Bognon *et al*. (2015) and Ouédraogo (2012) even if the latter did not conduct his study in the same conditions like ours. This means that temperature and rainfall of the rainy and dry seasons affect positively the maize revenue and the farm revenue up to a certain level above which each of these variables becomes harmful to crops. Clayey-sandy soils and irrigated lowlands have a negative effect on the maize revenue. Likewise, ferralitic soils have a negative effect on the maize revenue and the revenue of the farm. However, soil fertility has a positive effect on the maize revenue and the farm revenue. The utilisation of short-cycle maize variety, the practice of fallow as well as access to extension services have positive effects on the maize revenue and the farm revenue. Access to extension allows producers to improve the net revenue and the utilisation of short-cycle variety is among the most-used climate change adaptation strategies in Benin. On the contrary, production cost has a negative effect on maize and farm revenue. This can be explained by the practice of extensive agriculture that requires a sufficient budget due to the expansion of cultivated areas with a view to increasing production.

Table 19: ***Results of the regression models of maize revenue***

	Model without adaptation		Model with adaptation	
Variables	Coef.	t	Coef.	t
Climate variables				
Rainy season rainfall	-1461,04	-1,46	183,66	0,25
Scare rainy season rainfall	1,04	1,63	-0,09	-0,19
Dry season rainfall	-823,58	-0,2	835,74	0,29
Scare dry season rainfall	1,70	0,28	-1,80	-0,43
Rainy season temperature	3083734	0,87	1480936*	0,60
Scare rainy season temperature	-54204,01	-0,87	-26353,44*	-0,60
Dry season temperature	-3953658	-0,95	-5521025,00	-1,93
Scare dry season temperature	72519,64	0,96	99607,12	1,93
Edaphic variables				
Upland	-17241,48	-0,35	-28298,02	-0,85
Irrigated lowland	-23967,10	-0,36	-76277,10*	-1,69
Clayey-sandy soil	-12608,27	-0,77	-41619,02***	-3,56
Ferralitic soil	-83156,42	-1,57	-62934,99*	-1,77
Non-irrigated lowland	28341,62	0,55	12351,41	0,35
Soil fertility	13873,81	0,92	33680,34***	3,15
Socioeconomic variables				
Utilization of short-cycle variety			71192,80***	7,20
Practice of fallow			26967,73***	2,83
Utilization of animal traction			9687,13	0,30
Contact with extension			19481,42**	1,97
Size of the household			1589,21	1,16
Access to formal education			4607,45	0,46
Production cost per hectare			-0,83***	-16,59
Constant	1,06E+07	0,14	5,56E+07	1,03
Number of observation	300		300	
F	3,11***		21,75***	
R^2	0,13		0,62	

Source: Survey results 2017 FARA/INRAB

Table 20: Results of the regression models of the farm revenue

	Model without adaptation		Model with adaptation	
Variables	**Coef.**	**t**	**Coef.**	**t**
Climate variables				
Rainy season rainfall	-1601,93	-1,44	132,43	0,14
Scare rainy season rainfall	1,20*	1,68	0,03	0,06
Dry season rainfall	-3425,44**	-2,01	-5833,21***	-3,64
Scare dry season rainfall	5,44**	2,52	8,05***	3,8
Rainy season temperature	342672,10	0,10	-1477036	-0,51
Scare rainy season temperature	-5962,18	-0,10	25952,96	0,51
Dry season temperature	-2637189,00	-0,94	-888252,9	-0,36
Scare dry season temperature	50065,99	0,97	18006,35	0,4
Edaphic variables				
Upland	17168,37	0,40	5733,35	0,17
Irrigated lowland	-16290,87	-0,35	-24219,93	-0,66
Clayey-sandy soil	-16373,17	-0,90	-40349,37***	-2,7
Ferralitic soil	-54255,87	-0,98	-26932,15	-0,62
Non-irrigated lowland	59772,43	1,38	46309,22	1,34
Soil fertility level	36928,81**	2,22	43918,27***	3,18
Socioeconomic variables				
Utilization of short-cycle maize variety			83287,09***	7,02
Practice of fallow			26997,43**	2,19
Utilization of animal traction			18043,36	0,44
Contact with extension			30534**	2,48
Size of the household			2334,522	1,47
Access to education			5875,205	0,48
Production cost per hectare			-0,81***	-12,87
Maize as main crop			-168933***	-5,32
Constant	3,07e+07	0,42	3,29e+07	0,54
Number of observations	370		370	
F	5,60***		16,47***	
R^2	0,18		0,51	

Source: Survey results 2017 FARA/INRAB

Sensitivity of agricultural revenues in relation to climate

Indicators used to evaluate the sensitivity of agricultural revenues in relation to climate are: the marginal impact of the climate and rainfall and the revenue elasticity in relation to temperature and rainfall. The marginal effect of the temperature of the rainy season is significant at the threshold of 10 percent for the model with adaptation (Table 21). The results of the same table indicated that an increase in the average temperature of the rainy season by 1°C decreases maize revenues by FCFA 4760.29/hectare on average for all the farmers in the sample.

The marginal effect of the rainfall in the dry season is significant at the threshold of 1 percent for the model with adaptation (Table 22). This implies that a decrease in the average annual rainfall by 1 mm of water generates an increase in the revenue of the farm of the producers of the sample by Fcfa 500.17/ha for those who already practise adaptation to climate change. This means that in these zones of the study, rainfall in the dry season is no longer normal, meaning that there was more rain than needed during the dry season over the last five years. These results justify the change in the rainy seasons that pushes farmers to change their way of producing over time.

The results of the elasticities indicated that during the rainy season, an increase of 1 percent in temperature led to a decrease in the maize revenues of 2.67 percent. During the dry season, an increase of 1 percent in the rainfall leads to a decrease in the farm revenues of the sample by 4.26 percent.

Table 21: Climate marginal effect and elasticity on maize revenue

Variables		**Rainy season**		**Dry season**	
		Model without adaptation	Model with adaptation	Model without adaptation	Model with adaptation
Temperature	Marginal effects	27939,1	-4760,29*	64496,55	-2013,30
	Elasticities	15,31	-2,67	64,42	38,71
Rainfall	Marginal effects	49,92	54,08	427,06	-489,05
	Elasticities	-1,35	0,85	2,79	-3,22

Source: Survey results 2017 FARA/INRAB

Table 22: Climate marginal effect and elasticity of the farm revenue

Variables		**Rainy season**		**Dry season**	
		Model without adaptation	Model with adaptation	Model without adaptation	Model with adaptation
Temperature	Marginal effects	4812,96	-6358,897	134251,4	108502,2
	Elasticities	3,31	-9,02	70,50	47,79
Rainfall	Marginal effects	72,94*	182,92	852,87	500,17***
	Elasticities	-0,04	1,57	-0,67	-4,26

Source: Survey results 2017 FARA/INRAB

Conclusion and suggestions

In summary, we can note from this study that the main endogenous strategies used by the farms are resorting to rain makers, sacrifices and the exogenous ones are short-cycle varieties of rice and maize, and mulching using plant residues. From these exogenous strategies, the utilisation of short-cycle maize varieties increased the net revenue of maize per hectare. It is the same thing for the utilisation of short-cycle rice variety on the net revenue per hectare. But despite the increase generated by climate change adaptation strategies on the net revenue of the farms, they did not reduce GHG emissions at the level of their farms. Maize revenues and the revenues of the farms surveyed are sensitive to temperatures and annual rainfall amounts. However, the practice of adaptation allows the farms to reduce slightly financial losses caused by the consequences of climate change on the yield and thus on the revenues.

The study revealed that utilisation of mineral fertilisers is a factor that contributes to GHG emissions especially in rice plots. In view of these facts, it is suggested that utilisation of fertilisers be regulated in order to respect the recommended doses to be used. Producers must be followed and supervised closely, and encouraged to use the optimal quantities of mineral fertilisers.

The results showed that although the adaptation strategies disseminated allowed producers to adapt to climate change and to improve their revenues, they did not allow them to reduce GHG emissions at the level of their farms. In conclusion, these measures are not “climate-smart”; they are not sustainable since the reduction of GHG is not effective for these adaptation strategies. It would therefore be convenient to define climate-smart practices to allow producers to produce sustainably. Therefore, the study suggests that in the frame of other projects on the adaptation to climatic risks, climate-smart measures be considered and disseminated. It would also be desirable to focus priorities on these types of measures, especially for rice.

References

Adégbola, P. Y. et Adékambi, S. A. (2008). Taux et déterminant de l'adoption des variétés améliorées d'igname développées par l'ITAA. ITAA,
PAPA, IFAD, p.25

Agossou D. S., Tossou C. R. Vissoh, V. P. K. E. Agbossou (2012). Perception des perturbations climatiques, savoirs locaux et stratégies d'adaptation des producteurs agricoles béninois. *AfricanCrop Science Journal*, Vol. 20, 565-588.

Agossou, S., 2008. Adaptation aux changements climatiques : Perceptions, savoirs locaux et stratégies d'adaptation des producteurs des communes de Glazoué et de Savalou au centre du Bénin. Thèse d'Ingénieur Agronome, Abomey–Calavi, FSA/UAC. 197 pages

Aho, N., Ahlonsou, E. et Agbahungba, G. (2006) Evaluation concertée de la vulnérabilité aux variations actuelles du climat et aux phénomènes météorologiques extrêmes. Rapport de synthèse. PANA -Bénin/ MEPN-PNUD, Cotonou, 52p.

Arodokoun U., H. Dedehouanou, R. Adeoti, P. Adegbola, S. Adekambi, A. Katary. (2012). Rôle des NTIC dans l'adaptation aux changements climatiques par les producteurs de coton du Centre-Bénin, African Crop Science Journal, Vol. 20, Issue Supplement s2, pp. 409 - 423 ISSN 1021-9730/2012.

Bravo-Ureta, B. E., Solis, D., Cocchi, H. et Quiroga, R. E. (2005). The impact of soil conservation and output diversification on farm income on Central American hillside farming. *Agricultural economics*, 35 (2006), p.271

Bokonon-Ganta, E., Hounkponou, K., Nouatin, G., Gnangassi, C., & M. Ahounou, 2009. Changements climatiques au Bénin: Vulnérabilité et stratégies d'adaptation. In Changements climatiques, entre résilience et résistance, AGRIDAPE, vol 24 n°4, Février 2009. Pp.8-10.

Bryant C.R., Smit B., Brklacich M., Johnston T.R. Smithers, J. Chiotti, Q. B.Singh (2000). Adaptation in Canadian agriculture to climatic variability and change. Climate Change 45, 181–201.Diagne, A., Dontsop-Nguezet, P. M., Kinkingninhoun-Medagbe, F. M., Alia, D., Adegbola, P. Y., Coulibaly, M., Diawara, S., Dibba, L., Mahamood, N., Mendy, M., Ojehomon, V. T., et Wiredu, A. N. 2012. «The Impact Of Adoption Of Nerica Rice Varieties In West Africa», Spia Pre-Conference Workshop; 28th Iaae Conference, Foz Do Iguaçu, Brazil, August 18, 2012. 58p.

Dontsop-Nguezet, P. M., Diagne, A., Okoruwa, V. O. And Ojehomon, V., 2011. «Impact Of Improved Rice Technology (Nerica Varieties) On Income And Poverty Among Rice Farming Household In Nigeria: A Local Average Treatment Effect (Late) Approach», Quarterly Journal Of International Agriculture, 50(3), 267-291

FAO. 2006. Demands for products of irrigated agriculture in sub-Saharan Africa. FAO Water Report No. 31, 142pp. FAO, 2008. Current World Fertilizer Trends and Outlook to 2011/12. Food and Agriculture Organization, Rome

GIEC, 2007. Résumé à l'intention des décideurs. In M.L. Parry, O.F. Canziani, J.P.Palutikof, P.J. vander Linden and C.E. Hanson, (éds.), Bilan 2007 des changements climatiques: Impacts, adaptation et vulnérabilité. Contribution du Groupe de travail II au quatrième Rapport d'évaluation. Rapport du Groupe d'experts intergouvernemental sur l'évolution du climat. Cambridge University Press, Cambridge, Royaume -Uni.Heckman J And Vytlacil E., 2005. Structural Equations, Treatment Effects, And Econometric Policy Evaluation. Econometrica 73: 669-738.Heckman, J. J., 2010. «Building Bridges between Structural and Program

Evaluation Approaches to Evaluating Policy», *Journal of Economic Literature*, 48(2), 356-398.

Glèlè, E. K. A., Adékambi, S. A., Agli, C.K Tamègnon B.A., ,Adégbola, P. Y. (2008). Impact socio-économique de l'adoption des variétés améliorées de manioc au Bénin. 51p

Heckman, J., J., and Vytlacil, E., J., 1999. «Local instrumental variables and latent variable model for identifying and bounding treatment effects», *Economics Sciences*, 96, 4730-4734.

Houndékon, V. et Gogan, A. (1996). Adoption d'une technologie nouvelle de jachère courte à base de mucuna. Cas du département du Mono-Couffo dans le Sud Bénin. INRAB-IITA, Bénin.

Houessou-Goe, S., 2008. Agriculture et changements climatiques au Bénin : Risques climatiques, vulnérabilité et stratégies d'adaptation des populations rurales du département du Couffo. Thèse d'Ingénieur Agronome, Abomey–Calavi, FSA/UAC. 160 pages.

Howden M, J-F Soussana, F. Tubiello, N. Chhetri, M. Dunlop, H. Meinke (2007). Adapting agriculture to climate change, PNAS, December 11, 2007, vol. 104, no. 50, 19691–19696.

Howden, S.M., Soussana, J.F., Tubiello, F.N., Chhetri, N., Dunlop, M., Meinke, H., (2007). Adapting agriculture to climate change. Proceedings of the National Academy of Sciences of the United States of America 104, 19691–19696.Huffaker (2003). In *A.Ramirez. (2010). The impact of climate change on rice production. 5p*.

IPCC. 2007. Climate change (2007). Synthesis. Summary for policy makers. Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge GIEC (IPCC) (2007). www.ipcc.ch/pub/syrgloss.pdf.

Kelkar U., Narula K.K., Sharma V.P., U.Chandna. (2008). Vulnerability and adaptation to climate variability and water stress in Uttarakhand State, India. Global Environmental Change: Human and Policy Dimensions 18, 564–574.

MEPN. (2008). *Convention cadre des Nations Unies sur les changements climatiques. Programme d'Action National d'Adaptation aux changements climatiques du Bénin (PANA- Bénin). République du Bénin*.

Messner D. et Brüntrup. (2007). *Changement climatique :* Tendances mondiales et avenir des zones rurales. Institut Allemand de développement (DIE). Agriculture et Développement Rural 14 (1) : 51-55.

Ramirez A. (2010). The impact of climate changes on rice production .5p.

Rubin, D., 1974. Estimating Causal Effects Of Treatments In Randomized And Non-Randomized Studies. Journal Of Educational Psychology 66: 688-701.

Ouédraogo M. (2012). Impact des changements climatiques sur les revenus agricoles au Burkina Faso. *Journal of Agriculture and Environment for International Development* – JAEID 2012, 106 (1): 3 – 21

Schneider, K. Et Gugerty, M. K., 2011. « Agricultural Productivity And Poverty Reduction: Linkages And Pathways», The Evans School Review, 1(1), 56-74.

Sall, S., Norman, D., Featherstone, A. M. (2000). Quantitatives assessment of improved rice variety adoption: The farmer's perspective. Agric. Syst. 66, 129-144.

Suri, T., 2011. «Selection And Comparative Advantage In Technology Adoption», Econometrica, 79(1), 159-209

Sperling F. *et al.* (2003). Pauvreté et changements climatiques. Réduire la vulnérabilité des populations pauvres par l'adaptation. Préparé par : Banque Africaine de Développement, Banque Asiatique de Développement, Banque mondiale, Département du Développement International, Royaume Uni ; Direction Générale du Développement, Commission européenne ; Ministère des affaires étrangères–Coopération internationale, Pays Bas ; Ministère fédéral de la coopération économique et du développement, Allemagne ; Organisation de Coopération et de Développement Economiques ; Programme des Nations Unies pour le Développement ; Programme des Nations Unies pour l'Environnement. *Report*. In Agossou et al. (2012).42 p.

VanIttersum M.K., Howden S.M., S. Asseng (2003). Sensitivity of productivity and deep drainage of wheat cropping systems in a Mediterranean environment to changes in CO2, temperature and precipitation. Agriculture, Ecosystems and Environment 97, 255–273.