Factors influencing the adoption of climate smart agriculture by farmers in Ségou region in Mali

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Abstract

Climate change and its impacts on agriculture are major concerns for a food secured economy especially for developing countries like Mali. The carbon footprints of agriculture also a concern for future climate. These make sustainable agricultural practices a prerequisite for crop production today. This study analysed the adoption of Climate Smart Agriculture (CSA) by farmers in Ségou region in Mali. Data was collected on 432 households covered by climate smart villages using multivariate probit and poisson regressions. The result showed that, out of five CSA practices, row planting was the main practice adopted by the farmers. The adoption of various CSA strategies was significantly influenced by socioeconomic, institutional and climate related factors. The study concluded that CSA adoption is low among the farmers. Nonetheless, policy factors such as extension service delivery can be triggered to enhance CSA adoption.

Key words: Climate change, climate smart agriculture, multivariate probit, poisson regression, Ségou region, Mali,

Résumé :

Le changement climatique et ses impacts sur l'agriculture sont des préoccupations majeures pour la sécurité alimentaire, en particulier l'économie pays en développement comme le Mali. L'empreinte carbone de l'agriculture est également une préoccupation pour le climat futur. C'est pourquoi les pratiques agricoles durables sont aujourd'hui une condition préalable à la production de cultures. Cette étude a analysé l'adoption de l'agriculture intelligente par les agriculteurs de la région de Ségou au Mali. Des données ont été collectées sur 432 ménages dans les villages intelligents en utilisant des régressions multivariées de probit et de poissons. Le résultat a montré que, sur cinq pratiques d'agriculture intelligente, la plantation en rangs était la principale pratique adoptée par les agriculteurs. L'adoption de diverses stratégies d'agriculture intelligente a été fortement influencée par des facteurs socioéconomiques, institutionnels et climatiques. L'étude a conclu que l'adoption de l'Agriculture intelligente est faible chez les agriculteurs. Néanmoins, des facteurs politiques tels que la prestation de services de vulgarisation peut être un moyen favorable pour l'adoption de l'Agriculture intelligente.

Mots clés : Changement climatique, agriculture intelligente, régression multivariée de probit et régression de poisson, Ségou, Mali

Introduction

Climate change have become a global threat as its impacts are noticeable in all sectors and all regions. Its impact is also high on agrarian communities that formed a large portion of developing countries such as Mali. Therefore, this study analysed farming households' adaptation to climate change through CSA. The scientific evidence of the impacts of climate change are in no doubt established. This recognition led to the adoption of the Sustainable Development Goal (SDG) 13 that seeks to take urgent action to combat climate change and all its impacts. One of the major impacts of climate change is on food security. This is obvious from the current levels of food insecurity in the world that has been on the increase despite the commitment in SDG 2 that seeks to achieve zero hunger by 2030. Globally, one out of every nine person (10.9 percent, representing 821 million people) were undernourished in 2017 and this is higher than 804 million people in 2016 (FAO, IFAD, UNICEF, WFP, & WHO, 2018), and in sub-Saharan African (SSA), 23.2 percent of the population is undernourished in 2017. The food insecurity situation is more prevalent in SSA as there is an increasing level of undernourishment in all of its regions except Eastern Africa. For instance, the prevalence of undernourishment in Western Africa (where Mali is located) increase from 10.4 percent in 2010 to 10.7 percent in 2014, 12.8 percent in 2016 and 15.1 percent in 2017 (FAO, IFAD, UNICEF, WFP, & WHO, 2018). These observed trends of undernourishment are similar to the observed levels of food insecurity measured through food insecurity experience scale that shows that food insecurity is worsening and requires more attention than before.

Climate variability and extreme events are key contributing factors to the increasing food insecurity levels whose impacts are noticeable on all the dimensions of food security (FSIN, 2018; FAO, IFAD, UNICEF, WFP, & WHO, 2018;Tripathi et al., 2016). Therefore, not only is climate change leading to low food production or availability but also, a decline in the quality of foods (Tripathi et al., 2016). Smallholder farmers are one of the most vulnerable groups to climate change and variability. Climate change leads to wearing out of all efforts made by farmers in savings and resources accumulation. Mutabazi et al. (2015) explained that households that lack effective safeguards to risks are likely to be more prone to poverty and other vulnerability traps. Food production is expected to increase by 60 percent in order to meet the increasing food demands, and this objective is unattainable under business-as-usual response to climate change (FAO, 2013). Farmers, therefore, need to take adaptive measures that would minimize the impacts of climate change. These adaptation strategies must lead to higher food production without depletion of natural resources. For sustainable food production, one of the important strategies is CSA. This is defined as 'agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances the achievement of national food security and development goals' (FAO, 2013). The objective of CSA is not to introduce new sustainability principles, but to integrate specificities of adaptation and mitigation into sustainable agricultural policies, programs and investments (Lipper & Zilberman, 2017). The emergence of CSA is due to different opinions on the concepts and approaches to sustainable agriculture and the lack of integrating climate change into agriculture policies and their role in ensuring food security (Lipper & Zilberman, 2017). Unlike conventional food production, CSA integrates climate change and agricultural development planning efforts (Sain et al., 2016). This implies that CSA has become a necessary condition to sustainable agriculture due to three major factors. These include increase climate change and events that worsens rainfed agriculture, permanent changes in weather patterns which led to non-productivity at certain locations, and the need to reduce agriculture's contribution to greenhouse gas concentration in the atmosphere (Lipper & Zilberman, 2017).

CSA has become an important adaptation and mitigation strategy to climate change (Partey et al., 2018) and to provide food for the increasing population (Totin et al., 2018). Maguza-Tembo et al. (2016) estimated that the adoption of CSA leads to an increase in maize yield between 9-37 percent and an increase in crop revenue between 36-60 percent; depending on the CSA strategy. These are indications of positive gains from the adoption of CSA. Considering the significant roles of CSA, there is the need to engage in its promotion. Unfortunately, it appears the adoption of CSA is low among farmers in arable land zone in Mali. Therefore, the main question this study seeks to answer is what factors influence or limits the adoption of CSA by farming households in the climate smart village in Ségou region. This is aimed to provide policy indicators that must be considered and promoted to enhance the adoption of CSA in the region. The findings of this study are particularly useful for the Government of Mali on its planting for food and jobs policy. Other non-governmental organizations working with farmers such as IFDC and CCAFS can rely on the recommendations in this research to promote CSA in Mali. Maize farmers are considered in this study because maize is the number one food security crop in Mali, where almost every farmer cultivates maize and almost every household consumes food from maize. However, among the major food grains (maize, rice, sorghum and millet), maize is the most affected by climate change (Tripathi et al., 2016). These therefore means that sustainable maize production amidst climate change is a necessary condition for sustainable food security in Mali.

1. Methodology

1.1 Study location

The study was conducted in Ségou region in Mali. This area covers 64,821 km^2 (5%) of Mali's land area and located in the middle part of the country. Agriculture (crop, fishing and animal husbandry) is the main stay for the majority of households in the region. Due to its location Segou is characterized by a semi-arid climate, close to Tombouctou region that is dessert or semi-dessert, it is naturally warm and also experiences an average rainfall 513 mm. This make households in the region more vulnerable to climate change and climate shocks such as drought. However, agriculture is the main economic activity of the economically employed in this region. The major grain crops cultivated include maize, rice, sorghum and millet. For sustainable food production and reduced poverty among households in the region, it is appropriate that farmers in the region adopt CSA technologies.

1.2 Sampling and data collection

The target population of the study is the maize farming households. The study collected data on all farmers convers by the project of climate smart agriculture. In the first stage, purposive sampling was used in the choice of Ségou region in Mali for the study. The choice is based on the researcher's in-depth knowledge in this region and the high vulnerability of farming households to climate change in this part of Mali. In the second stage, all the farmers covered by the project smart climate village in Cinzana in Ségou region. In all, a total of 300 households were interviewed for the study.

The data was collected using questionnaire administering. Trained research assistants who can speak both French and the community dialect (Bambara) helped in the data collection. This helped in minimizing possible errors in translating the various questions. The data was entered into and analysed by STATA 14.

1.3 Data analysis

The study analysed the determinants of the adoption of CSA technologies among farming households. This was analysed using multivariate probit regression for the specific strategies and a poisson regression for the count of the technologies. In this study, the number of climate smart technologies considered are five, and this suggests that the individual adoption equations are five. Theoretically, the multivariate probit model is an extension of the probit and bivariate probit models. Its applicability differs from multinomial probit where the individual observations (farmers in this case) are fixed to choose only a single option from more than two options. For the multivariate probit model, the options are independent, therefore, the farmers are allowed to choose more than one options simultaneously. In this study, a household is free to adopt more than one of the five technologies simultaneously. The MVP result was complemented with a poisson regression that uses the count of CSA adopted by the farmers. Empirically, the model estimated is:

$$\begin{aligned} climate\,smart = {} & {}_1Sex + {}_2Adults + {}_3Farm\,hours + {}_4Land\ source + {}_5Experience + {}_6Education \\ & + {}_7Farming\ system + {}_8Commercial\ production + {}_9Extension + {}_{10}FBO + {}_{11}Credit\,access + \\ & {}_{12}Drought + {}_{13}Flood + {}_{14}Pest\,infestation + {}_{15}Climate\ perception \end{aligned} \quad (5)$$

Table 1 shows the list of variables used in the study, their definition and descriptive statistic.

Table 1: Definition and descriptive statistics of respondents

Variable	Definition
Sex	Dummy: 1 if farmer is a male and 0 if a female
Adults	The total number of household members with age 18 and above
Farm hours	The average number of hours a farmer spends on farm daily
Land source	Dummy: 1 if farmer own the land used for cultivation, 0 otherwise
Experience	Total number of years of maize cultivation
Education	Total number of years of formal education.

Farming system	Dummy: 1 if monocropping and 0 if mixed cropping.
Commercial production	Dummy: 1 if farmer produce beyond subsistence motive and 0 solely for subsistence
Extension	Dummy: 1 if a farmer had access to extension service, 0 if not.
FBO	Dummy: 1 if farmer belonged to an FBO, 0 if not.
Credit access	Dummy: 1 if farmer had access to credit for crop production and 0 if not.
Farm size	Total number of acres of maize cultivated by a farmer.
Drought	Number of times a farmer experience drought within the past ten years
Flood	Number of times a farmer experience flood within the past ten years
Pests infestation	Dummy: 1 if farmer perceived that pest infestation is increasing, 0 if decreasing.
Climate perception	Dummy: 1 if farmer perceived precipitation as increasing and temperature as decreasing, 0 if otherwise.

Source: Authors, (2019)

2. Results and discussions

2.1 Level of adoption of climate smart technologies

Table 2 shows the climate smart technologies considered in this study. The first section of the table shows the adoption level of each of the technologies while the second section shows the combination or rate of adoption of the five technologies. Among the five technologies, only row planting recorded an adoption level beyond 50.0%. This implies that the level of adoption of the climate smart technologies is low among the farmers. Specifically, only 29.9%, 31.5%, 23.6% and 30.1% of the household heads adopted drought resistant varieties, CA, ISFM and IPM, respectively. In terms of adoption rate, as high as 22.5% of the farmers adopted none of the five CSA technologies while only 1.4% adopted all five technologies. The highest percentage (26.4%) of the household heads adopted only one of the technologies. It can be concluded from this result that the adoption of CSA is low among the household heads. Considering the changing climatic conditions and the need for climate adaptation to ensure sustainable food production, the result of this study is rather revealing, therefore, the need for policy makers to redirect their efforts in promoting these technologies among farming communities of Ségou region in Mali.

Table 2: Level of adoption of climate smart technologies

	Adopters		Non-adopters	
CSA technology	Freq.	%	Freq.	%
Drought resistant	129	29.9	303	70.1
CA	136	31.5	296	68.5
ISFM	102	23.6	330	76.4
Row planting	218	50.5	214	49.5
IPM	130	30.1	302	69.9
Adoption level				
None of the technologies	97	22.5		
Only one technology	114	26.4		
Any two technologies	110	25.5		
Any three technologies	69	16.0		
Any four technologies	36	8.3		
All five technologies	6	1.4		
Total	432	100		

Source: Authors, (2019)

2.3 Factors influencing the adoption of climate smart technologies

Table 3 shows the factors influencing the adoption of each CSA technology (multivariate probit estimates) and the adoption intensity of farmers (poisson estimates). The result shows that a number of socioeconomic, institutional and climate related factors had significant influence on the adoption decision and/or intensity of the farmers. These factors are discussed in this section.

The sex of the household head had a positive significant effect on the adoption of row planting but a negative significant effect on the adoption of IPM. This means that while the male heads have a higher probability of adopting row planting, the female heads on the other hand have a higher probability of adopting IPM. The estimated positive effect of sex on row planting is consistent with the findings of Mentire & Gecho (2017). Contrary to this finding, Donkor et al. (2016) estimated that female farmers have a higher probability of adopting row planting of rice in northern Ghana. The number of adults in a household is used as a proxy for labour availability for farm activities. The result shows that higher number of adults in a household significantly decreases the probability of adopting drought resistant varieties, ISFM and IPM. This finding discounted studies such as Lunduka et al. (2017) and Idrisa et al. (2014). Education plays a crucial role in improving the human capital and the understanding of climate change and the need for adaptation. The result shows that although education leads to a reduction in the probability of adopting ISFM, higher education leads to the adoption of more CSA technologies. Consistently, Mutua-Mutuku et al. (2017) also estimated a negative effect of education on the adoption of ISFM. Aura (2016) on the contrary estimated that education enhances the adoption of ISFM.

The source of land had a mixed effect on the adoption of CSA. While it had positive significant effects on the adoption of drought tolerant varieties and row planting, it had negative significant effect on the adoption of CA and adoption intensity of the farmers. Empirically, Donkor et al. (2016) also estimated a positive effect of land source on the adoption of row planting, although insignificant. The number of years a farmer had in maize production decreases the probability of adopting drought resistant varieties but increases the adoption intensity of the farmers. Generally, the experienced farmers are conversant with the production process and are able to adjust their production activities other than just the adoption of CSA. While farming system had significant effect on the adoption of individual strategies such as drought tolerant varieties and IPM, it had a positive significant effect on the adoption intensity of the farmers. Commercial production had a negative significant effect on the adoption of CA but positive significant effects on the adoption of ISFM, row planting and IPM technologies. Deressa et al., (2011) also estimated a negative effect of farm size on climate adaptation.

The effect of access to extension services is positive and significant in explaining ISFM and IPM adoption decision by farmers. Thus, farmers who had access to extension services in the cropping season had higher probability of adopting these technologies than those who did not access extension services. Extension officers are generally responsible for transferring technologies to the farmers. Therefore, it is expected that the farmers become more aware of these technologies and their importance, hence the high adoption probability. This justified the need for enhancing the provision of extension service to farmers, especially, in the era of climate change and the rapid technological advancement. Mutua-Mutuku et al. (2017) also estimated a positive effect of extension access on ISFM adoption.

FBO membership had positive significant effects on the adoption of drought resistant varieties and IPM technologies. These are justifiable findings. In addition to the provision of labour assistance to each other and sharing knowledge among groups, the groups also serve as a contact for most climate intervention programs. Because the groups offer the opportunity to contact large number of farmers at a time, programs that aim at promoting CSA are done through the groups. Thus, groups have become a conveying belt for CSA in most farming communities. Consistently Mwungu et al. (2018) estimated that FBO members have higher probability of adopting improved varieties.

Access to credit leads to a higher probability of adopting row planting but leads to the adoption of lesser number of CSA technologies. Since row planting are done using human labour, it implies that the demand for labour would increase and this would mean that more capital is required for farming. It is therefore consistent that farmers who had access to credit would adopt row planting. However, credits may come with some terms and conditions that may favour the adoption of specific technologies other than several technologies. Consistently, Imran et al. (2018) explained that adoption of CSA is limited by low access to farm services such as credit. Also, Deressa et al., (2011) found a positive effect on the adaptation to climate change by farmers.

Climate perception and pest infestation had significant effects on the adoption of IPM technologies. These are all positive, implying that, farmers who perceives the direction of change in temperature and precipitation appropriately as well as perceived an increasing level of pest infestation have higher probabilities of adopting IPM. This justify the need for improving the understanding of farmers on climate change and enhancing their local knowledge in predicting the patterns of most climatic variables, particularly, precipitation.

Table 3: Factors influencing the adoption of climate smart technologies

	Drought resistant		CA		ISFM		Row planting		IPM		Count (Poisson model)	
Variable	Coef. (Std. err.)	Z-value [P-value]	Coef. (Std. err.)	Z-value [P-value]	Coef. (Std. err.)	Z-value [P-value]	Coef. (Std. err.)	Z-value [P-value]	Coef. (Std. err.)	Z-value [P-value]	Coef. (Std. err.)	Z-value [P-value]
Sex	-0.128 (0.179)	-0.71 [0.475]	-0.050 (0.164)	-0.3 [0.762]	-0.270 (0.175)	-1.54 [0.123]	0.292* (0.161)	1.81 [0.071]	-0.537*** (0.169)	-3.18 [0.001]	-0.100 (0.092)	-1.09 [0.275]
Household adults	-0.070*** (0.024)	-2.96 [0.003]	0.017 (0.020)	0.83 [0.409]	-0.069*** (0.023)	-3.05 [0.002]	-0.031 (0.020)	-1.57 [0.117]	-0.055** (0.022)	-2.49 [0.013]	-0.034 (0.022)	-1.57 [0.117]
Education	0.007 (0.014)	0.50 [0.618]	0.021 (0.013)	1.63 [0.103]	-0.036** (0.015)	-2.37 [0.018]	0.006 (0.013)	0.41 [0.680]	0.017 (0.014)	1.21 [0.225]	0.210*** (0.079)	2.66 [0.008]
Farm hours	0.022 (0.040)	0.56 [0.575]	0.127*** (0.038)	3.32 [0.001]	-0.035 (0.042)	-0.84 [0.398]	-0.050 (0.037)	-1.34 [0.180]	0.016 (0.040)	0.41 [0.684]	-0.002 (0.003)	-0.64 [0.524]
Land source	0.728*** (0.157)	4.63 [0.000]	-0.304** (0.139)	-2.20 [0.028]	0.055 (0.152)	0.36 [0.718]	0.739*** (0.137)	5.40 [0.000]	-0.159 (0.145)	-1.09 [0.274]	-0.222*** (0.077)	-2.87 [0.004]
Experience	-0.030*** (0.007)	-4.37 [0.000]	0.000 (0.005)	0.02 [0.982]	0.005 (0.005)	1.01 [0.313]	0.001 (0.005)	0.28 [0.778]	0.008 (0.005)	1.50 [0.134]	0.242*** (0.085)	2.85 [0.004]
Farming system	-0.631*** (0.149)	-4.23 [0.000]	-0.101 (0.138)	-0.74 [0.461]	0.064 (0.150)	0.43 [0.670]	-0.197 (0.136)	-1.44 [0.149]	-0.515*** (0.142)	-3.61 [0.000]	0.155* (0.080)	1.94 [0.053]
Commercial production	0.196 (0.165)	1.18 [0.236]	-0.347** (0.164)	-2.11 [0.035]	0.337** (0.167)	2.02 [0.044]	1.037*** (0.162)	6.39 [0.000]	0.341** (0.159)	2.14 [0.032]	0.126 (0.080)	1.56 [0.118]
Extension	0.199 (0.158)	1.26 [0.207]	-0.074 (0.142)	-0.52 [0.604]	0.259* (0.154)	1.68 [0.093]	-0.181 (0.141)	-1.28 [0.200]	0.717*** (0.147)	4.88 [0.000]	0.075 (0.087)	0.87 [0.386]
FBO	0.285* (0.152)	1.88 [0.060]	-0.052 (0.139)	-0.37 [0.710]	0.175 (0.156)	1.12 [0.262]	-0.160 (0.139)	-1.15 [0.248]	0.426*** (0.149)	2.85 [0.004]	0.001 (0.007)	0.14 [0.889]
Credit access	0.078 (0.177)	0.44 [0.658]	0.021 (0.154)	0.14 [0.891]	0.165 (0.165)	1.00 [0.317]	0.442*** (0.158)	2.80 [0.005]	-0.268 (0.165)	-1.63 [0.104]	-0.125*** (0.032)	-3.93 [0.000]
Farm size	0.010 (0.012)	0.79 [0.427]	-0.019 (0.020)	-0.95 [0.342]	0.009 (0.012)	0.76 [0.447]	0.006 (0.015)	0.44 [0.656]	0.003 (0.012)	0.26 [0.791]	-0.105** (0.042)	-2.48 [0.013]
Climate perception	0.335 (0.214)	1.56 [0.118]	0.285 (0.188)	1.51 [0.130]	0.096 (0.207)	0.47 [0.642]	-0.100 (0.184)	-0.55 [0.584]	0.344* (0.203)	1.69 [0.091]	0.085 (0.123)	0.69 [0.488]
Drought times	0.011 (0.053)	0.20 [0.840]	-0.088* (0.049)	-1.79 [0.074]	-0.352*** (0.072)	-4.89 [0.000]	-0.091* (0.051)	-1.78 [0.076]	-0.232*** (0.066)	-3.52 [0.000]	-0.036*** (0.012)	-2.98 [0.003]
Flood times	-0.227*** (0.083)	-2.72 [0.007]	-0.005 (0.063)	-0.08 [0.937]	-0.163** (0.079)	-2.06 [0.039]	-0.067 (0.066)	-1.02 [0.308]	-0.005 (0.072)	-0.06 [0.949]	0.148 (0.111)	1.34 [0.181]
Pests infestation	0.301 (0.231)	1.30 [0.193]	0.043 (0.204)	0.21 [0.832]	-0.124 (0.235)	-0.53 [0.596]	-0.100 (0.200)	-0.50 [0.617]	0.510** (0.233)	2.19 [0.029]	0.004 (0.008)	0.51 [0.612]
_cons	-0.583 (0.431)	-1.35 [0.176]	0.343 (0.385)	0.89 [0.373]	0.368 (0.421)	0.88 [0.381]	0.135 (0.376)	0.36 [0.720]	-0.709 (0.412)	-1.72 [0.085]	0.852 (0.223)	3.82 [0.000]

*NOTE: ***, ** and * indicates significant levels at 1%, 5% and 10%. Values in (.) are standard errors and values in [.] are P-values*

Source: Authors, (2019)

Unexpectedly, farmers who experienced drought within the past ten years have lesser probabilities of adopting CA, ISFM, row planting and IPM. Again, farmers who experienced floods in the last ten years have lower probability of adopting IPM technology. Although the mechanisms through which farmers who experienced floods and droughts may resist the adoption of CSA technologies is not clear in this study, it is possible that these farmers are laggards and may not adopt these technologies despite the impacts of drought or flood. Contrary to the findings of this research, Mwungu et al. (2018) estimated that farmers who have experienced any climate shock have higher probability of adopting minimum tillage. Also, Deressa et al. (2011) estimated that an increase in observed precipitation leads to a decrease in climate adaptation by farmers.

Conclusions and recommendations

The negative impacts of climate change on the performance of agriculture as well as the potential role of CSA to ensure sustainable food production has become increasingly evident. Within this framework, it is crucial that research efforts are intensified to promote and analyses the adoption of various CSA technologies, especially in areas of Ségou region in Mali, where climate change impacts are more noticeable and experienced. The descriptive statistics and marginal success prediction show that the adoption of row planting is higher than that of the other technologies. The factors that influenced the adoption of each CSA vary in terms of magnitude, direction and significance. For the adoption level, education, land source, experience, farming system, credit access, farm size and drought had significant effect on adoption. These clearly indicates that for the promotion of adoption of various climate smart technologies, specific factors must be considered, although targeting some variables for the adoption of one technology may have a replication effect on the adoption of another technology. Considering the low level of adoption and the positive effect of education on adoption of more technologies, there is the need to improve farmers' knowledge on the need for CSA. This also justify the need for intensifying the delivery of extension services by the Ministry of Agriculture and Rural development to promote the adoption of climate smart agriculture. However, considering the low extension to farmer ratio in Mali, and the positive effect of FBO membership on the adoption of CSA technologies, farmers are encouraged to join community farmer groups to enhance extension services' provision through these groups.

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