Life in the midst of changes in climate conditions: adoption of sustainable land management practices in the Niger basin of Benin

Abstract

Climate change constitutes a serious challenge for the world, especially for developing countries. For the structural transformation of African agriculture, African farmers have to adopt strategies to mitigate the adverse impacts of climate change on their activities such as declining agricultural productivity. Thus this paper examines farmer perception of climate change and adoption of sustainable land management practices in the Niger basin of Benin. A variant of the Heckman two-step procedure, which is composed of a univariate probit at the first stage, and a multivariate probit at the second stage was used to analyze the determinants of the perception of climate change and of adoption of sustainable land management practices. The results of the correlation coefficients of the error terms indicate that there are complementarities between different sustainable land management practices being used by farmers. Results confirm that secure land tenure, distance to nearest market, tractor use, plow use, have heard about climate change and membership of farmers' organizations are some of the important determinants of perception of climate change and of the adoption of farm-level sustainable land management practices. Policies aimed at easing the structural transformation of agriculture, have to provide basic services to farmers such as better access to market, to appropriate roads, to education, to relevant extension services and to climate information.

Key words: Adaptation strategies, Climate change, Heckman two-step, Multivariate Probit, Perception, Sustainable land management practices.

1. **Introduction**

Climate change constitutes a serious challenge for the world, especially for developing countries. Climate change is a significant and lasting change in the statistical distribution of the state of the climate due to natural variability or human actions [Intergovernmental Panel on Climate Change (IPCC) 2007; IPCC 2013]. Thus, it is considered as changes in weather patterns (rainfall, temperature and wind patterns, etc.) such as the occurrence of floods, droughts, strong winds, erratic rainfall, dry spells, etc. that occurs over a long period of time (decades or longer). Climate change will likely compromised agricultural production in many African countries and regions, and this could lead to food insecurity and malnutrition exacerbation (IPCC 2007). According to Di Falco and Veronesi (2012), Sub-Saharan production environment is characterized by low land productivity and harsh climate conditions such as high average temperature, scarce and erratic rainfall, and these lead to very low yield levels of food crops and food insecurity. Yet, these countries contribute less to the emissions of greenhouse gases that are the main causes of climate change. These emissions are mainly from developed countries. According to Ogalleh et al. (2012), despite the various national agricultural policies, smallholders are still facing more challenges such as poor infrastructure, poverty, poor policies and poor governance that impede agricultural productivity.

West Africa that is composed mainly by developing countries is considered one of the regions to be most affected by climate change (Callo-Concha et al. 2013). According to these authors, land degradation, increasing discrepancy between water demand and supply, and, as a consequence, declining agricultural productivity, and subsequent changes in livelihoods are expected to occur in the rural areas. Agriculture is the main source of livelihoods for West African rural population, is mostly rain-fed and therefore is affected by climate change. Indeed, Roudier et al. (2011) reviewed 16 studies that showed that yield impact of climate change is larger in northern West Africa (Sudano-Sahelian countries; -18% median response) than in the southern part of West Africa (Guinean countries; -13%). It is worth noting that agriculture is an important contributor to greenhouse gas emissions; it represent 14% of the global total greenhouse gas emissions.

Agriculture is the main contributor to employment and to the Gross Domestic Product (GDP) for Sub-Saharan Africa in general and for Benin in particular. It contributed to 35% of the region's GDP, up to 60% to employment, and income generation [Economic Community of West African States (ECOWAS) 2009]. Moreover, agricultural exports occupy a preeminent place in the West Africa's external trade and agriculture is one of the major vehicles for regional market integration. Therefore, a well-developed agriculture is important to achieve pro-poor economic growth, to tackle food insecurity, and to achieve sustainable development goals (SGDs). Indeed, food security is one of the greatest challenges of the world, and climate change impacts on food security will be worst in countries, already suffering high levels of hunger, and will worsen over time (Wheeler and von Braun 2013). Thus, people and communities, who are vulnerable to the effects of extreme weather now, will become more vulnerable in the future, and less resilient to climate shocks, in the case nothing is done in terms of development and adoption of appropriate adaptation strategies.

For the structural transformation of African agriculture, African farmers have to adopt strategies to mitigate the adverse impacts of climate change on their activities such as declining agricultural productivity. Indeed, the structural transformation of African agriculture can pass, among others, through increasing agricultural productivity in the midst of climate change. For instance, IPCC (2007) predicted that yields will fall up to 50% and crop revenue will fall by as much as 90% by 2100 in Africa. Moreover, agriculture losses of between 2-7% of GDP is expected in Sub-Saharan Africa, 2-4% and 0.4-1.3% in Western and Central Africa and in Northern and Southern Africa respectively [Food and Agriculture Organization (FAO) 2009a]. The main adaptation strategies adopted by farmers include crop diversification, changing planting dates, planting trees, planting quick-maturing crop variety, use of pesticides or fungicides, irrigation, mixed crop-livestock farming systems, income diversification (development of off-farm activities), soil and water conservation techniques (Okonya et al. 2013, Nhemachena et al. 2014). According to Kurukulasuriya and Mendelsohn (2008), farmers even make crop choice in regard to climate conditions.

However, all these adaptation strategies are not appropriate because leading to environmental degradation. Therefore, greater attention is thus being given to alternative models of intensification, in particular through sustainable land management technologies (Branca et al. 2013). Sustainable land management practices have the potential to generate private benefits for farmers, by improving soil fertility and structure, conserving soil and water, enhancing the activity and diversity of soil fauna, and strengthening the mechanisms of element cycling (Branca et al. 2013). Moreover, such practices can generate significant public environmental goods such as climate change mitigation, by reducing greenhouse gas emissions and increasing the removal of greenhouse gas through carbon sequestration (FAO 2009b, 2010; Branca et al. 2013). To combat poverty and environmental degradation sustainable agricultural development is very important (Antle and Diagana 2003).

Most of the recent papers have focused on adaptation strategies due to urgency of adaptation. However, all the adaptation strategies cannot be considered as sustainable land management practices. They focused on either perceptions or adaption (e.g., West et al. 2008; Mengistu 2011; Haden et al. 2012; Kisauzi et al. 2012; Moyo et al. 2012; Wiid and Ziervogel 2012; Maponya and Mpandeli 2013; Yegbemey et al. 2013; Nhemachena et al. 2014; Tanellari et al. 2014) or have linked farmers adaptation strategies to climate change perception (e.g., Maddison 2007; Gbetiboua 2009; Apata 2011; Okonya et al. 2013; Kansiime et al. 2014). The difference between these two categories of papers is that the first category ignores the two-stage process of adaptation. Indeed, adaptation process involves firstly perception stage and secondly adaptation decision. However, there is also a body of literature on adoption of sustainable land management practices (e.g., Ajayi et al. 2007; Asafu-Adjaye 2008; Kassie et al. 2009; Willy and Holm-Müller 2013). Branca et al. (2013) provided an important literature review on food security, climate change, and sustainable land management.

The previous recent papers concluded that farmers are most of the time aware about climate change, even though their awareness is not always consistent with historical climate records. Many factors such as gender and the education level of the household head, access to extension services and the number of relatives in a village are found to play an important role in the adaptation process. However, the findings of these studies are relatively local-specific, vary substantially across adaptation strategies, and it is hard to find studies that analyze the determinants of perception and adoption of adaptation strategies in the context of Benin. Moreover, as it is important to give up the previous model of intensification there is a need to undertake research on the adoption of sustainable land management practices.

Therefore, there is lack of research on both perception and adoption of sustainable land management practices in the context of Benin. Yegbemey et al. (2013) analyzed farmers' decisions to adapt to climate change under various property rights in Northern Benin, but have focused on maize producers and did not account for the two-stage process of adaptation. Moreover, Oyerinde et al. (2014) analyzed hydro-climatic changes in the Niger basin and consistency of local perceptions and have identified adaptation strategies adopted by farmers. Their identification of adaptation strategies is done through descriptive statistics and any further analyses have not been done.

This research aims to contribute in filling this gap by analyzing the determinants of farmers' perception and farm-level sustainable land management practices in the context of the Niger basin of Benin. Therefore, the specific objectives of this research are (i) to analyze farmers' perception about climate change; (ii) to analyze sustainable land management practices adopted by farmers to deal with the impacts of climate change in regard to their perception; and (iii) to find substitutability and complementarity between the various sustainable land management practices adopted by farmers. Based on the findings, policy implications will be drawn in order to strengthen the awareness of farmers of climate change and improve the adoption of appropriate technologies that will enable to increase agricultural productivity and to contribute to mitigating greenhouse gas emissions for the structural transformation of the agriculture. Indeed, SGDs can be achieved in economy in which agriculture has a great important through sustainable agriculture (Asafu-Adjaye 2008).

The remainder of this research is organized as follows. The next section is about the methods. Then, the results and discussion are presented. And finally, there is the conclusion.

2. Methods

2.1. Research field

The research focusses on farmers of the Niger basin of Benin. The Niger basin of Benin is located in the extreme north of the country and more specifically between latitudes 11° and 12°30’ N and longitudes 2° and 3°20’40 E and has an area of 43,313 km^2 out of the 114,763 square kilometers of Benin. It belongs to the watershed of the Middle Niger. The Niger River is the largest in West Africa (4,200 km of length and a watershed of 1,125,000 km^2). The Niger basin of Benin covers five agro-ecological zones (AEZs) (wholly and partially) out of the eight of the country. It belongs to Soudan savannah zone and has a unimodal rainfall pattern. The basin covers three departments out of the 12 of the countries; Alibori is wholly included in the basin while Borgou and Atacora are partially included. Farmers in the basin use mostly family labor, and rely relatively less on improved inputs, production methods and farm equipment. The state is the owner of land. However, the traditional ownership system is also respected. Basically, the first individual that settles claims its ownership and delimitates it, and each household is responsible for its land.

The historical climate records show an increasing trend in temperature in the Niger basin of Benin. According to United Nations Development Program (UNDP 2012), in Benin, mean annual temperature has increased by 1.1°C since 1960, with an average decadal increase rate of 0.24°C. The past climate data reveal that annual rainfall in Benin is highly variable on inter-annual and inter-decadal timescales (UNDP 2012). Thus, long-term trends are difficult to identify in annual rainfall patterns. According to UNDP (2012), even though there is no indication of a long-term trend in the annual rainfall record in Benin between 1960 and 2006, the record is punctuated by wetter and drier periods; rainfall decreased between the early 1960s and the 1980s, but has since recovered since this particular dry period (Figure 1). It has been noticed that the decrease is most consistent in April-May-June (AMJ) rainfall throughout the period 1960 to 2006 (Figure 2). Global Climate Models (GCMs) projections indicate that the mean annual temperature is projected to increase in Benin by 1.0 to 3.1°C by the 2060s, and 1.5 to 5.1°C by the 2090s, and the projected rate of warming is more rapid in the northern inland regions than the coastal regions (UNDP 2012). Furthermore, the proportion of total annual rainfall that falls in heavy events tends towards increases in the ensemble projections.

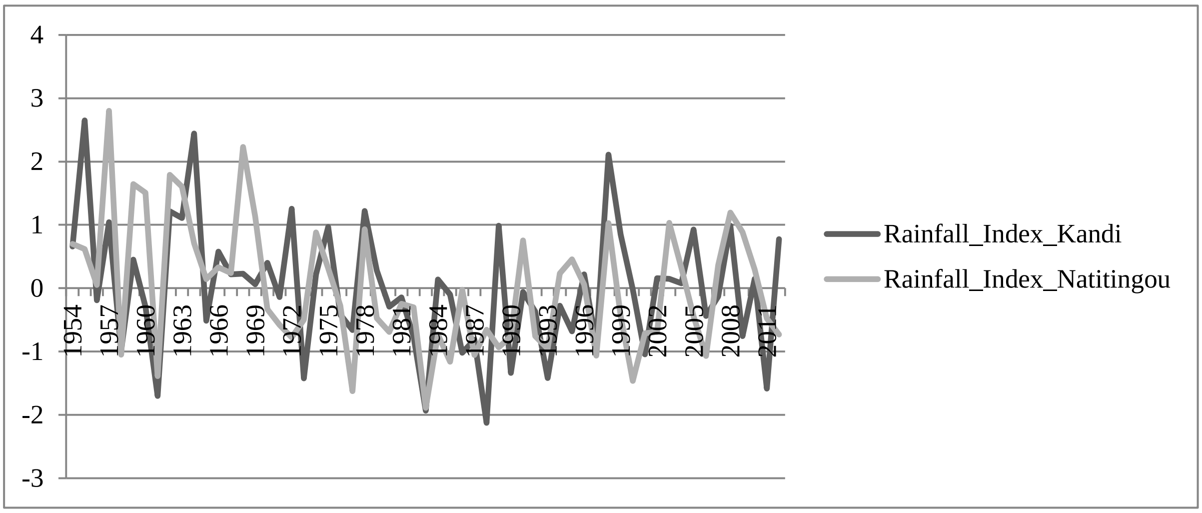

Figure 1. Rainfall index[1] evolution between 1954 and 2012 in Kandi and Natitingou

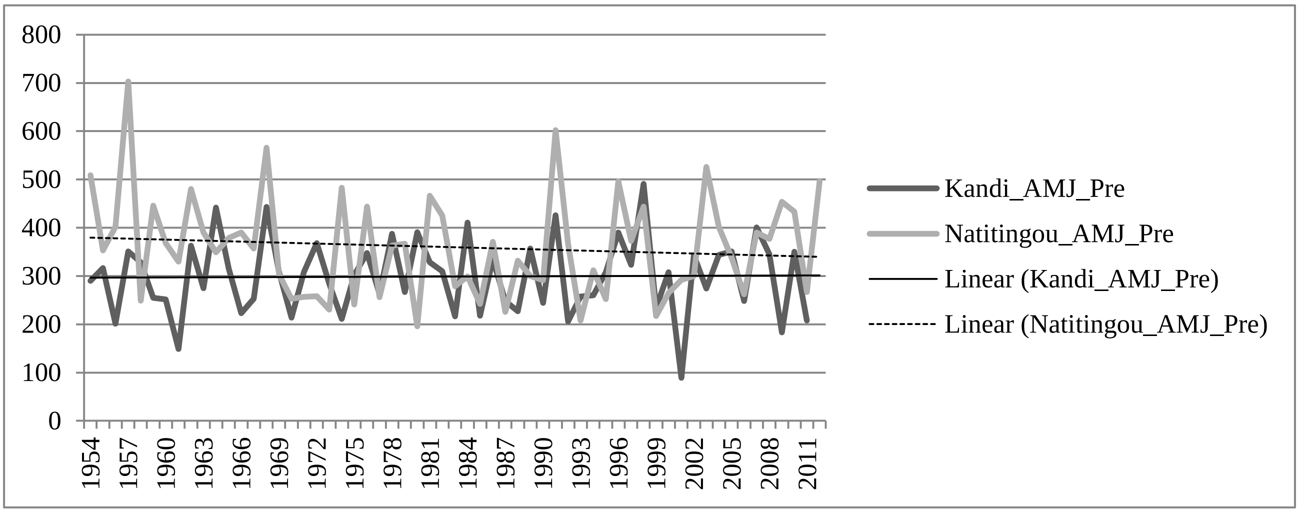

Figure 2. AMJ rainfall evolution between 1954 and 2012 in the Niger basin of Benin

2.2. Model

Adaptation to climate change is a two-stage process involving perception and adaptation stages. The first stage is whether the respondent perceives that climate change is occurring or not, and the second stage is the choice of adaptation strategies, conditional to the perception at the first stage. The choice of adaptation strategies is a sub-sample of the perception stage, and there is a possibility that this sub-sample is non-random, and differs from the sample of those that do not perceive climate change, and may be source of sample selection bias. Thus,

[1] $Rainfall\ index_t = \frac{Rainfall_t - Mean}{Standard\ deviation}$

a variant of the Heckman two-step procedure (Heckman 1976) is used to account for this two-stage process, due to its advantages over other models used in adaptation studies, such as multinomial logit, multinomial probit and multivariate probit models, as these models are not suitable for analyzing the two-step procedure of adaptation described above.

Thus, we have the following two equations:

$$y_i = x_i'\beta + \varepsilon_i \quad (4.1)$$

$$z_i^* = w_i'\gamma + \mu_i \quad (4.2)$$

$$z_i = \begin{cases} 1 & if\ z_i^* \geq 0 \\ 0 & otherwise \end{cases} \quad (4.3)$$

where x_i and w_i are vectors of explanatory variables, $z_i = 1$ if we observe y_i and 0 otherwise, and ε_i and μ_i are the error terms. The first stage of the Heckman sample selection model is the perception of climate change and this is the selection model (equation 4.2). The second stage, which is the outcome model (equation 4.1) is the choice of sustainable land management practices, conditional on the first stage that is the perception.

The outcome equation in the context of this research is a multivariate probit model in order to overcome the limitations of the univariate and multinomial discrete choice models. The multivariate probit model is characterized by a set of m binary dependent variables y_{ij} such that[2]:

$$y_{ij} = 1\ if\ x_i'\beta_j + \varepsilon_{ij} > 0,$$

$$= 0\ if\ x_i'\beta_j + \varepsilon_{ij} \leq 0, j = 1, 2, \dots, m. \qquad (4.4)$$

where x is a vector of explanatory variables, $\beta_1, \beta_2, \dots, \beta_m$ are conformable parameter vectors, and the random error terms $\varepsilon_{i1}, \varepsilon_{i2}, \dots, \varepsilon_{im}$ are distributed as multivariate normal distribution with zero means, unitary variance and $m \times m$ contemporaneous correlations matrix $R = [\rho_{jk}]$, with density $\phi(\varepsilon_{i1}, \varepsilon_{i2}, \dots, \varepsilon_{im}; R)$.

Micro-econometric analysis is usually associated with problems of heteroskedasticity and multicolinearity and the effect of outliers (Greene 2012). Multicolinearity among explanatory variables can yield imprecise parameter estimates. To detect potential multicolinearity among

[2] Refer to Nhemachena et al. (2014) and Cappellari and Jenkins (2003) for full details on the multivariate probit models.

the explanatory variables, the Variance Inflation Factor (VIF) is calculated for each of the explanatory variables. The VIFs ranges from 1.06 to 5.91 which does not reach the conventional threshold of 10 used in regression diagnosis. Therefore, multicolinearity does not appear to be a problem. To address the possibilities of heteroskedasticity in the model, a robust model that compute a robust variance estimator is estimated.

2.3. Variables

The dependent variables for the outcome equation are five binary variables characterizing the adoption of the sustainable land management practices: planting trees, stone bunds, less fertilizer application, crop rotations and intercropping with nitrogen-fixing crops such as beans, groundnut and soybeans. The dependent variable for the selection equation is whether farmer perceives climate change or not (It takes the value 1 if the farmer perceives at least a change in rainfall patterns or in temperature, and 0 otherwise.). Table 1 presents descriptive statistics of perception and the identified main sustainable land management practices.

Table 1. Perception of farmers and main farm-level sustainable land management practices

Variables	Percent
Perceive at least a change in temperature or in rainfall patterns	85.14
Planting trees	57.80
Stone bunds	8.07
Less fertilizer application	21.47
Crop rotations with nitrogen-fixing crops	31.56
Intercropping with nitrogen-fixing crops	09.72

Based on literature the independent variables are: education of household head, the size of the household, household head gender, livestock value, access to credit, non-irrigated farm size, distance to the nearest market, farming experience, access to extension services, social network (number of close friends, number of relatives within the village), asset value excluding land and livestock, access to electricity, having the major land as own land, having major land as family land, distance from dwelling to paved or tarred roads, having the major part of farm near a river/lake/stream, have used tractor, have used plow, being a subsistence farm household, membership of labor sharing groups, membership of farmers' organization, and have heard about climate change. A detailed description of the independent variables, their descriptive statistics, and their expected signs are presented in Table 2.

Table 2. Detailed description of the explanatory variables, their descriptive statistics and their expected signs

Variables	Description	Mean	Standard deviation	Minimum	Maximum	Expected signs[a]
Livestock asset value	In local currency	1,149,589	4,726,039	0	9.91e+07	+/-
Asset value excluding land and livestock	In local currency	309,505	440,833	0	4,770,000	+/-
Access to electricity	Dummy variable (1 if yes and 0 if no)	0.22	0.42	0	1	+
Major land is own land	Dummy variable (1 if yes and 0 if no)	0.69	0.46	0	1	+
Major land is family land	Dummy variable (1 if yes and 0 if no)	0.27	0.44	0	1	+
Household size	In number of persons	7.94	4.55	1	32	+/-
Male headed household	Dummy variable (1 if male and 0 if female)	0.97	0.18	0	1	+/-
Education level of household head in years	In number of validated years	1.69	3.18	0	15	+
Experience in farming	In years	22.71	15.02	2	80	+
Distance from dwelling to nearest market	In km	2.27	3.67	0.01	25	-
Distance from dwelling to paved or tarred roads	In km	11.06	18.42	0	150	+/-
Number of relatives	In number of persons	8.85	13.33	0	120	+/-
Number of close friends	In number of persons	2.74	2.83	0	30	+/-
Non-irrigated farm size	In ha	6.85	5.85	0	45	+/-
Have major part of farm near a river/lake/stream	Dummy variable (1 if yes and 0 if no)	0.41	0.49	0	1	+/-
Have used tractor	Dummy variable (1 if yes and 0 if no)	0.12	0.32	0	1	+
Have use plow	Dummy variable (1 if yes and 0 if no)	0.55	0.50	0	1	+
Subsistence	Dummy variable (1 if yes and 0 if no)	0.92	0.27	0	1	+/-
Access to extension services	Dummy variable (1 if yes and 0 if no)	0.38	0.48	0	1	+
Access to credit	Dummy variable (1 if yes and 0 if no)	0.16	0.36	0	1	+
Membership of labor sharing groups	Dummy variable (1 if yes and 0 if no)	0.24	0.43	0	1	+/-
Memberships of farmers' organization	Dummy variable (1 if yes and 0 if no)	0.36	0.48	0	1	+/-
Have heard about climate change	Dummy variable (1 if yes and 0 if no)	0.87	0.33	0	1	+

[a] The expected signs are relative to both perception and sustainable land management practices.

2.4. Data

This research used cross-sectional data from the farm household survey collected in 2013 in the Niger basin of Benin on 545 farm households[3]. It is the part of the dataset that included farmer perception of climate change, adaptation strategies adopted by farmers and perceived barriers to adapt to climate change that is used in this research. Climatic data (precipitation and temperature) come from the World Meteorological Organization (WMO) and the Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar (ASECNA).

3. Results and discussion

The findings of the perception stage are presented in Table 3. Livestock asset value of the farm households affects positively their perception of climate change, but the impact is not significant. Likewise, farm household asset value also affects positively but not significantly the perception of climate change. Rich farmers can have easily access to information through televisions and radios. Access to electricity is negatively and non-significantly associated with the perception of climate change. This result is not in line with the expectation. It may be due to the fact that farmers that have access to electricity do not use this access toward getting relevant climate information, ceteris paribus. Secure land tenure is positively associated with the perception of climate change. Indeed, the findings show that having major land as own land influences positively but not significantly the perception, whereas having family land is positively and significantly associated with perception. Therefore, securing land ownership will be beneficial in raising the awareness of farmers on climate change.

Large household size is negatively and significantly associated with perception of climate change. Indeed, each of the farm-household members may have different perceptions of climate change and this could lead the farm household to do not really perceive a trend in climate. Having a male household head decreases non-significantly the likelihood to perceive climate change. More the head of the household is educated higher is the likelihood to perceive climate change. Experience in farming affects positively and significantly perception of climate change. Indeed, well-educated and experienced farmers can easily detect a change in climate patterns. Distances from the dwellings to markets and to paved or tarred roads are negatively associated with perception of climate change. However, the result is significant for only distance from dwellings to markets. Remote farmers cannot have easily access to climate information in order to be able to detect changes in climate patterns.

[3] For more information on the survey method and data collected see Lokonon (2015).

Social capital variables are positively associated with perception. The number of relatives within the villages is positively and significantly associated with the perception of climate change. Although the number of close friends is positively associated with the perception, the effect is not significant. Farmers with strong social capital can easily have access to relevant information in terms of climate change. Non-irrigated farm size is negatively and non-significantly associated with the perception of climate change. Having the major part of the farm located near a river/lake/stream affects positively and non-significantly the likelihood to perceive climate change. Indeed, those that are close to a river/lake/stream can easily detect changes in climate conditions by looking at the level of water.

Table 3. Results of the perception equation (simple probit regression)

Variables	Coefficients	P-values
Livestock asset value	3.66e-08	0.292
Asset value excluding land and livestock	4.41e-07	0.216
Access to electricity	-0.192	0.284
Major land is own land	0.389	0.225
Major land is family land	1.148***	0.004
Household size	-0.035*	0.070
Male headed household	-0.031	0.950
Education level of household head in years	0.022	0.413
Experience in farming	0.021***	0.002
Distance from dwelling to nearest market	-0.035*	0.062
Distance from dwelling to paved or tarred roads	-0.002	0.680
Number of relatives	0.045*	0.068
Number of close friends	0.052	0.304
Non-irrigated farm size	-0.023	0.143
Have major part of land near a river/lake/stream	0.127	0.464
Have used tractor	1.241**	0.012
Have use plow	-0.471***	0.008
Subsistence	0.358	0.176
Access to extension services	-0.012	0.945
Access to credit	-0.324	0.111
Membership of labor sharing groups	-0.014	0.940
Membership of farmers' organization	0.425**	0.025
Have heard about climate change	-0.943**	0.011
Constant	0.769	0.272
Observations	545	
Log pseudolikelihood	-173.146	
Wald $\mathcal{X}^2(23)$	64.80	
$Prob > \mathcal{X}^2$	0.000	

***, **, * significant at 1, 5 and 10% respectively.

Tractor use affects positively and significantly the likelihood to perceive climate change, whereas plow use decreases this likelihood. Indeed, rich farmers use more technologies than the poor farmers, and due to their level of well-being, they can have better access to climate information than the poor. Subsistence farmers are found to perceive climate change more than the remaining farmers. However, the effect is not significant. Access to extension services and to credit are negatively and non-significantly associated with the perception of climate change. Membership of labor sharing group influences negatively and non-significantly the perception of climate change. However, membership of farmer organizations influences positively and significantly the perception of climate change. Hear about climate change affects negatively and significantly the perception of climate change. This means that the quality of climate information and/or the channels through which farmers received it is not good. Therefore, there is a need in a basin to provide relevant weather and climate information to farmers through appropriate channels.

This research estimated at the second stage a multivariate probit model and for comparison with a univariate probit model for each of the five sustainable land management practices. Results of the multivariate probit model of determinants of sustainable land management practices are presented in Table 4. The results of the correlation coefficients of the errors terms are significant for many pairs of equations indicating that they are correlated. They indicate that there are complementarities (positive correlation) between different sustainable land management practices being used by farmers. The findings support the assumption of interdependence between the different sustainable land management practices which may be due to complementary in the different practices, and also from omitted household-specific and other factors that affect uptake of all of them. It is worth noting that there are substantial differences in the estimated coefficients across equations that support the appropriateness of differentiating between sustainable land management practices.

The findings reveal that the following pairs of options are significantly complement: planting trees and stone bunds, planting trees and less fertilizer application, planting trees and crop rotations, planting trees and intercropping, stone bunds and less fertilizer application and crop rotations and intercropping. The joint use of any of these pairs of options leads to optimal performance of farm activities, and it is not optimal to use one without the other. A likelihood ratio test, based on the log-likelihood values of the multivariate and univariate models, indicate significant joint correlations $\mathcal{X}^2(10) = 27.0363$; $probabbility > \mathcal{X}^2 = 0.0026$ justifying estimation of the multivariate probit that considers different sustainable land management practices as opposed to separate univariate probit models, and consequently the unsuitability of aggregating them into one sustainable land management practice. The Inverse Mills Ratio coefficients are significant in two equations justifying the fact that it is included. Thus, the non-inclusion of the Inverse Mills Ratio will lead to biased results attributed to sample selection bias.

Male-headed farm-households are more non-significantly likely to take up planting trees, less fertilizer application, and intercropping. However, male-headed farm-households have non-significant low chances to take up stone bunds and crop rotation. These findings are relatively in line with those of Yegbemey et al. (2013). However, they are inconsistent with those of Willy and Holm-Müller (2013); they found that male-headed households are significantly more likely to take up soil conservation. Livestock asset value increases significantly the probability of uptake of stone bunds. It increases non-significantly the likelihood of uptake of crop rotations and intercropping, and decreases non-significantly the likelihood of uptake of the remaining practices. Indeed, Apata (2011) found that livestock ownership increases significantly the likelihood to adapt to climate change. Farmers with high livestock asset value are considered as mixed crop-livestock farmers and therefore, they are better able to cope with changes in climate patterns compare to specialized crops or livestock farmers (Nhemachena et al. 2014).

More the farm-households have asset less they are non-significantly willing to adapt to climate change through less fertilizer application and intercropping. However, the wealthiest farm-households are significantly willing to taking up planting trees, and non-significantly stone bunds and crop rotations. Indeed, farmers with more financial resources at their disposal are able to change their management practices to respond to climate change (Nhemachena et al. 2014). Access to electricity increases non-significantly the likelihood of taking up planting trees, less fertilizer application and crop rotations. Farmers with access to electricity have easily the opportunities to have access to information on adaptation through televisions and radios. However, it decreases non-significantly the probability of uptake of stone bunds and intercropping. Nhemachena et al. (2014) found that access to electricity increases the likelihood to take up adaptation strategies.

Having the major part of farm as own land increases significantly the likelihood to take up intercropping, and non-significantly planting trees and crop rotations. It decreases non-significantly the likelihood of taking up stone bunds and less fertilizer application. Indeed, private property increases the probability to take up adaptation strategies (Nhemachena et al. 2014). Likewise, having the major part of farm as family land increases significantly the likelihood to take up intercropping, and non-significantly stone bunds and less fertilizer application. However, it decreases significantly the probability of adapting through planting trees and non-significantly the likelihood of uptake crop rotations. Yegbemey et al. (2013) found that having inheritance land increases the probability to take up adaptation strategies.

These findings suggest that secure land tenure is positively associated with the likelihood to take up sustainable land management practices. Therefore, there is a need to secure land ownership, through enforcing laws, to strengthen the uptake of adaptation strategies in order to improve agricultural productivity and to contribute to mitigating the emissions of greenhouse gases.

Large farm-households have non-significant low chances of adapting through crop rotations. However, large farm-households have non-significant high chances of adapting through the remaining sustainable land management practices. The findings are relatively in line with those of Gbetibouo (2009). Farm-households with relatively well educated heads have significant high chances to take up crop rotations and intercropping and non-significant high chances to uptake less fertilizer application. However, they have non-significant low chances to take up planting trees and stone bunds. Indeed, Yegbemey et al. (2013) found negative and positive impacts of household head education level on the adoption of adaptation options.

Experienced farmers have non-significant high chances to adapt through stone bunds, less fertilizer application and crop rotations. However, they have non-significant low chances of uptake of planting trees and intercropping. These findings are not in line with those of previous papers such as Yegbemey et al. (2013) and Nhemachena et al. (2014). Experienced farmers are usually leading and progressive farmers in most rural communities and therefore, they can be targeted in promoting sustainable adaptation management to non-experienced farmers (Nhemachena et al. 2014).

High distance to the nearest market increases significantly the likelihood of uptake of less fertilizer application, and non-significantly the one to take up crop rotations and intercropping. However, it decreases significantly the likelihood of uptake stone bunds and non-significantly planting trees. This is relatively consistent with the results of Nhemachena et al. (2014). High distance to paved or tarred roads decreases significantly the probability of uptake of planting trees, stone bunds and crop rotations, and non-significantly the one to take up less fertilizer application. However, it increases non-significantly the likelihood to take up intercropping. Indeed, remote farmers lack access to relevant information on the sustainable land management practices.

Farmers with high number of relatives within the village have significant high chances of uptake of planting trees, and non-significant high chances to take up stone bunds and intercropping. However, they have non-significant low chances to take up less fertilizer application and crop rotations. Farmers with high number of close friends have significant low chances to take up planting trees, stone bunds and intercropping, and non-significant low chances of uptake of the remaining practices. Strong network is therefore relatively detrimental to uptake of sustainable land management practices. Willy and Holm-Müller (2013) found that social capital facilitates participation in collective action initiatives which then is beneficial for individual soil conservation efforts.

Farmers with high non-irrigated farm size have significant high chances to take up crop rotations, and non-significant high chances of uptake intercropping. However, they have significant low chances to take up stone bunds, and non-significant low chances of uptake of the remaining practices. Indeed, Gbetibouo (2009) found that farm size is positively associated with high likelihood to uptake adaptation strategies. Asafu-Adjaye (2008) and Willy and Holm-Müller (2013) found that farm size is significantly positively and negatively respectively associated with soil conservation efforts. Having the major part of the farm located near a river/lake/stream decreases significantly the likelihood to take up different planting dates, and non-significantly crop rotations. However, it increases non-significantly the probability of uptake of the remaining sustainable land management practices. Indeed, less the farm is close to the nearest river more farmers are significantly likely to take up soil conservation (Willy and Holm-Müller 2013)

Tractor use increases significantly the likelihood to take up stone bunds, less fertilizer application, crop rotations, and non-significantly planting trees. However, it decreases significantly the likelihood to take up intercropping. The findings are relatively in line with those of Nhemachena et al. (2014). Plow use increases significantly the probability to take up less fertilizer application, and non-significantly planting trees. However, it decreases non-significantly the probability to take up the remaining practices. Therefore, it is important to ensure the availability of cheap technologies to the farmers, especially small-scale farmers in order to significantly increase their use of other adaptation options (Nhemachena et al. 2014).

Subsistence farm households are more significantly likely to take up stone bunds, less fertilizer application and crop rotations and non-significantly planting trees and intercropping. The findings are consistent with those of Nhemachena et al. (2014). As they do not sell a part of their crops to the market, they are oblige to adapt to changes in climate conditions in order to be able to feed themselves.

Table 4. Results of the multivariate probit model

Variables	Plant trees	Stone bunds	Less fertilizer application	Rotations	Intercropping
Livestock asset value	-1.18e-09	2.62e-08**	-1.00e-08	1.77e-08	9.99e-09
Asset value excluding land and livestock	6.94e-07**	1.82e-07	-4.35e-09	1.57e-07	-1.65e-07
Access to electricity	0.179	-0.126	0.005	0.042	-0.051
Major land is own land	0.241	-0.171	-0.248	0.104	4.032***
Major land is family land	-0.664**	0.024	0.378	-0.111	3.811***
Household size	0.006	0.032	0.019	-0.022	0.011
Male headed household	0.109	-0.123	0.080	-0.205	0.367
Education level of household head in years	-0.033	-0.037	0.001	0.036*	0.049**
Experience in farming	-0.008	4.25e-05	0.002	0.004	-0.002
Distance from dwelling to nearest market	-0.010	-0.046*	0.062***	0.007	0.013
Distance from dwelling to paved or tarred roads	-0.016***	-0.005*	-0.002	-0.021***	0.005
Number of relatives	0.014**	0.009	-0.006	-0.009	0.004
Number of close friends	-0.080***	-0.151**	-0.038	-0.042	-0.057*
Non-irrigated land size	-0.022	-0.061***	-0.012	0.027**	0.019
Have major part of land near a river/lake/stream	-0.312**	0.079	0.166	-0.222	0.208
Have used tractor	0.242	1.123***	0.754***	0.526**	-0.619*
Have use plow	0.230	-0.044	0.336**	-0.019	-0.124
Subsistence	0.296	1.093***	1.372***	0.957***	0.422
Access to extension services	-0.069	-0.254	0.061	-0.187	-0.311
Access to credit	-0.211	-0.369	-0.100	-0.054	-0.101
Membership of labor sharing groups	0.358**	0.007	-0.159	0.331**	0.141
Memberships of farmers' organization	-0.122	0.483**	0.046	-0.056	-0.448**
Have heard about climate change	0.376*	-0.805***	0.645**	0.547**	-0.318
Inverse Mills ratio	-0.332	2.552***	1.289**	0.657	-0.271
Constant	-0.016	-1.951***	-3.530***	-2.714***	-5.614***
	Rho1	Rho2	Rho3	Rho4	Rho5
Rho2	0.182*				
Rho3	0.186**	0.182**			
Rho4	0.183**	0.033	0.090		
Rho5	0.99**	0.129	0.161	0.218**	
Observations = 545	Log pseudolikelihood = -1101.249	Wald $\mathcal{X}^2(120)$ = 1827.18	$Prob > \mathcal{X}^2$ = 0.000		

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: $\mathcal{X}^2(10) = 27.0363; probabbility > \mathcal{X}^2 = 0.0026$. *, **, *** Significant at 10, 5 and 1% respectively.

Access to extension services increases non-significantly the likelihood to take up less fertilizer application. However, it decreases non-significantly the likelihood to take up the remaining practices. Nhemachena (2014) and Yegbemey et al. (2013) found mixed results regarding the effect of extension services on the likelihood to take up adaptation options. Access to extension services is positively and non-significantly associated with soil conservation efforts (Willy and Holm-Müller 2013). Through extension officers, farmers have access to relatively relevant information in terms of appropriate adaptation options to be adopted. However, these findings suggest that the information extension officers give to farmers do not support the uptake of sustainable land management practices. Therefore, it is urgent to train extension officers on the relevance of sustainable land management practices. Access to credit decreases non-significantly the likelihood to take up the five identified sustainable land management practices. These findings are relatively similar to those of Yegbemey et al. (2013). Access to credit should increase the financial resources of farmers, and should enable them to take up sustainable land management practices. Indeed, more farmers have financial resources more they will be able to meet transaction costs associated with the various adaptation options they might want to take (Nhemachena et al. 2014). The findings are due to the fact that farmers in the basin have access to credit through cotton production, and therefore the credit system has to be redesigned.

Membership to labor sharing groups increases significantly the probability to take up planting trees and crop rotations, and non-significantly stone bunds and intercropping. However, it decreases non-significantly the probability to take up less fertilizer application. Membership to farmers' organizations increases significantly the likelihood to take up stone bunds, and non-significantly less fertilizer application. However, it decreases significantly the probability to take up intercropping, and non-significantly planting trees and crop rotations. Farmers have the opportunity to discuss among themselves in these groups, in terms of appropriate adaptation strategies including sustainable land management practices, to be adopted to cope with the impacts of climate change in their livelihoods. Therefore, policy-makers should encourage and promote membership to these groups.

Have heard about climate change increases significantly the likelihood to take up planting trees, less fertilizer application and crop rotations. However, it decreases significantly the probability to take up stone bunds and non-significantly intercropping. These findings are relatively in line with those of Gbetibouo (2009). Indeed, farmers that are aware about changes in climate conditions have higher chances of taking adaptation strategies

(Nhemachena et al. 2014), and their awareness is an important precondition to respond to climate change (Maddison 2007).

4. Conclusion

This research focused on the perception of farmers of climate change and the sustainable land management practices they adopted in response to changes in climate conditions. This research is important for the structural transformation of Sub-Saharan African agriculture in general and Benin agriculture in particular. The paper analyzed the determinants of farmers' perception of climate change and also those of five sustainable land management practices (planting trees, stone bunds, less fertilizer application, crop rotations and intercropping with nitrogen-fixing crops) using a variant of the Heckman two-step procedure (an univariate probit model at the first stage which is the perception and at the second stage a multivariate probit model). This modeling procedure allowed to take into account the two-stage process of adaptation to changing climatic conditions by accounting for the selection bias. Moreover, it allowed to simultaneously model the determinants of all the five sustainable land management practices and to explore the complementarities and substitutabilities among them.

The results of the correlation coefficients of the error terms indicate that there are complementarities (positive correlation) between different sustainable land management practices being used by farmers, although these findings could also be due to unobserved farm household socio-economic and other factors. The results of the estimations confirm that secure land tenure, distance to nearest market, tractor use, plow use, have heard about climate change and membership of farmers' organizations are some of the important determinants of perception of climate change farm-level sustainable land management practices. Designing policies that aim to improve these factors for the farmers have great potential to improve their adaptation to changing climate conditions and the mitigation of greenhouse gas emissions for the structural transformation of the agriculture. As all the sustainable land management practices adopted by farmers may not be efficient, future research could assess their effectiveness in mitigating the adverse impacts of climate change on agriculture.

References

Ajayi OC, Akinnifesi FK, Sileshi G & Chakeredza, 2007. Adoption of renewable soil fertility replenishment technologies in the southern African region: Lessons learnt and the way forward. Natural Resources Forum 31(2007): 306-317.

Antle JM & Diagana B, 2003. Creating Incentives for the Adoption of Sustainable Agricultural Practices in Developing Countries: The Role of Soil Carbon Sequestration. American Journal of Agricultural Economics 85(5): 1178-1184.

Apata TG, 2011. Factors influencing the perception and choice of adaptation measures to climate change among farmers in Nigeria. Evidence from farm households in Southwest Nigeria. Environmental Economics 2(4): 74-83.

Asafu-Adjaye J, 2008. Factors Affecting the Adoption of Soil Conservation Measures: A Case Study of Fijian Cane Farmers. Journal of Agricultural and Resource Economics 33(1): 99-117.

Branca G, Lipper L, McCarthy N & Jolejole MC, 2013. Food security, climate change, and sustainable land management. A review. Agronomy for Sustainable Development DOI 10.1007/s13593-013-0133-1.

Callo-Concha D, Gaiser T, Webber H, Tischbein B, Müller M & Ewert F, 2013. Farming in the West African Sudan Savanna: Insights in the context of climate change. African Journal of Agricultural Research 8(38): 4693-4705.

Cappellari L & Jenkins SP, 2003. Multivariate probit regression using simulated maximum likelihood. The Stata Journal 3(3): 278-294.

Di Falco S & Veronesi M, 2012. How African Agriculture Can Adapt to Climate Change? A Counterfactual Analysis from Ethiopia. Working Paper Series, No 14, Department of Economics, University of Verona.

ECOWAS, 2009. Regional Partnership Compact for the Implementation of ECOWAP/CAADP.

FAO, 2009a. Climate change in Africa: The threat to agriculture. Food and Agricultural Organization of the United Nations, Rome. Regional Office for Africa.

FAO, 2009b. Food security and agricultural in developing countries: options for capturing synergies. Food and Agricultural Organization of the United Nations, Rome.

FAO, 2010. “Climate-smart” agriculture. Policies, practices and financing for food security, adaptation and mitigation. Food and Agricultural Organization of the United Nations, Rome.

Gbetibouo AG, 2009. Understanding Farmers’ Perceptions and Adaptations to Climate Change and Variability. IFPRI Discussion Paper 00849.

Greene WH, 2012. Econometric Analysis. Seventh Edition, Prentice Hall.

Haden VR, Niles MT, Lubell M, Perlman J & Jackson LE, 2012. Global and Local Concerns: What Attitudes and Beliefs Motivate Farmers to Mitigate and Adapt to Climate Change? PLoS ONE 7(12).

Heckman JJ, 1976. The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. Annals of Economic and Social Measurement 5(4): 475-492.

IPCC, 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker TF, D Qin, GK Plattner, M Tignor, SK Allen, J Boschung, A Nauels, Y Xia, V Bex & PM Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press. 976 pp.

Kansiime KM, Wambugu SK & Shisanya CA, 2014. Determinants of Farmers' Decisions to Adopt Adaptation Technologies in Eastern Uganda. Journal of Economics and Sustainable Development 5(3): 189-199.

Kassie M, Zikhali P, Manjur K & Edwards S, 2009. Adoption of Organic Farming Techniques: Evidence from a Semi-Arid Region of Ethiopia. Environment for Development Discussion Paper Series, EfD DP 09-01.

Kisauzi T, Mangheni MN, Sseguya H & Bashaasha B, 2012. Gender Dimensions of Farmers' Perceptions and Knowledge on Climate Change in Teso Sub-Region, Eastern Uganda. African Crop Science Journal 20(s2): 275-286.

Kurukulasuriya P & Mendelsohn R, 2008. Crop switching as a strategy for adapting to climate change. African Journal of Agricultural and Resource Economics 2(1): 105-125.

Lokonon KOB, 2015. Farmers and Communities Vulnerability and Resilience to Climate Shocks and Adaptation Policy Responses in the Niger Basin of Benin. Ph.D Dissertation. Université Cheikh Anta Diop de Dakar.

Maddison D, 2007. The perception of and adaptation to climate change in Africa. Policy Research Working Paper No 4308. The World Bank.

Maponya P & Mpandeli S, 2013. Perception of Farmers on Climate Change and Adaptation in Limpopo Province of South Africa. J Hum Ecol 2(3): 283-288.

Mengistu DK, 2011. Farmers' perception and knowledge of climate change and their coping strategies to the related hazards: Case study from Adiha, central Tigray, Ethiopia. Agricultural Sciences 2(2): 138-145.

Moyo M, Mvumi BM, Kunzekweguta M, Mazvimavi K, Craufurd P & Dorward P, 2012. Farmer Perceptions on Climate Change and Variability in Semi-Arid Zimbabwe in Relation to Climatology Evidence. African Crop Science Journal 20(s2): 317-335.

Nhemachena C, Hassan R & Chakwizira J, 2014. Analysis of determinants of farm-level adaptation measures to climate change in Southern Africa. Journal of Development and Agricultural Economics 6(5): 232-241.

Ogalleh SA, Vogl CR, Eitzinger J & Hauser M, 2012. Local Perceptions and Responses to Climate Change and Variability: The Case of Laikipia District, Kenya. Sustainability 4: 3302-3325.

Okonya JS, Syndikus K & Kroschel J, 2013. Farmers' Perception of and Coping Strategies to Climate Change: Evidence From Six Agro-Ecological Zones of Uganda. Journal of Agricultural Science 5(8): 252-263.

Oyerinde GT, Hountondji FCC, Wisser D, Diekkruger B, Lawin AE, Odofin AJ, and Afouda A, 2014. Hydro-climatic changes in the Niger Basin and consistency of local perceptions. Regional Environmental Change. DOI 10.1007/s10113-014-0716-7.

Roudier P, Sultan B, Quirion P & Berg A, 2011. The impact of future climate change on West African crop yields: What does the recent literature say? Global Environmental Change 21: 1073-1083.

Tanellari E, Kostandini G, Bonabana-Wabi J & Murray A, 2014. Gender impacts on adoption of new technologies: the case of improved groundnut varieties in Uganda. African Journal of Agricultural and Resource Economics 9(4): 300-308.

UNDP, 2012. Climate Change Country Profiles. Benin.lowres.report.pdf. http://country-profiles.geog.ox.ac.uk (Accessed 08/22/2012).

West CT, Roncoli C & Ouattara F, 2008. Local perceptions and regional climate trends on the Central Plateau of Burkina Faso. Land Degradation & Development 19: 289-304.

Wheeler T & von Braun J, 2013. Climate Change Impacts on Global Food Security. Natural Systems in Changing Climates 341: 508-513.

Wiid N & Ziervogel G, 2012. Adapting to climate change in South Africa: commercial farmers' perception of and response to changing climate. South African Geographical Journal 94(2): 152-173.

Willy DK & Holm-Müller K, 2013. Social influence and collective action effects on farm level soil conservation effort in rural Kenya. Ecological Economics 90(2013): 94-103.

Yegbemey RN, Yabi JA, Tovignan SD, Gantoli G & Kokoye SHE, 2013. Farmers' decisions to adapt to climate change under various property rights: A case study of maize farming in northern Benin (West Africa). Land Use Policy 34: 168-175.