Journal of Agricultural Science; Vol. 8, No. 8; 2016
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Drivers of Multiple Cropping-Systems as Adaptive Strategy to Climate Change in Central-Benin (West Africa)

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Received: May 16, 2016 Accepted: July 1, 2016 Online Published: July 15, 2016

doi:10.5539/jas.v8n8p48 URL: http://dx.doi.org/10.5539/jas.v8n8p48

Abstract

Climate change is currently one of the most important global environmental issues that negatively affect agriculture in Sub-Saharan Africa. This importance has resulted in a great interest to understand both the farmers' perception of and adaptation to observed climate change. A good number of previous studies did explicitly focus on several adaptation strategies. Nevertheless, a better understanding of the socio-economic drivers underlying specific adaptive measures to climate change is crucial to inform specific adaptation components that will fall into a wider adaptation plan. In this respect, the present study focuses on the use of multiple cropping systems consisting of growing two or more crops on the same field either at the same time or one after another as climate change adaptation strategy. Accordingly, this paper examines different strategies commonly used to intensify agricultural production in tropical agriculture. These include crop rotation and association in the center of Benin.

Data were collected in central Benin through interviews with 80 farmers selected by using a multistage random sampling technique. Data analysis was carried-out by using descriptive statistics and a Probit regression. The results showed that the major drivers of multiple cropping systems as adaptive strategy to climate change include contacts with extension services, education level, and farm size. Major constraints to the use of multiple cropping systems are gender, adult literacy, perception of adaptation to climate change, experience with climate change impacts, and farmer location. Policy options should include, among others, production of information related to impacts of climate change and their dissemination through formal services such as extension services; identification of potential ways to greatly improve returns on extra agricultural activities, and investigating on the effects of past adoption strategies on the different cropping systems.

Keywords: climate change, multiple cropping systems, adaptation, Benin

1. Introduction

Agriculture plays a significant role in the economic development of most developing countries because of its relatively high contribution to the Gross Domestic Product (GDP), and foreign exchange earnings. It is an important source of employment and provides food and income, especially for rural populations (World Bank, 2013). However agricultural production in most of these countries is dominated by a large proportion of smallholder farmers, with (very) low productivity. Very often, these farmers have limited access to the required resources and technology to improving their agricultural productivity (Breman, 1996; Murphy, 2010). Furthermore, their production systems are mostly rainfed and therefore, highly dependent on weather hazards such as climate change. Characterized by long term variabilities of temperature and rainfalls (IPCC, 2007; Tadross et al., 2005), climate change, is of an increasingly economic concern over the past thirty years (Holman et al., 2008). With respect to agriculture, climate change is argued to be one of the major factors responsible for lower productivities because of its contribution to soil fertility degradation and increased crop infestation by pests and diseases (Deressa et al., 2011; Müller et al., 2011).

Many studies have reported how farmers perceive and adapt to climate change. Some indicated that farmers are conscious of climate change and its harmful impacts, and subsequently adopt different coping strategies (Thomas et al., 2007; Ishaya & Abaje, 2008; Mertz et al., 2009; Nouatin et al., 2014; Yegbemey et al., 2014). Others investigated different socio-economic and environmental factors that may drive farmers' adaptive measures to climate change (Semenza et al., 2008; Sampei & Aoyagi-Usui, 2009; Akter & Bennett, 2011). From a comprehensive perspective, adaptation strategies commonly used by farmers include among others adoption of different crop varieties, multiple or double sowing, multiple cropping, use of manure, use of fertilizers, etc. (e.g., Mertz et al., 2009; Nouatin et al., 2014).

Multiple cropping systems, which consist of growing two or more crops on the same field either at the same time or one after another (Francis, 1986; Norman et al., 1995), are production intensification strategies commonly used in tropical agriculture. Such cropping systems have the advantage of lowering the risk of complete crop failure, thus ensuring high level of production stability for farmers (Francis, 1986). Adequate cropping systems, especially in areas that are highly affected by the impacts of climate change, are perceived as an important adaptation strategy (O´Brien et al., 2000; Thomas et al., 2007). Waha et al. (2013) showed that mean crop yields in sequential cropping systems were greater than mean crop yields in single cropping systems, suggesting that sequential cropping systems contribute to minimizing climate change impacts compared to single cropping systems.

In Benin, number of previous studies examined the farmers' adaptation strategies to climate change (Ozer et al., 2013; Vissoh et al., 2013; Yegbemey et al., 2013, 2014; Padonou et al., 2015; Tovihoudji et al., 2015). Yegbemey et al. (2013), for instance, used a simultaneous modelling approach based on a Multivariate Probit model to examine factors determining farmers' decisions to adapt to climate change. Vissoh et al. (2013) studied farmers' perceptions of climate change and the adaptation strategies developed by them. Intensification of agricultural production through adoption of improved varieties with shorter growing cycle, the use of fertilizers, and income diversifying activities are the adaptation strategies identified in their study. Whereas these studies are very useful to better understanding the potential strategies towards climate change adaptation in Benin, they cover a broad range of adaptation alternatives. As a result there is still paucity of information on how specific adaptation options are developed and most importantly selected by farmers. For instance, it is not clear whether multiple cropping systems are widespread, and which factors drive their adoption. Against this backdrop, the present study focuses on multiple cropping systems as a climate change adaptation. In that respect, it also explores major factors that may drive the farmers' decision to adopt multiple cropping systems in central Benin. The expected results will be useful as they can inform policy-makers and development organizations working to build farmers' resilience to climate change. In this study we assumed that different socio-economic and environmental factors affect the farmers' adaptation behaviors and thus the choice of a given cropping system. This assumption was tested by using data obtained from a household survey on a sample of 80 farmers in central Benin.

2. Materials and Methods

2.1 Study Area and Data Base

The study was conducted in the municipal area of Ouessè, central Benin (Figure 1). Ouessè benefits from an intermediary climate between the semi-arid climate of the northern and the sub humid climate of the southern parts of Benin. The mean annual rainfall varies between 1,100 and 1,200 mm. Agriculture in the area is mostly rainfed. The prevailing farming systems are intensified mixed crops, especially cotton-based and traditional production systems with cereals (e.g. maize, and lowland rice), pulses (e.g., peanut and bambara nut) and tubers (e.g., cassava and yam). Crops rotation and association are the most observed cultural practices. The common rotation systems are (1) cassava-maize-peanut, (2) cassava-maize-bambara nut/soybean-peanut, (3) maize-peanut -cotton-Bambara nut/soybean-maize/cassava, (4) maize-peanut, (5) maize-peanut-bambara nut, and (6) peanut-maize-cotton. Association of crops is also frequent. The frequently observed associations are cassava-bambara nut, maize-peanut, cassava-peanut, cassava-maize, maize-sorghum, and cassava-yam.

Over the last two decades, the area has showed a high tendency towards less rainfall and one rainy season per year (instead of two), resulting in high drought risk. To adapt to these changes, famers adopt different agricultural intensification strategies, including multiple cropping systems.

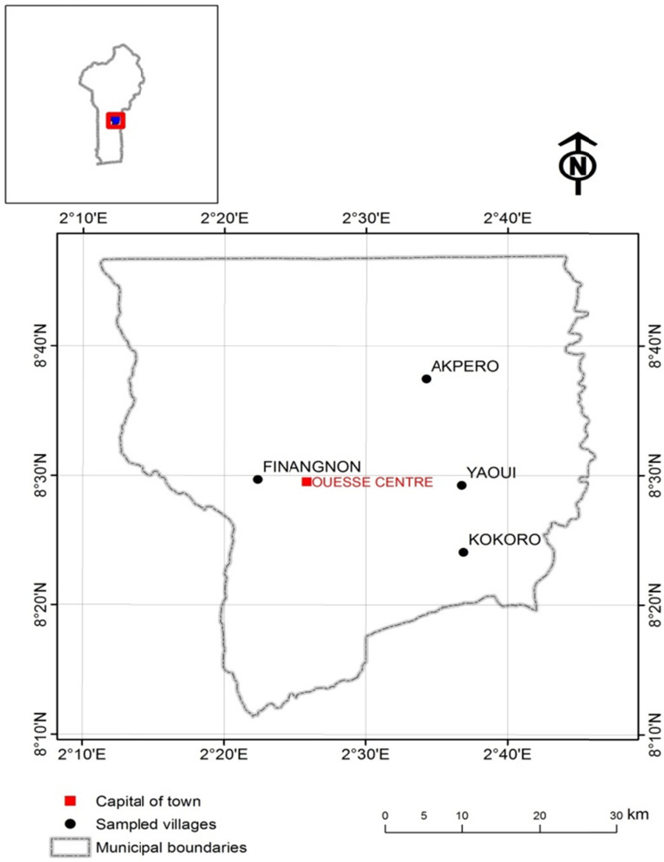

Figure 1. Study area

Information was collected from secondary data sources through desk research and primary data sources through interviews with farmers in central Benin. Secondary sources include articles, research reports, working papers and documents related to the studied subject. Quantitative primary data were obtained from a cross-sectional household survey on a sample of 80 farmers. Data concerned the 2014/15 production year. These data were completed by qualitative data obtained through focus group discussions with the selected farmers.

In the municipal area of Ouessè, villages were purposely selected with respect to the production of different crops encountered in the main rotation and association systems, and the accessibility of the locations. Within each selected village, a random sampling technique was used to select farmers based on the lists of farmers provided by the agricultural extension officers. Fifteen to twenty farmers were randomly selected from the list in each village. Main information collected during the survey is different socioeconomic characteristics of the respondents, their perceptions of climate change and their adaptation strategies.

Focus-group discussions were organized to collect qualitative information on the farming systems and to gain a more holistic view of the study area in terms of climate-related issues as well as constraints (biophysical as well as socio-economic constraints) farmers are faced with. Two main criteria were used by farmers: presence of cassava in the cropping system of the main rainy season, and presence of cotton in a cropping system of the short rainy season. The combination of these two criteria led to four groups of farming system (system 1) presence of cassava in the cropping system of the main rainy season, and absence of cotton from the cropping system of the short rainy season; (system 2) presence of cassava in the cropping system of the main rainy season, and presence of cotton in the cropping system of the short rainy season; (system 3) absence of cassava from the cropping system of the main rainy season, and absence of cotton from the cropping system of the short rainy season; and (system 4) absence of cassava from the cropping system of the main rainy season, and presence of cotton in the cropping system of the short rainy season (Table 1). In addition to the combination of the two criteria, the categorization of farming systems also included rotation and association of crops. System 1 has a 3-year rotation of cassava-maize-peanut for the cropping system of the main rainy season. In such a system, maize comes first with the average farm size of 3.9 ha. Cassava represents the second crop in the system with the average farm size of 3.19 ha. Peanut in this system is produced on only 1.7 ha on average. Cowpea and/or soybean are sometimes also produced in association with the aforementioned crops, i.e. maize and cassava. During the short rainy season, the rotation is as follows: peanut-soybean-maize, with average farm size of 3.7 ha, 2.6 ha and 2.19 ha respectively.

System 2 has a 4-year rotation during the main rainy season, constituted of cassava-maize-bambara nut-peanut, with average farm size of 1.79 ha, 1.8 ha, 0.8 ha, and 0.8 ha, respectively. Soybean is sometimes produced in lieu et place of bambara nut. Peanut comes first in the cropping systems during the short rainy season, followed by maize, cotton, and cassava. The farm size for these crops is 3.67 ha, 1.17 ha, 1.5 ha, and 0.65 ha, respectively. Like in system 1, the widely encountered associations are cassava/peanut, cassava/maize, cassava/bambara nut,

As for the identified third system (system 3), neither cassava nor cotton is part of the cropping systems. Maize and peanut are the main crops that farmers generally produce during the two rainy seasons. The average farm sizes for maize are 2.35 ha and 1.25 ha for the main rainy season and the short rainy season, respectively; while those of peanut are 0.9 ha during the main rainy season, and 3.5 ha during the short rainy season. In addition to these two main crops, other crops such as cassava, bambara nut, yam, and soybean are also produced, but on a very small farm size.

System 4 is characterized by the cropping rotation of maize (average farm size of 3.7 ha)-peanut (average farm size of 0.9 ha)-bambara nut (average farm size of 0.5 ha) for the main rainy season, while the predominantly observed rotation in the short rainy season is peanut (average farm size of 3.5 ha)-maize (average farm size of 1.12 ha)-cotton (average farm size of 1.5 ha). In addition, soybean is sometimes produced during the main rainy season on the average farm size of 0.5 ha, and cowpea and bambara nut during the short rainy season on the average farm sizes of 0.3 ha and 0.75 ha, respectively.

Table 1. Characteristics of the main cropping systems

System	The main crop rotations		Crop associations	Crop rotations commonly observed
	Main rainy season	Short rainy season		
1	Cassava (3.19)-maize (3.9)-peanut (1.7)	Peanut (3.7)-Soybean (2.6)-maize (2.19)	Cassava/maize Cassava/peanut Cassava/yam	Cassava-Maize or Peanut-bambara nut or Soybean-Cotton Maize-Cassava or Peanut-Cassava-Cotton-Maize Peanut-Maize-Soybean or bambara nut-Cassava
	Cowpea (0.8)-Soybean (0.75)	Cassava (1.9)-bambara nut (1)-Cowpea (0.6)		Cowpea or bambara nut-Maize or Peanut-Cassava
2	Cassava (1.79)-maize (1.8)-bambara nut (0.8)	Peanut (3.67)-maize (1.17)-Cotton (1.4)	Cassava/peanut Cassava/maize	Cassava-Maize or Peanut-Cotton-Maize-Cassava Cassava-Cowpea or bambara nut-(Maize-Soybean-Maize) or-(Maize-Cassava)
	Peanut (0.8)-Cowpea (0.7)	Cowpea (0.6)-Cassava (1)-Soybean (1.5)		Maize-Peanut or Cotton-Cassava Maize-Cowpea or Soybean-Cassava Peanut-Maize or Cotton-Maize-bambara nut or Cowpea-Peanut Cotton-Maize, Peanut or Soybean-Cassava Cotton-Soybean-Maize-Cowpea or Soybean Yam-Maize-Cotton-Maize, Peanut-Cassava, Soybean
3	Maize (2.35)-peanut (1.25)-bambara nut (1)	Maize (1.3)-Peanut (1.2)-Soybean (1)	Cassava/peanut maize/sorghum maize/peanut	Maize-Peanut or Soybean-Cassava, Peanut-Maize Peanut-Maize-Soybean or sorghum-Maize Yam or Soybean-Maize-Peanut associated with Cassava
	Soybean (0.75)-Cowpea (0.75)			
4	Maize (3.7)-peanut (0.9)-bambara nut (0.5)	Maize (1.12)-Peanut (3.5)-Cotton (1.5)	Cassava-bambara nut Maize/peanut Cassava/peanut	Cassava or Maize-Peanut or Cotton-Cowpea or Soybean Peanut-Maize-Cassava, Peanut or Cotton-Maize, bambara nut or Cassava
	Soybean (0.5)	Cowpea (0.3)-bambara nut (0.75)		Cotton-Maize or Peanut-Soybean-Maize Soybean or Cowpea-or encore bambara nut-Maize or Peanut-Cotton-Maize-Cassava

2.2 Empirical Model Used in Data Analysis

Data collected through focus group discussions were analyzed using content analysis to understand the different cropping systems in the study area, and identify the major ones. In addition, descriptive statistics were computed to characterize the surveyed sample. The dependent variable (y_i) represented each of the four identified cropping systems. It takes the values 0 (No) or 1 (Yes). Subsequently a Probit regression was estimated to identify and analyze the drivers underlying the farmers' decision to adopt a given cropping system as an adaptation method to climate change.

Adaptation to climate change follows the (probable) perception of climate change. Thus, adaptation would likely be a non-random phenomenon and as such could be subject to selection bias (e.g., Deressa *et al.*, 2011). In this study, all the respondents perceived climate change impacts; although the perceived impacts may differ from one farmer to another. This figure suggests that adaptation processes in the present study is likely a random process, and that a sample selection bias is likely not to be an issue. Therefore, a one-step maximum likelihood estimation procedure was used through a Probit model.

The theoretical foundation of Probit model assumes that there exists an underlying relationship which consists of the latent equation given by:

$$y_i^* = x_i \beta_i + \varepsilon_i \quad (1)$$

Where (y_i^*) represents whether a farmer adopts or does not adopt a given cropping system as an adaptive response to climate change, x_i is a vector of observable factors that affect the farmers' decision to adopt any cropping systems, and ε_i is the error term. The observed dependent variable (y_i) depends on some value of a latent variable modeled in Equation (1).

With the decision to adopt any cropping system to adapt to climate change impacts given by $y_i = 1$ and $y_i = 0$ otherwise, the observed variable (adoption of any identified cropping systems) is explained as:

$$y_i = \begin{cases} 1, if \ y_i^* > 0 \\ 0, if \ y_i^* \leq 0 \end{cases} \quad (2)$$

A standard probit model is set up as follows:

$$P(y_i = 1) = P(x_i'\beta_i + \varepsilon_i > 0) = P(\varepsilon_i > -x_i'\beta_i) = P(\varepsilon_i < x_i'\beta_i) = \Phi(x_i'\beta_i) \quad (3)$$

Where, $\Phi(.)$ is the cumulative distribution function with an error term that is independent and normally distributed. Data were analyzed by using STATA.

The explanatory variables are selected from the wide literature on climate change adaptation and based on data availability as well. These variables include: gender of the farmer, secondary activity, education of the farmer, literacy of the farmer, non-farm income, member of an association, age of the farmer, household size, number of children in the household, years of experience in agricultural production, the available farm size, perception of climate change, have experience climate change impacts, adaptation to climate change, and contact with extension services. Table 2 summarizes the variables used in the Probit model.

Table 2. Codes, names, modalities and expected signs of variables used in the model

Codes	Names of variable	Modalities	Expected signs
NZON	Farmer's location	Dummy: takes the value of 1 if farmer lives in *Nago* zone, 0 if farmer lives in *Mahi* zone	+/-
NSEX	Sex of the farmer	Dummy: takes the value of 1 for male; 0 otherwise	+
PSECON	Secondary occupation	Dummy: takes the value of 1 if farmer has a secondary occupation, 0 otherwise	-
INSTRU	Education level of the household head	Dummy: takes the value of 1 if the farmer received a formal education; 0 otherwise	+/-
ALPHA	Adult literacy	Dummy: takes the value of 1 if farmer has literacy in local languages, 0 otherwise	+/-
EXTRA	Non-agricultural income-generating activities	Dummy: takes the value of 1 if farmer has a non-agricultural income-generating activity, 0 otherwise	+/-
ASSO	Member of at least one farmers' association	Dummy: takes the value of 1 if farmer is a member of at least one farmers' association, 0 otherwise	+/-
SUPTOT	Total available farming area	Continuous: Hectare	+/-
INDCLIM	Perception of climate change	Dummy: takes the value of 1 if farmer has good perception of climate change, 0 otherwise.	+/-
CONSCLIM	Have experienced climate change impacts	Dummy: takes the value of 1 if perceived, and 0 otherwise	+/-
ADAPCLIM	Perception of adaptation to climate change	Dummy: takes the value of 1 if perceived as an adaption option to climate change and 0 otherwise	+/-
CONTACT	Number of contacts with extension agents/year	Continuous: Number	+/-

3. Results and Discussion

The descriptive statistics revealed that majority of the interviewed farmers were males (75 per cent). The average age of the farmers was 41 years ±13.55, with 41 years ±14.16 and 42 years ±11.83 for men and women respectively. About 41 per cent of the farmers interviewed had formal education, and about 26 per cent had literacy in mother tongues. About 85 per cent and 29 per cent of the farmers had secondary activities and extra agricultural activities, respectively (Table 3).

Table 3. Descriptive statistics of the variables introduced in the model

Qualitative Variables	**Absolute frequencies**	**Relative frequencies (%)**
Sex of the farmer (Men)	60	75
Farmer living in Nago zone	39	49
Farmer with formal education	33	41
Farmer with literacy in local language	21	26
Farmer with secondary occupation	68	85
Farmer with off-farm activities	23	29
Member of at least one farmers' association	56	70
Farmer having a perception of climate change	44	58
Farmer having experience with climate change impacts	33	43
Farmer having a perception of an adaptation strategy to climate change.	61	81
Quantitative Variables	**Means**	**Standard deviation**
Age (all farmers)	41	13.55
Age (Men)	41	14.16
Age (Women)	42	11.83
Total available area (ha)	11.86	9.64
Number of contacts with extension agents per year	3	5

The average available farm size was 11.46 ha ±9.64, whereas the average farm size exploited during the 2014-2015 cropping season is 4.26 ha ±3.32 for males (5.43 ha ±4.21 during the main rainy season and 3.08 ha ±2.84 during the short rainy season), and 1.94 ha for females (2.79 ha ±1.72 during the main rainy season and 1.09 ha ±0.78 during the short rainy season).

After claiming to have perceived changes in climate and observing negative impacts of these changes on their farm productivity, farmers interviewed were subsequently asked if they have developed any adaptation strategy. To mitigate the negative impacts of climate change, farmers use some agronomic practices, including crop associations and rotations which were grouped into four different systems as described above. The partial correlation coefficients showed that all the estimated models have no problems of multi-correlations between the explanatory variables. The Probit model was run, its goodness of fit was tested as well.

The results showed that the likelihood functions of the four models were all significant at $p = 0.05$, $p = 0.10$, $p = 0.05$, and $p = 0.01$ for the systems 1, 2, 3, and 4 respectively. This indicates that the null hypothesis that all the coefficients for that explanatory variables in each model are jointly equal to zero is rejected (Table 4). The pseudo R^2 in the estimated models are 0.33, 0.34, 0.58, and 0.55 respectively. These values imply that the sample variations of about 33 per cent for the cropping system 1, 34 per cent for the cropping system 2, 58 per cent for the cropping system 3 and 55 per cent were accounted for by the explanatory variables investigated.

Table 4. Results of the probit models

Variables	System 1	System 2	System 3	System 4
Farmer' location	-1.43 * (0.57)	0.75 NS (0.48)	-	-0.61 NS (0.49)
Sex of the farmer	-	0.9 NS (0.58)	-	-3.62 ** (1.08)
Secondary occupation	-0.70 NS (0.47)	2.3 ** (0.57)	-1.86 NS (1.22)	-3.62 * (0.57)
Education level of the household head	0.34 NS (0.49)	-0.42 NS (0.52)	4.16** (1.47)	0.72 NS (0.65)
Adult literacy	-0.68 NS (0.51)	0.35 NS (0.53)	-3.58* (1.65)	0.35 NS (0.49)
Non-agricultural income-generating activities	0.21 NS (0.6)	-1.34 * (0.54)	-	1.19 * (0.65)
Member of at least one farmers' association	-0.1 NS (0.58)	-0.69 NS (0.54)	-1.95** (0.97)	2.46** (0.80)
Total available farm area	0.74 NS (0.58)	0.94 NS (0.43)	0.02** (1.49)	2.11 * (0.45)
Perception of adaptation to climate change	-0.138 NS (0.72)	0.89 NS (0.55)	0.82 NS (1.08)	-1.63 * (0.76)
Perception of climate change	0.44 NS (0.58)	-0.91 * (0.48)	2.92 NS (2.1)	1.02 ** (0.5)
Have experienced climate change impacts	-0.28 NS (0.67)	0.14 NS (0.51)	-2.45 * (1.24)	0.44 NS (0.62)
Number of contacts with extension agents per year	0.29 * (0.66)	0.29 * (0.56)	-	16.12*** (0.72)
Constant	8.07 * (4.04)	-3.38 NS (3.21)	0.67 NS (7.9)	-6.28 * (3.25)
Log Likelihood	-19.39	-29.57	-6.87	-19.62
Wald Chi²	31.68**	31.17*	28.08**	43.94***
Pseudo R^2	0.33	0.34	0.58	0.55

Note. Significance level: *: 10%; **: 5%; ***: 1%; NS: Non Significance; Standard deviation in parentheses.

The results revealed that the identified cropping systems for adaptation to climate change are affected differently by the explanatory variables. Only few variables positively influenced the farmers' decision to adopt cropping systems as an adaptation strategy to mitigate climate change: number of contacts with extension services per year, being educated, and total available farm area. Factors that hamper the adoption of such cropping systems include farmer's gender (whether the farmer is male), adult literacy, perception of adaptation to climate change, perception of climate change impacts, and living area. However, secondary occupation, non-agricultural income-generating activities, member of at least one farmers' association, and perception of climate change have unpredictable signs, as their expected effects on farmers' decision to adopt any of the cropping systems as an adaptation strategy to climate change are uncertain.

Number of contacts with extension services was found to be positively correlated with the farmers' decision to adopt cropping systems as a way to mitigate climate change. The positive correlation between cropping systems adoption and number of contacts with extension services implies that the higher the number of visits made by extension agents per year, the higher the probability to adopt one of the identified cropping systems. This suggests that farmers give importance to information from formal sources such as extension services. This finding is found to corroborate earlier studies in communication sociology that indicated that information from formal sources such as extension services is perceived as of great value (Rogers, 1983; Long, 1992). In the present study, the high number of visits made by extension agents per year may be seen as an encouragement to adopt these cropping systems. Because of low education level, knowledge validated by formal structures such as extension services tend to be valued highly.

Farmers' education level has a significantly positive influence on the decision to adopt cropping systems that can help to mitigate climate change. Thus, being educated has a positive influence on one's ability to adapt to climate change, thereby on one's willingness to adopt adequate cropping systems that help to mitigate these impacts. As pointed out by recent studies (Adger et al., 2004; Toya & Skidmore, 2007; Blankespoor et al., 2010), being educated may improve one's ability to cope with disasters such as climate change. The available farm area is positively related to farmer's decision to adopt cropping systems that can help to mitigate climate change. This finding can be explained by the fact that multiple cropping systems such as crop associations and rotations require that farmers possess larger farm size, as a large farm size may facilitate longer rotations (Shively, 1997). This finding is in line with some earlier studies on innovation adoption that predicted higher adoption rate on large farms (Feder & O'Mara, 1981; Feder et al., 1985; Shively, 1997). For example the study by Scherr (1995) revealed higher adoption rates for agroforestry on large farms.

The results of the estimated models showed that farmers' living area has significant and negative influences on their decision to adopt cropping systems to mitigate climate change impacts. Farmers living in *Nagot* zone tend to adapt more effectively to climate change than their peers in *Mahi* zone using different cropping systems. This could be probably explained by the differences in climate change perceptions of the populations in the two zones, because of variations in environmental changes, such as soil erosion and degradation between them. The adoption of cropping systems to mitigate climate change impacts is also negatively affected by farmer's gender (one of the four estimated models). This implies that female farmers in the study area have a higher probability of adopting crop rotations and associations in responding to climate change, and thus adapt better to climate change. This is contrary to the common findings that male farmers have a higher probability of adopting agricultural technologies (e.g., Buyinza & Wambede, 2008). The probable reason could be that female farmers perceive more (and are more subject to) climate change impacts on their agricultural productivity than male farmers. For example about 61 per cent of the interviewed female farmers perceived irregular rainfall patterns against only 44 per cent of male farmers. Such over-perception of climate change impacts from female farmers may justify the higher proportion of females adopting crop rotations and associations. This is in line with Rao et al. (2011) who argued that the higher the perception of risks of climate change, the higher the adoption of new technologies such as fertilizer use and adoption of new seed varieties.

Adult literacy of the farmers is found to be significantly, but negatively related to farmers' decision to use crop rotations and association in response to climate change. This result is contrary to our expectation that the more adult literate the farmer, the higher he is likely to adopt. Because adult literacy like formal education increases one's ability to assess, interpret, and process information about a new technology (Rogers, 1993; Alene & Manyong, 2007), the negative influence observed could be due to the fact that most of the documents are written in official language, i.e. French.

Farmers' perception of climate change is found to influence significantly their decision to adapt by using crop rotations and associations, but it affects differently the different cropping systems used to mitigate climate change. The positive and significant influence on adaption is in line with our expectation that the higher the perception of climate change, the higher the probability to adopt desirable adaptation behavioral changes. The negative and significant effects of perception of climate change on adaptation strategies can be explained through two different ways. Firstly, it could be due to its reverse causality effects. This means that the past adoption of adaptation practices such as cropping systems has reduced climate change-related risk perceptions, thus reducing the farmers' perception level of climate change. Thus future research that accounts for the past adoption effects of the different cropping systems could provide more information about such effects. Secondly, such negative effects of perception of climate change on adaptation strategies could be due to the type and/or sources of information about awareness of climate change. In fact information from peers is often general in nature and not always in-depth compared to information received from formal sources such as extension services (from public services as well as non-governmental organizations) (Pimpa, 2003).

The perception of having experienced climate change is shown to influence significantly adaptive measures to mitigate climate change impacts. Its negative effect is however contrary to the study expectation that having experienced climate change impacts would significantly and positively affect the adoption of desirable adaptive measures (Blennow et al., 2012). The negative effect of the perception of having experienced climate change could be due to the conflictual effect of information dissemination on climate from farmer-to-farmer and from formal extension services to farmers (Mauceri et al., 2007), as it is argued that disseminating information on climate change is seen as a strategy to increase perceptions of having experienced climate change, and hence encourage people to consider the need to take adaptive measures (Blennow & Persson, 2009; Blennow et al., 2012).

Having secondary activities affects differently the different identified cropping systems. It has positive and significant effect on cropping system 2 and negative and significant effect on cropping system 4. Conversely, non-farm income-generating activities affect negatively the adoption of cropping system 2 and positively that of the cropping system 4. The negative and significant effects of having secondary activities and non-agricultural income-generating activities on adaptive measures to mitigate climate change impacts could be due to the presence of cotton in the two cropping systems of the short rainy season. The two cropping systems (2 & 4) are characterized by the presence of the cotton crop in rotations during the short rainy season. Because cotton production is very demanding in time and energy, the possession of extra agricultural activities, although crucial in generating incomes for satisfying basic household needs, may add to the burden of cotton production operations. This suggests that there is a minimum amount from which extra agricultural activities such as secondary activities and non-agricultural income-generating activities would start contributing positively to the adoption of adaptive strategies to mitigate climate change impacts.

4. Conclusion

Farmers' adaptive measures to climate change are numerous and diverse, including multiple cropping systems. The present study assessed the major drivers of multiple cropping as an adaptive response to climate change. Cropping systems adopted by farmers, as adaptive measures to climate change, are diverse and can be grouped into four main categories. Different factors were found to affect the use of the identified cropping systems. The results of the Probit models suggested that farmer's gender, adult literacy, perception of adaptation to climate change, experiences with impacts of climate change, and location were significantly and negatively correlated with the farmers' decisions to adopt any of the identified cropping systems as a strategy to adapt to climate change. Thus, policy actions towards building the smallholder farmers' capacity to adapt to climate change might include among others, elaboration of information about impacts of climate change, and their dissemination through formal services such as extension services; identification of potential ways to greatly improve returns on extra agricultural activities, and investigations on the effects of past adoption strategies of the different cropping systems.

Like any studies, our study presents some limitations. It focuses on a part of Benin, so the generalizability of the findings cannot be inferred. Extension of the current study to other parts of the country and other countries with similar climates is clearly required. It would be important to explore whether similar patterns are found in other regions of Benin, like the northern and southern parts.

Acknowledgements

We acknowledge the helpful contribution of Ulrich A. Arodokoun, the language help of Rosaine Yegbemey and the pertinent comments of the anonymous reviewer.

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