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Working Paper

Impacts of adaptation to climate change on farmers' income in the Savana region of Togo

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ZEF-Discussion Papers on Development Policy No. 255

Pilo Mikémina, Nicolas Gerber, and Tobias Wünscher

Impacts of Adaptation to Climate Change on farmers' income in the Savana Region of Togo

Bonn, March 2018

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Abstract

West African farmers are among those most likely to suffer from climate change, partly due to the agro-climatic characteristics of the regional system and to their limited scope for coping with shocks. Climate change adaptation has thus been touted as a necessary path for rural poverty reduction and development in the region. Yet, do farm households who implemented climate change adaptation earn higher income compare to those who did not? We attempt to answer this question in the context of crop and livestock income in the Savana region of Togo. To that end, we build a bio-economic model based on farm household model theory. Using survey data collected from a representative sample of 450 savanna farm households of the agricultural year 2014/2015, we identify farm-household types through cluster analysis and apply them in the simulation model. From the simulation results, we conclude that at their current costs, soil and water conservation techniques and irrigation practives can on average provide higher income even under climate change, since they are able to mitigate at least 63 % of the impacts of climate change on crop and livestock income. By contrast, reducing the quantity of applied fertilizer, mentioned as an adaptation option by farmers, increases the farm households' vulnerability to climate change. The policy message we draw from this study is to encourage Soil and Water Conservation techniques and sustainable irrigation as sound strategies for higher income under climate change in the region. These are "no regret options" with a positive impact on livelihoods while preserving the resource base.

Keywords: adaptation, bio-economic model, Savana region of Togo

1 Introduction

The agricultural sector still playing a central role in Sub-Saharan African (SSA) countries' economic development. It supports the welfare of most of the residents directly or indirectly. However, recent agricultural performance trends of the region are discouraging. Indeed, the agricultural productivity growth in SSA region has been lower compared to the rest of the world (Willy and Holm-Müller, 2013) and some authors have suggested that the region is falling further away from the agricultural productivity frontier, thus contradicting the convergence hypothesis (Wurlod and Eaton, 2015). This situation may, among other things, be a signal of low land productivity in agriculture. The latter can be partly attributed to the low investment in agricultural sector, high rates of land fragmentation, intensive tillage of land, nutrient mining and extraction of crop residues to feed livestock, and climate variability and change (e.g., high average temperature, scarce and erratic rainfall) which characterized agricultural activities of the region (Di Falco et al, 2011; Willy and Holm-Müller, 2013, OCDE, 2015). Climate change and variability are major challenges to SSA agriculture today because they not only increase production costs and the risk of crop failure, but also put at risk the stability of the whole agricultural production chain (Wheeler and von Braun, 2013). Scientific evidence on climate change suggests that even with a strong mitigation policy the observed lower and stagnant agricultural performance of the SSA region will persist or even get worse if the sector does not find ways to adapt to climate change (IPCC, 2007) under a business-as-usual scenario for agricultural sector.

Climate change brings with it changes in rainfall patterns, increases the frequency and severity of extreme events and raises average temperatures. Clearly, this has adverse impacts on agriculture in developing countries in general and SSA countries in particular, which are theoretically and empirically well documented (Rosenzweig et al. 2014; Calzadilla et al. 2014; Parry et al. 2005; Rosenzweig and Parry 1994; Cline 2007; IPCC, 2007; Seo and Mendelsohn, 2008; Calzadilla et al, 2013). These studies converge in predicting considerable loss in yields from crops and livestock. In the worst case, agricultural productivity can be reduced by 90% by 2020 (Boko et al, 2007). These uncomfortable prospects highlight the crucial role adaptation has to play in the progress towards a world without hunger. Adaptation practices have the potential to reduce yield loss from weather changes. Many authors support the notion that rural communities can successfully deal with the adverse impacts of climate change thanks to the implementation of adaptation practices (Frankhauser and Burton, 2011; Wheeler et al, 2009). This belief triggered many efforts all over the world to promote adaptation strategies through projects and programmes such as the Africa Adaptation Programme (AAP), Infoclim in Senegal, Project to Support Agricultural Development in Togo (PADAT), Pacific Adaptation to Climate Change (PACC) for thirteen pacific countries, Asia Pacific Adaptation Network (APAN).

Farmers have always and will continue to adapt to the changing climate. However, it is unclear whether they are able to identify practices and options that are appropriate to respond to climate change as the required adjustments may fall beyond their range of experience (Seo and Mendelsohn, 2008). The implication of this is the possibility of maladaptation resulting in transitional losses of unknown duration (Di Falco et al, 2011). By maladaptation we mean any practice which is more harmful than helpful, by contrast to an adaptation, which is more helpful than harmful. That is, adaptation practices, if not appropriately implemented, can increase vulnerability to climate change. Thus, it is wrong to think that adaption is an easy process. It is difficult to build resilience to climate change.

Determining the productive implications of adaptation to climate change is therefore crucial. It helps understand how the set of strategies implemented by the farmers (e.g., Irrigation, low fertilizer use, soil conservation techniques, etc.) in response to changes in environmental conditions affect farm income from cropping and livestock. More specifically, it is necessary to assess whether the farm households that actually did implement adaptation strategies are getting benefits in terms of an increase in farm income. This is central if adaptation strategies need to be put in place. Although there is an overwhelming number of studies dealing with adaptation, quantitative estimates of adaptation and its impacts are only starting to emerge (e.g. Seo and Mendelsohn, 2008; Di Falco et al., 2011; Zhang and Zhao, 2015; Shah and Dulal, 2015.

The impacts of adaptation to climate change are traditionally estimated using agronomic models or Ricardian analysis (Di Falco et al., 2011). Agronomic models first estimate climate change impact and then feed the results into behavioural models that assess the impact of different agricultural system on farm income. The Ricardian approach isolates the impact of climate change by implicitly incorporating the potential of adaptation since it assumes that farm households have been adapting optimally, an assumption that is not necessarily verified for the reasons mentioned above.

In our study we use a bio-economic model for empirical estimates. This type of model has been used because of its capability to handle economic and agricultural interactions that prevail within a given farm system.

Two approaches are commonly retained in the use of these models when applied to households. The first one aggregates all households into what can be called a “mega household” (Okumu, 2000) and then simulates the needed impacts. Unfortunately, this approach does not recognize the heterogeneity that may likely exist among households even within a very small community. The second approach accounts for this drawback and assumes that farm households’ agricultural performances depend on their decision regarding land use, technology choice, the objective function and the constraints they face. To cater for the drawback of the mega household approach, we identified different categories of farm households that differ in land size, production type, adaptation option, etc. to construct a bio-

economic model for the Savana region of Togo to empirically assess the welfare implication of autonomous adaptation practices implemented by farmers operating in the region.

The remainder of the paper is structured as follows: Section 2 presents data and materials while section 3 develops the bio-economic model. In section 4 we walk the reader through the simulations of the identified adaptation strategies and discuss the empirical results in section 5. The paper concludes with section 6.

2 Related review of literature

Agricultural and livestock performances are at risk from climate change among a variety of pressures. Because economic and social development are alimented by agriculture particularly in countries falling behind, worries have been expressed by development stakeholder about how long term climatic change will affect agriculture. This concern led to an overwhelming research on climate change and agriculture with a substantial bias towards climate change impact. Climate change affects crop and livestock production through hydrologic balances, input supplies and many other agricultural system components (IPCC, 2007). However, the magnitude of its impacts relies on human responses to them. Recently, in the context of guiding adaptation policies, research on the impact of climate change adaption has gain more interest.

Adaptations to climate change are adjustments or interventions, which take place in order to manage the losses or take advantage of the opportunities presented by a changing climate (IPCC 2001). As mentioned above, farmers have always been struggling over the history to adjust their practices and activities to climate variability. However, the challenges poses by current climate change goes beyond the common variability. The common cited farm households' adaptation strategies include soil and water management techniques, irrigation, planting dates change (Vervoort et al, 2016)

Studies of the impact of adaptation have based their analyses on both field and modelling approaches (Gunda et al, 2017; Vervoort et al, 2016; Choi et al; 2015; Wood et al, 2014). Field studies capture real-world responses to adaptation. Their major limitation has to do with the impossibility of a dynamic analysis. The modelling approaches of evaluating climate change adaptation impact by allowing for long term assessment play crucial role (Ash et al, 2007). The modelling approaches used include agronomic-economic models, cross-section methods, bio-economic models.

3 Data and materials

3.1 Data

The data used in this study come mainly from a cross-sectional, representative farm household survey in the Savana region of Togo during the agricultural year 2014/2015 on 450 households. The survey is representative of the four zones of the Savana region which were identified as most vulnerable to food insecurity and income shocks by the PADAT project.[1] The survey collected information on farmers' perception of current and future states of rainfall, adaptation strategies developed by farmers, household assets and livestock. Additional data were gathered from literature and interviews with extension service managers that operate in the region.

3.2 Materials and Methods

We employ a bio-economic model based on risk-averse, constrained profit maximizing behaviour and apply it to the Savana region of Togo. Characterized by high climate variability and frequent climatic shocks, the Savana region of Togo has soils of average productivity (relative to other regions in Togo) and a landscape which ranges from flat to gently rolling hills. The region activities are dominated by rain-fed agriculture associated with livestock raising (crop-livestock farming). Its climate varies from tropical to Savana with the main climatic risks, according to the National Adaptation Programme of Action (NAPA, 2011), being poor distribution of rainfall, flood and drought.

Crop-livestock farming is a mixed farming system Crop-livestock farming is the main farming system of the region. In this system many adaptation strategies are adopted by farmers in their attempts to withstand climatic shocks that the region is experiencing. To simulate the impact of these strategies in this farming system we link a model of constrained profit maximization for risk averse farmers (allowing for alternative adaptation options) to a biophysical model.

3.2.1 Biophysical inputs of the bio-economic model

A typical bio-economic model includes a biophysical model which simulates plant growth, development and yield, along with nutrient cycling and nonpoint source water pollution, hydrology, and greenhouse gas emissions, for example. A commonly used biophysical model in bio-economic simulations is the Environmental Policy Integrated Climate model (EPIC) (Egbendewe-Mondzozo et al, 2015; Belhouchette et al. 2011; Barbier and Bergeron, 2001). We could not run the EPIC model because of considerable missing data constraints. Instead, the biophysical components of our model comprise data characterizing the biophysical

1 PADAT (Projet d'appui au développement agricole du Togo) is part of Togo's national agricultural investment and food security program (PNIASA).

context of the study site (type of soil, states of rainfall). In particular, we retained five types of rainfall states for the survey.

3.2.2 Specification of the crops yield

For the sake of analysis we distinguish two type of crops: i) the traditional crops and ii) the cash crops. The traditional crops include millet, groundnut, and beans while the cash crops include rice, maize and cotton. The traditional crops are assumed to depend on rudimentary technologies as is the case for most of the Sub-Saharan African countries where it can be assumed that inputs are used in fixed proportion (Dutilly-Diane et al, 2003). Consequently, the two most important factors determining the yield level of traditional crops are the prevailing rainfall condition and the adaptation practice used. Thus the yield level which accounts for adaptation strategy implemented and the state of rainfall is therefore specified as:

$$y_{jqs} = min\{\alpha_{jqs} X_i\} \quad (1)$$

y_{jqs} represents yield level of crop j cultivated under the adaptation strategy q and the rainfall condition s. X_i is the level of *i*th input and α_{jqs} are constant production coefficients representing the necessary input per unit of output.

The choice of functional form of the production function is not a trivial matter: empirical estimates, hence policy implications, are critically sensitive to the choice of functional form. Traditionally four groups of criteria can guide the choice of functional form: criteria related to hypotheses, estimation, data and application (Anderson et al., 1996). We choose our functional form based on the criterion of application, the literature on the topic and the theory. The application criterion allows us to retain two type of inputs that are labour and fertilizer (urea and NPK). This is the result of our knowledge on the type of farming practiced in the study region. Guided by theory, we adopt a Cobb-Douglas yield function, since this functional form is well behaved from a theoretical point of view (Debertin, 2012). In principle, a properly estimated production function provides a wealth of information to guide farmers in their input and output decisions. The regression then should yield not just ratios but functions relating inputs to output reflecting the law of diminishing returns and input substitution relationships, properties that the Cobb-Douglas function possesses. Consequently, for the sake of this analysis the yield level of cash crops was then specified as follow:

$$y_{kqs} = \beta_0 * L_k^{\beta_1} * F_{1k}^{\beta 2} * F_{2k}^{(1-\beta_1-\beta_2)} \quad (2)$$

y_{kqs} stands for the yield level of the cash crop k practiced under the adaptation strategy q and the rainfall condition s. β_0 , β_1 and β_2 are parameters while L_k, F_{1k} and F_{2k} are production factors representing labour, urea and NPK respectively.

2.2.3 Specification of the livestock yield

Grazing is the dominant livestock farming system in the Savana region of Togo. To capture how a given adaptation strategy influences the size of livestock heads on the one hand, and

on the other, how rainfall patterns could affect it in the other, we specify the yield of livestock as follow:

$$y_{mqs} = max\{aX_{mqs}\} \quad (3)$$

y_{mqs} stands for the yield level of livestock m (beef, sheep, etc.), depending on forage X devoted to livestock m, practiced under the adaptation strategy q and the rainfall condition s.

4 The regional Mathematical Programming Model to simulating adaptation impacts

It would be unreasonable to say that farmers are risk neutral. Most agricultural producers in Africa are risk averse, particularly smallholders (Antle, 1987; Binswanger, 1981). They face a variety of yield, price and resource risks that make incomes unstable. All these risks can be classified into production and price risks (Hardaker et al, 1997). Most empirical measures of decision under risk are based on the expected utility (EU) approach (Buschena and Zilberman 1994; Hardaker 2000).

However, much criticism is addressed to the EU model. The main issues are that a growing number of empirical observations report violations of some of its axiomatic foundations and a divergence of observed decisions from what is predicted by the EU approach (Gameiro et al. 2016; Atwood et al. 1988; Buschena and Zilberman 1994; Hazell and Norton 1986).

For these reasons, our analysis is based on Telser's safety first (SF) model, a downside risk approach. The general structure of Telser's safety first model is the following:

$$\text{Max: } E(Z) = E_Y' X$$

$$\text{S.t : } \begin{cases} AX < b \\ \\ \text{Prob } (Z < g) < \alpha \end{cases}$$

In the above specification, $E(Z)$ represents the total expected gross margin, AX a set of resource constraints, b resource endowments, (Z) is income level, (*g*) is exogenously determined minimum level of income a household must earn to meet obligations of high priority, and (⍰) is the acceptable limit on the probability of failing to meet that minimum level of income.

Telser's SF approach accounting for the rainfall risk, adaptation to climate change and the subsistence level of farming in the Savana region of Togo is empirically specified as follows.

4.1 Specification of the objective function

Maximize: $E(Z) = \left(\sum_j \overline{C_j} X_j^P - iX^J\right) + \left(\sum_k \overline{C_k} X_k^P - iX^K\right) - \sum_{l=1}^{12} P_w' X_l^F - \sum_{i=1}^{12}(1 + i)P_w X_t^l + \sum_{t=1}^{12} P_w X_t^o + \sum_{liv=1}^{4} \sum_{l=1}^{12} P_{liv} X^L - \sum_{liv=1}^{4} \sum_{l=1}^{12} P_W X_l^{liv}$ (4)

Where $\overline{C_j}$ = expected gross margin of traditional crop production activity j,

$\overline{C_k}$ = expected gross margin of cash crop production activity k,

X_j^P = jth traditional crop production activity measured in hectare,

X_k^P = kth cash crop production activity measured in hectare,

X^{liv}= livth livestock production activity . liv= {chicken, goats, sheep and caws}

P_w = Wage rate in franc CFA per Man-Day (MD),

P_w' = reservation wage rate which accounts for household leisure demand. It has been set in the range of 50% of P_w for wealthier farmers and 0% of P_w for poor farmers in the study of Dessalegn (2005) in the Upper East Region of Ghana. This means that poor farmers' leisure time is negligible. Given the similarities between our study area and that region, we used the same reservation wage rate.

X_t^o= tth month off-farm activity in Man-Days (MD),

i = interest rate, a rate which accounts for the cost of capital and the transaction costs in the credit market. It usually differs between farmers depending on the farmer's wealth. For instance, in the case of Dessalegn (2005) study in Ghana, it was set in the range of 50% for poor farmers and 25% for wealthier farmers,

X_t^l = tth month hired labour hiring activity (in MD),

X_t^F = tth month family labour used for crop farming (in MD),

X_t^L = tth month labour used for livestock farming (in MD),

X^J = borrowing activity related to traditional crop production in Franc CFA,

X^K = borrowing activity related to cash crop production in Franc CFA,

$$\overline{C_j} = E(gm_j),\ \overline{C_k} = E(gm_k)$$

$$gm_j = Y_{jqs} * P_j - X^J\ ,\ gm_k = Y_{kqs} * P_k - X^K$$

$$E(gm_j) = \sum_{s=G,N,B,F,D} P_s Y_{js} * P_j - X^J, \qquad E(gm_k) = \sum_{s=G,N,B,F,D} P_s Y_{js} * P_j - X^K$$

Where gm_j, gm_k are gross margin per hectare of traditional crop j and cash crop k respectively, which are gross return in rainfall state s, less capital cost per hectare. The capital cost includes cash cost on fertilizer, seed, tractor/bullock. And Y_{js} and Y_{ks} is the yield level of traditional crop j and cash crop k respectively in state of rainfall s. The rainfall conditions are grouped into five states namely: G=good, B=bad, N= normal, F= disastrous due to flood and D=disastrous due to drought.

4.2 Specification of the set of constraints

In the following sections, the various constraints to be incorporated in the programming model are discussed.

4.2.1 Land Constraint

The sum of crop allocated surface under each type of land (compound land, irrigated land, bush land, water and soil conservation area) cannot exceed total available surface for the given type. For the sake of analysis, this study identifies four land types that are compound land, non-irrigated bush land, Irrigated land, Water and soil conservation area. For each of these land type we implement a corresponding constraint. For compound land it is specified as:

$$\sum_{j=1} X_{jc}^{P} \leq L_c$$

Where X_{jc}^{P} is production activity of crop j (measured in hectares) on compound plots and Lc is total compound land available. The superscript p indicates that the activity is a production activity on the other hand the suffix c indicates that the production activity is on compound land. The remaining constraints relative to land are presented below.

$$\sum_{j=1} X_{jB}^{P} \leq L_B \qquad \text{Bush Land Constraint,}$$

$$\sum_{j=1} X_{jI}^{P} \leq L_I \qquad \text{Irrigated land constraint}$$

$$\sum_{j=1} X_{js}^{P} \leq L_s \qquad \text{Water and soil conservation constraint}$$

4.2.2 Labour Constraint

Labour is the most important factor of production constraining agricultural and livestock production in the study area. There is a relatively working labour market so the model assumes that farm households can both hire-in and hire-out labour. Households make labour allocation decision both during the rainy and dry seasons mainly between crop and livestock farming. Traditionally, during the rainy season labour is allocated between rainfed agriculture production and livestock rearing, while during the dry season the allocation is made across livestock rearing, temporary irrigation, leisure, and off-farm activities. Thus the labour constraint can be represented as:

$$L_R^F + L_D^F + L^o - L_R^H - L_D^H - L_R^L - L_D^L \leq \overline{L} \qquad \text{Household annual labour constraint,}$$

$$L_R^F - L_R^H - L_R^L \leq L_1 \qquad \text{Rainy season labour constraint,}$$

$$L_D^F + L_D^o + l - L_D^H + L_D^L \leq L_2 \qquad \text{Dry season labour constraint,}$$

Where the super- and subscripts R stands for rainy season and D for dry season, F for farm labour, H for hired labour, O for off farm labour and L for livestock labour, while l is leisure and $\overline{L}$ total household labour endowments over the year respectively. L_1, L_2 represent rainy season and dry season specific labour endowments. Because of the seasonality of most

farming activities, supply of labour may be more critical at some time of the year than others (Hazell and Norton, 1986). Disaggregating the labour allocation schedule into shorter time intervals increases the precision and incorporates details about the activities (Hazell and Norton, 1986). Thus, labour allocation is disaggregated into monthly labour in this research since the data structure allows us.

4.2.3 Fertilizer and Credit Constraints

The fertilizer type commonly used in the study area is a combination of Nitrogen, Phosphorus and Potassium nutrients (NPK) and Urea. Due to the risk associated with rainfall variability farmers apply fertilizer mainly on cash crops. All fertilizer used is purchased from the market. The fertilizer constraints on these fields can be specified as:

$$\sum_{j=1} a_{fj} X_j^P - X_f \leq 0 \qquad \text{Fertilizer balance,}$$

Where a_{fj} = Kg. Of fertilizer f required to produce a hectare of jth crop activity and X_f= Amount of fertilizer purchased in Kgs.

$$\sum_{j=1} a_{jk} X_j^P + \sum_{t=1} P_w X_t^j - X^k - \sum_{t=1} P_w X^o \leq K \quad \text{Credit constraint,}$$

$$X^k \leq \overline{K} \qquad \text{Credit market constraint,}$$

Where:

a_{jk} = the amount of direct cash cost required to produce a hectare of the jth crop activity, X^k = the amount of borrowed fund, K = total available own fund in CFA and $\overline{K}$= amount of cash available from credit market (rationing in the credit market). The rationing constraint accounts for the fact that under the existing market condition, households can access to only limited amount of cash. The rationing system in the credit market can be clearly observed in agricultural input markets where farmers get fixed amount of in kind input credit.

4.2.4 Consumption Constraint

Farm household food consumption comes from two sources: own farm production (self-consumption) and markets. Different ways exist to account for household consumption requirements in programming models. The theoretically recommended approach is to estimate a set of demand functions from the utility maximization behaviour of the consumer; these functions are named Marshallian demand functions (Hazell and Norton, 1986). These functions give the quantity of goods a consumer will consume as a function of prices and income. In developing countries, the estimation of demand systems functions becomes however more difficult because of time series data missing. Most of the time the available data is cross sectional data from small geographical locations. Such data has a considerable drawback in estimating demand systems since they lack the necessary variability in prices. Thus, imposing a lower bound constraint on the production of the required food crops is the simplest feasible and the most straight forward approach in developing countries like Togo. Since the production consumed is not then sold, cash income can only be measured in the model by separating the production and selling activities with the aid of balance row. The

major limitation of this latter formulation is that the household's food consumption is assumed to be fixed regardless of its level of income. A more sound approach should allow the household consumption to vary according to the level of its income within the model. In this situation a realistic approach is to estimate Engel curves and generate the necessary parameters, such as income elasticity from the estimated Engel Curves.

4.3 Estimating Engel curves

Households in the study area consume a whole set of food and non-food items. The major consumables are cereals such as Millet, Groundnut, beans and Rice. On the other hand households solely depend on the market for the purchase of some consumable items such as sugar, salt, root and tuber crops and non-food items such as kerosene.

Consumption estimates usually use Calories to measure the quantity of food consumed, this approach has advantage in aggregating different food types and also when there is policy interest to know the nutritional implication of the consumption decisions. In our case the main modelling interest is to incorporate the impact of consumption decision on overall household resource allocation decision, for which units like Kg are more useful than Calorie units, since farmers think in terms of Kg, not in Mega joules. Therefore, in order to keep consistency and ease of integration into the matrix the quantitative terms (in Kg) of consumption are retained. The empirical specification of the Engel curves is specified by the below equation.

$$KG_p = b_0 + b_1\, TOTINC + b_2\, HHSIZE + e_p$$

KG_P = is Kg of crop P consumed, which includes Maize, Soya, Beans and Rice, TOTINC = is total household expenditure in CFA, HHSIZE= is household size measured in the number of household members (not weighted by age or gender, for lack of data) , and b's are parameters to be estimated while e is the error term.

4.4 Imposing Probabilistic Constraints

The probabilistic constraint in a Telser's SF model is specified as: $pr(Z<g)< \alpha$ Where (Z) is income level, (g) is exogenously determined minimum level of income a household must earn to meet obligations of high priority, pr (.) is the probability of event and (α) is an acceptable limit on the probability of goal failure.

In order to incorporate the probabilistic constraint into a linear programming model one needs to either make assumption on the distribution of income or use distribution free methods. Here, we implemented Atwood (1985) where a Lower Partial Moment (LPM) based constraint allows optimization algorithms to endogenously select the appropriate and least constraining level of (t) given statistical data set. Indeed, Atwood (1985) demonstrated that the sufficiency constraint necessary to impose the probabilistic constraint, $(\Pr(Z < g) \leq \alpha)$

is: $t - L^{*}Q(t) \geq g$. Where t is a reference level below which deviations are measured, Q (t) is the LPM.

5 Simulation of the impact of adaptation

In their daily life, agricultural households are faced with changes in climatic parameters such as temperature, precipitation, etc. To reduce the adverse impacts of these changes on their activities, farmers continuously develop, adopt and modify adaptation strategies. Several adaptation strategies are implemented by farmers in the study site. They range from minor adjustments like the adoption of new crop varieties, change in planting dates to changes in farming practices like irrigation or water and soil conservation techniques. The complete adaptation strategies found in the Savana region of Togo are presented in Figure 1 below.

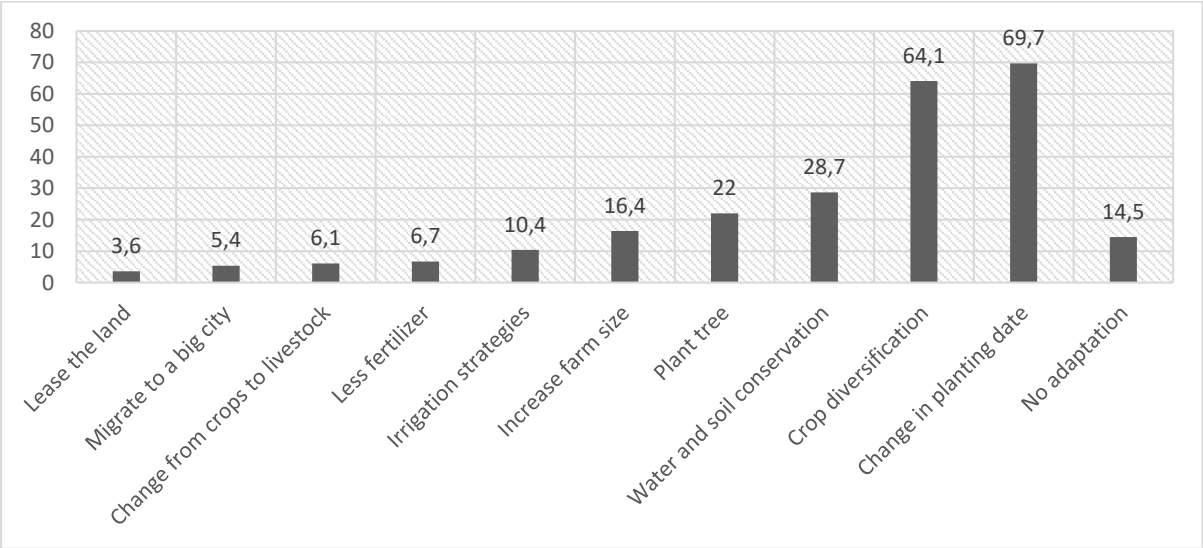

Figure 1: Adaptation strategies used by farmers in the Savanna region, Togo (% of respondents)

Source: Authors, 2016 from survey data

As one can note from Figure 1, most of the adaptation strategies implemented by farm households are minor adjustments. Most of these strategies such as crop diversification, tree planting etc do not represent true adaptation as discussed by Lobell (2014). He refers to these options as "adaptation illusion". Indeed, most of the identified strategies are merely describing farmers' profit maximization tendency because they would likely have been implemented in the absence of climate change. We consequently consider in the simulation experiment only irrigation and Soil and Water Conservation (SWC) techniques which fall under true adaptation strategies according to Lobell (2014). In addition to these strategies, we simulate the impact of using less fertilizer as adaptation measure because of its potential to increase farmers' vulnerability.

Because the units of analysis (the farm households) most likely behave differently, including in their uptake of adaptation strategies, grouping them based on similar characteristics is a prerequisite condition for valid simulations.

5.1 Farm Household Classification

One approach is to aggregate all households into a mega household (e.g. Okumu, 2000). This approach ignores the heterogeneity among farm households which prevails even within a very small area. To avoid this paramount drawback, a second approach assumes that farm households' land use and technology choice decisions are governed by their objectives and constraints. The major limitation of this second approach is that it ignores the interactions among farm household groups. Because interactions among farmers are most likely not truly significant, we follow this approach in this study.

To classify farm households we first select clustering variables using factor analysis. Seventeen variables representing the households' technology use, resource endowments and adaptation strategies were used for factor analysis. We hypothesize that these choices implicitly incorporate the objectives of the farmers. The Kaiser-Meyer-Olkin (KMO[2]) and Bartlett's test of sphericity indicated that all the variables included were relevant. Six factors which cumulatively explain about 65.21 percent of the total variance of the seventeen variables were identified. These factors have been retained according to Kaiser's criterion.

From the factor analysis results, the following variables had the largest factor loading on the first factor: operated land, quantity of fertilizer bought (NPK and Urea), farm equipment value, available own funds, credit obtained, number of household members. Since these variables measure household resources status the factor is referred to as *Resources Endowment*. The second factor has more factor loadings from the variables assets value and livestock value, thus it is referred to here as *Wealth*. The third factor has more factor loading from household irrigation practice and from the access to water for irrigation; therefore it is referred to here as *Irrigation development capacity.* The fourth has the largest loadings from crop diversification and plant different varieties (of the same crop); we refer to it as *on farm diversification*. The fifth factor has the largest loadings from farm size reduction and change from crop to livestock so we refer to it as *livestock development*. The last factor has the largest loadings from the variables measuring off farm activities and stone bunds development; this last factor is named *Soil and Water Conservation techniques development capacity*. It is worth justifying the name given to this last factor. Off-farm activities are not soil and water conservation (SWC) technique but we posit that because off-farm activities development provides resources necessary for SWC practices, it can be consider as contributing to SWC capacity building. The results of Factor Analysis (FA) are presented in table 1 below.

[2] Kaiser-Meyer-Olkin (KMO) is a statistics that measures the adequacy of a variable to be included in factor analysis based on correlation and partial correlation. There is a KMO statistic for each individual variable, and their sum is the KMO overall statistic. KMO varies from 0 to 1.0 and KMO overall should be 0.60 or higher to proceed with factor analysis. If it is not, the lowest individual KMO statistic values will be adopted, until KMO overall rises above 0.60.

Table 1: Results of Factor Analysis

Variables	Components						Total
	1	2	3	4	5	6	
Operated land	**0.823**	-0.163	0.062	-0.071	-0.016	-0.089	
Urea bought in 50 kg-bag	**0.801**	0.322	0.092	0.008	0.108	0.008	
NPK bought in 50 kg-bags	**0.798**	0.372	0.138	0.001	0.046	-0.009	
Farm equipment value	**0.756**	0.378	-0.079	-0.053	-0.113	0.102	
Available own fund	**0.629**	0.374	-0.037	-0.165	-0.036	-0.133	
Credit obtained	**0.489**	-0.168	-0.280	0.180	-0.121	0.022	
HH members	**0.339**	-0.10	-0.154	-0.163	-0.127	0.028	
Assets value	0.286	**0.854**	0.034	-0.020	-0.080	0.040	
Livestock value	0.142	**0.851**	0.015	-0.041	-0.006	0.056	
Access to water for irrigation	-0.077	0.053	**0.815**	0.015	0.034	0.038	
Irrigation dummy	0.051	-0.033	**0.809**	0.166	-0.104	0.056	
Has developed crop diversification	-0.225	0.082	0.011	**0.707**	0.074	0.132	
Has developed plant different varieties	0.047	-0.146	0.154	**0.575**	0.019	-0.113	
Has developed reduce farm size	-0.104	-0.329	-0.090	-0.011	**0.808**	0.233	
Has developed change from crop to livestock	0.018	0.119	0.041	0.136	**0.701**	-0.255	
Off activities	0.05	-0.169	-0.045	-0.102	-0.157	**0.753**	
Has developed Stone bunds	-0.131	0.084	0.68	0.131	0.238	**0.696**	
Summary							
Sum of squares (Eigenvalues)	4.18	1.77	1.56	1.35	1.16	1.06	11.08
Percentage of trace	24.64	10.41	9.17	7.96	6.83	6.21	65.21

Source: Authors from survey data

Based on the identified factors, we select representative farm households using cluster analysis (see Hair et al., 1998 for more details on cluster analysis). There are several clustering techniques; here we used a Ward hierarchical method in combination with a non-hierarchical method. By doing this the advantage of the hierarchical method is complemented by the ability of the non-hierarchical approach to "fine-tune" the results by allowing the switching of cluster membership. Thus, the 444 farm households in the dataset were grouped into 6 clusters, one of them a single cluster (consisting of one farm only) and another one a pair cluster (consisting of two farms only). The single cluster and the pair-cluster are discarded since we conclude that they are too different from the rest of the sample. Finally, four clusters

with the size of 90, 8, 40 and 303 are retained. The analysis of the characteristics of the clusters reveals that the cluster 2 (with 8 observations) has the highest level of asset value, farm equipment, own fund and operated land; so we refer to it as *wealthier farmers group*. By contrast, the cluster 4 (with 303 observations) has the lowest level of asset value, farm equipment, own fund and operated land; we refer to it as *poorer farmers group*. These two clusters represent the "extreme cases" in our dataset. We undertake simulation analysis first for these two clusters and complement our analysis with simulations for the remaining two "middle" clusters, in order not to lose any information these two groups can provide.

6 Results and discussions

6.1 Some descritive statistics of the Identified Clusters

The four clusters show significant differences in total land holding, farm equipment, total own funds, asset value, family size and received credit. Cluster 2 has the greatest own fund followed by the cluster 1 while the cluster 4 has the smallest own fund amount. Regarding farm equipment, the cluster 2 is also ranked first followed by cluster 3. On the other hand, the highest asset value is owned by the households within the cluster 2 followed by the cluster 1 while the clusters 3 and 4 had almost equal asset value.

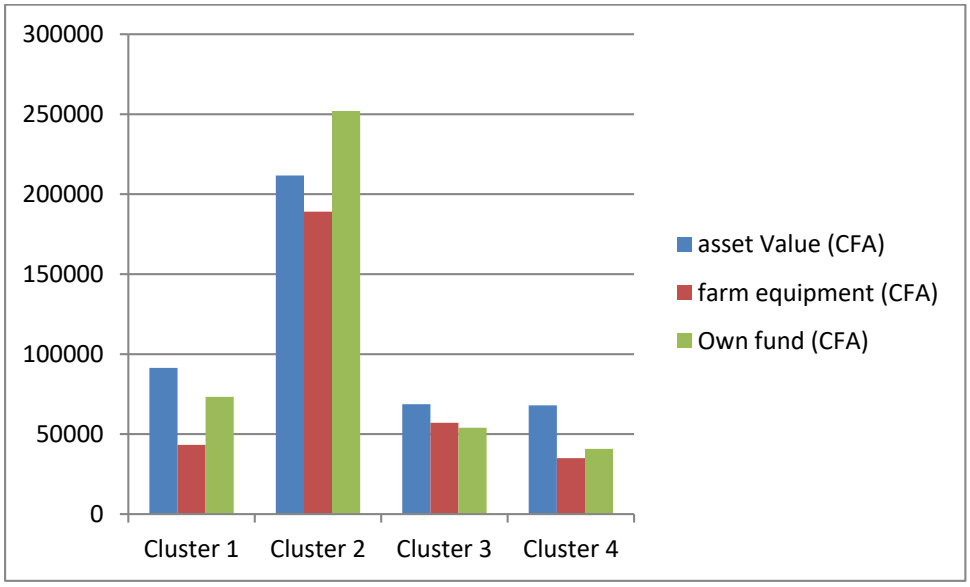

Figure 1: Assets ownership across clusters

Source: Authors' estimates in SPSS 20

Other important differences among the four clusters were their difference in family size and operated land. It can be seen in the figure 2 that Cluster 2 had both the largest land holding and household size. The cluster 1 was ranked second regarding these two variables while the cluster 3 and 4 had almost the same size of land holding and family size.

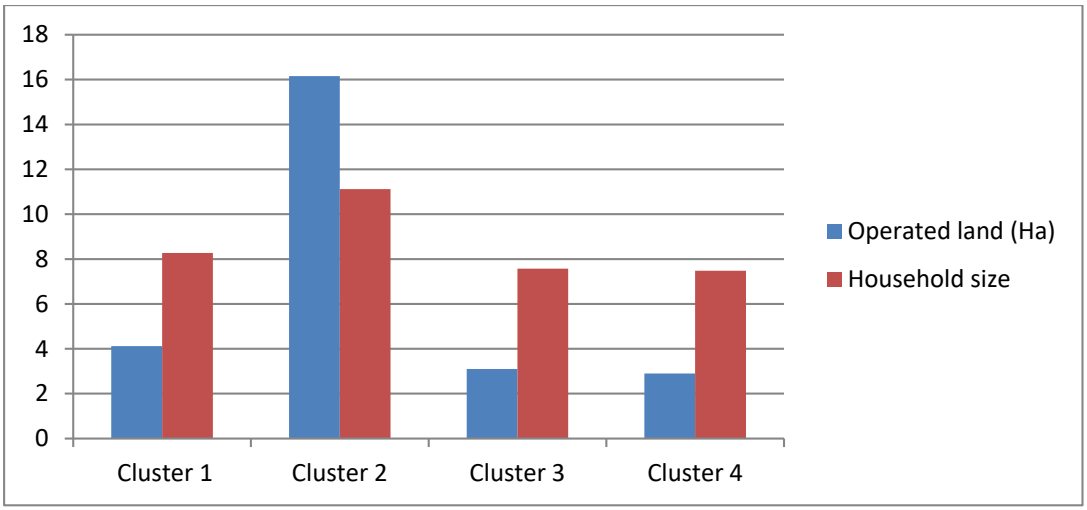

Figure 2: Land and family size across clusters.

Source: Authors' estimates in SPSS 20

In addition to its asset ownership cluster 2 receives more agricultural credit followed by cluster 3. Their asset and credit access positions should enabled households in clusters 1 and 3 to be the clusters that is practicing irrigation agriculture. However, none of the households that fell within the cluster 2 irrigate and only 7.7% of the households that belong to the cluster 3 do ractice irragation. This situation is, however, not so surprising given that it can be justified by lack of access to water for irrigation purpose. Indeed, in the survey, many farmers had cited lack of water for irrigation as constraint to adopting irrigation practices.

Another important feature that significantly discriminates among the four clusters is the use of stone bunds at farm level to adapt to climate change adverse impacts (figure 4). Almost all households within the cluster 1 (87.8%) had developed stone bunds while only 37.5%, 17.5% and 12.2% households respectively within the cluster 2, 3 and 4 had adopted stone bunds.

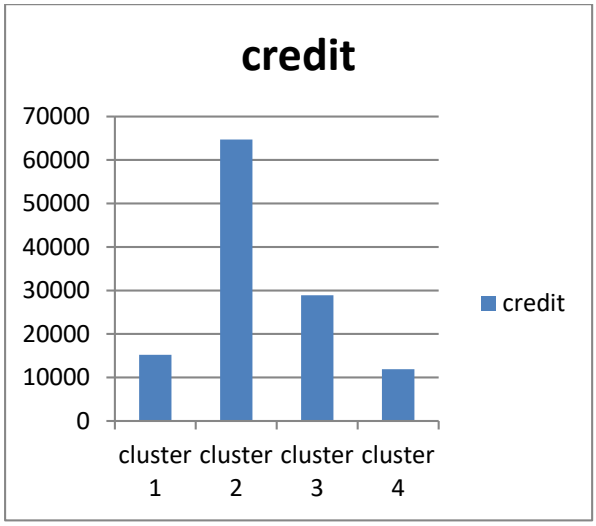

Figure 3: Credit amount across clusters

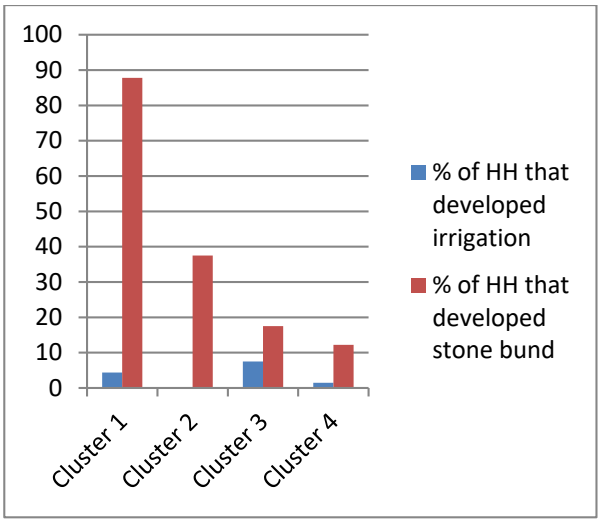

Figure 4: % of households using stone and irrigation

6.2 Evaluation of rainfall conditions

Farmers' perceptions of rainfall risks, reflected in their evaluation of rainfall conditions in the area, were used as a reference to elicit their subjective probabilities. The most important consideration in eliciting subjective probabilities is to organize the questions so as to help the respondents to make judgments that are consistent with their real feelings of uncertainty and as well as with the rules of probability (Dessalegn, 2005). In our survey farmers were asked to evaluate the rainfall conditions of their community for the period from 2003 to 2012 as good, normal, bad, disastrous due to flood or disastrous due to drought. Some of the questions employed in the elicitation exercise were: "Following your characterization of the rainfall conditions in this locality, how many of the years between 2003 and 2012 had good, normal, bad, disastrous due to flood or disastrous due to drought?". In addition, farmers were asked to name a representative year for each rainfall condition between 2003 and 2012 so as to help them have a good focus on the past rainfall events. The results of the elicitation process, indicate that on average good, normal, bad, disastrous due to flood, disastrous due to drought conditions have a probability of 0.29, 0.34 and 0.24, 0.04 and 0.09 respectively.

6.3 Base Run Scenario

This section tests how well the previous constructed model serves its intended purpose. Naturally, the model cannot replicate each and every empirical observation. However, this is rarely realised because of information gap between the modeller and the decision maker. Thus, the realisable approach consists to value the extent to which certain model outputs, which are of policy and research interests, are depicted. For example Dessalegn (2005) used land use as an indicator variable to validate their model. Land allocation across different land

use types is of much importance in this study, therefore we retain it as our indicator variable. Figure 2 shows how correctly the model predicts the observed data.

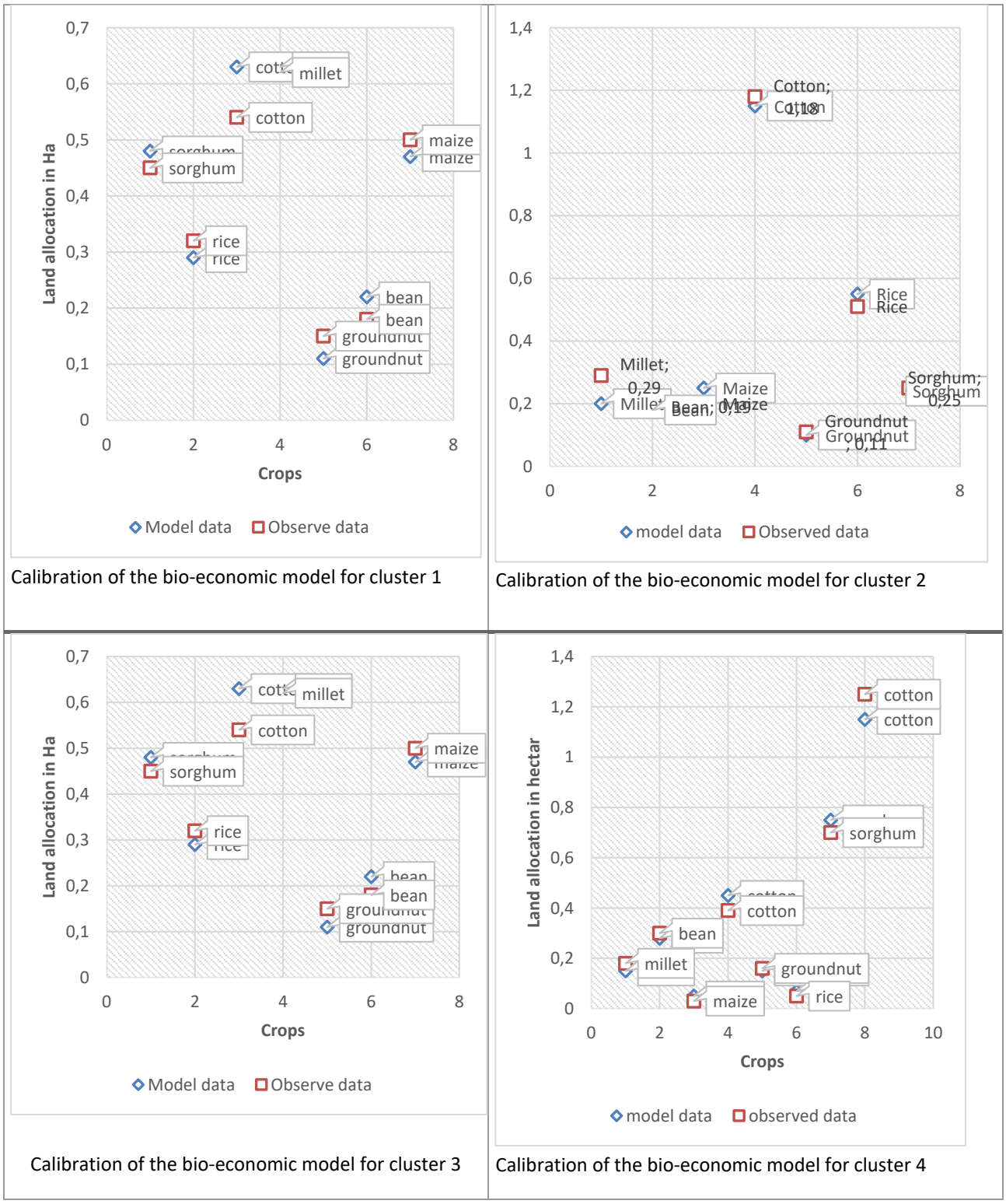

Figure 2: The calibration of the bio-economic model

Source: Authors, 2018 from simulations in GAMS

We used in addition to the plotted figures above, the regression technique to assess the association of the model values with observed values. This is captured as bellow:

$$X^M = \beta_0 + \beta_1 X^o$$

X^o is observed land use type, X^M is modelled land use while $\beta_i' s$ are parameters. For a valid model there is a high association between the model results and observed values and the intercept tends to be zero while the slope is one. The table 1 below gives the results of the regression.

	$\boldsymbol{\beta_0}$	$\boldsymbol{\beta_1}$
Values	-0.009827	1.047698
P-Values	0.545	0.000

R-squared = 0.9770

The value of the slope is 1.048 and significant at 1% level while the constant was not significantly different from zero. In addition, the R-square of 0.9770 implies that there is a very good association between modelled and observed land use. Thus, the constructedmodel can be used for simulation purpose.

6.4 Simulation experiment

A climate change scenario is implemented in the model through the creation of an additional climate file representing possible future climate. This scenario is based on farmers' subjective perception of future climate given the absence of scientific forecast of future climate for the study area. The new climate is an average weather condition of the five states of nature prevailing in Togo, namely: good rainfall condition, normal rainfall condition, bad rainfall condition, disastrous due to flood and disastrous due to drought. This new climate is obtained by asking farmers to state their subjective perception of future rainfall conditions based on their past experience. The exact question was: "Based on your experience, in the ten coming years (2013 to 2023), how many years are you expecting to be Good, Normal and Bad in terms of rainfall, disastrous due flood and disastrous due to drought? The new climate file is substituted to the baseline[3] climate file (S0) to simulate the climate change scenarios (S1). The outcomes of the scenario S1 are then compared to the outcomes from the scenario S0 for the four farmers' groups retained. To assess the impact of adaptation strategies, we introduce successively the retained strategies in the scenario S1. Thus, we first introduce irrigation by converting 25% of the operating area into irrigated area, this scenario is referred to as S2. For soil and Water conservation (SWC) techniques, we supposed these techniques are implemented on 25% of the operated land, this scenario is named scenario S3. For fertilizer reduction, we reduce applied fertilizer quantity by 25%, this is the scenario S4. These figures

[3] The baseline scenario in this study represents simulation outcomes from the calibration procedure

are guided by the ongoing country policy debates regarding adaptation. The results are presented in the table 2 below.

Table 2: Annual average operating profit per hectare

Scenarios (Sn)	Profits/Benefits (US$)		Percentage of variation		Residual Impacts	
	Wealthier farmers (cluster 2), n=8	*Poor farmers (cluster 4), n=303*	*Wealthier farmers (cluster 2)*	*Poor farmers (cluster 4)*	*Wealthier farmers (cluster 2)*	*Poor farmers (cluster 4)*
S0	710.54	582.34	-	-	-	-
S1	451.45	335.23	-36.46%	-42.47%	-36.46%	-42.47%
S2	693.82	487.45	+32.89%	+27.43%	-3.57%	-16.76%
S3	549.08	397.00	+ 12.94%	+ 18.34%	-24.19%	-24.54%
S4	379.86	268.16	-10.78%	12.09%	-46.99%	-54.78
	Cluster 1 (n=90)	Cluster 3 (n=40)	Cluster 1	Cluster 3	Cluster 1	Cluster 3
S0	630.32	588.90	-	-	-	-
S1	355.00	340.23	-43.67%	- 42.22%	-43.67%-	-42.22%
S2	582.17	517.67	+36.04%	+30.13%	-07.64%	-12.09%
S3	486.95	375.76	+20.93%	+06.03%	-22.75%	-36.19%
S4	289.43	269.00	-10.40%	-12.09%	-54.08%	-54.32%

Source: Authors, 2016 from simulations in GAMS

The overall research question of this study is: to which extent do private adaptation strategies mitigate climate change impacts on farm income from crops and livestock? To answer this question, the bio-economic model is solved introducing sequentially the retained strategies. From the results one can note that adaptation strategies in terms of irrigation and SWC techniques do mitigate climate change impact for all the four identified groups although the impacts vary from one group to another. Specifically, if a representative wealthier farm group household converts 25% of its operated land into irrigated area, this will mitigate on average 96.43[4]% of the climate change[5] impacts. However, this will reduce climate change impact by only 83.24%, 92.36% and 87.10% on average if the representative household was from cluster 4 (the poor group), or from clusters 1 or 3 (the middle groups), respectively. These performances fall to 75.81%, 75.46%, 77.25% and 63.81% for cluster 2 (wealthier), cluster 4

[4] To estimate the percentage of irrigation mitigation we used the formulae $[\frac{S_2-S_0}{S_1-S_0}] * 100$, for SWC techniques $[\frac{S_3-S_0}{S_1-S_0}] * 100$ and for fertilizer reduction $[\frac{S_4-S_0}{S_1-S_0}] * 100$. In these calculations only the number in the column Profits/Benefits are considered.

[5] See section 5.2 for more clarification on what we mean by climate change in the context of our model.

(poor), cluster 1 and cluster 3 (middle groups), respectively, if the converted area was devoted to SWC techniques. As one could have predicted, the reduction of applied fertilizer quantity by 25% increases the four groups' vulnerability to climate change[6] (by 10.53% for the wealthier farm group and 12.31% for the poor farm group, for instance). The variation of impacts observed between groups is more likely the result of differences in households' managerial skills and farms' specific characteristics, though specific categories of technologies might be of various quality and efficiency across income groups (e.g. both apply water conservation, for instance rain water tanks, but not of the same quality). Clearly, irrigation practice appears to be the superior strategy for the four groups. It should be the first target for any policy aiming to reduce climate change adverse impacts on farm households' income. SWC techniques should not be ignored in the pursuit of this aim since irrigation practices could merely be impossible for some farms.

6.5 Implications in terms of food security

Food security is a general concept with four dimensions which are food availability, accessibility, utilisation, stability. In a subsistence farms context like Togo, the most important determinant of food security is food productivity (FAO, 2002). Here, food availability to farm households is tightly linked to food productivity. According to the World Bank, small-scale ("subsistence") farms account for 95% of the national agricultural production, of which about 75% is self-consumed at household level (World Bank, 2007). Thus, food security prospects are closely associated with climate given the high reliance on rain-fed agriculture. Because climate change will act in most cases in disfavour of agricultural productivity through its exposure and sensitivity (Cline, 2007, Parry et al, 2005), how well farm households will adapt to the changing climate has to do with the level of food productivity, hence food security (Shah and Dulal, 2015; Cline, 2007; Parry et al, 2005). The simulation exercise undertaken above provides evidence on the positive impacts of soil and water conservation techniques and irrigation practices on food productivity under climate change context. This is to say that adaptation to climate change is a vehicle for moving towards a world with higher food security. In other words, adaptation to climate change, if appropriately implemented can help improve food security. This implication of the results is not new for the climate change adaptation literature. For instance Di Falco, 2011 and Shah and Dulal, 2015 have already found similar results in their research in Ethiopia and Trinidad Tobago by establishing that adaptation increases food security.

[6]By vulnerability to climate change we refer to the degree to which these groups' profits are impacted by climate change.

7 Conclusion

Achieving food security under the climate change context is a crucial challenge especially for countries relying heavily on rain-fed agriculture like in Togo. For these countries, it is crucial for agriculture to adapt to the changing climate. However, quantitative analysis of the impacts of adaptation strategies is only starting to emerge since most studies have been focusing on the impacts of climate change and adaptation adoption rather than its implications on welfare. We contribute to filling this research gap by simulating climate change adaptation options and assessing their impact on farm income from crops and livestock in the Savana region of Togo. Contrary to the existing studies on the topic, a farm modelling approach is used. The approach represents the integration of the economic decision making environment with the spatial and temporally biophysical conditions. The findings reveal that irrigation and soil and water conservation techniques can be used to deal with the adverse impacts of climate change on farm households' income. These are of course win-win strategies with adaptation and conservation pay-offs coupled with productivity impacts. However, fertilizer reduction, an adaptation strategy used by farmers in the study area, decreases income for all farm types covered in our model: Wealthier farm group, poorer farm group and the middle farm groups. Given the social benefits and private costs nature of water and soil conservation techniques, policy makers should consider their promotion to stimulate farmers' adaptation to climate change. Irrigation is also shown to have strong adaptation benefits in our model. Yet, given its high costs, there are definite financial barriers to its adoption at individual level. Support to institutional arrangements, such as community-based irrigation schemes based on local water user associations, could pay high dividends by allowing farm households to benefit from economies of scale in irrigation infrastructure. The community-based irrigation developed in the Sidiki village of the Savanna region could serve as an example in the move towards such a system. The Sidiki village-based irrigation system is co-managed by the village development committee (CVD), one of the village coordination mechanisms, and the ministry of agriculture.

One caveat of our results is that they are based on a subjective evaluation of states of rainfall and conditional yield of production activities to fill data gaps. This technique, however, suffers from long recall periods and a simple guess by respondents with low farming experience. Future research interested in farm household modelling of climate change adaptation could use climate scenarios from actual climate models. The dynamic aspect in decision making should also be addressed in future research, as well as the role of downside risk in the adoption of adaptation strategies. This combines with the failure to account for interactions are the main weaknesses of our modelling approach. The use of Multi-agent approach which include downside risk component should be considered.

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