The potential impact of agricultural policies on cropland allocation in the context of promoting a sustainable agriculture

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Abstract

Agricultural sector role both in the mitigation and adaptation to climate change has become a key concern in recent national and international debates regarding climate change issue. The present work aims to understand how green policies may influence farmers' incomes and land allocation in the context of promoting a sustainable agriculture. Thus, a positive programming model with a representative risk-neutral and profit maximization economic agent is applied to understand farmers' behavior in terms of cropland allocation in the context of sustainable farming versus conventional farming systems. The data used come from a survey of 423 farmers. The findings show a great sensitivity of farmers to policies that are adopted in order to incite them to engage into sustainable agriculture. In addition, we found that a combination of a subsidy policy and a credit offer policy should be the best incentivize strategy since it both contributes to promote the adoption of sustainable practices and increases farmers' revenues.

Key words: sustainable farming, conventional farming, positive programming, profit, crop allocation.

Introduction

Climate change is expected to cause several impacts on agriculture and studies have underlined how less developed regions and more vulnerable farmers tend to be specially affected by climate change, since they lack the basic economic and social capital needed for adaptive strategies, such as access to irrigation and drought-tolerant crops (Maia, Miyamoto, & Garcia, 2018). Indeed, significant research projects are now underway to investigate agriculture's ability to adapt and mitigate, because it is important to determine how much to control global greenhouse gas (GHGs) emissions and to identify which actions could make agriculture more resilient. Increasing policy and consumer concerns about food safety and environmental impacts has led innovation in agriculture to be associated with more environmental-friendly production technologies. As people confront population growth, increased food demand, climate change, and the globalization of agricultural markets, agricultural landscapes are undergoing unprecedented transitions (Omer, Pascual, & Russell, 2010). The transition aims to shift from conventional production techniques to eco-friendly production practices such as the application of manure, compost and minimum tillage.

Greening agricultural practices through agroforestry and organic farming practices provide short and long-term development benefit (AfDB, 2012). Indeed, there are ample evidences which show that sustainable land management practices can improve resilience and adaptive capacity while also increasing average agricultural output. Specifically, increasing agricultural production in Africa on a sustainable basis requires a diverse toolkit, including green and conventional practices, with the clear goal of preserving the ecological systems upon which food security depends (AfDB, 2012). Even though that Western Africa has thus achieved the MDG 1 (Millennium Development Goal 1), many other regions like Eastern Africa are severely threaten by hunger (FAO, 2015). A situation which requires continuous promotion of sustainable practices in agricultural sector not only to eradicate hunger but also, to help those who have already achieve this goal to maintain level.

In line with the promotion of green practices in agricultural sector, the study aims to analyze farmers' choices in terms of cropland allocation with regard to two cropping systems: sustainable systems and conventional system. Thus, the fundamental research question is expressed as follow: what is the impact of sustainable policies on farmers' choices in the context of developing a sustainable agriculture? Specifically, how is cropland allocated among farmers? Do sustainable policies incite farmers to adopt green practices? What is the benefits associated to each policy implemented? To address the above research question, the main objective of the study is to analyze cropland use allocation in the context of alternative production systems and agro-climatic variability. Specifically, this paper seeks to:

- Analyze cropland allocation for alternative cropping systems,
- Assess the potential impact of sustainable policies on farmers' land use allocation
- Evaluate the benefit associated to each policy.

The reminder of the work is organized as follow: the next section presents the literature review while the following section describes the methodological approach applied herein. The fourth section reports the findings of the study which is followed by the conclusion.

1 Literature review on sustainable agriculture

1.1 Theoretical review of sustainable conservation

The concept of 'sustainability' has emerged in relation to the contemporary ecological crisis. Environmental sustainability is not a static model which may be realized by particular means, but rather as an approach for learning about the ecological challenges facing humanity. Agricultural sustainability is not about technical fixes and expertise, rather it is development processes which need to incorporate societal and ecological knowledge through changes in institutions, policy, and behavior (Saifi & Drake, 2008).

In terms of agro-biodiversity analysis, there exist a contrast view of point on interactions between agricultural production and ecological processes. The competitive view of agricultural production which has dominated the agricultural production practices (particularly in industrial countries), defends an approach which adjust the environment in the way that growing conditions for a particular species "the crop" are optimized whereas those for competing species are wilfully worsened (Omer et al., 2010). Thus, this approach is increasingly criticized in regards of scientific discovery on ecosystem functioning as stated above. The second view point underlines that long term productivity and stability is more likely linked to maintenance of specific ecosystem functions rather than the number of species per se. Thus, agro-biodiversity is likely to contribute to enhance agro-ecosystem functioning when assemblages of species are added whose presence results in unique or complementary effects on ecosystem functioning. This lead to the importance of promoting conservative or sustainable agriculture.

Considered as the raw material in plant breeding, biodiversity contribute significantly to the productivity of agricultural systems. Higher-yielding plant and animal varieties are generated from the natural variation in plants and animals (Heal, 2004). Promote a sustainable agriculture (such as organic farming) leads to preserve the ecosystem, and therefore contribute to improve agricultural productivity. Thus, organic products a part from being popularly known for their health-related benefits, organic farming can also be a part of the solution to the growing social concern for ecosystem conservation in rural zones (Uematsu & Mishra, 2012). Environmental benefits of sustainable farming include but are not limited to improved soil condition, better carbon sequestration, improved water quality due to diminished pesticide residues, and reduced nutrient pollution.

1.2 Empirical review of agricultural sustainability

Being considered both as one of the greatest contributor and one of the most vulnerable sector to climate change, agricultural sector has attracted the attention of many researchers who have been interested in assessing the impact of green practices both on the sector and environmental preservation. Various techniques have been developed to promote sustainable agriculture; but these techniques need to be evaluated in order to draw the trade-off between environmental improvement and farmers' performances (in terms of productivity and profit). Thus, the present part attempts to address this aspect by analyzing various studies that have been carried out on sustainable agriculture.

Sustainable agricultural management contract is a type of strategy that has been developed to promote sustainable agriculture in some regions. Thus, Duke, Borchers, Johnston, & Absetz, (2012) were interested in assessing the social benefits for sustainable management practices and agricultural land conservation in the case of US. A choice experiment approach was adopted to analyze the impact of three illustrative practices that affect, carbon sequestration, soil erosion and water quality: no-till cropping, fertilizing with a broiler litter product, expanding riparian buffers. Results identify substantial benefits for riparian buffers, the use of broiler litter, and land preservation but not for conservation tillage. In addition, Results suggest that the estimated household benefits of all these three sustainable management techniques combined are similar in magnitude to the benefits from land preservation alone.

Bio-economic models are a kind of modelling approach that are widely used by researchers to assess the socio-economic and environmental benefits of sustainable agriculture. Bio-economic models are usually defined as biological process models to which an economic analysis component has been added (Douglas, 2000). At other scale, they are also defined as economic optimization models which incorporate various bio-physical components as activities among the plural choices for optimization. This poses an issue since biological and bio-physical process models and economic models are structured differently. This is the main subject of Attwood et al. (2000) in their works who attempted to demonstrate how the differing spatial scales may be reconciled. They adopted an agricultural model with state and country-level-based geographical boundaries and a watershed model incorporating watershed boundaries. The method used in the study aims to show a national-level analysis incorporating state and sub-state level economic results and small watershed environmental results.

Smallholder farmers play an important role in poverty reduction plan in most Sub-Saharan African countries. However, they face several challenges such as land degradation, market imperfections, and climate variability and change. As a response to such challenges, conservation agriculture (CA) has been widely suggested by many researchers and international organizations such as the Food and Agriculture Organization (FAO). Thus, Tessema, Asafu-Adjaye, Rodriguez, Mallawaarachchi, & Shiferaw (2015) applying a bio-economic model were interested in assessing the potential impact of conservation agriculture (CA) and identify its binding constraints for adoption in smallholder farming systems in central Ethiopia. The model applied is a dynamic household bio-economic model which takes into account the existing farming system, market imperfections and resource constraints. Unfortunately, the results showed that the proposed conservation agriculture which consist of mulching and crop diversification and, minimum tillage, does not appear to be the best interest practice for smallholder farmers. This is explained by a set of constraints including risk aversion, time preference, limited credit and market access.

1.3 Various types of sustainable practices that are usually applied in agricultural sector

Many researches have indicated that agriculture is one of the major contributor to climate change through its important emission of greenhouse gases. According to (Spash & Hanley, 1994) between 1950 and 1980 , global annual production of nitrogen (N_2O) in fertilizer has increased by seven times, and it is implicated in the 0.2 – 0.4% per year increases of nitrogen in the atmosphere. The anthropogenic emissions of nitrogen is estimated to be approaching 50% of natural releases. Further, the trend in methane (CH_4) concentration seems strangely to coincide with the changing trends of population and may be caused by industrial and agricultural activities associated with the production of food and energy. A situation which calls to a more attention on the importance of sustainable practices adoption.

There exist a variety of mitigation practices that could be applied in agricultural sector in order to reduce its GHG emission. The prominent options are improved crop and grazing land management (e.g., improved agronomic practices, tillage, nutrient use, and residue management), restoration of degraded lands and restoration of organic soils which are drained for crop production (Smith et al., 2007). Other mitigation techniques exist even thought that their impacts are little but still significant. Among these we may are improved rice and water management, agro-forestry and land use change (for instance conversion of cropland to grassland), as well as improved livestock and manure management. An addition, the technological progress could be a key driver to implement more rapidly and more efficiently these mitigation techniques. Thus, integrating technological progress in mitigation practices should be taken into account in order to improve mitigation impacts on climate change.

In line with the necessity to become more greenly, there is an emergence of a new practice which consists of using bio-fertilizers rather than chemical fertilizers in agricultural sector. Thus, several studies have tried to demonstrate the benefits associated with the implementation of a conservative agriculture. Organic farming has become during the last decades, one of the most thriving segments in many countries such as in U.S. farm sector, mainly due to growing demand for healthy food products (Uematsu & Mishra, 2012). According to U.S. department of Agriculture, in 2007 more than 600,000 acres operated by 9000 farms were undergoing the transition from conventional to organic farming. This is mainly due to the health-related benefit that is associated with organic product.

The benefit associated with organic farming is not only limited to health improved but include also a number of environmental benefits such as nutrient pollution reduction, better carbon sequestration, enhanced biodiversity, and soil condition improvement (Uematsu & Mishra, 2012). Indeed, the use of chemical fertilizers during the recent last decades had provided a glimmer of hope due to increase in crop yield and subsequent financial benefits that was associated. However, overtime the disadvantages in the use of chemical fertilizers has come to surface and these include water basins leaching and pollution, making crops more susceptible to attack from diseases, microorganisms and friendly insects destruction, soil fertility diminution (Lawal & Babalola, 2014). All these adverse effects have leaded to the necessity to adopt sustainable practices which could help to preserve the biodiversity.

Bio-fertilizers that depend on available microorganisms have come up as a replacement for chemical fertilizers to improve soil fertility and crop yield in sustainable agriculture. The main sources of bio-fertilizers are bacteria, fungi, and cyanobacteria. Further, these bacteria are involved in important ecosystem developments which include biological control of plant pathogens, nitrogen (N) fixation, mineralization of nutrients, and phytohormones production. And these bacteria are also called the plant growth-promoting rhizo-bacteria (PGPR). Hence, both partners derive benefits from each other. Further, bio-fertilizers have the advantage of activating soil biologically, restoring soil fertility, stimulating plant growth and providing protection against drought and some soil borne diseases. In terms of economic benefits, it has been shown that bio-fertilizers are cost effective, eco-friendly and, reduce the costs towards fertilizers use, particularly in the case of phosphorus use (Lawal & Babalola, 2014). Thus, biologic fertilizers application may bring benefits from an economic, social, and environmental aspect.

2 Methodological process

The study aims to simulate how agricultural policies implementation application could contribute to promote a sustainable agriculture.

The model used herein is based on a bio-economic model with a representative risk-neutral and profit maximization economic agent. The model consist of integrating biophysical-geographic information system (GIS) in a regional economic mathematical programming model. The model has been used to investigates the spatial impact of climate change on agriculture in the Economic Community of West African States (ECOWAS) (Egbendewe-Mondzozo et al. 2016). Indeed, it has been used to simulate the implications of climate change on land use and crop production under two Representative Concentration Pathways and various prevailing socio-economic conditions. Thus, the model is applied in this study in order to capture the effects of sustainable agriculture on farmers' productivity (in terms of yield and profit) and assess sustainable agricultural resilience to climate variability.

The model is a compound of economic, climatic and programming models used in previous studies. For instance, the spatial mathematical programming model for the United States (U.S.) agricultural sector, Agricultural Sector Model (ASM) has been used to simulate market equilibrium effects for resources (land, water and labor) and commodities (domestic use, imports and exports of primary and secondary or processed items) (Attwood et al., 2000). Further, in order to estimate revenue impacts of climate change in California, Statewide Agricultural Production Model (SWAP), a price-endogenous optimization model calibrated with the Positive Mathematical Programming (PMP) method was applied (R Howitt, Medellín-Azuara, & MacEwan, 2009). All these models have been used to develop our model which is a supply-oriented model and considers climate factors such as precipitation, and agro-climatic zones as well as non-climate factors such as soil fertility, and output prices as exogenous variables (Egbendewe-Mondzozo al. 2016).

2.1 Economic mathematical programming model

The farming system considered herein is characterized by four cropping systems and five livestock types. Thus, the cropping systems are cereals (maize, sorghum, and millet) and paddy rice. The five livestock types are goat, cattle, sheep, chicken and guineafowl. The assumption made in this study is that farmers allocate labor, land, and cash to choose a portfolio of the four cropping systems and the five livestock types which maximizes the sum of the discounted farm profits.

$$\max_{x_{zj}x_{zis}^{c}h_{zt}} \left(\sum_z \sum_j x_{zj} * P_j + \sum_z \sum_i \sum_s y_{zis} * x_{zis}^{c} * P_i^{c} - \sum_t \sum_z w_{zt} * h_{zt} - \sum_t f_t^{a} - \sum_z \sum_i \sum_s \sum_{km} x_{ziskm}^{c} * T_{iskm} - \sum_z \sum_i \sum_s x_{zis}^{c} * P_z^{L}\right) \quad (1)$$

Subject to :

$$\sum_i x_{zis}^{c} \leq \beta_{zs}^{L}, \quad \forall z, \forall s \quad (2)$$

$$\sum_z \sum_i \alpha_{it}^{c} * x_{zi}^{c} \leq f_{zt} + h_{zt}, \quad \forall z \quad (3)$$

$$\sum_z \sum_s \sum_{km} m_{ikm} * x_{zis}^{c} + \sum_t f_t^{a} + \sum_t w_{zt}^{h} + \sum_t w_{zt}^{h} * h_{zt} + \sum_z \sum_i \sum_s x_{zis}^{c} * P_z^{L} \leq R_{is} \quad (4)$$

Parameters and variables used in the model are defined in table 1.

In the objective function expressed above, six expressions may be identified. The first expression which represents the total discounted livestock revenue is the following one: $(\sum_z \sum_j x_{zj} * P_j)$. Note that, all animals produced are not supposed to be sold, the expression enables just only to account for the total livestock value in the objective function. The second term $(\sum_z \sum_i \sum_s y_{zis} * x_{zis}^{c} * P_i^{c})$ indicates the total discounted crop production revenue from all crops. The third term is the total discounted labor costs and is expressed as follow: $(\sum_t \sum_z w_{tz} * h_{tz})$. The overall discounted livestock feeding and veterinary service costs is expressed throughout the following fourth term: $(\sum_t f_t^{a})$. The fifth expression which indicates the overall discounted technology costs takes the following form: $(\sum_z \sum_i \sum_s \sum_{km} x_{ziskm}^{c} * T_{iskm})$. The sixth and last expression which indicates the total discounted land cost is expressed in the following form: $(\sum_z \sum_i \sum_s x_{zis}^{c} * P_z^{L})$. Further, input constrains are expressed throughout equations (2), (3) and, (4). Equation (2) expresses land resource constraints. Labor resource constraints are accounted by equation (3) while equation (4) accounts for cash (capital) constraints.

Table 1: list of variables and parameters.

Sets, parameters and variables	Definitions
Sets	
i	Set of four crops studied in the model
j	Set of five livestock types studied in the model
s	Set of two types of farming system (conventional & sustainable farming)
km	Set of four technologies (manure, compost, bio-fertilizer, and chemical fertilizers) used in crop production
t	Set of 12 months of the year
z	Set of 3 agro-climatic zones
Parameters	
β_{zs}^{L}	Crop land per ACZ (ha)
α_{it}^{c}	Labor requirement per month (man-days)
h_{zt}	Hired labor per month (man-day)
P_i^c	Crop prices (FCFA per ton)
y_{zis}	Yield of crop i per ACZ (ton/ha)
T_{iskm}	Technology costs of crop i per system (FCFA)
w_{tz}	Hired labor wage per ACZ, month, and period (FCFA per man-day)
f_{zt}	Family labor per ACZ, and per month (man-days)
P_j	Livestock prices per livestock type (FCFA per head)
f_t^a	Livestock feeding expenses per month (FCFA)
P_z^L	Land costs per ACZ (FCFA)
R_{is}	Working capital (FCFA)
μ	Number of working days per month
Variables	
x_{zis}^c	Quantity of land in each ACZ allocated to crop i (ha)
x_{zj}	Number of animals produced in each ACZ, per livestock type (head)
h_{zt}	Hired labor to complement family labor per month (man-days)

2.2 Parameterization of the model

Many parameters have been used in the model and these are from various sources. Parameters used are the following one: crop land, crop labor requirement, crop yields, crop prices, cost of veterinary services, livestock ration feeding, livestock prices, technology costs, family reservation wage, hired labor wage, family labor, working capital requirements, land costs, and number of monthly working days. A survey was conducted to collect data on the major part of parameters. Further, several previous works have been used to complete data on the remaining socio-economic parameters that were missed in the survey (Egbendewe-

Mondzozo et al. 2016); (Gary & Pasquale, 1981), (Louhichi & Gomez y Paloma, 2014). In addition, other socio-economic parameters were collected from the FAO database (FAO, 2015) and from the World Development Indicators (WDI) (World Bank, 2015). The remaining parameters were estimated based on previous works and reports.

2.3 Study area

This part of the study covers the whole country of Togo. Indeed, Togo is a West African country bordered by Ghana to the west, Benin to the east, Burkina Faso to the north and Atlantic Ocean to the south providing to the country a maritime coastline of about 55 km subject to erosion threat. With a total area of 56,600 km², Togo is located between 6° and 11° North latitude and between 0° and 1°40 East longitude. The country is a tropical, sub-Saharan nation, whose economy depends highly on agriculture, with a climate that provides good growing seasons.

The climate is in general tropical with average temperatures ranging from 27.5 °C on the coast to about 33 °C in the northernmost regions, with a dry climate and characteristics of a tropical savanna. The climate is tropical and humid for seven months (from April to October) while the dry desert winds of the harmattan blow south from November to March, bringing cooler weather. Average rainfall varies between 800 and 1,400 mm. Even though the average rainfall is not very high for the whole country, the southern part is characterized by two seasons of rain (the first between April and July and the second between September and November) whereas the northern region is characterized by one rainy season (from April to October).

The arable land in the country is estimated at close to 3.4 million hectares (64% of the country). Further, the total irrigable land covers roughly 86,000 hectares, and the country's exploitable shallows span 175,000 hectares. Surface and groundwater are estimated at between 17 and 21 billion cubic meters of water each year, for annual consumption of about 3.4 billion m^3. In the north part of the country, land is characterized by a gently rolling savanna while in the center it is characterized by hills. The south of Togo, on the other hand, is characterized by savanna and woodland plateau and extend to a coastal plain with extensive lagoons and marshes.

Marshes and mangroves characterize_the coast of the country in terms of flora and fauna. Further, forest destruction combined with species endangering due to high human population growth is becoming a serious challenge for the country. Plant formations have been significantly degraded and the rate of deforestation stands at around 15,000 ha/year, compared with a pace of reforestation which barely exceeds 3,000 ha annually. For the purpose of the study, the country is divided into three agro-climatic zones as it can be seen in figure 6. The classification of zones is based on soil characteristics (type of soil and level of fertility) and climatic conditions (precipitation and temperature).

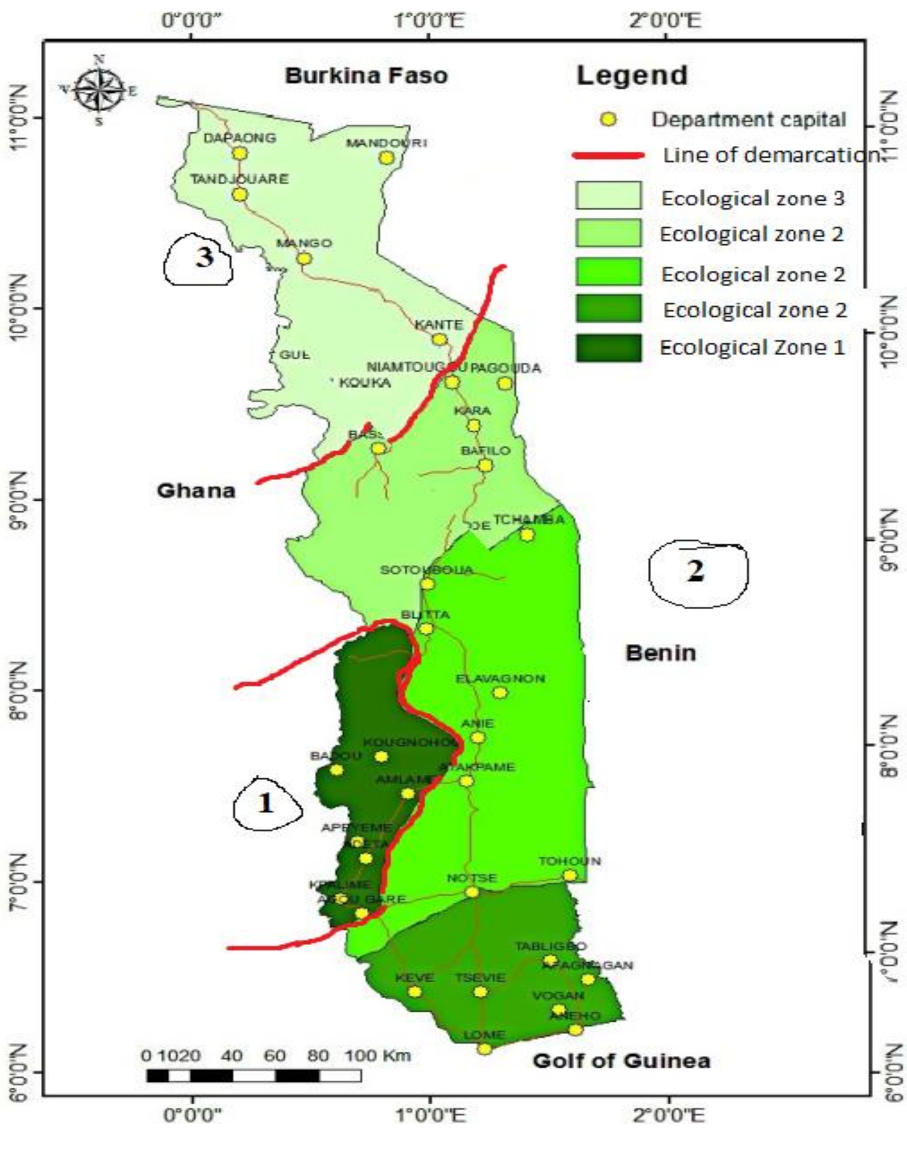

Figure 1: Agro-climatic zones

2.4 Data sources

A survey was conducted across the country and over 422 farmers have been surveyed. The surveyed farmers are classified into two groups namely: conventional farmers and green famers. The distinction is based on the cropping techniques and type of fertilizers that are applied. Thus, we mean conventional farmers all famers that apply traditional farming techniques and use chemical fertilizers whereas, green farmers are those applying new and improve cropping techniques that are friendly with the environment such as the use of manure and compost. In addition, three agro-climatic zones were identified in the country and the survey was conducted taking into account this aspect. The distribution of the surveyed farmers is displayed in table 2.

Table 2: Farmers' distribution in respect to crops

Zones	Systems	Acreages per crop				Total Number
		Maize	Sorghum	Millet	Rice	
Zone 1	Conventional	1.26	0.50	1.20	0.27	134
	Sustainable	0.43	-	-	0.31	4
Zone 2	Conventional	0.65	0.52	0.1	0.47	179
	Sustainable	0.75	0.67	-	0.18	27
Zone 3	Conventional	1.12	0.87	0.51	0.48	92
	Sustainable	**0.73**	**0.74**	**0.41**	**0.31**	**58**

2.5 Calibration of the model

The model calibration consist of reproducing observed data for the base year. It aims to reproducing the closest value of observed land allocation for various crops. The positive mathematical programming (PMP) method was therefore applied herein to calibrate the model. The choice of PMP approach relies on previous works (Howitt, 1995). The model has been used on several policy models at the sectorial, regional and farm level such as the price-endogenous optimization model calibrated with the PMP method by Howitt et al. (2009). The great advantage of applying PMP calibration method is that the model's solution is close to the observed data (Louhichi et al., 2010). In addition, the PMP approach uses the farmer's crop allocation in the base year to generate self-calibrating models of agricultural production and resource use, consistent with microeconomic theory, which accommodate heterogeneous quality of land and livestock.

The PMP calibration applies three stages. In the first step, the constrained linear programming (LP) model is applied to generate cropland allocation. The results show that all crops are grown in all zones except sorghum that is not grown in zone1 and millet in zone 2. In the second stage, the model is rerun with land use constrained by the observed cropland. At the third stage, the shadow prices from the second step are used to specify the coefficients of the marginal yield functions that are then applied to calibrate the model as a nonlinear quadratic optimization model. Following this process, the model is able to predict cropland allocation for the baseline year with an average absolute percentage deviation that is within the acceptable range in modeling farmer behavior (Howitt, 1995).

3 Results and discussion

The calibration of the model using the PMP approach was able to predict cropland use allocation of the baseline year. The predicted cropland use are reported in Table 3. We notice that land use and productions differ across zones, underlying the disparities in agricultural and climatic conditions on the ground level. All crops, in this step, are grown in all zones for the two type of farming systems except for the zone 1 for which farmers adopting sustainable farming system have not been recorded. The profit associated is estimated at about FCFA 1,887,200 (about $ 3,500).

As already mentioned above, the results show that all crops are grown in all zones except sorghum in zone 1 and millet in zone 3. In zone 1, there is no cropping using sustainable farming system, all the land use is allocated to conventional farming. This can be seen through the acreages allocated to maize and millet (1.26 and 1.21 ha respectively) which are somewhat higher than the average acreage allocated in other zones, appearing as a compensation for what should be shared between the two cropping systems.

Table 3: Cropland use allocation for the baseline year (in hectare)

Zones	Systems	Maize	Sorghum	Millet	Rice
Zone 1	***Conv***	*1.26*	*0*	1.21	0.27
Zone 1	**Sust**	0	0	0	0
Zone 2	**Conv**	0.65	0.52	0	0.47
Zone 2	**Sust**	0.75	0.67	0	0.19
Zone 3	**Conv**	1.12	0.87	0.51	0.47
Zone 3	**Sust**	**0.74**	**0.74**	**0.4**	**0.31**

Further, the allocated land use for conventional farming in zone 3 is higher than the one allocated to sustainable farming for all type of crops. This is the opposite in zone 2 where the allocated land use for sustainable farming is greater than the one allocated to conventional farming except for rice. The aforementioned observation is characteristic of agricultural and climatic disparities that exist across the country. The type of farming system adopted and the type of crop that is grown in a region or zone is usually dependent on the agro-climatic characteristics of this zone. This aspect may be confirmed in the works of Lokonon et al. (2016) who found that acreages and productions differ across countries, showing the disparities in agricultural conditions on the ground. In this line, Galdeano-Gómez et al. (2017) underlines that any analysis on sustainability should be defined geographically (e.g. region, nation, world, farm, system, community,) and limited to a specific study period (e.g. short-term or long-term).

For instance, the national agricultural statistics reveal that most of crops that are grown in zone 1 are cash crop (cacao and coffee), produced for exportation. Zone 1 represents the highest wet and fertile region in the country. Thus, growing cash crops in this region seems to be more benefic for farmers than growing cereals. Indeed, growing cash crops usually leads to the application of intensive farming in competitive vision of agricultural production (Omer et al., 2010), explaining the reason why conventional farming system is widely adopted in zone 1. In response to promoting sustainable farming among farmers, a number of policies can be adopted and their expected impact are reported in the following part of the work through policy simulation that have been run.

3.1 Green credit offer policy

The first policy simulation developed in this work is the implementation of a 'green credit' policy. By green credit policy we mean the adoption of a specific policy which consist of providing credit to all farmers willing to engage in sustainable cropping system. We assume that it is a state program which aims to help smallholder and not to make profit. In line with this objective, the assumption made is that farmers will reimburse at the end of each cropping season the exactly amount they have received (the amount they will pay to support credit services is also assumed to be negligible). The credit offered should depend on the type of crop that is grown and the acreage exploited. The proposed credit policy offer is presented in table 4 and results are reported in Table 5.

Table 4: Proposed amounts of credit offered

	Systems	Maize	Sorghum	Millet	Rice
Amount per hectare (CFA)	Sustainable	400,000	300,000	300,000	600,000
	Conventional	100,000	100,000	100,000	100,000

Note: 1West African CFA = 0.0018 U.S.$

The proposed amounts are assumed to be identic for all regions and zones. The obtained results after simulation running are reported in Table 5.

All crops are grown but with a significant reduced acreages that are allocated to conventional farming, especially in zones 3 and 1. The findings show that an implementation of a green credit policy could incite more farmers to engage in environmental friendly cropping practices. However, we notice no changes in acreages that are allocated to sorghum. This can be explained by the fact that growing sorghum does not require a great quantity of fertilizer. Regarding the benefit associated, the profit remains approximately identic and is estimated at about FCFA 1,857,000. This notice is in accordance with the works of Uematsu & Mishra (2012) who found in their study that certified organic farmers do not earn significantly higher household income than conventional farmers.

Table 5: Cropland use allocation with a green credit policy

Zones	Systems	Maize	Sorghum	Millet	Rice
Zone 1	***Conv***	*0.24*	*0*	0.18	0.27
Zone 1	**Sust**	0	0	0	0
Zone 2	**Conv**	0.24	0.52	0	0.36
Zone 2	**Sust**	0.75	0.67	0	0.19
Zone 3	**Conv**	0.24	0.87	0.18	0.36
Zone 3	**Sust**	**0.74**	**0.74**	**0.4**	**0.31**

The fall in profit is due to the difficulty to exploit a large acreage of production when applying a sustainable production system such as the use of manure and compost. The use of manure and compost often requires great efforts than the use of chemical fertilizers that are too much easier to be carried. Further, the sector still remains traditional and its production system that relies on rudimentary tools don't help to exploit large scale farm area. As asserted by Saifi & Drake (2008) the development of a sustainable agriculture requires to influence many subsystems and to implement changes in production techniques and land use as short-term responses to the problem, and resource allocation, technological development, and changes in values as long-term responses. Indeed, there is great need to accelerate the pace of farming mechanization that could allow farmers to exploit large acreages.

3.2 Subsidy policy

The subsidy policy adopted herein is inspired by the existence of a project named GIFT (Gestion Intégrée et Fertilisée des Terres) in the country. The project consist of providing freely bio-fertilizer to farmers that are interested in adopting sustainable farming. So, based on that example, the model was simulated to capture farmers' behavior in case a policy is put in place and consist of offering bio-fertilizers at a zero price. The simulation results are reported in Table 6.

The results show no change in cropland allocation. This can be explained by two factors. First, the analysis of data collected indicates a lower level of cost production for the use of manure and compost compare with the use of chemical fertilizers. Second, the use of manure and compost requires a lot of efforts and limits the exploitation of large area of cropping. Thus, the combination of these two factors explain this no change of farmers' behavior in the presence of a subsidy policy. As explained above, use manure and compost need to be accompanied by appropriate technology that could help farmers to exploit easily large acreages of cropping. Further, the profit associated when introducing a subsidy policy is about FCFA 1,981,700. This is higher than the profit obtained in the case of non-policy implementation (FCFA 1,887,200).

Table 6: Land allocated in presence of a subsidy policy

Zones	Systems	Maize	Sorghum	Millet	Rice
Zone 1	**Conv**	1.26	0	1.21	0.27
Zone 1	**Sust**	0	0	0	0
Zone 2	**Conv**	0.65	0.52	0	0.47
Zone 2	**Sust**	0.75	0.75	0	0.19
Zone 3	**Conv**	1.12	0.87	0.51	0.47
Zone 3	**Sust**	**0.74**	**0.74**	**0.40**	**0.31**

3.3 Combination of policies: green credit and subsidy policies

We decided in this case to implement a combination of the two previous policies in order to understand farmers' behavior and choices. We assume an offer of a green credit per hectare of land exploited and per crop. The proposed amounts represent half of the ones that were proposed in the case of a single 'green credit' policy. In addition, we assume a subsidy policy that consist of offering bio-fertilizers at a zero price.

The idea here is that farmers receive both a small amount of credit and a small but reasonable quantity of organic-fertilizer (particularly bio-fertilizer). Cropland allocation is reported in Table 7.

All crops are grown with reduced acreages for conventional farming as in the case of green credit policy. Cropland allocation is exactly the same one obtained when simulating a green credit policy. Based on the obtained results, one can draw that the green credit policy is more effective than the subsidy policy. The profit obtained in the case of policy combination is equal to FCFA 1,952,000. This is somewhat higher than the one obtained with single green credit policy (FCFA 1,857,000), but somewhat lower than the one obtained in the case of subsidy policy (FCFA 1,981,700). This situation can find its explanation in the fact that in the case of subsidy policy farmers don't have anything to reimburse while in the case of green credit policy they must reimburse the credit obtained which reduces their profit. A summary of results are reported in Table 8.

Table 7: Cropland allocation for policy combination

Zones	Systems	Maize	Sorghum	Millet	Rice
Zone 1	***Conv***	*0.24*	*0*	0.18	0.27
Zone 1	**Sust**	0	0	0	0
Zone 2	**Conv**	0.24	0.52	0	0.37
Zone 2	**Sust**	0.75	0.67	0	0.19
Zone 3	**Conv**	0.24	0.87	0.18	0.37
Zone 3	Sust	0.74	0.74	0.4	0.31
Zone 3	**Sust**	**0.74**	**0.74**	**0.4**	**0.31**

3.4 Policy implication

The analysis of outcomes reveals two distinct cases: a case where all crops are grown with the two cropping systems approximately at the same level of acreages (baseline model + subsidy policy) and a second case where conventional farming is applied with reduced level of acreages. In terms of profit, the findings show that profits obtained don't vary significantly from one policy to another. We can explain this by a compensation process due to acreage modification when implementing in each policy. Thus, the choice of policy to be implemented will depend on the objective at which it is targeted.

If the target is to increase the area allocated to sustainable farming, implementing a green credit policy or combining it with a subsidy policy should be the appropriate decision. But, if profits that are associated need to be added to the target, a combination of the two policies should be the best way. However, combining these policies will require great sacrifices from government that, especially in developing, are usually constrained by economy weakness. In case the target aims to improve only farmers' wellbeing, implementing a subsidy policy should be the best choice since it increases farmers' profit. Finally, we observe that in a situation without any policy application, farmers will likely prefer the baseline scenario since the profit associated is somewhat high. Uematsu & Mishra (2012) argued that the lack of economic incentives can be an important barrier to conversion to organic farming.

Table 8: Summary of the main results

Policy	Cropland allocation	Profit (FCFA)
Baseline model	*All crops are grown with the two cropping systems.*	*1,887,200*
Green Credit	All crops are grown with reduced acreages for conventional farming systems.	1,857,000
Subsidy	All crops are produced with the two cropping system as in the baseline model	1,981,700
Green Credit + Subsidy	All crops are grown with reduced acreages for conventional farming systems as in the case of green credit policy.	1,952,000

Conclusion

The study was carried out to understand farmers' behavior in the context of agro-climate variability. A representative risk-neutral and profit maximization economic agent modelling approach was applied herein. The findings reveals two specific behavioral choices of farmers with regards of the three types of policy that were simulated. The first behavioral case is the one where conventional and sustainable production systems are both applied. This case that correspond to the baseline situation appears when the subsidy policy is implemented. The second case is the one where only sustainable farming is adopted by farmers to grow crops except for sorghum. That situation appears when the green policy or a combination with the subsidy policy are implemented. Thus, the lesson drawn herein is that agricultural policy can significantly influence agricultural sector and reshape its development path. However, the impact of policies may vary across regions and differ from one farmer to another. Kuyvenhoven et al. (1998) asserted that "the effectiveness of policy instruments to influence farm household behavior is conditioned by possible trade-offs between different productive and consumptive objectives, as well as different supply response reactions due to uneven levels of market integration and attitudes towards risks".

We found in this study that implementing a green credit policy or combining it with a subsidy policy was the effective strategy to increase area allocated to sustainable farming. But, in terms of improving farmers' profit (farmers' welfare in other consideration) combining green credit policy with subsidy policy seems to be the best way to go. Do African government have enough mean to do it? That crucial question reveals barriers that could prevent agricultural transformation toward a sustainable one. Tessema et al. (2015) to argue that, the proposed conservation agriculture which consist of mulching and crop diversification and, minimum tillage, does not appear to be the best interest practice for smallholder farmers. This is explained by a set of constraints including risk aversion, time preference, limited credit and market access. In addition, Uematsu & Mishra (2012) underlined the lack of economic incentives that can be an important barrier to conversion to organic farming.

One thing is to promote sustainable farming system among farmers; but the other is to capture the effect of sustainable agricultural policies on their choices. Aldy et al. (1998) asserted that public policy may play a positive role to drive an economy along a sustainable path of economic development. However, public policy in agriculture remains a complex matter due the fact that many policies have failed to improve the sector, especially in developing countries. Mouysset (2014) to argue that the management of biodiversity in farmlands is still an open question, especially with ongoing debates about ways to improve the use of the dedicated budget into agricultural policy. Indeed, a practice effective in reducing emissions at one region can be less effective or even counterproductive elsewhere. Accordingly, the IPCC report underlines there is no universally applicable list of mitigation practices or strategies; practices need to be assessed for individual agricultural systems based on climate, social setting, edaphic, and historical patterns of land use and management (Smith et al., 2007).

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