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**TOPIC**

# REMOVING MARKET CONSTRAINTS AND SMALLHOLDER'S ADAPTATION TO CLIMATE CHANGE

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**Abstract**

This study aims to analyse the extent to which removing market constraints can foster smallholder's adaptation to climate change. To that end, the study makes use of an optimization model by relying on the Agricultural Household Model (AHM) theory. The model is applied to survey data collected from the central part of the Republic of Benin.

**Keywords:** agricultural household model, bioeconomic model, climate change, market constraints

## 1. Introduction

In most regions of Africa, climatic factors are instrumental in determining food crop production as well as agricultural productivity. The rainfall pattern during the farming season largely determines the type of crops grown and affects the productivity of most farmers. Given that agricultural production remains the most critical source of income for many communities in Benin, the increased risk of crop failure, accompanied by the negative effects of climate change, poses a major threat to food and income security as well as poverty reduction. Additionally, the start of the raining season is increasingly becoming difficult to predict; the total duration of the dry season is revealed to have increased whilst the duration of the rainy season has shortened (Amikuzuno & Donkoh, 2012).

Uncertainty about the future patterns of climate on one hand pushes smallholders, notably risk-averse farmers, to use conservative risk strategies that reduce average crop yield, increase cost of production, decrease farmer's profitability and efficiency (Meza, Hansen, & Osgood, 2008), and on the other hand limits the adoption of innovations by increasing the risk of financial losses (Zinyengere et al., 2011). Most studies conducted on the economic impact of climate change on agriculture in Africa illustrate that such effects can significantly be reduced through adaptation (Kurukulasuriya & Mendelsohn, 2006). The fundamental approach of overcoming climate change associated risks, is by introducing new and innovative production techniques, especially high yielding-drought resistant seeds, use of pesticides and chemical fertilisers to existing traditional knowledge. Past experience has established that the use of technological innovations such as new varieties and improved management practices can lead to higher yield and offset yield losses by 40% (Thornton, Jones, Alagarswamy, & Andersen, 2009). Technical changes in the form of improved agricultural production technologies have also been well documented to have positive impacts on agricultural productivity in most agrarian economies (Nin, Arndt, & Precktel, 2003), although adaptation to these technologies are very low among farmers in Africa in general and especially in Benin.

The capacity to adapt is dependent on socio-economic and environmental circumstances and the availability of information and technology (UNFCCC, 2011). Different authors have identified a number of factors constraining adoption of technologies for climate change adaptation especially in developing countries. Enete & Onyekuru (2011), Bryan et al. (2009) and Deressa (2009) identified lack of financial resources due to lack of credit facilities while Ellis-Jones et al. (2012) and Antwi-Agyei et al. (2013) identified the lack of ready markets. Furthermore, Lee & Thornsbury (2010) postulate that agricultural markets' structure (presence and functioning) can impede the transformation of agronomics gains obtained through implementation of various adaptation technologies into economics gains.

From the above discussion, the major question worth asking is; what can be the effects of markets structure on farmers' ability to manage or avoid production and income risks induced by climate change. Consequently, the study seeks answers to these specific research questions: (i) what is the outcome of labour market conditions on the climate adaptation strategy? (ii) what is the outcome of credit market conditions on the climate adaptation strategy? and (iii) what is the outcome of agricultural output market conditions on the climate adaptation strategy?

This study offers vital information to guide policy makers on the best technological options for managing climate change-induced risks among smallholder farmers, noticing that knowledge of these factors would help improve the welfare of these smallholder farmers. It will also help improve upon the works of stakeholders involved in the designing and implementation of programs and policies aim at improving smallholder household adaptation to climate change. Most studies conducted focussed on the regional or landscape level, while few have addressed the household and plot level. This study will therefore examine the impact of climate change at the household level by developing a bioeconomic optimization model. The new features of these simulation models could inspire other researchers and stakeholders interested in climate change and its impacts on smallholder farmers. The study would therefore serve as a source of reference for other research scientists and stakeholders interested in conducting studies on climate change. Furthermore, adaptation to climate change by smallholder farmers is relevant for economic growth and the alleviation of rural poverty. Information gotten from this study would contribute to the debate on climate change and the best ways of increasing the capability of these farmers. Based on the above, suitable policy strategies would be formulated to ensure that the maximum potential of smallholder farmers is realized for the benefit of the whole country.

## 2. Literature review

Scientists noticed a slow but regular trend of increasing surface temperature and decreasing rainfall in Africa in general and in West Africa especially (Barrios, Ouattara, & Strobl, 2008; Intergovernmental Panel on Climate Change (IPCC), 2007, 2012) over the last few decades due to the increase in anthropogenic greenhouse gases concentrations (IPCC, 2014). Projections of the increase of temperature in the future in West Africa where Benin is located range from 2°C to 4°C around 2090 (IPCC, 2012). Nelson *et al.* (2009) and Paeth, Capo-Chichi, & Endlicher (2008) predicted that temperature would increase in the same range (2°C to 4°C) but around 2025 in Benin whereas Jalloh *et al.* (2013), based on different simulation models, predicted an increase in surface temperature between 1°C and 2.5°C for Benin by 2050. Moreover, Boko, Kosmowski, & Vissin (2012) already noticed a 1% temperature rise in the whole country except the coastline since 1995. The augmentation in temperature in the tropics will induce an increase in relative humidity, water evaporation, crops transpiration, yields reduction and weed and pest proliferation (Nelson *et al.*, 2009; Paeth *et al.*, 2008).

Concerning rainfall, Paeth *et al.* (2008) found that Benin would receive in the future almost the same amount of rainfall like previously whereas Jalloh *et al.* (2013) projected that rainfall would probably decrease or stay stable in the South, increase in the North by 2050 and at that time there would be a concentration of the rains within a short period that would increase the length of the dry season and create floods in the country. The analysis of the trend of precipitation received in the past (last five decades) confirmed the idea of a decrease of amount of rainfall and rainy days over time (Boko *et al.*, 2012). The total amount of precipitations and the number of rainy days have decreased slowly throughout the last five decades in Benin, with about 3.7% and 3% decrease per decade for rainfall quantities and rainy days respectively (Boko *et al.*, 2012; Hountondji, Longueville, & Ozer, 2011).

Climate change, *which refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer*, will increase the frequency of occurrence of extreme events such as droughts and floods (IPCC, 2007). WFP (2014) indicated that Benin faced about fifteen major climatic disasters (floods and drought) since 1984 with important damages.

Decisions on policies that can reduce climate change and variability damages depends heavily on the prediction and estimate of the damages attributable to climate change (Kumar, 2009). One school of thought postulates that climate change will increase agricultural yields in West Africa in general and in Benin in particular in the future (Adejuwon, 2006; Fischer, Shah, Tubiello, & van Velhuizen, 2005; Liu *et al.*, 2008). The scientists from this school argue that there are several agro-ecological zones that are currently sub-optimal (deficit of water or temperature or relative humidity) but will become optimal due to modifications brought by climate change. Also climate change could make some regions that were once unsuited to agriculture, because they were receiving too much or too less water or facing other climatic challenges, now suitable for agriculture. Moreover, the production of some crops could become possible in areas where it was not possible in the past because of the rise in temperature and decrease in water or vice versa.

On the other hand, the second school of thought suggests that climate change will decrease agricultural yields by further increasing the temperature that will lead to diminution of water available within the root zone of most crops and harm the agricultural sector in tropical countries (Ben Mohamed, Van Duivenbooden, & Abdoussallam, 2002; Butt, Mccarl, Angerer, Dyke, & Stuth, 2005; Fischer *et al.*, 2005; Jones & Thornton, 2003; Lobell *et al.*, 2008; Mendelsohn, Dinar, & Dalfelt, 2000; Nelson *et al.*, 2009; Paeth *et al.*, 2008; Parry, Rosenzweig, Iglesias, Livermore, & Fischer, 2004; Schlenker & Lobell, 2010; Van Duivenbooden, Abdoussalam, & Ben Mohamed, 2002). Summarizing the arguments from both schools of thought, Roudier, Sultan, Quirion, & Berg (2011) built a meta-database from sixteen recent studies and found uncertainty and divergence in projections but estimated that climate change will decrease agricultural yields by 11% (median response) in West Africa and by 13% (median response) in southern West African sub-zone which includes Benin.

The rapid change of climatic patterns in most developing countries create a need to assist local communities in lowering the burden of such conditions (Stigter, 2004). But climate change will not only create damages, it will also lead to some positive impacts. In Benin, climate change will probably stimulate an increase in rainfall in the north of the country and therefore create a favourable environment for improvement in yields of some crops. Boko *et al.* (2012) consider that situation as a redistribution of the cards, creating winners and losers. Climate change will make some farmers' environment worse off while improving the environment of others. But in all cases it is vital to help farmers with additional resources to reduce damages and improve benefits depending on the prevailing situation.

## 3. Methods

### 3.1. Study area

The data used for this study are exclusively from primary source and have been collected from five municipalities of the Collines Region in Benin. A questionnaire was design and administrated at the household level to the head of household through face to face interviewed. Benin is a coastal country located in West Africa. It is divided into twelve Regions including the region of Collines. Located in the center of Benin, Collines Region covers an area of 13,931 km2 which represents 12% of the total area of Benin. According to the last general census of the population in 2013, it has 716,558 inhabitants, representing 7.2% of the total population of Benin. The region is divided into six municipalities: Bante, Dassa-Zoume, Glazoue, Ouessè, Savalou and Save. The economic activities of the area are primarily based on agriculture (71%). Regarding agriculture, the Region provide a very important part of the national supply as evidenced by production statistic. The region is the largest producer of roots and tubers and vegetables in Benin. As regards cereals, the region usually ranks second or third position. This is an ideal area for the analysis of livelihood strategies of people given the diversity of crops grown. Yet, this is one of the poorest regions of Benin, with an incidence of poverty estimated at 46% in 2011 (INSAE, 2013). The food situation in the Region is also critical despite the amount of agricultural production that comes from this region.

### 3.2. Data

The study used the multistage sampling procedure where it started with a purposive selection of the Collines Region. There are six municipalities within the Region. Based on the importance of agricultural activities in the municipalities, five municipalities out of six served as the study area: Bante, Dassa-Zoume, Glazoue, Ouessè, Savalou. Multi-stage sampling technique was employed for this study. Each municipality is divided into districts, and in each district we have a certain number of villages/communities. First, we randomly selected 50% of the districts in each municipality and where the number of district is odd, we chose the maximum (for example if the number of the district is 09, we retained 05). Within the districts, we purposively chose one village/community proportionate to the number of the farm household in each village (they are also the main agricultural production villages). The share of the farm household in each municipality and district was obtain from the National Statistical Institute of Benin. In each village, we randomly selected 5% of the total farm households and based on the information provided by the agricultural extension officers and the farmers based organizations. The farm households that were enumerated were randomly selected from the total agricultural household list of the villages.

### 3.3. Model

This study makes use of an optimization model by relying on the Agricultural Household Model (AHM) theory (Hazell & Norton, 1986; Singh *et al.*, 1986; Sadoulet & de Janvry, 1995). Under this framework, the household is considered as jointly engaged in production, consumption, and labor supply (Singh *et al.*, 1986). The advantage of optimization models is the ability to generally produce the outcomes that best achieve the specified objective which can be either profit maximization, or cost minimization given specified constraints. These models also allow to simulate adaptation strategies. The empirical model is a recursive dynamic optimization model (the horizon of the model is 10 years) where some parameters are updated every year based on the results of the previous growing period. The model accounts for labor and credit market imperfections. A previous version of the model is used by Lokonon et al. (2015).

Climate change enters in the model through its impact on crop yields. The optimization model includes the main crops, and livestock production. We assume that animal sell/buy transactions are made at the start of the planning period. Therefore, animals bought are considered in the animal feed intake planning and animals sold are excluded from the animal feed considerations. The optimization model is specified as follows:

$$Max\ Z = [1/(1+i)^t][\sum_{c=1}^{n} SOLD_{ct}px_{ct} - \sum_{c=1}^{n} capn_{ct}X_{cst} - IntCRED_t - wagein_tHIRIN_t + wageout_tHIROUT_t + \sum_{a=1}^{m} priceliv_{at}(ZZ_{at} - NN_{at})],\quad t = 0, 1, \dots, 10 \quad (1)$$

$$\sum_{c=1}^{n} X_{cst} \leq A_{st}\,,\ \ s = 1, 2, 3, 4 \quad (2)$$

$$\sum_{s=1}^{4} Y_{cst}X_{cst} = CONSS_{ct} + SOLD_{ct},\ \ c = 1, 2, \dots, n \quad (3)$$

$$\sum_{c=1}^{n}\sum_{s=1}^{4} w_{cpt}.X_{cst} \leq [(MEN_t + 0.75WOMEN_t + 0.5CHILDREN_t)actpop - \tau]availw_p + HIRIN_t - HIROUT_t - LEISURE_t,\ p = 1, 2, 3, 4 \quad (4)$$

$$HIRIN_t \leq UPPERHIRIN_t \quad (5)$$
$$HIROUT_t \leq UPPERHIROUT_t \quad (6)$$
$$\sum_{c=1}^{n}\sum_{s=1}^{4} npk_{ct}X_{cst} \leq NPK_t \quad (7)$$
$$\sum_{c=1}^{n}\sum_{s=1}^{4} urea_{ct}X_{cst} \leq UREA_t \quad (8)$$
$$\sum_{c=1}^{n}\sum_{s=1}^{4} capn_{ct}X_{cst} \leq CAP_t + CRED_t - wagein_tHIRIN_t + wageout_tHIROUT_t \quad (9)$$
$$CRED_t \leq 500{,}000 \quad (10)$$
$$CONSS_{c1t} - \beta_{1c1,t}.Z_t - \beta_{2,c1,t}.SIZE_t - \beta_{0,c1,t} \geq 0,\ \ c1 = 1,\ 2, \dots, n_1 \quad (11)$$
$$\alpha X_{jt} = X_{kt}, \qquad j \neq k \quad (12)$$
$$\theta_{at} \leq WW_{at} + NN_{at} - ZZ_{at} \leq \varphi_{at},\quad a = 1, 2, \dots, m \quad (13)$$
$$\sum_{a=1}^{m} feed_{at}.(WW_{at} + NN_{at} - ZZ_{at}) \leq \sum_{c=1}^{n}\sum_{s=1}^{4} yr_{ct}.X_{cst} \quad (14)$$
$$X, CRED, CONSS, SOLD, HIRIN, HIROUT, NN, ZZ, LABOR, d \geq 0 \quad (15)$$

The objective of the farmers (equation 1) is to maximize the discounted expected cash income from cropping, livestock, and off-farm activities ($i$ is the discount rate). Equation (2) refers to land constraints. $c, s, and\ t$ are the indices of the crops, land types, and years respectively, $X$ is the land size in ha and $A$ is the total land size. Production constraint is captured by equation (3); production should serve as self-consumption and as means to get cash income. $Y$ is the yield level, $CONSS$ is the quantity of crop kept for self-consumption and $SOLD$ is the quantity of crop sold. Equation (4) represents labor constraints; four periods are considered in order to take into account the peak and slack periods. $w$ is labor requirement, $p$ is the index of the period, $MEN, WOMEN\ and\ CHILDREN$ are the number of men, women and children. $actpop\ and\ availw$ are the proportion of active population and available working day, and $HIRIN, HIROUT, and\ LEISURE$ are hired and hired-out labor and leisure respectively. $\tau$ is used to account for labor use for livestock. Labor market imperfection constraints under the assumption that hired and family labor are not perfect substitute are through equations (5) and (6) with $UPPERHIRIN\ and\ UPPERHIROUT$ being the upper bound of hired labor and off-farm labor supply respectively. Equations (7) and (8) are relative to fertilizer balance. $npk, urea, NPK\ and\ UREA$ are NPK requirement, Urea requirement, available NPK, and available Urea respectively. Credit constraint is through equation (9), while equation (10) captures credit market constraint. $capn, CAP, CRED, wagein, and\ wageout$ are the capital requirement, the available own fund, credit, the wage rate of hired labor, and the wage rate of off-farm labor supply respectively.

Consumption is included in the model by equation (11). $CONSS, \beta_1, \beta_2, \beta_0, c1, and\ SIZE$ are self-consumption, the marginal propensity to consume crop out of income, the coefficient of variable size in the Engel curve, the lower bound of consumption requirement, the index of self-consumed crops, and the household size respectively. Equation (12) captures crop rotations. Equation (13) is livestock buying and selling constraint. $\theta, WW, NN, ZZ, \varphi\ and\ a$ are the minimal number of animal, the initial number of animal, the number of animal bought, the number of animal sold, the maximal number of animal and the index of livestock type respectively. Equation (14) accounts for crop residue necessary to feed the livestock. $feed\ and\ yr$ are crop residue requirement and crop residues per ha respectively. Non-negativity constraints are through equation (15).

The model is run with General Algebraic Modeling System (GAMS).

**Results**

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