Economic evaluation of climate information in Sahel: case of farm households in Burkina Faso

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Abstract

This study highlights the perception and the option value of climate information in the sahelian and sudano-sahelian agro-climatic zones of Burkina Faso. It shows that the climate information is asymmetrically distributed to a minority (21.78 %) of the sampled farmers. The analysis reveals that the majority (93%) of the farmers need climate information to guide their decision in planning agricultural activities. Option value shows the interest granted by farmers using climate information. 64% of the farmers willing to pay would pay an average of CFA 546.34 Francs to obtain climate information. The willingness to pay is determined by the ability of the farmers to predict the climate, to use radio as a means of information, awareness of farmers on the previous forecast and early onset of the rainy season. While farmers considered benefit from the use of climate information, it is clear that its contribution to farm income remains a field of research to explore. Thus it is necessary to experiment with individual farms and to evaluate the contribution of climate information to the added value of different crops and farmers' income.

Keys words: *farmers, climate information, willingness to pay, Burkina Faso.*

Introduction

The use of seasonal climate forecasts based on indigenous knowledge is a traditional strategy of West African farmers to reduce climate risk on their crop yields (Roncoli, 2006; Nyong et al., 2007). Forecast guides their decision making for the choice of fields, crop varieties, crop rotation, sowing date and precautions to maintain the crop production. The main indicators of endogenous seasonal climate forecasts are environmental (moon, cloud, wind), biological (animals, plants), magic and religious (Phillips et al., 2002). They are transmitted from one generation to another by oral tradition.

Despite their importance, these forecasts are becoming less reliable because of climate change over the past four decades (Ingram et al., 2002). The distortions in the transmission of indicators from one generation to another question the reliability of these forecasts (Roncoli et al. 2008). Therefore, farmers are looking for new strategies for seasonal climate forecasts to better plan production of seasonal crops (Ingram et al., 2002).

Climate information is one possible way to mitigate the adverse effects of climate change on agricultural productivity (Hansen, 2002). It consists of publishing seasonal forecasts from climate models to farmers (Klopper et al., 2006). The seasonal predictions usually provide information about the probability of the starting and ending dates of the rainy season, the length of the season, the number of rainy days, the annual cumulative rainfall, the average and maximum duration of dry spells during the rainy season.

The purpose of this paper is to analyze the perception of farmers on climate information in Burkina Faso and to identify the determinants of their option value. We formulated two research hypotheses. First, we assume that the majority of farmers perceive climate information as probative adaptation strategy to climate change. Second we expect that the willingness to pay of farmers for climate information depends on their ability to conduct seasonal forecasts on climate change.

Material and method

The study was conducted in the sahelian and Sudano-sahelian agro-climatic zones of Burkina Faso, a landlocked country in West Africa (Figure 1). The sudano-sahelian zone is characterized by rainfalls ranging between 600 and 900 mm during a 4 to 5 months rainy season. In the sahelian zone annual rainfalls range between 300 and 600 mm and are characterized by a more irregular spatial and temporal distribution. This area is the driest of the country sometimes with less than three months rainy season.

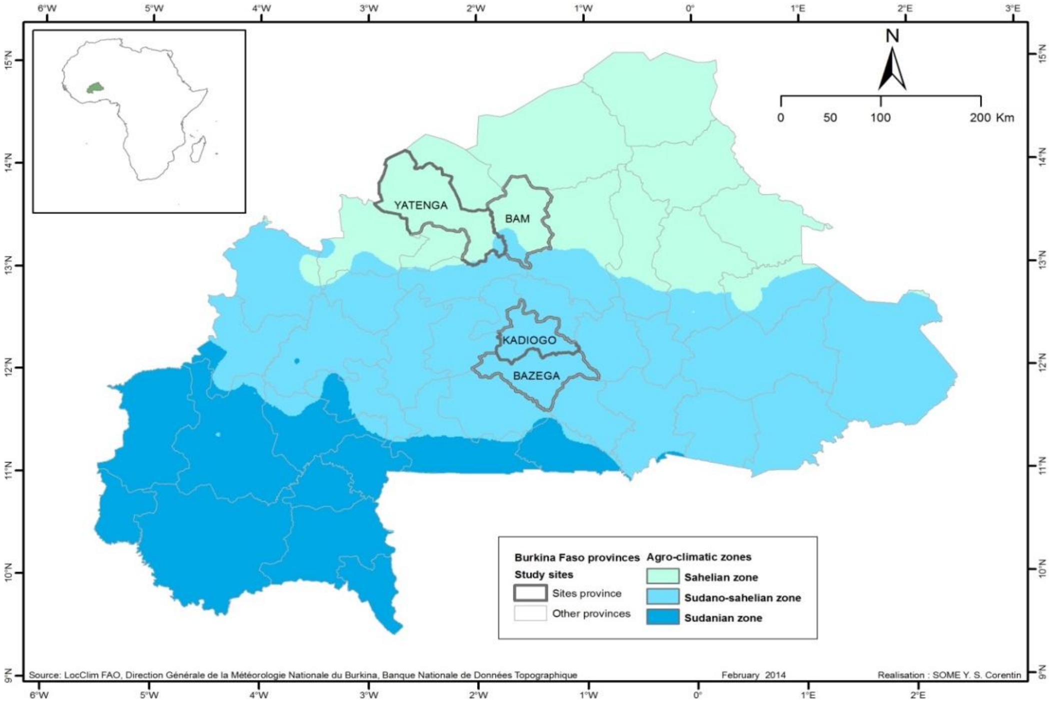

Figure 1. Location of study sites in agro-climatic zones of Burkina Faso

The data collection was performed on the basis of a stratified sampling at three levels identified in collaboration with the team of the project of *supplemental irrigation and climate information* and with the Provincial Directorates of the Ministry of Agriculture and Water Resources. The different levels are the provinces, villages and farmers (Figure 1). The number of farmers per village was obtained on the basis of updated data from permanent agricultural survey made by the Ministry of Agriculture and Water Resources. From this basis, 629 farmers spread over eleven villages were surveyed from January to February 2013 in the provinces of *Yatenga*, *Bam*, *Kadiogo* and *Bazega*. In each village, a third of the farmers were surveyed randomly.

Data were collected using a structured questionnaire referring to socio-economic characteristics of farmers and planted crop during the year 2012-2013. They were also related to endogenous seasonal forecasts of farmers and their perception of climate information. Afterwards farmers were questioned about their willingness to pay (WTP) to benefit from good quality IC using the contingent valuation method.

The approach of contingent valuation method (CVM) is to construct a hypothetical market on goods or service proposed for economic agents (Randall et al., 1974). The objective of CVM is to reveal the marginal willingness to pay of an individual by simulating operation of a market (Ami and Desaigues, 2000). To comply with the principle of this method, the advantages and limitations of the use of climate information were first explained to farmers. After ensuring that farmers have understood the challenges of using the climate information, we asked them to comment on their need for climate information.

The Chi-square test was used to compare the perception of farmers for seasonal climate forecasts and socioeconomic characteristics of potential users at significance level p = 5%. Analysis of variance and the Kruskal-Wallis test were used respectively to compare the average and median income in grain production and farmers' WTP threshold of significance p = 5%. Average and median WTP were calculated excluding the true zeros.

The estimated true zeros are null of WTP given by farmers because their agricultural productivity will not be improved even if they benefit from the climate information. On the contrary false zeros are null WTP by farmers when they need the climate information to guide their decision making to plan agricultural production.

According to Terra (2005), when the proportion of true zeros of the sample is small (10% threshold), the appropriate model for the analysis of the determinants of WTP is the Heckman (1979) model. Otherwise the Tobin (1958) model is indicated. It analyzes the positive valuations (WTP > 0 and true zeros) excluding false zeros. The Heckman (1979) model consists of two steps. In the first step, we calculate the inverse Mills ratio for each observation using the Probit model that separates the population into two parts: one is zero and the other positive WTP. The structure of the Probit model representing possible decisions y_i^* of farmer i to adopt climate information or not is:

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

$y_i = 1$ if the farmer needs climate information (WTP > 0) and $y_i = 0$ otherwise (WTP = 0) with σ the constant, δ the vector of parameters to be estimated, x_i the explanatory variables and ε_i the term of error. Table 1 shows the hypotheses assigned to each variable.
The estimated Probit model using the maximum likelihood method provides an estimate of the coefficients δ and the inverse Mills Ratio ($\hat{\lambda}_i$).

$$\hat{\lambda}_i = \frac{\phi(\sigma + \delta x_i)}{\varphi(\sigma + \delta x_i)} \quad (2)$$

Where φ is the density function for a standard normal variable and ϕ the cumulative distribution function for a standard normal distribution.
The second step is to perform a regression on the WTP > 0 with different explanatory variables w_i and the inverse Mills ratio.

$$\text{WTP}\ (y_i = 1) = \gamma + \beta\lambda_i + \beta' w_i + \mu_i \quad (3)$$

Where γ is the constant, β and β' are the vectors of parameters and μ_i the error term. The estimated regression model uses the ordinary least square method.

The Tobin (1958) model deals with positives WTP and true zeros excluding false zeros. The true zeros (nulls) of WTP are considered censored variables. The model equation is:

$$\text{WTP}_i^* = \alpha x_i + \mu_i \quad (4)$$

$$\text{WTP}_i = \text{WTP}_i^* \text{ if } \text{WTP}_i^* > 0 \text{ and } \text{WTP} = 0 \text{ if } \text{WTP}_i^* \leq 0 \quad (5)$$

Where x_i are the explanatory variables, α the vector of parameters to be estimated and μ_i the error term normally distributed $[0, \sigma^2]$. Estimation of the model is done by maximizing the logarithm function given by the equation:

$$L(\beta, \sigma) = \prod_{\text{WTP}_i > 0} \frac{1}{\sigma}\varphi\left(\frac{y_i - \alpha x_i}{\sigma}\right) \prod_{\text{WTP}_i > 0} \phi\left(-\frac{\alpha x_i}{\sigma}\right) \quad (6)$$

Where ϕ is the probability density function and φ the cumulative probability function of a normal distribution.

Results and discussion

Table 1 shows that a minority of farmers in the sample (21.78%) had access to seasonal forecasts prior to the agricultural campaign of 2012/2013. An asymmetry of information exists within and between climate zones ($p < 0.001$). Compared to other provinces, farmers in the *Yatenga* province (40.48%) were aware of climate forecasts. This asymmetry of information could derive from the presence of other projects experimenting climate information with some farmers in the *Yatenga* province.

Despite this asymmetry, the sources of information are not significantly different among farmers ($p > 0.000$). Nearly 65.85% of the farmers in the sample received the seasonal forecasts prior to the agricultural campaign of 2012/2013 by listening to the radio. Farmers also have similar behavior towards the use of seasonal forecasts ($p > 0.000$). Approximately, 76% of them have taken into account the seasonal forecasts in their decision making. They recognize that seasonal forecasts have supported their decisions in planning and implementing of agricultural activities. Seasonal forecasts facilitate choice of crop rotation, crop varieties and soil type (Klopper et al., 2006).

Table 1. Differential dissemination of seasonal forecasts

Characteristics of the access and use of the current forecasts	Sahelian provinces		Sudano-sahelian provinces		Total	p-value
	Yatenga	*Bam*	*Kadiogo*	*Bazega*		
Access to seasonal climate forecasts climate information						0.000
No (%)	59.52	89.50	82.35	88.89	78.22	
Yes (%)	40.48	10.50	17.65	11.11	21.78	
Information sources						0.104
Radio (%)	58.72	90.00	82.35	66.67	65.85	
Other farmers	41.28	10.00	17.65	33.33	34.15	
Taking seasonal climate forecasts to make decision						0.874
No (%)	22.35	33.33	27.78	25.00	24.19	
Yes (%)	77.65	66.67	72.22	75.00	75.81	

Table 2 shows that 93% of farmers needing climate information. This fraction is equitably distributed within and between the two agro-climatic zones ($p > 0.05$). The need expression of farmers for climate information shows they are well aware of climate risks on agricultural production (Tarhule and Lamb, 2003; Roncoli et al., 2008). Farmers' need relates to the beginning of the rainy season (74.95%), its length (19.52%) and the end of the rainy season (5.52%). Strong aversion of sowing plants on drought risk may justify the choice of the beginning of the rainy season by the majority of farmers ($p < 0.001$). According to Hammer et al. (2001), nearly a quarter of farmers' planting failures are due to poor rains start. The perception of farmers for rainfall changes may explain the differences observed in their needs for climate information within and between agro-climatic zones. For example the decrease in rainfall is perceived by 28.2% of farmers in the Sahelian zone and 45.6% in the Sudano-Sahelian zone (Ouédraogo et al., 2010).

Radio is the most used channel for the dissemination of climate information according to 60.96% of farmers. Although all provinces are covered by the national radio. Radio stations are also located in provinces (*Bam* and *Yatenga*). Differentiated choice of radio ($p < 0.000$) as a means of information on climate information within and between provinces is related to the rate of possession of radios by farmers and their purchasing power to purchase rechargeable batteries (Roncoli et al., 2008).

According to 55.54% of farmers surveyed, April is the suitable period for getting climate information. This month is the start of agricultural activities: *zaï*, bunds, application of organic manure in the fields. The heterogeneity ($p < 0.001$) choices of broadcasting periods on climate information derives from farmers' agricultural practices and the beginning of the rainfall of the previous campaign within and between agro-climatic zones (Ingram et al. 2002).

Table 2. Farmers' need for climate information

Characteristics of the need of climate information	Sahelian provinces		Sudano-sahelian provinces		Total	p-value
	Yatenga	*Bam*	*Kadiogo*	*Bazega*		
Farmers needing climate information						0.451
No (%)	5.24	6.50	8.82	9.40	7.00	
Yes (%)	94.76	93.50	91.18	90.60	93.00	
Types of climate information						0.000
Start of rainfall (%)	58.29	86.63	93.55	65.63	74.95	
End of rainfall (%)	2.01	2.14	4.30	28.13	5.52	
Duration of season (%)	39.70	11.23	2.15	6.25	19.52	
Broadcasting						0.000
Radio (%)	52.76	75.40	40.86	73.44	60.96	
Other (%)	47.24	24.60	59.14	26.56	39.04	
Broadcasting period						0.000
April (%)	21.39	87.36	59.14	62.30	55.34	
May (%)	62.03	12.64	40.86	36.07	38.45	
June (%)	16.58	0.00	0.00	1.64	6.21	

The analysis shows that the majority of the farmers are ready to contribute financially to benefit from the climate information to reduce climate risks on agricultural productivity (Table 3). About 64% of the farmers showed a strictly positive WTP. However 29% of the farmers need climate information but are not willing to pay for. Only 7% of farmers don't want to integrate climate information in their decision process for agricultural production. These behaviors are recurrent within and between climate zones ($p > 0.000$). The mean of WTP is estimated CFA 546.34 Francs per farmer. The median WTP shows that 50% of farmers in Yatenga, Bazega and Bam are willing to pay CFA 200 Francs to benefit from the climate information compared to CFA 300 Francs in *Kadiogo*. Although they are not significantly different within and between agro-climatic zones ($p > 0.000$), the average and median WTP reveal the interest of farmers for using climate information (Kenkel and Norris, 1995). Hanemann (1984) recommended using median WTP to measure the economic level because average WTP can be very sensitive for small changes in the distribution of WTP, while the median is much more robust to these effects.

Table 3. Farmers' willingness to pay for climate information

Farmers' willingness to pay	Sahelian provinces		Sudano-sahelian provinces		Total	P-value
	Yatenga	*Bam*	*Kadiogo*	*Bazega*		
Farmers needing climate information						0.316
True zeros (%)	5.24	6.50	8.82	9.40	7.00	
False zeros (%)	33.81	26.50	23.53	27.30	28.59	
WTP > 0 (%)	60.95	67.00	67.65	63.30	64.41	
Central values						
Average WTP	659.05	525.50	450.78	463.25	546.34	0.137
Median WTP	200	200	300	300	200	0.235

The Heckman model (1979) was used to analyze the determinants of farmers' WTP because the proportion of false zeros is greater than the true zeros (Table 4). The Chi-square test (Prob > chi2 = 0.000) shows that the model is statistically valid at the 1% level (Kpad and Rom, 2013). The inverse Mills ratio indicating the value of farmers' WTP is linked to their decisions to use climate information or not at the threshold of 10 %. The results reveal a difference between the determinants of demand of climate information and WTP (Table 6). The variables significantly affecting farmers demand for climate information are the age of the farmer, the literacy level of the farmer, their marital status and practice of maize and sorghum production and the income from production. The ability of farmers to receive climate forecast by main radio, awareness of farmer on previous forecast and early starting period of rainfall are the variables determining farmers'WTP to benefit for climate information.

The education of farmers significantly influences the demand for climate information at 5% threshold. This can be explained by the fact that education increases the ability of farmers to understand the necessity of climate information to make their decisions in terms of agricultural production in the context of climate change. The effect of education on the use of climate information is in line with the finding of Lybbert et al. (2007) in Kenya and Ethiopia. Marriage also has a significant impact on the use of climate information by farmers at 5 %. It increases the size of farmers while increasing their grain needs through the number of marriages and annual births (INSD, 2009). This increase in grain needs and increases married farmers' need for climate information to better organize grain production. However youth farmers (age < 45 years) negatively affect the demand for climate information at a threshold of 10 %. Indeed, young farmers showed disinterestedness in the use of climate information as they were more interested to non-agricultural activities that provide higher cash income (Thune, 2011). Moreover, membership of a farmer to a group acts favorably on the use of climate information. The grouping of farmers' facilitates their access to seasonal forecasts provided by agricultural services. According to Tarhule and Lamb (2003), discussion between agriculture organized groups allows them to better understand the issues related to climate change in the agricultural sector.

The cultivated area of maize and sorghum positively affect the demand of climate information by agricultural farmers at the threshold of 10%. Farmers believe that corn is very sensitive to drought compared to other grain crops. This reason justifies the use of climate information to plan its production. The important contribution of the sorghum production to grain needs by the farmers may explain its positive impact on the demand of climate information (MAH, 2012). The analysis shows however, that the income from grain production negatively affects the demand for climate information as if farmers were reluctant to inject their grain income into expenditure allowing them to get climate information. Grain production is intended for food consumption of farmers. Farmers rarely sell grain production since they usually cover their food needs (Janin, 2010). Unlike grain revenue, off-farm income positively affects the demand for climate information of farmers. Farmers consider paying for the benefit of climate information from revenues generated by activities such as gold mining, trade, masonry.

Broadcasting of climate forecasts during the rainy season of 2012/2013 has a positive impact on the value of WTP for climate information. Producers believe that the expectations have guided their decisions during the planning of agricultural activities. These reasons justify the value placed on the climate information through their WTP. The use of radio as a means to be informed about climate information affects the value of farmers' WTP. Indeed farmers believe that climate information should be free if they are broadcasted by radio channel (Lybbert et al. 2007). Therefore, they are not willing to pay for climate information. They prefer to pay if climate information is issued by other means of communication such as telephone and agricultural services. Broadcasting forecasts on the starting dates of rainfall affected farmers' WTP for climate information at the threshold of 10 %. Indeed predicting the rainfall starting dates allows farmers to plan the sowing date (Klopper et al. 2006). However, they are not willing to pay for only the dates of rainfall. Rather they want to pay for a package of climate information constituted by starting dates of rainfall, length of the season and its end.

Table 4. Factors affecting the decisions of farmers

	Probit model (First step)			Regression model (second step)		
Variables	Coefficients	Standard error	P-value	Coefficients	Standard error	P-value
Age	-0.224*	0.116	0.053	110.7271	113.598	0.330
Marital	0.563**	0.225	0.012			
Education	0.355**	0.121	0.003			
Organization	0.230*	0.126	0.069			
Endogenous	-0.176	0.121	0.145	222.0637*	116.388	0.056
Information				204.972*	122.249	0.094
Radio				-317.006**	105.385	0.003
Start				-307.142**	136.304	0.024
End				-343.234	222.852	0.124
Duration	--	--	--	--	--	--
Maize	0.294**	0.122	0.016			
Millet	0.141	0.165	0.393			
Rice	-0.282	0.214	0.187			
Sorghum	0.359**	0.174	0.039			
Income	-5.91E-07**	1.88E-07	0.002	-10.4 E-05	19.24 E-05	0.589
Off-income	-5.91E-07**	1.88E-07	0.002	-10.4 E-05	19.24 E-05	0.584
Constant	-0.563*	0.319	0.078	1445.125***	207.295	0.000
Mills Ratio	-555.371*	313.846	0.077			
Rho	-0.526					
Sigma	1056.175					
Number of observations = 573 ; Observations uncensored = 388; observations censored = 185 ; Wald chi2(6) = 23.197 ; Prob > chi2 = 0.000						

Note: ***, ** and * respectively denote significant levels of 1%, 5%, and 10%.

Conclusion

This study highlights the perception and the option value of climate information in the sahelian and sudano-sahelian agro-climatic zones of Burkina Faso. It shows that the climate information is asymmetrically distributed to a minority (21.78 %) of the sampled farmers. The analysis reveals that the majority (93%) of the farmers need climate information to guide their decision in planning agricultural activities. The determining factors of the demand for climate information are the age of heads of the household, their literacy level, marital status, their maize and sorghum production and also the added value of grain production. Option value shows the interest granted by farmers using climate information. 64% of the farmers willing to pay would pay an average of CFA 546.34 Francs to obtain. The willingness to pay is determined by the ability of the farmers to predict the climate, to use radio as a means of information, awareness of farmer on the previous forecast and early onset of the rainy season. While farmers considered benefit from the use of climate information, it is clear that its contribution to farm income remains a field of research to explore. Thus it is necessary to experiment with individual farms and to evaluate the contribution of climate information to the added value of different crops and farmers' income.

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