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Farmers' Willingness to Pay for Climate Information Services: Evidence from Cowpea and Sesame Producers in Northern Burkina Faso

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Abstract: Climate information is recognized as a powerful tool to reduce the effect of climate risk and uncertainty on crop production and increase the resilience and the adaptive capacity of farmers in semi-arid zones. This paper estimates farmers' willingness to pay (WTP) for climate information within cowpea and sesame value chains in Northern Burkina Faso. The study used the contingent valuation method for a monetary valuation of farmers' preferences for climate information. Data were collected using a structured questionnaire from 170 farmers. The study found that 63% of respondents were willing to pay for climate information services (CIS) such as seasonal climate forecast (SCF), decadal climate information (10-DCI), daily climate information (1-DCI) and agro-advisories. The predicted value for the WTP was XOF 3496 for SCF, XOF 1066 for 10-DCI, XOF 1985 for 1-DCI and XOF 1628 for agro-advisories. The study also showed that several socioeconomic and motivation factors have greater influence on farmers' WTP for CIS. These included the gender, age, education of the farm head and the awareness of farm head to climate information. The outcomes of this paper should support policy makers to better design an efficient mechanism for the dissemination of climate information to improve the adaptive capacity of farmers to climate risks in Burkina Faso.

Keywords: climate risk management; adaptation; agriculture; West Africa

1. Introduction

In West Africa, the rainfall regime is characterized by a strong spatial and temporal variability [1,2]. The inter-annual rainfall variability differs between the north and the south of the region with a decrease of the mean annual rainfall from south to north [1] and a shift in the seasonal cycle from a two-season regime in the south to a single rainy season in the north [3]. The year-to-year rainfall variability ranges from 10 to 20 percent in the coastal areas to over 40 percent in the northern Sahel [4]. The variability of West Africa climate is also marked by recurrent droughts balanced out by a few number of heavy rainfall years (above the average rainfall years) [5]. The rainfall variability has been, and continues to be, one of the principal sources of fluctuations in food production in West Africa in general and in the Sahel region in particular. Given that agriculture in West Africa is mostly rain-fed, its performance depends heavily on seasonal characteristics of rainfall. Rainfall unpredictability poses enormous threats to food security with deficits leading to localized food crises every year. Intra-season drought may lead to harvest losses and crop failure even in years where the total rainfall would allow a normal harvest.

To cope with climate variability and risks, local communities have relied on indigenous climate forecasting methods to plan agricultural activities [6]. The traditional seasonal climate forecast is a system of knowledge that people of a particular geographical area use to predict the weather and the climate. It is embedded in the art, history and culture of the people concerned and transmitted from one generation to another [7]. It is often based on generations of experience and includes both biophysical and mystical indicators [6]. With the increase in rainfall variability and climate extreme events (such as droughts, floods and strong winds) as consequences of climate change in the Sahel [8], the endogenous forecasts, are becoming less reliable [7]. This means that climate change is bringing and increasing risk and uncertainty on agricultural production. The impacts of climate change are already constraining the achievement of productive and secure livelihoods among the most vulnerable people in the region [9]. However, climate change uncertainties can be understood, managed and used to inform decision-making in agriculture. The ability to understand, monitor and predict climatic variability, provides an opportunity for farmers to put historical experiences into perspective and to evaluate alternative management strategies for informed decision-making. This may help them to take advantage of good years and minimize the losses during poor years. Climate information reduces uncertainty and can help farmers make better use of inputs and technologies. Moreover, climate information has the potential to improve the resilience of agriculture to climatic shocks. It can be used to help manage current climate risks and build resilience to future climate. For example, farmers can use information on the onset of the next rainy season to make decisions about which crops to plant and when to plant them. Roudier [10] showed that seasonal forecasts can help improve farmers' incomes and lower the risks of poor harvests in West Africa. The provision of climate information services (CIS) is one of the main ways in which farmers can deal with climate change and variability in order to improve decision-making in agriculture. Climate services can be understood as activities that deal with generating and providing climate information to a wide range of users in order to support climate resilient development. Climate services involve the production, translation, transfer, and use of climate knowledge and information in climate-informed decision making and climate-smart policy and planning. Climate information prepares the users for the weather they actually experience. It is therefore imperative for climate and weather services to operate in close tandem, so as to be seamless to the end-user. In agriculture, climate and weather data are combined with non-meteorological data, such as agricultural information to produce agro-met-advisories. In this study, CIS is used in a border sense including climate services (seasonal forecast), weather services (daily and decadal weather forecasts) and agro-met advisories (use of agricultural options based on climate and weather information).

In Burkina Faso, cowpea and sesame are widely produced by small-scale farmers under rain-fed system. They are usually grown in intercropping systems with cereals such as millet and sorghum. However, mono-crop cultivation systems are now common in market-focused areas of the country. For the past ten years, cowpea and sesame have increased tremendously. Cowpea production increased from 253,190 tons in 2007 to 554,286 tons in 2016 [11,12]. Similarly, the production of sesame rose from 18,802 tons in 2007 to 163,920 tons in 2016 [11,12]. Cowpea has recently transitioned from a food security to a cash crop status, providing income for many small scale cowpea growers. Sesame also became the third exported commodity from Burkina Faso after gold and cotton. The annual exports were estimated at XOF 96.9 billion in 2015 [13]. Both crops are promising value chain crops promoted by the government through several development projects. Cowpea is predominantly a woman's crop from production to processing while women represent about 43% of sesame producers in Burkina Faso. Both crops benefit from many opportunities including existence of an increasing demand at both local and international markets with higher prices for sesame oil. This notwithstanding, erratic rainfalls and increased droughts exacerbate the already existing constraining factors of cowpea and sesame production such as poor soil fertility.

Since 2011, the CGIAR research program on Climate Change, Agriculture and Food Security (CCAFS) has been piloting how the dissemination of climate information services (CIS) at its intervention sites (called climate-smart villages (CSV)) in Burkina Faso could be an important tool to reducing the effects of climate risk and uncertainty on cowpea and sesame production and increasing the resilience and adaptive capacity of farmers. Climate information was disseminated to cowpea and sesame growers through face to face meetings and radio broadcasts under the auspices of CCAFS. As the CCAFS project prepares to end, it is viewed that among other factors, the continued use of CIS will depend on the continued demand for CIS by farmers and farmers' willingness to pay for CIS. This study is therefore novel and aimed to assess the willingness of cowpea and sesame farmers to pay for CIS as an entry point to bringing CIS to scale and sustaining its use by farmers in Burkina Faso.

2. Materials and Methods

2.1. Study Area Description

The study was conducted in Yatenga in the Northern region which is one of the CSV sites of CCAFS in Burkina Faso. It is a 30 km × 30 km block consisting of 51 villages (Figure 1). Geographically, the Northern region of Burkina Faso covers 16,130 km^2, representing 5.9% of the country. In 2015, the region had a population of 1,502,527 inhabitants (representing 8.5% of the total population of the country) with an average annual growth rate of 2.2% between 1996 and 2006. The population is young with 57.5% of the people under 20 years old. The region is the poorest in the country with a 68.1% poverty incidence [14]. The region's economy is based on activities of the primary sector, focusing mainly on agro-sylvo-pastoral production, of which farming is by far the most dominant. However, both artisanal and industrial mining occupy an important place in the economy of the region. Agriculture in the region is mostly rain-fed subsistence systems that are characterized by small family farms. Sorghum and millet are the major staple crops. Cowpea, sesame, groundnut and vegetables are the main cash crops. Major agricultural constraints include the highly variable spatial and temporal distribution of rainfall and the inherently low fertility of the soils. The climate of the region is a Sub-sahelian type, characterized by the alternation of two seasons, a long dry season ranging generally from October to May and a short rainy season from June to September [15]. The annual rainfall ranges between 403 mm (in 1990) to 968 mm (in 2012) mm with an average of 672 recorded in the period: 1985–2014. For the past 30 years, about 50% of annual rainfalls have fallen below the 1985–2014 average.

In order to reduce its vulnerability to droughts and water shortages, Burkina Faso has built many dams to collect water for irrigation of vegetable crops during the dry season, contributing to the country's agricultural diversity. Diverse soil and water conservation technologies (including stones bunds, zaï, half-moon, earth bunds, and grass strips) are used to cope with the adverse effects of high climatic risks, especially in the central and northern parts of the country [16]. Despite these initiatives, climate risk is still a recurrent problem in Northern Burkina Faso. This is why CCAFS piloted the dissemination of climate information services to farmers in this region. Four types of CIS have been communicated to farmers since 2011: (i) downscaled seasonal forecasts; (ii) 10-day forecasts; (iii) daily climate information and; (iv) agro-met-advisories. Prior to the agricultural season (normally in June), a one-day workshop is usually organized to present the seasonal forecasts to farmers and discuss with them about which adaptation strategies to implement. The information shared consists of the nature of the rainy season (normal, below or above the normal), the beginning and end dates of the rainy season, and spell drought periods during the rainy season. A second workshop takes place in July (every year) to communicate updated climate forecasts for the period of July to September. The 10-day forecasts of weather (mainly rainfall, spell drought periods) as well as daily climate information (mainly rainfall, wind) were disseminated through radio shows. A rural radio station (Voice of Farmers, Ouahigouya) was contracted for climate information broadcasting. Farmers were also reached through agricultural extension officers from the cowpea and sesame value chain development initiative Projet d'appui aux filières agricoles (PROFIL). All the above climate information were accompanied by agro-advisories based on the climate and weather information received.

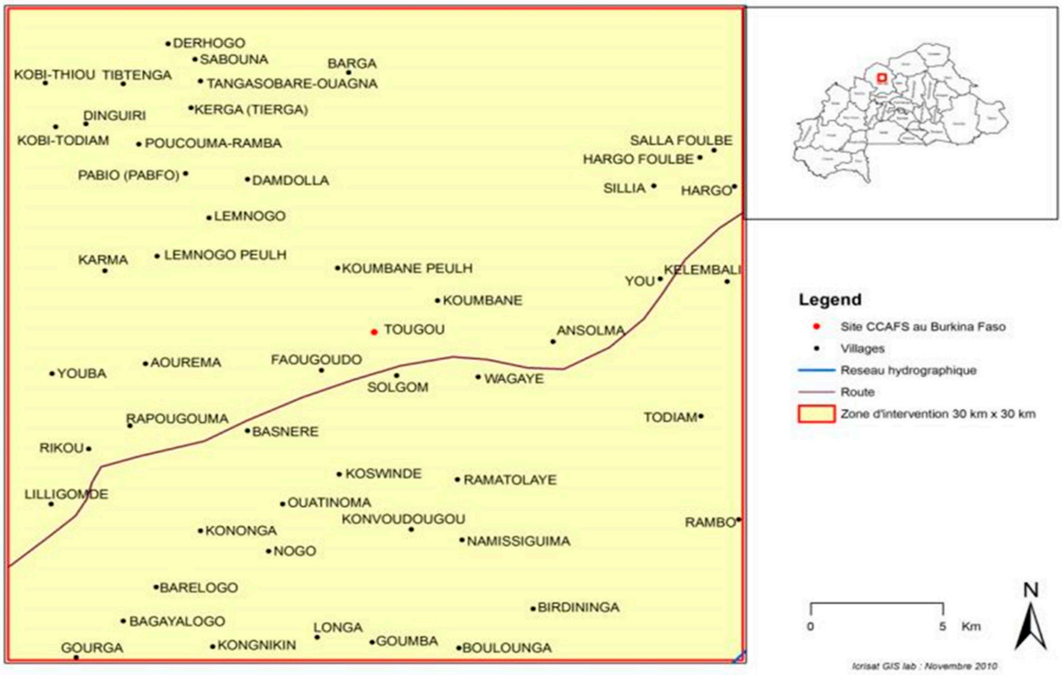

Figure 1. The Yatenga site of CCAFS in Northern Burkina Faso with cluster of villages.

2.2. Data Collection and Analysis

Seventeen (17) villages were randomly chosen within the Yatenga 900 km^2 block. Ten farmers within each of the selected villages were randomly selected from a complete list of farmers generated within the villages. A total number of 170 farmers were interviewed in 2014 for this study. Respondents were farmers involved in cowpea and sesame production. A structured questionnaire was administered to each farmer by trained enumerators to collect information on household and farm characteristics (demography, livelihoods, farm practices, farm assets, access to credit and inputs subsidies, access to training and climate information services, etc.) and farmer's willingness to pay (WTP) for climate information services using the contingent valuation method. Enumerators received comprehensive training in order to perform the contingent valuation surveys. The data were collected through in-person interviews with open-ended question method to elicit farmers' WTP for CIS. Farmers were first asked whether or not they would like to purchase the CIS for agricultural production. Those with positive responses were then asked a series of follow up questions to know what types of CIS are most preferred, and how much they would like to pay for CIS. The questions were stated as follows: (i) Are you ready to pay for CIS for agricultural production (Yes or No)?; (ii) If yes, what types of CIS are you willing to pay for (Seasonal climate forecast, decadal weather information, daily weather information and agro-met advisories)?; (iii) How much are you willing to pay to get this type of CIS (XOF)? In relation to the CVM, farmers were also asked about their knowledge of climate and weather information and the usefulness of this information. This was relevant to minimize any biases that may result from the CVM. The questions were: (i) have you ever heard of climate and weather information (Yes, No)?; (ii) do you think this information is useful for your agricultural production (Yes or No)? and (iii) have you ever used climate and weather information for your agricultural production (Yes or No)? Farmers' WTP were collected. Data was registered in Excel and transferred to Stata software for analysis using descriptive statistics and econometric modeling procedures where applicable. Average and median empirical WTP were calculated. The WTP is analyzed according to the main characteristics of the sample through descriptive statistics and econometric modeling. The Tobit model was used with regard to the importance of zero values (more than 5%).

2.3. Conceptual and Theoretical Framework

Values for non-market goods (e.g., climate information services that are not typically paid for by the public in an established market) can be estimated using contingent valuation method (CVM) [17]. This method is an economic valuation which refers to the assignment of monetary values of changes in environmental services and functions and to stocks of environmental assets [18]. It involves the use of field surveys to elicit information on the value people assign to non-market goods. Several studies have assessed WTP for climate services in agriculture using CVM. For example, Mabe et al. [19] used the CVM to elicit the amount farmers were willing to pay for accessing unpriced weather forecast information in the Savelugu-Nanton Municipality of the Northern Region of Ghana. Zongo et al. [7] used the same method to assess farmers' WTP for climate information in Burkina Faso. Other authors used the CVM to assess the WTP for improved weather forecasts in Benin, Zimbabwe and Italy [20–22]. The CVM is underpinned on the theory of consumer behavior and the theory of the maximization of utility. The principal assumption upon which the theory of consumer behavior is built is that a consumer is rational and attempts to allocate his/her limited money or income among available goods and services in order to maximize his/her utility (satisfaction). In other words, an individual seeks to maximize utility of a good (in this case climate information services) subject to a given constraint. It is assumed that every farmer pursues the objective of maximizing utility, but each farmer has his/her own perception of utility and constraints and makes willingness to pay decisions based on the unique attributes of his/her own situation [23]. Thus, the WTP for climate information services is assumed to depend upon the set of attribute values that apply to the particular household.

The econometric analysis for the WTP depends on the type of elicitation method, the type of question and the structures of the responses. In cases where the dependent variable has a zero value for a significant fraction of the observations, a Tobit model is required [24] because standard Ordinary Least Square technique results in biased and inconsistent parameter estimates i.e., they are biased even asymptotically [25].

The Tobit model can be defined as [26]:

$$WTP_i^* = \beta' X_i + \mu_i$$

$$WTP_i = \begin{cases} WTP_i^* \; if \; WTP_i^* > 0 \\ 0 \; if \; WTP_i^* \leq 0 \end{cases}$$

where, WTP_i^* is latent or unobserved willingness to pay for CIS; WTP_i^* is farmer's willingness to pay for CIS in a year; X_i is a vector of independent variables that are hypothesized to influence the WTP; β is unknown parameter vector to be estimated; ε_i is an error term which are assumed to be normally distributed with mean zero and constant variance. The model parameters are estimated by maximizing the Tobit likelihood function of the following form.

$$L = \prod_{WTP^*>0} \frac{1}{\sigma} f ln\left(\frac{WTP_i - \beta X}{\sigma}\right) \prod_{WTP^* \leq 0} \frac{1}{\sigma} F\left(\frac{-\beta X}{\sigma}\right)$$

where, f and F are the density probability function and cumulative distribution function of WTP_i^* respectively.

Given that the Tobit coefficients do not directly give the marginal effects of the associated independent variables on the dependent variable, McDonald and Moffit [27] proposed techniques to decompose the effects of explanatory variables into the probability of WTP and intensity of WTP effects as follows [23]:

1. The effects of a given explanatory variable on the probability of *WTP* is:

$$\frac{\partial F(Z)}{\partial X_i} = f(z)\frac{\beta_i}{\sigma}$$

2. The marginal effect of an explanatory variable on the expected value of the dependent variable is:

$$\frac{\partial E(WTP_i)}{\partial X_i} = F(z)\beta_i$$

3. The change in the amount a respondent is willing to pay with respect to a change in explanatory variable among individuals who are willing to pay is:

$$\frac{\partial E\left(WTP_i/WTP_i^* > 0\right)}{\partial X_i} = \beta_i\left[1 - Z\frac{f(z)}{F(z)} - \left(\frac{f(z)}{F(z)}\right)^2\right]$$

where, $\frac{\beta_i X_i}{\sigma}$ is denoted by z, following Madala [28].

Whereas: $F(z)$ is the cumulative normal distribution of Z, (z) is the value of the derivative of the normal curve at a given point (i.e., unit normal density), Z is the z-score for the area under normal curve, β is a vector of Tobit maximum likelihood estimates and σ is the standard error of the error term.

The marginal effect of an explanatory variable on the expected value of the dependent variable was considered in this study.

2.4. Empirical Model

We used a Tobit model to analyze the determinants of WTP for each type of CIS including the seasonal climate forecast, the decadal climate information, daily climate information and agro-advisories.

2.4.1. Dependent Variable

In the Tobit model, the dependent variable represents the amount of money the farmer is willing to pay for each climate information service.

2.4.2. Independent Variables

As mentioned above, farmers' willingness to pay for CIS is assumed to depend on the set of attribute values that apply to the particular farm. This includes farmers' socioeconomic characteristics, farm-specific characteristics, and farmers' attitudes towards experiments and risks. In this study, we considered the following independent variables: gender, education, age, household size, farm size, use of indigenous forecast, exposure to climate information, use of stone line, use of organic manure, secondary activity (e.g., livestock) and production orientation.

Age of farm head: It is a continuous variable defined as the age of the head of farm at the time of interview measured in years. Older farmers are less reliant on information, and therefore do not get in touch with innovations as early as their younger colleagues. Therefore, in this study it is hypothesized that young farmers are more likely to purchase CIS than elders.

Sex of farm head: It is a dummy variable taking the value of 1 for male-headed farm and 0 if otherwise. The sex of the farm head was included to differentiate between male and female farm heads in their participation in making a decision on income distribution. In this study, it is hypothesized that male head farms are likely to purchase CIS than female head farms. The expected effect on the willingness to pay for CIS is positive.

Household size: It is a continuous variable measured as the number of people living under one roof. Higher family size is accompanied by high labor potential for farming activities. In addition, more family members require more funds to cover their basic needs which eventually reduces the overall purchasing power of the household. This could have negative effect on the willingness to pay for CIS.

Education of farm head: It is a dummy variable taking 1 if the respondent received a formal education and 0 if the respondent is illiterate. More educated respondents are expected to take scientific oriented decisions. Therefore, it is hypothesized to have a positive influence on farmers' willingness to pay for CIS.

Farm size: It is a continuous variable measured as the number of hectare (ha) of land of the farm. Increasing farm size is one of the strategies usually undertaken by farmers to maintain their total production when their farm productivity per ha is reducing [29]. This means that the farm size is expected to have negative effect on the willingness to pay for CIS.

Use of indigenous forecast: It is a dummy variable taking a value of 1 if a farmer is using an indigenous indicator for climate forecasts and 0 if otherwise. To cope with climate variability and risks, many local communities have for years relied on indigenous climate forecasting methods for planning agricultural activities [6]. The reliability of the technique will affect the WTP for climate information services. So the expected effect of this variable on the WTP could be positive or negative depending on the reliability of the indigenous forecast used by farmers.

Exposure to climate information services: It is a dummy variable taking a value of 1 if farmer is exposed to CIS from any source and 0 if otherwise. For farmers to adopt a practice, they must first know about it. Being exposed to or experiencing CIS plays a key role in adopting CIS. In this study, it is expected to have positive effect on the WTP for CIS.

Use of stone bunds and use of organic manure: Both variables are dummy variables taking a value of 1 if a farmer is using stone bunds and organic manure and 0 if otherwise. Stone bunds and organic manure are considered as adaptation strategies to climate variability [28]. If a farmer perceived CIS as an option to perform in stones bunds and organic manure use, the expected effect will be positive. On the other hand, if a farmer thinks that the investment in stone bunds and organic manure is enough to cope with climate variability, he won't be willing to pay for CIS. In that case, the expected effect will be negative. The expected effects from the two variables are undetermined.

Secondary activity–livestock: It is a dummy variable taking 1 if the respondent has livestock as a main secondary activity and 0 if otherwise. It is expected to influence the willingness to pay for CIS either positively or negatively. In fact the income from livestock could have positive influence on overall household income and subsequently on the willingness to pay for CIS. On the other hand, it may have negative impact if farmers are content with livestock as the best climate risk management strategy and do not need more adaptation options.

Market-oriented: It is a dummy variable taking 1 if the respondent produces cowpea and/or sesame for sale and 0 if otherwise. It is expected to influence the willingness to pay for CIS positively. This is because of the fact that the income from sale of crop product has positive influence on income and in turn income has positive influence on *WTP* for CIS.

3. Results

3.1. Socio-Economic Characteristics of Farmers

Table 1 shows the descriptive statistics of respondents' characteristics. The results showed that 67% of farms were male-headed. The age of respondents ranged from 18 to 77 years with an average of 44 years. Most farm heads were married (96%) with 52% receiving no formal education. The household sizes were relatively big with an average of 16 people including 9 active people per farm. Most farmers were indigenous (88%). The main secondary activities of farmers were livestock, gold mining and small commerce which were engaged by 46%, 20% and 16% of farmers respectively. Most farmers (52%) were registered with farmers' organizations including cowpea producers' organization (18%), sesame producers' organization (18%).

Farmers interviewed had more experience in cowpea (8 years) production than sesame (5 years). Cowpea and sesame were mostly planted as monocrops with more focus on commercial gains. In terms of farm size, Table 1 shows the area owned by farmers ranged from 0.5 to 60 hectares (ha) with an average size of 4.4 ha. The cropped areas ranged from 0.5 to 16 ha with an average of 3.3 ha. The mean cropped areas were 0.16 ha for sesame and 0.13 ha for cowpea.

Table 1. Descriptive statistics on the characteristics of respondents.

Variables	Categories	Frequency	Percent
Gender	Man	113	66.86
	Woman	56	33.14
Marital status	Married	162	95.86
	Single	6	3.55
	Widow/divorced	1	0.59
Education level	Non educated	88	52.07
	Literate	46	27.22
	Formal education	35	20.71
Origin of farm head	Indigenous	149	88.17
	Migrant	20	11.83
Main secondary activity	Livestock	77	45.56
	Gold mining	34	20.12
	Commerce	27	15.98
	Gardening	17	10.06
	Other	14	8.27
Member of farmers organization	None	81	47.93
	Cowpea producers association	30	17.75
	Sesame producers association	31	18.34
	SWC techniques	20	11.83
	Cowpea and sesame association	5	2.96
	Gardening producers association	2	1.18
Objective for cowpea production	Only consumption	29	17.16
	Consumption and selling	59	34.91
Objective for sesame production	Only consumption	2	1.18
	Only selling	50	29.59
	Consumption and selling	32	18.93
Cowpea production system	Associated	12	7.10
	Pure	77	45.56
Sesame production system	Associated	10	5.92
	Pure	74	43.79

Source: Field surveys (2014). Number of observations = 169.

3.2. *Access to Climate Information Services*

3.2.1. Traditional Climate Forecasts

The surveys showed that 51% of the farmers interviewed use traditional climate knowledge to adapt to inter-annual climate variability. They predict the coming rainy season using various natural indicators: the state of stars, trees, insects, birds, wind or temperature. Ant migration from low lands to plateaus or good production of shea trees are for instance signs for a good rainy season, whereas birds nesting in low branches of the trees or fall of non-mature fruits are bad signs.

3.2.2. Modern Climate Forecasts

The study showed that 79% of farmers had had climate information during the survey year. This comprised seasonal climate forecast (to know the length, start and end of the rainy season), decadal weather forecast (to identify drought spells, flood periods, and farms operations such as weeding, fertilizer and pesticide applications) and daily weather information. They got these climate information from rural radios as well as during dissemination workshops (Table 2). However, daily climate information were mainly delivered through rural radios (according to 74% of farmers).

Table 2. Access to climate information by dissemination channels.

Type of Information	Percent	Channel of Climate Information Services				
		Workshop	Rural Radio	National Radio	Extension Service Agent	From Other Farmers
Nature of the rainy season	73.96	27.81	44.97	5.26	0.59	0.59
Length of rainy season	65.68	18.34	46.15	5.26	0.59	0.59
Start of the rainy season	53.25	14.20	37.87	5.26	0.59	0.59
End of the rainy season	53.85	10.06	42.01	5.27	0.59	0.59
Drought spells periods	68.64	14.79	52.66	5.25	0.59	0.00
Floods	50.89	4.14	46.75	0.00	0.00	0.00
Daily rainfall information	75.74	1.17	73.99	5.19	0.58	0.00

Source: Field surveys (2014); Number of observations = 169.

3.2.3. Appropriate Sources for Climate Information Dissemination

Table 3 shows that radio was by far the most appropriate channel by which climate information could reach more people. Only 4% and 2% of farmers thought that television and cell phones respectively could be the most appropriate channel to reach more farmers.

Table 3. Appropriate channels for climate information dissemination.

Channel of Information	Frequency	Percent	Cumulative Frequency
Radio	116	68.64	68.64
Television	6	3.55	72.19
Workshops (face to face meetings)	2	1.18	73.37
Mobile phone	3	1.78	75.15
Extension agent	4	2.37	77.51
Farmer′ organisation	1	0.59	78.11
No response	37	21.89	100.00
Total	169	100	

Source: Field survey (2014).

3.3. Willingness-to-Pay for Climate Information Services

About 63% of farmers were ready to pay for at least one type of CIS. About 53% of farmers were willing to pay for the seasonal forecast and the daily climate information. About 33% and 39% were willing to pay for decadal climate information and agro-advisories respectively. The main reasons for which some farmers were not willing to pay for CIS were the lack of money (confirmed by 28% of farmers) and the need for evidence on the profitability of the use of CIS (confirmed by 11% of respondents).

The results indicated that the average annual willingness-to-pay was about XOF 3706 for seasonal climate forecast, XOF 1113 for decadal climate information, XOF 1923 for daily climate information and XOF 1674 for agro-advisories. Table 4 shows the observed willingness to buy (WTB) and pay (WTP) for climate information within the study sample.

Table 4. Descriptive statistics for the willingness of farmers to accept and pay for climate information in Yatenga, Burkina Faso.

Statistics	Seasonal Climate Forecast	Decadal Climate Information	Daily Climate Information	Agro-Advisories
N	169	169	169	169
Mean	3706	1113	1923	1674
Median	300	0	100	0
Standard deviation	6723	3930	4749	4526
Minimum	0	0	0	0
Maximum	25,000	25,000	25,000	25,000
WTB (%)	53	33	53	39

Source: Field survey (2014).

Table 5 shows the descriptive statistics of WTP according to farmers' characteristics. The *WTP* was higher for men than for women for each of the CIS. Younger farmers (less than 40 years) had higher WTP for any CIS than the old farmers. Farmers with farm sizes between 4 and 6 ha had a higher WTP for each CIS than those who had less than 4 ha or more than 6 ha. Farmers with a household size of 6 to 10 people had higher WTP for seasonal climate forecast (SCF) and daily climate information, while farmers with less than 6 members had a higher WTP for decadal climate information. Those with more than 10 members had higher WTP for agro-advisories. Farmers who use endogenous forecast had higher WTP for SCF, decadal climate information and agro-advisories. Farmers who use soil and water conservation techniques had lower WTP for each CIS. Farmers who use organic manure had higher WTP for all CIS. The educated farmers as well as non-market-oriented farmers had higher WTP for each CIS. Farmers practicing livestock as main secondary activity also had a higher WTP for seasonal forecast, decadal and daily climate information.

Table 5. WTP (XOF*) for climate information services according to farmers' characteristics.

Variables	N	Seasonal Climate Forecast	Decadal Climate Information	Daily Climate Information	Agro-Advisories
Gender					
Men	113	4145	1252	2339	1916
Women	56	2820	831	1084	1184
Age					
Less than 40	66	4521	1852	2600	2022
40 to 60 years	87	3125	628	1490	1575
More than 60 years	16	3500	703	1488	772
Cropping area					
Less than 4 ha	104	3490	1180	1871	1756
4 to 6 ha	43	4792	1251	2365	1866
More than 6 ha	22	2600	523	1307	907
Active population					
Less than 6 person	59	3413	1377	1569	1141
6 to 10 person	69	3870	1010	2377	1942
More than 10 person	41	3851	905	1668	1989
Endogenous forecast					
Don't use indigenous indicator	81	3415	1065	2035	1288
Use indigenous indicator	88	3973	1157	1820	2029
Awareness to CI					
Not exposed	61	1748	348	875	925
Exposed	108	4812	1545	2515	2097
Soil and water conservation (SWC) technique					
Not adopted SWC techniques	118	4158	1328	2276	2161
Adopted SWC techniques	51	2658	614	1107	547
Education					
Not educated	134	3360	1053	1872	1620
Educated	35	5029	1343	2120	1880
Use of organic manure					
Not adopted organic manure	69	2598	1030	1362	829
Adopted organic manure	100	4470	1170	2310	2257
Livestock					
No livestock	92	3359	850	1841	1768
Practice livestock	77	4119	1427	2021	1561
Market orientation					
Non market oriented	119	3792	1320	1925	1858
Market oriented	50	3501	620	1919	1235
Total	**169**	**3706**	**1113**	**1923**	**1674**

Source: Field survey (2014); * 1 EUR = 655.957 XOF.

3.4. Determinants of the Willingness-to-Pay for Climate Information Services

Factors influencing farmers' willingness to pay for CIS were analyzed using Tobit model. The dependent variable is a continuous variable which is the respondents' willingness to pay for CIS in the study area. A total of 11 regressors were considered in our Tobit model. Results of the estimated parameters and the marginal effects of their explanatory variables that were hypothesized to affect WTP for CIS are presented in Tables 6 and 7. The chi-square results showed that likelihood ratio statistics are highly significant ($p < 0.001$) for all the 4 regressions, confirming each model as a whole was statistically significant. Out of 11 variables, 3 to 6 variables were found to significantly ($p < 0.05$) influence the willingness to pay for CIS.

Table 6. Coefficients and marginal effect of explanatory variables on WTP for seasonal climate forecast and decadal climate information.

Variables	Seasonal Climate Forecast		Decadal Climate Information	
	Coefficient	**Marginal Effect**	**Coefficient**	**Marginal Effect**
Sex male	5824.99 *** (2133.30)	2503.63 *** (831.88)	3745.14 ** (1815.41)	842.18 ** (370.18)
Educated	−33.79 (2232.58)	−15.83 (1045.00)	−3657.87 * (1972.73)	−757.16 ** (340.46)
Age	−121.42 (86.56)	−56.93 (40.53)	−216.19 *** (75.03)	−53.92 *** (18.94)
Household size	91.51 (167.17)	42.91 (78.47)	54.34 (139.78)	13.55 (34.88)
Farm size	−104.25 (150.53)	−48.88 (70.74)	−82.08 (132.65)	−20.47 (33.11)
Indigenous forecast	1468.60 (1856.84)	686.82 (865.35)	1866.44 (1568.25)	463.45 (387.31)
Awareness to CIS	8414.33 *** (2039.17)	3563.83 *** (772.67)	4844.48 *** (1722.45)	1089.27 *** (354.30)
Stone bunds	−1520.31 (2020.72)	−690.21 (889.33)	−4809.52 ** (1922.07)	−988.98 *** (332.57)
Organic manure	4894.90 ** (1908.99)	2207.61 *** (829.02)	1639.68 (1616.18)	398.89 (383.16)
Secondary activity–livestock	1363.31 (1735.66)	642.66 (823.46)	1717.26 (1464.70)	434.98 (377.10)
Market oriented	833.51 (1943.45)	396.66 (937.42)	−1352.27 (1656.94)	−321.40 (377.31)
Constant	−9148.61 * (4658.70)		−1370.96 (3917.38)	
Sigma	9681.28 *** (776.08)		7172.08 *** (730.45)	
Number of obs	169		169	
LR chi2(11)	37.05		32.61	
Prob > chi2	0.0001		0.0006	
Pseudo R2	0.0184		0.0260	
Log likelihood	−987.65		−610.88	
Left-censored observations (<=0)	80		114	
Uncensored observations	89		55	
Right-censored observations	0		0	

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Field surveys (2014).

Table 7. Coefficients and marginal effect of explanatory variables on WTP for daily climate information and agro-met advisories.

Variables	Daily Climate Information		Agro-Met Advisories	
	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Sex male	5471.56 *** (1474.08)	2023.92 *** (481.72)	4469.12 ** (1845.78)	1305.66 *** (487.20)
Educated	−2953.05 * (1542.95)	−1094.42 ** (500.75)	−1902.28 (1952.48)	−568.35 (536.76)
Age	−178.94 *** (59.38)	−75.34 *** (25.13)	−114.23 (75.87)	−36.99 (24.61)
Household size	42.36 (112.42)	17.83 (47.35)	153.70 (141.65)	49.78 (45.82)
Farm size	−48.78 (100.85)	−20.54 (42.50)	−270.14 (172.71)	−87.49 (55.67)
Indigenous forecast	141.22 (1238.55)	59.43 (520.91)	2610.37 (1590.74)	840.90 (509.70)
Awareness to CIS	5745.50 *** (1389.97)	2167.75 *** (467.56)	4696.45 *** (1701.12)	1394.19 *** (464.40)
Stone bunds	−1072.17 (1370.20)	−434.91 (536.11)	−2417.99 (1774.13)	−720.70 (488.09)
Organic manure	3074.98 ** (1290.98)	1245.08 ** (503.29)	4449.98 *** (1648.35)	1368.42 *** (485.29)
Secondary activity–livestock	862.08 (1178.38)	364.99 (500.97)	359.84 (1488.09)	116.81 (483.99)
Market oriented	1095.09 (1301.84)	475.99 (582.17)	−955.06 (1675.67)	−300.77 (514.12)
Constant	−2622.36 (3138.12)		−7481.36 * (4090.67)	
Sigma	6463.43 *** (501.84)		7700.16 *** (719.24)	
Number of obs	169		169	
LR chi2(11)	42.19		30.92	
Prob > chi2	0.0000		0.0011	
Pseudo R2	0.0216		0.0207	
Log likelihood =	−957.15		−731.52	
Left-censored observations (<=0)	79		103	
Uncensored observations	90		66	
Right-censored observations	0		0	

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Field surveys (2014).

In relation to seasonal climate forecast, the results showed that gender (male), awareness of climate information and the use of SWC techniques such stone bunds had positive effect on the willingness to pay for SCF (Table 6). The WTP for seasonal climate forecast was increased by XOF 2503 when farmers were men and by XOF 2563 when they were exposed to climate information. In addition, it is increased by XOF 2208 when farmers are using organic manure as climate-smart agriculture (CSA) technologies. Similarly, Table 6 shows that gender (male) and awareness of climate information had a positive effect on the willingness to pay for decadal climate information while the education and age of respondents had a negative effect on it. Being a man and exposed to climate information increased the WTP for decadal weather information by XOF 842 and XOF 1089 respectively. Being educated and old decreased the WTP for decadal weather information by XOF 757 and XOF 54 respectively.

Moreover, the results revealed that gender (male), awareness of CIS and use of organic manure had a positive effect on the willingness to pay for daily climate information (Table 7). Conversely, education and age had a negative effect on the WTP of daily climate information. Being a man, exposed to climate information and using organic manure increased the WTP for daily climate information by XOF 2023, XOF 2168 and XOF 1245 respectively. Being educated and old decreased the WTP for daily climate information by XOF 1094 and XOF 75 respectively.

Furthermore, the results showed that gender (male), awareness of climate information and the use of organic manure and stone bunds had a positive effect on the willingness to pay for agro-advisories (Table 7). Being a man, exposed to climate information and using organic manure increased the WTP for agro-advisories by XOF 1306, XOF 1394 and XOF 1368 respectively.

3.5. Predicted WTP and Estimation of Consumer Surplus of Climate Information Services

The predicted value of the WTP per year was used as a measure of aggregate value of CIS in this study. The predicted WTP for CIS was XOF 3496 per farmer per year for seasonal climate forecasts, XOF 1066 for decadal climate information, 1985 XOF for daily climate information and 1628 XOF for agro-advisories. As indicated in Table 8 the aggregate WTP was calculated by multiplying the predicted WTP by the total number of households expected to have a valid response in the study area. Following this, the aggregate WTP for CIS was estimated as XOF 23,312,723 for the seasonal climate forecasts, XOF 4,394,357 for the decadal climate information, XOF 13,388,368 for the daily climate information and XOF 8,050,094 for the agro-advisories.

Table 8. Value for climate information services at the CCAFS CSV site of Yatenga in 2014.

CIS	Total Households at the CSV Site	% Households Willing to Pay for CIS	Expected Number of Households Willing to Pay CIS	Predicted Value of the WTP Per Year	Aggregated Value (XOF) *
Seasonal forecast	12,662	52.66	6668	3496	23,312,723
Decadal information	12,662	32.54	4121	1066	4,394,357
Daily information	12,662	53.25	6743	1985	13,388,368
Agro-advisories	12,662	39.05	4945	1628	8,050,094

Source: Field surveys (2014); * 1 EUR = 655.957 XOF.

4. Discussion

The study showed that there is a high demand for CIS (63%) in the Yatenga province which is consistent with the results of the few studies conducted in the region (e.g., Zongo et al. [7]). The high demand for CIS can also be related to the high variability of climatic parameters experienced by farmers in the region. Zongo et al. [7] found that 64% of farmers from four provinces in Burkina Faso including Yatenga were willing to pay XOF 546 for CIS. This amount is lower compared to what was found from our study. However, Mabe et al. [19] found that farmers in Northern Ghana were willing to pay an amount of GH¢41.20 (about XOF 5500) annually for weather forecast information. This is greater than what we found in this study. This means that the WTP for climate information services depend on many factors including physical environment of farmers and their socio-economic characteristics. Meza et al. [30] argued that the value of seasonal forecasts for agriculture depends on many factors including farmers' risk attitudes, insurance, policy environment and scale of adoption.

The study revealed that farmers' WTP for CIS depends on the type of CIS. The most requested CIS were the seasonal climate forecast and the daily weather information for which 53% of farmers were willing to buy. Agro-advisories and the decadal climate information come next with 39% and 33% of farmers willing to buy respectively. The value of predicted WTP follows the same trend as the observed WTP with XOF 3496 for seasonal climate forecast, XOF 1985 for daily climate information, XOF 1689 for agro-advisories and XOF 1066 for decadal climate information. The importance accorded to the seasonal climate information can be explained by the fact that farmers use it to make strategic and tactical decisions such as selection of crops and varieties to grow, choice of location (more humid low lands or plain) and size of plots [9]. On the other hand, daily climate information was used for the day-to-day crop management such as choosing the date of land preparation, plowing, sowing/planting, fertilizing, hoeing, weeding, pest control, harvesting and threshing [9].

The study showed that factors such as gender, age, education, awareness of climate information, use of SWC techniques and organic manure significantly influenced farmers' WTP for CIS. Farmers willing to pay for all climate information and services tended to be younger people or non-educated. This contradicts the results of other authors [7–19] who reported that age has a positive effect on the WTP for climate information demand in Ghana and Burkina Faso. Zongo et al. [7] showed that education of farmers positively influences the demand for CIS. This study also showed that awareness of climate information had a higher positive effect on farmers' WTP. This means that farmers will need to experiment CIS before they can be willing to pay for the service. The results also showed farmers using stone bunds were unlikely to pay for the decadal information perhaps because of its ability to improve farmers' adaptation to climate variability [31].

The study showed that the total WTP for seasonal forecast was about XOF 23 million for 53% of farmers. If this percentage increases to 58%, the total WTP will cover the cost of the pilot project for the dissemination of CIS in the study area which was XOF 25 million for year 2014. This means that there is a potential market for CIS in the study region if the number of people who want to buy the CIS can be increased by at least 5%. To do this, we have to convince 11% of farmers who still need more evidence of the profitability of climate information use to adopt the service. We also have to support 28% of farmers who are not willing to buy CIS for lack of money. In any of these instances, a deep and holistic economic assessment is needed to assess the potential for the development of a viable business model on CIS in the study area. This assessment may take into account all the steps for CIS including production, translation, transfer, and use of climate knowledge and information by farmers.

5. Conclusions

We used the contingent valuation method to empirically assess farmers' preferences for climate information services at the CCAFS CSV site of Yatenga in Burkina Faso. The study assessed farmers' willingness-to-pay (WTP) for CIS and analyzed its determinants. While there was a general increased demand for climate information, the magnitude of such demand depended on the type of climate information. Seasonal climate forecasts and daily weather information were most demanded (53%). The WTP for climate information also depended on farmers' characteristics. In the context of this study, factors such as gender, age, education, awareness of climate information, use of SWC techniques and organic manure were particularly more influential in determining farmers' WTP for CIS. The results of this study provided information on the type of CIS to prioritize in the study area, most appropriate dissemination channels and the cost implications that must be mainstreamed into future scaling up to achieve large-scale adoption by farmers.

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