Comparing farmers' perception of climate change and variability with historical climate data in the Upper East Region of Ghana

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Abstract

Perception of climate change and variability supported by local knowledge has helped to advance understanding of climate change and its impacts on agricultural land-use systems. This study compares farmers' perception of climate change and variability in four communities of the Upper East Region of Ghana. Using a sample of 186 households from these four communities, farmers' perception was compared with historical climatic data from the closest weather station of the study area. Also, logistic regressions were used to estimate factors that influence the perception of climate change and variability in the area. Findings show that 71% of respondents perceived an increase in temperature which matches with the climatological evidence. On the other hand, decreasing rainfall with a shortening period was observed by 95% of respondents. From the climatological data, no real evidence of reduction in the amount of rainfall was apparent due to the high inter-annual variability. Unlike the rainfall data, there is an agreement between climatological data and farmers' observation that the onset of the rainy season is now shifting from April to June, accompanied by an increasing dry spell. In contrast, there is a divergence concerning the length of the growing season which is explained by the strong influence of the onset rather than by the end of the rainy season. From the findings of the binary logistic analyses, the local topography and the information on weather and climate were significant in determining the likelihood of a good perception of climate change and variability. Therefore, for any policy directed at farmers to adopt adaptation measures to climate change, more attention should be given to the role of the local environment and access to climate-related information.

Keywords: Adaptation, Climate change, Perception, Climatological evidence, Upper East

Region of Ghana.

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Introduction

Africa is one of the most vulnerable continents to climate change and climate variability where the situation is aggravated by the interaction of multiple stresses, occurring at various levels, and low adaptive capacity (Boko *et al.*, 2007). Much of the population depends on agriculture, particularly rain-fed agriculture, but at the same time widespread poverty renders people vulnerable to climate stress (Livingston *et al.*, 2011). For instance, the recurrent droughts in many African countries have demonstrated the effects of climate variability on food resources (Stanturf *et al.*, 2011). As a result, many people face food insecurity, adding to already existing poverty. Sub-Saharan Africa, for instance, is one of the regions where farming is the main activity in semi-arid rural areas. However, the region is particularly vulnerable because of its ecological fragility, institutional weaknesses and political instability, now aggravated by climate change (Dixon *et al.*, 2001; Livingston *et al.*, 2011). In Africa, little is known about how climate interacts with other drivers of change in agricultural systems and broader development trends. The likely impacts of climate change on the vulnerability of agricultural systems need to be better understood, so that the resilience to current climate variability as well as the risk associated with longer-term climate change can be gauged and appropriate actions taken to increase or restore resilience where it is threatened or lost (Thornton *et al.*, 2008).

Like other parts of the West African Savannah, the Upper East Region (UER) of Ghana has been, since colonial times (1904–1957), the poorest part of the country. The area suffers from difficult climatic conditions, relatively high population density and patterns of underdevelopment, which are the result of discriminatory colonial and post-colonial policies (Laube *et al.*, 2012). Accordingly, apart from climate change, rapid population growth has occurred over the last century, which has led to increasing pressure on natural resources such as soils, pastures and forests. Degrading resources have led to decreases in the output of the traditional agro-pastoral production system consisting of rain-fed agriculture and livestock husbandry (Laube *et al.*, 2012). Given the dynamics and complexity of the agricultural land-use systems in rural West Africa (Boserup, 1965) and other livelihood strategies, there is a great need to better understand the impacts of climate change on the vulnerability of these systems. In this case, the complexity of the situation means that for many in Africa, adaptation is not an option but a necessity (Boko *et al.*, 2007). Accordingly, it is believed that adaptation can greatly reduce vulnerability to climate change by making rural communities capable of adjusting to climate change and variability, dealing with moderate potential damages, and coping with adverse consequences (IPCC, 2001).

However, in the context of the West African savannah, agricultural adaptation is about decisions and changing conditions at farm and local levels (Bryant *et al.*, 2000). In fact, farmers have diversified their livelihoods to adapt to uncertain environmental conditions in various ways including changes in crop management practices, livestock management practices, land use, land management and livelihood strategies (Boko *et al.,* 2007; Bryan *et al.,* 2013; Laube *et al.,* 2012). Previous studies suggest that in order to improve estimates of climate impacts on agricultural systems and contribute efficiently to adaptation research, there is a need to know more about how farmers perceive climate and how they respond, in both the short- and long-term, to variable climate conditions, including the magnitude and frequency of extreme conditions (Smit *et al.*, 1996). Moreover, literature on adaptation also makes it clear that perception studies are necessary for adoption of adaptation strategies (Maddison, 2006). Thus, a number of studies in Africa (Okonya *et al.*, 2013; Simelton *et al.*, 2013; Moyo *et al.*, 2012; Penaranda *et al.*, 2012; Gbetibouo, 2009; Maddison, 2006) have suggested that the success of any adaptation measures would depend on a good farmers' perception about climate change and variability.

Studies conducted by Salick and Byg (2009) indicated that local knowledge and experience have helped to advance understanding of climate change and its impacts on agriculture. For example, a study among coffee producers in Central America and Mexico (Tucker *et al.*, 2010) supports the importance of local knowledge and perception of climate as a critical ingredient in guiding policy responses on adaptation. In South Africa and Ethiopia, research highlighted the role of perception in understanding the importance of education and awareness building and in identifying available options to enable farmers adapt to changing climate (Bryan *et al.*, 2009).

Legesse et *al*. (2012) contended that understanding perception and adaptation strategies of individual households helps to generate additional information relevant to policy and interventions to address the challenges of sustainable development in the light of variable and uncertain environments. Mahmood et *al*. (2010) reiterated the importance of measuring perception level about climate change and formulation of coping strategies. Thus, a better understanding of farmers' perception of climate change and ongoing adaptation measures as well as their decision-making process is important in formulating policies aimed at promoting successful adaptation of the agricultural land-use system. Although in the study area much has been done in implementing adaptation research, there is little to indicate that farmers perceive the threat of climate change sufficiently to warrant their adopting adaptation measures (Yaro, 2013; Kemausuor *et al.*, 2011; Fosu-Mensah *et al.*, 2010;). In fact, one of the proposals of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) is the need to continue generating and sharing new knowledge from different fields and sectors because climate change is dynamic and complex (Vermeulen, 2014). Therefore, adaptation will require the involvement of multiple stakeholders, including first and foremost, farmers, but also policymakers, extension agents, NGOs, researchers, communities and the private sector (Bryan *et al.*, 2013).

Noting that effective adaptation rests on the integration of both scientific ideas and local perception of farmers (Jarawura, 2014; Simelton *et al.*, 2013), the following research question will be addressed by this study: how does farmers' perception of climate change and variability compare with official climatological data in the study area? This research acknowledges the bridge initiated by previous studies in integrating qualitative and quantitative data (Moyo *et al.*, 2012, Simelton *et al.*, 2013), and focuses on the analyses of farmers' perception in comparison with climatological evidence. Also, factors that influence farmers' perception of climate change and variability in the study area were investigated.

Methods

Conceptual framework

A conceptual framework (Figure 1) that integrates the components of the socio-cultural context of the study area, the local climate and the climatological records is developed in order to guide the discussion of findings of this research.

This framework helps to organise and contrast both farmers' perception data and the quantitative climatological data. The framework is designed as a flowchart composed of three levels. The first level describes the aforementioned components where the links between them are not explicitly described. The second level shows a link between the two sources of data on climate change and variability. As a result, the indigenous ecological knowledge of people has a great influence on their perception (Villamor et al., 2014; Salick & Byg, 2009; Ellis & Swift, 1988). Also, perception is determined by learning factors (Maddison, 2006) where indicators such as age, experience, environment and information on weather and climate play a very important role in the awareness of climatic parameters (Roncoli et al., 2002). The changes over time determine the variability and therefore the implications of climatic parameters and rainy season characteristics for climate change. Then, the trends in climatic conditions are analysed in considering the normal periods (1961-1990 or 1971-2000) (WMO, 2007). Finally, the last level of the framework highlights the influence of the awareness and interpretation of climate phenomena on farmers' decision and choice of responses. Therefore, the way farmers perceive climate change and variability, choose their land-use and adjust their cropping systems assures researchers and policy makers that they are talking about the same weather, climate change and variability as the farmers they intend to assist (Simelton et al., 2013).

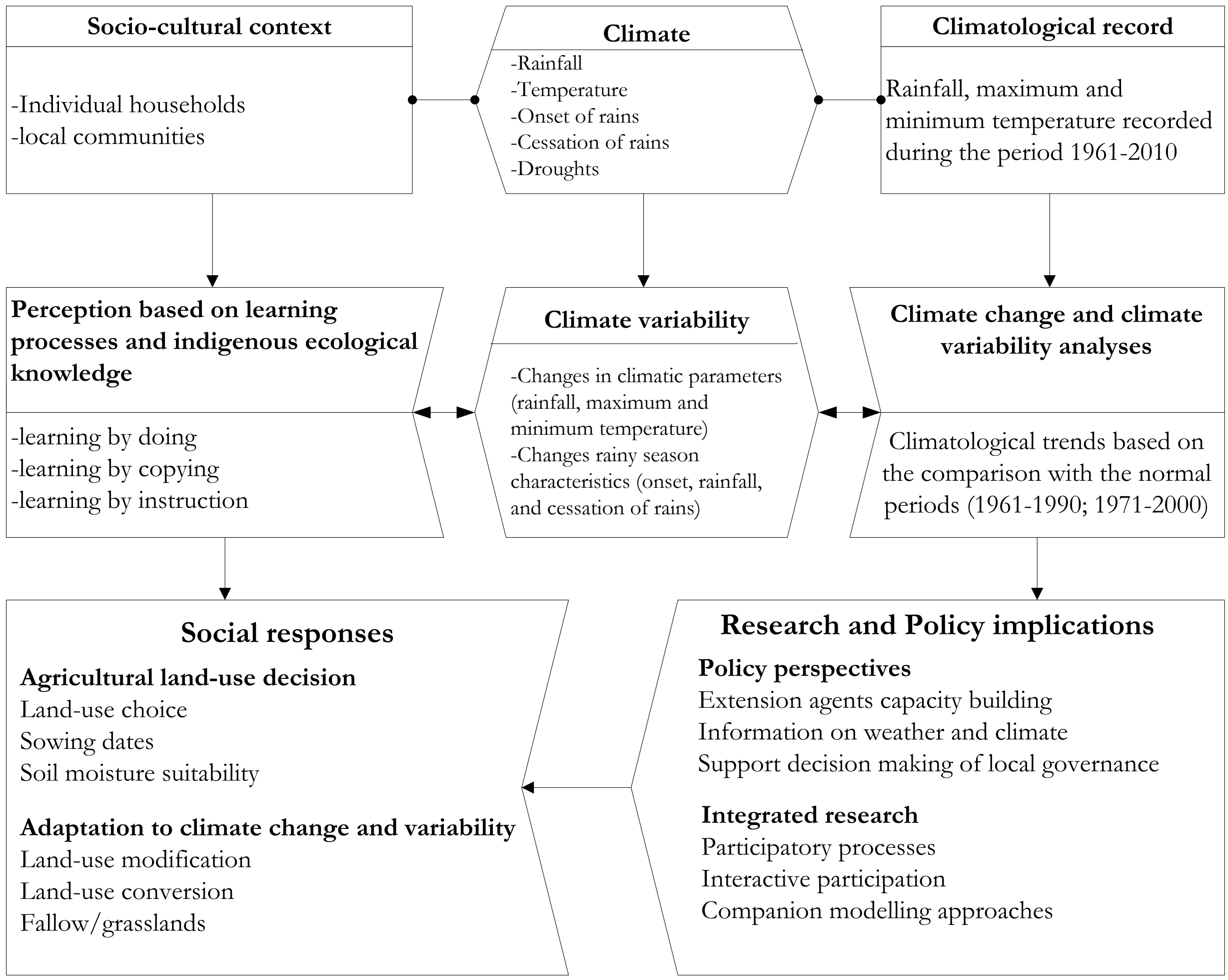


Figure 1: Conceptual framework integrating the socio-cultural context, climate and the climatological record

Study area

The study area is located within the catchment of the Atankwidi River, a tributary of the White Volta in the Upper East Region of Ghana. Its upper reach is in Burkina Faso (Martin, 2006). Geographically, the study area is located between latitude 10º50'41" - 11º00'35" N, and longitude 1º03'47" - 0º53'02" W, along the border between Ghana and Burkina Faso. Within the catchment, the study focused on the area (192 km^2) populated by four villages: *Sumbrungu* in the Bolgatanga Municipal District, *Sirigu* and *Kandiga* in the Paga district and *Yuwa* in the Navrongo district (Figure 2). This area is in the Sudano-savannah agro-ecological zone where the loss of land productivity is negatively affecting communities who are relying on natural resources for their subsistence lifestyle (Higgins, 2007). The vegetation is dominated by scattered trees such as the baobab (*Adansonia digitata*), locust bean (*Parkia biglobosa*), acacias (*Acacia spp*.) and sheanut (*Butyrospermum parkii*) (Salifu & Agyare, 2012). The area is also characterized by a mono-modal rainfall distribution with a distinct rainy season lasting approximately from May to September. The long-term mean annual rainfall is 990 mm at the Navrongo weather station which is close to the study area. The temperature is high throughout the year with an average daily maximum temperature of 35 °C and an average daily minimum temperature of 23 °C. Relative humidity is highest (65 %) during the rainy season. It drops quickly after the end of the rainy season in October, reaching a low value of less than 10 % during the Harmattan period in December and January (Martin, 2006).

Although agriculture is the main economic activity, many households are engaged in activities such as handicrafts, trading, wood cutting and livestock rearing which constitute the main source of cash income. Most available lands are used for small-scale agriculture in the rainy season. The area is covered by scattered compound houses that are usually surrounded by farmland of mixed cropping of cereals, groundnuts and rice. Some uncultivated patches are usually scattered within the croplands, serving as grazing land for the local livestock. In addition to the aforementioned characteristics, the area was chosen because it is located in one of the poorest regions of Ghana, where research on the impact of policy interventions on local socio-economic and agro-ecological conditions could be of high importance, especially for supporting sustainable improvement of local living conditions.

Data collection on perception of climate change and variability

The data were collected by means of a semi-structured household questionnaire which was pre-tested with 10 farm households in Bolgatanga in November 2012 while the main survey was carried out between January and April 2013. Qualitative and quantitative data were collected on the following: (1) farming systems, (2) farmers' perception of climate change and variability and (3) adaptation strategies. A total of 186 households distributed among the four villages were randomly selected and surveyed. Proportional to the official list of farmers provided by the MOFA (Ministry of Food and Agriculture) of each district, the following farm numbers of households were randomly selected per study community: 51 households in *Sirigu*, 62 households in *Sumbrungu*, 32 households in *Kandiga* and 41 households in *Yuwa*. The sample was composed of 15% female headed households; of which 66% of the heads were widows, while 85% were male headed households. As key decision maker within the house, the household heads were interviewed. Most of them fell within the ages of 30 to 76. The surveys were conducted with the help of Agricultural Extension Agents (AEAs) who were used as enumerators because they represent a crucial link between the government and the local communities within their enumeration areas. The AEAs were trained to ensure effective administration of questionnaires. The data were analysed using XLSTAT 2013 and R packages.

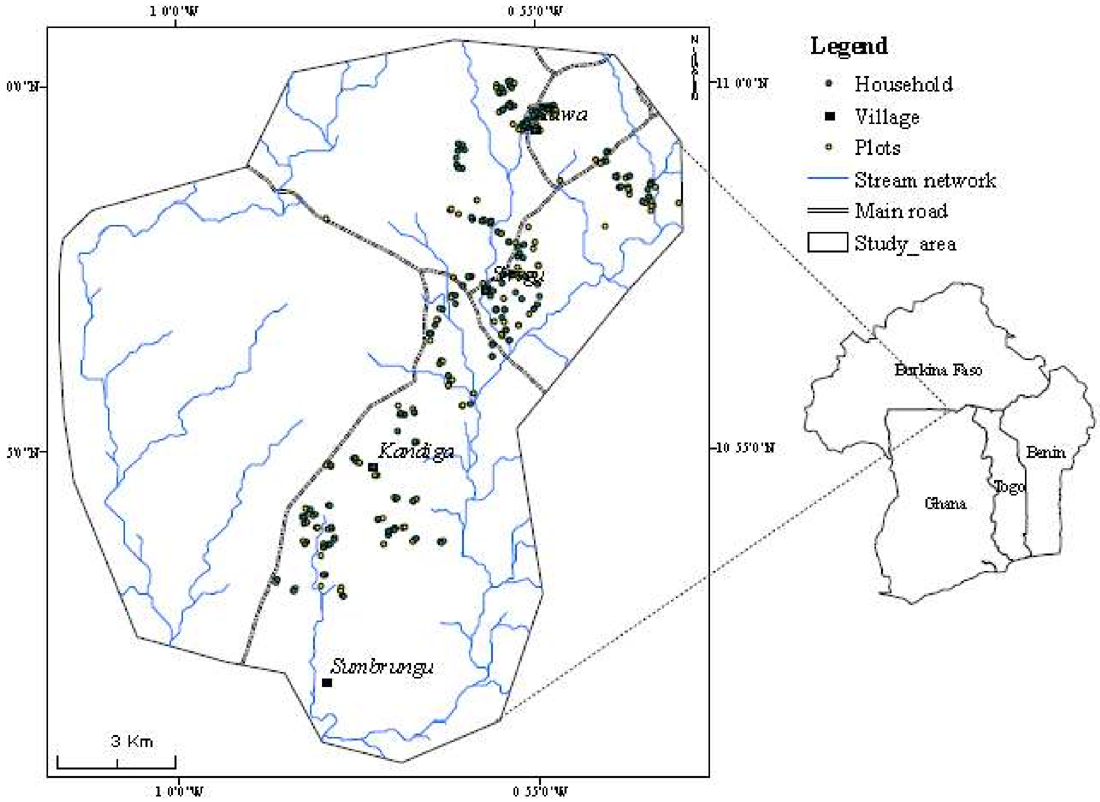


Figure 2: Study area

Climatological evidence

The historical climatic data from the Navrongo weather station (Ghana Meteorological Services) was analysed and compared with farmers' perception of climate change and variability in the study area. The choice of this weather station was based on its position in relation to the entire study area and the availability of long climatic records which covered a period of nearly 50 years (1961-2010). These data were used to compute the annual average temperature (minimum and maximum) and rainfall. Other parameters related to the rainy season such as onset, cessation dates and number of days without rain (i.e., drought) were computed over a period of 40 years because only data for 1970-2010 had been recorded on a daily basis.

When computing the average of annual rainfall values, only the seasonal period of seven months (i.e., from April to October) for each year was considered in order to ensure that only the effective crop growing period was used. Thus, the agro-climatologic approach was applied to compute the dates of onset and end of the rainy season and the number of intra-seasonal days without rain (dry spells):

- Onset of the rainy season: In the literature, several models have been proposed for determining the dates of onset of the rainy season, depending on the area of interest (Ati *et al.*, 2002). The definition used in this study is based on the daily rainfall data with respect to the length of the dry spells as supported by several authors (Sivakumar, 1988; Sivakumar, 1990; Morel, 1992; Diallo, 2001; Punyawardena, 2002; Stern *et al.,* 2005). In this regard, the date of the onset of the rainy season was defined as the date after the first of April when rainfall accumulated over three consecutive days is at least 20 mm and when no dry spell within the next 30 days exceeds 20 days.

- End of the rainy season: The definition of the end of the rainy season was based on the water balance approach which refers to the soil drying process in order to determine the end of the growing season (Aviad *et al.,* 2004). Therefore, the date of the end of the rainy season is defined as the date after first October when soil with 60 mm of field capacity is totally depleted by a daily evapotranspiration loss of 5 mm (Stern *et al.,* 2005; Morel, 1992). Then it is assumed that the soil is at field capacity of 60 mm on the last day of rain.
- Intra-seasonal dry spell: The dry spell was defined as consecutive days without rain (Stern *et al.,* 2005). Since a long dry spell after the start of the growing season (onset) causes a 'false start' or crop failure, it is very important to consider the parameter in this analysis, especially in this case where farmers themselves indicated during the surveys that 'the drought after the sowing dates causes death of crops', referring to crop failure. Based on the importance accorded to this concern by farmers in the study area, the dry spell was computed during the next thirty days after the date of the onset. And the average date of the onset of the rainy season in this area is stated at 122 Julian days, which corresponds to first May (Table 1).
- Duration of the rainy season: The duration or length of the rainy season which refers to the length of the growing season in this analysis is calculated by subtracting the date of the beginning (onset) from the date of the ending of the rainy season. This parameter, in addition to those defined previously, was assumed to be the main concern of agriculturists in the West African savannah (Edoga, 2007).

The climatic parameters were standardised in order to determine the climate trend of the study area and explore its inter-annual variability. To do so, the standardised anomalies were computed using the difference between an annual mean as observation and average of the data series divided by the standard deviation (Equation 1). The average of the data used is in line with the requirements of the World Organisation of Meteorology (WMO) which suggested the following periods as normal (30 years) for any climatological studies: 1961-1990, 1971-2000 and recently 1981-2010 (WMO, 2007). Then the following formula was used to calculate the standardised anomalies:

$$\text{Standardised anomaly} = \frac{X_i - \overline{X}}{\delta} \quad 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (1)}$$

Where X_i represents the annual value or observation of year i, $\overline{X}$ is the climatological average and δ is the standard deviation of the normal period.

Table 1 Descriptive statistics of climatic parameters used to analyse farmers' perception of climate change and variability (1970-2010).

Parameter	Mean	Max	Min	Standard deviation	Coefficient of variation	*Change
Temperature max (°C)	35	36	34	0.48	0.20	1
Temperature min (°C)	23	24	22	0.46	0.28	1
Rainfall (mm)	974	1360	632	154	2.24	-5
Start season (Julian day)	122	162	95	17	2.21	9
End season (Julian day)	282	299	275	7	0.38	4
Duration (day)	160	193	122	16	1.61	-5
Dry spell in May (day)	10	17	5	3	5.01	3
Rain days (day)	70	85	58	7	1.60	-1

*Change corresponds to the difference of the extreme values (first year and last year) of the trend line. (Data source: Meteorological services Agency of Ghana)

Data analysis

Farmers' perception of climate change is considered as an aggregated awareness about the trend of the following five climatic parameters (rainfall, temperature, onset, drought and the end of the rainy season) generated from the historical climate records of the research area. During the surveys, farmers were asked whether they had observed any long term changes in temperature and rainfall over the last 20 years. In other words, farmers were simply asked whether the number of hot and rainy days had increased, decreased, or stayed the same over the last 20 years. The same approach was used for the onset, the end of the rainy season and the dry spell. Farmers gave their points of view on these last three parameters which characterised the rainy season through the following answers: (1) earlier; (2) late; (3) no change; (4) increased; (5) decreased; or (6) do not know.

To consider that a respondent has perceived climate change and variability correctly, all of the five following parameters must be in agreement with the respondent's responses: 1) decrease in rainfall, 2) increase in temperature, 3) late dates of the onset of the rainy season, 4) early dates of the end of the rainy season, and 5) increase in drought frequency. Any disagreement in one of the five parameters leads to a deviated perception of the respondent on climate change. This conception of changes is based on the projection of the IPCC, when it was predicted that changes in climate variability and extremes are likely to increase (IPCC, 2001) especially when agriculture, food and water are the key vulnerable sectors identified, as in the case of Sub-Saharan Africa (Boko *et al.*, 2007).

Further, the binary logistic regression model was used to determine the factors that influence farmers' perception of climate using the formula in Equation 2:

$$\log\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_{ik} \quad \ldots\ldots\ldots. \quad \text{Equation (2)}$$

Where i denotes the i^{th} observation in the sample and P_i is the predicted probability of farmers' perception which is coded as a dummy variable with the value of 1 when a farmer has a good perception of the climate change and 0 otherwise ($1 - P_i$). β_0 is the intercept term, and β_1, β_2, and β_k are the coefficients associated with each explanatory variable X_1, X_2 and X_k. The term (P_i /1-P_i) indicates the odds ratio. The coefficients in the logistic regression were estimated using the maximum likelihood estimation method.

Binomial model variables

Dependent variable

Farmers' perception as a dependent variable was used as a dummy variable represented by 1 when a respondent gave the right answers on the long term changes for all the following five climatic parameters: rainfall, temperature, onset, drought frequency and end of the rainy season and 0 when one of the five answers was wrong (see section 2.4). Since farmers' perception of climate change is a categorical variable with binary outcomes, the binomial logistic regression was considered appropriate for analysing these data (Train, 2009; Greene, 2002; 2012). In the area of adaptation studies, farmers' perception of climate change is typically based on the perception of average change of rainfall and temperature which are the main climatic parameters used in previous studies. The questions always pertain to the long-term change and are placed into several categories such as perceived increase, perceived decrease, and no change. In the data analyses of whether farmers perceived climate change or not, the binary model was used (Bryan *et al.*, 2013), but the probit model was deployed as well (Deressa *et al.*, 2008, Gbetibouo, 2009). In the current research, in addition to rainfall and temperature, onset of the rainy season, end of the rainy season and drought or number of days without rain were used to analyse farmers' perception.

Explanatory variables

In the area of adaptation studies, the household characteristics, the institutional factors and the environmental attributes are usually used to understand the factors that determine farmers' perception of climate change and variability. In this research, the following variables were hypothesised to influence farmers' perception of climate change and variability: (1) age, gender and farming experience of the household heads as characteristics of the households; (2) the information about weather or climate received from extension officers or any media as an institutional factor and (3) the values of slope and elevation of the location of the households as agro-ecological factors (Table 2). All these variables have been used in previous studies (e.g., Deressa *et al.,* 2008; Gbetibouo, 2009; Bryan *et al.,* 2013) for the purpose of exploring farmers' perception of climate change and variability. The hypothesised influence expected from these explanatory variables is also indicated in Table 2. Since the climatic data of only one weather station were used and also because of the small size of the study area (192 km^2), temperature and rainfall were assumed to be quite uniform and only the slope and elevation were considered as two factors which could have a sensitive influence on the ecological conditions of the landscape in the area. The explanatory variables used for empirical estimations are summarised below, where some hypotheses and their expected influence are developed.

Household head age and Farming experience: It was assumed that the older the farmer, the more experienced he is in farming activities. With respect to the results of the surveys, the variables age of the household head and experience in farming have a positive relationship. Also, the farmers best placed to pronounce on whether climate change has occurred are presumably those who have had the most experience of farming. As a result, it appears that the more experience farmers have, the more likely they are to claim that temperatures have increased and the less likely they are to claim there has been no change. The results for precipitation are also very similar (Maddison, 2006). Therefore, age and experience of farmers are hypothesised to positively influence the perception of climate change.

Gender: Studies showed that both male and female were aware of climate change. The perception of climate change did not differ significantly on all parameters except on frequency of droughts, with women more likely to perceive increased drought frequency compared with men (Kisauzi *et al.*, 2012). It was also found that difference between them was more observed in the impacts caused by weather changes (Pradesh, 2010). For that reason, it is expected that female and male head households differ significantly in their ability to perceive climate change.

Information on climate change*:* Information on climate may strongly help to uptake the right decision to adapt to climate change (Maddison, 2006; Nhemachena & Hassan, 2007; Deressa *et al.*, 2008), because, access to weather and climate information increases the probability of perceiving changes in temperature and rainfall (Gbetibouo, 2009).

Agro-ecological setting (Elevation, Slope): In addition to the climatic variables (rainfall and temperature), agro-ecological factors such as elevation, slope, etc. could also vary across different agro ecologies, influencing farmers' perception of climate change (Okonya *et al.*, 2013). Therefore, the agro-ecological setting is expected to positively influence the farmers' perception.

Results

Comparative analysis of farmers' perception and climatological data

Rainfall and temperature

Among the farmers interviewed in the study area, 82% perceived the long-term changes in temperature over the last 20 years (Figure 3a). About 71% of them perceived temperature to be increasing, in contrast to the 11% who perceived that temperature was decreasing. In comparing this perception with the actual trends of the maximum and the minimum temperature recorded during the last 50 years (Figure 3b and 3c), a clear increase was noted, suggesting that farmers' perception in terms of long term changes in temperature was supported by the climatological evidence.

The majority of respondents (96%) interviewed also perceived the long-term changes in rainfall pattern over the last 20 years. About 95% of them claimed that they observed a decrease in the amount of rainfall and in the length of the rainy season (Figure 3a). In contrast, 2% of respondents reported rainfall that had increased during the last 20 years.

Unlike temperature, rainfall seemed to be better observed by farmers since 16% of them did not observe any change while 11% observed a decrease in temperature. Nevertheless, a comparison of farmers' perception with the recorded climate data showed that there was no real evidence that rainfall in terms of amount had reduced, as claimed by 95% of farmers (Figure 3a). Even though the trend of the rainfall pattern during the last 50 years is decreasing, the decrease is not significant (R^2= 0.0001) at all due to the high inter-annual variability of the rainfall (Figure 3d). This observation raises the question of whether farmers' perception of climate change and variability has a limit over time or whether farmers may be more interested in climatic parameters which are more relevant for them because they are more related to their farming activities.

Table 2 Variables hypothesised to influence the farmers' perception of climate change and variability

Variable	Description	Expected effect	Data source
Dependent variable			
Perception of climate change	Binary responses based on the answers of responder about the change in the five climatic parameters		Field surveys (2012)
Independent variable			
Characteristics of household head			
Age	Age of the household head	(+/-)	Field surveys (2012)
Gender	The gender of the household head	(-)	Field surveys (2012)
Farming experience	Number of years of farming experience of the household head	(+)	Field surveys (2012)
Institutional or policy related factors			
Climate information	Dummy variable on whether the household is getting information about weather or climate from extension officer or any media	(+)	Field surveys (2012)
Agro-ecological setting of the household's location			
Elevation	Value of the elevation (m) of location of the household	(+)	GIS based calculations
Slope	value of slope (degree) the location of the household	(-)	GIS based calculations

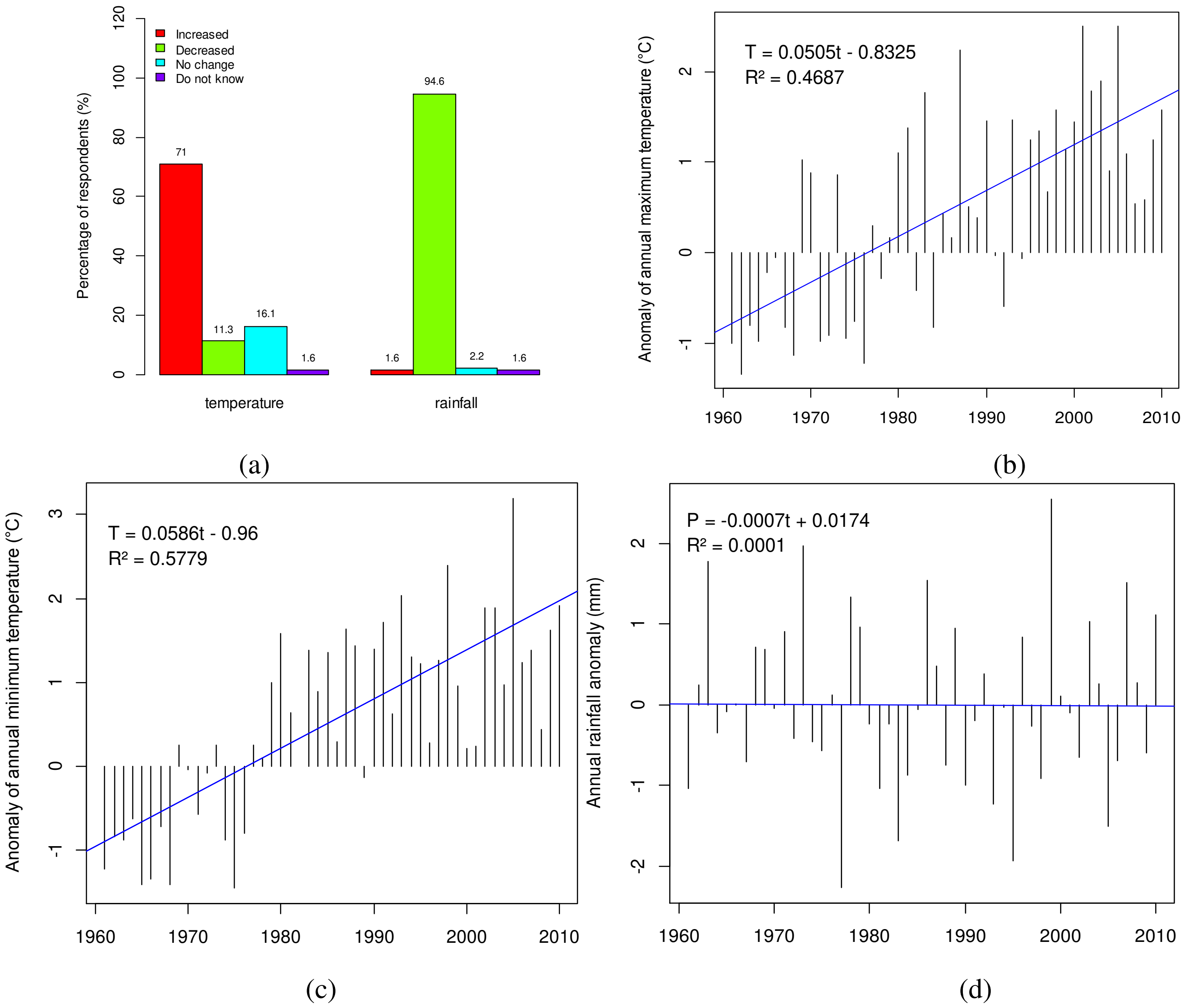


Figure 3: Farmers' perception of long term changes in (a) temperature and rainfall, (b) the trends of maximum temperature, (c) minimum temperature, and (d) rainfall

Onset and end of rains

Farmers of the study site paid much attention to the characteristics of the rainy season over time. About 99% and 98% of interviewed farmers reported that there is a long-term change in the start and end of the rainy season, respectively (Figure 4a). In terms of the date of the onset of rainy season, 97% of respondents indicated the late dates of onset which have been shifting from April to June during the last 20 years while only 2% of them reported that the dates of the onset are early (Figure 4a). On the other hand, currently the dates of the end of the rainy season are early, having shifted from November to October over the last 20 years according to 96% of farmers interviewed; only 3% of farmers thought that the rainy season was ending late. In comparison with the climatological data, the trend of the annual onset dates of the rainy season during the last 40 years (1961-2010) shows a clear increase, suggesting that the rainy season is starting late (Figure 4b). Thus, there is an agreement between the climatology and the farmers' perception about the late dates of onset.

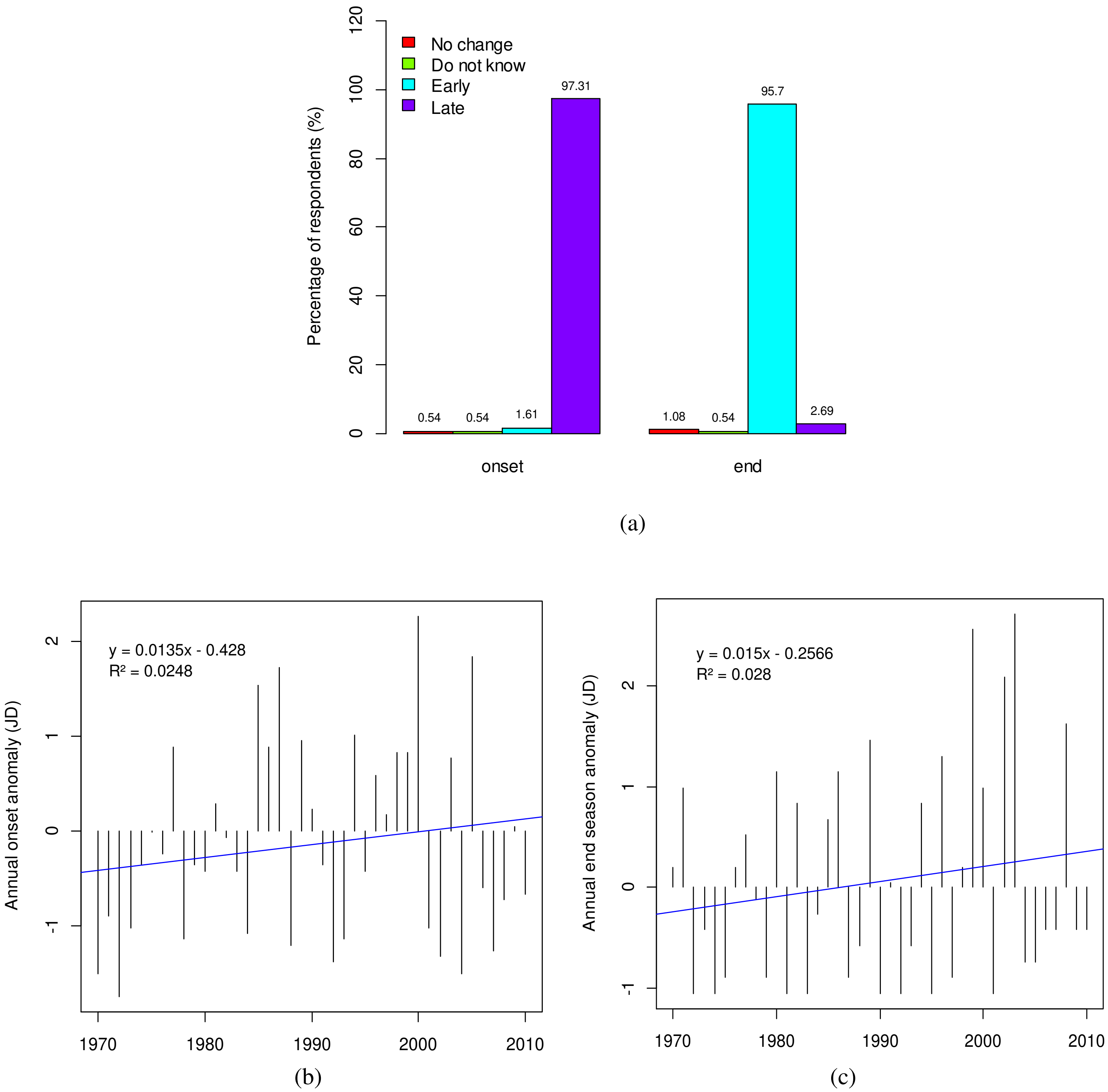
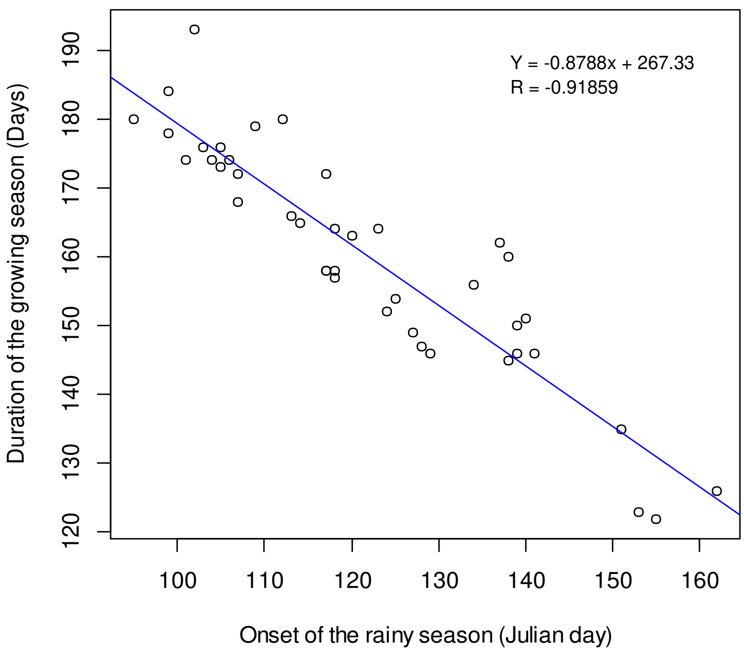
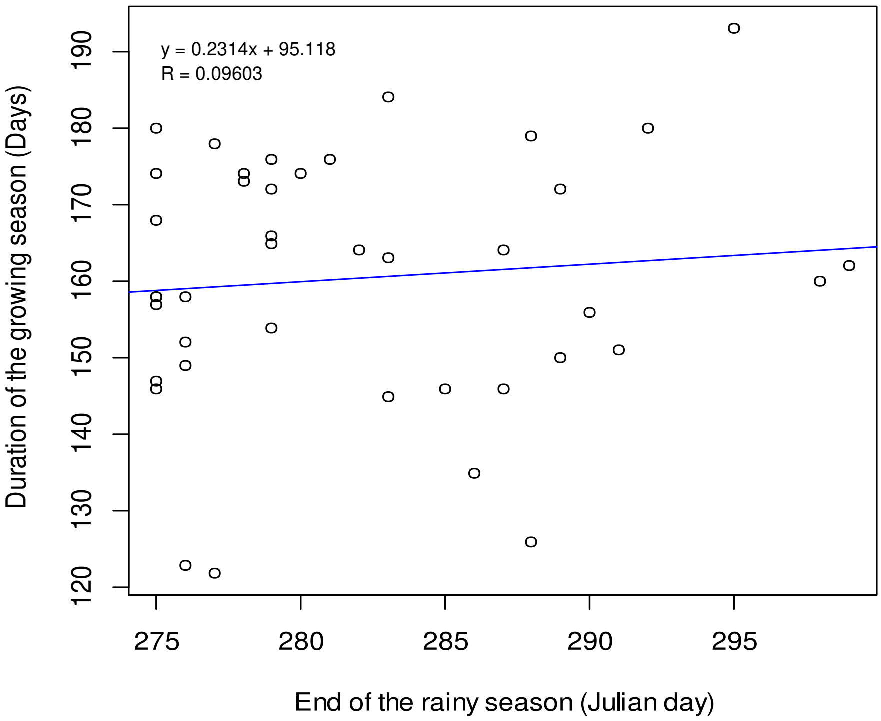


Figure 4: Farmers' perception of long term changes of (a) onset and end of the rainy season, standardized anomalies of (b) the onset dates and (c) cessation dates of the rainy season computed respectively based on the dates of the onset and end of rains in Julian days.

However, there is a contradiction between the climatological data and the perception of farmers concerning the cessation dates of the rainy season (Figure 4a). Thus, for 96% of respondents, the rainy season is ending early while the trend of the end season anomaly shows a slight increase, suggesting that the rainy season is ending late (Figure 4c). In fact, the trends of onset and end of the rainy season are also not statistically significant because of the high inter-annual variability that existed in the recorded data. In order to understand this perception of the respondents about the end of the rainy season, the relationship between the duration of the rainy season and the dates of both the onset and the end of the rainy season over the last 40 years (1970-2010) was explored (Figure 5). The duration of the rainy season corresponds to the effective growing period as stated earlier. The results show a strong negative correlation (R = - 0.918) between the duration of the growing season and the dates of the onset (Figure 5a). This suggests that the earlier the onset date is, the longer the growing period. On the other hand, a very weak correlation exists (R = 0.09603) between the duration of the growing season and the dates of the cessation of the rainy season (Figure 5b), suggesting that during the last 40 years, the duration of the growing period was not related to the end of the rainy season at all. This finding helps to understand the following statement reported by the respondents: "*whenever the onset of the rainy season (referring to the sowing dates at the beginning of the rainy season) is missed, it is very likely to lead to a poor yield, especially for some cereal crops like early millet*". In conclusion, the late start of the rainy season has a great influence on the period of the growing season, and farmers attribute this reduction of the growing period to both parameters: the onset and the end of the rainy season. For farmers, even though the rainy season starts late, they still expect to get the same length of growing period they are used to.



(a)



(b)

Figure 5: (a) Duration of the rainy season in days as related to the onset dates in Julian days (Julian day 100 corresponds to the 9th of April and Julian day 160 corresponds to the 8th of June) and (b) duration of the rainy season in days as related to the dates of the end of the rainy season in Julian days (Julian day 275 corresponds to the 01st October and Julian day 295 corresponds to the 21st of October). The inter-annual variability is very high for the start of the rainy season (onset dates), having varied from April to June during the last 40 years; unlike the end of the rainy season which has been much more stable during the last 40 years when the dates have varied only within one month (October).

Dry spell

During the surveys, respondents claimed that the drought is a serious matter that causes crop failure at the beginning of the growing period. For this reason, the stated concern was considered in the analysis by examining the number of days without rain (dry spells) in the study area for the first thirty (30) days after the average date of the onset (01 May) during the last 40 years (Table 1). As a result, there was an increased trend of dry spells during the next thirty days after the planting date (Figure 6b), which is in agreement with farmers' perception as illustrated in Figure 6a, showing that 75% of farmers perceived an increase in drought frequency. Moreover, the area has experienced a continuous high frequency of dry spells during the last 10 years (2000-2010). This anomaly is not only in agreement with farmers' perception but also supports their concern about the increasing crop failures during the last 20 years. On the other hand, 9% of the respondents reported that the frequency of drought had decreased.

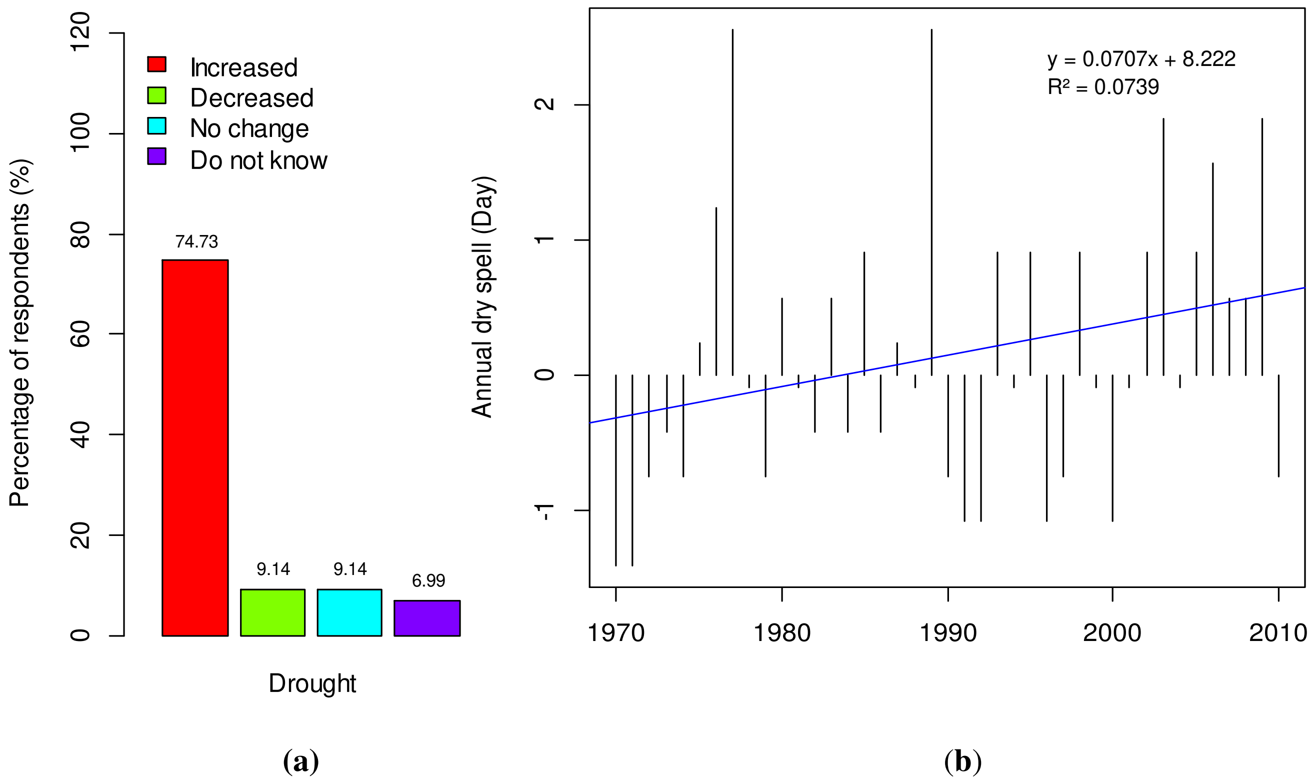


Figure 6: (a) Farmers' perception of drought frequency and (b) the trend of the dry spell of the next thirty days after the sowing date (date of onset). Note: The average date of onset during the last 40 years is stated at Julian day 122 which corresponds to 1st May.

Determinants of farmers' perception

The empirical binary logistic sub-model which determines factors that influence farmers' perception of climate change and variability in the study area is depicted in Table 3. The likelihood ratio test showed that this sub-model is highly significant ($p = 0.001$) in exploring farmers' perception of climate change and variability. Among the explanatory variables, only two (Table 3): access to climate information from agricultural extension agents ($p < 0.036$) and elevation ($p < 0.000$) have a significant association with a good perception of climate change and variability. These variables suggest that receiving climate information from agricultural extension services and a 1 metre increase in terms of elevation increase significantly the odds of having a good perception of climate change and variability (Table 3).

Table 3 Results of the binary logit regression model for predicting farmers' perception of climate change and variability**.**

Source	Value	Standard error	Wald Chi-Square	Pr > Chi²	Odds ratio
Intercept	-7.301***	2.319	9.911	0.002	
Gender	-0.480	0.460	1.089	0.297	0.619
Age	0.012	0.017	0.463	0.496	1.012
experience	-0.024	0.016	2.125	0.145	0.977
Elevation	0.040***	0.010	14.327	0.000	1.040
Slope	-0.153	0.123	1.554	0.213	0.858
Information	0.699**	0.333	4.405	0.036	2.011

Fitness and accuracy of the model

Likelihood test (chi-square statistics): 24.10 *df* = 6 p = 0.001

***, ** and * indicate the significance level of 1, 5 and 10% respectively

The sub-model has a good predictive power with an overall percentage of correct prediction of 65%. And this sub-model is much better at predicting farmers with good perception of climate change and variability because when the probability of good perception equals 1 the percentage of correct prediction reaches 74% (Table 4).

Table 4 Percentage of correct prediction

from \ to	0	1	Total	% correct
0	48	39	87	55 %
1	26	73	99	74 %
Total	74	112	186	65 %

Discussion

Does farmers' perception of climate change agree with empirical climatological evidence?

The findings of this research support the growing evidence that temperature is continuously increasing while rain becomes less predictable and shorter in duration (Maddison, 2006; Thornton et *al.,* 2006). As elsewhere in the developing countries (Mendelsohn & Dinar, 1999), the majority of farmers in the study area believe that the climate has changed, including the three additional parameters (the onset of the rainy season, the end of the rainy season and the number of days without rain, or drought). The implication of these three characteristics of the rainy season in this study is related to their importance for farmers in terms of a good start of the cropping system which is one of the key conditions for good crop production. Also, the onset is the most important variable to which all the other seasonal characteristics are related (Laux and Kunstmann, 2008). For instance, the rainfall characteristics in terms of length of growing season have always been uncertain due to high variability of the onset and cessation of the rainy season. In some years the rains start early while in others they arrive late. Hence, the inter-annual variability makes it difficult to determine the sowing date, the selection of the crop type and crop varieties. In this context, farmers are very conscious that their production is suffering significantly with either a late onset or an early cessation of the growing season, and/or a high frequency of dry spells (Mugalavai *et al.*, 2008).

However, a number of farmers among the investigated communities reported that temperature has increased and rainfall has decreased. If the first farmers' assertion is in line with the trend of the historical maximum and minimum temperature (Figure 3b and Figure 3c), the second assertion is not much supported by the historical data since farmers are overestimating the decrease in the rainfall in the area (Figure 3d), given the very insignificant trend in terms of annual average of rainfall from the climatological evidence. In other words, though there is a high inter-annual variability in the amount of rainfall, the rainfall pattern in terms of average amount has not greatly decreased in the area, a situation which is in accord with the observation of Gbetibouo (2009) in the Limpopo basin of South Africa. In a recent study in Kenya, Bryan *et al.* (2013) found that an overwhelming majority of farmers perceived an increase in temperature (94%) and a decrease in precipitation (88%) over the last 20 years. Some of the reasons explaining farmers' perception of long term decrease in rainfall may be based on their experiences with rainfall variability, increasing dry spells, and particularly shifts in timing through late onset and distribution of rainfall rather than on average quantities of annual rainfall. This may explain why farmers perceive a decrease in rainfall associated with climate change despite the fact that actual data have not shown a significant change in trend.

The analysis of the rainy season characteristics (onset dates, cessation dates, drought and duration of the growing period) is also very relevant for farming systems since these are key factors in planning activities within the season. On this basis, the majority of farmers believed that the rainy season starts late and ends early compared to the past twenty years (Figure 4a). Looking at the trends of these two parameters, though the rainy season starts late nowadays, it does not end early (Figure 4a and Figure 4b.) as claimed by the majority of the respondents. The end of the rainy season does not change much and it has been occurring slightly late since 1990 (Figure 4c). The previous statement is also supported by Figure 5b which shows that for the last 40 years the end of the rainy season has varied only within the month of October. Oladipo & Kyari (1993) investigated the fluctuation in the onset, cessation and length of the growing season in Northern Nigeria and reported that the length of the growing season is more sensitive to the onset of the rains than to their cessation. Mugalavai *et al.* (2008), in their study on the analysis of rainfall onset, cessation and length of growing season for Western Kenya, also indicated that cessation of rainfall shows strong localised influences, mainly surrounding Lake Victoria and forested areas.

From the findings of the analysis on the relationship of the rainy season characteristics, the early onset dates of rains result in a longer growing season and the late onset dates result in a shorter growing period (Figure 5a). In the study area, the average date of the onset of the rainy season is stated to be Julian day 122 which corresponds to the first (01) May and the average length of the growing season was 160 days during the last 40 years (Table 2). When the rainy season starts early (around Julian day 100, corresponding to the 09th of April) then the growing period could reach the 180 days (six months), which effectively cover the cycle of the late varieties (Figure 5a). In contrast, for the late onset of the rainy season (Julian day 150 corresponding to the 29th of May), the growing period could never reach the five months, which is too short for the local varieties with long cycles. This relationship between the onset and the duration of the rainy season is in line with the work of Sivakumar (1988; 1990) in the Sudano-Sahelian zone, particularly at the Niamey weather station using a longer historical database (1904-1984) with similar results. The relationship between later onset and shorter length of the growing period is also supported by Punyawardena (2002). Understanding the relationship among these characteristics of the rainy season is a key factor in making decisions about land-use and planning farming practices, especially in the context of a changing environment (Moyo *et al.*, 2012). However, this research found that climate change due to the changes in average climatic parameters used to define farmers' perception does not always attract the attention of most farmers. For instance, as discussed previously, due to the fact that farmers give much more importance to the intra-annual variability of rainy season characteristics such as rainfall intensity, they misperceived the duration of the growing season. As a result, farmers attribute the shortness of the growing season to the early end of the rains, a claim which is not supported by the records. As a result, farmers' perception is considered as partially consistent with the science of climate change (Jarawura, 2014).

With regards to the results of the regression analysis, only two factors (information on climate and agro-ecological setting) significantly influence farmers' perception of climate change and variability. A positive relationship between the perception of climate change and access to extension services indicates that having extension advice is very likely to increase the farmers' awareness of climate change and variability as hypothesised in this study and supported by Deressa *et al.* (2008), Gbetibouo (2009) and Weber (2010). However, it was found that even though farmers acknowledged these sources of information, they still had their own perception of climate change (Yaro, 2013). Also, farmers' perception of the local environment could be related to the topography of the area which exerts a strong influence in the agro-ecology. As a result, farmers living in the highlands are more likely to have a good perception of climate change and variability. This is in contradiction of the findings of Deressa *et al.* (2008) who indicated that farmers living in lowland areas are hypothesised to be more likely to have perceived climate change than the midlands and highlands. According to them the lowlands are already hotter and a marginal change in temperature can be perceived more easily. However, the limitation to this study is related to the fact that farmers were asked to indicate their awareness of the changes of five climatic parameters (temperature, rainfall, onset dates, dates of cessation of the rainy season and drought), which formed the basis for explaining their perception of climate change. However, the approach discounts the role of other drivers of climate change (economic, cultural, government, technological and environmental forces) which may amplify, negate or otherwise modify the impacts of climate on agricultural systems (Smit *et al.*, 1996).

Implications of climate change adaptation and future research outlook

The findings of this work support the previous contributions in the area of adaptation research in the sense that they support the collaboration between stakeholders, policy makers, development agencies, and researchers in the effort to understand the multidisciplinary dimensions of climate variability. In this way, the contribution suggests that the perception model should be considered in adaptation research in order to analyse appropriate adaptation measures stimulated by climate variability since the literature on the subject also makes it clear that perception is a necessary prerequisite for adaptation (Smit *et al.*, 1996; Maddison, 2006). It was found that farmers adopted a range of practices in response to perceived climate change (Bryan *et al.*, 2013) and as a result, the most common responses included changing crop variety, planting dates and crop type. A study conducted in Ghana showed that diversifying crop type and changing crop planting dates were identified as the major adaptation strategies to a warmer climate (Badmos *et al.*, in press). Similarly, about 41% of farmers appeared to have changed their management in response to declining precipitation, with crop diversification and shifting planting dates being the most important adaptation measures (Fosu-Mensah *et al.*, 2010).

With regards to the above, an important issue related to adaptation is how farmers' perception of climate change is translated into decisions concerning agricultural land-use, especially when it is recognised that farmers' responses can vary even when they experience the same stimuli and operate within the same area (Bryant *et al.*, 2000). Accordingly, since perception of climate change itself is fundamentally determined by learning factors (Maddison, 2006), which include information on climate (*learning by instruction*), the experience of farmers (*learning by doing*) and the local environment (*learning by copying*), then it can be appropriately analysed using a multidisciplinary approach such as Multi-Agent Simulations for technology diffusion and policy analysis (Maddison, 2006). Thus, research on the implications of climate change in agriculture land-use goes beyond crop yield modelling to estimate production and economic implications. Increasingly, studies include adaptation, most commonly by assuming that farmers employ certain adaptive practices better suited to the specified climate scenarios. In this case, there is clearly a need to test these assumptions by empirically examining actual adaptive behaviour of farmers to identify pertinent stimuli, relevant constraints and general adaptive response functions to variations in climatic conditions over time (Bryant *et al.,* 2000; Vermeulen, 2014).

Conclusion

The findings on farmers' perception of climate change and variability in the study area show that farmers' knowledge of past climate variability matches closely the empirical observations. Therefore, this research has brought out the usefulness of both perception studies and empirical analysis. Combining both data sources strengthens the bridge between quantitative and qualitative approaches and informs debates on the need for more inclusive adaptation and development policies on climate change (Simelton *et al.*, 2013). A number of farmers in the study area are aware of the increasing temperature trend, the late onset of rains and the increasing drought frequency which are in accord with empirical climatological records. However, due to the fact that farmers give much more importance to the intra-annual variability of rainy season characteristics such as rainfall intensity, they have a different perception of the duration of the growing season, as they attribute the shortness of the growing season to the early arrival of the end, a position which is not supported by the records. Also, the results of this research indicate that the local environment and access to climate information are the two main factors which influence perception of climate change and variability.

Through the framework, this study shows that even though farmers' behaviour may be influenced by their values and interests, their awareness of weather and climate may also be considered as a consistent indicator of their perception. For that reason, farmers observe the local climatic conditions and respond through decisions on agricultural land-use and adaptation to climate change according to what they perceive. As a result, this research is very relevant in agricultural land-use decision analyses, since it contributes toward answering the question of whether or not certain factors driving agricultural land-use choice are beyond farmers' characteristics which are assumed to be driving forces. This is in line with IPCC's policy objectives to improve tools for integrated assessment, including risk assessment, to investigate interactions between components of natural and human systems and the consequences of different policy decisions (IPCC, 2001). Therefore, the study recognises that the role of climatic variations in promoting changes in agriculture cannot be understood without careful consideration of the role of other forces: economic, policy and environmental. Successful implementation of adaptation related policy is dependent on a decision-making framework that is informed by scientific and local knowledge. As observed by Howden *et al.* (2007), stakeholder perception serves to inform adjustment strategies to climate change impacts while simultaneously preserving cultural values that are meaningful to local communities.

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