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Analysis of Observed and Perceived Climate Change and Variability in Arsi Negele District, Ethiopia

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Introduction

Climate change and variability is a global concern (IPCC 2014) and it has been detected in Ethiopia (NMA 2006, McSweeney *et al*., 2008). Climate variability refers to variations in the mean state and other statistics of the climate on both temporal and spatial scales beyond the individual weather events (IPCC 2014). While climate change is a change in climate over comparable time periods (a decade or more) which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere (IPCC 2014). Between 1951 and 2006, the annual minimum temperature in Ethiopia was increased by about 0.37°C per decade (NMA 2006, Adem and Bewket 2011). The IPCC's mid-range emission scenario (IPCC 2007) shows that the mean annual temperature in Ethiopia was increased by 1.3°C between 1960 and 2006, which is an average rate of 0.28°C per decade (McSweeney *et al*., 2008). According to this emission scenario, the mean annual temperature also expected to increase in the range of 0.9°C to 1.1°C by the year 2030 and 1.7°C to 2.1°C by the year 2050 as compared to the 1961 to 1990. With respect to annual precipitation, for the same scenario and base period, the expected variation is in the range of 0.6 to 4.9% by 2030 and 1.1 to 18.2% by 2050 (Mekonnen and Hailemariam 2000, NMA 2006, Regassa *et al*. 2010). The frequency of drought in Ethiopia particularly in the recent decades is an indication of the realty of the variation in climate. There were 19 drought events which occurred in Ethiopia between the period 1900 and 2002, which is almost once in six years in 1900 to 1987(14 drought events) and roughly in three years in 1988 to 2002 (5 drought events) (NMSA 1987, World Bank 2005). In the period between 1999 and 2008, drought and flooding affected nearly 21 million people (19.7 million by drought and the remaining by flooding) in Ethiopia (OFDA/CRED 2009).

The livelihoods of smallholder farmers are mainly dependent on climate change and variability sensitive sectors such as agriculture and natural resources. These communities live with a range of livelihood risks (Gandure *et al*. 2013). Climate change impact is more intense when it is combined with other environmental changes (Mertz *et al*. 2009, IPCC 2014). Households that perceived the variability and change in climate can cope and adapt to the change and hence less vulnerable to the impacts than those who did not perceive it (UNFCCC 2007). These households respond to the change and variability via practicing different indigenous coping and adaptation techniques as the perception enables their decision-making (Gyampoh *et al*. 2009, NAC 2010, Osbahr *et al*. 2011, Kumar 2014, Tilahun and Bedemo 2014, Huda *et al*. 2016, IFAD 2016).

Hence perception of the long term changes in climate by them plays an important role in shaping their behaviour (Abid *et al*. 2014). Perceptions of risk and cognitive process of primary decision makers are important for the adoption of different adaptation decisions (Grothmann and Patt, 2005, Nyanga *et al*. 2011, Simelton *et al*. 2011, Amdu *et al*. 2013, Burnham 2014). In this regard, several studies (*e.g*. Egeru 2012, Amdu *et al*. 2013, Varadan & Kumar 2014) indicated smallholder farmers' experience of climate change and variability regarding decreasing and unpredictable rainfall, increasing temperature, and delayed onset of rainfall, which were also validated with actual climate trend analysis. As smallholder farmers are engaged actively with their natural environment in their day-to-day lives, they have accumulated sizable and sophisticated bodies of knowledge and practices about their environment, its variability and transformation which is a basis for indigenous adaptation and provide important insights into processes of modern adaptation to climate variability and change (Nakashima *et al.* 2012). In our context, indigenous, local or community and traditional knowledge are used synonymously. Community-based and local knowledge may offer valuable insights into environmental change instigated by climate change, and complement broader-scale scientific research with local precision and nuance. Ignorance of such knowledge, however, reduces individual perception of the risks posed by climate change as well as affects the costs and benefits of different adaptation options: adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC 2014). Local perceptions and knowledge provide a crucial foundation for community-based climate change adaptation measures (McLean *et al.* 2011, Nakashima *et al.* 2012, Ramos and McLean 2012) and acknowledged by IPCC as invaluable for developing adaptation and natural resource management strategies in response to environmental and other forms of change (IPCC 2007, Gyampoh *et al.* 2009, IPCC 2010a, Magni 2016, Ford *et al.* 2016). As the local perceptions and the resulting indigenous knowledge are location and site specific, there investigation in different socioeconomic setting is worthwhile. Nevertheless, limited attention has been given to the knowledge and practice emanated from the perception of smallholder farmers and the accumulated knowledge and long time experience about their environment. The knowledge and practice in this regard is very important as the combination of the knowledge obtained from the community's perceptions and observed data can be used for better understanding about climate change and variability in general and what response strategies can be taken. This study was specifically designed to i) assess households' perception and knowledge of climate change and/or variability, and ii) establish the observed changes in climate parameters with community perceptions and climate anomalies.

Materials and methods

Description of the study area

The study was conducted in Arsi-Negele district, which is located in West Arsi zone of the Oromia Regional State, Ethiopia. The district is located between 7.15°N to 7.75°N latitudes and 38.35°E to 38.95° E longitudes. The altitude of the district ranges between1500 to 3000 meters above sea level. The topography encompassed the central rift valley floor, including lakes Langano, Shalla and Abijata, and extended to the eastern escarpment of the central rift valley of Ethiopia. The district's average annual temperature varies between 10°C and 25°C while the annual rainfall varies between 500 and 1000mm.
Demographically, between the periods 1994 to 2007, the rural population was increased by 83% while the urban population increased by 119%. The rural population of the district accounts 83% of the total population in 1994 and 80% in 2007 (ENC 1994, 2007, CSA 205).

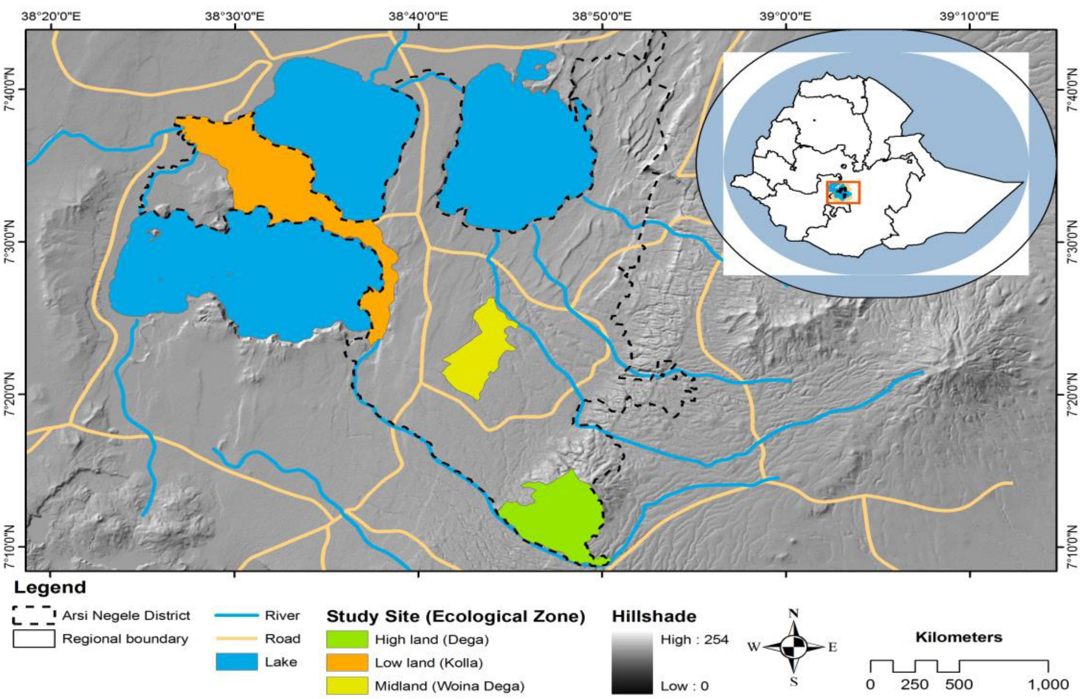


Figure 1: Map of the study area

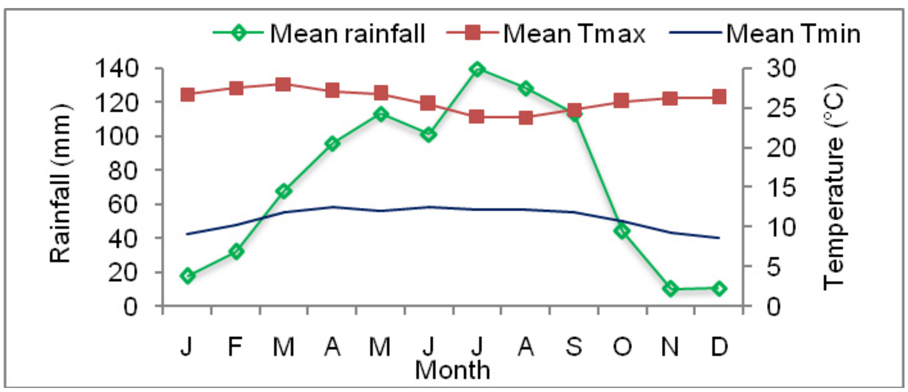


Figure 2: Diagram showing variation in climate variables over Arsi Negele District (1983 to 2014)

Methods

In this study both the qualitative and quantitative data collection methods were employed. The study was a cross-sectional survey of respondents from six kebeles, the lowest administrative division in Ethiopia's geopolitical administration, and three agro-ecologies–two kebeles from each agro-ecology. This was supplemented with 18 focus group discussions, three from each kebele (2 kebeles/ACZ x 3 focus groups/kebele x 3 ACZs = 18 focus groups), and 30 key informant interviews, five from each kebele. It also complemented by secondary sources from measured and satellite climatic data.

Sampling design

This study employed multistage sampling techniques. In the first stage, Arsi Negele district was selected purposively as it represents three distinct agro-ecologies such as lowland, midland and highland, which can be used to show the spatial dimensions of climate change and variability. In the second stage, six kebeles, two each from each agro-ecology were selected based on the representativeness of an agro-ecology. The third stage was selecting the sample households from 4257 households in the area. A total of 355 households (163 poor, 124 medium and 68 better off) were selected through stratified random sampling. Then proportional numbers of households at each kebele were randomly selected based on wealth categories and gender for household interview. The sample representing the population were selected on the basis of normal distribution with confidence level of 95% and margin of error 5% followed by finite population correction (FPC) to get the true sample (*i.e.* n = (s x N) / (s +N-1); where: n is true sample, s is sample of 50% distribution ~ 385, N = 4257) (Israel 1992, Bartlett *et al.* 2001).

Hence to collect data at household and community level, three major primary data collection methods were used. These include key informant interviews, focus group discussion and household survey.

As key informants interview, those people who have relatively knowledgeable about their community situation, local natural resources, climate conditions, the culture of the community, overall development and the respective changes in these are used (Smith and Sharp 2012). Hence, they shared their built up knowledge and experience to the interviewer. To select these key informants, a snowball method at which one key informant was contacted based on kebele officials information and document. Then, s/he would inform us the second, the second would tell the third and so forth until a saturation number was reached (Bernard 2006).

*The Focus group discussion*s were made representative of the community including youth, women and elders. These focus group discussions were made with three independent groups per kebele at which each group consisted of 8-10 peoples. The focus group discussions was on different issues including farming calendar, establishing local criteria for wealth categorization, perception of climate change and variability (temperature and rainfall) as well as environmental degradation and causes of local climate variation. The members of a group were selected randomly including women, elders and youth to obtain varied knowledge and views. At least one key informant was included in each group to triangulate information. The focus group discussion had made use of participants' feelings, perceptions and opinion about local climate variations and change. To understand climate change and variability in local context, we, the facilitator and FGD participants, first have defined what was considered normal in local context before thirty years ago.

The household survey was conducted with sample households. To select the sample households, list of all households have been taken from kebele administration office which were already categorized in to three groups, namely poor, medium and better off- based on the kebele's wealth categorization criteria. After this, we had discussed on the list with key informants in the community with those categories and had allowed them to categorize the households with their own criterion such as asset possession, better house, income and fertile farmland. Those that have intersected with the kebele and key informants' categorizations were considered in the sampling randomization. Then proportional number from each category has been taken randomly- 163 poor, 124 medium and 68 better off- making a total of 355 sample households. Sample households were taken from each wealth category proportionally to improve the reliability of the data and to capture differential perception and knowledge about climate change and variability among social status. The interview was designed in semi-structured and structured forms and translated into local language - *Afan Oromo*.

As secondary data, satellite images and meteorological data obtained from National Meteorological Agency (NMA) were used for observed climate trend analysis. Using the satellite *data,* Arsi Negele district has been divided in to 49 grids cells of size 10 X 10 km spatial and daily/monthly temporal resolutions and climatic data has been reconstructed by NMA personnel in 2015 for the geographic location of the district between 7.15 to 7.75°N and 38.35 to 39.95°E. Then latitude lines 7.25°N, 7.35°N and 7.55°N were chosen representing and dissecting the lowland, midland and highland agro-ecologies of the district, respectively.

Data analysis

Data was analyzed using descriptive statistics such as frequencies, means, percentages and graphs as well as time series analysis using ordinary least square for temperature and rainfall. In addition, correlational statistics are used to describe the relationship and prediction of climate variables: observed vs. perceived. Statistical software such as SPSS v. 20 and Minitab v.17 were used to analyze the quantitative data obtained from survey and secondary information (meteorological data). The qualitative data from focus group discussions and key informants interviews were analyzed and interpreted in the form of narratives, trend analysis and descriptions. The reconstructed grid cells climate data were compared with observed climate data from weather station. Comparison was made for weather station located in the district and an F-test was made for those years with full temperature and rainfall data to see whether there is statistical significant difference between the mean annual values of the observed and gridded data types. The F-test analysis showed that there is no statistical significant difference between the two data sets. As a result, satellite data was used for temporal and spatial climate variability analysis which avoids the missed data gaps in the observed temperature and rainfall data (Dinku *et al*. 2013, 2014).

Results

Observed climate variability

The analysis of observed climate data shows that there was variability in climate in Arsi Negele district. This is supported by the analysis of both temperature and rainfall data. The result shows that the variation has both temporal and spatial dimension. The analysis of temperature data from 1983 to 2014 showed that the mean maximum temperature varies from 24.52°C in 1993 to 27.76°C in 2009. The ranges of variation for the mean annual maximum, minimum and average temperatures were [-2.28, 2.42], [-1.72, 3.82] and [-1.48, 3.08] standard deviations respectively (fig. 3b). As indicated in figure 3a from Arsi Negele Station (7.35°N, 38.66°E, 1913 m a.s.l.), the mean annual maximum temperature, the mean annual minimum temperature and mean annual temperature showed an increasing trend of 0.047°C, 0.028°C and 0.038°C per annum, respectively (fig. 3a). For the mean maximum temperature in the study area, the maximum positive deviations were observed in the years 1988, 1999 and 2012 and the maximum negative deviation in 2010. Similarly, the maximum positive deviation for the minimum temperature was observed in 1988 while the negative highest deviation was in 2014. For the mean annual temperature, the highest positive and negative deviations were in 2012 and 2000 respectively. The rainfall data analysis for the period 1983 to 2014 has showed that there was variation in the total annual rainfall (TARF) with the peak in 2004 with 1486.5 mm and sharp drop in 2013 with 206 mm. This variation ranges from [-2.44, 2.42] standard deviations from the mean for Arsi Negele station (Figure 3b). The total annual rainfall has declined by 10.16 mm per annum with the highest positive and negative deviations in 2003 and 2013 respectively.

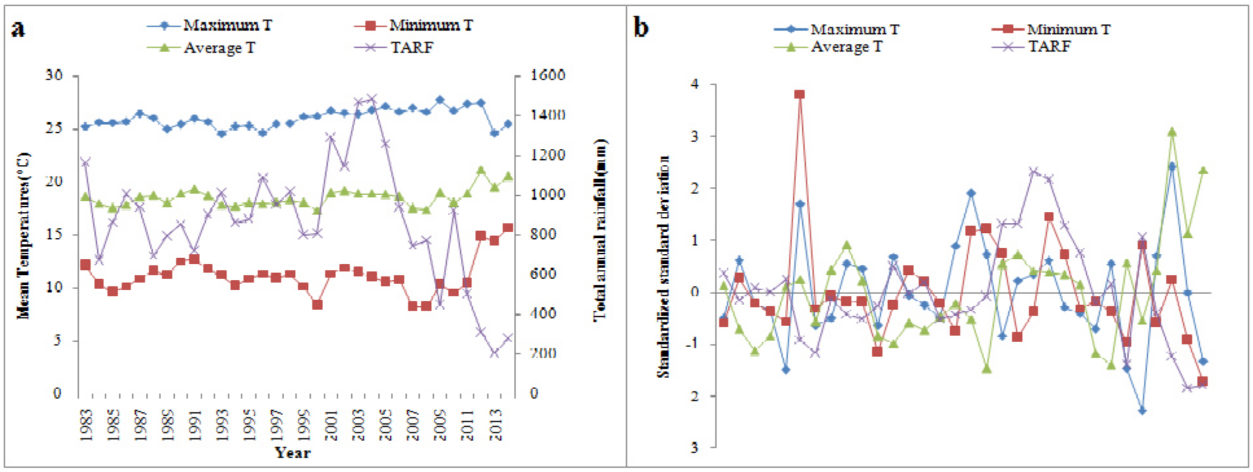


Figure 3: Temperature and rainfall trends (a) and their respective standardized anomalies (b) from Arsi Negele station

Spatial and temporal variations

The analysis of Satellite data for the period 1982 to 2011 has showed that there was variation in temperature and rainfall both spatially and temporally. For the grid cells along 7.15°N latitude the temperature and rainfall showed decreasing trend as one go from west to east except that the minimum temperature was at peak for the grid cell 38.65°E in both periods (fig. 4i). The minimum temperature along the 7.35°N grid cells showed somewhat declining trend at first then increasing from 38.45 to 38.75°E and then somewhat decline when running from west to east for both the three decades (fig. 4d). While the maximum temperature has showed a general declining trend for both periods (fig 4e) and the rainfall has showed a declining trend for the grid cells between 38.35 to 38.55°E. It continued with similar trend for the decades 1992 to 2001 and 2002 to 2011 and increasing trend for the decade 1982-1991 (fig.4f) as one go from east to west. For the grid cells along 7.55°N which represents the lowland climate, the temperature has showed an increasing trend then somewhat decline.

The rainfall has generally showed a declining trend for both decades as we go from east to west (fig. 4g-i). The analysis on a same grid cell showed that the temperature was more or less higher for the decade 1982 to 1991 than the other two decades but the average temperature for 2002 to 2011 is higher than 1992 to 2001 for all grid cells along 7.25°N, 7.35°N and 7.55°N. Nevertheless, the total annual rainfall was generally lower in 2002 to 2011 than in 1982 to 1991 and 1992 to 2001 at almost all of the grid cells along latitude 7.25°N and 7.35°N. However, the total rainfall was higher for the decade 2002 to 2011 for the grid cells along 7.55°N latitude (fig. 4a-i).

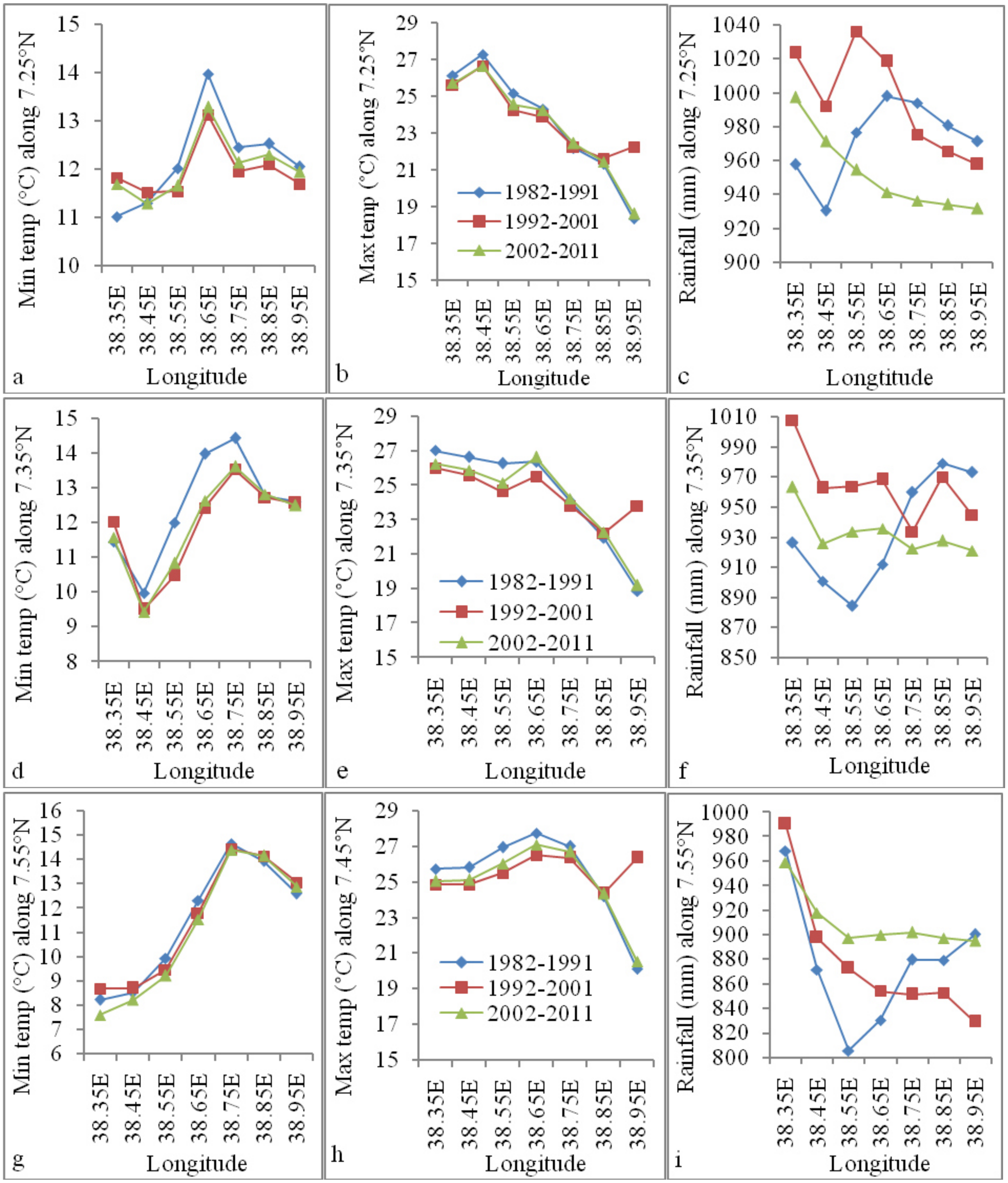


Figure 4: Spatial and temporal climate variability in Arsi Negele District

Seasonal climatic variations

Rainfall

The analysis of climatic variables in the study area showed a high vriability of rainfall with r^2 ranging from 0.023 for June-July-August (JJA) -Ethiopian summer season- to 0.090 for March-April-May (MAM) -Ethiopian spring season- during the period 1983/84 to 2014/15 (fig. 5). During this same period, the rainfall has declined by 2.198 mm, 4.541 mm, 1.814 mm and 1.608 mm per annum for JJA, MAM, September-October-November (SON)-Ethiopian autumn season- and December-January-February (DJF)-Ethiopian winter seasons- respectively.

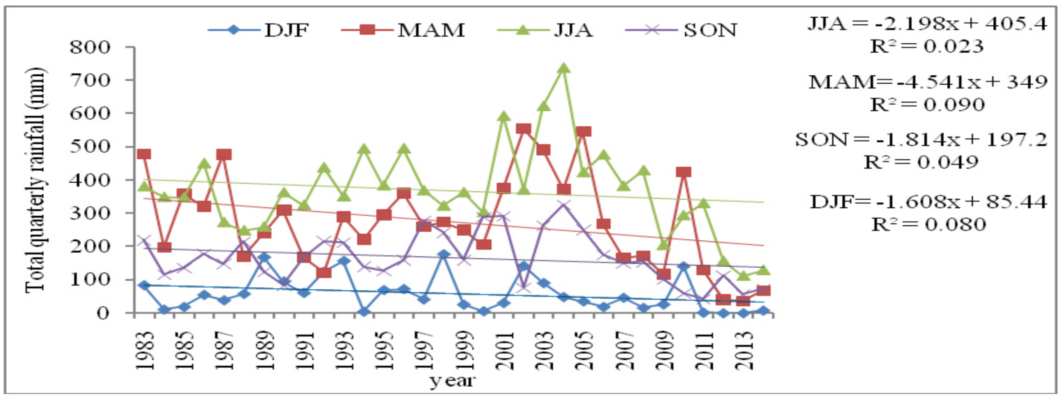


Figure 5: Seasonal variation of rainfall in Arsi Negele district (Where: x is year 1, 2, 3… 32 at which 1 is year 1983 and 32 is year 2014)

Minimum temperature

The variation in minimum temperature in the study area is high. The r^2 values for all four seasons are very small indicating that there is high variation. In the study area, the mean minimum temperature has showed a decrease of 0.014°C and 0.016°C per year for summer and spring seasons respectively. On the other hand, the minimum temperature has showed an increase of 0.07°C and 0.069°C per annum for autumn and winter seasons respectively (fig. 6).

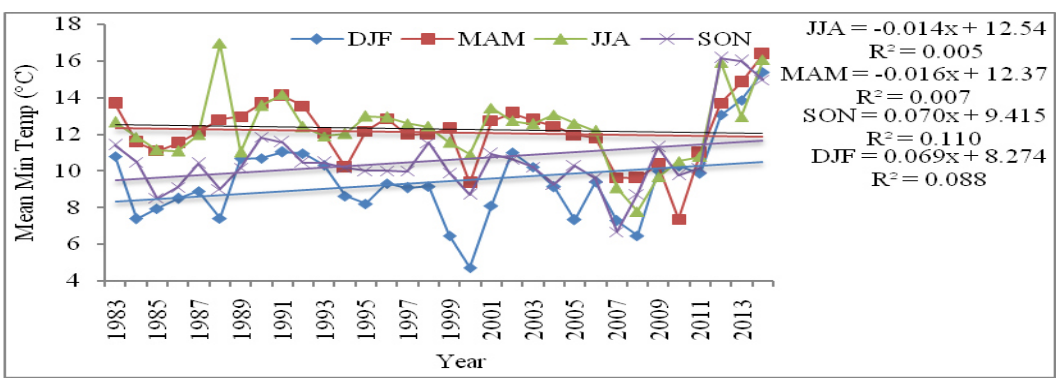


Figure 6: Seasonal variation of minimum temperature from Arsi Negele district (Where: x is year 1, 2, 3… 32 at which 1 is year 1983 and 32 is year 2014)

Maximum temperature

The analysis for the maximum temperature in the study area showed the highest variability for spring season with r^2 = 0.096 followed by autumn (r^2 = 0.187), winter (r^2 = 0.217) and summer (r^2 = 0.317) respectively. The mean maximum temperature of the study area had showed an increment of 0.035°C, 0.049°C, 0.044°C and 0.065°C per year for spring, winter, autumn and summer seasons respectively (fig. 7).

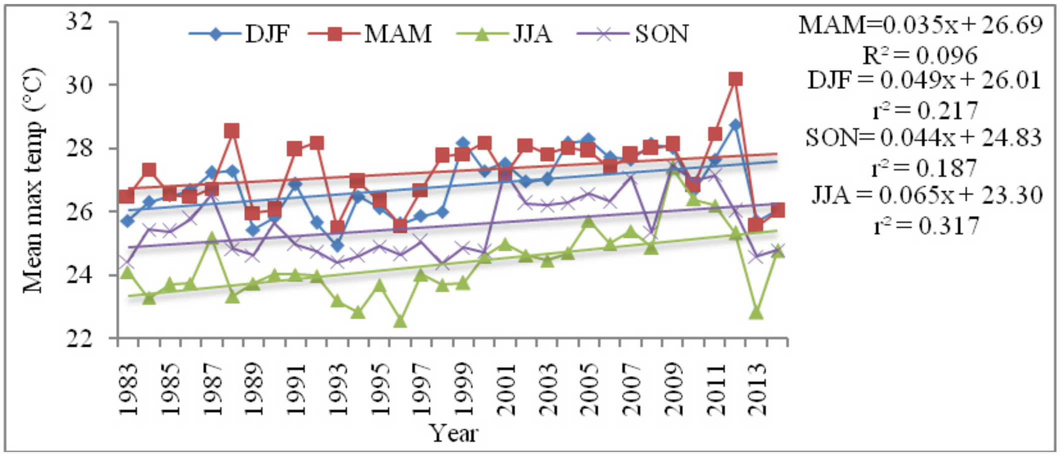


Figure 7: Seasonal variation of maximum temperature from Arsi Negele district (Where: x is year 1, 2, 3… 32 at which 1 is year 1983 and 32 is year 2014)

Perceptions of climate variability

Households and communities perception to climate change and variability in the study area was also assessed using focus group discussions and key informants interviews. In this regard, both sources underlined that there was clearly climate change and variability in their village as compared to thirty years ago. They perceived this change in terms of variation in temperature and rainfall. They characterized the variation in rainfall as declined in amount, discontinuous in distribution and erratic in its onset and ending. Regarding the variation in temperature, it was indicated as it has been increased to the extent they felt it as they couldn't wear clothes which they used to wear before. The respondents explained the variation in climate change with respect to three different periods. These periods were the periods in which three different regimes in Ethiopia existed. The first period was the period called Imperial (pre-1974), the second period was when the Dergue (Military committee) government took power (1974 to 1991) and the third period is the period the incumbent regime/EPRDF (since 1991). In this regard, they indicated that the climate was better during the Imperial than the Dergue and was better during the Dergue than the present, they added. Even in the year 1984, which was called the drought year in Ethiopian drought history, there was slight rain in summer, but nowadays the drought and intensity of heat has become more severe than that, the witnesses supplemented. The key informants and focus group members asserted that the rain season was longer and its distribution was uniform in the past than nowadays.

The responses of group discussion and key informants were similarly reflected in individual household interview (Table1). These farmers' perception of increasing temperature and declining rainfall are similar to the observed trends discussed in the previous sections except that farmers give more focus on the distribution of rainfall rather than the total amount that can be downpour at once. Besides, people in group discussions have described that a small rain for continuous ten days is better for crop growth than a heavy rain for only one or two days.

Table 1: Trends of climate and climate-related variables as perceived by farmers

Climate/related variables	Scales compared to 30 years ago	Percent of respondents who realized the variations			
		Lowland (n=104)	Midland (n=103)	Highland (n=148)	Total (N=355)
Total rainfall	No change	0.00	0.00	1.67	0.63
	Increased	2.00	0.00	4.17	2.19
	Decreased	98.00	100.00	94.17	97.19
Rainfall distribution	No change	0.00	0.00	7.50	2.81
	Uniform	7.00	20.00	24.17	17.50
	Erratic	93.00	80.00	68.33	79.69
Rainfall onset	No change	0.00	0.00	0.83	0.31
	Delayed	97.00	100.00	87.50	94.38
	Early	3.00	0.00	11.67	5.31
Average temperature	No change	0.00	0.00	1.67	0.63
	Increased	95.00	95.00	77.50	88.44
	Decreased	5.00	5.00	20.83	10.94
Frost occurrence	No change	1.00	5.00	12.50	6.56
	Increased	49.00	37.00	31.67	38.75
	Decreased	50.00	58.00	55.83	54.69
Hailstorm frequency	No change	9.00	7.00	25.00	14.38
	Increased	38.00	35.00	18.33	29.69
	Decreased	53.00	58.00	56.67	55.94
Drought frequency	No change	0.00	1.00	11.67	4.69
	Increased	79.00	70.00	61.67	69.69
	Decreased	21.00	29.00	26.67	25.63
Flood frequency	No change	3.00	0.00	8.33	4.06
	Increased	34.00	47.00	61.67	48.44
	Decreased	63.00	53.00	30.00	47.50

Farmers have recognized the variations and changes in climate by cognitive learning, awareness given by different communication tools as well as from indigenous knowledge. For example, about 98.4 % of respondents perceived the existence of climate change and variability by feeling warm due to increased temperature than usual (Table 2).

Table 2: Different means of knowing the existence of climate change and variability by respondents

Means of knowing	Percent of respondents answering yes				*Chi-square* (X^2)
	Lowland (n=104)	Midland (n=103)	Highland (n=148)	Total (N=355)	
Learned from cognition					
Observing changes in tree flowering	87.00	92.00	86.64	88.40	189.113a
Observing changes in wind speed and frequency	89.00	93.00	87.49	89.70	201.613a
Observing fluctuation in total rainfall	93.00	94.00	96.66	94.70	255.613a
Observing erratic and unpredictable rainfall	98.00	99.00	93.33	96.60	277.513a
Observing changes in animal behaviour	96.00	87.00	91.68	91.60	221.113a
Feeling warm due to increased temperature	100.00	100.00	95.84	98.40	300.313a
Observing changes in the timing of rainfall onset	72.00	77.00	70.82	73.10	68.450a
Learned from different communications tools					
Weather forecast and report form TV news	29.00	39.00	61.64	44.40	4.050a
Weather forecast and report form radio news	78.00	75.00	87.52	80.60	120.050a
Extension service provided by public organizations	84.00	97.00	88.33	89.70	201.613a
Extension services by civic organizations	75.00	98.00	81.64	84.70	154.013a
Public meetings	98.00	98.00	95.83	97.20	285.013a
Development committee and/or 1:5 farmers arrangement	95.00	97.00	92.48	94.70	255.613a
Field demonstration on climate impacts	86.00	92.00	86.67	88.10	186.050a
Public education on climate change	78.00	90.00	80.83	82.80	137.813a

a. No cells have expected frequencies less than 5. The minimum expected cell frequency is 178 for the total.

Indigenous knowledge about climate

The role indigenous knowledge with respect to climate variation and change prediction is known to be very important in the area. That is, the communities in the study area, especially elders and local *Aba Geda*- traditional leader of the Oromo community- have accustomed to several indigenous knowledge to predict climatic situations (Table 3). These communities indigenous knowledges (CIK) plays important role, not less than the information from National Meteorology Agency (Woldekiros Dube, 07/12/2015, Key informant, among others), in that farmers could adjust, plan and implement their farming activities accordingly. Key informants dictated that the main growing season in the study district is June to August (summer in Ethiopia). The normal sowing dates for xafii (Orm), *teff* (Amh.), *Eragrostis tef* (Zucc.) is end of July to beginning of August. In the beginning of the 2015 growing season, there were predictions by CIK and NMA in reference to the prevailing El Nino events. On one hand, key informants claim that by observing the size and position of the moon they predicted as the rain will stop in September and gave advice to make adjustment on the sowing dates of *E.tef* to the middle of July. On the other hand, farmers heard through radio that NMA has predicted as the rain will extended up to November and advised farmers to extend the sowing dates of *E.tef* at the end of August. Finally, the rain did stop in September as predicted by CIK while most farmers had sown *E.tef* as suggested by NMA and they lost production due to shortage of rain, key informants said. This shows that lack of integration of CIK and scientific knowledge leads to misconception on farmers' agricultural activities.

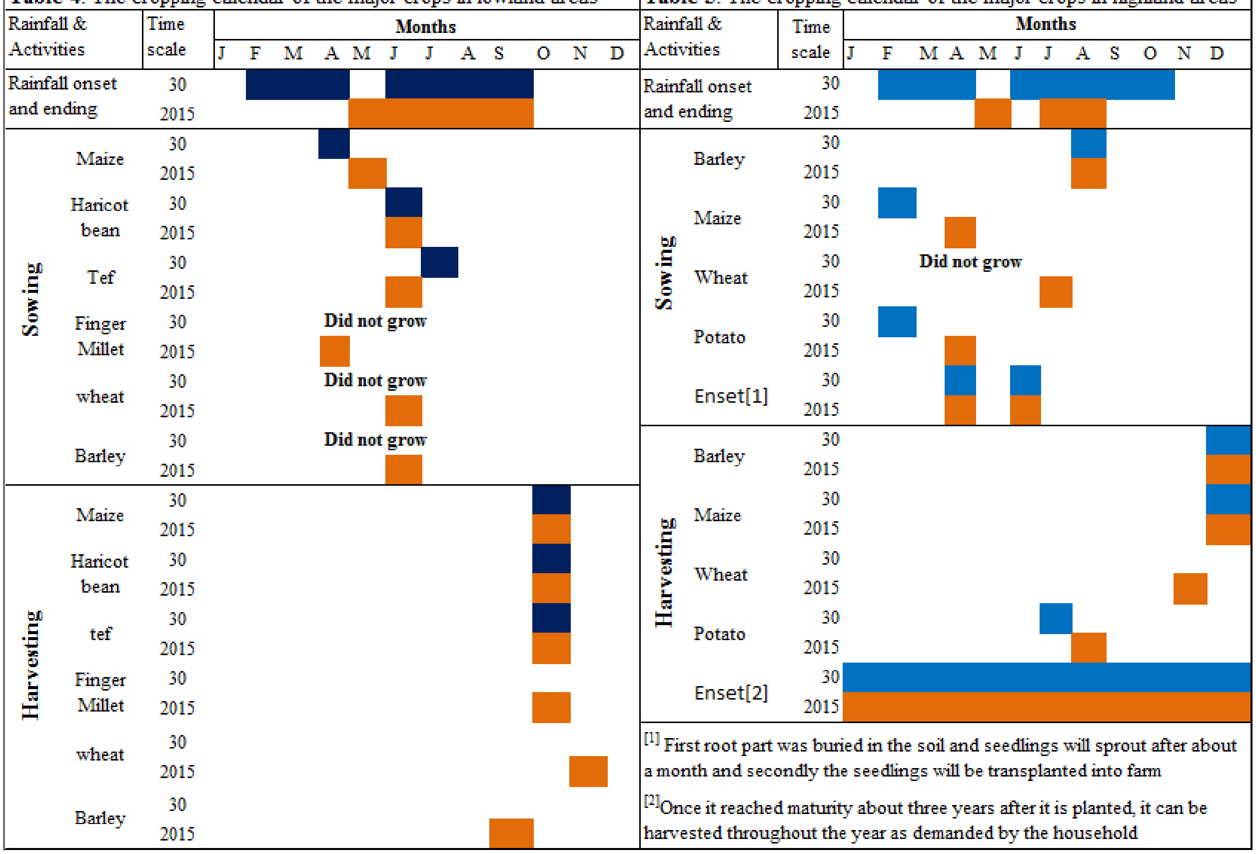
Table 3: Community indigenous knowledge and their local narratives of predicting climate

Bases of CIK	**Local narratives and interpretation**
Size and position of the moon	• When the size of the moon is full and tilted to the left, we believe that there will be good rainfall; • When its size becomes very thin (crescent) and has no tilt in its position, we believe that there will be no rainfall
Length of dry season	• When the number of dry months is five or more in a year, we considered it a drought year • When the number of dry months is four or less in a year, we considered it a good rainy year
Wind direction	• When the wind starts to blow from highland to lowland, we believe that the rain is to come soon in the next few days • When the wind starts to blow from lowland to highland, we believe that there will be no rain in the locality
Cloud speed and direction	• When the cloud moves fastest from west to east in a particular day, we believe as it rains just on that day • When clouds move slower from west to east in a particular day, we believe as it rains the next day • When clouds change direction from normal, we believe as it results in no rain
Timing of rainbow	• When rainbow is observed after rain, we believe as the rain is going to stop • When the rainbow is observed at the period of no rain, we believe as the rain is going to come
Timing of rainfall	• When the rain start to come during sunset, we believe as it is "good summer" with enough rainfall • When the rain start to come during sunrise, we believe as it is "poor summer" with shortage of rainfall
Animal behaviour	• When bulls started to caper from here to there in the field in a dry time, we believe that the rain is going to come soon • Bees will migrate ("godinsa kanissa") to the lowlands (Langano area) when the rain starts to rain in that area and come back to the highlands when it stops • When red colour ants start to roam around people's home and around fences, we consider it as indicator that rain is going to come • When hyenas screams ("warabeesii yoo yusuu") in a slow and continuous ton and roams around village and breaks fences to eat what it gets, we considered as the rain is going to come
Tree flowering	• Most of the trees including acacias, ficus spp., *Croton macrostachyus* (Del.), *Celtis africana* (Burm.) and *Podocarpus falcatus* (Thunb.) have shifted their flowering period at least by one month earlier or delayed. • Most of the above species produce immature seeds even after flowing due to the shortage of rainfall distribution, they said.

The change in cropping calendar is indicated as one of the evidences for climate change and variability in the study area. In the study area, the main stay of livelihood in the study area is mixed agriculture at which crop production takes the lion share. However, crop cultivation is mostly rain fed and highly impacted by rainfall distribution. In the focus group discussions, the farmers explained that the delay on rainfall onset has obliged them to shift their cropping calendar what they were accustomed before 30 years ago (1985) (Tables 4 & 5). It has been understood from farmers' opinions that some crops have shifted their agronomic rages towards the highland and lowland agro-climatic zones. Wheat is the case in point which did not grow in the lowlands and higher highlands before 30 years ago from 2015, while it does at the current times.

Table 4: The cropping calendar of the major crops in lowland areas

Table 5: The cropping calendar of the major crops in highland areas



Perception on causes of climate change and variability

For the causal factors of climate variability, the respondents suggested that the rainfall decline followed the decline in deforestation/forest cover and the decline in forest cover followed the increase in population and agricultural expansion; the temperature has increased due to the shift of warmer (lowland) climate into the highlands; industrial expansion in nearby towns and other areas as we learnt from extension and radio, but do not know the scientific bases; and the other cause is, as we believe, is natural phenomena (Fig. 8).

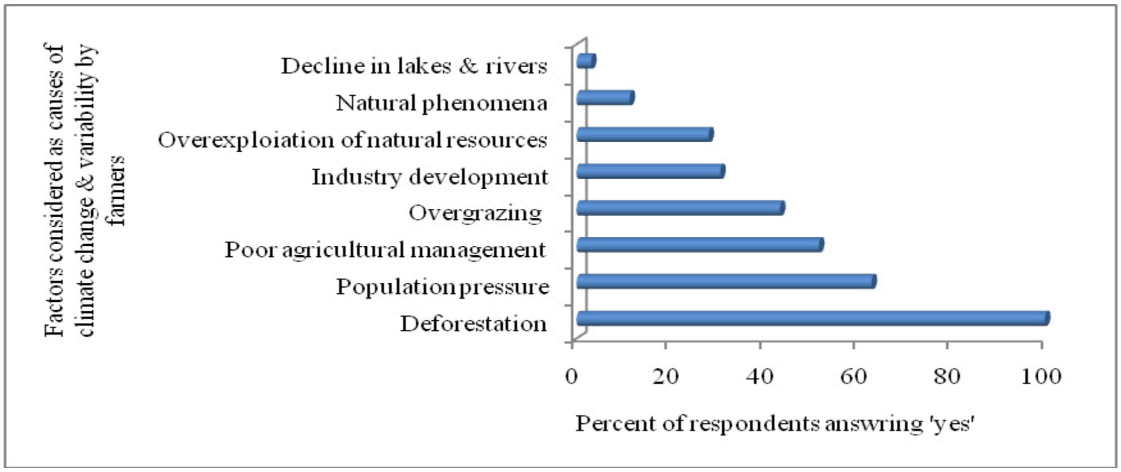


Figure 8: Causes of local climate change and variability as perceived by farmers

Discussion

Observed climate change

Climate change is assessed by using meteorological observations and/ or farmers perceptions. The analysis of climate variables from the reconstructed grid cells and actual measurements for the study district has showed that there is high variability of temperature and rainfall both spatially and temporally. This variability has been proved for other parts of Ethiopia and Africa (McSweeney *et al*. 2008, Adem and Bewket 2011, Okonya *et al*. 2013, Amekudzi *et al*. 2015, Asante and Amuakwa-Mensah 2015, Tierney *et al*. 2015, McPhaden 2015, Muluneh *et al*. 2016). The rainfall variability in Ethiopia is generally correlated with the movement of the Inter-Tropical Convergence Zone (ITCZ) in the long rain season and with the warming of the Indian Ocean in the short rain season (Simelton *et al*. 2011). For the study area in general, the temperature has showed an increasing trend while the rainfall a declining trend. Observed climate parameters from stations which are in the adjacent districts (lowland) to the study district showed that the rainfall varies between [-1.46, 2.5], [-2.36, 3.0] and [-1.50, 2.0] standard deviations from the mean for Bulbula (7.72°N, 38.65°E, 1606 m a.s.l.), Ziway (7.933°N, 38.7°E,1640 m a.s.l.) and Adami Tulu (7.856°N, 38.703°E, 1653 m a.s.l.) stations respectively (fig. 9). Additional climate data from Degaga station (7.43°N, 38.84°E, 2067 m a.s.l.) which reside in the study district (highland) also showed similar trend [-1.83, 2.15].

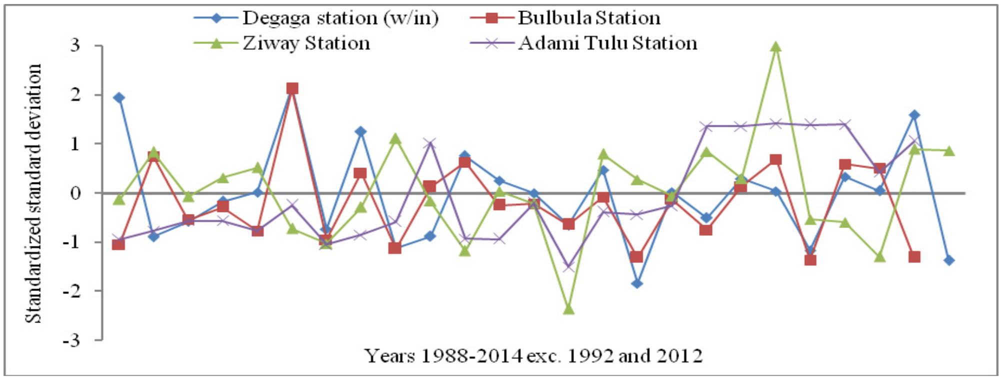


Figure 9: Standardized rainfall anomalies at different stations within and nearby Arsi Negele district

Perceived climate change

The analysis of the household survey, key informant interviews and focus group discussions shows the reality of climate change and variability in their locality. Considering what had been the existed situations before 30 years ago as normal, an increase of temperature, an increase of drought frequency, a decrease of total rainfall, erratic nature of its distribution and the tardiness of its onset had been perceived by 88%, 70%, 97%, 80% and 94% of the respondents, respectively. This was in line with the observed climate trend. The perceived delayed onset of rainfall is supported by meteorological evidence of declining rainfall, erratic rainfall distribution by seasonal variability, rainfall termination by declining monthly rainfall and shorter rainfall duration by increase in number of dry days (Simelton *et al.* 2011). Deforestation as a casual factor of climate change and variability had been perceived by 99.7% of the respondents. This anthropogenic activity had been also confirmed by scientific studies as it emits CO_2 and is the main driver of climate change and variability (Houghton *et al.* 2012, FAO 2014, IPCC 2014, Stocker and Joos 2015). Studies in different parts of the world underscored that indigenous knowledge, including climate predictions, has been used by people to implement their day to day agricultural activities (Egeru 2012, Moyo *et al.* 2012, Varadan and Kumar 2014, Ndambiri *et al.* 2014). Farmers also use an adjustment to their agricultural calendar as a response to climate variability (Yegbemey *et al.* 2014). Simelton *et al.* (2011) stated that this knowledge of farmers' perceptions of how climate is changing is crucial in anticipating the effects of climate change, as only farmers who perceive a problem will adapt to it indicating that assessing the impact of erratic rainfall, for example, is more important for farmers' decision and outcomes than crop models with meteorological data. In this study it was understood that indigenous knowledge and perception of climate change and variability by farmers have enabled them to devise local coping strategies that are oriented towards survival such as crop diversification and firewood sale to escape from immediate climate change impacts. These local level coping strategies are the basis for adaptation to climate change which again enables them to devise adaptation strategies that are oriented towards longer term livelihoods security (Dazé *et al.* 2009) such as water harvesting, enhancement in irrigation, mulching, changing sowing date and time of soil cultivation, soil fertility management, minimize post-harvest losses, and so on.

Strengths and limitations of observed, satellite and perceived climate change and variability

Observed climate change and variability analysis has its strength by being used as a basis for satellite climate data, more focus on meteorological drought (based on below average annual rainfall) and has got standard and is more reliable. It has limitations of incomplete data and less focus on agronomic drought (due to increase in temperature and evaporation) (Simelton *et al*. 2011). Climate change and variability analysis from satellite data provide information on temperature and precipitation even over remote parts where weather stations are not available. This is very useful to fill gaps in the time series at which weather stations suffered from. In this study, the correlations between satellite data and measured data were highly significant for rainfall ($p < 0.001$, $r^2 = 0.91$), minimum temperature ($p < 0.001$, $r^2 = 0.99$) and maximum temperature ($p < 0.001$, $r^2 = 0.95$). Despite its usefulness, satellite climate data has shortcomings: (i) time period of observation is very short, (ii) accuracy at higher temporal and spatial resolutions might be poor, and (iii) it lacks homogeneity in time series (Dinku *et al*. 2013). In parallel, downscaled climate data analysis uses complex mathematical rules and helps to predict future trends even if it has limited use at the community level, liable to systematic bias and lacks contextual analyses which recognize that perception from past events can influence responses to future events (Macchi *et al*. 2014)). Perceived climate change and variability analysis is fundamental for gaining a better understanding of the impact of climate change, supplements scientific climate analysis and help improve the coarse spatial resolution of climate forecasts by using simple practical approximations. However, it has its own limitations in that farmers are unable to remember long time climate events, inconsistence in use of terms and failure to differentiate climate and weather patterns, has no standard and might be unreliable and focused on agronomic drought which is based on the livelihood impacts the climate has on individual farmers. For instance, even during a year of above average annual rainfall according to observed data, farmers may consider it as a year of agronomic drought ("bara gogiinsa") if their crop failed for some other reasons. This failure might be due to anthropogenic drought that has been brought about by management or policy or institutional failures that reduce or increase the farming system's sensitivity to drought.

Conclusion

It is apparent that climate change is a reality at the global and National levels. This study proved that climate change and variability is also a reality at the very local level. The mean maximum and minimum temperature from Arsi Negele Station (7.35°N, 38.66°E, 1913 m a.s.l.) for the period 1983 to 2014 showed an increasing trend with annual increase of 0.047°C and 0.028°C respectively. The total rainfall has declined by 10.16 mm per annum. The increase in temperature and decline in total annual rainfall from observed data and reconstructed grid cells had been validated with farmers' perception. Perception of long term changes in climate by farmers is a fundamental pre-indicator in undertaking adaptation process to calm down the impacts of climate change and variability on farmers' livelihoods and plays an important role in shaping their behaviour. The current situation of climate in the study area, as compared to 30 years ago, the total rainfall perceived to be decreased, the rainfall distribution perceived to be erratic, rainfall onset perceived to be delayed and ended earlier, average temperature perceived to be increased, frost and hailstorm frequencies perceived to be decreased, drought frequency perceived to be increased, and flood frequency perceived to be more or less balanced between increase and decrease. Perceptions of risk and cognitive process of primary decision makers are important for the adoption of different adaptation decisions such as adjusting cropping calendar with the shift in the rainfall. This study has come up with that communities have several indigenous knowledges of predicting climatic situations which play important roles in climate risk management. Therefore, it calls for any planned interventions by stakeholders to incorporate with the perception and indigenous knowledge of people to come up with concrete solution for climate change and variability impacts on human livelihoods.

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