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African Journal of Agricultural Research

Full Length Research Paper

Analysis of farmers' perceived and observed climate variability and change in Didessa sub-basin, Blue Nile River, Ethiopia

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Farmers' local knowledge of how the climate is changing is crucial in anticipating the effects of climate change, as only farmers who know/perceive the impacts will develop coping and adaption measures. The study is designed to assess farmers' perception and understanding in climate variability and change and to establish the observed climate change parameters with farmer's perception and climate anomalies. Household survey, semi-structured interviews, focus group discussions and 30 years of climate data was employed. Non-parametric test using Mann-Kendall climate trend analysis and Sen's slope estimator was employed to test the variability of climate using MAKESENSE software. The findings revealed that farmers perceived climate change in terms of increase in temperature, decrease in rainfall, increase in drought conditions and change in seasonal rainfalls. Analysis of the observed climate data for the sub-basin showed that average annual temperature trends has exhibited a positive slope and increased by 1.4°C and above the national average (1.3°C) over the study periods (1986-2014) at mean temperature rise with an average rate of 0.181°C in the last decade. The observed climate variability was confirmed by farmer's perception. The Mann-Kendall rainfall trend analysis showed that annual and monthly precipitation variability in terms of intensity and distributions declined and vary across agro ecological zones. The analysis indicated that annual rainfall variability in Dega agro ecological zone (CV>63%) and in Kola agro ecological zone (CV>104%) was extremely variable. However, in terms of amount and distributions of precipitation, farmers understanding of precipitation in relation to observed precipitation data showed disparities. This disparity was due to understanding of agronomic drought (farmer's view) and metrological drought (scientific view). Therefore, based on the findings, scientist and policymakers has to integrate the metrological information into farmers' perception and knowledge of climate variability for future climate adaptations measure.

Key words: Climate variability, farmers' perception, climatological normal, local knowledge.

INTRODUCTION

Global climate variability and change threatens the life and livelihoods of people in the world (IPCC, 2014). Climate variability refers to variations in the mean state of the climate on both temporal and spatial scales beyond

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the individual weather events (IPCC, 2014). On the other hand, climate change is a change in climate over periods of time, which credited directly or indirectly to human activity and alters the composition of the global atmosphere (IPCC, 2014).

The changes in climate variability worsens the already existing vulnerabilities of the poorest peoples who depend on climate variables and sensitive sectors such as agriculture and natural resources for survival (Mubaya et al., 2012) and live with a range of livelihood risks (Gandure et al., 2013; IPCC, 2014). Studies showed that unless adequate measures are taken to adapt to the adverse effect of climate change, a decline of 2 to 7% of GDP by 2100 in some parts of sub-Sahara Africa; 2- 4% in West and Central Africa and 0.4 to 1.3% in Northern and Southern Africa is expected (IPCC, 2014).

There is considerable evidence that the climate in Ethiopia is changing and projections suggest that the rate of changes will increase in the future. Mean annual temperature has risen by 1.3°C with an average rate of 0.28°C per decade (CRGE, 2011). Climate models suggest that Ethiopia will see further warming in all seasons between 0.7 and 2.3°C by the 2020's and between 1.4 and 2.9°C by the 2050s (Conway and Schipper, 2010). As a result, under moderate global warming, cereal production in Ethiopia is expected to decline by 10 to 12% (MOA, 2011).

The changes in climate and variability demand coping and adaptation mechanisms largely depending on farmer's perception and knowledge's of climate change, variability, along with its impacts on their livelihoods. About 95% of sub Saharan African agriculture was impacted by climate change and the consequence are significant particularly for those who directly depend on unreliable weather patterns for livelihood. Farm households that perceived climate variability and change can adapt to the change and hence less vulnerable compared to farmers who did not perceive it (UNFCCC, 2007; Tadross et al., 2009).

Perception of the long-term changes in climate by indigenous local people plays an important role in shaping their behavior toward climate variability and change (Abid et al., 2014). Perceptions of risk and cognitive process of primary decision makers are important for the employment of different adaptation options (Nyanga et al., 2011; Simelton et al., 2011; Amdu et al., 2013; Berman et al., 2014).

There are alternative ways to assess how climate is changing. These are the quantitative mode (relay on observed climate data) and the qualitative approach (participatory). The important difference between the qualitative (participatory) and top-down modeling (quantitative) approaches is that contextual analyses recognizes the experiences from and perceptions of past events by local people in influencing responses to future events. Metrological observation of changes in climatic patterns with perception of farming community about the

climate variability and change as well as its impacts on agricultural activities are paramount to the importance of adaptation strategies/polices as "perception is a pre requisite for adaptation" (Madisson, 2007). Despite this, change in rainfall rarely produces the type of significant trends that climate data does (Boko et al., 2007).

Even though climate change may bring conditions beyond previous experience, local knowledge and perceptions remain the foundation for any local response. In this research contexts, indigenous, local, community or traditional knowledge were used synonymously. "Local perceptions" refers to the way local people identify and interpret observations and concepts (Byg and Salick, 2009; Vignola et al., 2010). Hence, rural societies have in-depth knowledge of local climate variability as part of their traditional ecological knowledge (TEK), that is, their knowledge acquired and transferred through generations (Berkes et al., 2000). However, the capacity to cope with climate change are often constrained by socio economic, policy/institutional integration which can further exacerbate existing problems and reduce adaptation options (Stringer et al., 2010).

Previous studies has dealt with perceptions of seasonality (Bryan et al., 2009), risks threats related to climate variability (Thomas et al., 2007; Adger et al., 2009; McCarthy, 2011; Deressa et al., 2009; Fisher et al., 2010) and local knowledge in predicting the climate variability and adaptation (Mertez et al., 2009) as well as agro ecological zones in influencing farmers perception of climate variability and change (Simane et al., 2012; Joshua et al., 2013).

Nevertheless, limited attention has been given to the knowledge and practice that emanated from the perception of smallholder farmers (Maddison, 2007; Deressa et al., 2011; Legesse et al., 2013). Assessments of meteorological data or refute is given in previous studies (Deressa et al., 2009; Fisher et al., 2010; Simane et al., 2012; Maddison, 2007). Besides, local perceptions and the resulting indigenous knowledge are location and site specific.

Consequently, this study was specifically designed to assess whether there is a common understanding among stakeholders of *what* aspect of climate (exposure) is changing, or *how* it is changing, along with its perceived impacts in the Didessa sub-basin in combination with meteorological evidence for over a 30-year period (1986 to 2015) from close proximity stations. Hence, local perspectives combined with scientific knowledge of climate data to generate useful policy-relevant information for future adaptation strategy.

Descriptions of the study area

The study was conducted in the Didessa sub-basin (DSB) of the Blue Nile Basin where agriculture is the major economic activity, among   which coffee production, crop

cultivation and livestock production are the dominant sectors, undertaken by smallholder farmers. It is the largest tributary of the Blue Nile Basin in terms of volume of water contributing roughly a quarter of the total flow as measured at the Sudan border (BCEOM, 1998).

Topographically, the sub-basin has an area of 27,000 km^2. It is located at 36° 02' and 36° 46' East longitude and between 7° 43' and 8° 13' North latitude. The altitude in the sub-basin ranges approximately between 630 to 3130 m above sea level excluding mountains of height greater than 3500 m above sea level (Bizuneh, 2011). The sub-basin is divided into three agro-ecological zones, namely Dega[1] (7% of the sub-basin), Woyna-dega[2] (45.8% of the sub-basin) and Kola[3] (47% of sub-basin) (USGS, 2016). The southern highland parts of the basin are higher in altitude greater than 127 m above sea level. The lowlands have lower altitude less than 1100 m above sea level in the Northern parts of the sub-basin. Mean annual rainfall is 1675 mm with only one summer rainy season. The mean max-min temperature is 29 and 11.47°C respectively (Figure 1) (NMA, 2015).

MATERIALS AND METHODS

The study primarily relies on climate data and cross sectional household surveys. The primary data were collected from household surveys, semi-structured interviews, focus group discussions and field observations. Survey was conducted in three agro ecological zones (Dega, Woyina-Dega and Kola) of Didessa sub-basin. The selection and classification of the agro-ecology was based on three specific criteria: (1) climate variables, temperature and rainfall (2) soil and (3) farming system. A total of 450 household heads in three agro ecologies (100, 200 and 150 from Dega, Woyna-Dega and Kola respectively) in 18 villages in four districts were asked about local perception of change in climate variability and its impact on people and livelihoods. Systematic random sampling (SRS) was the technique used to get the final respondents.

In addition, six (6) focus group discussions, 2 from each agro ecology and key informant interviews were also used. Moreover, secondary source of observational climate data of 30 years obtained from National Meteorological agency (NMA).

World Metrological Organization (1992) recommends a minimum of 30-year climatological normal data series for a study to detect trends in hydro-climatic time series. As a result, rainfall and temporal records of four stations (Agaro, Arjo, Anger and Kemashi) representing the three agro ecologies were assembled from National Meteorological Agency of Ethiopia (NMA) (Table 1). The climate data was broken and there are missing observations. However, the missing values were filled by averaging the nearby records and proxy station records considering the maximum flexible thresholds of 10% missing values adopted by Ngongondo et al. (2011). This categorization helps to have a better comparative analysis at agro ecological levels and highlights how climate characteristics were spatially distributed in the study area.

The research employed qualitative and quantitative data analysis methods. Qualitative information from farmers in each agro ecological zone (AEZ) along with their views on climate variables were organized, coded, themed and processed qualitatively whereas quantitative climate data was analyzed using a non-parametric test of climate data series called Mann-Kendall trend analysis and Sen's slope estimators with the Macro software MAKESENS (Olofintoye and Sule, 2010; Kendall, 1975; Mann, 1945; Hirch et al., 1991; Loftis et al., 1991).

In climate study, non-parametric test called Mann-Kendall trend analysis and Sen's slope estimator was employed to study the spatial and temporal trends climatic series. These are because of the skewed nature of the marginal distribution of climate data, prevalence of non-normality with too large sample size (Hirsch et al. 1991; Loftis et al. 1991; Kendall, 1975) as well as difficulty in identifying the normality distribution of the data beforehand (Hirsch et al. 1991). Mann-Kendall test is relatively robust against missing value and not greatly affected by gross data error or outliers along with truncated observation (Sonali and Nagesh, 2013; Berryman et al., 1988). The model was used when more than one station was tested in a single study (Hirch et al., 1991). The model has two phases in climate analysis. First, Mann-Kendall trend tests for the presence of monotonic increase or decrease in climate data. Second whereas Sen's slopes estimator tests for the magnitudes of the trends. Correlation coefficient of the meteorological variables was computed to determine the better strength and understanding of the linear relationship between variables (Hirsch et al., 1991).

The Man-Kendall test assumed that a value can always be declared less than, greater than, or equal to another value that are independent; and that the distribution of data remains constant in either the original or transformed units (Hirsch et al., 1991). The null hypothesis in the Mann-Kendall test is that the data are independent and randomly ordered. In this study, let for instance, X1, X2, X3…Xn represents n data points where Xj represent the data point at time series j. Thereafter, the Mann-Kendall test was used to compute the difference between the later measured value and all early measured values $(Xj - Xi)$ where $j>i$, and test statistics S is calculated using the formula

$$S = \sum_{i=1}^{n-1} \sum_{i=1j-1+1}^{n} sign(Xj - Xi)$$

(1)

$$sign\,(Xj - Xi) = [+1, \text{if } (xj\text{-}xi) > 0|\ ][0, \text{if } (xj\text{-}xi) = 0|\ ]$$

(2)

Where, S is Mann-Kendell test statistics, Xi and Xj are climate data values of year i and j (j>i), and 'n' is the length of time (Motiee and Mcbeen, 2009; Abrha and Simhadri, 2015). A positive/negative value of 'S' indicates an upward/downward trend (Drapela and Drapelova, 2011). A large positive number of 'S' reveals that the later-measured values tend to be larger than earlier values and an upwards trend is indicated. When S is a large negative number, later values tend to be smaller than earlier values and a downward trend was indicated. When the absolute value of S is small, no trend was shown.

Kendall (1975) assumes that for a data series n ≥ 10, the statistic S is approximately normally distributed with the mean and variance and then computed (Yenigun et al., 2008) as follows: E(s) = 0 The variance (s^2) for S-statistics, in a situation where there may be ties (same values) in the x value, is given by:

$$Var(s) = \frac{n(n-1)(2n+1) - \sum_{i=1}^{m} ti(ti-1)(2ti+5)}{18}$$

(3)

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[1] Dega is an agro ecological classification characterized by tepid to cool climatic zone

[2] Woyina-dega agro ecological classification characterized by mid highlands

[3] Kola is an agro ecological classification characterized by hot to warm moist lowland

Agroecological Based Classification of Didessa Sub Basin of Blue Nile River, Ethiopia
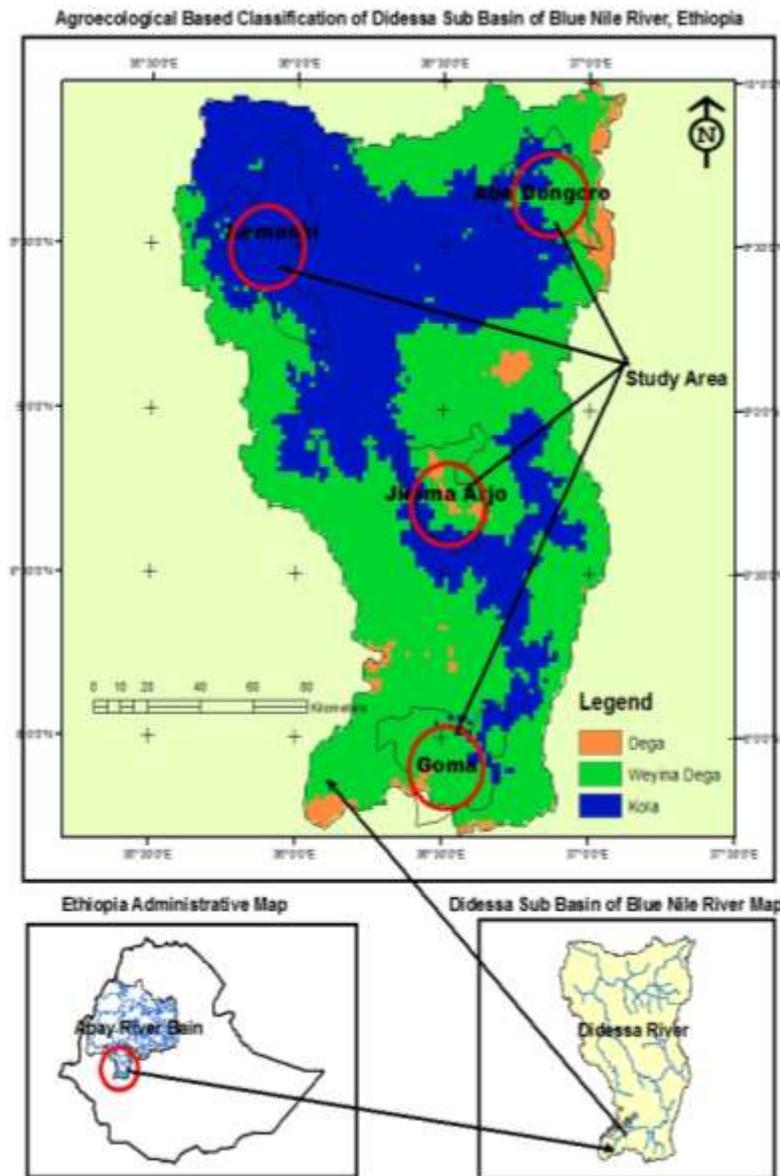
Figure 1. Location of the study area, boundary, agro-ecological classification.
Source: USGS, 2016.

Where the summation term in the numerator is used only if the data series contains tied values, m is the number of tied groups, and t_i is the number of data points in the tied group. The standard test Z_s statistic is calculated as follows:

$$\frac{S-1}{\sqrt{var(S)}} \text{ if s>0} \quad 0 \text{ if s=0} \tag{4}$$

$$\frac{S+1}{\sqrt{var(S)}} \text{ if s<0}$$

Z score follows a normal distribution. The presence of a statistically significant trend was evaluated using the Mann-K test. In a two-sided test for trend, the null hypothesis (H_0) should be accepted

if Mann-Kendall is at a choice of α=0.05 (95%) level of significance and has a two-sided alternative. For instance, for 5% significance level, value of Z1-a/2 is equal to -1.96 to 1.96 (from the standard normal table). The trend was said to be decreasing if Z is negative and the absolute value is greater than the level of significance while it is increasing if Z is positive and greater than the level of significance. If the absolute value of Z is less than the level of significance, there is no trend (Refat and Uddin, 2013, Abrha and Simhadri, 2015). An EXCEL template MAKESENS tested the Z score significance level at α: 0.001, 0.01, 0.05 and 0.1 (Refat and Uddin, 2013). However, when n is 9 or less, the absolute value of S is compared directly to the theoretical distribution of S derived by Mann-Kendall (Gilbert, 1987).

Many climate data exhibit a marked right skeweness partly due to fluctuation and deviation from a normal distribution and do not follow a normal distribution (Refat and Uddin, 2013). Consequently,

Table 1. Selected metrological station and their characteristics in the selected agro ecologies.

Climate station	Station name			
	Jimma Arjo	Gomma	Anger	Kemashi
Field work carried	**April - May 2015**			
FGD,HH interviews	2Focus groups (n=12) HHinterviews (n=100)	2Focus groups (n=12) HH interviews (n=200)	2Focus groups (n=12) HH interviews (n=150)	
Altitude (m)	2300-3200 m	1500-2300 m	500-1500 m	
Farming system	Wheat, Neug, Pulses Barley (2 Crops/Year in the high lands of the basin, Livestock Sheep, Cattle, Goats, horses, Bees, Poultry Cattle,shoats, chicken. Honey	Tef, Maize, Enset Neug, Barley Maize, Sorghum, Tef, Enset, (Rare) Wheat, Finger millet, Barley, Coffee, chat. Livestock: Cattle, goats, sheep, horses, donkeys, bees, poultry Cattle, goats, mules	maize, sorghum, finger millet, sesame, groundnuts and mangoes Taro, Sugar, Coffee, Orange Sorghum, Teff (Rare), Neug, Finger, Millet, Groundnuts, sesame Livestock: Cattle, goats, donkeys, bees, poultry	
Growing season	**June/July to October (*kiremt*)**			
Years of Obsn.	**1986-2015**			
Latitude	8° 33' -8° 55N	7° 40-8° 04 N	9°25'&10° 05'N	9°30'N 11°39'N
Longitude	36°22'-36° 44'E	36° 17'-36° 46' E	36° 85 -37° 22'E	34°20'E 36°30'E
Annual Rainfall	1850-2750mm	1500-1850mm	900-1500mm	
agro ecology	Dega	Woyina-Dega	kola	

Source: Authors Own Construction, 2015.

Theil-Sen slope (Sen, 1968) also known as "Kendall's slope" or "nonparametric linear regression slope" estimator was used in this study due to its relative insensitivity to extreme values and better performance even for normally distributed data (Karpouzos et al., 2010).

The slope was estimated following the procedure of Sen (1968). This means that linear model f (t) can be described as if a

$$f(t) = Qt + B)$$ (5)

Where Q is the slope, B is a constant and t is time. To derive an estimate of the slope of Q, the slopes of all data pairs was calculated using the equation

$$\frac{Xj-Xi}{j-i}, \text{ i= 1, 2, 3.......N}\quad j>I$$ (6)

If there are n values X_j in the time series there will be as many as $N = \frac{n(n-1)}{2}$) slope estimates Q_l. To obtain estimates of B in the equation, the n values of differences $Xi - Qti$ are calculated. The median of these values gives an estimate of B. The estimates for the constant B of lines of the 99% and 95% confidence intervals were calculated by a similar procedure. Data was processed using an EXCEL macro names MAKESENS created by Salmi et al. (2002) for detecting and estimating trends.

RESULTS AND DISCUSSION

Local perception and observed climate variability

Agro ecology based classifications were strongly

influenced by prevailing climate conditions, which is in many ways a proxy for soil type or slope as well as farming systems. Precipitation, temperature and altitude are also the most influential variables (Simane et al., 2013) in climate study. Consequently, the study area was agro-climatically characterized by tepid to cool (Dega), sub humid and tropical mid highlands (Woyna-Dega), and hot to warm moist lowland (Kola). These differences in classification lead to differences in socio-economic development, which actually vary in local farmer's perceptions to climate variables and adaptation strategies.

Local perceptions about temperature and precipitation changes

From the survey data within the Didessa sub-basin, a farmer perception on climate change is shown in Table 2. Out of the respondents interviewed on perception of long-term changes in temperature in the agro-ecologies, most of the farmers (82% of Dega, 92% of Woyina-Dega and 83.33% of Kola) perceived that temperatures have been increasing. It was only 18, 5 and 12% of Dega, Woyina-Dega and Kola farmers respectively that noticed a decrease in temperature while 3% of farmers in Woyina-Dega and 4.67% of Kola noticed that temperature had stayed the same throughout the years.

As indicated in Table 2, farmers' perceptions regarding temperature change varied across agro-ecologies due to variation in altitude, socio economic, ethnic-cultural

Table 2. Farmers perception of towards change in temperature.

Perceived change in temperature	HL (N=100)	ML (N=200)	LL (N=150)
Increased	82	92	83.33
Decreased	18	5	12
No change	0	3	4.67

*All values in the table presented in percent (%) in a given agro-ecology).
Source: Survey Result, 2015

Table 3. Climatic zones and their characteristics in the study area.

AEZ	Altitude	Area (%)	Properties	AMRF (mm)	Rainfall (mm)	MaxTemp (°C)	MinTemp (°C)
Dega	2300-3200	7	Mean	163.06	1956.69	21.41	11.47
			Std Dev		69.59	2.03	0.52
			CV (%)		63	9	5
Woyina-Dega	1500-2300	45.8	Mean	130.49	1565.88	28.35	12.12
			Std Dev		56.87	1.48	0.89
			CV (%)		61.4	5	7
Kola	500-1,500	47.2	Mean	125.25	1502.94	29.6	16.07
			Std Dev		64.8	2.87	1.13
			CV (%)		104	10	7
Didessa	500-3200	100	Mean	139.59	1675.17	26.45	13.22

Source: Authors Calculation from NMA, 2015

setting, farming system, and soil characteristics. Accordingly, farmers living in Woyina-Dega had perceived increasing temperatures trend as compared to the farmers in the Kola areas (Table 2). These variations in perception lead to differences in production philosophy, farming systems and adaptation strategies toward climate changes. Evidences showed that the variations in perceptions of climate change leads to difference in production systems, overall socio-economic profile, adaptation measures and interventions towards building adaptive capacity to climate change (Simane et al., 2013; Gutu et al., 2012; Maddison, 2007).

Temperature trends in DSB (1986-2015)

To verify the farmers' perception of long-term change in temperatures, climate data was statistically analyzed to depict its trend over the decades. The results indicated that the annual temperature for the basin has shown increasing trends for the last three decades (1986 to 2015). The mean annual temperature over the study period was 19.84°C with average maximum and minimum temperature of the basin measured at 26.45 and 13.22°C respectively (Table 3 and Figure 2). The lowest and the highest of the mean annual temperatures within the periods were 11.47 and 29.6°C in the Dega

and Kola agroecology respectively. This result was similar to Yilma and Awlachew (2009) where annual mean maximum–minimum temperatures in the Blue Nile Basin varies between 20 - 33°C and 6.5 - 19°C, respectively.

The study projected the average annual temperature of the study area using linear trend (y = 0.009x + 19.68) and showed that there was clear rising trends of temperatures during the past three decades (Figure 2). The standard deviation of annual mean maximum temperature is 2.03°C in Dega, 1.48°C in Woyina-Dega and 2.87°C in Kola whereas the standard deviation of mean minimum temperature of the study period is 0.52, 0.89 and 1.13°C in Dega, Woyina-Dega and Kola AEZs respectively. High temperatures were exhibited in the Kola agro ecology with maximum of 35°C. The average annual temperature trend line (minimum, maximum and mean) has exhibited a positive slope indicating that the average temperature has increased by 1.40°C in the past 30 years (Figure 2a) which is greater than the national average annual level temperature (1.3°C) (MOA, 2011).

Temperature rises with an average rate of 0.181°C in the last decade showing that the basin was warming slower and/or temperature had risen in 10 years compared to the national level increase (0.23 to 0.25°C per decade) over the past 55 years (NMA, 2007; Gebrehiwot and Anne, 2013). Similar study by Asamirew

(a) Average Maximum and Minimum temperature in Didessa sub-basin
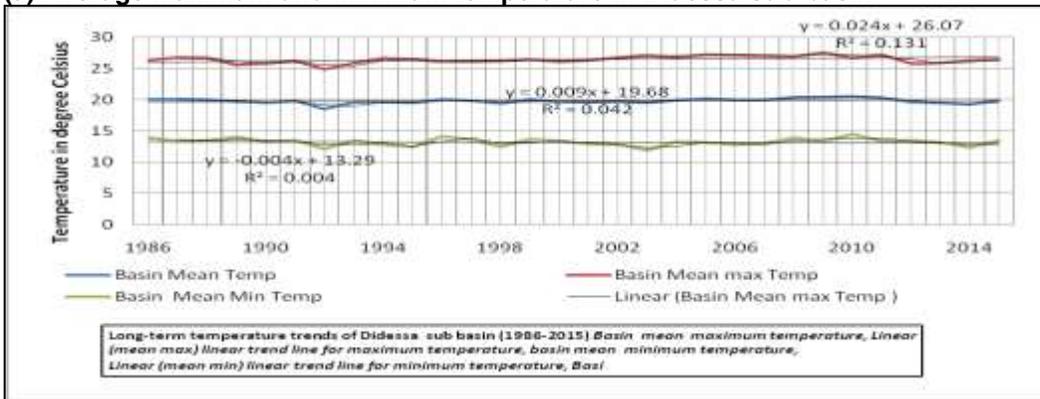
(b) Mean annual temperature trend in Didessa sub-basin
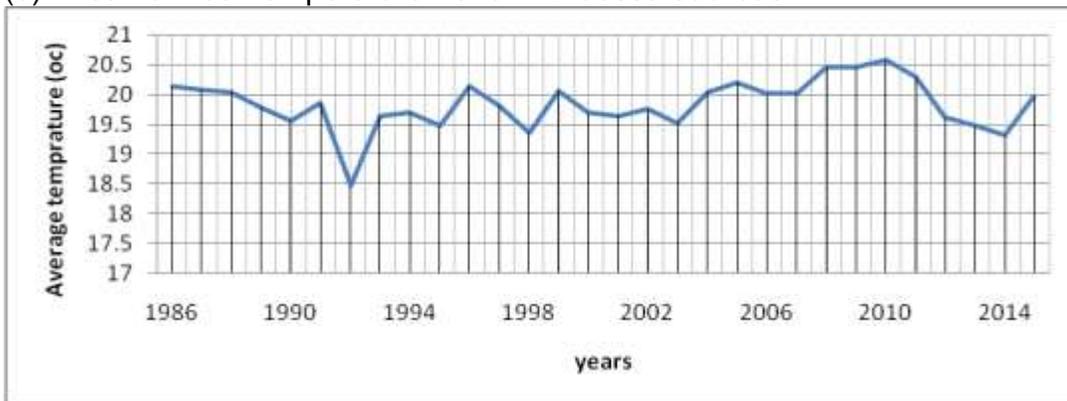
(c) Average temperature anomaly in Didessa sub-basin
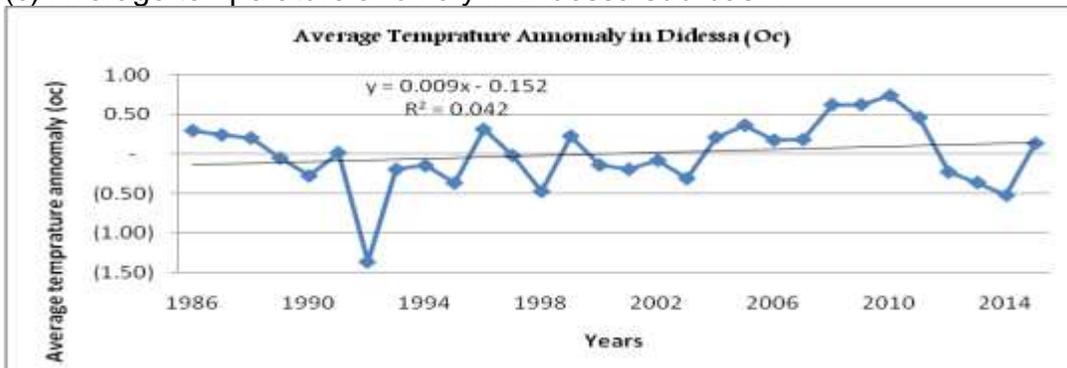
(d) Average maximum Temperature anomaly in Didessa sub-basin
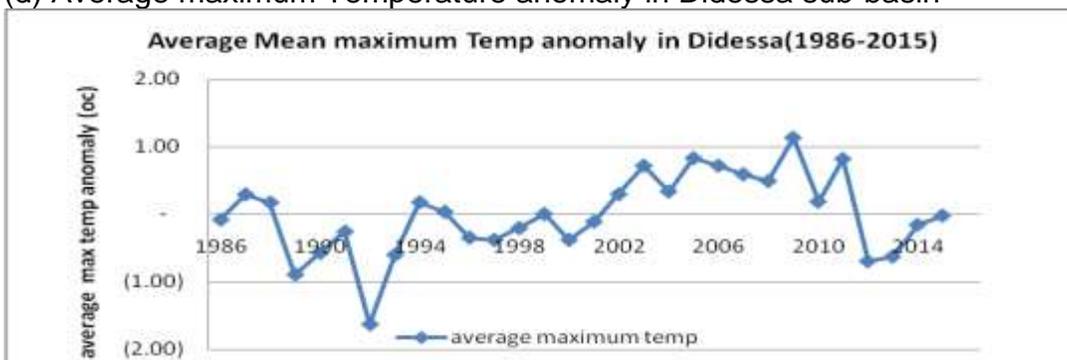
(e) Average minimum Temperature anomaly in Dudes' sub-basin

Figure 2. Trends in temperature in the DSB (1986-2015). Source Based on NMA Climate Data, 2015.

Table 4. Mann-Kendall Trend Analysis and Sen's Slope estimator across Agroecology (1986-2016).

Month	Dega–Max		Dega	Min	Woyina-dega–Max		Woyina-dega Min		Kola – Max		kola Min	
	Test Z	Sen's slope	Test Z	Sen's slope	Test Z	Sen's slope	Test Z	Sen's slope	Test Z	Sen's slope	Test Z	Sen's slope
Jan	3.07	0.048**	1.07	0.003	-1.16	-0.029	1.11	0.02	1.29	0.039	-1.28	-0.021
Feb	3.61	0.090***	0.13	0.000	0.00	0.00	0.2	0.00	4.34	0.081***	-1.54	-0.052
Mar	3.82	0.045***	-0.58	0.000	-0.34	-0.011	1.29	0.048	3.54	0.080***	0.59	0.019
Apr	2.9	0.093**	0.58	0.000	0.41	0.011	1.33	0.038	2.85	0.067**	-0.9	-0.015
May	3.02	0.068**	-0.02	0.000	0.39	0.011	0.95	0.044	1.57	0.062	-0.61	-0.006
Jun	1.9	0.047+	1.04	0.000	-1.27	-0.075	1.2	0.027	3.22	0.038**	-1.51	-0.034
Jul	1.26	0.046	-0.02	0.000	-0.3	-0.016	1.04	0.029	4.63	0.089***	-0.9	-0.033
Aug	3.35	0.042***	0.23	0.000	2.02	0.045*	1.27	0.035	2.18	0.038*	-1.31	-0.023
Sep	2.99	0.033**	-0.18	0.000	0.88	0.025	0.59	0.015	1.58	0.015	-1.36	-0.027
Oct	3.35	0.072***	0.81	0.008	-1.59	-0.025	-0.64	-0.017	1.77	0.022+	-1.61	-0.042
Nov	3.15	0.068**	0.32	0.000	-1.59	-0.046	-1.54	-0.05	2.5	0.025*	-2.51	-0.068*
Dec	3.58	0.049***	0.16	0.000	-2.18	-0.050*	-1.02	-0.038	1.88	0.021+	-3.28	-0.098**

***, ** and * indicate that the trends are significant at 99, 95 and 90% level of confidence, respectively; S- Sen's slope Z- Mann-kendall test of trend.
Source Based on NMA climate data, 2015

and Dirba (2015) confirmed the study results based on 30 years of temperature data revealing that there was high variability from year to year in the maximum temperatures over North Shoa, which increases between 0.5 to 2°C for the last three decades. This certainly varies across agro ecology (Table 3 and Figure 2f).

The Mann–Kendall test of climate trend analysis of the study areas climate also confirmed that the temperature showed an increasing trend over the study periods with a confidence level of 99, 95 and 90% (Table 4) across agro ecology. The analysis result showed that the rise in maximum temperature was significant in almost all the months (p<0.01 and p<0.05) in the Dega and Kola AEZs except for the months of June and July (Table 4). The Sen's slope estimate showed 0.048 (P<0.05) in January, 0.090 (P<0.01) in February, 0.045 (P<0.01) in March, 0.093 (P<0.05) in April, 0.068 (P<0.05) in May, 0.047+ in June, 0.046 in July, 0.042 (P<0.01) in August, 0.033 (P<0.05) in September, 0.072 (P<0.01) in October, 0.068 (P<0.05) in November and 0.049 (P<0.01) in December.

The Mann–Kendall test further showed that, Woyina-Dega mean maximum temperature increased in the month of August with statistical significance at p<0.1. Decreasing slopes were shown in the month of December at 0.050°C/month for highest maximum temperature. These results coincided with MOA (2011) finding where an increase in temperature in Ethiopia was shown in the months of June, August and September at the rate of 0.32˚C. In the case of lowest minimum temperature, decreasing trends were found in the Dega and Kola agro ecologies in almost all the months with increasing trends in Woyina-Dega agro ecology.

Statistically significant decreasing trends were found in November and December with Sen's Slope estimates of

0.068 and 0.098°C, 0.068°C/month and 0.098°C/month for lowest minimum temperature in November and December respectively in the Kola agro ecology. Climate prediction in Ethiopia depicted that the mean annual temperature in the country would increase by 1.1 to 3.1°C by the year 2060s and 1.5 to 5°C by the year 2090s and will reduce the GDP by about 3-10% by 2025 (MOA, 2011).

Farmers' perception about precipitation changes

Regarding perceived precipitation changes across the agro-ecology, about 81% of Dega, 54.5% of Woyina-Dega and 73.33% of Kola farmers perceived that rainfall was decreasing. It was only 10, 38.5 and 13.33% of Dega, Woyina-Dega and Kola farmers respectively that noticed an increase in rainfall. About 9% of farmers in Dega, 7% in Woyina-Dega and 13.33% of Kola farmers, respectively noticed seasonality change in rainfall as well as increase in drought frequency (Table 5).

Meteorological rainfall trend analysis (1986-2015)

To verify the farmers' perceptions of long-term changes in precipitation, the historical monthly rainfall data for the period 1986 to 2014 was analyzed. The analysis result indicated that the overall rainfall amount and distributions were highly varied from time to time especially in the last few years with an annual average precipitation of 1675.17 mm in the sub-basin and varies with 1956.70, 1565.88 and 1502.94 mm in Dega, Woyina-Dega and Kola agro-ecologies respectively. These were quite

Table 5. Perception of farmers towards rainfalls.

Perceived change in precipitation	Dega (N=100)	Woyina-Dega (N=200)	Kola (N=150)
Increased	10	38.5	13.33
Decreased	81	54.5	73.33
Change in season of rainfall	7	6.5	12
Increase in frequency of drought	2	0.5	1.33

*All values in the table presented in percent (%) in a given agro-ecology).Source Survey result, 2015.

emphasized by positive and negative anomalies (Figures. 3a to d and Table 3) and are similar to Yilma and Awlachew (2009) in the upper Didessa Basin which showed annual rainfall ranging from 1200 to 2200 mm. The annual temporal precipitation data across AEZs showed high rainfall variability and deficiencies in Woyina-Dega and Kola compared to their long-term mean for most years.

There was variation in the monthly amount of rainfalls in terms of intensity and distribution (Table 3) across the agro-ecologies. Climate analysis of the study showed that the mean monthly rainfall was 163, 130.49 and 125.24 mm in Dega, Woyina-Dega and Kola, respectively. The coefficient of variation in most stations revealed that rainfall in the basin has high inter-annual variability. The result indicated that annual rainfall variability at Dega (CV>63%) and at Kola (CV>104%) were extremely variable. Similarly, high monthly coefficient of variation was found in Kola (96%), in Dega (77%) and in Woyina-Dega (64%) agro-ecology (Table 3 and Figures 3b, c and d and 4).

The Mann-Kendall trend and Sen's slope estimators showed that, precipitation in the month of March was significantly decreasing at p<0.1 level in the Woyina-Dega AEZ while the months of May, June, July, August and September rainfalls trend was positive and significantly increasing at p<0.01 level in the Dega agro-ecology (Table 6). Precipitation in the Kola agro ecology has an increasing and positive trend in all the months and is significant at P<0.05 (January, April, May, September and November) and p<0.01 (in February, March August, October and December). In Blue Nile Basin in general as well as in the sub-basin in particular, the two main crop seasons are Belg and Kiremt seasons. *Kiremt (*June-September) is the main rainy season with highest rainfall records in the months of June, July and August preceded by a small rainy season *Belg* (*February-May*) (Figure 4). This finding confirms that of CSA (2012) which showed dry spell months in the Southwestern parts are few and receive rainfall for about 8 months.

The Mann-Kendall trend analysis of monthly rainfall results showed variation in the spatiotemporal distribution and gradual concentration of rainfall in a few months to increase the prevalence of lengthy dry-spells across agro-ecologies.

The declining trends in March and May (in *Belg* season) and June and July (in *Kiremt* season) in Woyina-Dega agro-ecology is an indication of the common place nature of late start and early ending rainfall to affect the number of rainy days (and the growing season) and crop production during the two rainy seasons. Rainfall during Kiremt season exhibited a significantly growing trend in the Dega, whereas that of Belg rainfall had a significant declining trend in the Woyina-Dega AEZs (Table 6) due to the recent afforestation program by the government.

The onset of rainfall for the Dega and Woyina-Dega agro-ecologies are in March and cessations are in October while the Kola rain starts in the months of April with monthly rainfall variability between 83.16 to 125.07 mm. Rainfall in Kola and Dega AEZ has an extreme inter-annual variability (Table 3). The results coincided with a study in Ethiopia where a declining trend was noticed in monthly rainfall with variability ranging from 23.5-146.16 mm (Asamirew and Dirba, 2015) as well as decreasing rainfall trends over the past several decades in South Africa and in the Sahel region of Africa (Gbetibouo, 2009; Mertez et al., 2009). Additionally, in Tanzania, a finding indicated a decreasing trend of rainfall for the last 35 seasons from 1973/74-2007/08 (Mongi et al., 2010). However, the result contradicts a study conducted by MOA (2011) where rainfall projection in South West of Ethiopia showed an increasing trend in the months of October, November and December.

Comparison observation climate variability and climate perceptions

Climate change was assessed by using meteorological observations and/or farmers perceptions. The analysis of climate variables (temperature and precipitation) for the study sub-basin has shown that there is high variability of temperature and rainfall both spatially and temporally. The study tried to compare farmers' observations and perception with historical meteorological trends in the study area. Farmer's observation and perception related to temperature were consistent with the meteorological records indicating a clear increase in temperature across agro-ecologies with slight variations (Tables 2 and 3 and Figure 2a to d). Hence, farmers can accurately perceive climate variability and change as well as its   impacts   on

(a)   Annual rainfall with liner trends and a two –year moving average
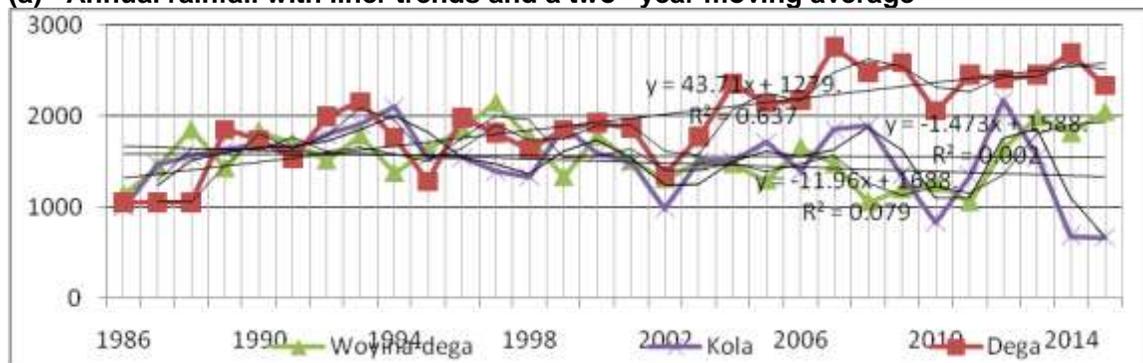
(b)
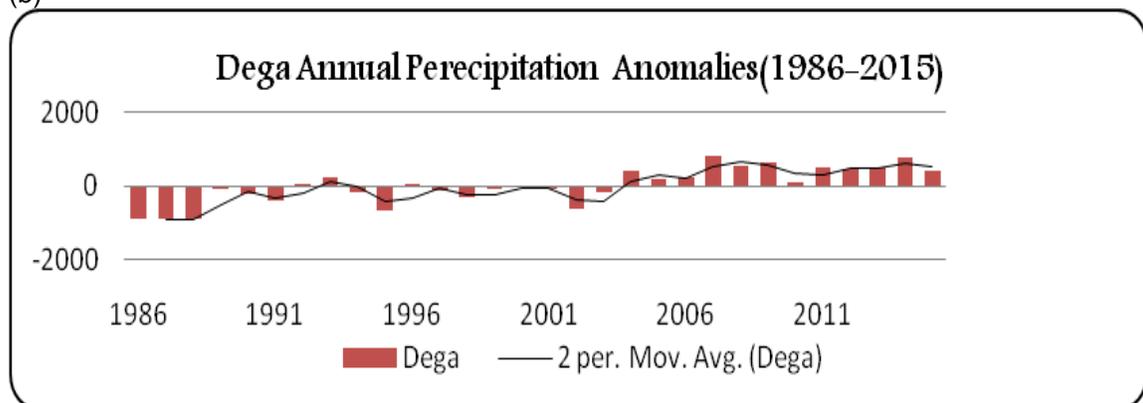
(c)
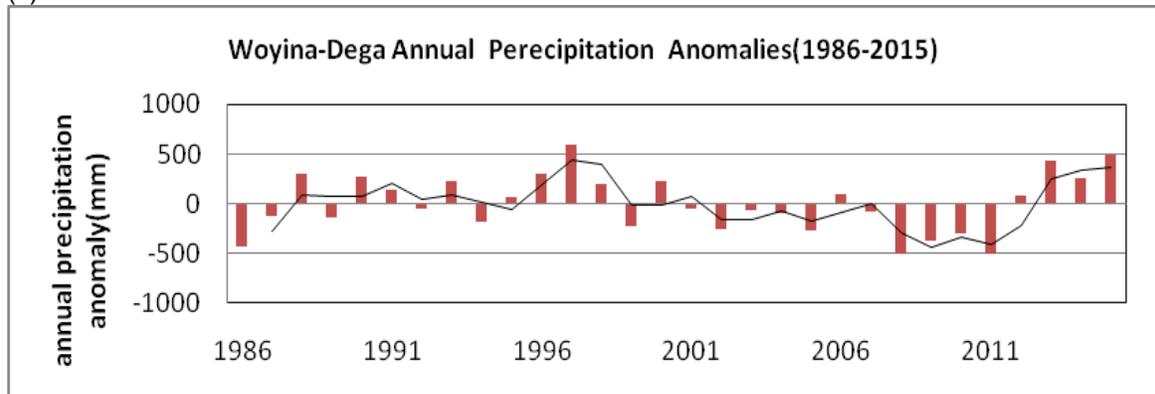
(d)
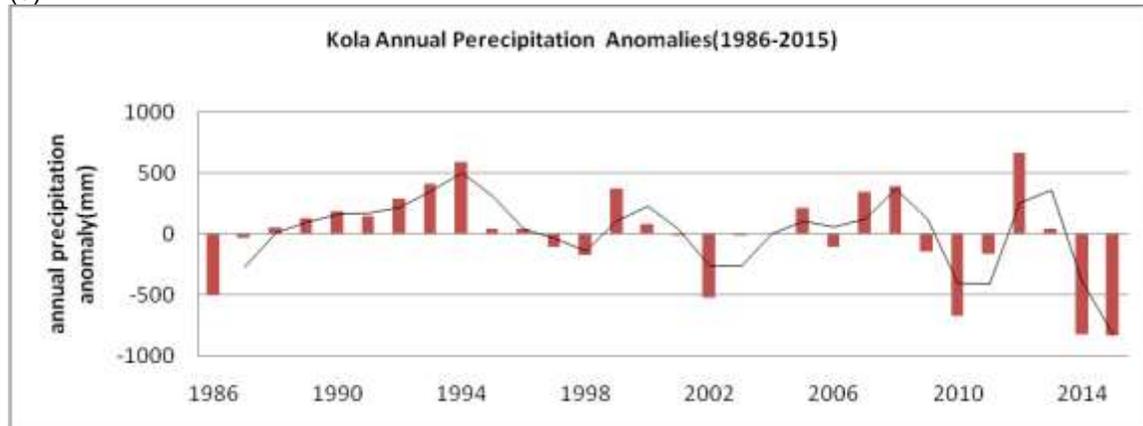
Figure 3. Trends in Rainfall in the DSB (1986-2015). Source Based on NMA Climate Data, 2015.

Table 6. Mann-Kendall and Sen's slope estimator for monthly Precipitation.

Months	Kola –RF		Woyina-Dega –RF		Dega – RF	
	Test Z	Sen's slope	Test Z	Sen's slope	Test Z	Sen's slope
Jan	3.07	0.048**	0.21	0.045	0.83	0.253
Feb	3.61	0.090***	0.00	0.000	0.92	0.2
Mar	3.82	0.045***	-1.96	-2.007*	0.93	1.64
Apr	2.9	0.093**	0.16	0.306	1.13	0.7
May	3.02	0.068**	-0.02	0	3.83	9.028***
Jun	1.9	0.047+	-1.21	-1.465	4.15	7.369***
Jul	1.26	0.046	-1.77	-2.413+	4.83	8.447***
Aug	3.35	0.042***	0.75	2.093	3.29	5.815***
Sep	2.99	0.033**	1.46	2.052	4.43	8.714***
Oct	3.35	0.072***	0.63	1.358	-0.68	-0.638
Nov	3.15	0.068**	1.3	0.614	1.52	1.295
Dec	3.58	0.049***	-0.05	0	-1.56	-0.465

***, ** and *trends are significant at 99, 95 and 90% level of confidence, respectively, S- Sen's slope estimate   Z- Mann-Kendall test of trend. Source Based on NMA climate data, 2015.

their livelihoods for short term periods. However, the observed and perceived pattern in precipitation showed variability in terms of amount and distributions and does not fit the metrological data across the agro-ecologies (Table 3, Figure 3 and Appendix Box 4.1).

In the focus group discussion (FGD), the farmers revealed that: *"the rain does not come on time anymore. After we plant, the rain stops just as our crops start to grow. And it begins to rain after the crops have already been ruined."* Most farmers felt that the rainy season commenced later and stopped earlier in recent past as compared to a long time in the past. They are aware of climatic changes related to the rainy seasons than other seasons. Farmers in all of the agro-ecology said that rainfall was becoming 'increasingly unpredictable' with temporal variations.

The late start and early stop of rainfalls does not only cause failure in harvest but also a delay in farm preparation for the next productive season and prevents planting of long cycle high-yielding crops (maize and sorghum) during *Belg* season. The decreased trends for *Belg* rainfall in Woyina-Dega means a lot for local farmers who used to rely on *Belg* rains for food production (Table 6 and Appendix Box 4.2).

Conversely, availability of Belg rain water assist in the regeneration of grazing lands, land preparation and for planting of long cycle high yielding crops (maize and sorghum). The significant increased rainfall in Kola (in both Kiremt and Belg) is crucial for the production of long cycle high yielding lowland crops (maize, sorghum and millet).

Kiremt rainfall in the Dega agro ecology (90-95% national total cereal output) is paramountly important for the production of highland crops such as tef, barley and wheat respectively. Of course, the smallholder farmers' perceptions of decrease in rainfalls might have been influenced by other factors such as distribution of rainfall, farm inputs and farming system. Study by Simelton et al. (2011) on African farmers' perceptions of erratic rainfall showed that farmers financial, physical, social status, and access to inputs influences how they are affected by rainfall changes and how they perceive those changes, as well as how they can respond to or adapt to those changes.

According to the study, key informants perceptions about precipitation are influenced by farmers own beliefs and expectations as well as experience related to their agronomic practices. Consequently, the same amount of rainfall can result in a good year for some and a bad year for others; perceptions therefore are closely associated with (expected and previously experienced) impacts, not only the actual rainfall levels. Besides, the farming practices and farmers farm calendar also influences the perception of rain in one season or another that could lead to a mismatch in the actual meteorological data and farmer's perceptions.

There are reasons for discrepancies: The study offers a few conceivable explanations below. Farmers can not accurately track probabilistic changes in climate and are more likely to recall recent years of unusual extreme events in rainfalls and classic drought, rather than the rainfall and long-term climate events in intermediate years. This is because memory can be faulty, with unique events attributed to climate change while incremental change goes unnoticed.

The study asked participants of FGD about their feelings and compelled them to offer a story in line with a dominant narrative of climate change where their perceptions viewed as expectations of change or stability can influence one's capacity to detect probabilistic changes. Farmers' accounts and meteorological data differ in climate-related phenomena. Hence, there are
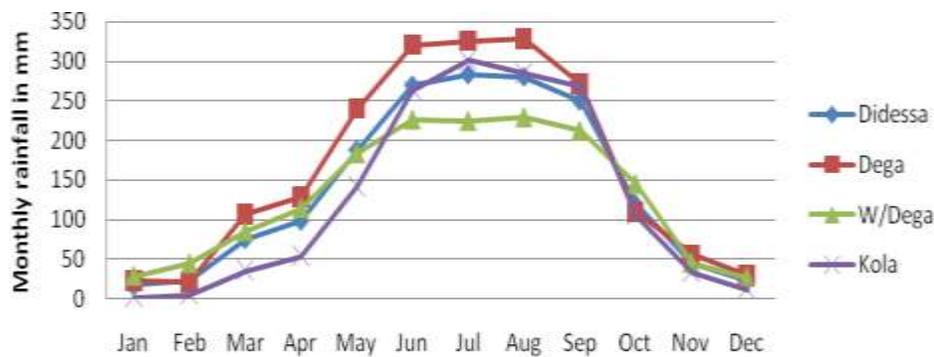
Figure 4. Monthly average rainfalls and trends across agro-ecology. Source Based on NMA climate data, 2015.

disparities among farmers in the study area and statistical trends detected in meteorological records. Farmers understand the *agronomic distinctiveness* but not *meteorological drought.* For instance, rising temperatures in the months of summer may result in reduced soil moisture during planting, even without a decrease in summer rainfall. It may be a change as this that farmers interpret as decrease in summer rainfall.

Perceived causes of climate variability and change

Focus group discussion (FGD) of the study indicated that, a significant portion of smallholder farmers consider that humanity activities (anthropogenic) and super natural forces are the primary causes of climate changes. Accordingly, disobedience and unfaithfulness to religious following, failure to glorify God and alteration from the age-old study area tradition believed led to "divine intervention" type punishments, like rainfall variability in terms of amount and distribution as well as crop failure. This spiritual perspective is widespread throughout Africa (Patt et al., 2009; Gandure et al., 2013; Tumbo and Abdoulaye, 2013).

Teka et al. (2013) reported that farmers in Benin partly attributed climate variation to failure in observance of traditional customs and indigenous laws by the indigenous community. Besides, farmers in FGD also associated the variations in climate change with environmental explanation that identifies cause of deforestation and pollution from industries. These anthropogenic causes of climate change have a number of implications for agricultural productivity although the aggregate impact of these is not yet known or quantified, especially at the farm scale (Gornall et al., 2010).

Perception of the effect of climate variability and change

Climate change is perceived to have adverse ecological, social and economic impacts. Consequently, farming

practices in a particular location are strongly influenced by the long-term mean climate state, the experience and infrastructure of local farming communities. The existing climate trends and irregularities in the amount and pattern of rainfall over the study periods in Didessa Basin together with traditional backward farming system results in an unsustainable agricultural production that threaten the lives and livelihoods of many poor families. Accordingly, the study showed that smallholder farmers in the study area face numerous risks/vulnerabilities to climate variability and changes (Figure 5).

According to many of the respondents, for instance, about 29, 38 and 38.34% of Dega, Woyina-Dega and Kola agro-ecology respondents' view of extent of vulnerability level to climate variability and change was rated as highly vulnerable. They claim that due to lack of feed and shortage of water for animals, increased incidence of plant, animal and human diseases and shortage of food for the households were indicated as major consequences of climate change in Didessa Sub-basin.

Moreover, majority of farmers within the study area are directing their livelihoods into mixed farming that involves both crop (95%) and livestock production. However, their farming practices in the Didessa sub-basin affected by the increased temperature and decrease in rainfall as well as the shift in timing, amount and distribution of rainfall, changes in the length and quality of the growing season. According to the key informant interview, changes in climate variables exacerbate shortage of feeds and water for animals, which causes frequent death of animals, delay in seed precipitation, reduction of forest cover, degradation of natural resources, and changes in the distribution of disease putting more people at risk from incidences of malaria and dengue fever.

IPCC (2007) noted that an increase in average temperature will adversely affect crop production, especially in lowland areas where heat has become a limiting factor. This in turn increases evapo-transpiration rate of plants, and increases chances for severe drought. Hence, agriculture in Ethiopia is mostly described by
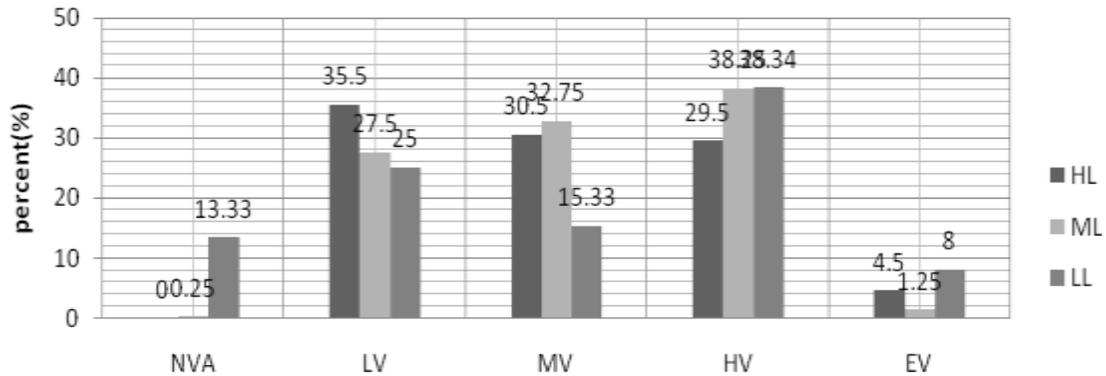
Figure 5. Farmers view of extent of vulnerability levels to climate variability and change in the surveyed agro ecologies (percent). NVA, Not Vulnerable at All; LV, less vulnerable; MV, more vulnerable; HV, highly vulnerable; EV, extremely vulnerable.

extreme dependence on rain systems (Woldeamlak, 2009) and most of the farmers pay more attention to recent climate information, noticed by Maddison (2007) and Gbetibouo (2009).

In his study on the central highlands of Ethiopia, Woldeamlak (2009) reports increasing incidences of agricultural pests and diseases as one of the manifestation of climate change. Besides, Abate (2009) indicated in his study on climate change impact on farmers' livelihood and coping mechanism in the west Arsi zone, that drought and delay in the onset of rain leads to poor grass regeneration and forage deficit, water shortages and heat stress on livestock.

To this end, farming activities are highly vulnerable to climate variability and change. This is aggravated due to low economic capability to adapt at a household level and their high dependence on rain fed agriculture for their sustenance. Therefore, it is clear from the analysis that a particular type of farming system and productivity depends upon the climate variability and change already happening, adaptation capacity and willingness to adapt to changing climate situations.

CONCLUSION AND RECOMMENDATION

It is apparent that climate change is a reality that the world is facing. This study proved that climate change and variability is a reality at the micro (agro ecological) level. This study compared observational climate data analysis with local farmers' knowledge in the Didessa sub-basin. Farmers' perception can help to leverage knowledge from the observational data (metrological evidences).

The study showed that majority of the farmers in the Didessa sub-basin perceived shifts in the timing of seasons, increases in temperature, and decreases in rainfall. Farmers perceived changes in the rainy season more than other seasons. They expressed shortening of the rainy season and increased variability in terms of

intensity and distribution. The analysis of the climate data also revealed that temperature is increasing while rainfall is decreasing across agro ecological zones. This observed temperature variability is compatible with the farmers' local perceptions.

However, for long-term periods it was difficult to relate perceptions precipitation changes over time because there are disparities among farmers in the study area and statistical trends detected in climate records. Farmers understand the *agronomic distinctiveness* but not *meteorological drought.* The study found that the most common causes of climate change were supernatural forces, deforestation, and pollution according to farmers' perceptions. This result in perceived impacts on the lives and livelihoods of farmers in Didessa sub-basin with variation across agro ecological zones

Complementing observational data analysis with local knowledge is a new way of deepening scientific understanding, especially where observational records are rare and uncertain. Therefore, we recommend that farmers perceptions of climate variability and change needs to be taken seriously by scientists and policymakers in dealing with ways of utilizing the metrological information to develop and implement useful options that will rescue the farming households from the impacts of climate change and variability. In addition, scientists and policymakers have to integrate the metrological data into farmers' perceptible way of climate variability for future adaptation and mitigation mechanisms.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

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APPENDIX

Box: 4.1. Farmers' explanations of climate variability and change (Household survey, 2015)

A farmer in his late 50s explained from Arjo (Dega agro ecology) that: I used to cultivate ''daguja and Maize (long duration sorghum variety and maize) from year to year and the crop harvests were much higher (about 80 ''qunna'' which is equivalent to 4 tons per hectare). In recent years, however, I am not able to plant ''daguja'' and "maize" because the rain starts too late. In previous years, *when I was younger, effective rain (belg rain) used to start early in the month of February,* and continued until the end of October but in recent times it starts later (usually mid of July) and ends earlier (early September or sometimes mid of August). Furthermore, in the past, the amount of rainfall per rainy day was not too much or too little but recently, it looks as if ''it gets people angry'', that is, higher rainfall intensity over shorter periods. In the past, the planting dates were on time and almost consistent from year to year, but recently we have followed the approach of ''Robnaan Facaasi'' which means sow whenever it rains because*, rains are now unpredictable.* As a result, crops face severe moisture stress starting from the early development stages and yield is usually low. Besides, livestock are extremely affected by shortage of food.

Box: 4.2. Farmers' perception and explanations of climate variability and change (Household survey, 2015)

Another, 69 years old farmer at Agaro mentioned his perception of climate change: "I have been living here in Agaro (Woyina-Dega) agro ecology. However, in recent years, it is too hot to live. Our local community (where they live and sustain their livelihoods) is becoming hotter and hotter. I am in fear that it is going to be as hot as areas where people are talking about (e.g. afar, and other lowland areas of Ethiopia). In the past, the rainy season begins on time, and once the rainy season has started it extends into October. In recent years, the rainy season starts late and is short. Previously, Agaro was a midland zone well known for coffee production that dominated in terms of production, although recently changes in climate (coffee bear disease), coffee production and productivity reduced. For example, I had produced a lot per hectare of coffee but now I have only produced five quintal. Crop yields have reduced. We have not experienced any food insecurities so far, but, I anticipate such things in the future if it continues like this.