Observed and Perceived Climate Change and Variability and Small Holder Farmers' Vulnerability: The Case of Janamora District, Northwestern Ethiopia

Adamsew Marelign[1] Solomon Addisu[2] Asnake Mekuriaw[2]
1.Department of Natural Resources Management University of Gondar, Gondar Ethiopia
2.Department of Natural Resources Management, College of Agriculture and Environmental Sciences, Bahir Dar University, Bahir Dar, Ethiopia

Abstract
In the context of observed climate change and variability and their impact on livelihoods; This study intended to assess farmers' vulnerability to climate change and variability in Janamora district, northwestern Ethiopia. Primary data for the study was collected through questionnaire from 138 respondents selected through multi-stage sampling technique based on agro-ecology. Secondary data was collected from meteorological stations. Mann-Kendall and Chi-square tests were employed to test observed and perceived climate change and variability respectively. While LVI and LVI-IPCC methods were used to assess farmers' vulnerability to climate change and variability using SPSS version 23. The results revealed significant increasing trend in annual average temperature in all stations except Debark and insignificant trend in annual rainfall as well as a higher rainfall variability. Similarly, 69.6 and 80.4% of the interviewed farmers were aware of an increase in temperature and a decrease in rainfall respectively. Moreover, χ^2 test showed that a significant variation (significant at $P<0.05$) in perception to temperature and rainfall between agro-ecology. The overall vulnerability result in the case of LVI was 0.425, 0.454 and 0.471 for Dega, Woyna Dega and Kolla agro-ecological zones respectively. Similar result was found using the LVI-IPCC approach which was 0.035, 0.041 and 0.049 for Dega, Woyna Dega and Kolla agro-ecological zones respectively. Both LVI and LVI-IPCC results revealed that Kolla was the most vulnerable and Dega was the least vulnerable to climate change and variability. The study suggested improving the literacy level and integrating rural development schemes to increase adaptive capacity. Similarly, further studies should be conducted in the future.
Keywords: Perception, Vulnerability, Climate Change and Variability, Livelihood, Janamora
DOI: 10.7176/JEES/9-8-04
Publication date: August 31st 2019

Introduction

Climate change is the most significant environmental threat of the 21st century (Edame *et al.,* 2011). The world's climate is continuing to change at rates that are projected to be new in recent human history (ILRI, 2006). The IPCC (2001) report showed that, the global mean surface temperature has been increased by 0.6$^{\circ}C$ (0.4$^{\circ}C$ to 0.8 $^{\circ}C$) over the last 100 years. This increasing global mean surface temperature is lead to changes in precipitation and atmospheric moisture (IPCC, 2001). Evidences indicated that the natural climatic variability in combination with climate change will adversely affect millions of livelihoods around the world (IPCC, 2007a). In Africa, mean temperature levels have increased whereas precipitation levels have declined (IPCC, 2001). Temperature increases between 3$^{\circ}C$ and 4$^{\circ}C$ in Africa by the end of the 21stcentury (Bryan *et al*., 2010). Africa is the most vulnerable continent to climate change and climate variabilities (Challinor *et al*., 2007). Many African countries are vulnerable to climate change since their economies highly depend on climate sensitive agricultural production (Mahmud Yesuf *et al*., 2008). Like other sub-Saharan countries, in Ethiopia, there has been a warming trend increasing by about 0.37$^{\circ}C$ every ten years (NMA, 2007). Climate change presents Ethiopian farmers and pastoralists with a new set of challenges (MOARD, 2010). It is highly connected to poverty, loss of coping and adaptive capacity (Temesgen Deressa *et al.,* 2008; Kaur *et al*., 2010; Temesgen Deressa, 2010).

Ethiopia is one of the most highly vulnerable to future climate change among African countries (Conway and Schipper, 2011). Agriculture, water and human health sectors are the most vulnerable to climate variability and change as well as in terms of livelihood approach smallholder rain-fed farmers and pastoralists are found to be the most vulnerable (NMA, 2007; Kaur *et al*., 2010). Ethiopia experienced 10 wet years and 11 dry years over the last 55 years, demonstrating the strong inter-annual variability (NMA, 2007). Mountain regions of Ethiopia are more susceptible to climate change impacts and vulnerabilities (Belay Simane *et al*., 2014). Particularly *Janamora* district is mountainous and often-rugged landscape dominated by the great Semien mountain block (specifically *Chennek* and *Bwahit* mountains) with prevailing and highly variable climate conditions.

Livelihood vulnerability index: composite index approach and IPCC framework approach

The livelihood vulnerability index (LVI) composite index approach uses multiple indicators to measure vulnerability to natural disasters and climate variability, social and economic characteristics of households that affect their adaptive capacity, current health, food, and water resource characteristics that determine their sensitivity to climate change impacts (Hahn *et al*., 2009). A balanced weighted approach is utilized in computing the LVI. The livelihood vulnerability index IPCC approach (LVI-IPCC) was developed as an alternative method for calculating the LVI that incorporates the IPCC vulnerability definition (IPCC, 2007b). LVI-IPCC used to assess exposures, sensitivity and adaptive capacity that make the contributing factor of vulnerability to climate change and variability.

The LVI has been used in varied studies. For instance, Can *et al*. (2013) used this method to assess risks from flood incidence. Similarly, Shah *et al*. (2013), Koya *et al*. (2017) and Etwire *et al*. (2013) applied the livelihood vulnerability index for vulnerability assessment. Particularly in Ethiopia Solomon Addisu *et al*. (2016) used the livelihood vulnerability IPCC approach (LVI-IPCC) in assessing climate change impacts in lake *Tana* sub-basin. Similarly, Chala Dechassa *et al*. (2016) and Theodrose Sisay (2016) used this method to assess the vulnerability of farmers to climate variability and change. The LVI-IPCC conceptual framework diagram (Figure 1) illustrates how LVI sub-components (far right) relate to major components (second from right) that determine scores for LVI-I PCC contributing factors (second from left), which make up the overall LVI-IPCC vulnerability (left) for the study area. On the other hand, the difference between exposure and adaptive capacity multiplied by sensitivity gives vulnerability that means (exposure – adaptive capacity) *sensitivity equals to vulnerability (Figure 1).

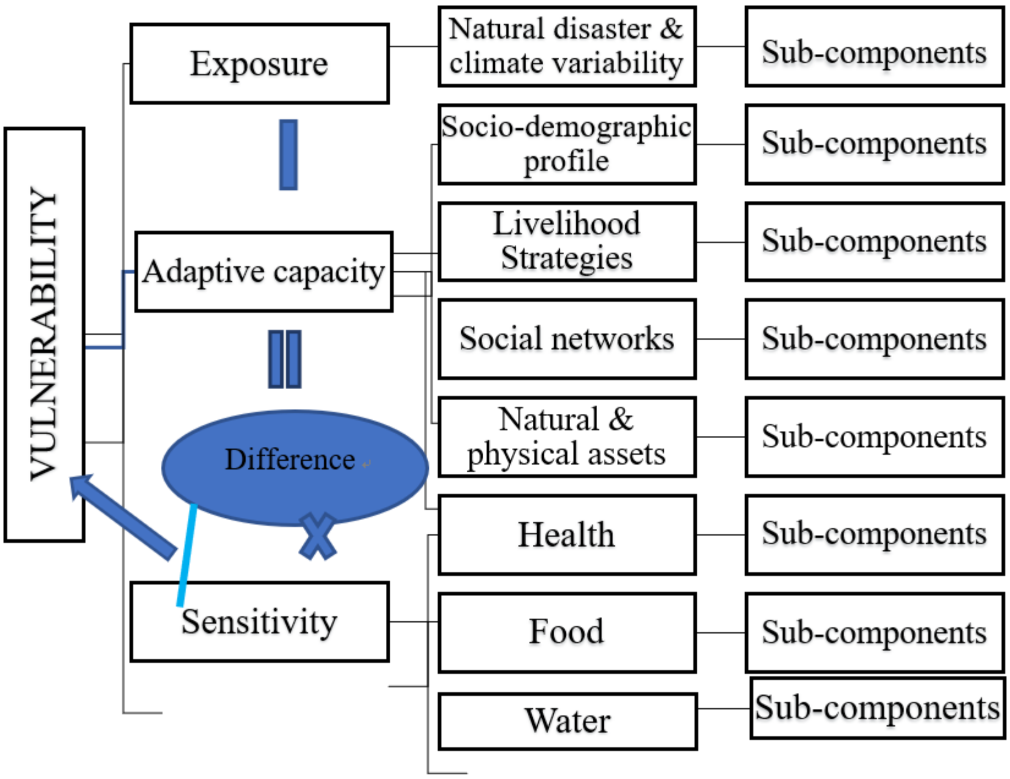


Figure 1: LVI and LVI-IPCC framework (Source: modified from Solomon Addisu *et al*., 2016).

Few studies assessed the impact of climate change in Ethiopia. For example, a research conducted in the regional states of Ethiopia by Temesgen Deressa *et al*. (2008) tried to assess Ethiopian farmer's vulnerability to climate change across regional states.

However, most of these studies are very general and the results are aggregated at national or State levels. Therefore, all may not reflect local contexts of *Janamora* district because site-specific issues require site-specific knowledge and experience (IPCC 2007a). Due to high projection of significant future climate change in Ethiopia in the coming decades (Belay Simane *et al*., 2014) aggregate national vulnerability result does not capture the complexity of vulnerability at agro-ecological level, so agricultural productivity remains challenged. This is particularly true for *Janamora* district with variable topographical region with variable climatic condition with the occurrence of droughts negatively affect the livelihoods. As a result, assessing the farmers' vulnerability to climate change and variability is very crucial.

ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) DOI: 10.7176/JEES
Vol.9, No.8, 2019

Materials and Methods

Description of the study area

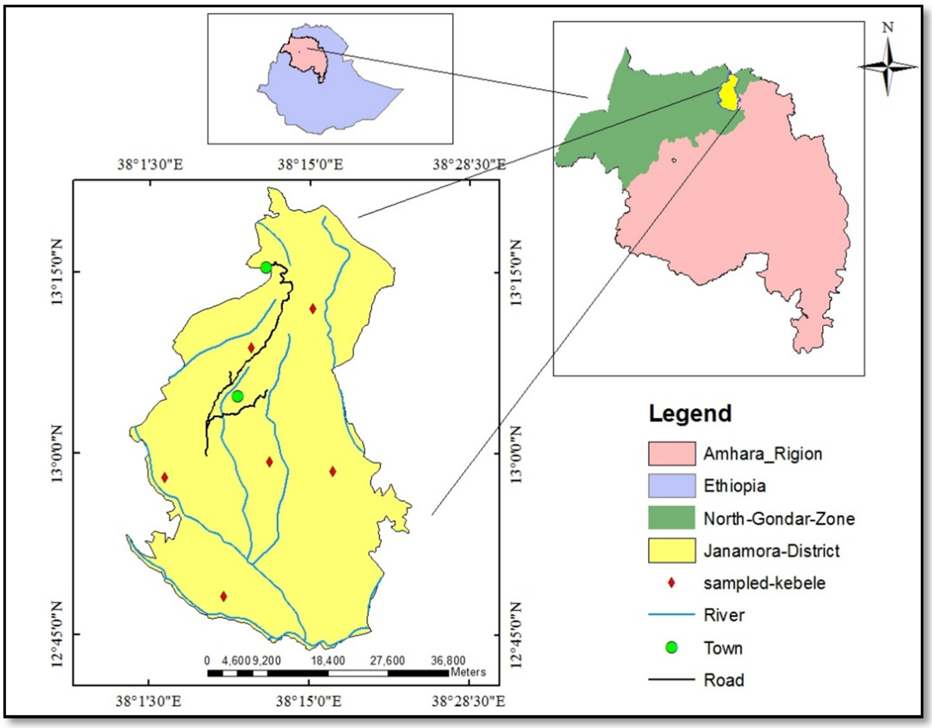


Figure 2 Location map of the study area

The study was conducted in *Janamora* District North *Gondar* Zone of Amhara National Regional State, Ethiopia. Geographically, it is located between 12° 44' 21.2" N - 13° 21' 19.3" N and 38° 0' 0.3" E - 38° 22' 40.5" E (Figure 2). Elevation of the district ranges from 1238- 4512 m a.s.l. The district is part of the Simien mountains national park. About 104 Km^2 area of the park is under *Janamora* district and about 9 *kebeles* of the district is found in and around the park. The total annual precipitation of *Janamora* district is 984.3 mm from 2004 - 2016. The district is characterized by unimodal (one rainy season) type of rainfall. Monthly rainfall and monthly minimum, maximum and average temperature for the study area starting from year 2004 to 2016 is illustrated in Figure 3. *Janamora* district is characterized by steeply dissected and variable topography. It is found between 1238 - 4512m a.s.l. Most area of the district is very steep slope ranges from 0 - 250% of gradient. Based on traditional agroecological zones of Ethiopia (Ministry of Agriculture, 2000), the district is classified in to three major agro-ecological zones of *Dega* (highland), *Woyna Dega* (midland) and *Kolla* (lowland). *Kolla* consists of 25% of the district; *Woyna Dega* consists 27%, and *Dega* consists of 49% of the district. The entire population of *Janamora* district is 208719 with 44408 households in 2017. From this 49% were male and 51% were female. The socioeconomic characteristics includes agriculture, small scale trade, micro and small enterprise. However, above 90% of the people livelihood is mixed farming which is a subsistence form of agricultural production. Some of the population also depends on aid from Productive safety net program (PSNP).

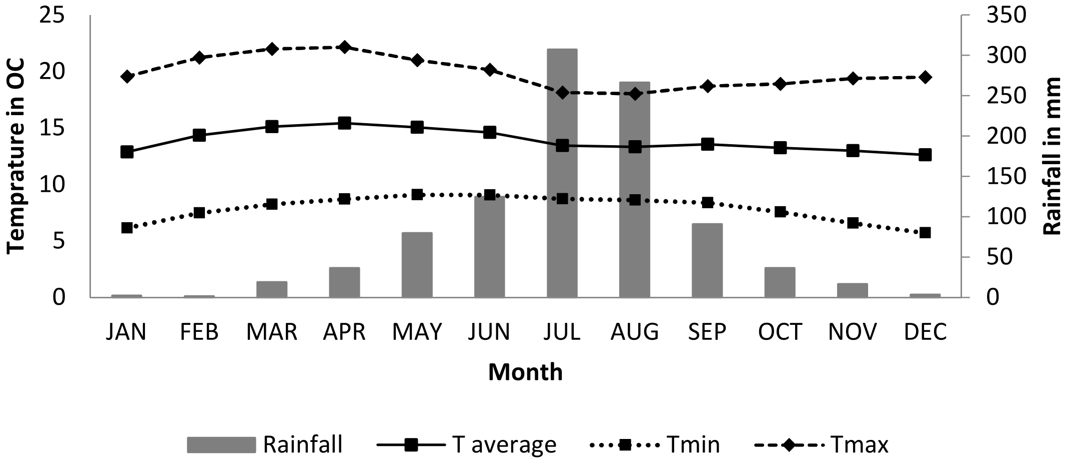


Figure 3. Monthly total rainfall and average temperature for the study area (2004 – 2016)

Sampling Design and Sample Size

Multi stage Sampling was used because the population characteristics within the district is heterogonous in agroecology. In the first stage stratified random sampling was carried out by considering *Kolla* (lowland), *Woyna Dega* (midland) and *Dega* (highland). From total of 34 kebeles of the district *Dega* consists of 16 *kebeles* but, *Woyna Dega* and *Kolla* consist of nine *kebeles* each. In the second stage two *kebeles* were randomly selected from each agro-ecological zone (a total of six *kebeles*) and randomly selecting households from the six sampled *kebeles* using probability proportional to size (PPS). The sample size for household interview was calculated based on Cochran (1977) formula.

$$n = \frac{z^2pq}{d^2}$$

Where n = required sample size (when population is >10,000), Z = 95% confident limit (1.96), p = proportion of population to be included in the sample which is 10% of the total population, q = 1-P = 1-0.1 = 0.9, N = total number of population and d = margin of error (5%). Then $n = (1.96)^2*0.1 * 0.9 / (0.05)^2 = 138$. Therefore, the sample size for this study was 138. After determining the sample size, the next step was determining the number of households for each sampled kebeles using probability proportional to size method. So, a total of 138 households (*Dega* = 46, *Woyna Dega* = 46 and *Kolla* =46) were selected. The primary data for this study was collected using standard questionnaires prepared for the survey in July 2017. Secondary data were obtained from Bahir Dar meteorological service agency proxy stations of *Chennek* or Siemen Mountains (13.27° N and 38.18° E) *Debark* (13.16°N and 37.89°E), *Guhala* (12.77°N and 38.8°E) and *Amba-Giorgis* (12.77° N and 37.62°). To verify the quantitative data, qualitative data were collected through focused group discussion (FGD) and key informants' interview.

Method of Data Analysis

The statistical data were entered and analyzed using SPSS version 23 and Spreadsheet 2016. Mann-Kendall statistical method was applied to annual distribution of rainfall and temperature to detect any possible trends in the data over the study period. This is a non-parametric statistical test well suited to measure trend in data over time (Karpouzos *et al*., 2010). Positive (+) values indicate an increase over time while, negative (-) values indicate decrease. The test observes whether a random response variable monotonically increases or decreases with time. All trend significant test with the level of significance 0.05 ($Z\_\alpha/2 = \pm 1.96$). The hypothesis were null hypothesis (there is no significant trend) and alternative hypothesis (there is a significant trend). Mann-Kendall trend test was analyzed through XLSTAT 2016. Farmers' livelihood vulnerability to climate change and variability was analyzed at two sets of analysis. Calculation of a balanced weighted average LVI (referred to as model 1) and calculation of LVI based on the IPCC framework (IPCC, 2007b) (referred to as model 2). One-way ANOVA was used to revealed the significant difference in actual sub-components (vulnerability indicators) among the three agroecological zones.

Livelihood Vulnerability Index (LVI) Analysis: Composite Index Approach

The LVI developed by Hahn *et al.* (2009) was used to assess the rural households vulnerability to climate change and variability in *Janamora* district. In this approach, several sub-component combine into eight major components. Each of the eight major components is viewed as having an equal contribution (i.e. balanced weight) to a community's overall vulnerability (Sullivan *et al*., 2002). The computation of each indicator value followed the process of standardisation adopted from the computation of the life expectancy index of the HDI (Hahn *et al*. 2009). This computation is shown in Equation 1:

$$Index\ S_a = \frac{S_a - S_{min}}{S_{\max} - S_{min}} \quad \text{(Equation 1)}$$

In the index, S_a is the original (averaged) subcomponent for agro-ecology *a* and S_{min} and S_{max} are the minimum and maximum values for each subcomponent determined using data from the three agro-ecological zones of the district. The percent of households reporting in their community was set at a minimum of 0 and a maximum of 100. After each was standardised, the subcomponent was averaged using Equation 2 to calculate the value of each major component:

$$M_a = \frac{\sum_i^n indexS_{ai}}{n} \quad \text{(Equation 2)}$$

where M_a equals one of the major components for the agro-ecological zone *a* (SDP,LS SN,N&PA, H, F, W, NDCV), $indexs_a^i$ represents the subcomponents, indexed by *i*, that makes up each major component, and *n* is the number of subcomponents in each major component. Once values for each of the eight major components for the agro-ecology was calculated, it was averaged using Equation 3 or 4 to obtain the LVI at agro-ecological zone level of the district:

$$LVI_a = \frac{\sum_{i=1}^n W_{Mi} Ma}{\sum_{i=1}^n W_{Mi}} \quad \text{(Equation 3)}$$

which can also be shown as:

$$LVI_a = \frac{W_{SDP}SDP_a + W_{LS}LS_a + W_{SN}SN_a + W_{NPA}NPA_a + W_H H_a + W_F F_a + W_W W_d + W_{NDCV}NDCV_a}{W_{SDP} + W_{LS} + W_{SN} + W_{NPA}W_H + W_F + W_W + W_{NDCV}} \quad \text{(Equation 4)}$$

where LVI_a is the livelihood vulnerability index for the the agro-ecology within the district and the weightage of the eight major components, W_{Mi}, determined by the number of subcomponents that make up each major component, contribute equally to the overall LVI (Hahn *et al*. 2009; Sullivan 2002). The LVI was scaled from 0 (least vulnerable) to 1 (most vulnerable).

Calculating the LVI–IPCC framework approach

LVI-IPCC was developed by IPCC by considering the three contributing factors (exposure, sensitivity and adaptive capacity) of vulnerability. The final composite LVI-IPCC score for each contributing factor was calculated with the formula (Hahn *et al*., 2009).

$$CFa = \frac{\sum_{i=1}^n W_{Mi} * M_{ai}}{\sum_{i=1}^n W_{Mi}} \quad \text{(equation 5)}$$

where CF_a represents one of the IPCC-defined contributing factors to vulnerability for the agro-ecology *a*. M_{di} represented the major components for the agro-ecology *a* indexed by i, W_{Mi} is the weight of each major component, and n is the number of major components that made up each contributing factor. After the score for each contributing factor was calculated, they combined using this equation.

$$LVI - IPCC_a = (Ea - Aa) * Sa \quad \text{(equation 6)}$$

in which LVI-IPCC*a* is the LVI for agro-ecology as within the IPCC framework, *E* represented the score for exposure, *A* is the score for adaptive capacity, and *S* is the score for sensitivity. The scale for the LVI-IPCC is from -1.0 to 1.0 (Hahn *et al*., 2009).

Results and Discussion

The female headed household accounts 19.6% in Dega, 19.6% in Woyna Dega and 15.2% in Kolla agroecological zones. The mean age of the respondents were 47.4 years (Dega), 42 years (Woyna Dega) and 42.7 years (Kolla). The mean household size of the respondent was 6.065 (Dega), 5.826 (Woyna Dega) and 5.804 (Kolla). Which was greater than the national average household size (5.1 in rural and 3.9 in small town) of Ethiopia (CSA and World Bank, 2013). About 78.3%, 76.1% and 71.7% sampled household heads in Dega, Woyna Dega and Kolla agroecologies were illiterate. Similarly, mean landholding size was 0.716ha for Dega, 0.456ha for Woyna Dega, and 0.888ha for Kolla. Which was below the national average household farm size of 1.37 hectare (CSA and World Bank, 2013). The result was statistically significant (F=7.27, P=0.001). The difference in land size between agro-ecological zones were as result of population density (dense in Dega and Woyna Dega but, sparse in Kolla).

Observed and perceived Climate change and Variability

Temperature change and Variability

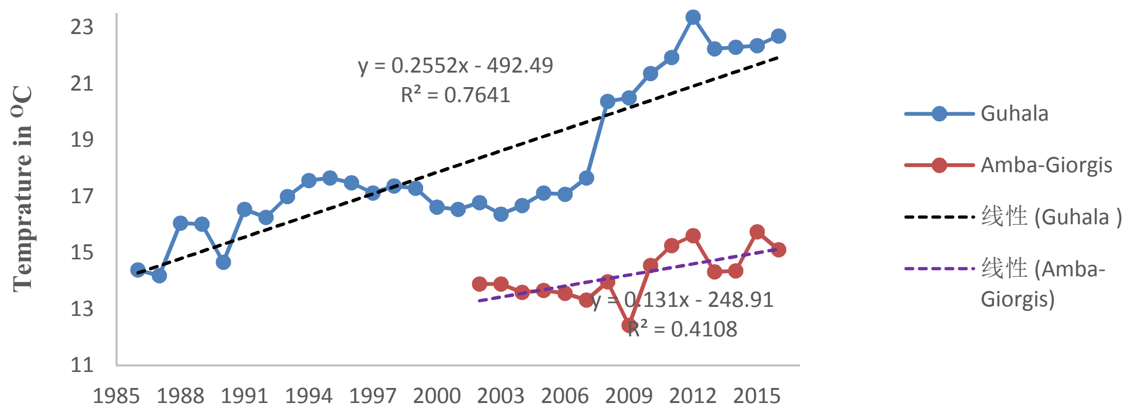
The Mann-Kendall trend test for annual minimum temperature revealed statistically significant increasing trend for *Chennek* and *Guhala* stations Similar to Birhanu Getachew (2017). However, annual minimum temperature showed an increasing trend in all stations (Table 1). Moreover, annual maximum temperature showed statistically significant increasing trend for *Amba-Giorgis* and *Guhala* stations (Table 1). Annual maximum temperature showed an increasing trend in all stations. Similarly, *Chennek* (P = 0.000) *Amba-Giorgis* (P = 0.010) and *Guhala*

(P = 0.000) stations showed statistically significant increasing trend for annual average temperature (Table 1).

Table 1. Annual temperature variability and Mann-Kendall trend Test

Station	Temperature	N	Min.	Max	Mean	SD	CV	Trend °C/year	Kendall's tau	P-value
Chennek	Tmin.	13	2.80	7.74	4.231	1.396	0.33	0.0024	0.788	0.000*
	Tmax.	13	12.1	15.7	14.04	0.993	0.071	0.0014	0.272	0.121
	T ave.	13	7.41	11.5	9.13	1.015	0.111	0.0018	0.727	0.000*
Debark	Tmin.	13	7.80	9.27	8.588	0.393	0.046	0.0026	0.303	0.096
	Tmax.	13	18.2	21.1	19.78	0.802	0.041	0.0028	0.212	0.186
	T ave.	13	12.9	15.2	14.18	0.559	0.039	0.0027	0.182	0.225
Amba- Giorgis	Tmin.	15	6.23	9.75	8.32	0.851	0.102	0.0033	0.154	0.251
	Tmax.	15	18.6	22.4	20.1	1.13	0.056	0.0141	0.670	0.000*
	T ave.	15	12.4	15.7	14.21	0.883	0.062	0.0087	0.473	0.010*
Guhala	Tmin.	30	4.39	15.9	10.38	3.027	0.292	0.0095	0.609	0.000*
	Tmax.	30	22.9	31.6	25.7	2.475	0.096	0.0075	0.513	0.000*
	T ave.	30	14.2	23.4	18.11	2.611	0.144	0.0085	0.655	0.000*

*is significant trend at P<0.05 level, SD = Standard Deviation, CV =Coefficient of Variance (Source: Bahir Dar meteorological agency, 2017).



However, annual average temperature of *Debark* station was statistically insignificant but an increasing trend. Moreover, Figure 4 showed that both *Amba-Giorgis* and *Guhala* stations showed a positive slope that revealed an increasing trend of average temperature. Generally, statistically significant increasing trend was observed on annual average temperature for *Chennek, Amba-Giorgis* and *Guhala* stations. This is in accordance with the current national temperature increment (increased by 0.03°C per year) of Ethiopia (Jury and Funk, 2012).

Perceived Temperature change and Variability

Most of the respondents from each agro-ecologies (73.78% from *Dega*, 56.42% from *Woyna Dega* and 78.12% from *Kolla*) perceived that temperature is increased (Table 2). The change in temperature occurred in all agro-ecologies and it was felt more or less equal by every farming community in the district. There was a significant difference in perception of male and female to temperature change (χ^2 =20.15) (Table 2). This difference in perception between gender is a reflection of the roles that the two sexes play in the society and the limited opportunities available to woman in terms of climate related information. Marther *et al.* (2016) and Alem Kidanu *et al* (2016) found significant difference perception between male and female.

Table 2: Perceived temperature change and variability

Agro-ecology	Perception on temperature (% of respondents)				χ^2	P-value
	I don't know	Decreased	Increased	No Change		
Dega	2.17	19.53	73.78	4.34		
Woyna Dega	10.85	28.21	56.42	4.34	10.21^{ns}	0.116
Kolla	10.85	10.85	78.12	0		
Gender	Perception on temperature (% of respondents)					
	I don't know	Decreased	Increased	No Change		
male	5.07	17.4	59.4	1.5	20.15*	0.000
female	5.07	5.07	5.07	1.5		
Educational Status	Perception on temperature (% of Respondents)					
	I don't know	Decreased	Increased	No Change		
Illiterate	12	22.2	63	2.8	9.93*	0.019
Literate	0	6.9	93.1	0		

^{ns} and* is non-significant and significant at 0.05 level respectively

Chi-square shows significant variation among the different educational status (χ^2 =9.93, P=0.019) (Table 2). The implication is that educated peoples are keener in noting changes in temperature more than uneducated people; they become very conscious about their environment.

Rainfall Change and Variability

All the months in *Amba-Giorgis* station varied from 33.2 % - 318.6% CV showing very high variability of precipitation (Hare, 2003). The annual variability of rainfall as indicated in Table 4, is moderately variable for *Amba-Giorgis* (CV = 28.33%) and *Chennek* (CV = 20.77%) stations. Whereas, *Debark* and *Guhala* stations were less variable.

Table 3. Annual rainfall variability and Man-Kendall trend analysis

Stations	N	Min.	Max.	Mean	SD	CV	Trend mm/year	Kendall's tau	p-value
Chennek	13	666.6	1610.4	1071.7	222.6	0.21	0.392	0.061	0.418 ns
Debark	13	811.9	1615.1	1127.8	208.2	0.19	-0.086	-0.12	0.684 ns
Amba- Giorgis	28	527.3	1701.7	1002.3	283.	0.28	0.462	0.154	0.251 ns
Guhala	13	569.3	939	733.7	110	0.15	-0.919	0.048	0.369 ns

ns is non-significant trend at 5% level, SD = Standard Deviation, CV =Coefficient of Variance and MK = Mann-Kendall

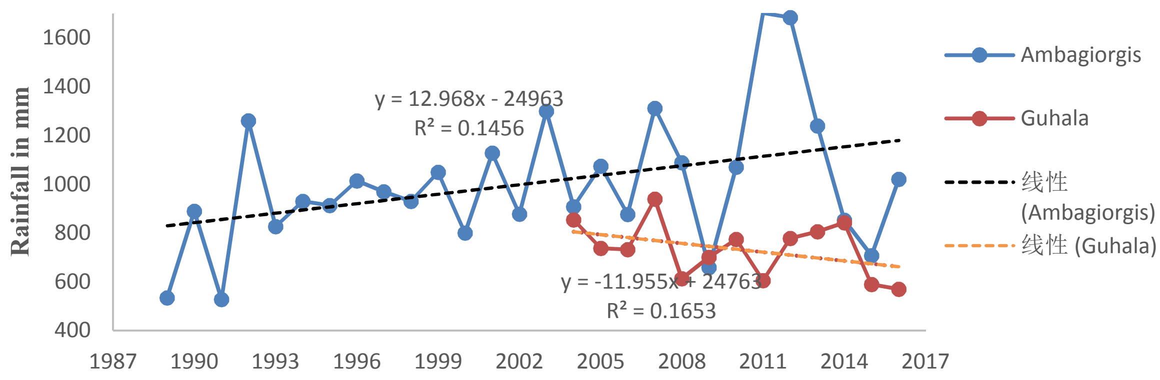


Figure 5: Trends of annual rainfall for *Amba-Giorgis* and *Guhala* stations respectively. (Source: Bahir Dar meteorological agency, 2017).

The Mann-Kendall trend test for annual rainfall revealed statistically insignificant trend for all stations. However, a decreasing trend was seen in *Debark* and *Guhala* stations (Table 3). Similarly, Birhan Getachew (2017) found insignificant trend in annual rainfall. Figure 5 showed that Amba-Giorgis have a positive slope with increasing rainfall and Guhala has a negative slope that revealed decreasing rainfall. In general, very high variability and insignificant trend of rainfall was observed. This implies that agricultural activities in the district are challenged by such high variabilities and a decreasing trend of rainfall. Most of the respondents (80.4%) believed a decrease in the amount of rainfall, and the remaining and 28.7% of the respondents did not give enough attention about the trend of the rainfall. Similarly, through Focus group discussion (FGD), farmers of the district generally concurred that the main problem in terms of rainfall distribution is the timing (late onset and early

Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) DOI: 10.7176/JEES
Vol.9, No.8, 2019

cessation) and falling in intense episodes in very short duration. statistical analysis showed significant variation of perception across different agro-ecological zones (χ^2 =22.19) (Table 5). Similar to ATPS (2013) study. This is probably because in *Kolla* agro-ecology, water is already very scarce, and a little change in the amount of rainfall could have high impact.

Table 4. Farmers' perception on rainfall change and variability

	Perception on temperature (% of respondents)				χ^2	P-value
Agro-ecology	I don't know	Decreased	Increased	No Change		
Dega	8.68	32.55	54.25	4.34		
Woyna Dega	10.85	6.51	78.12	4.34	22.19*	0.001
Kolla	6.51	2.17	86.8	4.34		
Gender	Perception on temperature (% of respondents)					
	I don't know	Decreased	Increased	No Change		
male	3.6	5.8	71.02	2.9	18.36*	0.000
female	5.07	0.73	9.42	1.5		
Educational Status	Perception on temperature (% of Respondents)					
	I don't know	Decreased	Increased	No Change		
Illiterate	9.2	21.1	66.1	3.7	13.45*	0.004
Literate	0	3.5	95.5	0		

ns and* is non-significant and significant at 0.05 level respectively

There was statistically significant variation of perception in rainfall by gender (χ^2 = 18.36) (Table 4) Marther W. *et al.* (2016), ATPS (2013) and Alem Kidanu *et al* (2016) also revealed that significant difference perception between male and female to climate change. Moreover, the statistical analysis for perception of rainfall change showed significant variation among the different educational status (χ^2 = 13.45) (Table 4). About 60.9%, 78.3% and 84.8% of respondents from *Dega*, *Woyna Dega* and *Kolla* agro-ecologies were well recognized the existence of drought in their local area respectively.

Farmers' Vulnerability to Climate Change and Variability

Livelihood vulnerability index results

The unit of analysis for the livelihood vulnerability of farmers was *Dega* (Highland), *Woyna Dega* (Midland) and *Kolla* (Lowland) agro-ecological zones (AEZs). The indexed sub-components, the major components, and the composite LVI for each agro-ecologies are represented in Table 6. Empirically, the vulnerability indices of the major components ranged from 0.314 - 0.577 as shown in Table 6.

The first major component is the socio-demographic profile which consists of five sub components. In case of socio-demographic profile, *Dega* (0.404) was found to be the most vulnerable followed by *Kolla* (0.377). But *Woyna Dega* was relatively the least vulnerable (0.352) Similarly, ANOVA test (p = 0.02) revealed a significant variation in dependency ratio among AEZs. On the other hand, *Dega* (19.6%) and *Woyna Dega* (19.6%) have a higher proportion of female-headed households than *Kolla* (15.2%). Majority of the household heads in *Dega* (78.3%) reported not having any formal education followed by *Woyna Dega* (76.1%). Illiteracy limits farmer's access to information especially from written sources, by increasing their susceptibility to climatic stresses (Etwire P.M. *et al.* 2013).

Livelihood strategy is the second major component which is made from three sub components. In livelihood strategy *Dega* (0.459) was the most vulnerable but *Woyna Dega* (0.418) was the least vulnerable. This was due to shortage of land, inadequate livelihoods option, and population pressure (similar to the findings of Chala Dechassa *et al* (2016)). In addition. 82.6%, 80.5% and 87% of the respondents dependent solely on agriculture in *Dega*, *Woyna Dega* and *Kolla* AEZs respectively. One-way ANOVA result (p = 0.041) revealed statistically significant variation in agricultural livelihood diversification index between AEZs.

The third major component is social networks which is also made up of three sub components. Even though the indices for the three AEZs were similar, *Kolla* (0.342) was found to be the most vulnerable in terms of social networking relative to *Woyna Dega* (0.321) and *Dega* (0.314) (Table 6). Average receive to give ratio of *Kolla* (0.443) was the largest ratio relative to *Dega* (0.319) and *Woyna Dega* (0.254).

Natural and physical asset is the fourth major component with two sub-components. In regard to natural and physical asset, *Woyna Dega* with index of 0.368 was the most vulnerable to climate variabilities and changes. Whereas *Dega* and *Kolla* agro-ecological zones are all most similar in vulnerability with index of 0.357 and 0.354 respectively. In addition, one-way ANOVA (p = 0.004) showed a significant different average land size index among AEZs. When population density increased, the land size given to each household becomes reduced.

Health is the fifth major component. When the three sub components are aggregated to form an index, *Kolla* with an index of 0.52 was the most vulnerable to health whereas, *Dega* (0.429) was the least vulnerable. The reason behind was malaria and other water born disease are dominant in *Kolla* (lowland) agro-ecology. The average time taken to reach a health facility was highest for *Kolla* (278.48 minute). Similarly, one-way ANOVA result (p = 0.016) revealed significant variation in time taken to reach a health facility between AEZs. This illustrates shortage of health service access resulting from lack of road and other infrastructures mostly in *Kolla* agro-ecological zone. There is significant (p = 0.002) difference percent of households with chronic illness between AEZs. Sickness increases the vulnerability of farmers to other external stresses. The overall index for health was the highest in Kolla and the lowest in *Dega* AEZs. Since the exposure of environment to disease in *Kolla* the increased availability of health facilities tends to reduce the overall index for health (Sattar *et al.,* 2017).

Food is the sixth major component made up of five sub components. The Households in *Kolla* was the most vulnerable to food inaccessibility with an index of 0.577 but, *Dega* (0.433) was relatively the least vulnerable. Almost all percentages of households in *Dega* (97.8%) and *Kolla* (97.8%) rely solely on their farm for food. The average number of months households struggle to find food was found to be highest in *Kolla* (6.11 months) and *Woyna Dega* (5.15 months) relative to *Dega* (4.15 months) and it was statistically significant (p = 0.000) between AEZs. The actual Average crop diversity index shows households grow 3.32 types of crops in *Dega*, 3.89 types of crops in *Woyna Dega* and 3.48 types of crops in *Kolla*. Similarly, crop diversity index was statistically significant (p = 0.000) among AEZs. So, farmers of *Woyna Dega* and *Kolla* grows relatively more types of crops than farmers of *Dega*. This is because climatic condition in *Dega* agro-ecology restrict the type of crops that grow. The smaller land size also affects the type of crops a farmer can grow.

The vulnerability index for the seventh major component (water) shows Woyna *Dega* (0.644) to be the most vulnerable but *Dega* (0.459) was the least vulnerable. *Woyna Dega* (82.6%) and *Kolla* (80.4%) recorded the highest percentage of households reporting conflicts over water resources in the past years. Households of *Kolla* and *Woyna Dega* travel an average of 129.89 and 141.3 minute to get water source respectively. Whereas farmers of *Dega* travel only an average of 76.739 minute to the water source as well as One-way ANOVA showed significant (p = 0.000) between AEZs Therefore, the average time taken to reach the water source is found to be highest (similar to the study of Chala Dechassa *et al* (2016)) in *Kolla.* This shows less accessibility of different water sources like bore holes and modern drinking water sources mostly in *Kolla* and *Woyna Dega* AEZs.

The eighth major component is the natural disasters and climate variability (NDCV) component which was comprised of six sub components. Respondents in *Kolla* with index of 0.471 were found to be the most vulnerable followed by *Dega* (0.467) but, households of *Woyna Dega* (0.437) was relatively the least vulnerable. In households of *Woyna Dega* highest average number of climate hazards (10.96 climatic hazards per decade) were occurred but in *Dega* the hazards were relatively lowest (7.935 climatic hazards per decade). Moreover, one-way ANOVA showed significant different number of hazards among AEZs. Majority of farmers (97.8%) in all three agro-ecological zones did not receive any warning about impending natural disaster such as floods or droughts. In addition, agricultural office report of the district realized that less ground water reserves, low vegetation cover, soil erosion and increased flooding and rainfall variability and shortage are some of the worst environmental externalities of the district.

The overall livelihood vulnerability index (LVI) score was the highest for *Kolla* (0.471) followed by *Woyna Dega* (0.454) AEZ. Whereas, it was the lowest for *Dega* (0.425) agro-ecology. This implies that farmers of *Kolla* was the most vulnerable (similar to the finding of Chala Dechassa *et al.* (2016)). On the contrary farmers of *Dega* was relatively the least vulnerable to climate change and variabilities.

Livelihood vulnerability index IPCC approach results

Table 5. LVI–IPCC contributing factors calculation for the study area

Major Component	No of Sub-components	Contributing factors	Contributing factors value		
			Dega	Woyna Dega	Kolla
SDP LS SN N &PA	5 3 3 2	Adaptive Capacity	0.388	0.363	0.382
Health Food Water	3 5 5	Sensitivity	0.442	0.554	0.557
NDCV	6	Exposure	0.467	0.437	0.471
		LVI-IPCC	**0.035**	**0.041**	**0.049**

households of *Kolla* with exposure score of 0.471 was the most exposed and farmers of *Woyna Dega* (0.437) was relatively the least exposed. Similarly, *Kolla* (0.557) might be the most sensitive to climate change impacts but, *Dega* (0.442) was the least sensitive. By adaptive capacity, *Dega* that showed the highest score (0.388) have the lowest adaptive capacity. However, *Woyna Dega* (0.363) that showed the lowest score (0.388) have the highest adaptive capacity. Generally, LVI–IPCC analysis results were 0.035, 0.041 and 0.049 for *Dega*, *Woyna Dega* and

Kolla AEZs respectively. Therefore, households of *Kolla* were the most vulnerable followed by that of *Woyna Dega*. whereas, farmers in *Dega* (LVI-IPCC = 0.035) were the least vulnerable to climate change and variability risks.

Table 6: Indexed sub-components, major components and overall LVI for the three agro-ecologies of *Janamora* district

Sub-components/Vulnerability Indicators	Dega	Woyna-Dega	Kolla	Major Component	Dega	Woyna Dega	Kolla
Dependency ratio	0.440	0.339	0.474	SDP	0.404	0.352	0.377
% of female-headed household	0.196	0.196	0.152				
Average age of female headed household (1/years)	0.472	0.336	0.400				
% of household heads haven't attended school	0.783	0.761	0.717				
% of households with orphans	0.13	0.13	0.142				
% of HHs working in a different community	0.174	0.217	0.196	LS	0.459	0.418	0.449
% of HHs dependent solely on agriculture	0.826	0.805	0.87				
Average agricultural LDI	0.376	0.233	0.28				
Average receive: give a ratio	0.319	0.254	0.443	SN	0.314	0.321	0.342
Average borrows: lend money ratio	0.319	0.405	0.367				
% of HHs who has not gone to their local government for assistance /12 months	0.304	0.304	0.217				
Inverse of average land size index	0.761	0.848	0.704	NPA	0.357	0.368	0.354
% of landless farmers	0.02	0.04	0.01				
Average time to health facility	0.158	0.207	0.365	Health	0.429	0.453	0.52
% of HHs with chronic illness	0.696	0.609	0.804				
% of HHs where a family member had to miss work in the past 2 weeks due to Illness	0.435	0.543	0.391				
% of HHs dependent solely on farm for food	0.978	0.935	0.978	Food	0.433	0.525	0.577
Average number of months, food shortage	0.287	0.377	0.465				
Average crop diversity index	0.205	0.272	0.223				
% of HHs that does not save crops	0.543	0.717	0.87				
% of HHs that does not save seeds	0.152	0.326	0.348				
% of HHs reported water conflicts	0.587	0.826	0.804	Water	0.459	0.644	0.558
% of HHs that utilizes a natural water source	0.848	0.957	0.978				
Average time to water source	0.094	0.185	0.169				
% of HHs that do not have a consistent water	0.5	0.761	0.478				
Water stored per HH (1/ the average number of liters)	0.264	0.490	0.363				
Average number of climate hazards/decade	0.424	0.64	0.511	NDCV	0.467	0.437	0.471
% of HHs that did not get a warning	0.978	0.978	0.978				
%of HHs with an injury/death	0.261	0.239	0.196				
Mean SD of monthly Tmax. (2004-2016)	0.268	0.322	0.269				
Mean SD of monthly Tmin. (2004-2016)	0.434	0.228	0.367				
Mean SD of monthly RF (2004-2016)	0.439	0.214	0.505				
Over all LVI					0.425	0.454	0.471

Conclusion and Recommendations

Generally, significant increasing trend was observed on annual average temperature for all stations except *Debark*. However, insignificant trend was observed on rainfall of all stations. but *Debark* and *Guhala* stations showed a decreasing trend. Similarly, farmers perception was in line with the observed climatic data. Both LVI and LVI-IPCC methods provide a detailed description of factors driving farmers' livelihood vulnerability to climate change and variability. Lack of climate information, fluctuations in precipitation, solely agricultural dependency and inadequate access to food and medicine and chronic illness were the constraining factor in increasing the vulnerabilities of farming communities in *Kolla* agro-ecology. Whereas, Woyna Dega agro-ecology is most vulnerable to water and natural and physical asset, while *Dega* is most vulnerable in terms of illiteracy, socio-demographic profile and livelihood strategies.

Stakeholders should to improve health, food and water supply in *Woyna Dega* and *Kolla* agro-ecological zones by undertaking different measures. Integrating rural development schemes aimed to increase adaptive capacity of farmers is recommended to the range of climate extremes that they experience. For the future, similar studies should be conducted by including governance indicators and other environmental factors with refinement of the social networks sub-components

Reference

Alem Kidanu, Kibebew Kibret, Jemma Hajji, Muktar Mohammed and Yosef Ameha. 2016. Farmers' perception towards climate change and their adaptation measures in Dire Dawa Administration, Eastern Ethiopia. Journal of Agricultural Extension and Rural Development. Vol.8(12), pp. 269-283.

ATPS (African Technology Policy Studies Network). 2013. *Farmers' Perception and Adaptive Capacity to Climate Change and Variability in the Upper Catchment of Blue Nile, Ethiopia* (Bewket Amdu, Azemeraw Ayehu, Andent Deressa), ATPS Working paper No. 77.

Belay Simane, Zaitchik J. D., and Foltz J.D. 2014. Agroecosystem specific climate vulnerability analysis: application of the livelihood vulnerability index to a tropical highland region. Mitig Adapt Strateg Glob Change 21 pp 39–65.

Birhan Getachew. 2017. Trend analysis of temperature and rainfall in south Gonder zone, Ethiopia. Journal of Degraded and Mining Lands Management. ISSN 5 pp 1111-1125.

Bryan E., Ringler C., Okoba B., Roncoli C., Silvestri S. and Herrero M. 2010. Coping with climate variability and Adapting to Climate Change in Kenya: Household and community Strategies and Determinants. Kenya Agricultural Research Institute (KARI), Washington, Nairobi, Kenya.

Can N. D., Tu V. H., and Hoanh C. T. 2013. Application of livelihood vulnerability index to assess risks from flood vulnerability and climate variability-A case study in the Mekong Delta of Vietnam. Journal of Environmental Science and Engineering, 2 (8A), 476–486.

Chala Dechassa, Belay Simane, Bamlaku Alamirew and Hossien Azadi. 2016. agro-ecological based small-holder farmer's livelihoods vulnerability to climate variability and change in Didesa sub Basin of Blue Nile River, Ethiopia. Academia Journal of Agricultural Research; Dechassa et al. V. 4(5) pp 230 – 240.

Challinor A, Wheeler T, Garforth C, Craufurd P, Kassam, A. 2007. Assessing the vulnerability of food crop systems in Africa to climate change. Climatic Change, 83 (3). 381 - 399. ISSN 0165-0009

Cochran, W. G. 1977. Sampling techniques (3rd ed.). New York: John Wiley & Sons.

Conway, D. and Schipper, F. 2011. Adaptation to climate change in Africa: challenges and opportunities identified from Ethiopia. Global Environmental Change, 21(1), pp.227-237.

CSA (Central Statistical Agency) and the World Bank. 2013. Ethiopia Rural Socio-economic Survey (ERSS). Survey Report.

Edame GE., Ekpenyong AB. and Fonta WM. 2011. Climate Change, food security and agricultural productivity in Africa: Issues and policy directions. International Journal of Humanities and Social Science. Vol. 1 No. 21 pp 205- 223.

Etwire P. M., Al-Hassan R. M., Kuwornu J. K. and Osei-Owus Y. 2013. Application of livelihood vulnerability index in assessing vulnerability to climate change and variability in Northern Ghana. Journal of Environment and Earth Science, 3(2), 157–170

Hahn MB., Riederer AM. and Foster SO. 2009. The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change a case study in Mozambique. Global Environmental Change19: 74-88.

Hare W. 2003. Assessment of Knowledge on Impacts of Climate Change Contribution to the Specification of Art. 2 of the UNFCCC.

ILRI (International Livestock Research Institute). 2006. *Mapping climate vulnerability and poverty in Africa.* 200p Nairobi (Kenya): ILRI.

IPCC (Intergovernmental Panel on Climate Change). 2001. Climate change: The scientific basis. Contribution of Working Group I to the Third Assessment Report of IPCC (Houghton J.T., Ding Y., Griggs D.J., Noguer M., van der Linden P.J., Dai X., Maskell K., and. Johnson C.A).

IPCC (Intergovernmental Panel on Climate Change). 2007a. Climate change 2007: Impacts, adaptation, and vulnerability. Contribution of working group II to the third assessment report of the intergovernmental panel on climate change. (Parry M., Canziani O., Palutikof J., Van der Linden P. and Hanson C. Eds.) Cambridge, United Kingdom: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). 2007b. Fourth Assessment Report. Climate Change 2007: Synthesis Report.

Jury M. R. and Funk C. 2012. Climatic trends over Ethiopia: regional signals and drivers. International Journal of Climatology. 33: 1924–1935 (2013).

Karpouzos D. K., Kavalieratou S. and Babajimopoulos C. 2010. Trend analysis of precipitation data in Pieria Region (Greece); European Water 30. 31- 40.

Kaur N, Million Getnet, Beneberu Shimelis, Zegeye Tesfaye, Gebeyehu Syoum and Endale Atnafu. 2010. Adapting to climate change in the water sector: Assessing the effectiveness of planned adaptation interventions in reducing local level vulnerability. Working Paper 18 Research-inspired Policy and Practice Learning in Ethiopia and the Nile Region. Debrezeit Road, PO Box 4812, Addis Ababa, Ethiopia

Koya M., Dash G., Kumari S., Sreenath K. R., Dash S. S., Ambrose T. V. and Zacharia P. U. 2017. Vulnerability of Coastal Fisher Households to Climate Change: A Case Study from Gujarat, India. Turkish Journal of Fisheries and Aquatic Sciences, 17, 193–203

Mahmud Yesuf, Salvatore D. F., Temesgen Deressa, Claudia R., and Gunnar K. 2008. The impact of climate change and adaptation on food production in low-income countries: Evidence from the Nile Basin, Ethiopia, IFPRI.

Marther W. Ngigi U. M. and Regina B. 2016. Gender differences in climate change perceptions and adaptation strategies: an intra-household analysis from rural Kenya, ZEF Discussion Papers on Development Policy No. 210, Center for Development Research, Bonn, March 2016, pp. 34.

MOA (Ministry of Agriculture). 2000. *Agroecological Zonation of Ethiopia*. Addis Ababa, Ethiopia.

MOARD (Minister of Agriculture and Rural Development). 2010. Ethiopia's Agricultural Sector Policy and Investment Framework. Addis Ababa, Ethiopia.

NMA (National Metrological Agency). 2001. *Initial National Communication of Ethiopia to the united Nations*

Framework Convention on Climate Change (UNFCCC). NMA, Addis Ababa. Ethiopia.

Sattar R. S., Wang S., Tahir M. N. and Caldwell C. 2017. Assessment of Smallholder Farmer's Vulnerability Due to Climate Change in Arid Areas of Pakistan. *Applied Ecology and Environmental Research.* 15(4) 291-312.

Shah K. U., Dulal H. B., Johnson C., and Baptiste A. 2013. Understanding livelihood vulnerability to climate change: Applying the livelihood vulnerability index in Trinidad and Tobago. Geoforum, 47, 125-137

Solomon Addisu, Olutayo OA, Sulaiman H. and Rao P. 2016. Assessing Climate Change Impacts in the Lake Tana Sub-Basin, Ethiopia Using Livelihood Vulnerability Approach. Journal of Earth Science and Climate Change. 7: 9: 368-378.

Sullivan C., Meigh J.R., and Fediw T.S. 2002. Derivation and testing of the water poverty index phase 1, Final Report. Department for International Development, UK,2002.

Temesgen Deressa, Hassen R., Ringler C. 2008. Measuring Ethiopian farmer's vulnerability to climate change across regional states. International Food policy Research Institute IFPRI Discussion Paper 00806.

Temesgen Deressa. 2010. *Assessment of the vulnerability of Ethiopian agriculture to climate change and farmers' adaptation strategies*. PhD dissertation. University of Pretoria. SA

Theodrose Sisay. 2016. Vulnerability of Smallholder Farmers to Climate Change at Dabat and West Belesa Districts, North Gondar, Ethiopia. Journal of Earth Science and Climate Change. 7: 365. doi: 10.4172/2157-7617.1000365.