Journal of Agriculture and Crops
ISSN(e): 2412-6381, ISSN(p): 2413-886X
Vol. 5, Issue. 12, pp: 237-250, 2019
URL: https://arpgweb.com/journal/journal/14
DOI: https://doi.org/10.32861/jac.512.237.250

Academic Research Publishing Group

Original Research Open Access

Smallholder Farmers Vulnerability Level to Climate Change Impacts and Implications to Agricultural Production in Tigray Regional State, Northern Ethiopia

Alemu Addisu*
PhD, Mekelle University, Ethiopia

Daniel Olago
Prof., Institutes for Climate Change and Adaptation, University of Nairobi, Kenya

Shem Wandiga
Prof., Institutes for Climate Change and Adaptation, University of Nairobi, Kenya

Silas Oriaso
Sen. Lecturer, Institutes for Climate Change and Adaptation, University of Nairobi, Kenya

Dorothy A. Amwata
Sen. Lecturer South Eastern Kenya University, Kenya

Abstract

Vulnerability to climate change impact is the most pressing issues for less developed countries whose economy mainly depends on the agricultural sector. The demand for food is growing swiftly whereas impacts of climate change on the global food production are increasing. More area specific research outputs and evidences-based policy directions are needed to tackle the ever changing climate and to reduce its impacts on the agricultural production. The aim of this study was to investigate subsistence farmer household's vulnerability level to climate change impacts and its associations with household's agricultural production. Then primary data was collected from 400 households from Kolla Temben District, Tigray Regional State, North Ethiopia. Multistage sampling techniques were applied to select households for interview from the district. In the first stage, 4 Kebelles (Kebelle - administration unit) were selected randomly out of 27 Kebelles and then400 households were selected for interview through systematic random sampling techniques (Figure 1). Multiple regressions were used to examine the associations between household's vulnerability to climate change impacts and agricultural production. Grounded theory and content analysis techniques were use to analyze data from key informant interviews and focus group discussions. For every single unit increase in household vulnerability to climate change impacts, there was an average agricultural production decrease between 16.99 and 25.83 (Table 4). For single unit increase in household's vulnerability to climate change impact, there was a decrease of total crop production, Total income, total livestock, total food consumption and food consumption per adult equivalent. Rainfall decrease, small farmland ownership, steep topography, frequent flood occurrences and large family size are among the major factors that negatively affect household's agricultural production and total income. The more the vulnerable the households, the less in total annual crop production, total livestock size, total income from agricultural production and the more dependent on food aid). There is a negative association between household's vulnerability level to climate change impacts and agricultural production (crop production, total livestock ownerships and total income from crop production). More access to irrigation and agricultural fertilizers, improved varieties of crops, small family size, improve farmland ownership size, more access to education and Agricultural Extension services are an effective areas of intervention to improve household's resilient, reduce households vulnerability level to climate change impacts and increase household's total agricultural production.

Keywords: Farmers vulnerability; Vulnerability calculation methods; Agricultural production and climate resilient.

1. Introduction

In the 21st century, agriculture remains central in tackling the three challenges of improved food security, adapting to the impacts of climate change and variability, and reducing greenhouse gas emissions at a time when resources are gradually becoming more limited for global food systems [1].

The impacts of climate change on economic bases, societies and environment is very significant [2]. Change in climate patterns (temperature and precipitation) and the distribution of the natural base leads to unpredictable and erratic rainfall pattern, warmer temperature and diminishing of water availability and agricultural production [3]. More investigation is essential to improve the understanding on the possible impacts of the changing climate in the food system in a 2^{o}C+ temperature world compare with the pre- industrial level as the international community

*Corresponding Author

agreed in the Paris Accord to limit temperature increase to 1.5-2^{o}C Thornton, *et al.* [4] and Masson-Delmotte, *et al.* [5].

Crop modelling studies have paid limited attention to adaptation, vulnerability level and other indicators related to agricultural performance in simulating crop yields and total income [6]. Sub-Saharan Africa will lose 26 million dollars by 2060 as a result of climate impacts [7]. Agricultural return and total income are likely to decrease [8]. Increasing levels of CO_2 concentration in the atmosphere enhances agricultural productivity with minimum nutrient content [9]. On the other hand, climate change and variability can have positive effects on agriculture production and income [10]. The impacts of temperature increase on agriculture production and total revenue in rainfed agriculture is negative but precipitation increase has positive effects [11].Temperature increase in irrigation supported area has positive impacts on agricultural production [11].

Significant changes may be needed to people's livelihood and agricultural production systems if household's food security status and total income is to be enhanced in the ever changing climate of East Africa [12] .Diversification of the means of livelihood improves household's incomes in the current ever changing climate [13].Although agriculture is the main source of many households' income in East Africa, the impacts of climate change and variability in the sector have not been adequately addressed [14].

According to Schipper [15], reductions of the vulnerability level of the poor through development is a better approach than reducing vulnerability through adaptation. The applications of climate vulnerability index(CVI) to sub national and community levels helps in identifying those mostly at risk and to allocate resources towards those in most need of it Sullivan and Meigh [2].Irrigation can help subsistence farmers to manage climate change impacts [16].The guidelines available to structure vulnerability assessments that can also be used to compare and to make generalizations is very little [17].Climate change will have different impacts on vulnerable groups [18]. Several adaptation measures have been put in place to mitigate climate change namely agro-forestry, diversification of livelihoods among others. For example, agro-forestry is important in reducing a household's vulnerability to climate change [19]. The trees sequester carbon and often provide other benefits such as food, fruits, firewood and soil and water conservation [17]. A lot of research remains to be done regarding food production vulnerabilities to climate change impacts [20]. All sectors and groups of societies are not at the same level of sensitivity and vulnerability level to climate change impacts.

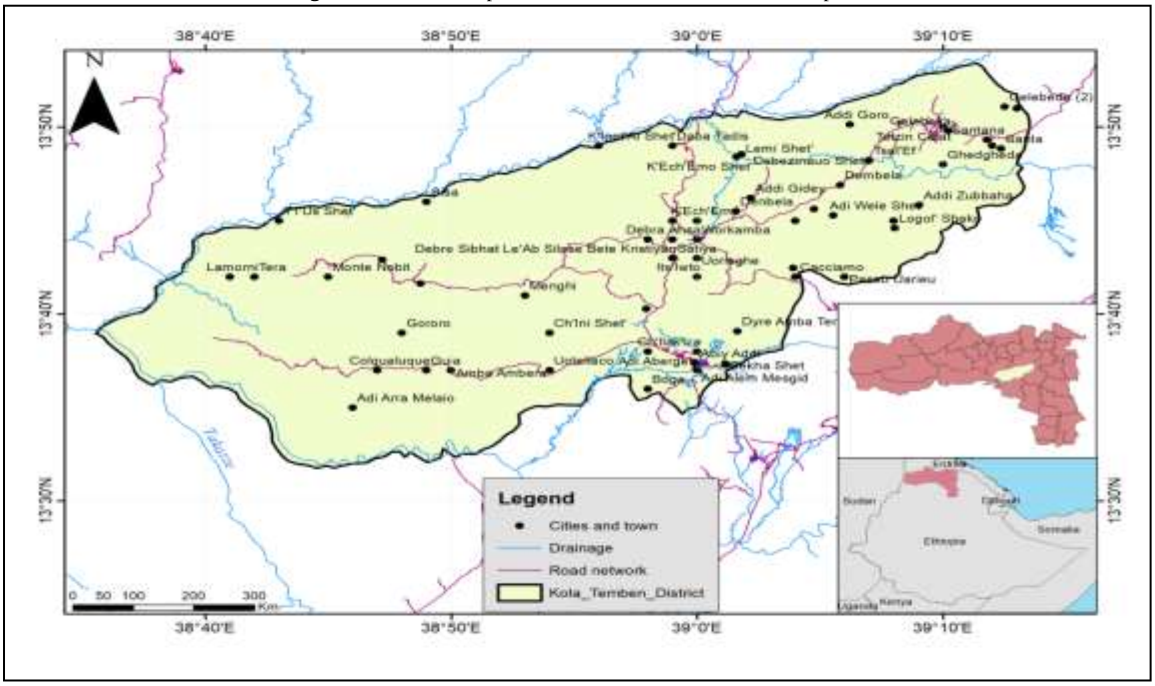
2. Methods and Description of the Study Area

2.1. Description of the Areas

2.1.1. Location

The study area, Kolla Temben District, lies in the central zone administration of the Tigray Region, 95 km west of Mekelle City, the capital city of the Regional State. The Kolla Temben District is bordered by Naeder Adet District to the northwest, Wereleke District to the north, Abergele District to the south, Western Zone District to the west, and Hawzen District to the east part (Figure 1).The road network of the Regional State comprises 4,949 km of dry weather roads, 2,522km all weather roads, and 497km of paved roads [21].

Figure-1. Location map of Kola Temben District, North Ethiopia



2.1.2. Climate

According to the Regional State Bureau of Agriculture, the Tigray Regional State has three Agro-Ecological Zones, namely, Lowland (hot area) at 1600 meters above sea level, Mid-Highland at 1600-2300 meter and Highland

(Cold land) at 2300-3000 m above sea level. The climate of the regional state issemi arid ("Kolla") at 39%, warm temperate ("Woinadega") 49%, and temperate ("Degas") at 12% for each of the three agro-ecological zones, respectively. The annual rainfall of the regional state is 450-980 mm and the estimated population density is 86.56 people per km^2.The average altitude of the Regional State Capital, Mekelle, is 2100 metres above sea level with temperatures between 11ºC and 23ºC with annual rainfall range of 900 to1800 mm. The altitude of the Kolla Temben District (study area) is 1400 to 2300 metres above sea level, and therefore covers the following climatic zones: Lowland (Kola), 'WeyinaDega' (midland) and 'Dega' (highland). The Kolla Temben District annual rainfall is 500 mm to 800 mm with an annual average temperature of 25-30ºC.

3. Method

3.1. Sampling Techniques

To determine household's vulnerability to climate change impacts, data on the farmer households exposure, sensitivity, and adaptive capacity to climate change impacts were collected from 400 households in Kolla Temben District, Northern Ethiopia. The sample size was determined as explained below, and the data collection instruments used in this study were structured and semi structured survey questionnaires.

To calculate the sample size, the total population and the number of households were obtained from the Kolla Temben District Finance and Economic development office. The formula used to calculate the sample size was from Yamane [22]:

$$n = \frac{N}{1+N(e)^2} \qquad \text{Equation (1)}$$

Where:

n –calculated sample size

N –total number of households in KollaTemben District

e – Level of precision

The total number of households in Kolla Temben District is 28,907 and the required sample size for the survey study according to the formula is 395 households but the study has used 400 households for the study.

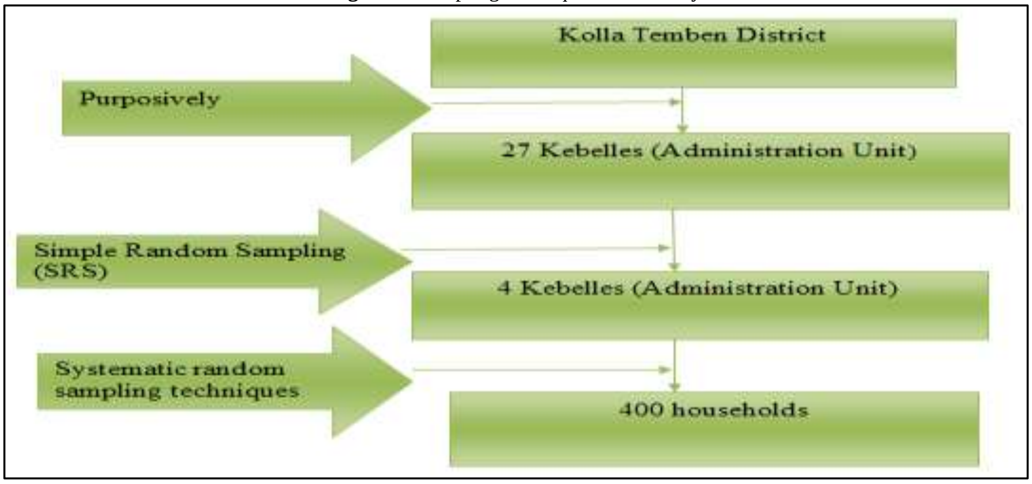
$$\frac{N}{1+N(e)^2}$$

$$\frac{28907}{1+28907(0.05\text{x}0.05)}$$

n = 394.54 households

The Multistage sampling technique was applied to select the specific 400 households for the survey. In the first stage, four Kebelles was selected using simple random sampling techniques out of the given 27 Kebelles in the District. After this, 400 households were selected from the lists of households in the four Kebelles (Newi, Awetbekalsi, Atakility and Begasheka) through the systematic random sampling techniques. The sample interval was calculated using total number of households divided by total sample size for each Kebelle and then selected the random start between the household listed in number one and the interval number .The sampling interval was repeatedly added to select the subsequent households up to all the required 400 households in all the 4 Kebelles were selected for interview. The total number of households in each of the Kebelles was: Newi 1325, Awetbekalsi 1130, Atakility 1679 and Begasheka 1373. This translated to the following number of household samples per Kebelle-Newi 96, Awetbekalsi 82, Atakility 122 and Begasheka 100.

Figure-2. Sampling techniques of the study



3.2. Data Collection Methods

3.2.1. Survey

To determine household's vulnerability to climate change impacts, data on the farmer households exposure, sensitivity, and adaptive capacity to climate change impacts were collected from 400 households in Kolla Temben District, Northern Ethiopia. Data was collected in Likert [23] scale (Table 1) to ease the data collection and analysis and also to accurately examine household's vulnerability level to climate change impacts.

Table-1. Household's vulnerability indicators- Hh-households

Categories	Cluster	Households status towards;	Choose one
Household's exposure level to climate change impacts	Biophysical	High flood incidents	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		Landslide incidents	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		Extreme temperature events	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		Wind extreme events	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		House damage by intense rainfall	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		Farmland's exposure to flood	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
		Farmland difficult for farming	Very low = 5, Low = 4, Medium = 3, High = 2 , Very high = 1
		Soil fertility status	Very low = 5, Low = 4, Medium = 3, High = 2 , Very high = 1
		Waterborne diseases because of contamination by floods	Very low = 1, Low = 2, Medium = 3, High = 4 , Very high = 5
Household's sensitivity to climate change impacts	Socio-economic	Types of Agriculture practices?	Agriculture without irrigation/fully rain dependent =2, with same irrigation supplement = 1, Agriculture with fully depend on irrigation = 0
	Socio-economic	Sources of energy for cooking energy source	Electric or Kerosene = 0, wood fuel or charcoal = 1, Exclusively depend on wood fuel = 2
	Socio-economic	Sources of water for domestic use	Piped water = 0, Spring water = 1, both = 2
	Socio-economic	Sources of household's livelihood	Fully Agriculture = 3. Agriculture and safety-net program = 2, Agriculture and non-farm activities = 1
Household's Adaptive capacity to climate change impacts	Socio-economic	Household assets in Ethiopia Birr (ETB)	<14,863 = 0, ≥14863- 16,332.20 = 1, 16333-190,300 = 2
	Socio-economic	Household land size hectare in ha	0ha = 0, <.25 ha = 1, ≥.25-0.5 ha = 2, >.05ha-1 ha = 3, >1ha-1.5 ha = 4, >1.5ha = 5
	Socio-economic	How many times hhs getting Agricultural Extension, services in year	Not all = 0, 1-2 times a year = 1, monthly = 2, Weekly = 3, Daily = 4
	Socio-economic	No of family member has attended or attending school	Three and above = 3,Two family = 2,One family member = 1, None = 0
	Health	No of family members have terminal illness?	Three and above = 0 two family = 1 one family member and above , None = 3
	Health	No of family member has physical disability	Three and above family member = 0, two family = 1, one family member = 2 None = 3
	Socio-economic	No of family members under working age group as local standard?	Three and above = 0. two family member = 1 one family member = 2,None = 3
	Socio-economic	Frequencies of hh visited by development agent and health extension workers in a year	Not all = 0, 1-2 times a year = 1, monthly = 2, weekly = 3, Daily = 4.

	Socio-economic	Hh residents distance from public transport,	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residents distance education	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residents distance from Kebelle centre	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residents distance from health station	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residents distance from URAP road	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residents distance from market centre	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1
	Socio-economic	Hh residents distance from agricultural extension station	<-5 km = 4, 5.-10 km = 3, >10 km <15 = 2, >15 Km = 1

3.3. Focus Group Discussion and Key Informants' Interviews

3.3.1. Focus Group Discussions (FGD)

Focus group discussions (FGD) were held with 40 people, selected with the help of the Kebelle administrators and development agents, during the period April to September 2016.The data collected from focus group discussion from all the four Kebelles (Newi 10 households, Awetbekalsi 10 households, Atakility 10 households and Begasheka 10 households) was focused on climate change and variability relation with agricultural production, factor affect agricultural production, main causes for household's high vulnerability to climate change impacts and possible solutions to address climate change challenges (Table 2).

Table-2. Profiles of focus group discussion (FGD) participants

Attributes	***FGD1***	***FGD2***	***FGD3***	***FGD4***
Name of Kebelle	Newi	Atakility	Begasheka	Awetbekalsi
Age	50-65	50-65	50-65	50-65
Education	1-12 grade	1-12 grade	1-12grade	1-12 grade
Farming experiences	30-45 years	30-45 years	30-45 years	30-45 years
No of famers	10 (5 female and 5 male)	10 (5 female and 5 male)	10 (5 female and 5 male)	10 (5 female and 5 male)
Kebelle Administrator	1	1	1	1
Development agent	1	1	1	1

Sources: Fieldwork 2016/2017

3.3.2. Key Informants' Interviews (KII)

Key informant interviews (KII) were conducted with 18 consisting of development agents deployed by the government to provide agricultural extension services to farmers and community leaders who were believed to be knowledgeable on climate change and food production issues in the district. They were selected with the help of the Kebelle administrators and development agents and their level of education, farming experiences and age were taken into considerations (Table 3). The interviews took place during the period April to September 2016. The key informant interviews were focused on rainfall and temperature trends, agricultural production and farmer's level of exposures to shocks and capacity to cope.

Table-3. Profiles of Key informant interview (KII) participants

Attributes	***KII 1***	***KII 2***	***KII 3***	***KII 4***
Name of Kebelle	**Newi**	**Atakility**	**Begasheka**	**Awetbekalsi**
Age	50-65	50-65	50-65	50-65
Education	5-12 grade	5-12 grade	5-12 grade	5-12 grade
Farming experiences	30-45 years	30-45 years	30-45 years	30-45 years
No of famers	4(2 male and 2 female)	4(2 male and 2 female)	4(2 male and 2 female)	4(2male and 2 female)
Kebelle administrator	1	1	1	1
Development agent	1	1	1	1

Sources: Fieldwork 2016/2017

3.4. Data Analysis Methods

3.4.1. Survey Data

Data on all the indicators for household vulnerability level were collected and indexed for ease of analysis and interpretations. All indexed results for household's vulnerability level were statistically tested to scrutinize the associations between household's vulnerability level to climate change impacts and agricultural production and total income.

The overall household's vulnerability level to climate change impacts was calculated using the IPCC [24] definition and as applied by Opiyo, *et al.* [25], Nkondze and Masuku [26] and Bobadoye [27] using the indicators in Table 1. It can be expressed as follows:

Household vulnerability = Adaptive capacity – (exposure + sensitivity). – Equation (2)

$Vi = (A_1X_{1J} + A_2X_{2J} + \dots + AnXnj) – (A_1Y_{1j} + A_2Y_{2j} + \dots\dots\dots AnYnj)$ – Equation (3)

Where:

Vi = vulnerability index

X = indicators for adaptive capacity

Y = indicators for exposure and sensitivity

J = Variables

A = First component score of each variable.

The household's vulnerability index was then calculated using the indicators (Table 1) for adaptive capacity, exposure and sensitivity; and quantified through Likert scales [23].This was used to determine household's vulnerability to climate change impacts in the Kolla Temben District.

Finally, a household's vulnerability level to climate change impacts was classified into one of three groups (low vulnerability, medium vulnerability, high vulnerability, Peris, *et al.* [28] based on the mean value of Vi (24.7) and its standard deviation (16.9), respectively. Thus, "low" comprised those whose score was less than the total mean (24.7), "medium" for those that scored 24.7 to 41.6 (sum of the mean and standard deviation), and "high" for households which scored greater than the sum of the standard deviation and mean (41.6). These three vulnerability categories of households were coded in the SPSS software as: 1 = High, 2 = Medium and 3 = Low to ease the statistical and crosstabs analysis of the data. This categorization was based on the principle that households with higher adaptive capacity are less vulnerable, and *vice versa*.

The relationship between household vulnerability level to climate change impacts, agricultural production and total income was also tested. The vulnerability indicators used in the analysis and their assigned weighted values are presented in Table 2.

Multiple regression analysis uses to examine a relationship between multiple independent variables with dependent variable [29]. The study used multiple regression analysis to examine the relationship between household's vulnerability to climate change impacts (continuous scale) with agricultural production and total income (household's total crop production in Kg, household's total income in ETB (Ethiopia Birr), household's total livestock ownership in Tropical Livestock Unit (TLU) and household's food consumption in Ethiopia Birr (ETB),household's annual food consumption in Kg from aid and household's total annual crop sales in Kilograms(Kg). Multi-co linearity test was done before the multiple regression analysis was underway to examine for multi-co linearity of variables through variance inflation factors (VIF) which could inflate the coefficients. A VIF values above 10 were taken as a multi-co linearity problem [30]. Accordingly, multi-co linearity problem was not found that demands removal of any variables from multiple regression analysis. Therefore, all variables were included in the multiple regressions for analysis. Stata 10 computer software was used to run the VIF for multi-co linearity test.

3.3.2. Focus Group Discussion and Key Informant Interviews Data Analysis

Grounded theory and content analysis techniques were used to analyze data from key informant interviews and focus group discussions [31]. In focus group discussion, most of researchers use text to examine what participants stated in group discussions [32]. In analyzing focus group discussion (FGD), the group is the unit of the analysis [33]. Content analysis uses to analyze qualitative data from focus group discussion (FGD) and help to determine the main concepts mentioned in the focus group discussion [34]. Hence, the study has used the content analysis techniques to analyze data from focus group discussion. The group was the unit of the analysis.

The key informant interview was analyzed using content analysis of the themes grounded theory and some quotes was also included to represent direct voices by key the informants**.** In the analysis of the key informant discussions (KII), three themes were identified; rainfall and temperature trends, factors affect agricultural production and farmer's level of exposures to shocks and capacity to cope.

4. Results

4.1. Farmer Households Vulnerability to Climate Change Impacts

The majority of households in Kolla Temben District (47.5%) fell in the high vulnerability level category to climate change impacts whereas 39.3 % and 13.3 % households constituted medium and low levels respectively (Table 4). This shows that the majority of households (47.5%) are highly vulnerable to climate change impacts.

Table-4. Status of Household vulnerability levels

Vulnerability level	Freq.	%
High	190	47.5
Medium	157	39.3
Low	53	13.3
Total	400	100.0

Sources; fieldwork, 2016/17

4.2. Relationship Between Household Vulnerability Level, Agricultural Production and Total Income

To determine the relationship on household's vulnerability level to climate change impact a multiple linear regression was carried out. First, a multi-co linearity correlation test of the independent variables was conducted to ensure variables included in the analysis were not correlated. Households' vulnerability levels to climate change impacts had a negative association with household's total crop production in Kilo grams (Kg), household total income in Ethiopia Birr (ETB), household's livestock ownership in tropical livestock unit (TLU), household's total food consumption, household's total food consumption per adult equivalent and total crop sales. Household's vulnerability level to climate change impact was found positively related with household's total food consumption from aid. For every single unit increase in household vulnerability to climate change impacts, there was an average agricultural production decrease between 16.99 and 25.83 (Table 5). For single unit increase in households vulnerability to climate change impact, there was a decrease of total crop production, total income, total livestock, , total food consumption and food consumption per adult equivalent (Table 5).This revealed that climate had negative impact on household's total agricultural production, household's food consumption and total crop sales in Kolla Temben District (Table 5).

Table-5. Multiple regression results of vulnerability to climate change impacts and food production

Multiple regression	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	21.412	2.247		9.530	.000	16.995	25.830
Household total crop production in Kg	-.003	.002	-0.091	1.751	.001	.000	.006
Household total income in ETB	-006	.000	-0.004	.008	.936	.000	.000
Households livestock ownership in TLU	-.769	.355	0.116	2.164	.031	.070	1.468
Household total food consumption in Birr	-005	.000	-0.004	.060	.952	-.001	.001
Food consumptions per adult equivalent	-.001	.002	-0.041	-.589	.556	-.004	.002
Household total annual crop sales in Kg	-.008	.002	-0.170	- 3.389	.001	-.013	-.003
Household annual food consumption in kg from aid	.001	.002	0.024	.462	.645	-.003	.004

Sources: fieldwork, 2016/17

4.3. Most impacted agriculture in Kolla Temben District

4.3.1. Most Impacted Crops by Climate Change and Variability

Majority of farmers (49.5%) listed maize as the most impacted crop and Sorghum was mentioned by (21%) farmers as the most impacts crop and the other 17.5% ,2.8%,6.8% farmers reported Sorghum, Teff, Millet and Bean as the most negatively impacted crops by climate change and variability respectively (Table 6). The study shows that maize was the most negatively impacted crop in Kolla Temben District.

Table-6. The most impacted crops by climate change and variability in Kolla Temben District

Crop types	Freq.	%
Maize	198	49.5
Teff	70	17.5
Sorghum	84	21.0
Millet	11	2.8
Bean	27	6.8
Total	390	97.5
No response	10	2.5
Total	400	100.0

Sources: fieldwork, 2016/2017

4.3.2. Most Impacted Livestock by Climate Change and Variability in Kollatemben District

Majority of famers (48.3%) reported that milking cows are the most impacted livestock to climate change impacts in Kolla Temben District. Other 20 percent households reported that climate change and variability had negatively impacted livestock health in the District. The rest 19.5 households reported that goat and sheep was negatively was impacted by climate change and variability (Table 7). This shows that the livestock sector in general and the milking cows in particularly have negatively impacted by climate change and variability in Kolla Temben District.

Table-7. The most impacted livestock by climate change and variability in Kolla Temben District

List of Livestock		Freq.	%
	Sheep and Goats	78	19.5
	Milking Cows	193	48.3
	All types of Cows(milking and none milking)	38	9.5
	Poultry (Chicken)	6	1.5
	Livestock health	80	20.0
	Total	395	98.8
Missing	System	5	1.3
Total		400	100.0

Sources: fieldwork, 2016/2017

5. Results from Focus Group Discussion and Key Informant Interview

5.1. Focus Group Discussion Results

The focus group discussions showed that almost all famers in the four Kebelles (Newi, Atakility, Awetbekalsi and Begasheka) of the Kolla Temben District attributed their vulnerability levels to factors such as rainfall variability, increase in temperature and low soil fertility which has reduced their agricultural production and total income (Table 4).This shows that climate variability and low soil fertility has negatively impacted household’s total agricultural production and total income in Kolla Temben District.

The focus group discussions participants in all the four Kebelles (Newi, Atakility, Awetbekalsi and Begasheka) reported that a decrease in rainfall, small landownership and large family size as some of the major factors that affect agricultural production and total income. On the other hand, in Newi and Atakility Kebelles, other additional factors that leads to reduction in agricultural production and income to include steep topography and frequent flood in Kolla Temben District (Table 8).

All focus group discussion (FGD) participants from the four Kebelles (Newi, Atakility, Awetbekalsi and Begasheka) mentioned that household’s large family size, small farmland ownership status, less access to education and agricultural extension services were the major causes of high vulnerability)of households in Kolla Temben District. The participants suggested more access to irrigation facilities, agricultural fertilizers and improved varieties of crops as effective measures to improve on household’s vulnerability level and total agricultural production(Table 8). This shows that vulnerability is context specific and each area requires specific demand driven solutions to address household’s vulnerability to climate impacts and improve agricultural production in Kolla Temben District.

.

Table-8. Focus group discussion (FGD) results

Guiding open ended questions forwarded by facilitator to the FGD (focus group discussion) participants	Concepts stated by the FGD (focus group discussion) participants (40) in four Kebelles Kolla Temben District, North Ethiopia			
	Newi Kebelle (10)	**Atakility Kebelle (10)**	**Begasheka Kebelle(10)**	**Awetbekalsi Kebelle (10)**
How do you see the issues of climate variability and change in relation to agricultural production and total income in your Kebelle?	Rainfall variability, temperature increase and low soil fertility are affecting agricultural production and total income	Rainfall variability and low soil fertility are affecting agricultural production and income from livestock production	Rainfall variability, temperature increase, low soil fertility is affecting agricultural production and income	Rainfall variability and low soil fertility are affecting agricultural production and income
What are the major factors affecting the total production and income of households in this Kebelle?	Rainfall decrease, Small land ownership, large family size and low soil fertility, steep topography and flood	Rainfall decrease, Small farmland ownership, steep topography and flood	Rainfall decrease and small farmland ownership	Rainfall decrease and small farmland
What are the causes for (Vulnerability) in this Kebelle?	Large family size, small farmland size, less access to education and Agricultural	Large family size, small farmland size, less access to education and Agricultural	Large family size, small farmland size, less access to education and	Large family size, small farmland size, less access to education and Agricultural

	Extension) and rainfall based agriculture	Extension and rainfall based agriculture	Agricultural Extension and rainfall based agriculture	Extension and rainfall based agriculture
What solution do you recommend to solve the problems of vulnerability in your Kebelle?	Improve access to irrigation, fertilizers and improved varieties of crops	More access to livestock feed, irrigation, fertilizers and improved varieties of crops	Improve access to irrigation, fertilizers and improved varieties of crops	Improve access to irrigation, fertilizers and improved varieties of crops

Sources: Fieldwork 2016/2017

5.2. Key Informant Interview Results

From the 16 key informants' interviews, the three drivers identified to influence vulnerability and agricultural production are: rainfall and temperature trends; factors affecting agricultural production and farmer's level of exposures to shocks and capacity to cope. The key findings from the KII are discussed below.

5.2.1. Changes in Rainfall and Temperature in Relation to Agricultural Production

All participants of the KII (Key informants' interview) said that the decline in rainfall pattern and increase in temperature has negatively affected their agricultural production. One participant from Begashika Kebelles aid and quoted 'the issue of rainfall is becoming very hard, my life is getting worst as result of rainfall decrease; rainfall start in July and stopped in the first week of September. Long time ago, rain was started in May and last to September but this time rainfall duration is getting shorten, lasted only for two months (Jully to August)and making my agricultural practices difficult. How can I survive in such situation and feed my family''? This shows that the impacts of climate change in Kolla Temben District are very severe and famers in the district are lacking the capacity to cope with such impacts.

All participants of the key informants interview (KII) stated that new pest infestations was becoming common on their farms and also they lack access to effective pesticides to control them. As stated by one participants from Newi Kebelle and quoted ''Temperature is increasing very rapidly and also we are experiencing very hot days in May and very cold one in October and November. Our sources of water for livestock and human consumption are getting dry and we are forced to travel long distance to access water. Our livestock have been affected by new animal diseases and the milk production is decreasing with some changes in its natural tastes. We need more help and technical advises from government bodies and experts."''I am not aware why the taste of the milk is changing and the new insects and pests are coming to my farm''. Another farmer from Awetbekalsi Kebelle said and quoted "Getting enough food at this time is difficult. 'I am now almost dependant on food aid from government and aid agencies to feed my family''. ''Rainfall is decreasing and the rainy period is getting too short to produce more food. Temperature for the months February, March and May are getting hotter than usual and exposing my household to malaria incidents''. This shows that rainfall has decreased significantly in Kolla Temben District and the agricultural production in the district has been negatively affected. It also revealed that increase of temperature has created conducive environment for malaria epidemics in Kolla Temben District. This also shows that famers have observed a new phenomenon (changes in the taste of their cow's milk, infestation of new insects and pests). This also confirmed that more empirical research is important to know if such phenomenon (changes in the taste of cow's milk, infestation of new insects and pests) observed in Kolla Temben are related with the changing climate in the study area. These changes might be a mal-adaptation (increased vulnerability or above the genetic limit to adapt impacts) and more research works is therefore needed in the district to identify the root causes.

5.2.2. Factors that Affect Agricultural Production and Income

All participants of the KII mentioned that low soil fertility, continuous decline of rainfall, steep topography, small land size ownerships, less access to irrigation and agricultural fertilizers were the major factors that affected agricultural production and total income**.** One participant from the Awetbekalsi Kebelles aid and I quote: 'The land size I own is less than a hectare and its fertility is also decreasing continuously but my family is getting bigger. I have no idea how I could feed this large family'. One participates from Newi Kebelle similarly also said and I quote: 'Many years ago, the rainfall, soil fertility, weather condition and agricultural production were good. Feeding a family was not a challenge but nowadays everything has changed. I can't even feed my family for more than five (5) months. My family has fully depended on food aid. The rainfall is not in my side. I have no irrigation facility. Life becomes too difficult'. This clearly shows that most of the famers in Kolla Temben District have been adversely affected by climate change impacts and the agriculture sector is under the stress of climate related impacts.

5.2.3. Farmer's Level of Exposures to Climate Related Shocks and Capacity to Cope

The third drivers from the KII (Key informants' interview) in Kolla Temben District were farmer's level of exposures to climate related shocks and capacity to cope. All participants from the four Kebelle(Newi, Atakility, Awetbekalsi and Begasheka)said that farmers were highly exposed to flood, heavy rain, landslides and food insecurity. They also reported that famers' capacity to cope with climate related stocks were very low and all supports requested from the local and central government have not delivered much. One participant from Atakility Kebelle said and I quote: 'Flood is damaging the farmland I have and as a result productivity is decreasing. Food insecurity is a big challenge to my family and I have no means to cope with such challenges except to ask the government for food aid '.

This shows that famers in Kolla Temben District are highly vulnerable to impacts of climate change and their capacity to cope with these impacts is very low. This also shows that climate change and variability have negatively impacted farmer's food security in Kolla Temben District.

6. Discussion

Luxon and Pius [35], reported that extreme climate events in Sub-Saharan Africa will be severe. According to Nkondze and Masuku [36] who reported that the number of family members in sickness, those with many dependants, large family sizes and less livestock ownership status adversely influence a household's level of vulnerability to climate change impacts. Opiyo, *et al.* [25] reported on farmers' vulnerability in Kenya that 27% of them are highly vulnerable, 44% moderately vulnerable, and 29% least vulnerable but in Kolla Temben District 47.5% households was found to be highly vulnerability to climate change impacts and only 13.3% and 39.3% were found in the low and medium vulnerability categories (Table 4). This study supports the findings of Nkondze and Masuku [36] who reported that livestock ownership status influence household's vulnerability levels. Similarly, Godber and Wall [37] revealed that climate vulnerability will affect livestock production in sub Saharan Africa. Findings from Kolla Temben District support the above conclusion that household vulnerability level to climate change impact has negative relationships with households total crop production, total income, total livestock size ownership, total annual crop sales (Table 5). This is also in agreement with the views of Moore, *et al.* [38] and Kotir [39] that vulnerability to climate change impacts can affect crop yields negatively in Sub-Saharan Africa.

Monirul, *et al.* [40] reported that income, agricultural activities and agricultural land has impacts on household's vulnerability to climate change; those findings are supported by the outcomes of this study that shows that there is negative relationship between household's vulnerability level to climate change impacts and household's total crop production and livestock size in Kolla Temben (Table 5). Similar findings have been reported by Hoffmann [41] who noted that climate change impacts have differential impacts on meat, milk and eggs production.

Majority of households (47.5%) in Kolla Temben District was found with high vulnerability level to climate change impacts. Only 13.3% of famers in the district were with low vulnerability to climate change impacts. The rest 39.3 % farmer households were with medium level of vulnerability to climate change impacts (Table 4). Opiyo, *et al.* [25], reported on farmers' vulnerability in Kenya that 27% highlyvulnerable, 44% moderately vulnerable and 29% less vulnerable to climate change impacts. This shows that there is no uniformity in famers' vulnerability level to climate change impacts. This also shows that farmers in Kolla Temben District are the most vulnerable to climate change impacts.

Household vulnerability level to climate change impact had negative relationships with households total crop production, total income, total livestock size, total food consumption and annual total crop sales (Table 5). Monirul, *et al.* [40], revealed that vulnerability to climate change impacts had direct impacts on meal consumption frequencies in the marginalized rural households. This result is in agreement with findings of Thornton, *et al.* [4] that climate negatively impact agriculture in Sub-Sahara Africa.

There was significant negative relationship between household's vulnerability level to climate change impacts and household's total crop production and total livestock size (Table 5).This result corroborate the findings of Nkondze and Masuku [26] that livestock ownership status influence household's vulnerability level. This is also in agreement with findings of Nkondze and Masuku [26] that household vulnerability to climate change impact and livestock production has direct relationship. The more the households are vulnerable to climate change impacts, the lesser in total crop production and livestock size they had. This supports the findings of Godber and Wall [37] that climate vulnerability will affect livestock production in sub Saharan Africa. There was a statistically significant negative relationship between household's vulnerability level to climate change impacts and household's total crop sales. Climate change had negative impacts on the availability of crop products in the markets. This confirms the results of Moore, *et al.* [38] that vulnerability to climate change impacts can affect crop yields and market stability negatively. The availability of crop products in the market were determined by households' vulnerability status to climate change impacts (Table 5). A single unit increase in household's vulnerability to climate change cause significant decrease in crop production. Vulnerability to climate change negatively affect agricultural production and total food consumption (Table 5).This finding is in support to the projection made by Kotir [39] that climate vulnerability in Sub-Saharan Africa is expected to affect food production. This shows that vulnerability to climate change impact has negatively impacted agricultural production. The more areas and the households vulnerable to climate change, the less in agricultural production and the more unstable markets and agricultural products prices.

The field study in Table 6 reported that 49.5 percent said that Maize was the most negatively impacted crops types in Kolla Temben District. Millet and Bean were the least impacted crop types by the impacts of climate change and variability. Only 17.5 percent households ranked 'Teff' as the most negatively impacted crop (Table 5).This is in support with the findings of Adu, *et al.* [42] that maize farming farmers are the most adversely impacted by climate change. This shows that maize is the most climate sensitive and hardily impacted crop types.

Milking cows were the most climate sensitive and negatively impacted livestock (Table7). Goats and sheep were found as the most climate sensitive livestock types next to milking cows (Table7). Poultry was found to be the least impacted livestock by climate change and variability (Table7). Rainfall variability, temperature increase and low soil fertility status had contributed for the continuous decrease in agricultural production (Table 8). Large family size, small farmland ownerships, less access to agricultural extension and education and dependency on rainfall based agriculture had contributions for household's high vulnerability to climate change impacts (Table 8). Hot environment damage livestock growth, meat and milk yield and quality [43]. This shows that climate change impact have negatively affected livestock size and quality of livestock products (milk and meat).More research works may need to be done on genotypes to produce milking cows with good phenotypic characteristics that can resist climate change impacts.

7. Conclusion

The relationship between household's vulnerability level to climate change impacts with agricultural production and total income is negative. Household's vulnerability level has significant negative impacts on total crop production, household's food security, total crop sales, total livestock ownership status, total income from crop production, total income from livestock, total crop sales and total income. The more vulnerable the households, the lesser in total agricultural production and total income. Household with lower vulnerability level to climate change has significantly higher total income, livestock ownership status and agricultural productions compare to those with higher level of vulnerability. The impacts of climate change on subsistence farmers are very stern. The taste of milk is changing but the causes for the change and its implications on human nutrition and health are not yet studied. Rainfall decrease has negatively impacted agricultural production and the availability of animal feeds. Farmers alleged that the frequency of occurrence of heavy rainfall and drought, malaria incidents, and migration trends have increased in the past three decades.

8. Declarations

8.1. List of Abbreviations

CVI Climate Vulnerability Index
CSA Central Statistics Agency
Km Kilo grams
Km Kilometre
Mm millimetre
Ha hectare
Hh Household
URAP Universal Rural Road Access Program
KII Key Informant Interview
IPCC Intergovernmental Panel on Climate Change
ETB Ethiopia Birr
TLU Tropical Livestock Unit
VIF Variance Inflation Factors
SRS Simple random sampling

8.2. Ethics Approval and Consent to Participate

Not applicable since this research did not involved any human and animal subjects.

8.3. Competing Interests

All the authors of the manuscript have declared that they do not have any competing interest.

8.4. Consent for Publication

Not applicable

8.5. Funding

The source of fund for this research project was the Mekelle University of Ethiopia. The funding body has no role in the design, analysis and interpretation of the study and writing of this manuscript.

8.6. Availability of Data and Materials

Data is available at Mekelle University and shared with especial request.

Acknowledgements

We would like to thank to the Mekelle University for its research fund support

References

[1] Beddington, J., Asaduzzaman, M., Clark, M., Fernandez, A., Guillou, M., Jahn, M., Erda, L., Mamo, T., Vanbon, N., *et al.*, 2012. "Achieving food security in the face of climate change. Technical report of cgiar,

research program plane on climate change, agriculture and food security, the commission for sustainable agriculture and climate change."

[2] Sullivan, C. and Meigh, J., 2005. "Targeting attention on local vulnerabilities using an integrated index approach: the example of the climate vulnerability index." *Water Science and Technology,* vol. 51, pp. 69-78.

[3] Ishaya, J. and Abaje, I. B., 2008. "Indigenous people's perception on climate change and adaptation strategies." *Journal of Geography and Regional Planning,* vol. 8, pp. 138-143.

[4] Thornton, K. P., Jones, P. G., Ericksen, J. P., and Challinor, J. A., 2011. "Agriculture and food systems in sub-Saharan Africa in a 4 °C+ world." *Phil. Trans. R. Soc.,* vol. 369, pp. 117–136.

[5] Masson-Delmotte, T. W. V., Zhai, P., Pörtner, H. O., Roberts, D., Skea, J., Shukla, P. R., and Connors, S., 2018. *IPCC, Summary for Policymakers. In: Global warming of 1.5 C. An IPCC Special Report on the impacts of global warming of 1.5 C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global*. Geneva, Switzerland.

[6] Reidsma, P., Ewert, F., Lansink, A. O., and Leemans, R., 2009. "Vulnerability and adaptation of European farmers: a multi-level analysis of yield and income responses to climate variability." *Regional Environmental Change,* vol. 9, p. 25.

[7] Dessalegn, O. G. and Akalu, D. S., 2015. "The impacts of climate change on African continent and the way forward." *Journal of Ecology and the Nnatural Environment,* vol. 7, pp. 256-262.

[8] Montle, B. P. and Teldemedhin, M. Y., 2014. "Assessments of farmers' perceptions and economic impacts of climate change in Namibia, case study in small scale irrigation of NdongaLinena irrigation project." *Journal of Development and Agricultural Economics,* vol. 6, pp. 443-454.

[9] Myers, S. S., 2017. "Planetary health: protecting human health on a rapidly changing planet." *The Lancet,* vol. 390, pp. 2860-2868.

[10] Olesen, J. E. and Bindi, M., 2002. "Consequences of climate change for European agricultural productivity, land use and policy." *European Journal of Agronomy,* vol. 16, pp. 239–262.

[11] Wanga, J., Mendelsohn, R., Dinar, A., Huang, J., Rozelle, S., and Zhang, L., 2009. "The impact of climate change on china's agriculture." *Agricultural Economics,* vol. 40, pp. 323–337.

[12] Jones, P. G. and Thornton, P. K., 2009. "Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change." *Environmental Science and Policy,* vol. 12, pp. 427-437.

[13] Yamba, S., Appiah, O. D., Siaw, P. L., and Asante, F., 2017. *Smallholder farmers' livelihood security options amidst climate variability and change in rural Ghana*. Scientifica Hindawi.

[14] Lunde, T. M. and Lindtjorn, B., 2013. "Cattle and climate in Africa: How climate variability has influenced national cattle holdings from1961-2008." *PeerJ,* vol. 1, p. e55.

[15] Schipper, E. L. F., 2007. "Climate change adaptation and development: Exploring the linkages." *Tyndall Centre for Climate Change Research Working Paper,* vol. 107, p. 13.

[16] Gwimbi, 2009. "Cotton farmers' vulnerability to climate change in Gokwe District Zimbabwe; impact and influencing factors." *Journal of Disaster Risk Studies,* vol. 2, pp. 81-92.

[17] Polskya, C., Neff, R., and Yarnal, B., 2007. "Building comparable global change vulnerability assessments: the vulnerability scoping diagram." *Global Environmental Change,* vol. 17, pp. 472–485.

[18] Bohle, H. G., Downing, T. E., and Watts, M. J., 1994. "Climate change and social vulnerability: toward a sociology and geography of food insecurity." *Global Environmental Change,* vol. 4, pp. 37-48.

[19] Thorlakson, T. and Neufeldt, H., 2012. "Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya." *Agriculture and Food Security,* vol. 1, p. 15.

[20] Richard, S. J. T., 2001. "Estimates of the damage costs of climate change." *Environmental and Resource Economics,* vol. 21, pp. 135–160.

[21] CSA, 2007. *Population and housing census of ethiopia, 3rd census of ethiopia*. Addis Abab.

[22] Yamane, T., 1967. *An Introductory statistics analysis*. 2nd ed. NewYork: Harper. p. 919.

[23] Boone, H. N. and Boone, D. A., 2012. "Analyzinglikert data." *Journal of Extension,* vol. 50, pp. 1-5.

[24] IPCC, 2012. *Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of working groups i and ii of the intergovernmental panel on climate change*. Cambridge, United Kingdom and New York, USA: Cambridge University Press. p. 582.

[25] Opiyo, E. O., Wasonga, V. O., and Nyangito, M. M., 2014. "Measuring household vulnerability to climate-induced stresses in pastoral rangelands in Kenya: Implication for resilience programmin pastoralism." *Research, Policy and Practice,* vol. 4, p. 10.

[26] Nkondze, S. M. and Masuku, B. M., 2013. "The impacts of climate change on Livestock production in Swaziland; the case of Mpolonjeni area development program." *Journal of Agricultral Studies,* vol. 2, pp. 2166-0379.

[27] Bobadoye, A. O., 2016. *Vulnerability assessment of Maasai pastoralists under changing climatic condition and their adaptation strategies in Kajiado County*. Kenya. Ph.D. Thesis, University of Nairobi, Kenya, Nairobi.

[28] Peris, R., Gimeno, M. A., Pinazo, D., Ortet, G., Carrero, V., Sanchiz, M., and Ibanez, I., 2002. "Online chat rooms: Virtual spaces of interaction for socially oriented people." *Cyber Psychology and Behavior,* vol. 5, pp. 43-51.

[29] Ghani and Ahmad, 2010. "Stepwise multiple regression method to forecast fish landing." *Procedia Social and Behavioural Sciences,* vol. 8, pp. 549–554.

[30] Neter, J., Kutner, M. H., Nachtsheim, C. J., and Wasserman, W., 1996. *Applied linear statistical models* vol. 4. Chicago: Irwin. p. 318.

[31] Strauss, A. L. and Corbin, J. M., 1998. *Basics of qualitative research: techniques and procedures for developing grounded theory*. 2nd ed. Thousand Oaks, CA: Sage Publications.

[32] Krueger, R. A., 1994. *Focus groups: A practical guide for applied research*. 2nd ed. Thousand Oaks: CA: Sage.

[33] Morgan, D. L., 1997. *Focus groups as qualitative research*. 2nd ed. Thousand Oaks: CA: Sage.

[34] Leech, N. L. and Onwuegbuzie, A. J., 2008. "Qualitative data analysis: A compendium of techniques and a framework for selection for school psychology research and beyond." *School Psychology Quarterly,* vol. 23, p. 587.

[35] Luxon, N. and Pius, C., 2012. "Climate change risk and vulnerability mapping and profiling at local level using the household economy approach." *Earth Science and Climatic Change,* vol. 3, p. 3.

[36] Nkondze, S. M. and Masuku, B. M., 2014. "The impacts of climate change on livestock production in swaziland; the case of mpolonjeni area development program." *Journal of Agricultral Studies,* vol. 2, pp. 2166-0379.

[37] Godber, F. O. and Wall, R., 2014. "Livestock and food security: vulnerability to population growth and climate change." *Global Change Biology,* vol. 20, pp. 92-102.

[38] Moore, N., Alagarswamy, G., Pijanowski, B., Thornton, P., Lofgren, B., Olson, J., and Qi, J., 2012. "East African food security as influenced by future climate change and land use change at local to regional scales." *Climatic Change,* vol. 110, pp. 823-844.

[39] Kotir, J. H., 2010. "Climate change and variability in Sub – Saharan Africa: a review of current and future trends and impacts on agriculture and food security." *EnvironDev Sustain,* vol. 13, pp. 587-605.

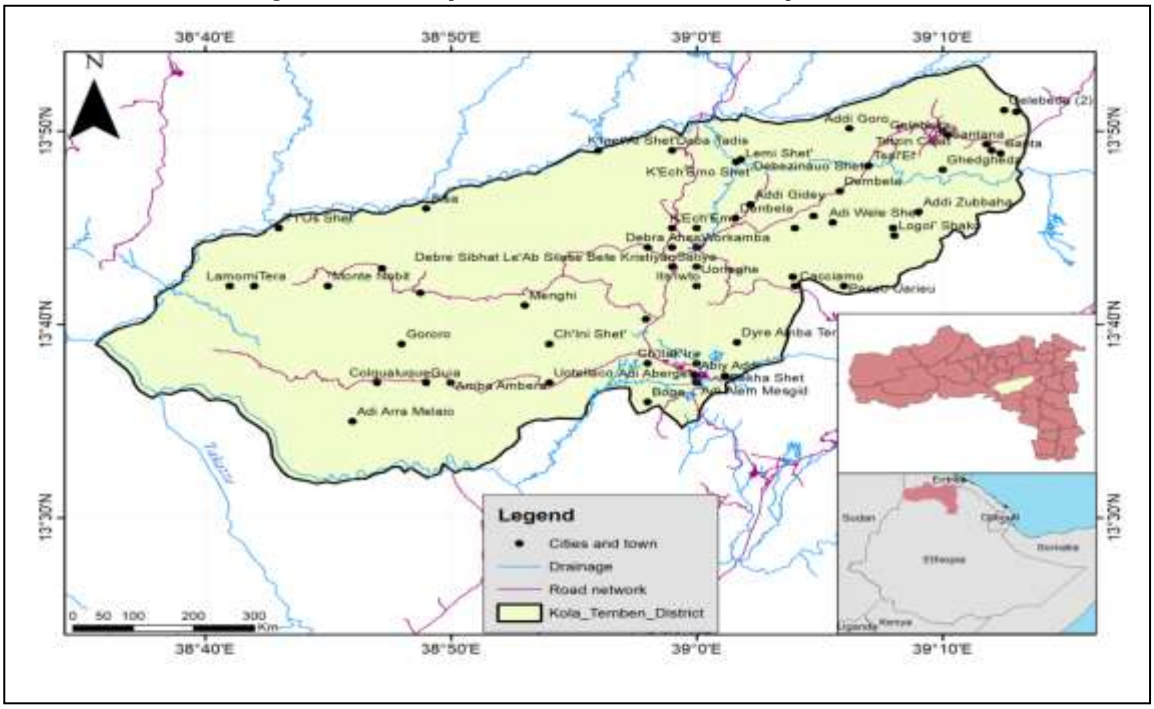
[40] Monirul, I. M. D., Susannah, S., Klaus, H., and Jouni, P., 2014. "Vulnerability of fishery-based livelihoods to the impacts of climate variability and change; insights from coastal Bangladesh." *Regional Enviromental Change,* vol. 14, pp. 281-294.

[41] Hoffmann, I., 2010. "Climate change and the characterization, breeding and conservation of animal genetic resources." *Journal of Animal Genetics,* vol. 41, pp. 32-46.

[42] Adu, D. T., Kuwornu, J. K., Anim-Somuah, H., and Sasaki, N., 2018. "Application of livelihood vulnerability index in assessing smallholder maize farming households' vulnerability to climate change in Brong-Ahafo region of Ghana." *Kasetsart Journal of Social Sciences,* vol. 39, pp. 22-32.

[43] Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M. S., and Bernabucci, U., 2010. "Effects of climate changes on animal production and sustainability of livestock systems." *Livestock Science,* vol. 130, pp. 57-69.

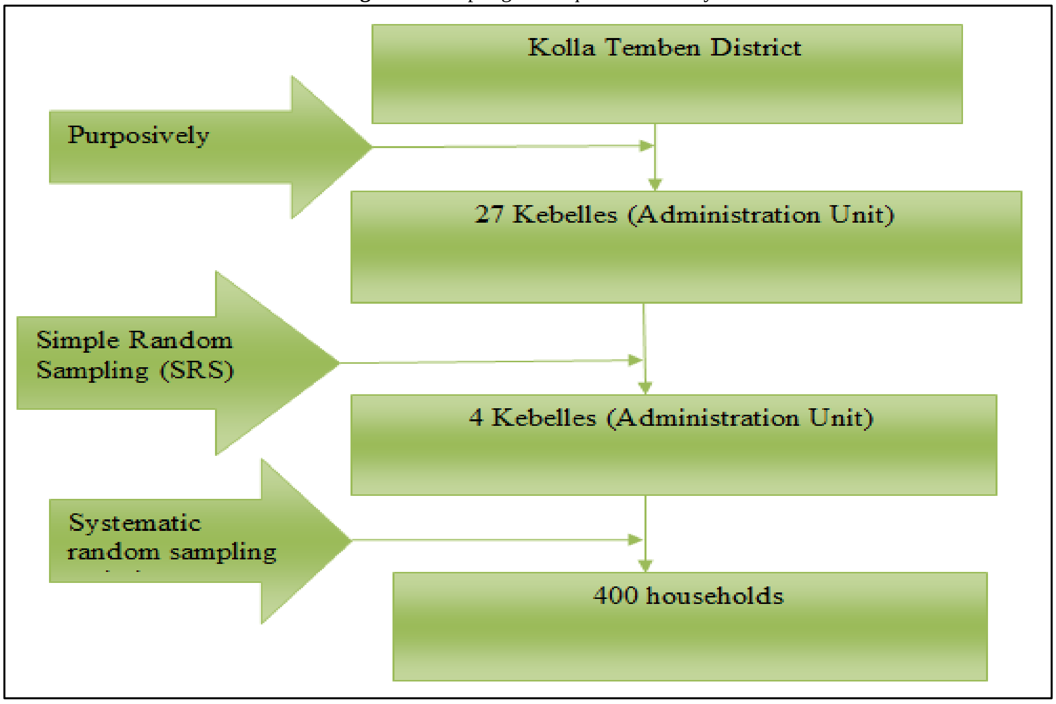
Figure-1. Location map of Kola Temben District, North Ethiopia



This is the location of the study area (KollaTemben District). Kolla Temben District, lies in the central zone administration of the Tigray Region, 95 km west of Mekelle City, the capital city of the Regional State. The Kolla

Temben District is bordered by Naeder Adet District to the northwest, Wereleke District to the north, Abergele District to the south, Western Zone District to the west, and Hawzen District to the east part.

Figure-2. Sampling techniques of the study



This figure shows in the graphically how the researcher has selected smallholder farmers in Kolla Temben District for interview. In the first stage, four Kebelles was selected using simple random sampling techniques out of the given 27 Kebelles in the District. After this, 400 households were selected from the lists of households in the four Kebelles through the systematic random sampling techniques.