Research Article

Rural communities' vulnerability to farmland poverty in varied ecological settings of northwest Ethiopia

Menberu Teshome[*]

Department of Geography and Environmental Studies, Debre Tabor University, Debre Tabor, Ethiopia. Po Box 272.

[*] menberuteshome@gmail.com, menberuteshome@dtu.edu.et

Abstract: Environmental and climate changes are among the serious threats to the world's land resources in the 21st Century. Particularly, in the developing countries the impact inevitably goes as the continuing toll on agricultural production, human lives, and properties. It is also a driving force of poverty and impediment of overall economic development in many less developed nations, like Ethiopia. Therefore, this paper assesses the rural communities' vulnerability to farmland poverty in different ecological settings of northwest Ethiopia. Data were collected from 525 randomly selected farming households using questionnaire. Meteorological data were collected from Global Weather Data for soil and water assessment tool (SWAT) from 1979 to 2010. Rainfall and temperature trends were characterized using simple linear regression model. Rural communities' vulnerability to farmland poverty was determined using livelihood vulnerability index (LVI). Indices were constructed using simple and weighted average approaches to measure farmlands' exposure, sensitivity and adaptive capacity. Overall communities' levels of vulnerability to farmlands poverty were found to be 0.61 in the lowland, 0.46 in the flat highland and 0.58 in the midland areas. In almost all indicators the lowland (Abay Valley) is more vulnerable to farmland-related troubles as the biophysical and socio-economic contexts were found to be the worst there. Communities and government and non-government officials have observed significant negative impacts of drought and extreme weather events on farmlands, and pasturelands with declining availability, productivity and quality of farmlands. This study suggests education and research interventions for enhancing community-based participatory integrated watershed management approach supported with best indigenous knowledge and farmers' practices. Adaptation interventions should also consider local communities' resource capacity (low-cost investment in sound farmland and soil management techniques).

Keywords: ecological setting, environmental change, farmland, northwest Ethiopia, vulnerability index

Introduction

Land is a highly valued natural capital for agrarian communities in the provision of valuable goods and services (Sullivan, 2002; Barungi and Maonga, 2011). However, this precious natural asset has experienced persistent pressure from a range of direct and indirect socio-economic driving forces (Sullivan, 2002). Indeed, they are severely affected by environmental and climatic changes exposing the rural communities to vulnerability to farmland poverty through deteriorating land resources due to exacerbated land degradation, soil erosion, evapo-transpiration, and harming of fauna and flora (Barungi and Maonga, 2011). Environmental and climatic changes are real ecological threats that are facing our world today and become the growing concern for scholarly and policy communities. The impact of climate change has become the continuing toll on land resources, human lives and properties and intern agent of pervasive poverty, particularly in many emergent countries (Lal, 2005; IPCC, 2007). Environmental

and climate changes occur as a result of both natural and human-induced causes. The natural causes may include the sun's solar radiation, earth's orbit, drifting continents, volcanic eruptions and greenhouse gases (GHGs). Before the Industrial Revolution, human activities including agriculture released very few gases into the atmosphere. After Industrial Revolution, through fossil fuel burning, changing agricultural practices and deforestation, the natural composition of atmospheric gases is increasing and began to alter the earth's climate system (Houghton, 2009). Indeed, human-induced climate change adds new unpredictable threats to societies not only due to the occurrence of these extreme events but also due failures to adequately address persistent poverty (Schipper, 2004) and mounting environmental resources degradations (World Bank, 2008; FAO, 2009)

Nowadays, majority of scientific evidences indicate that climate is changing in an accelerated rate and will continue so in the coming century (Adger et al., 2003; IPCC, 2007; Houghton, 2009). IPCC (2007) report asserted that the warming of the climate system is now unequivocal as is evident from the increasing atmospheric concentration of carbon dioxide from a pre-industrial value of 278 parts per million to 379 parts per million in 2005, the average temperature rose by 0.74° C, and increasing occurrence of extreme events over the past century. A particular rate of warming has taken place over the last 30 years since accurate records began about 100 years ago. Moreover, 12 of the 13 warmest years have occurred from 1995 to 2007 (UNFCCC, 2007; Houghton, 2009). The IPCC's projections for the 21st century further show that global warming will continue to accelerate even with ambitious reduction of greenhouse gas emissions. Predictions by 2100 range from a minimum of 1.4°C to a maximum of 5.8°C rise in average temperatures with far more than human experience (UNFCCC, 2007; Houghton, 2009).

Climate and environmental changes have posed considerable impact on natural resource dependent rural communities for their livelihoods. Ethiopia, one of the least developed countries of Sub-Saharan Africa, is highly vulnerable to climate change-induced extreme risks. The NMA (2001, 2007) assessment report asserts that agriculture, water resource and human health were found to be the most vulnerable sectors in Ethiopia. Recurrent droughts, floods and severe erosions on the fragile ecosystems have increased the probability of risk occurrence on poor people's livelihood resources on which future generations will also depend (You and Ringler,

2010; Admassie et al., 2006; NMA, 2007). Natural resources conservation efforts and extension packages intended for productivity gain for which millions of dollars have been spent since 1980s have been severely challenged. The recently designed participatory-community based integrated watershed development plans to augment environmental sustainability, enhance natural resource management and food security and then to reduce poverty have continued in trouble. Traditional coping mechanisms have failed, food insecurity continued, and in turn, dependency on external support is still common. This implies that climate change and land degradation are intimately interlinked in creating adverse effects on natural and human systems. In the light of this, Tesfaye (2003) argued that the legacy of the previous efforts did not leave northern Ethiopia with the outcomes promised three decades ago, regarding sustainable land use, natural resources management and food security.

Although there have been studies conducted on environment and climate change-related issues in Ethiopia some dealt with different shocks (Dercon, 2004) and shocks-consumption relationships (Dercon et al., 2005) while others examined the rainfall and crop production nexus in the zonal, state and national level without addressing vulnerability to climate change-induce risks (Segele and Lamb, 2005; Woldeamlak, 2009). Still others analyzed yield or monetary impacts and adaptation measures (NMSA, 2001; Yosuf et al., 2008, Temesgen, 2007; Temesgen et al., 2009; You and Ringler, 2010). Aklilu and Alebachew (2009) and Yohannes and Mebratu (2009) examined climate induced-hazards, impacts, responses, and local innovations in climate change adaptation restricted to the pastoral lowlands. Other handful studies were also done on perception and adaptation without integrating vulnerability (Conway and Schipper, 2010; Veronesi, 2010; Temesgen et al., 2009). Smit et al. (1999) and You and Ringler (2010) contend that without understanding the nature of vulnerability, and adaptive capacity, it is difficult to acquire better knowledge of adaptation.

To what extent the rural communities' are vulnerable to farmland poverty was not addressed except blaming drought events, severe land degradation, and misdeeds of the previous regimes. Albeit the efforts in searching for previous studies the author has failed to get research that investigated local communities' vulnerability to farmlands poverty in different ecological settings in an inclusive manner. Therefore, the objective of this study is to determine the vulnerability levels of rural

communities' to farmland poverty in three ecological settings of northwest Ethiopia.

Research Methods and Procedures

Description of the study area

Three ecologically different places namely Dabat, Denbia, and Simada were purposely selected from northwest Ethiopia. The three places stretch from the Abay Valley (Upper Blue Nile) to the northern (Semien) highlands, bearing similarities in some socio-economic aspects, but highly differing in ecological contexts. Specifically, 11 kebele administrations (KAs) (lowest administrative tiers

of Ethiopia) were included in the research drawn from the three ecological areas.

Dabat woreda (district) is located near to the highest peak of Ethiopia (Ras Dejen). It is bounded by Debark woreda in the north, Wogera in the south, Tsegede and Tach Armachiho in the west, and Debark and Wogera woredas in the east. The altitude ranges from 1,500 to 3,300 m above sea level (asl). Over half of its total area lies within the highland ecological zone (Dabat Woreda Communication Office, 2013). The specific sites of this woreda placed within the highland wheat-barley-sheep livelihood zone having relatively abundant water resources (ACCRA, 2011; Menberu, 2015; 1016).
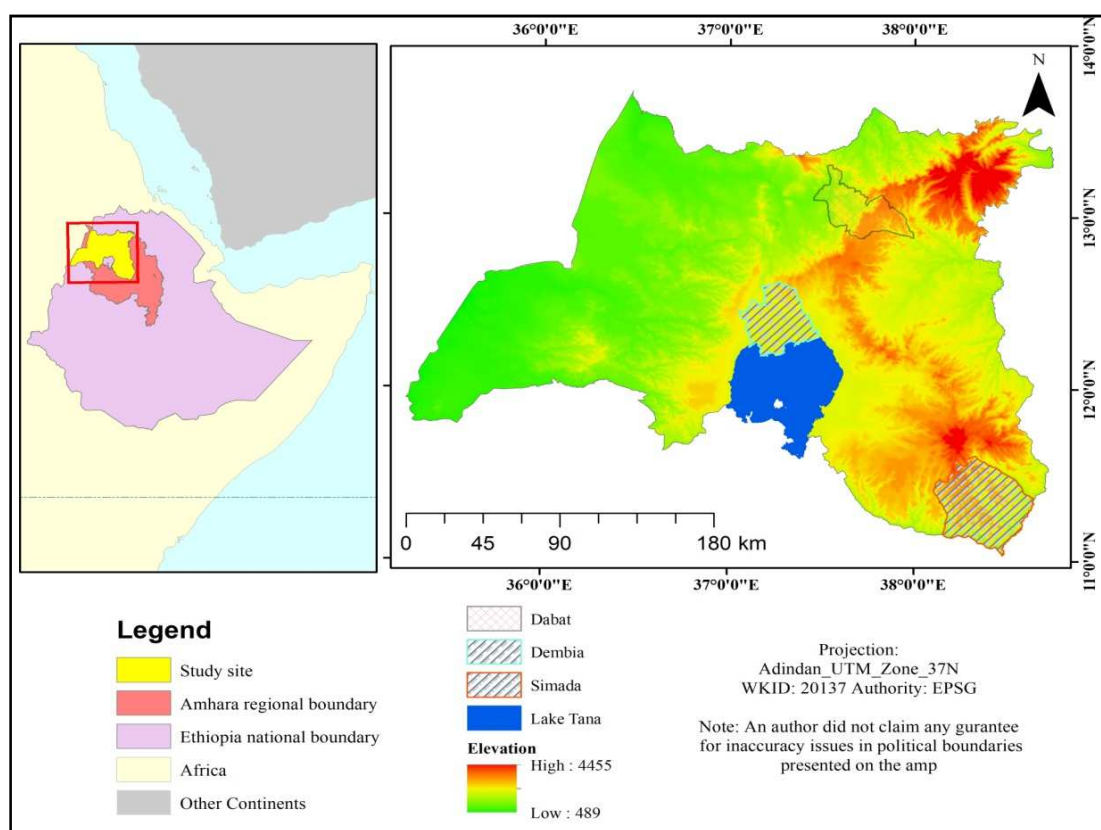

Figure 1. Location map of study areas in the State and National Settings

Dabat receives rainfall amount ranging from 700 to 2000 mm. Rain in March and April plays a critical role in land preparation for planting purpose in the coming May and June. The major rainfall extends from June to September although less frequent and smaller amounts are still expected in October. Early maturing crops are harvested in mid-September, and a second crop is planted in flat areas where the crop is expected to grow on residual soil moisture and the small rains

that follow in October (Menberu, 1016). Crop harvest extends from October to December (ACCRA, 2011). The main crops are barley, wheat, and beans while the main livestock are sheep, cattle and equines. This highland mixed farming zone faces food deficit every year. The regional government classified it as one of the food insecure woredas. The very poor and poor depend on labor markets for their income and many people are dependent on Productive Safety

net Program (PSNP) to supplement their food requirements (ACCRA, 2011).

Denbia woreda is almost entirely placed within the midland (*woyna-dega*) agro-ecological area with an elevation ranging from 1700 to 2600 m above sea level. The woreda experiences uni-modal (locally *Meher*) rainfall pattern from mid-June to September with average annual rainfall of 870 to1394 mm (NMSA 2012 unpublished office document). The topography of the area is characterized by 87% plain, 5% mountainous, 4.8 % valleys and 3.2% swampy (World Vision Office Document, 2007). The woreda is also entirely located in the Tana growth corridor livelihood zone where most wealth groups enjoy relatively good agricultural production. Crop sales provide three-quarters of income for all wealth groups.

The Abay Valley (Upper Blue Nile) is located in the Abay-Beshilo Basin livelihood zone of Simada woreda where famine, drought, land degradations and food insecurity are serious problems since the last three decades. The woreda is bordered in the southeast by the Beshilo River with South Wollo Administrative Zone, in the southwest by the Abay River with East Gojam Zone, in the northwest by Estie woreda, and in the north and northeast by Lay Gaynt and Tach Gaynt woredas respectively. Part of its boundary with Estie woreda is defined by the Wanka River, a tributary of the Abay. The woreda is located 774 km north of Addis Ababa and 209 km southeast of Bahirdar City. It is totally inclusive in the Abay Valley of Ethiopia (Menberu, 2015). The woreda is divided into lowland/*kola/* (60%), midland/*woyna-dega/* (30%) and highland/*dega/* agro-ecological areas (10%) (Tibebe, 2008). The area has high rainfall for the two months of summer in the year with less or no rainfall during other months of the year. Nevertheless, the wet season extends mostly from Mid-June to beginning of September. The major crops grown in the Abay lowland are sorghum, haricot bean, maize, and *teff* (Menberu, 1016).

Data collection

Three main data sources were identified as relevant for investigation in that they indicate the situations of vulnerability to climate and environmental changes in the three ecological areas. The first is the scholarly researches on theories, methodological approaches, and empirical findings which helped to gain initial insights to the concepts of vulnerability to climate change. The second source is meteorological records such as temperature, rainfall and extreme events and number of population by kebele which helped to gain initial insight into the research

problem and acquire baseline information about the study sites. The third data set is the biophysical and socioeconomic data collected through household survey supplemented with observation and interview techniques.

Secondary data: The meteorological data were gathered from Global weather data [*globalweather.tamu.edu*] for the period 1979 to 2010 to analyze the seasonal (temporal) temperature and rainfall variability and to compute exposure indices for the study community.

Primary data: Secondary data sources were found to be insufficient to answer all the specific research questions for the study populations. Therefore, it was determined that primary data collection methods to be the major data sources for this research. Accordingly, primary data were collected using household survey, field observation, and interview for the completion of the study.

Household survey: the household questionnaire survey was the main data source so as to determine the vulnerability of rural communities' to climate change-induced farmland poverty. The household survey was used to collect quantitative data on land size, farmland location, soil erosion rate, land fertility level, land exposure to flood, crop productivity on temporal scale, crop saving capacity for bad years and next cropping season, confidence on land tenure system, land certification, distance to agricultural input markets, input utilization, and about land management training (Refer to Table 2). The household survey was conducted in the period between March and September 2012 from 525 sample rural household heads using enumerators with close supervision of the author and supervisors. The Yemane's (1967) statistical formula referred by Israel (1992) was checked to determine sample household size. Then, the 525 households were distributed to the study areas using probability proportional to size (PPS) method to ensure equal representation of the studied population as there are different household sizes in each sampled site. The questions were organized mostly into close-ended forms supplemented with some open-ended forms in a suitable way to calculate livelihood vulnerability index (LVI) and other descriptive statistics for comparison between indicators. The survey questions were prepared in local language (Amharic) and then translated into English during data processing and analysis. In order to maintain the validity and reliability of the data, the questions were reviewed by experts in natural resource management, food security and disaster management affiliated in Agricultural

Development Office of the woreda. Pre-test of questions were made by distributing questionnaires to 10 farmers in each woreda who were not involved in the actual survey to assess whether the instruments were appropriate and suited to the study. Based on the comments from experts and observations of households' responses some amendments were made on confusing and sensitive questions. Pre-testing of the questions also helped to determine the mean interview length needed for covering the samples and to plan the days and data collectors required for the survey. The author trained data collectors with respect to the survey techniques to establish internal quality control procedures. For example, in case survey questions used ambiguous language that might lead to different answers, data collectors had common understanding. Moreover, after the training, the data collectors acquired practical experience while the author made face-to-face interview in the field.

Field observation: direct field observation was conducted to validate data gathered through household survey. Field observations focused on bio-physical characteristics, land degradation, flood affected areas, water resources and vegetation cover and land management practices. Vulnerable areas were documented through photographs by using digital camera.

Interview: in order to complement and cross-check the data gathered through household survey and secondary sources interviews were held with elders, local leaders and development agents at kebele level and agricultural experts at woreda level. The author identified a total of 33 key informant (KI) interviewees from the four kebele administrations i.e. three from each kebele. This was made to have the overall picture of the kebele administrations and obtain general information on the main research problem.

Methods of data analysis

Indicators of rural communities' vulnerability to farmland poverty demand quantitative methods combined with qualitative data analysis techniques. The quantitative methods of simple regression and standardized precipitation index are crucial in characterizing the temperature and rainfall conditions. Livelihood vulnerability index was used to determine the farming communities' vulnerability level to farmlands poverty based on the data collected from the household survey and the climate data gathered from meteorology station. These quantitative methods were supported with descriptive statistics like mean, percentage, maximum and minimum values of the distribution.

An assessment of rural communities' vulnerability to farmland poverty was done using livelihood vulnerability index (LVI). Indices were constructed using simple and weighted average approaches to measure communities' access to farmland-related assets and services (Hahn et al., 2009). The indicators were normalized as an index using the equation adapted by Iyengar and Sudarshan (1982) to classify Indian regions by their development differentials, United Nations Development Program (UNDP) to calculate life expectancy index, and Sullivan et al. (2006) to evaluate water poverty index.

Livelihood vulnerability index using functional relationships

The field of vulnerability assessment has emerged to quantify how communities can adapt to changing environmental conditions using different methods by integrating socio-economic and biophysical indicators. These are often combined into a composite index allowing diverse variables to be integrated. Many of these rely heavily on the IPCC working definition of vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC, 2001). According to formative measurement model all variables have impact on vulnerability.

In the empirical considerations, the indicators do not necessarily share the same theme and hence have no intercorrelation (Coltman et al., 2008). Individual and community vulnerability indicators were in different units and scales. The methodology used by Iyengar and Sudarshan (1982), Sullivan et al. (2006), Hahn et al. (2009) and UNDP Human Development Index (UNDP, 2010) was employed to normalize these different units of indicators. That is, in order to obtain figures which are free from the units and also to standardize their values, first they were normalized so that they all lie between 0 and 1. The value 1 corresponds to that ecological area with maximum value and 0 corresponds to the other ecological area with minimum value of each indicator. Vulnerability index (VI) was computed to determine the rural communities' vulnerability levels to farmland poverty using a simple and weighed average approaches. This method helps to assess communities' exposure and access to land and related indicators using the data collected from the sample households and secondary sources.

Table 1. Vulnerability Indicators and their functional relationships with vulnerability [based on Moss et al. 2001 and Hahn et al. 2009]

Components	Explanations of specific indicators	Hypothesized relationships to vulnerability
Farmland size, quality, policy Input use and Training	Inverse of total farmland size households own	Adaptive capacity ↓ as land size ↓ vulnerability ↑
	Household heads' farmland located in the rugged terrain	Sensitivity ↓ as population at risk ↓ vulnerability ↓
	Household heads who reported very high farmland erosion	Exposure ↑ as population at risk of erosion ↑ vulnerability↑
	Households' own farmlands with poor fertility	Sensitivity ↑ as own infertile land ↑ vulnerability ↑
	Percent of households whose farmland affected by floods	Sensitivity ↑ as households who own flooded ↑vulnerability ↑
	Crop yield index (yield per hectare)	Adaptive capacity ↑ as yield per hectare ↑ vulnerability ↓
	Crop yield trend stability	Adaptive capacity ↑ as crop yield stability ↑ vulnerability ↓
	Household heads who unable to save crops for the time of food deficit	Sensitivity ↑ as the HHs ↑ Vulnerability ↑
	Household heads who unable to put seeds for the next cropping season	Sensitivity ↑ as the HHs ↑ Vulnerability ↑
	Household heads who are in fear of losing their farmlands	Adaptive capacity ↓ as the No. of HHs ↑ ↑vulnerability ↑
	Household heads who didn't get certificate for their farmlands	Adaptive capacity ↓ as the No. of HHs ↑ vulnerability ↑
	Distance to fertilizer market center	Sensitivity ↑ as distance ↑ vulnerability ↑
	Household heads who failed to use modern fertilizers	Adaptive capacity ↓ as the No. HHs ↓ vulnerability ↑
	Inverse of the amount of modern fertilizer use	Adaptive capacity ↓ as the fertilizer use ↓ vulnerability ↑
	Household heads who do not get land management training	Adaptive capacity ↑ as trained HHs ↓ vulnerability ↑
	Mean standard deviation of average maximum temperature by month	Exposure ↑ as maximum T_o variability ↑ vulnerability ↑
Temperature	Mean standard deviation of average maximum temperature by year	Exposure ↑ as maximum T_o variability ↑ vulnerability ↑
	Mean standard deviation of average minimum temperature by month	Exposure↑ as minimum T_o variability↑ vulnerability ↑
	Mean standard deviation of average minimum temperature by year	Exposure↑ as minimum T_o variability↑ vulnerability ↑
Rainfall	Average monthly standard deviation of rainfall (1980-2011) by month	Exposure ↑ as rainfall deviation by month ↑ vulnerability ↑
	Average monthly standard deviation of rainfall (1980-2011) by year	Exposure ↑ as rainfall deviation by year ↑ vulnerability ↑
	Average number of hazards occurred in the past 10 years	Exposure ↑ as frequency of droughts ↑ vulnerability ↑
Hazards Frequency	Reported death of livestock in the past 5 years	Sensitivity ↑ as death of livestock ↑ vulnerability ↑
	HHs reported their family members faced injury/death by climate hazards	Health Sensitivity ↑as injury and death ↑ vulnerability ↑

Notes: HHs - Households

The vulnerability indicators measured were normalized by the following formula (Iyengar and Sudarshan, 1982, Sullivan et al., 2006; ICRISAT 2006; Hahn et al., 2009; UNDP/HDI, 2010):

$$V_i = \frac{X_i - Min\ X_i}{Max\ X_1 - Min\ X_i}\ (1)$$

Where: V_i = measure of vulnerability contributed by the ith indicator in the study area, X_i = numerical value of the ith indicator, Min and Max X_i = minimum and maximum value of the ith indicator being compared with other variables.

This method of standardization takes into account the functional relationship between the forecaster variable and vulnerability (refer to Table 1). ICRISAT (2006) identified two types of relationship: vulnerability increases with the increase (decrease) in the value of the indicator. In this type of relationship, the higher the value of the indicators, the more is the vulnerability. For example, the larger the change in temperature, rainfall, and distance indicators from any service center, the more is the vulnerability of the place or the community to climate change risks. In this case, the variables have a positive functional relationship with vulnerability and hence the standardization was done using Equation 1. For these types of variables, the average values are taken to represent the observed values. For variables that measure frequencies of events, the minimum value is set at 0 and the maximum at 100.

Let us see the distance rural household heads travel to reach to the nearest agricultural input market. It is too long for some households with a value of 260 minutes and it has the shortest distance of 5 minutes from some other households in the study woredas. The observed (average) value was found to be 92.48 minutes (Refer Table 3). Hence, the normalization of indicators were done as:

$$V_i = \frac{92.48 - 5}{260 - 5} = 0.34$$

In this approach, the normalized vulnerability scores for other similar indicators were computed by considering their functional relationships with vulnerability to farmland poverty. For indicators, which assumed to have an inverse relationship (adaptive capacity indicators) with vulnerability, the inverse scoring technique was applied in the normalization of values for each indicator using Equation 2 based on ICRISAT (2006) and NMSA (2007).

$$V_i = \frac{Max\ X_i - X_i}{Max\ X_i - Min\ X_i}\ (2)$$

In this case, let us consider farm size of households own, a high value of this variable implies better off households in the certain ecological areas. Farm size has inverse functional relationship with vulnerability; that is, as farm size increases vulnerability decreases and vice-versa. Therefore, the rural households who owned large farmlands have more capacities to cope with risks from environmental changes (O'brien et al., 2004; Wisner et al., 2004; Temesgen, 2010; Barungi and Maonga, 2011). Put differently, the vulnerability levels will be lower and farm size has an inverse functional relationship with vulnerability to farmland poverty. For example, farm size was found to be higher with a value of 5 hectares for some households in one ecological area, while it has a lower value of 0 for few households in another area. The observed value (represented by average farm size) was found to be 1.07 hectares. Thus, the normalized score for one ecological area is:

$$V_i = \frac{5 - 1.07}{5 - 0} = 0.79.$$

In this way, the normalized scores for each vulnerability indicator were computed for study areas. Then the indicators were averaged by Equation 3 to calculate the value of each component.

$$AV_i = \frac{\sum_{i=1}^{n} V_i}{n}\ (3)$$

Where: AV_i = average vulnerability index for a given component (land and climatic exposure indicators); V_i index of individual vulnerability indicator represented by i, and n is the number of indicators. In this study, the V_i is scaled from 0 to 1; 0 denotes least vulnerable or no vulnerability and 1 denotes most vulnerable system. By applying the same procedure, composite indices were computed for other sub-and major components and then for the overall vulnerability levels of communities across the three ecological areas. Once the index values for each major component were calculated, the composite index was computed using the weighted average with the following equation to obtain the livelihood vulnerability index (Hahn et al., 2009):

$$CV_i = \frac{\sum_{i=1}^{7} Ni\ V_i}{\sum_{i=1}^{7} Ni}\ (4)$$

Where: CV_i denotes Composite Vulnerability Index equals the weighted average of the important components; the weights of each main component, Ni is the number of indicators in sub-components that make up each major component (V_i).

The qualitative data analysis methods supported the quantitative data analytical techniques. Thematic analysis was used to interpret the qualitative data gathered using in-depth interview and field observations. Before directly start analysis, the collected information was converted into word processing documents (Creswell, 2012). Some interviews and observational notes taken by the author were transcribed. Transcription means the process of converting interview and field notes into text data. Then these text data were translated from local language (Amharic) to English for narrating and interpreting the answers obtained from the interviewees.

Results and Discussion

Temperature trends and anomalies

Temperature is a very important climatic variable in determining the vulnerability status of agrarian communities to farmland poverty. A statistically non-significant changing-temperature trend was detected in highland, midland, and lowland ecological areas of northwest Ethiopia over the past 32 years. Figure 2 presents the long-term average temperature trends of the three study areas over 1979 to 2010 period. The estimated trend line for average annual temperature in the highland is $y = 0.040x + 18.32$ and $y = 0.052+18.49$ in the midland while it is $y = 0.042+19.40$ in the lowland. The trend line has a positive slope showing that the average temperature has increased by 1.2^0C in the highland, 1.3^0C in the midland, and 1.61^0C in the lowland areas over the period considered (32 years). This indicates that there was faster rate of temperature increase in the lowland and midland than in the highland ecological area. The rates of increase in the three study areas were also faster than the national level temperature rise (0.2^0C -3^0C per decade) observed over the past 55 years (Menberu, 2015, 1016).

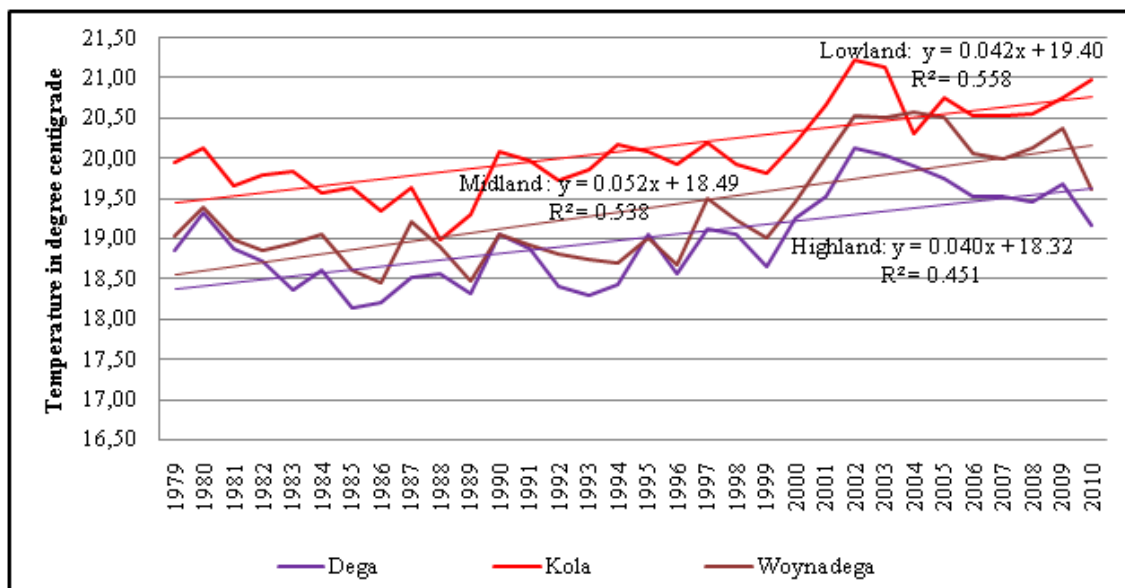
Figure 2. Long-term spatial and temporal temperature variability [Global Weather Data [http://globalweather.tamu.edu/]

This result is also supported by 95% of the surveyed households. While the highest temperature increment was detected from the meteorological data in the midland ecological area, the highest perception of temperature rise was reported by the households in the same ecological setting. Three distinct periods can be noted (Figure 2): the first one from 1979 to about 1989 where air temperature is actually decreasing over that period. Then the next period from 1989 to about 2002 or 2003 when the air temperature is increasing slightly and the third period then from 2003 to 2010 when again, air temperature was actually decreasing over that period. Each of these sub-periods would dramatically affect drought vulnerability (Menberu, 2015, 1016).

Maximum temperature increased fast while the minimum temperature increased gradually in the highland ecological area. For example, while the maximum temperature rose by 1.7^0C, the

minimum was by 0.8^0C over the past 32 years. According to the survey result, nearly 87% of the respondents supported these increasing trends of temperature. Although the rate of minimum temperature increase is almost similar to the national level increase (0.3^0C per decade), the maximum increasing rate is quite different from that of the rate of increase observed in Ethiopia (0.1^0C per decade). Only 9.3% of the surveyed households in the highland noticed the contrary, a decrease in temperature, whilst 3.9% of them have not noticed any change in temperature (Menberu, 2015).

Both maximum and minimum temperatures increased in the midland ecological area over the past 32 years (1979-2010). Similar to the highland area, maximum temperature increased faster than the minimum temperature. For example, the maximum temperature increased by 1.58^0C while the minimum temperature increased by 0.96^0C. This trend was again supported by 95% of the surveyed households who observed increasing temperature trend over the past 20 years. Only 2% of the households noticed a decrease in temperature, and 1.5% of them have not noticed any temperature change (Menberu, 2015).

An increasing trend of minimum and maximum temperatures was also detected in the lowland area from 1979 to 2010. The simple regression result indicates that the maximum temperature increased by 2.17^0C and the minimum rose by 1^0C in the same period. In the lowland ecological area, the rate of temperature change was found to be faster than in the highland, midland, and national level rate of increase (NMSA, 2001, 2007; Menberu, 2015, 1016) while maximum temperature in the midland was somewhat lower than those of in the highland and lowland areas. Only 4.2% of the households in the lowland noticed a decrease in temperature, while 6.1% of them have not noticed any change.

The direction of the temperature trend in the three ecological areas is consistent with the findings of Mongi et al. (2010) for Tanzania, which found out that both minimum and maximum temperatures showed mounting tendencies. This rising temperature inclination in the three ecological areas has paramount impact on water, land and vegetation resources through worsening evapo-transpiration with negative consequences on the productive capacities of these valuable resources.

Long-term inter-annual rainfall variability and change

Long-term inter-annual rainfall variability and change was examined using simple regression as was used by Mongi et al. (2010) and Gbetibouo (2009). The result indicated that there is significant inter-annual and spatial variability of rainfall and rate of decline across all the three ecological areas of northwest Ethiopia. Figure 3 illustrates the long-term spatial and temporal rainfall distribution and rates of change in three ecological areas from 1979 to 2010. It is clear from the Figure that the total annual rainfall distribution is going down from time to time. Rainfall is found to be very low in the lowland ecological area (red line). Long-term rainfall in the period appeared to decrease at statistically non-significant rates (R^2 = 0.066 for the highland and for the midland and 0.040 for the lowland), however. The main problem is the timing (late onset and early cessation) and failing in intense episodes in very short duration.
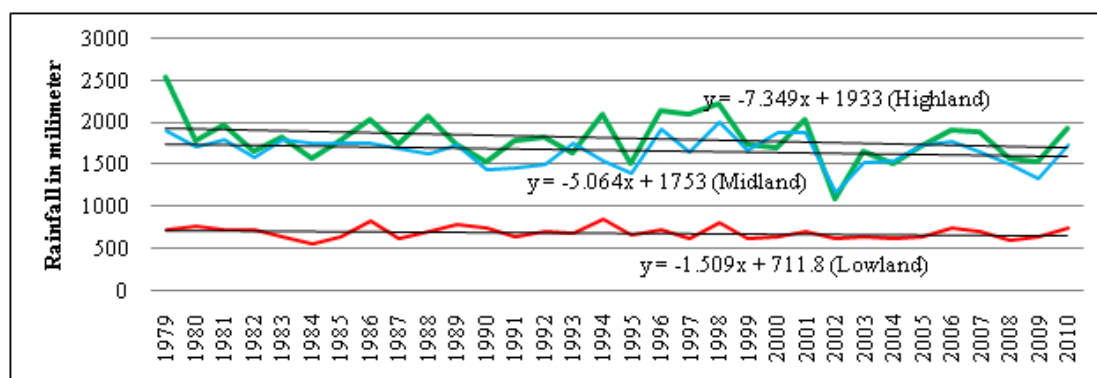

Figure 3. Long-term spatial and temporal variability of rainfall [Global Weather Data [http://globalweather.tamu.edu/]

The long-term reduced amount of rainfall calculated using simple regression for the observation period indicated that the rainfall declined by 46.78 mm in the lowland areas, 156.98 mm in the midland, and 277.82 mm in the highland over the past 32 years (14.62, 49.06, and 71.19 mm per decade respectively) [Refer to Figure 3]. These results are in line with several empirical research findings (AACCRA, 2011; Mongi et al., 2010; Gbetibouo, 2009; Mentez et al., 2008; Menberu, 2015, 1016). In the present study; however, the decreased amount of rainfall in the observation period is smaller in the lowland ecological area than in the highland and midland areas. The reason is that rainfall was already very low in the lowland area before the period considered.

Farmland erosion and fertility level

Farmland erosion severity and fertility levels are powerful vulnerability contexts in influencing the total production and productive capacities of rural communities who have settled and done their economic activities in the fragile landscapes. The descriptive statistics (Table 2) found out that farmlands situated in the dissected landscapes like rugged terrain, deep valleys, mountain ridges and flood-prone areas are highly sensitive to soil erosion, mass movement, landslide, flooding, and consequently to poor soil fertility and to very low crop productivity. As a result, the rural households are becoming highly vulnerable to climate change-induced risks. Table 2 shows the percentages of households by farmland location, intensity of reported soil erosion, and farmland fertility level in the three ecological areas. The results indicate that higher proportion of households in the lowland (65.4%) have owned farmlands located in a very rough topography which has made the farmlands most susceptible to severe soil erosion and fertility decline, and in turn agricultural production to go down than the flat highland *(36.4%)* and midland (22.6) households of Dabat and Denbia respectively

Figure 4 compares the landscapes in the valley, midland, and highland locations. The left, the middle and the right images represent the difficult landscapes in the valley land, midland and highland study areas. The land degradation processes in the lowland, flooding in the midland and land fracture in highland appear, particularly more severe, having significant implications for mitigation and adaptation to the adverse effects of environmental change. This is because the loss of biomass releases carbon into the atmosphere and in turn affects the quality of soil and its ability to hold water and nutrients for agricultural production (Menberu, 2015, 1016). In line with the proportion of the location of the farmlands, the households reported increased intensity of soil erosion, ranging from a very low proportion in the flat highland (6.2%) and midland (15.8%) ecological areas to a sharp increase in the fragile Abay Valley (44.1%).

Table 2: Households by farmland location, erosion intensity and fertility status

Vulnerability contexts	Indicators	Percent of respondents by type of ecology		
		Highland	**Midland**	**Lowland**
Farmland location	Fairly plain	63.6	76.7	31.9
	Rugged/valley	36.4	22.6	65.4
	Missing system		0.8	2.7
Farmland erosion intensity	High	6.2	15.8	44.1
	Average	66.2	51.9	45.2
	Low	25.6	30.8	8.0
	Missing system		1.5	2.7
Farmland fertility level	Fertile	19.4	13.5	2.7
	Medium	73.6	82.0	34.2
	Poor	7.0	3.8	60.5
	Missing system		0.8	2.7

Source: Household survey, March to September 2013

Moderate erosion level was reported by the highland (66.2%) households followed by the midland (nearly 52%) and the Abay Valley (45.2%) households. This different erosion intensity level has implications on the households' farmland fertility level in the three study areas. Based on the respondents' own evaluation, poor soil fertility condition was

asserted by nearly 61% of the sample households in the lowland corresponding to the nature of the topography (65.4%) they are located. Only 7% of the households in the flat highland area and nearly 4% in the midland reported the same. The majority of the respondents (82%) in the midland and nearly 74% in the highland rated their farmland fertility level as medium and 34.2% in the lowland reported the same fertility level. This farmland fertility level has in turn great implications on agricultural productivity and food security situations of the studied communities.

Figure 4. Example landscapes for the lowland, Midland and Highland study areas
[Source: Own field photo, 2013]

The results are mostly associated with the hazard-of-place model as these topographic contexts help to measure the communities' degree of exposure and sensitivity to environmental hazards (Cutter, 1996; Cutter et al., 2003). This model noted that the hazard potential is influenced by a geographic exposure such as site, situation, and proximity to the sources of hazards, and the socio-economic fabrics of places such as the ability to respond, to cope up with, to recover from, and to adapt to such environmental hazards.

Other studies also argue that the parameter of sensitivity is strongly linked to location and is evaluated by the inherent characteristics of places, considering human-environmental relationship, where both social and biophysical characteristics influence this relationship (Turner II et al., 2003; Gallopin, 2006; Menberu, 1016). Places having infertile land continue to suffer from low rates of economic growth and pervasive poverty. This situation is evident in the areas of Abay Valley. The fragile environment dominated by undulating topography there exposed the area to severe soil erosion resulting in poor farmland fertility and lamentable agricultural production. In the light of this result, FAO (2003) and UNESCO (2004) again underlined that slopes are one of the important parameters of the terrain to worsen land ruin and soil erosion.

Land degradation can be both an impact and an amplifier of changing weather patterns. When the field survey was carried out from March to the end of June 2012, large areas in the Abay Valley areas were completely devoid of green vegetation even during the rainy seasons, except cropped areas. Most areas have no soil cover left, bore soils and bedrocks can be seen over extensive areas; grazing lands are already over-stocked, and crop residues are used to feed animals. These and other contexts have worsened the vulnerability level of the studied communities to farmland poverty and the ecological systems change as a whole (See Figure 4).

Figure 4 also shows the already observable bedrocks in the lowland, flood plains area in the midland and deep soils but severely fracturing in the flat highland study areas. With increasing population pressure, the intensively cultivated areas are heavily used and grazing lands are now under increasing stress. The result is cracked land leading to deep gulley and rills (Figure 5). Gullies and rills are indicators of considerable topsoil loss in the slope depressions. The very low vegetation cover has fostered the erosion process affecting land resources, which in turn have worsened the situations of the respective ecological areas.

As it can be seen from Figure 5, overgrazing is a severe trouble in the over-populated places of the studied areas. Rangelands are under increasing pressure due to overgrazing and encroachment of crop farming. In addition to the widespread degradation of land resources, the increase in invasive alien species has been a recent-onset phenomenon from the early 1990s onwards in Ethiopia (Leulseged et al., 2013; Menberu, 1016).

Figure 5. Livestock pressure on grazing lands in the flat highland study area [Source: ACCRA, 2011(left) and own field photo (right), 2012]

Invasive weed species are usually characterized by rapid growth, and they typically replace other, more desirable indigenous plants. These species usually damage cultivated plants by competing with them for sunlight, water, and mineral nutrients. The spreading of the invasive alien plant species has also invaded vast areas in the Lake Tana shore of Denbia (the midland) ecological areas (see Figure 6).

These invasive alien species are called '*hyacinth*' or locally known as '*emboch*'. Experts working in the area stated that these plant species are evading vast swampy areas with devastating impact on indigenous plants. The areal coverage of these species has rapidly increased. In addition to harming the plants, this weed can poison livestock when eaten and spoil the flavor of the milk produced by cows that consume this weed. Fishing, one of the sources of income for the local community, are also now in danger. In the light of this, Leulseged et al. (2013) also recognized the impacts of invasive species in Ethiopia as one of the complex sets of factors in forcing huge change within the lives of the community in recent years. To alleviate the problems of these invasive species the local government bodies have undertaken massive clearing campaign through community mobilization in the winter seasons. However, the plants have been spreading quickly to the vast water bodies and wetland areas (see Figure 6) which have called for further integrated actions in order to curb the problems and to save the Lake Tana water from drying.

Figure 6: Water hyacinth around Lake Tana and the practice of weeding
[Source: Own field photo Nov., 2013]

Communities' exposure and vulnerability to farmland poverty

In this section, the indicators have been identified to analyze the vulnerability levels of the rural communities' farmland poverty. Accordingly, an assessment of farming households' vulnerability to farmland poverty was carried out based on farmland size, terrain characteristics of the areas where farmlands located; soil erosion severity, land fertility level, and crop yield based on households' response (refer to Table 3).

Communities' exposure to farmland poverty

The exposure of a system is determined by the amount of stress that impacts the unit of analysis. Exposure can be represented by a change in magnitude, frequency and duration of extreme climatic events (such as droughts, floods, storms, etc), climate variability or long-term climate patterns such as increasing temperature and decreasing precipitation to which farmers' livelihood assets like land, forest and water resources are exposed (Brooks, 2003; IPCC, 2007). Accordingly, exposure indices were constructed using changes in temperature, rainfall, and frequency of extreme events for the study locations. The radar diagram (Figure 7) demonstrates the communities' level of exposure to farmland poverty in the three landscapes. It is clear from the diagram that there are three main indicators: temperature, rainfall and hazard frequency (climate related extreme events). In terms of aggregate climate exposure indices, the midland and the Abay Valley are found to be more exposed at 0.54 and 0.51 scores respectively whilst relatively a low exposure status was dtermined in the flat highland topography at 0.31 exposure index value.

When the exposure indices are compared indicator-wise among different topographic features, temperatutre varaibility is higher in the midland with the index value of 0.66 followed by the lowland-valley (0.54) while its exposure index is relatively low in the highland (0.37). The exposure index which shows the extent of rainfall variability is slightly higher in the Abay Valley area (0.56) closely followed by the midland (0.54) while the highland area had a rainfall variability exposure score of 0.43. Again, climatic extreme events found to be more frequent in the Abay Valley (0.42) followed by the midland (0.37) topography. In sharp contrast, very low exposure index for climatic extreme events (0.08) was constructed in the highland terrain.
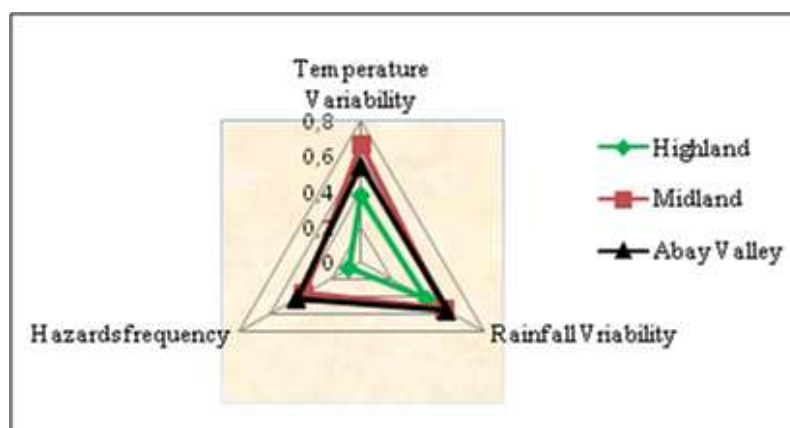

Figure 7. Vulnerability radar for climatic parameters

Communities' vulnerability to farmland poverty

Land degradation (soil erosion, nutrient depletion and deforestation) is severe problem in the highlands of Ethiopia. Similarly, it is a major problem in the Amhara Regional State with the land estimated to be eroding at very rapid rates of 16–50 tons/hectare per year. Because of erosion, the region accounts for more than 50% of the estimated annual soil loss in Ethiopia (Desta et al., 2000). Obviously, this situation has made the State more vulnerability to climate change and associated weather events. The size of farmland holding under cultivation in a community is a sub-indicator for the possible amount of agricultural production. In the rural communities, it is assumed that the larger the farmland holding allows for more opportunities to have more crops and yield, and hence the lower the vulnerability to climate change impacts though it is noted that labor availability and financial capital both affect the reality of how much land can be cultivated. On the contrary, less agricultural area is often attributed to the opposite characteristics that have a negative impact on the rural communities and increased farmers' levels of vulnerability to climatic risks (Barungi and Maonga, 2011). It is very clear from Table 3 that in overall land resource indicators the surveyed community members are found to be highly vulnerable to farmland poverty at 0.61 in the lowland, 0.58 in the midland and 0.46 in the flat highland ecological areas. The biophysical and socio-economic contexts were found to be the worst in the lowland valley. Communities are observing significant negative impacts of drought and extreme events on natural resources such as

farmlands, pasturelands, water sources, and vegetations. NGOs and government officials also mentioned the declining availability, productivity and quality of farmlands owned by the farming community. Rural communities' farmland ownership status is well described by the household survey. The average land holding was found to be 1.62 hectares per household in the midland, 0.79 in the lowland and 0.78 hectare in the highland. The average holding of farmland was found to be 1.06 hectares per household. The per capita farmland was found to be 0.46 hectare both in highland and in the valley, 0.77 in the midland. The maximum per capita farmland holding size was almost the same ranging from 3 to 3.5 hectares while the minimum ranged from zero in the lowland and the midland to 0.05 hectare in the highland-*dega* areas.

Table 3. Normalized values of farmland vulnerability indicators [Household survey, March to Sept 2012]

Farmland vulnerability	Unit	Actual	Max	Min	VI
Inverse of farmland size households own	Hectare	0.784	5	0	0.86
HHs whose land located in rugged terrain	%	36.4	100	0	0.36
HHs who owned highly eroded farmland	%	6.2	100	0	0.06
HHs owned poorly fertile farmland	%	7.07	100	0	0.07
Inverse of index of crop yield	Quintal	5.007	19.3	0.5	0.81
HHs who unable to save crops for the time of food shortage	%	89.1	100	0	**0.89**
HHs who unable to put seeds for the next cropping season	%	31.8	100	0	0.32
Crop yield trend stability	%	93.8	100	0	**0.94**
HHs who are in fear of loss of their farmland	%	6.2	100	0	**0.06**
HHs who have not got certificate for their farmland	%	12.4	100	0	**0.12**
HHs who have not got land management training	%	0.88	100	0	0.88
Distance to fertilizer market center	Minute	71.49	690.0	3.50	0.09
HHs who unable to use modern fertilizers	%	20.9	100	0	**0.21**
Inverse of amount of modern fertilizer use	k.g	87.54	325	0	**0.79**
Average farmland vulnerability index [Highland (A)]					**0.46**
Farmland vulnerability	Unit	Actual	Max	Min	VI
Inverse of farmland size households own	Hectare	1.07	5	0	0.79
HHs whose land located in rugged terrain	%	34.2	100	0	0.34
HHs who owned highly eroded farmland	%	77.7	100	0	0.78
HHs owned poorly fertile farmland	%	87.5	100	0	0.88
Inverse of index of crop yield	Quintal	4.09	19.3	0.5	0.81
HHs who unable to save crops for the time of food shortage	%	90.7	100	0	0.91
HHs who unable to put seeds for the next cropping season	%	23.5	100	0	0.24
Crop yield trend stability	%	88	100	0	0.81
HHs who are in fear of loss of their farmland	%	17	100	0	0.17
HHs who have not got certificate for their farmland	%	8.7	100	0	0.09
HHs who have not got land management training	%	85	100	0	0.85
Distance to fertilizer market center	Minute	92.48	260	5	0.34
HHs who unable to use modern fertilizers	%	27	100	0	0.27
Inverse of amount of modern fertilizer use	K.g.	36.89	175	0	0.79
Average farmland vulnerability index [Midland (B)]					**0.58**
Farmland vulnerability	Unit	Actual	Max	Min	VI
Inverse of farmland size households own	Hectare	0.799	5	0	**0.86**
HHs whose land located in rugged terrain	%	65.4	100	0	**0.65**
HHs who owned highly eroded farmland	%	45.3	100	0	**0.45**
HHs owned poorly fertile farmland	%	62.1	100	0	**0.62**
Inverse of index of crop yield	Quintal	2.766	19.3	0.5	**0.89**
HHs who unable to save crops for the time of food shortage	%	96.2	100	0	**0.96**
HHs who unable to put seeds for the next cropping season	%	31.2	100	0	**0.31**
Crop yield trend stability	%	92.4	100	0	**0.92**
HHs who are in fear of loss of their farmland	%	21.3	100	0	**0.21**
HHs who have not got certificate for their farmland	%	13.3	100	0	**0.13**
HHs who have not got land management training	%	75	100	0	**0.75**
Distance to fertilizer market center	Minute	282.60	690.00	3.50	**0.39**
HHs who unable to use modern fertilizers	%	49	100	0	**0.49**
Inverse of amount of modern fertilizer use	K.g.	33.7	325	0	**0.91**
Average farmland vulnerability index [Lowland-Valley (C)]					**0.61**

Source: Household Survey, March to September 2013

As the study found out that, the overall communities' vulnerability to farmland poverty was found to be 0.61 in the lowland valley, 0.58 in the midland, and 0.46 in the flat highland areas (see Table 3). Instability of crop yield trend contributes great to the land vulnerability in the highland (0.94) and in the lowland (0.92) while it is the third contributor in the midland. The first contributor of vulnerability to farmland poverty in the midland was found to be very low yield per hectare (0.83) while it is the second in the lowland (0.89) and the fourth in the highland (0.81). Farmland size is vulnerable at 0.88 both in the highland and in the lowland and 0.82 in the midland ecology.

Farmland location, intense soil erosion, and poor soil fertility contributes much more to communities' vulnerability to farmland poverty in the lowland than other agro-ecologies (0.62, 0.45, and 0.65) respectively against 0.36, 0.06, and 0.07 in the highland and 0.23, 0.16, and 0.04 in the midland. One government official at Office of Agriculture in the lowland ecological area noted the problem as: *"The production potential of the land is going down, due to shorter rainy seasons, recurrent droughts, intense rainfall events which cause severe erosion, and overgrazing. Pests and diseases infestations also has posed tremendous damage on cultivated crops"*

The structure of land holdings has significant impact on the productivity and development of agriculture in the rural communities. In other words, the type of land tenure system and the level of security it provides may have serious implications for the sustainable management of agricultural soils, and could indirectly affect crop productivity and environmental sustainability, consequently influencing households' degree of vulnerability to farmland poverty (Barungi and Maonga, 2011)..

Three different tenure arrangements were identified in the study communities. These were land obtained through government redistribution, land inherited, and land gifted from friends and relatives to the household. The overwhelming majority of the surveyed households (92.2% in the highland, 82% in the midland, and nearly 78% in the lowland) reported that they obtained their farmland through government tenure arrangement (redistribution).

Around 12% of the households in the highland, 11.4% in the midland, and 12.4% in the lowland owned their farmland through inheritance while insignificant proportion of households in the highland (1.55) and in the lowland (1.1%) reported gifts as one source of their farmland. This implies that households are more vulnerable in terms of farmland tenure system. Barungi and

Maonga (2011) argue that households who inherited their farmlands will have the most secure land tenure type on which they can undertake sustainable investment. On the other hand, it is argued that agricultural lands secured through inheritance and government redistribution has been fragmented from which agricultural holdings have been divided and passed down to the younger generations.

In addition to other means of securing agricultural land, some 43.4% of surveyed households in the highland, 36.8% in the midland, and 30.8% in the lowland who do not have farmland or smaller farmland relied on sharecropped-land which provided them with meager food supplies for their families. Hence, increase households' degree of vulnerability to farmland poverty exacerbated with extreme weather events and many other stressors.

Conclusions

This study assessed the rural communities' vulnerability to farmland poverty in spatially different ecological settings of northwest Ethiopia where severe environmental change risks exist. The lowland (Abay Valley) ecological area, where the worst biophysical contexts exist is more vulnerable by all indicators of land resources. The overall vulnerability level of communities to land poverty was found to be higher in the lowland than those in the highland and the midland areas. Instability of crop yield trend showed great contribution to rural communities' vulnerability to farmland poverty in the highland and the lowland while it is the third contributor in the midland. The first contributor of vulnerability to farmland poverty in the midland was found to be very low yield per hectare while it is the second in the lowland and the fourth in the highland. Land holding size is vulnerable in the three ecological/topographic features.

Locations of farmlands in the fragile landscapes, powerful soil erosion, and poor soil fertility have more contribution to communities' vulnerability to farmland poverty in the lowland area than other ecological areas. Three different tenure arrangements were identified in the study communities. These were land obtained through government redistribution, land inherited, and land gifted from friends and relatives by the household. The overwhelming majority of the surveyed households in the three ecological settings reported that they obtained their farmland through government tenure arrangement (redistribution). Land management strategies designed taking into account the ecological

contexts could provide a buffer against extreme environmental events need to be the primary concerns of the State government to minimize farmland poverty risks thereby increasing resiliency of rural households. Local leaders should enforce integrated land management practices and tree plantations to create enabling conditions to regulate the local climate and reduce environmental change-induced risks (droughts, soil erosion and floods).

References

ACCRA/African Climate Change Resilience Alliance. 2011. Understanding the Influence of Development Interventions on Adaptive Capacity at Local Level in Ethiopia, Africa Climate Change Resilience Alliance (ACCRA) Ethiopia Synthesis Report. Addis Ababa: Africa Climate Change Resilience Alliance (ACCRA).

Adger, W.N. 2003. Social capital, collective action, and adaptation to climate change. *Economic Geography* 79(4): 387-404.

Admassie, A., Adnew, B. and Tadege, A. 2006. Perceptions of Stakeholders on Climate Chnage and Adaptation Strategies in Ethiopia. Washington DC.: International Food Policy Research Institute.

Aklilu, A. and Alebachew, A. 2009. Assessment of Climate Change-induced Hazards, Impacts and Responses in the Southern Lowlands of Ethiopia. Addis Ababa: Cordaid and Forum for Social Studies.

Barungi, M. and Maonga, B.B. 2011. Adoption of soil management Technologies by Smallholder Farmers in Central and Southern Malawi. *Journal of Sustainable Development in Africa* 12 (3): 28-38.

Brooks, N. 2003. Vulnerability, Risk and Adaptation: A Conceptual Framework, Working Paper 38. East Aglia, Norwich: Tyndall Centre for Climate Change Research.

Coltman, T., Devinney, T., Midgley, D. and Veniak, S. 2008. Formative versus reflective measurement models: Two applications of formative measurement. *Journal of Business Research* 61(12): 1250-1262.

Conway, D. and Schipper, E. L. 2010. Adaptation to climate change in africa: challenges and opportunities identified from Ethiopia. *Journal of Global Environmental Change* 21: 227-237.

Creswell, J.W. 2012. Educational Ressearch: Planning, Conduction and Evaluating Quantitative and Qualitative Research. New York: Pearsons Educational Inc.

Cutter, S.L. 1996. Vulnerability to environmental hazards. *Progress in Human Geography* 20 (4): 529-539.

Cutter, S.L., Boruff, B.J. and Shirley, W.L. 2003. Social Vulnerability to Environmental Hazards. Social Science Quarterly, Volume 84, No. 2, Southwestern Social Science Association, pp. 242-262.

Dabat Woreda Communication Office. 2013. Documentation of the 2012 Best Practices on natural Resources Conservation and Rehabilitation, Unpublished Document, Dabat, Ethiopia.

Dercon, S. 2004. Growth and shocks: evidence from rural Ethiopia. *Journal of Development Economics* 74: 309- 329.

Dercon, S., Hoddinott, J. and Woldehanna, T. 2005. Shocks and consumption in 15 Ethiopian Villages, 1999-2004. Washington DC.: International Food Policy Research Institute.

Desta, L., Kessie, M., Benin, S. and Pender, J. 2000. Land degradation and strategies for sustainable development in the Ethiopian Highlands: Amhara region. Nirobi, Kenya: InternationalLlivestock Research Institue.

Food and Agricultural Organization (FAO). 2009. Coping with a Changing Climate: Considerations for Adaptation and Mitigation in Agriculture. Rome: Food and Agricultural Organization/FAO.

Gallopin, G.C. 2006. Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change* 16: 293-303.

Gbetibouo, G.A. 2009. Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability: The Case of the Limpopo Basin, South Africa. University of Pretoria: IFPRI Discussion Paper 00849.

Hahn, M.B., Riedere, A.M. and Foster, S.O. 2009. The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change - a case study in Mozambique. *Global Environmental Change* 19 (1): 74-88.

Houghton, J. 2009. Global Warming: The Complete Briefing, Fourth edition . Cambridge: Cambridge University Press.

Icrisat 2006 (March 15). Retrieved January 12, 2013, from the .icrisat website: www.icrisat.org/what-we-do/

IPCC/Intergovernmental Panel on Climate Change. 2001. Intergovernmental Panel on Climate change 2001: Impacts, adaptation and vulnerability. Cambridge: Cambridge University Press.

IPCC/Intergovernmental Panel on Climate Change. 2007. Adaptation to Climate Change in the Context of Sustainable Development. Cambridge: IPCC.

IPPC/Intergovernmental Panel on Climate Change. 2007. Adaptation to Climate Change in the context of Sustainable Development, Background Paper. Bonn, Germany: UNFCCC Secretariat.

Israel, G.D. 1992. Determining Sample Size. IFAS Extension, University of Florida, 1-7.

Iyengar, N. and Sudarshan, P. 1982 (December 18). A method of classifying regions from multi-variate data. Economic and Political Weekly, Special article, pp. 1-5.

Lal, R. 2005. Climate change, soil carbon dynamics, and global food security. In: Lal R, Stewart B, Uphoff N, et al., editors. Climate change and global food security. Boca Raton (FL): CRC Press, 2005.

Leulseged, Y., Nicol, A. and Srinivasan, S. 2013. Warming to Climate? Climate Policy and Agricultural Development in Ethiopia. www-future-argiculture.org: Future Agriculture.

Menberu, T. 2015. Farmers' vulnerability to climate change-induced water poverty in spatially different agro-ecological areas of Northwest Ethiopia. *Journal of Water and Climate Change* 8 (4), DOI: 10.2166/wcc.2015.140

Menberu, T. 2016. Rural households' agricultural land vulnerability to climate change in Denbia woreda, Northwest Ethiopia. *Environmental Systems Research Journal* 5(14), Springer Open access, DOI 10.1186/s40068-016-0064-3.

Mertez, O., Mbow, C., Reenberg, A. and Diouf, A. 2008. Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental Management* 43 DOI 10.1007/s00267-008-9197-0, 804-816.

Mongi, H., Majule, A.E. and Lyimo, J. 2010. Vulnerability and adaptation of rain-fed agriculture to climate change and variability in semi-arid Tanzania. *African Journal of Environmental Scence and Technololgy* 4(6):371-381.

Morrow, B.H. 1999. Identifying and mapping community vulnerability. *Disaster* 23 (1): 1-18.

Moss, R.H., Brenkert, A.L. and Malone, E.L. 2001. Vulnerability to Climate Chnage: A Quantitative Approach. Washington DC.: The U.S. Department of Energy.

NMSA/National Meteorological Service Agency. 2007. Climate Change National Adaptation Program (NAPA) of Action of Ethiopia. Addis Ababa: NMSA.

NMSA/National Meteorological Services Agency. 2001. Initial National Communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC). Addis Ababa, Ethiopia: National Meteorological Services Agency under the GEF supported.

NMSA/National Meteorological Services Agency. 2012. Meteorology data for Dabat and Denbia Woredas, Unpblished Office documents, Bahir Dar Branch, Bahir Dar.

O'Brien, K., Leichebko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., Javed, A., Bhadwal, S., Barg, S., Nygaard, L. and Westa, J. 2004. Mapping vulnerability to multiple stressors: climate change and globalization in India. *Global Environmental Change* 14(4): 303-313.

Schipper, E. L. 2004. Exploring Adaptation to Climate Chnage: A Development Perspective. East Angelia: East Angelia University Press.

Segele, Z. and Lamb, P. 2005. Characterization and Variability of Kiremt Rainy Season over Ethiopia. *Meteorology and Atmospheric Physics* 89: 153-180.

Smit, B., Burton, I., Klein, R. and Street, R. 1999. The Science of Aaptation: A Framework for Assessment. Mitigation and Adaptation Strategies for Global Change 4. Ontrario,Canada , 199-213.

Sullivan, C. 2002. Calculating a water poverty index. *World Development* 30 (7): 1195-1210.

Sullivan, C., Meigh, J.R. and Lawrence, P. 2006. Application of the water poverty index at different scales: a cautionary tale. *Water International* 31 (3): 412-426.

Temesgen, D. 2007. Measuring The Economic Impact of Climate Change on Ethiopian Agriculture: Ricardian Approach. World Bank Policy Research Working Paper 4342. Washington DC: World Bank.

Temesgen, D., Hassan, R.M., Ringler, C., Alemu, T., and Yesuf, M. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change* 19: 248-255.

Temsegen, T. 2010. Assessment of the Vulnerability of Ethiopian Agriculture to Climate Change and Farmers Adaptation Strategies. PhD. Thesis. Pretoria: University of Pretoria.

Tesfaye, B. 2003. Understanding farmers: Explaining Soil and Water Conservation in Konso, Wolaita and Wello, Ethiopia. Wageningen: Ph.D Thesis, Wageningen University.

Tibebe, B. 2008. Water Resources Potential Assessment of Simada Woreda with Particular Reference to Groundwater: A Case Study of Bijena-Muge River Catchments, South Gondar Ethiopia. Arbaminch University: Unpublished MSc Thesis.

Turner II, B.L., Kasperson, R.E., Matsone, P.A., McCarthy, J.J., Corellg, R.W., Christensene, L., Eckleyg, N., Kasperson, J.X., Luerse, A., Martellog, M.L., Polskya, C, Pulsiphera, A. and Schiller, A. 2003.. A framework for vulnerability analysis in sustainability science. *Proceeding of the National Academy of Sciences of the United States of America* 100(14): 8074-8079.

UNDP/United Nations Development Program. (2010). Human Development Index Trends, 1980-2010, Table 2, Statistical Annex 151. New York: UNDP.

UNESCO/United Nations Educational, Scientific, and Cultural Organization. (2004). National Water Development Report (Final), World Water Assessment Program. Addis Ababa: Ministry of Water Resources and UNESCO.

UNFCCC/United Nations Framework Convention on Climate Change . (2007). Climate Change: Impacts, Vulnerabilties, and Adaptation in Developing Countries. Bonn, Germany: United Nations Framework Convention on Climate Change Secretariat.

Veronesi, M. 2010. On Adaptation to Climate Change and Food Productivity:A Micro-perspective from Ethiopia. Hohenheim: Food Security Center, University of Hohenheim.

Wisner, B., Blaikie, P., Cannon, T. and Davis, I. 2004. At Risk: Natural Hazards, People's Vulnerability and Disasters. London: Routledg, Tancis Group.

Woldeamlak, B. 2009. Rainfall Variability and Crop Production in Ethiopia: Case Study in Amhara Region. In: Proceedings of the 16th International Conference of Ethiopian Studies, ed. by Svein Ege, Harald Aspen, Birhanu Teferra and Shiferaw Bekele, (pp. 823-836). Trondheim.

World Bank. 2008. The Economics of Adaptation to Climate Change. New York: International Bank for reconstruction and Development.

World Vision Ethiopia.2007. Denbia Area Development Program Document, Programme number: 00558, phase number of the program: (2008-2012, Phase I), Bahir Dar, Ethiopia.

Yesuf, M., Falco, S.D., Ringler, C. and Kohlin, G. 2008. The Impact of Climate Change and Adaptation on Food Production in Low Income Countries: Evidence from the Blue Nile, Ethiopia. Washington DC.: IFPRI.

Yohannes, G. and Mebratu, K. 2009. Local Innovation in Climate Change Adaptation by Ethiopian Pastoralists. Addis Ababa: PROLINNOVA-Ethiopia and Pastoralist Forum Ethiopia (PFE).

You, G.J.Y. and Ringler, C. 2010. Hydro-Economic Modeling of Climate Change Impacts in Ethiopia. Washington DC., Addis Ababa; New Delhi: International Food Policy Research Institute.