Vulnerability of Smallholder Farmers' to Climate Change and Variability in the Central Highlands of Ethiopia

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Abstract

This study investigates vulnerability of smallholder farmers to climate change and variability in three districts (Basona Werana, Efratana Gidim and Menz Gera Meder) located in different agroecological zones (AEZs) in the central highlands of Ethiopia. Household level data about livelihood capitals and climate related variables were used to develop vulnerability indices and determine vulnerability patterns across the study area. Our results identify Basona Werana as the most vulnerable in terms of physical and financial capital indicators while Efratana Gidim is the most vulnerable in natural capital indicators and climate factors. Vulnerability score of 3 out of the 6 indicators are the least for Menz Gera Meder. Statistically significant differences of vulnerability are observed in 9 of the 39 sub-components indicating differences in the level of vulnerability across agroecological zones. The findings have implications for planning and prioritizing adaptation interventions in the study area, while the methodology is applicable to other parts of rural Ethiopia as well.

Keywords: climate change; vulnerability; farmer, North Shewa, Ethiopia

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Introduction

Ethiopia is highly exposed to climate change impacts (Conway and Schipper 2011) and often placed in the top list of most vulnerable countries (Krishnamurthy *et al*. 2014). Significant influence of current climate variability and extreme events are observed and expected to increase in the future **(**Dazé 2014). Agriculture is generally one of the most affected sectors by climate change and variability (IPCC 2014). The vulnerability of Ethiopian agriculture to climate change and variability is attributed to environmental, socio demographic and economic factors (Dercon 2004; Deressa 2010). The poor performance of the sector is mostly associated with changes in rainfall patterns which cause both droughts and floods (Deressa 2010; Conway and Schipper 2011). Future climate change and variability are likely to slow down agricultural growth and thereby reduce opportunities for economic development and eradication of poverty (Wagesho et al. 2013; Dazé 2014).

High levels of poverty and extreme dependence on natural resources have exposed smallholder farmers of Ethiopia to the adverse impacts of climate change. In the central highlands, as in much of the country, agriculture is predominantly rain-fed and landholdings are about 1.0 ha per household, which is also the national average. Very few households have access to irrigation and non-farm income to supplement their existence. Land degradation and loss of productivity is a major contributor to the widespread poverty and climate change vulnerability of communities in the area (Alemayehu and Bewket 2016).

Available studies (e.g., Deressa et al. 2008; Tesso et al. 2012; Gebrehiwot and van der Veen 2013; Teshome 2016; Simane et al. 2016) indicate that smallholder farmers in Ethiopia are generally highly vulnerable to climate change and variability. Deressa et al. (2008) reported that most farmers in the Nile Basin of Ethiopia are vulnerable to the impact of climate change. In a study of analysis of vulnerability and resilience to climate change induced shocks in North Shewa Administrative Zone of Oromia Region, Ethiopia Tesso et al. (2012) observed that most households were vulnerable to natural shocks in the area. The study by Gebrehiwot and van der Veen (2013) in east Tigray Region, Northern Ethiopia revealed that the districts deemed to be most vulnerable to climate change and variability overlapped with the most vulnerable populations. In a different study on agroecosystem specific climate vulnerability analysis, Simane et al. (2016) reported that both farmers in the *Dega* and *Kolla agroecological* zones were more vulnerable than those in the midland agroecological zone in their study in the Choke Mountain area, Blue Nile basin of Ethiopia. Teshome (2016) identified that households are increasingly vulnerable to climate change risks in Dembia woreda, Northwest Ethiopia.

Previous studies have shown that Ethiopian farmers are vulnerable to the adverse impacts of climate change and variability. However, the extent of vulnerability and options for adaptation vary across space and in time. This suggests that there is a need to understand local scale climate patterns and trends and vulnerability context so as to implement effective adaptation measures.

Most of the available literatures on vulnerability in Ethiopia (e.g. Deressa et al. 2008; Tesso et al. 2012; Gebrehiwot and van der Veen 2013) are based on principal component analysis following the Intergovernmental Panel on Climate Change (IPCC) (2001) definition of vulnerability. In a study of agroecosystem specific climate vulnerability analysis Simane et al. (2016) used IPCC's Livelihood Vulnerability Index (LVI-IPCC) to measure community vulnerability. Teshome (2016) studied rural households' vulnerability to climate change using a Livelihood Vulnerability Index approach, developed by Hahn *et al*. (2009). In this study, we use both the LVI and the LVI-IPCC approaches to assess vulnerability patterns based on 39 indicators consisting of livelihood capitals and climate factors. Examining the current and future level of vulnerability of smallholder farmers to climate change and variability is important to design appropriate adaptation strategies (Skjeflo 2013). Vulnerability varies across spatial and temporal scales, and household level assessment of vulnerability is particularly important for designing effective adaptation strategies.

The general objective of this study is to examine vulnerability of smallholder farmers to climate change and variability in the central highlands of Ethiopia. The specific objectives are to: i) develop vulnerability index and map vulnerability, ii) investigate extent of household level vulnerability, iii) asses determinant factors that contribute to vulnerability, and iv) compare two index development and vulnerability assessment approaches (LVI and LVI-IPCC). In the following section, we present a brief description of the study area and materials and methods of the study, and this is followed by the results and discussion section. Conclusions are presented in section 4.

Research Methodology

Description of the Study Area

Smallholder farmers in the central highlands of Ethiopia are facing different types of climate change related risks such as reduced or variable rainfall, warming temperatures, crop and livestock pests and diseases, flooding, shortage of water and soil erosion (Alemayehu and Bewket 2017). Current climate variability contributes to reduced agricultural productivity (Alemayehu and Bewket 2016), and the future sustainability of the sector in the area depends on the types of coping and adaptation strategies used by farmers. Planned adaptation to climate change is urgent in parts of Ethiopia such as the central highlands where communities are almost entirely rainfall dependent and food insecure. Reducing exposure and sensitivity along with increasing adaptive capacity and strengthening the adaptation processes through building on existing adaptation practices are suggested.

The study covers three districts (*Woredas* in Amharic), namely Menz Gera Meder, Basona Werana and Efratana Gidim, of the North Shewa Administrative Zone of the Amhara National Regional State (ANRS) of Ethiopia (Figure. 1). According to the Central Statistical Agency (CSA) (2013), the total population of the three districts is 371,890 out of which 188,820 are males and 183,070 are females. Menz Gera Meder is in the *Dega* (highland) agroecological zone while Basona Werana and Efratana Gidim are in the *Weyna Dega* (midland) and *Kolla* (lowland) agroecological zones (AEZs), respectively. Elevation ranges from 1140 masl in Efratana Gidim to 3554 masl in Menz Gera Meder. Some 37% of the total area of the three districts is mountainous, 21% is rugged terrain and 42% is plain lands. Based on the FAO/UNESCO soil classification system, Vertisols cover about 37% of the districts, Nitosols cover about 24%, Chernozems cover about 30% and others account for some 9%. The major land use types include croplands (47%), forest and bush (23%), and grazing (10%) (North Shewa Zone Agriculture Office 2013). Annual rainfall is >1000 mm and mean annual temperature ranges from 13.5 ^{0}C in Basona Werana to 21.5 ^{0}C in Efratana Gidim (Alemayehu and Bewket 2017).

Mixed farming is the dominant livelihood source in the area. Selling local alcoholic drink (*Araki*), fuel wood, charcoal and the multipurpose *Guassa* grass (*Festuca grass*) (a perennial tufted grass used for livestock feed, traditional house construction, and home to many endemic species of fauna and flora of the Afroalpine ecosystem) are used to supplement local livelihoods. Most of the districts in the North Shewa Zone are food insecure, and the problem is worse in the *Dega agroecological* zone (North Shewa Zone Food Security Coordination and Disaster Prevention Office 2013). According to information from the Zone's Food Security Coordination and Disaster Prevention Office and discussions with key informants, large parts of the Zone are beneficiaries of the Productive Safety Nets Program, which is the major food security program of the government. Environmental challenges such as occurrence of droughts and floods, land degradation and declining soil fertility have contributed to the deterioration in the livelihood of smallholder farmers in most of the districts of the Zone. Socioeconomic and demographic constraints also aggravated the livelihood challenges. The Zone belongs to one of the most vulnerable areas to climate change and variability in the country where a large segment of its population is already food insecure (North Shewa Zone Food Security Coordination and Disaster Prevention Office 2013).

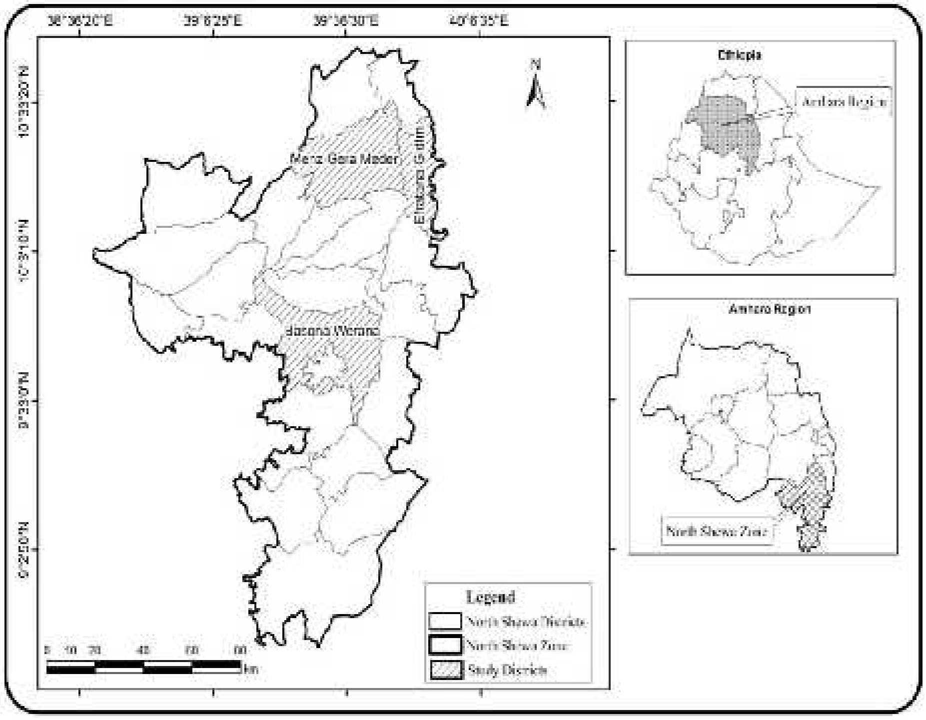


Figure 1. Location of the study area
Source: CSA (2007)

Data and Methods

Data Collection and Methods of Analysis

Two stages of sampling with a combination of purposive (to select sample districts and kebeles[3] that have different AEZs) and random sampling (to select sample households) were used. In the first stage, three districts of North Shewa Administrative Zone comprising Kolla (lowland), Woinadega (midland) and Dega

[3]the lowest tiers in the administrative structure of the country

(highland) agro-ecological regions were selected purposively to capture variations across agro-ecology. We selected one kebele from each district purposively. The documents available at sample kebeles were used as sampling frames and the sample size was determined proportional to total number of household heads. We found 1073 household heads in Efratana Gidim, 1411 household heads in Basona Werana and 1208 household heads in Menz Gera Meder, respectively. The kebeles with larger number of total households had larger sample size and vice versa. In the second stage, sample households were selected using a simple random sampling technique which gives equal chance to be selected for all households. Thus, 200 farmers (household heads) were selected randomly (58 in Efratana Gidim, 76 in Basona Werana and 66 in Menz Gera Meder, respectively).

The surveyed farmers were asked questions about the five livelihood capitals (natural, social, human, financial and physical) and climate factors (their perception of climate change/ variability and impacts/ hazards (CCVI)) to determine their vulnerability.

Measuring Vulnerability

Assessing vulnerability is a key to understand vulnerable households, places and possible adaptation options (Füssel and Klein 2006). The econometric and indicator assessment methods are widely used to measure vulnerability to climate change (Deressa et al. 2008). The econometric method frequently uses household-level socio-economic survey data to analyze the level of vulnerability and welfare loss due to shocks (Hoddinott and Quisumbing 2003).The indicator method of quantifying vulnerability involves selecting some indicators/proxies from a diverse set of potential indicators and merging them to identify the levels of vulnerability at different scale of analysis. In the indicator approach two options are available for measuring vulnerability. The Livelihood Vulnerability Index (LVI) developed from livelihood capitals and climate factors by Hahn *et al*. (2009) to study risks from climate variability and change in Mozambique, and the IPCC's vulnerability index (LVI-IPCC) which measures vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC 2001). Practically the assessment of vulnerability is difficult by itself because there are many related factors such as natural resources, economic and social conditions such as demography and climate change comes on top of all these interactions and dynamics. As a result, we used two vulnerability measurement approaches developed by previous researches (LVI and LVI-IPCC) to identify vulnerable households, to understand factors contributing to their vulnerability at household level and prioritize the potential interventions.

The LVI analysis is a practical method to identify vulnerable households and to design impactful adaptation interventions in the locality. Hahn *et al*. (2009) reported that the LVI approach is a robust and flexible tool for measuring livelihood vulnerability to climate change impacts. Household level data about livelihood capitals and climate related variables were used to develop vulnerability indices and determine vulnerability patterns across the study area. The LVI-IPCC on the other hand is an integrated vulnerability assessment approach which considers both the biophysical and the socioeconomic indicators in assessing vulnerability. In this study we compared the two vulnerability assessment approaches (LVI and LVI-IPCC).This allowed us to identify the most vulnerable households and areas at the local level and to design impactful adaptation interventions. Following Sullivan (2002), we assumed all indicators to be equally important and hence to have equal weight.

Constructing an index for vulnerability involves selection of indicators, standardization to a common scale, and weighting to a final value to form overall vulnerability index which is known as the composite index of vulnerability (Tate 2012). We assigned 0 (lowest, least vulnerable) and 0.5 (highest, most vulnerable). However, when there is a negative/inverse relationship between variables, we used the inverse of the indicator.

The LVI, for this study consisted of five major components (natural, social, human, financial and physical capital) and climate factors having many sub components under each category. The formula is:

$$index S_d = \frac{S_d - S_{min}}{S_{max} - S_{min}}$$

Where, S_d = original (observed) value of sub component of indicator for a household, for a district, d.

S_{max} and S_{min} = the highest and lowest values of sub component indicator for a household, indicating high and low vulnerability, respectively.

Next, after standardizing each value, the average of the sub-components was calculated using the following formula

$$M_d = \frac{\sum_{i=1}^{n} index\, S_{di}}{n}$$

Where M_d = one of the six major components for the district d, natural (N), social (S), human (H), financial (F) and physical (P) capitals and climate factors and (CCVI)$index_{Sdi}$ = represents the sub-components, indexed by i, that make up each major component, and

n = denotes the number of sub-components in each of the major components.

After each sub component was estimated, they were averaged as:

$$\text{LVI}d = \frac{\sum_{i=1}^{6} WMi\ Mdi}{\sum_{i=1}^{6} WMi}$$

Where LVI*d*= the Livelihood Vulnerability Index for district d, is the weighted average of the six major components.
WM_i = is the weight of each major component, which were determined by each sub-component at equal proportion.
Md_i= is one of the six major components for district d

This can be expressed in a simplified and expanded form as:

$$LVId = \frac{WNNd}{WN} + \frac{WNSd}{WS} + \frac{WNHd}{WH} + \frac{WNFd}{WF} + \frac{WNPd}{WP} + \frac{WNCCVId}{WCCVI}$$

Where N=natural capital, S=social capital, H=human capital, F= financial capital, P= physical capital and CCVI =climate factors

The LVI-IPCC can be calculated as as a function of a system's exposure and sensitivity to climatic stimuli and its capacity to adapt to the impacts.

$$\text{CFd} = \frac{\sum_{i=1}^{n} WMi\ Mdi}{\sum_{i=1}^{n} WMi}$$

where CF_d is contributing factor based on the IPCC (2001) definition (exposure, sensitivity, or adaptive capacity) for district d, Md_i are the major components for district d indexed by i, WM_i is the weight of each major component, and n is the number of major components in each contributing factor. After calculating exposure, sensitivity, and adaptive capacity, the three contributing factors were combined as follows:

$$LVI - IPCC = (Ed - Ad) * Sd$$

where LVI-IPCC is the LVI for district d expressed using the IPCC vulnerability framework, E is the calculated exposure score for district d (climate change/variability and impacts/hazards), A is the calculated value of adaptive capacity for district d (socio-demographic characteristics, livelihood sources and institutional support, etc.), and S is the calculated sensitivity score for district d (farmland, water, etc.). The sub-components used under LVI were also used in the LVI-IPCC and similar procedures were followed in the calculation of indicators and their sub-components. For LVI-IPCC, we assigned -1 (lowest, least vulnerable) and 1 (highest, most vulnerable). Many researchers used both the LVI and LVI-IPCC methods to assess relative vulnerability to climate change (Hahn *et al*. 2009; Shah *et al*. 2013; Ahsan and Warner 2014; Amos *et al*. 2015; Panthi et al. 2016). Table 2 shows the indicators and sub-components of vulnerability used in this study with the assumed functional relationship with overall vulnerability.

Table1. Indicators, sub-components and assumed functional relationship with vulnerability

Indicators of vulnerability	**Functional relationship**
Social capital	
Households who don't get access to credit	Accessing credit increases adaptive capacity
Percent of households with PSNP support	PSNP support increases adaptive capacity
Physical capital	
Households whose house is prone to floods	Prone to flood imply more sensitivity
Households whose house wall is not made of stone	stone walled imply less sensitivity
Households whose house is not iron roofed	Iron roofed imply less sensitive
Distance to agriculture office	Shorter distance imply less sensitivity
Distance to market	Shorter distance imply less sensitivity
Distance to credit source	Shorter distance imply less sensitivity
Distance to water source	Shorter distance imply less sensitivity
Distance to reach to nearby health center	Shorter distance imply less sensitivity
Distance to school	Shorter distance imply less sensitivity
Natural capital	
Households who reported their area is deforested	Deforestation increases sensitivity
Households which reported rugged farm	Rugged farm land imply more sensitivity
Households which reported infertile soils	Infertile soil imply more sensitivity
Households which reported sever erosion on their farm	Sever erosion imply more sensitivity
Households who don't practice irrigation	Access imply less sensitivity
Inverse of farm size	
Households reporting conflict in use of water	More size imply more adaptive capacity Conflict increases sensitivity
Inverse of water consumption	More consumption imply less sensitivity
Human capital	
Sex of household head	Female headed household implies more sensitivity
Family size	More family size imply less adaptive capacity
Dependency (number of dependents)	More dependent imply less adaptive capacity

Inverse of farm experience	Experience imply better adaptive capacity
Households who don't get access to radio	Information increases adaptive capacity
Households who are illiterate	Education increases adaptive capacity
Financial capital	
Households who don't have cash crops	Cash crops increases adaptive capacity
Households with insufficient food from own farm for a year	Households with insufficient food imply more sensitivity
Number of food insufficient months	More months imply more sensitivity
Households who don't get access to non-farm income	Non-farm income increases adaptive capacity
Inverse of crop diversification	Crop diversification increases adaptive capacity
Inverse of Total Livestock Unit (TLU)	More TLU imply higher adaptive capacity
Climate factors	
Trends in minimum temperature	Warming imply higher exposure
Trends in maximum temperature	Warming imply higher exposure
Variation in annual rainfall	Variability imply higher exposure
Perceived impact of drought	More impact imply higher exposure
Perceived impact of flooding	More impact imply higher exposure
Perceived impact of land slide	More impact imply higher exposure
Crop and animal pests/diseases	More impact imply higher exposure

Note: Data source for the five livelihood capitals and perception on climate change variability was own survey; variability and trends on temperature and rainfall was own calculation from data obtained from the National Meteorological Agency.

Results and Discussion

Rainfall and Temperature Variability and Local Adaptation Strategies

In a previous paper (Alemayehu and Bewket 2017), a detailed analysis of rainfall and temperature variability and trends in the study area were presented based on monthly data for 132 points of 10×10 km grids reconstructed from weather stations and meteorological satellite observations. In this paper, we present only a brief summary of the key findings to indicate changes observed in the local climate. In all the study districts, the main rainy season (*Kiremt rainfall*) contributed the largest to annual rainfall with highest contribution in Basona Werana (73%) and lowest in Efratana Gidim (66%). The short rainy season (March – May, known as *Belg*) also made a considerable contribution to annual rainfall which ranges from 19% in Menz Gera Meder to 21% in Efratana Gidim. Annual rainfall shows statistically significant decreasing trend in Basona Werana but non-significant trend in Efratana Gidim and Menz Gera Meder. *Belg* rainfall shows significant decreasing trend in all the three sites, which indicated a loss of the secondary rains which are important for *Belg* season crop production in the area. *Kiremt* rainfall shows significant increasing trend only in Menz Gera Meder. Considerable inter-annual variations in rainfall were observed in the study area. In Basona Werana, the 1980s and 1990s were wet compared with the dramatic decline in 2000s. Based on liner trend analysis, close to 90% of the total number of grid points (n=132) in this district show significant decreasing trends. In addition, some 23% of the total number of observations is under different drought categories which have implications on agriculture, food security and water resource in the area. In Efratana Gidim and Menz Gera Meder, the 1980s and 2000s were relatively drier than the 1990s. Seasonal rainfall anomalies also show similar patterns as annual anomalies but *Belg* rainfall anomalies are relatively more positive in the driest decade of the 1980s than the others.

The mean annual maximum and minimum temperatures show warming trends in all the three districts for the period 1981-2013. The warming trends in the maximum and minimum temperatures for Basona Werana and Efratana Gidim are statistically significant. The 2000s was the warmest decade compared to the 1980s and 1990s. Local increase and variability in temperature affect soil moisture and evapotranspiration.

In response, farmers in the study area use a range of strategies against short term impacts (coping) and long term impacts (adaptation) in response to mitigate the adverse impacts of climate change and variability. A detailed analysis of local coping and adaptation strategies in the study area is reported in a separate paper (Alemayehu and Bewket 2017). Here, we present only a brief summary of the key findings. The strategies can be grouped into four broad categories as land management (soil and water conservation, tree planting, irrigation, and fertilizer and manure application); crop management (changing crop planting dates, crop diversification, use of drought tolerant and fast maturing crops, and improved seeds); livelihoods diversification and adjustment (off farm income, seasonal migration, change in consumption pattern, taking credit, getting support from the productive safety nets programme of the government, land renting and remittance); and livestock management (decreasing livestock numbers, use of cross-bred animals and diversification). However, the strategies are rated as moderately effective to mitigate the adverse impacts of climate change and variability, and future climate change constitutes a major challenge to farmers.

Vulnerability Index Components

We investigated the vulnerability of smallholder farmers in the central highlands of Ethiopia using two measurement approaches: the LVI and the LVI-IPCC. The following subsection discusses the LVI, and this is followed by another subsection on the LVI-IPCC. Table 2 presents the LVI results.

Livelihood Vulnerability Index (LVI)

Natural Vulnerability

We found that Efratana Gidim was naturally most vulnerable when compared to Basona Werana and Menz Gera Meder each having a vulnerability score of 0.50, 0.42 and 0.44, respectively. Located in the most sensitive landscape, vulnerability scores for water and farmland characteristics were high in this district. Problems in accessing water for household activities, conflict in use of water resource and limited water consumption were the main sources of vulnerability which is common in the lowland areas where water shortage is a critical problem. In addition, some households (22% of respondents) rely on unprotected water sources from streams, wells and ponds which are vulnerable to water borne diseases. In general, the water vulnerability score for this district is 0.54. The farmland component of natural vulnerability was accounted for by taking soil erosion, soil fertility, farm size, farm topography and accessing irrigation. These components are important indicators of land quality and hence adaptive capacity. In this regard, Menz Gera Meder followed by Efratana Gidim had the highest vulnerability scores of 0.50 and 0.47, respectively. Land degradation and soil erosion have become the most important environmental concerns in the study area. Only 28% of the area in these districts is plain which is suitable for farming while the remaining part is susceptible to land degradation and soil erosion. In a previous study, we reported that land degradation and soil erosion coupled with current climate variability are major challenges to crop production in the area (Alemayehu and Bewket 2016).Accessing irrigation is an important adaptation strategy to climate change and variability in the rainfed dependent farming. A shift in seasonal and annual rainfall has a direct effect on crop production which is an indication of the sensitivity of the sector to climate change and variability. However, due to the lack of water for irrigation, the percentage of farmers practicing irrigation was small for all districts with a vulnerability score of 0.53 in Menz Gera Meder, 0.63 in Basona Werana and 0.51 in Efratana Gidim indicating almost all households are vulnerable. Vulnerability in terms of forest was measured by using the percentage of farmers reporting the status of forest cover lost. The results revealed that all the three districts have high vulnerability score ranging from 0.55 to 0.59. Despite the fact that tree cover showed improvement over the last 30 years and played an important role in climate change adaptation in all the three districts, more than 78% of households reported that their area was deforested in the last three decades.

Physical Vulnerability

In terms of physical vulnerability, Basona Werana was categorized as most vulnerable compared to Menz Gera Meder and Efratana Gidim, each having vulnerability scores of 0.52, 0.46 and 0.48, respectively. The main source of vulnerability in this district was limited access to transportation and communication having a vulnerability score of 0.62. Access to basic infrastructure and services increases adaptive capacity. However, the average distance is more than twice as long to travel to the nearest town.

This creates difficulty to accessing credit, information about climate change and input and output markets which are important for adaptation to climate change and variability. Housing security as measured in terms of housing condition (percentage of households having stone walled and iron roofed houses, and location of the house in the flood hazard area) was also taken as indicator of physical vulnerability. Accordingly, the vulnerability scores of housing security for the three districts varied from 0.24 (Menz Gera Meder) to 0.39 (Efratana Gidim) indicating that most households are vulnerable. The percentage of households responding their house is prone to flood was higher for Efratana Gidim having a vulnerability score of 0.47. Only 14% of households in this district owned stone-walled house which helps as adaptation to such hazards. Traditionally, farmers construct stone-walled houses in the *Dega agroecological* zone due to cold climate and relative shortage of trees. Moreover, housing conditions vary based on different economic and cultural factors. Households having iron roofed houses are allowed to access credit from local institutions by registering their house as collateral.

Financial Vulnerability

Financial vulnerability as shown in the livelihood activities for the three districts ranged from 0.52 (Efratana Gidim) to 0.56 (Basona Werana), indicating that most households are vulnerable. Financially, Basona Werana showed greater vulnerability score as the percentage of households with access to cash crop and non-farm income was small. However, vulnerability score in terms of the percentage of households reporting insufficient food from own farm for a year and the number of food insufficient months was relatively low in this district with a vulnerability score of 0.50 and 0.32, respectively. Only 10% of the respondents in the study districts reported producing sufficient food from their own farms and saved seeds for the next growing season. The vulnerability score for inverse of crop diversification is higher for Basona Werana. This is because farmers in this district do not grow fruit trees, especially apple (*Malus sylvestris)* which is grown in the highland districts, nor *Masho* (*mung bean*) and *Shiferaw (Moringaoliefera)* which are grown by farmers in the lowlands district that has helped diversification (Alemayehu and Bewket 2017). This in turn raises farmers' income and enhances adaptive capacity. Livestock ownership is important livelihood source for climate change adaptation. Values for TLU are high for Efratana Gidim and Menz Gera Meder than Basona Werana. This shows perhaps that farmers prefer livestock raising as topographic and climate factors are not conducive for crop production compared to the Basona Werana which is midland and has more favorable climate.

Social Vulnerability

Social vulnerability was measured by taking the percentage of households accessing credit and receiving PSNP. Social vulnerability in the area was relatively low, having a vulnerability score of 0.30 (Basona Werana and Efratana Gidim) and 0.28 (Menz Gera Meder). However, when vulnerability score of each contributing factor was considered a clear difference exists. For example, the vulnerability score of access to credit ranged from 0.18 to 0.23 while the vulnerability score of support through the PSNP ranged from 0.36 to 0.41. A previous study showed that crop production in the study area shows declining trends and farmers have low adaptive capacity (Alemayehu and Bewket 2016). Therefore, social supports such as through the PSNP could have implications to mitigate food security challenges. Nonetheless, only 38% of the respondents are beneficiaries of the PSNP. Results further showed that accessing credit is still a major challenge for most famers perhaps due to lack of collateral and high interest rate (up to 18% per annum). This contributes for the low adaptive capacity in the area.

Human Vulnerability

Human vulnerability was similar across the three districts. But, it was relatively high for Basona Werana and Menz Gera Meder having vulnerability score of each 0.48. Female headed households, large family size and number of dependents are assumed to have less adaptive capacity. Female headed households have limited access to resources due to socio-cultural barriers and are more vulnerable. Vulnerability score in terms of family size and number of dependents was slightly higher in Efratana Gidim (0.41) and low in Basona Werana (0.37). This could affect food security of households as there was total dependence on rain fed agriculture on approximately a hectare of landholding. These households tend to consume more instead of saving and investing in productive assets. Educational level of the household head is assumed to be an important source of information on climate change and adaptation strategies. However, educational level in the area is in general low where more than 90% of farmers have not attended any formal education. This has implication on use of adaptation technologies. A previous study reported that older farmers have long years of farming experience to notice changes in their environment and to take up adaptation strategies (Deressa *et al*. 2009). Moreover, access to communication media like radio which is an important source of information on climate change was a significant factor in adaptation decisions (Fosu-Mensah *et al*. 2012). Compared to other components of human vulnerability, the vulnerability score of access to information on climate change as measured by the percentage of households who have access to radio was higher for Menz Gera Meder (0.84).

Vulnerability to Climate Factors

Vulnerability to climate factors (climate change and variability and perceived impacts/hazards) was high for Efratana Gidim (0.54). The percentage of households responding perceived impacts of drought, flooding, crop and animal pests/diseases and land slide was highest in Efratana Gidim indicating the district is more exposed to extreme climate conditions. Vulnerability to drought, however, was common for the three districts. Furthermore, vulnerability score of contributing factors for climate change and variability as measured by the observed trends and variability in temperature and rainfall was highest in this district (0.53). Observed variation in annual rainfall (measured in coefficient of variation) and trends in the minimum and maximum temperatures were also highest in Efratana Gidim.

Overall Vulnerability Score

Based on the aggregate vulnerability index score, all the study districts were vulnerable to climate change and variability. However, we subjectively classified the districts into three classes as high, medium and low to provide comparative vulnerability analysis. In general, Efratana Gidim was under high vulnerable category with overall LVI of 0.47 while Menz Gera Meder had an LVI of 0.42 indicating least vulnerable. Comparison of means (at $p < 0.05$ and $p < 0.1$ levels) using analysis of variance for indicators of vulnerability revealed that 9 of the 39 sub-components showed statistically significant differences for vulnerability across agroecological zones; i.e., differences in exposure, sensitivity and adaptive capacity. Vulnerability was found to be statistically different with respect to distance to farmland, size of farm land, perceived impact from climate change and variability on crop and animal production, occurrence of pests/ diseases and conflict in use of water resources at $p < 0.05$ level. Similarly, accessing irrigation, family size, TLU, location of house in the flood prone area and crop diversification showed statistically significant differences of vulnerability at $p < 0.1$ level.

Table 2. LVI results for the study area

Indicators of vulnerability	Vulnerability score by District		
	Menz Gera Meder	Basona Werana	Efratana Gidim
Social capital			
Households who don't get access to credit	0.2	0.23	0.18
Percent of households with PSNP support	0.36	0.37	0.41
	0.28	0.30	0.30
Physical capital			
Households whose house is prone to floods	0.18	0.11	0.48
Households whose house is not iron roofed	0.33	0.27	0.20
Households whose house wall is not made of stone	0.21	0.56	0.5
Distance to market	0.67	0.7	0.6
Distance to credit source	0.67	0.7	0.6
Distance to agriculture office	0.55	0.63	0.5
Distance to water source	0.4	0.45	0.43
Distance to school	0.55	0.63	0.5
Distance to reach to nearby health center	0.55	0.63	0.5
	0.46	0.52	0.48
Natural capital			
Households who reported their area is deforested	0.55	0.59	0.58
Households reported rugged farm	0.40	0.25	0.44
Households reported infertile soils	0.53	0.40	0.51
Households reported sever erosion on their farm	0.50	0.45	0.43
Households who don't practice irrigation	0.55	0.63	0.51
Inverse of farm size	0.48	0.47	0.45
Households with problems in accessing water for household activities	0.11	0.23	0.48
Households reporting conflict in use of water	0.06	0.08	0.33
Inverse of water consumption	0.75	0.7	0.8
	0.44	0.42	0.50

Human capital			
Sex of household head	0.06	0.08	0.05
Family size	0.42	0.45	0.50
Dependency (number of dependents)	0.31	0.32	0.31
Inverse of farm experience	0.67	0.68	0.68
Households who don’t get access to Radio	0.84	0.78	0.77
Households who are illiterate	0.56	0.57	0.50
	0.48	0.48	0.47
Financial capital			
Households who don’t have cash crops	0.48	0.5	0.41
Households with insufficient food from own farm for a year	0.51	0.50	0.55
Number of food insufficient months	0.42	0.32	0.35
Households who don’t get access to non-farm income	0.42	0.48	0.36
Inverse of crop diversification	0.88	0.93	0.83
Inverse of Total Livestock Unit (TLU)	0.61	0.63	0.60
	0.55	0.56	0.52
Climate factors			
Trends in minimum temperature	0.03	0.45	0.48
Trends in maximum temperature	0.16	0.2	0.93
Variation in annual rainfall	0.14	0.12	0.17
Perceived impact of drought	0.88	0.87	0.9
Perceived impact of flooding	0.35	0.31	0.47
Perceived impact of land slide	0.06	0.03	0.1
Crop and animal pests/diseases	0.67	0.55	0.74
	0.33	0.36	0.54
LVI (overall)	0.42	0.44	0.47

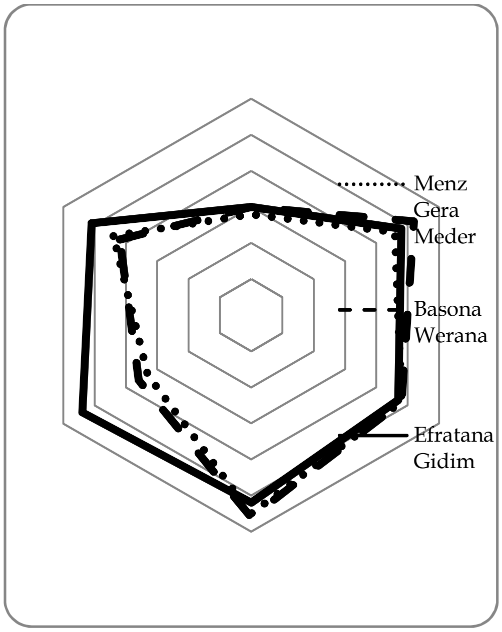
The IPCC’s Vulnerability Index (LVI-IPCC)

The LVI-IPCC also revealed similar result with the LVI for the three districts. As observed in the LVI, Menz Gera Meder had the least LVI-IPCC overall score (-0.05) and Efratana Gidim had the highest (0.05) indicating Efratana Gidim and Menz Gera Meder are categorized under the highest and lowest vulnerable districts, respectively (Figure 2). In the physiographic context, Menz Gera Meder in the *Dega agroecological* zone was the least vulnerable, and this is followed by Basona Werana and Efratana Gidim in the *Weyna Dega* and *Kolla agroecological* zones, respectively. Figure 3 shows map of vulnerability which combines all the indices for each district.

Limited adaptive capacity coupled with high sensitivity and exposure made Efratana Gidim as the most vulnerable of the three districts. However, when the -1 to +1 scale is compared to the 0 to 0.5 of LVI, all the three districts fall within the 'mid-range' but in the same order of vulnerability as did in the LVI. Results of the LVI-IPCC showed that Efratana Gidim was more exposed to climate factors, contributed by trends and variations in rainfall and temperature (0.50). All households surveyed perceived at least one aspect of change in temperature and rainfall and the majority of them noted effects of droughts and floods in the three districts. Perceived impacts of drought, flooding, crop and animal pests/diseases and land slide are highest in Efratana Gidim indicating the district is more exposed to extreme climate conditions. However, drought is a common source of vulnerability across the study districts.

Sensitivity indicators were also high in the three districts but Efratana Gidim was highly vulnerable in most subcomponents. Vulnerability assessment results showed that land and water were the most sensitive sectors. However, the main source of vulnerability in this district was the water sector with a score of 0.54. For example, if we consider water which is one of the most sensitive sectors to climate change and variability, the percentage of farmers reporting problems in accessing water for household activities and conflict in using water was high. Lack of water for irrigation is also a common challenge across the study districts. Land resource is the other sensitive sector. The percentage of households identifying rugged farm topography, severe soil erosion and depleting soil fertility was high in Efratana Gidim and Menz Gera Meder.

Adaptive capacity in the area in general was low showing future climate change and variability will be challenging to smallholder farmers; given high sensitivity and exposure. It is important to minimize sensitivity and enhance adaptive capacity to reduce the vulnerability of smallholder farmers to climate change and variability. Planned adaptation interventions to climate change and variability for different sources of vulnerability is suggested in order to make the smallholder farmers resilient to current and future impacts of climate change and variability. Improving institutions like rural finance, improving access to safe and adequate water supply, diversifying livelihood opportunities, minimizing soil erosion and improving soil fertility, promoting early maturing and drought resistant crops, strengthening early warning systems and expanding irrigation and water management practices are suggested not only for adaptation to long-term climate change but also to improve farm productivity and food security of households in the short-term.



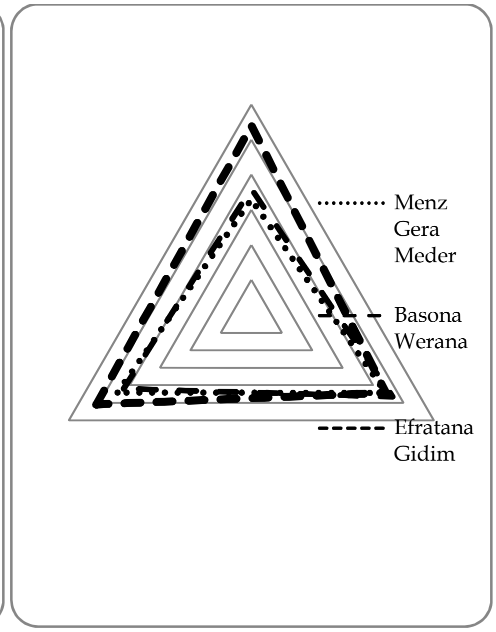


Figure 2. (a) Vulnerability spider diagram of the major components of the Livelihood Vulnerability Index (LVI); (b) Vulnerability triangle diagram of the contributing factors of the LVI-IPCC

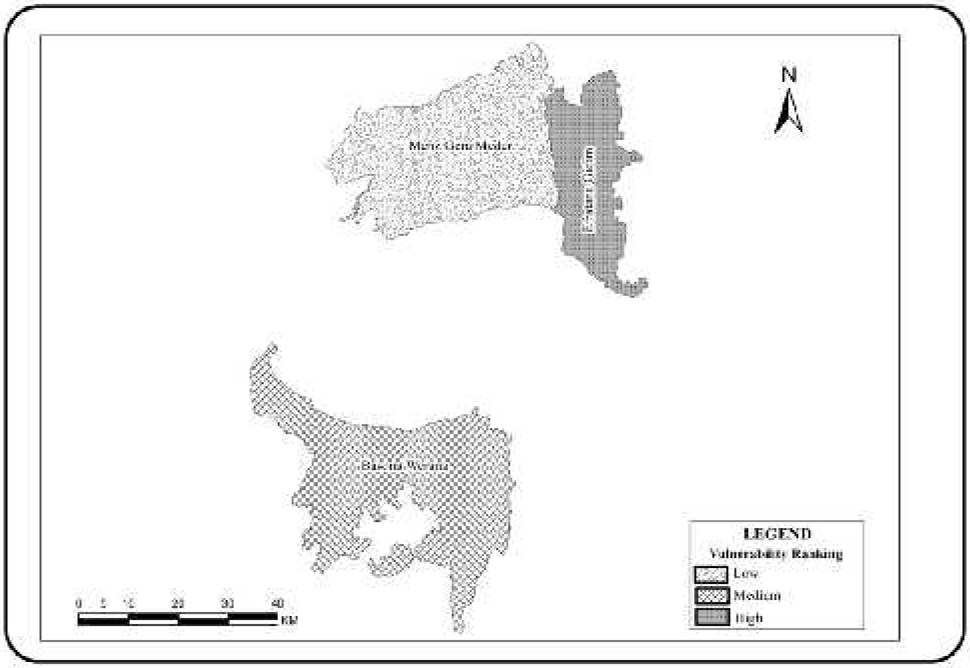


Figure 3. Vulnerability map of the study area

Our findings are supported by Teshome (2016) who observed that farmers in the *Kolla agroecological* zone were more vulnerable to the effects of climate change and variability compared to those in the *Dega agroecological* zone. However, Tesso et al. (2012) reported in a different manner and those farmers in the *Dega agroecological* zone were more vulnerable to the effects of climate change and variability due to land degradation and less experience in adaptation. On the other hand, Simane et al. (2016) reported that both farmers in the *Dega* and *Kolla agroecological* zones were more vulnerable than those in the *Weyna Dega* agroecological zone.

Conclusion

This study analyzed vulnerability of smallholder farmers to climate change and variability in three districts located in different agroecological zones using the LVI and LVI-IPCC methodologies. Household level data about livelihood capitals and climate related variables were used to develop vulnerability indices and determine vulnerability patterns across the study area. This helps to design impactful adaptation interventions in the locality to reduce vulnerability of smallholder farmers and communities to climate change at the grassroots level. Results of the vulnerability assessment confirmed that all the three districts are vulnerable to climate change. However, in relative terms, Menz Gera Meder in the *Dega* (highland) agroecological zone is the least vulnerable, and Efratana Gidim in the *Kolla* (lowland) agroecological zones (AEZs) is the most vulnerable. As extent of vulnerability and options for adaptation vary across space and in time, this household level assessment of vulnerability is useful to identify and prioritize vulnerable areas and contributing factors for adaptation planning. Therefore, this study can inform policies to deliver better for communities and smallholder farmers at the grassroots level.

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