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# Rural households' agricultural land vulnerability to climate change in Dembia woreda, Northwest Ethiopia

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## Abstract

**Background:** Climate change is one of the greatest environmental threats facing our world in recent decades. As Ethiopia is dependent on rain-fed agriculture, it becomes one of the most vulnerable countries to climate change. Therefore, this study analyzed farmers' agricultural land vulnerability to climate change in four randomly selected kebeles of Dembia woreda (District). The 372 sample respondents were randomly selected. The primary quantitative and qualitative data were collected using household survey, field observation, and interview methods. Accordingly, the study employed both quantitative and qualitative methods to analyze the data. The rainfall and temperature trends were analyzed using simple linear regression and standardized precipitation index (SPI). Livelihood vulnerability index was used to analyze the levels of rural households' agricultural land vulnerability to climate change supported with percentages, averages, maximum and minimum values.

**Results:** The results revealed increasing temperature, decreasing rainfall and abnormal precipitation distribution over past 32 years. Likewise, the livelihood vulnerability indices (LVIs) calculated for agricultural land and climatic exposure indicators revealed that households are increasingly vulnerable to climate change risks.

**Conclusion:** For building more climate-resilient community the government in collaboration with stakeholders should enhance apt land management mechanisms and provide training, education, and required agricultural land inputs to the community.

**Keywords:** Agricultural land, Climate change, Functional relationship, Northwest Ethiopia, Vulnerability index

## Background

The climate of the earth is part of the wider environmental landscape, involving variability and change from time to time and from place to place. Climate change has become a distressful event throughout the world in recent years and it will continue to be even more so in the decades to come (Yohannes 2012). Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report asserted that warming of the climate system is unequivocal, and many of the observed changes are unprecedented since the 1950s. Human influence on the climate system is clear and recent anthropogenic emissions of greenhouse gases are the highest in the history

of human civilization with widespread climate change impacts on life and life support systems in recent times (IPCC 2013).

Climate change is a change in the long-term average value of a particular climate parameter, including both more variability and more extreme weather events. Most people define it as the alteration of the earth's climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere observed over comparable time periods (United Nations Framework Convention on Climate Change/UNFCCC 2007). However, scientists in the network of IPCC (2007) often use the term for any change in the climate, whether arising naturally or from anthropogenic causes. They define it as a change in the state of the climate that can be identified by changes in the mean and/or the variability of

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its properties and that persists for an extended period, typically decades or longer (Fussler and Klein 2005; IPCC 2007).

Future climate change will have a range of adverse effects on human society and the environment in the globe in general and Africa in particular. The larger the changes in climate, the more adverse effects will predominate in the vulnerable countries of the world (UNFCCC 2007). Climate change has severe impact on biophysical environment and in turn, on human wellbeing through affecting the overall development endeavors of the nations. Although the valuable components of natural resources (also known as natural capital), such as land, water and vegetation are providers of goods and services and are highly valued by the community, they have been experiencing persistent pressures and stresses from a range of direct and indirect forces. Climate change is one of these stressors, which can deteriorate these valuable assets through increasing severe land degradations, soil erosion, evaporation and harming of fauna and flora (Sullivan 2002; Barungi and Maonga 2011). Indeed, environmental changes severely affect farming households leading them to live in pervasive poverty situations. The frequency of climate change related shocks and stresses have been increasing from time to time and vary from place to place based on the adaptive capacity and resource endowment of geographical areas (National Meteorology Agency/NMA 2007; Zhai 2009; Zhai and Zhuang 2009).

Africa, the second largest continent, has a variety of climates ranging from the hyper-arid to the very humid climates. Africa's vulnerability to climate variability is well acknowledged and the vulnerability level of the continent largely depends on its current and future adaptive capacities (IPCC 2007; Hahn et al. 2009). This in turn, is influenced by the level of economic development, education, access to credit and technology adoption.

As part of Sub-Sahara African countries, Ethiopia is not an exception to the adverse impacts of climate change as its economy is highly dependent upon climate sensitive rain-fed agriculture. Ethiopia is situated in the horn of Africa where environmental change has critical implications for agriculture, water, health, and forestry. The country is among the most vulnerable nations to climate and ecological change, given that only a small proportion of its cultivated land is irrigated and food production is dependent mainly on traditional rain-fed agriculture (NMA 2007). The economic development is heavily reliant on more climate change sensitive agriculture. Thus, climate-related extreme events, vulnerable livelihoods and low national economic growth are likely to highly affect poverty reduction and development efforts of the country (Mamo and Getachew 2010).

In Ethiopia, the farming community is the most vulnerable social group; even within the farming community, small-scale subsistence farmers and pastoralists are more vulnerable to climate change related hazards like drought; and dry sub-humid, semi-arid and arid areas are also vulnerable to desertification and drought (Temesgen 2006; Ministry of Finance and Economic Development/MoFED 2007). A recent vulnerability mapping in Africa categorized Ethiopia in the group of most sensitive countries to environmental change with heavy dependence upon subsistence rain-fed agriculture (Mamo and Getachew 2010). The long-term climatic change in precipitation and temperature patterns is most likely to increase the frequency of droughts and floods (World Bank 2010). Ethiopia's entrance to new millennium with high hopes of renaissance and a dream of better life for all citizens in the coming decades have been challenged by climate variability through deteriorating agricultural land resources (Mamo and Getachew 2010). Hence, climate change will highly disrupt the livelihood systems of large sections of the population who reside in the lowlands and highlands and will continue to suffer more from climate change in the future (World Bank 2010).

The magnitude of climate change-induced extreme events in Dembia woreda are increasing from time to time and in turn, worsening the specific local problems of smallholder farmers. Both decline in precipitation and increase in temperature are currently observed in the woreda. Weather-related hazards such as drought and flood are frequently occurring, all of which have severe effects on farmers' land resources, soil fertility and overall agricultural productivity. In extreme cases, the people who have settled in the coastal kebeles of Lake Tana have been forced to be displaced and settled in temporary shelters almost every summer season.

Some scholars have conducted research to measure the expected impacts of climate change on agriculture in developing nations, including Africa (Temesgen 2006, 2010; Maddison 2006; Molla 2008). Few studies assessed the impact of climate change in Ethiopia. For example, the study in pastoralist area conducted by Prolinnova and Pastoralist Forum Ethiopia (PFE) found out several adaptation mechanisms to reduce farmers vulnerability to climate change, regarding crop production; a research conducted in the Blue Nile Basin (Ethiopia) by Temesgen et al. (2008); analysis of rainfall variability and crop production in Amhara Region by Woldeamlak (2009), to mention a few. However, most of these studies are very general and the results are aggregated at national or State levels. So, all may not reflect local contexts of Dembia woreda because site-specific issues require site-specific knowledge and experience (IPCC 2007). Moreover, none of these studies analyzed rural households' agricultural

land vulnerability to climate change using livelihood vulnerability index approach.

Therefore, this study was conducted to assess the vulnerability levels of farming households' agricultural land to climate change in Tana Basin of Dembia woreda. This study adopts a vulnerability approach to assess the implications of climate change as opposed to adopting the biophysical impacts approach. This is because vulnerability to climate change is stacked on an existing vulnerability, such that the impacts of climate change are greatly worsened.

## Theoretical framework of vulnerability assessment

### Conceptual framework

Vulnerability is the most contested term for various scholarly communities. Vulnerability refers to the degree to which a system is likely to experience harm due to exposure to a hazard usually associated with floods, droughts and poverty (Turner et al. 2003; Fussel and Klein 2005). Vulnerability has its origins in the natural hazards and food security literatures (Cutter 1996). It is now a central concept in the livelihood, food security, sustainability science, land-use change, natural hazards; disaster risks management, public health and global environment and is now increasingly used in climate change research communities (Schroter et al. 2004; Fussel 2006).

Vulnerability is commonly considered to be the ability to anticipate, resist, cope with and respond to a hazard (Wisner et al. 2004; IPCC 2007). However, vulnerability definitions reveal a distinction in the literature between the two main epistemological approaches. The natural hazards school of thought arises out of a positivist vein, and hence focuses on the objective studying of hazards. Under this approach, emphasis is placed on a particular environmental stress, and vulnerability refers to the risk of exposure of an ecosystem to a natural hazard. In contrast, the human ecology and political economy schools of thought have arisen out of interpretive social science paradigms based on relativist and constructivist ontologies. In these cases, vulnerability refers to a particular group or social unit of exposure and especially to the structures and institutions—economic, political and social—that govern human lives (Vincent 2004).

One of the heavily relied up on definitions of vulnerability in the context of climate change studies is from IPCC (2001, 2007). IPCC defines vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. The same institution provides two more definitions that are not specified as natural or social vulnerability, but fit into the separate climate research streams. From the natural standpoint, the IPCC defines vulnerability as “a function of the character,

magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity” (IPCC 2001: 995). From a social point of view, it describes vulnerability as the degree to which a system is susceptible to injury, damage or harm. Along the same line, vulnerability is considered as a risk of falling into poverty in the future, even if the person is not necessarily poor now; it is often associated with the effects of shocks such as drought and floods with a drop in farm production. Thus, social vulnerability is typically broken into three overlapping components: exposure, sensitivity and adaptive capacity (Turner et al. 2003).

Exposure is the magnitude, frequency, intensity, and duration of climate-related hazards such as hurricanes, droughts, floods, and storms, changing distribution of temperature and rainfall, which adversely affect farmers' livelihood assets (IPCC 2007). Sensitivity is the degree to which the rural household is adversely affected by the exposure to the changing climatic variables. Sensitivity can be measured by the proportion of people who have been faced with food shortage, water scarcity, number of months in food shortage, and level of access to different services. Adaptive capacity on the other hand refers to people's ability to adapt and recover from climate exposure by facilitating access to livelihood resources for adaptation. Sensitivity and adaptive capacity largely depend on the main livelihood activities practiced by a farmer and the specific livelihood resources needed to carry out these activities (Luers et al. 2003; Turner et al. 2003; IPCC 2007).

In this line of argument, Schroter et al. (2004) noted that agricultural vulnerability to climate change in terms of not only exposure to higher temperatures, but also crops yield sensitivity to high temperatures and farmers' ability to adapt to the effects of that sensitivity by planting more heat-resistant cultivars or different crops. Thus, one can conclude that exposure, sensitivity, and adaptive capacity are inherently interlinked (Gallopín 2006). For example, greater amounts of exposure will give to greater sensitivity, while adaptive capacity can reduce the system's sensitivity. In practice, these steps do not happen chronologically, but instead play a continuous role in enhancing or diminishing each other. Consequently, many studies combine sensitivity with exposure or combine sensitivity with adaptive capacity depending upon the indicator under consideration. These varied theoretical frameworks reflect vulnerability in specific places at specific time (Adger 2006). Indeed, vulnerability is place and time-specific requiring different methods to measure vulnerable places and communities to climate change risks.

Climate change has affected the farmers' land resources so that exacerbate their exposure and sensitivity to

climatic risks. Exposure to high frequencies and intensities of climate risk deteriorate agricultural land and in turn reduce crop yield from time to time. The IPCC's definition of vulnerability contains the integrated vulnerability assessment approach to measure the vulnerability levels of farmers with respect to agricultural land (IPCC 2007).

Land refers to cultivated land (Ellis 2000), soil fertility, and topographic features that can affect the ability of the people to generate means of survival and adapt to climate change (Maddison 2006). Vulnerability is also represented by farm size, farmland location, crops produced, and changes in climatic conditions such as unexpected flood, increasing temperature, decreasing rainfall and increasing frequency of extreme weather events. Thus, areas with unexpected flood, increasing temperature and decreasing rainfall and increasing frequency of extreme weather events will be identified as areas more exposed to climate change.

#### **An index approach to study vulnerability to climate change**

In many literatures quantitative assessment of vulnerability is usually done by developing vulnerability index. It is based on several set of variables producing a single number that can be used to compare various regions and sectors. Some literature on index construction argues that a good measure of the validity of the index is the internal correlation between the individual indicators used in the index. The relevance of this criterion will, however, depend on the relationship between the indicators and the construct they are intended to measure (Coltman et al. 2008).

There are models used as the basis for construction of vulnerability indices so as to measure latent variable: reflexive and formative measurement models: In reflexive measurement model the latent constructs exist in absolute sense (independent of measures). In this model, the index is a measure of an underlying construct which is thought to influence the indicators. Directional causality flows from construct to indicators. As a result, change in a construct causes change in the indicators. Furthermore, the indicators are evoked by the underlying construct and have positive and, desirably, high inter correlations in empirical consideration. Since reflective indicators have positive inter correlations, measures such, average variance and internal consistency are used to empirically assess the individual and composite reliabilities of the indicators (Coltman et al. 2008). A poverty index is most often an example of a reflexive model, whereby the construct, poverty, is thought to influence the various indicators chosen, such as literacy, expenditure, housing standard and ownership of assets (Leichenko et al. 2004).

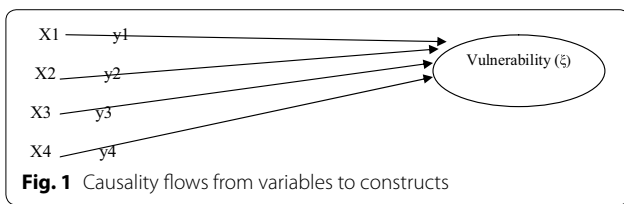
Conversely, the formative measurement model was the characteristic of positively correlated measure as a necessary condition in the construction of vulnerability index. In a formative measurement model, all the indicators chosen by the researcher have impact on the vulnerability of the region, or a system, or an individual positively or inversely (Leichenko et al. 2004; Coltman et al. 2008). In a formative measurement model, the index is measuring a construct which is influenced by the indicators. The latent constructs does not exist an independent entity and all the indicators have an impact on vulnerability. For instance, HDI is a composite measure of human development in health, education and income. The directional causality flows from the indicators to the construct. Therefore, a change in the indicator results change in the construct under study. In the empirical considerations, the indicators do not necessarily share the same theme and hence have no inter correlation. Since they define the construct, the domain of it is sensitive to the number and types of indicators representing the construct. It is not simple, easy and universally accepted criteria exist for assessing the reliability of formative indicators (Coltman et al. 2008). Therefore, vulnerability index is a formative measurement and the indicators chosen need not have internal correlation (ICRISAT 2006). As Tarling (2009) stated latent<sup>1</sup> constructs are variables which cannot be measured directly rather the measurement scale has to be constructed from manifest variables. The author employed formative measurement model. The dependent variable in the empirical estimation of this study was vulnerability which is the latent construct of formative model and indicators which influence vulnerability are explanatory variables.

The model specification is  $\xi = \sum_{i=1}^n y_i x_i + \varepsilon$ , where  $y_i$  is a coefficient reflecting the effect of the indicators on the latent constructs,  $X_i$  is the indicators (variables),  $\xi$  the latent construct, and  $\varepsilon$  is disturbance term comprises remaining indicators of the constructs.

The causality flows in this model is from the variables to the constructs (see Fig. 1).

The model variables for the analysis were categorized under the determinants of vulnerability levels which encompassed exposure indicators (temperature change, rainfall variability and frequency of extreme climatic events), capacity and sensitivity indicators (farmland size, land location, erosion rate and land policy, access to and use of farm input, land management training). The integrated vulnerability assessment approach was adopted to combine these socio economic and biophysical indicators so as to develop vulnerability indices on the basis of

<sup>1</sup> Latent constructs are variables which cannot be measured directly rather measured by manifest variables.



formative measurement model (IPCC 2007; Hahn et al. 2009; Temesgen 2010). Countries with higher levels of human knowledge are considered to have greater adaptive capacity. Areas with greater frequency of drought affected the sensitive agricultural sector (yield reduction). Furthermore, increasing temperature and decreasing rainfall were identified regions more exposed to vulnerability to drought.

On the bases of prior knowledge and vulnerability literatures, measurable vulnerability indicators were identified.

**Study area**

Dembia woreda is located in the North Gondar Zone of the Amhara Regional State, northwest Ethiopia. It is bounded with Gondar city and Lay Armachiho woreda in

the north, Gondar Zuria woreda in the east, Chilga and Alefa woredas in the west and part of Lake Tana in the south (see Fig. 2). The woreda capital, Koladiba, is located 750 km North of Addis Ababa which is branched to west from Addis-Gondar highway at Azezo about 35 km away from Gondar city.

The elevation of Dembia woreda is ranging from 1500 to 2600 m above sea-level characterized by flat terrain, flood-plain, and swamps. The woreda is entirely located in the Tana zuria livelihood zone, which is considered to have good potential for agricultural production (Woreda Office of Agriculture 2012). However, recent climate change and associated extreme weather events are having a significant and new impact. The woreda is increasingly affected by heavy flooding, malaria, and outbreak of crop pests and disease.

The woreda is mainly woyna-dega (midland) in terms of agro-ecology with elevation ranging from 1700 to 2600 m above sea level. According to the data obtained from the woreda Agriculture Office, the topography of the area is characterized by plain (87 %), mountainous (5 %), valleys (4.8 %) and wetland (3.2 %). Out of the total area of the woreda, 32.97 % is being used for annual crop

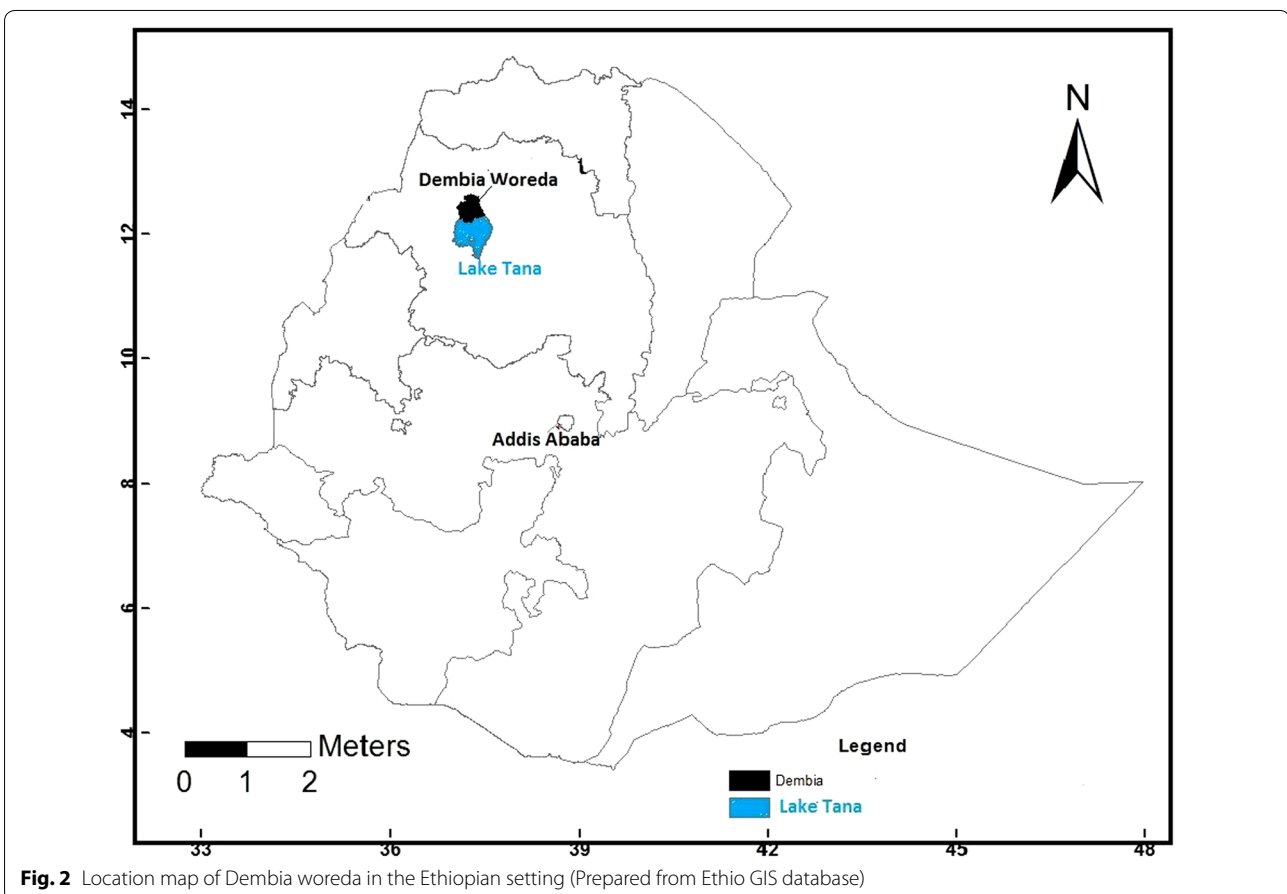


Fig. 2 Location map of Dembia woreda in the Ethiopian setting (Prepared from Ethio GIS database)

production, 12.75 % for grazing, 5.65 % for forest development, bush and shrubs, 15.95 % is degraded (unproductive) land and the residential areas constitute about 4.37 % (Creswell 2012).

The land is gradually degrading due to natural and human causes of deforestation that result in serious soil erosion in the hilly areas and deposition over the plains. Soil degradation is being further accelerated due to uncontrolled deforestation for fuel and construction purposes. This in turn, has brought about the removal of topsoil from cultivated lands and in turn, agricultural productivity decline from time to time.

Similar to any other rural areas of Ethiopia, crop production and livestock keeping are the dominant economic sectors in Dembia woreda. The average landholding size of the households is 0.87 hectare. The area is endowed with natural resources such as perennial river, spring, pond and well water resources, which are good for small-scale irrigation and other water development schemes. Accordingly, there is a practice of small-scale traditional irrigation in some parts of the woreda. The data from the woreda Agriculture Office indicates that a total of 3051 hectares of land is being cultivated with traditional irrigation, from which only 80 hectares of land is cultivated under modern irrigation.

The major crops grown in the woreda are *teff*, maize, barley, red highland sorghum and finger millet. In addition, the farmers produce legumes and pulses such as chickpeas and cowpeas. They also grow some cash crops like paper, niger seed, fenugreek, *tikurazmud*, *nechazmud* and rice with limited amount of farmlands. However, fruit production is not known in the woreda.

According to the information obtained from the Woreda Agriculture Office (2013), the estimates of animal population by their types are 151,979 cattle, 10,379 sheep, 9754 goats, 20,327 donkeys and 617 mules and horses. Farmers more often sell sheep to earn income for regular expenses in the course of the year. During religious festivals when community members individually or collectively purchase animals for slaughter, there is higher demand in the town markets. Cattle are high value assets mostly owned by middle and better-off households and the holders sell them sparingly, especially fertile females. Livestock and butter sales also make a substantial complement to the dominant crop sales. The main diseases to livestock are anthrax, trypanosomiasis, pasteurellosis and black leg.

Although such good biophysical contexts characterize Dembia woreda, it is found to be more vulnerable to the risks of climate change and other extreme weather events. Climate-related hazards are major threats to food production in the woreda, like elsewhere in Ethiopia. Consequently, the majority of the households reported decreasing food crop and livestock production,

which may not be enough to cover household expenses. Although households from all kebeles reported food shortage, the problem is much severe in Tana-woyna kebele where there is very low crop yield per hectare of farmland. Most of the people have suffered from food insecurity resulting from flooding, erratic and untimely rainfall, snowfalls, degraded farmlands, crop pests and diseases infestations, livestock disease, malaria and other human diseases, and small landholdings among other factors.

## Research methods

### Research design and Sampling

The study used cross-sectional research design with combining both quantitative and qualitative research methods. The use of mixed method designs provide the opportunity to avoid deficiencies and weakness that come from using a single method. Since the area is vast and is difficult to undertake a survey in all the kebeles, four kebeles (the lowest administrative units of Ethiopia) namely Gerarge, Jenda, Seraba-dablo and Tana woyna were selected using simple random sampling technique. Sample size was determined from each kebele using probability proportional to size (PPS) method to make equal representation of households in each kebele based on Yemane (1967) as cited in Israel (1992).

Mathematically presented as:  $n = \frac{N}{1+N(e)^2}$  where  $n$  = designates the sample size the research uses,  $N$  = designates total number of households in all *kebeles*,  $e$  = designates maximum variability or margin of error 5 % (0.05), and 1 = designates the probability of the event occurring.

The mathematical formula provided 372 sample sizes those were proportionally distributed to the four-kebele administrations using the following formula.

$$n_i = \frac{n \times N_i}{\sum N_i}$$

where  $n$  = determined sample size the research uses,  $n_i$  = households of the  $i$ th kebele, and  $N_i$  = total households of the  $i$ th kebele (Table 1).

Sample households were selected using systematic random sampling technique. For doing so, sampling frames were obtained for each kebele by taking the list of all household heads from the kebele offices. The sample households were drawn from each administrative unit from the list of names after a certain sampling interval ( $K$ ) that was determined by dividing the total number of households by the predetermined sample size of each kebele. Next, a number was selected between one and the sampling interval ( $K$ ) using lottery method, which is called the random start and was used as the first number included in the sample. Then, every  $K$ th household head

**Table 1** Number of total and sample households of study areas (Dembia Woreda Administration Office (2014) unpublished population statistics)

Kebele	Total population	Total household	Sample household
Gerargie	3311	659	46
Jenda kobla	7395	1525	106
Seraba dabelo	6882	1560	108
Tana woyna	7475	1618	112
Total	25,063	5362	372

after that first random start was taken until reaching the desired sample size for each kebele administration. Systematic sampling is to be applied only if the given population is logically homogeneous within the respective strata (kebele administration in this case), because systematic sample units are uniformly distributed over the population (Feige and Marr 2012). In this case, sampling units are rural households who are uniformly distributed in the respective kebele administrations.

#### Methods of data collection

Assessing the rural households' agricultural land vulnerability to climate change require good-quality data and/or information. Three main data sources were identified as relevant for investigation in that they indicate the situations of vulnerability to climate change in Dembia. The first is the scholarly researches on theories, methodological approaches, and empirical findings which helped to gain initial insights regarding 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 site. The third data set is the biophysical and socioeconomic data collected through household survey supplemented with observation and interview techniques.

#### Secondary data

The 32 years meteorological data were gathered from Gorgora Meteorology Station and Global weather data (<http://globalweather.tamu.edu>) for the period 1979–2010 to analyze temperature and rainfall trends, and seasonal variations and SPI to compute drought duration, magnitude and intensity of the study area.

#### Primary data

As data from secondary sources include only meteorology and kebele population data the secondary data was found 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 thesis. Accordingly, primary data were collected using household survey, field observation, and interview, which have brought the study to completion.

#### Household survey

The household questionnaire survey was the main data source so as to determine the vulnerability of rural households' agricultural land to climate change. The household survey was used to collect a range of 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 questions were organized mostly into close-ended and supplemented with some open-ended forms. The data sets are very important for calculating livelihood vulnerability index (LVI) and computing percentage, maximum and minimum values of the observation used 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 thoroughly 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 ten farmers in each site who were not involved in the actual survey to assess whether the instruments were appropriate and suited to the study. Necessary amendments were made through deleting and modifying questions having confusing and sensitive ideas based on the comments from experts and observations of households' responses. Pre-testing of the questions also helped to determine the mean interview length needed for covering the samples and to plan the time, days and data collectors required for the field survey. The author trained data collectors with respect to the survey techniques and confidentiality protocol to establish internal quality control procedures. For example, in case survey questions used ambiguous language that might lead to different answers depending on respondent's interpretation, data collectors had common understanding. Moreover, after the training, the data collectors acquired practical experience while the author made face-to-face interview during the actual data collection in the field.

Trained data collectors administered the household survey with close supervision of the author in the period between April and June 2014. Household heads were

approached, but in his/her absence, the spouses were contacted. When difficulties faced to meet the selected households due to absenteeism (after repeated visits) or unwillingness, the next household head in the list replaced them. Most of the farmers were contacted on their homesteads and few of them around churches and community gathering places. The author's former university students had played paramount role in choosing the data collectors who have been working in the community in the areas of agriculture and teaching. As they have been living in the community for many years they better know the area and easily approach and handle respondents.

#### Field observation

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

#### Interview

Interviews were held with elders, local administrators and development agents at kebele level and agricultural experts at woreda level in order to supplement the data collected through other data collection methods.

#### Methods of data analysis

This study used both quantitative and qualitative data analysis methods. The former include simple linear regression (SLR), standardized precipitation index (SPI) and livelihood vulnerability index (LVI) supported with descriptive statistics such as mean, frequency counts, percentage, maximum and minimum values of a distribution.

#### Simple linear regression (SLR)

SLR was used for analyzing temperature and rainfall trends as it is the most commonly used method to detect and characterize the long-term trend and variability of temperature and rainfall values at annual time scale (Mongi et al. 2010). The parametric test considers the SLR of the random variable  $Y$  on time  $X$ . The regression coefficient is the interpolated regression line slope coefficient computed from the data as was used by (Mongi et al. 2010) is:

$$Y = \beta x + c \quad (1)$$

where,  $Y$  = changes in rainfall and temperature during the period;  $\beta$  = slope of the regression equation;

$x$  = number of years from 1979 to 2010;  $c$  = regression constant.

#### Standardized precipitation index (SPI)

the SPI was used to identify droughts during the period under consideration using annual rainfall data. The SPI is a statistical measure to detect unusual weather events making it possible to determine how often droughts of certain strength are likely to occur. The practical implication of SPI-defined drought, the deviation from the normal amount of precipitation, would vary from 1 year to another. It can be calculated as:

$$SPI = \frac{X - \bar{X}}{\sigma} \quad (2)$$

SPI refers to rainfall anomaly (irregularity) on multiple time scales;  $X$  represents annual rainfall in the year  $t$ ;  $\bar{X}$  is the long-term mean rainfall; and  $\sigma$  represents the standard deviation over the period of observation (McKee et al. 1993; Woldeamlak 2009). Hence, the drought severity classes are: Extreme drought ( $SPI < -1.65$ ); moderate drought ( $-0.84 > SPI > -1.28$ ), severe drought ( $-1.28 > SPI > -1.65$ ); and no drought ( $SPI > -0.84$ ).

Drought duration, magnitude, and intensity were analyzed based on quantified SPI values. Drought duration is the period between drought starts and ends expressed in months or years. Drought magnitude (DM) is the sum of the negative SPI values for all the months or years within the period of drought (McKee et al. 1993). Mathematically it can be expressed as:

$$DM = \sum_{j=1}^x -(SPI_{ij}) \quad (3)$$

where,  $j$  starts with the first month/year of a drought and continues to increase until the end of the drought ( $x$ ) for any of the  $i$  time scales (the  $i$ th month or year from the observation period).

Drought intensity (DI) is the ratio of the drought magnitude to the duration event, which can be expressed as  $M_i/L_i$  where  $M_i$  is drought magnitude and  $L_i$  is the drought duration (McKee et al. 1993). Although drought analysis used both the monthly and yearly time scale, the yearly scale was selected for detecting the long-term temporal patterns of drought in the studied area.

#### Livelihood vulnerability index using functional relationships

An assessment of the vulnerability levels of the farmers was done using the livelihood vulnerability index (LVI) based on the household survey data. The indices were



constructed using weighted average approach to measure households' access to a set of livelihood assets and climate change exposures (Hahn et al. 2009). On the basis of the theoretical framework, indicators were selected for farmland quantity and quality indicators and climatic factors using expert judgment, observation, and vulnerability literatures (Iyengar and Sudarshan 1982; Moss et al. 2001; Sullivan et al. 2002; ICRISAT 2006; UNDP 2010) (Table 2).

Vulnerability index (VI) was computed to analyze the vulnerability levels of rural households using a simple average approach. This method helps to assess

households' access to land and related indicators. The vulnerability indicators measured were normalized as the ratio of the difference of the actual value and pre-selected minimum, and the range of maximum and minimum values of indicators for each indicator determined using the data collected from the sample households and secondary sources (Sullivan et al. 2002; ICRISAT 2006):

$$\begin{aligned} & \text{Vulnerability index value} \\ &= \frac{\text{Observed values} - \text{Minimum values}}{\text{Maximum values} - \text{Minimum values}} \quad (4) \end{aligned}$$

**Table 2 Vulnerability indicators and their functional relationships with vulnerability [Compiled 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 ↑
Temperature	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 $\bar{t}_0$ variability ↑ vulnerability ↑
	Mean standard deviation of average maximum temperature by year	Exposure ↑ as maximum $\bar{t}_0$ variability ↑ vulnerability ↑
	Mean standard deviation of average minimum temperature by month	Exposure ↑ as minimum $\bar{t}_0$ variability ↑ vulnerability ↑
Rainfall	Mean standard deviation of average minimum temperature by year	Exposure ↑ as minimum $\bar{t}_0$ variability ↑ vulnerability ↑
	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 ↑
Hazards frequency	Average number of hazards occurred in the past 10 years	Exposure ↑ as frequency of droughts ↑ vulnerability ↑
	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 ↑

This method of normalization takes the functional relationship between the predictor variable and vulnerability (refer to Table 2). 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, 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 normalization was done using Eq. 4. For these types of variables, the average values are taken as 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 min and it has the shortest distance of 5 min from some other households in the study woreda. The observed (average) value was found to be 92.48 min (refer Table 4). Hence, the normalization of indicators for the study woreda were done by:

$$\text{Normalized value} = \frac{92.48 - 5}{260 - 5} = 0.34$$

In this way, the normalized vulnerability scores for similar indicators were computed by considering the functional relationships of indicators with vulnerability. 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 by Eq. 5 based on ICRI-SAT (2006) and NMA (2007).

$$\begin{aligned} &\text{Inversed Index values} \\ &= \frac{\text{Maximum values} - \text{Observed values}}{\text{Maximum values} - \text{Minimum values}} \end{aligned} \quad (5)$$

In this case, let us consider farm size of households own, a high value of this variable implies better off households in the woreda. 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 climate change risks (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 climate change-induced risks. For example, farm size was found to be higher with a value of 5 hectares for some households, while it has a lower value of 0 for few households.

The observed value (represented by average farm size) was found to be 1.07 hectares. Thus, the normalized score for the woreda is: Normalized value =  $\frac{5-1.07}{5-0} = 0.79$ .

In this way, the normalized scores for each vulnerability indicator were computed for study woreda. Then the indicators were averaged by Eq. 6 to calculate the value of each component.

$$\text{Average VI} = \frac{\sum_{i=1}^n \text{Index}}{n} \quad (6)$$

where, MCVI refers to indicators for land and climatic variables; index refers to the indicator, represented by  $i$ , and  $n$  is the number of indicators. In this study the VI is scaled from 0 to 1; 0 denotes least vulnerable or no vulnerability and 1 denotes most vulnerable system.

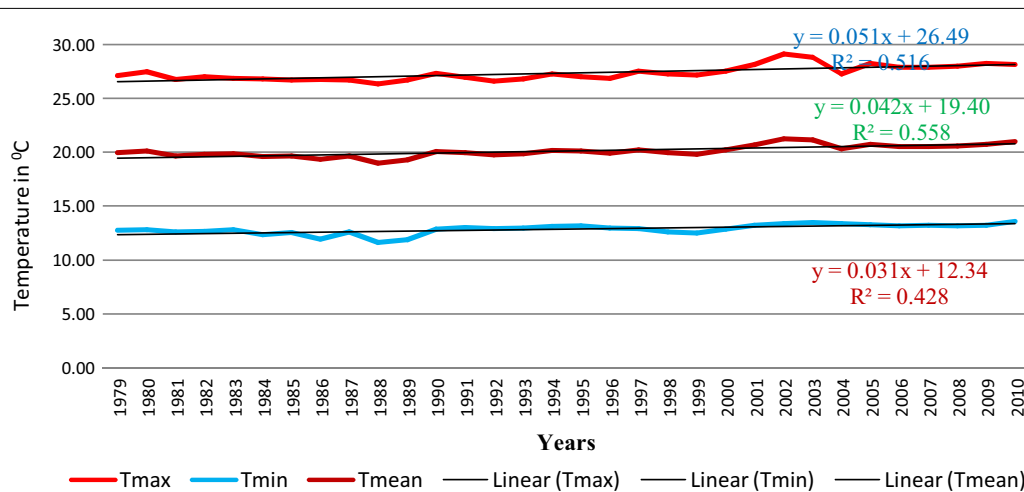
The quantitative analysis was supplemented with qualitative data analysis methods. The qualitative data gathered through in-depth interview and field observations were analyzed thematically. Before directly getting into analysis, the collected information was converted into word processing documents. Because qualitative data collection takes long time and funds (Creswell 2012), the author has taken only some interviews and observational notes were transcribed (refer to "Methods of data collection" section). 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 and analyzed through narrating and interpreting the answers obtained from the interviewees.

## Results and discussion

### Temperature change

The results of the meteorological data show that annual temperature in the study area had been in increasing trends for the last three decades (1979–2010). Figure 3 presents the maximum, minimum and average temperature trends of Dembia woreda. The estimated trend line for average annual temperature is  $y = 0.042 + 19.40$ . The trend line has a positive slope indicating that the average temperature has increased by 1.30 °C in the past 32 years. Temperature rose by 0.41 °C per decade indicating that there was faster rate of temperature rise in the period (1979–2010). It is also found out that the rate of temperature increase in the woreda was faster than the national level increase (0.23–25 °C per decade) over the past 55 years (NMA 2007).

The maximum and minimum temperature trends were also calculated using simple regression equation for the mentioned period. It was found that both of them showed increasing trends in the study area. Maximum temperature increased faster while the minimum temperature increased gradually. For example, the former



**Fig. 3** Long-term temperature trends of Dembia woreda (1979–2010). [Global weather data for soil and water assessment tool (SWAT) (<http://globalweather.tamu.edu>)]. *Tmax* maximum temperature, *Linear (Tmax)* linear trend line for maximum temperature, *Tmin* minimum temperature, *Linear (Tmin)* linear trend line for minimum temperature, *Tmean* mean temperature, *Linear (Tmean)* linear trend line for mean temperature

increased by 1.58 °C while the later increased by 0.96 °C in the past 32 years. In decadal time scale, the maximum temperature rose by 0.49 °C and the minimum increased by 0.30 °C. This changing pattern is similar with other empirical findings done in Dabat and Simada woredas (Teshome 2015).

Perception of households was analyzed based on their local observations as it is a prerequisite for adaptation. The household survey raised questions about the observations of rural households to the patterns of temperature over the past two or more decades. Responses to the questions about whether the household had witnessed changes in temperature were classified into one or more of three different categories: 'increased', 'decreased' and 'no change'. About 95 % of the surveyed households observed increasing temperature trend over the past 20 years. Only 2 % of the households noticed the contrary and only 1.5 % of them have not noticed any change.

The direction of the temperature trend in the study woreda was found to be consistent with the findings for Tanzania (Mongi et al. 2010), which found out that those both minimum and maximum temperatures showed increasing trends. However, in Tabora Urban and Uyui Districts of Tanzania minimum temperature increased faster while maximum temperature increased slowly. This increasing temperature trend has adverse effects on land resources through exacerbating evaporation with negative consequences on the productive capacities of farmers.

In terms of the pattern of perception to climate change, it is quite different from the study conducted in semi-arid Tanzania by Mongi et al. (2010) as it pointed out different perceptions among social groups in terms of level of education, location, age and gender. In the case of this study,

interview and discussion results confirmed that there is no varied understanding on the trends of temperature and rainfall by level of education, age and gender in the study site. In terms of perception, the local communities unanimously agree that the climate is continually changing and getting worse and worse from time to time. In the study site, it is commonly agreed that the temperature is getting much hotter across times. Such a situation therefore results in poor performance in agriculture and food security efforts.

#### Rainfall variability and change

The meteorology data for the period 1979–2010 indicate that the overall rainfall amount and distribution varied from time to time in the woreda. The range of total annual rainfall has become 870–1394 mm. The woreda has experienced unimodal (*Meher*) rainfall pattern. The rainfall occurs mostly during the summer season (usually from Mid-June to Mid-September), often falling as intense storms. Over 78 % of the rainfall was received in this season (refer to Figs. 4, 5, 6 and Table 3).

The standard deviation is one way of summarizing the spread of a probability distribution; it relates directly to the degree of uncertainty associated with predicting the value of a random variable. High values reflect more uncertainty than low values. Table 3 clearly reveals that July (11.9267) and August (11.2115) in Dembia woreda had the highest standard deviation. The highest amount of average monthly rainfall was recorded in July (581.10 mm) followed by August (524.18), and the lowest was recorded in February (1.41 mm) followed by December (1.50 mm). From the analysis, it was observed that rainfall is at its peak between June and September (Fig. 4).

**Table 3 Statistical analysis of daily precipitation data (1979–2010) [Generated from the precipitation data using pcp-STAT.exe]**

Month	PCP_MM	PCPSTD	PCPSKW	PR_W1	PR_W2	PCPD
January	1.53	0.5718	17.1128	0.0276	0.4902	1.59
February	1.42	0.3124	8.9888	0.0359	0.4636	2.16
March	17.40	2.9232	12.3975	0.1027	0.6947	8.19
April	37.85	3.6917	6.2742	0.1860	0.7656	13.88
May	113.88	5.4781	2.5068	0.3320	0.8604	23.26
June	327.11	9.6655	1.3659	0.7917	0.9487	29.25
July	581.10	11.9267	1.6732		0.9677	31.00
August	524.18	11.2115	1.7314		0.9677	31.00
September	187.27	5.7845	2.4780	0.5600	0.9508	29.22
October	69.18	4.4010	4.2057	0.2261	0.8525	21.19
November	11.88	1.3132	4.6355	0.0847	0.6711	7.13
December	1.50	0.4395	12.1876	0.0232	0.4091	1.38

PCP\_MM average monthly precipitation [mm], PCPSTD standard deviation, PCPSKW skew coefficient, PR\_W1 probability of a wet day following a dry day, PR\_W2 probability of a wet day following a wet day, PCPD average number of days of precipitation in month

The month to month precipitation changes are considerable across the years. When the standard deviation values are examined, it is observed that the values are higher in June, July, and August than other months (see Table 3). This relation between the standard deviation and the average values indicates that the deviation from the normal distribution cannot be ignored.

To test whether the annual rainfall data follow a normal distribution, the skewness and kurtosis were computed. Skewness is a measure of symmetry or, more precisely, the lack of symmetry. The data set is said to be symmetric if it looks the same to the left and right from the center point. The skewness for a normal distribution is zero, and any symmetric data should have skewness near zero. Positive values for the skewness indicate that the data are skewed to the right. Positive kurtosis indicates a peaked distribution and negative kurtosis indicates a flat distribution. Hence the annual rainfall distribution under consideration did not follow normal distribution (refer to Fig. 4).

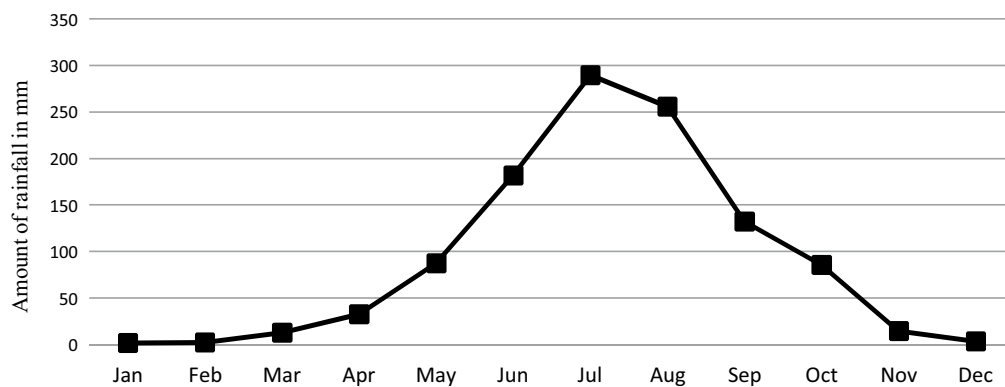
The simple regression results computed based on Mongi et al. (2010) and Gbetibouo (2009) indicate that there is momentous inter-annual variability of rainfall and slight rate of decline in the worda over the past decades considered in this study (Fig. 5).

It is clear from Fig. 5 that the total annual rainfall distribution is gradually declining from time to time. However, long-term rainfall change in the selected time span, appeared to decrease at a non-significant rate ( $R^2 = 0.066$ ). The main problem in terms of rainfall distribution is the timing (late onset and early cessation) and falling in intense episodes in very short duration. The long-term reduced amount of rainfall calculated using SLR for the observation period indicates that the rainfall declined by 516.99 mm. These results are in line with other empirical

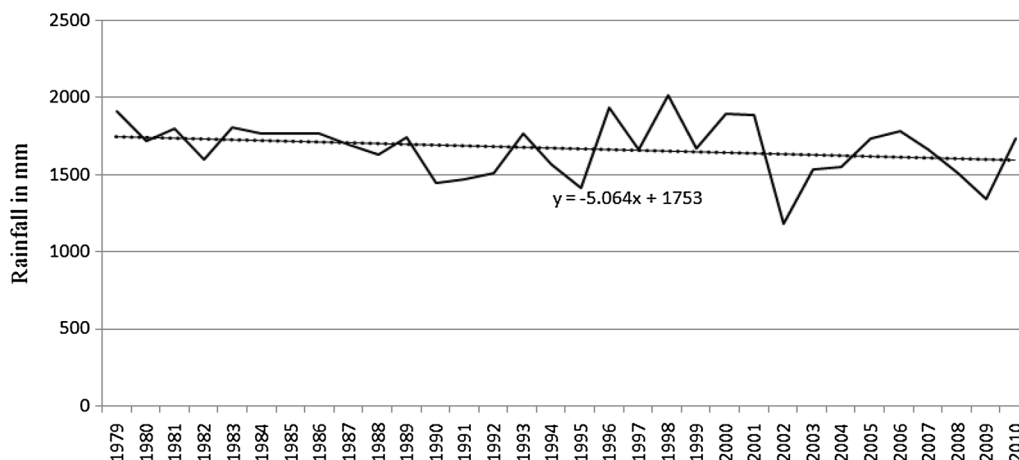
research findings conducted in Ethiopia and other nations of Africa. For example, a study in Debark worda of northwest Ethiopia indicates that the rainfall has shown a decreasing trend (ACCRA 2011). The study made in Tanzania also supported this finding which declared decreasing trends of rainfall for the last 35 seasons from 1973/74 to 2007/08 (Mongi et al. 2010). Similarly, studies in South Africa (Gbetibouo 2009) and in the Sahel region of Arica (Mertez et al. 2008) also found decreasing rainfall trends over the past consecutive decades.

Households' perception to precipitation changes was analyzed based on their local observations. Accordingly, the household survey raised questions about the observations of rural households to the patterns of precipitation over the past two or more decades. Responses to the questions about whether the household had witnessed changes in precipitation were classified into one of the four different categories: 'increased', 'decreased', 'change in timing/erratic in distribution', and 'no change'. About 88.7 % of the surveyed households observed precipitation changes over the past 20 years.

The result of this study is therefore, supported by the perception of the surveyed households. For example, of the 88.7 % of the surveyed households who have already perceived changing precipitation pattern nearly 27 % the households perceived rainfall to be decreasing through time with shorter rainy seasons. Almost 79 % of the households noticed the erratic nature of rainfall—a change in the timing of the rains, coming either earlier or (mostly) later than expected time. Bryan et al. (2011) suggested that the farmer's perceptions of long-term decreases in rainfall from the household survey are actually based on their experiences with rainfall variability, and particularly changes in timing and distribution of rainfall.



**Fig. 4** Long-term monthly average rainfall distribution in Dembia woreda (1979–2010) [Global weather data for SWAT (<http://globalweather.tamu.edu>)]



**Fig. 5** Long-term rainfall trend of Dembia woreda (1979–2010) [Global weather data for SWAT (<http://globalweather.tamu.edu>)]

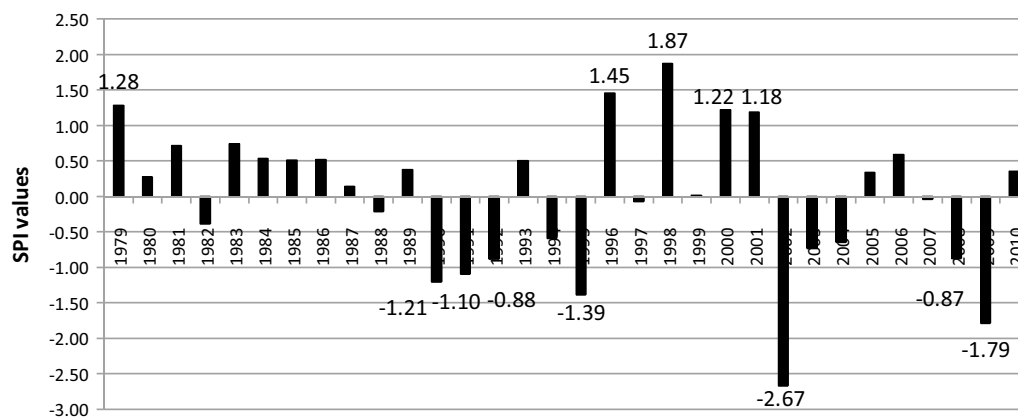
#### Meteorological drought analysis (1979–2010)

Drought can be marked by precipitation deficiency that threatens the livelihood resources and overall development efforts of nations and specific places through worsening water shortage. Therefore, analysis of drought frequency/pattern, duration, magnitude and severity is highly demanded for designing appropriate mitigation and adaptation strategies. Standardized precipitation index (SPI) was used for analyzing the long-term drought pattern in the woreda (refer to Fig. 6).

It is clear from Fig. 6 that the rainfall is described by alteration of wet and dry years in a periodic pattern. Out of 32 years, 14 years (43.75 %) recorded below the long-term average annual rainfall amount while 17 (53.13 %) years recorded above-average. Only the year 1999 received equal rainfall amount with the long-term average rainfall. Most of the positive SPI values occurred before 1990 (9 out of 12 years). Consecutive

negative SPI values occurred from 1990 to 1995 and 2002 to 2004. The 2002 rainfall amount was the lowest record in the observation period with SPI value  $-2.67$ . According to the drought assessment method by Agnew and Chappel (1999) referred by (Woldeamlak 2009), there were seven drought years in the period spanning from 1979 to 2010 in the site, with varying severity.

There were two extreme (2002) and (2009), one severe drought (1995) and five moderate (1990, 1991, 1992, 1995 and 2008) drought years, which together account for 21.88 % of the total number of observations. In contrast, 1998 was the wettest year in the period followed by the year 1996 (almost consistent with the anomalies of Amhara region by (Woldeamlak 2009)). This wettest year may be associated with the probability of flood incidences with SPI values of 1.87 and 1.45 in 1998 and 1996 respectively.



**Fig. 6** Standardized Precipitation Index (SPI) for Dembia woreda (1979–2010) [Global weather data for SWAT (<http://globalweather.tamu.edu>)]

The SPI result indicates that long-term drought characteristic in the woreda was found to be 12.54-magnitudes and 1.05-intensity in the 12 years of duration implying high exposure of agricultural land to intense drought conditions in the woreda.

#### Households' agricultural land vulnerability to climate change

In this study, the indicators have been identified to analyze the vulnerability levels of the rural households' agricultural land to climate change. Accordingly, an assessment of farming households' levels of agricultural land vulnerability 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 4).

The total LVI result contributed by different indicators indicated that the vulnerability level of households measured by farmland was found 0.58 in the woreda. Households' inability to reserve crops for the time of food shortage (0.91), households who owned from poor to medium farmland (0.88), limited access to land management training (0.88), instability of crop yield trend and inverse of crop yield per hectare (0.81 for each), the reported high to medium soil erosion rate (0.78) and land shortage and inverse of modern fertilizer use (0.79 for each) contribute greatly to the vulnerability levels of rural households' agricultural land (refer to Table 4).

The vulnerability score for total farm size was very high which might be explained by the fact that the per capita farmland was found to be 0.77. The maximum per capita land holding size was almost the same ranging from 0 to 3.5 hectares. Farmland location/topographic characteristics (0.34), distance to fertilizer markets (0.34), proportion of households who use fertilizer (0.27) and households' inability to reserve seeds

for future cropping season (0.24) also contribute more to the overall vulnerability situations of the surveyed households in Dembia woreda. Intense soil erosion also contributes to have farmlands with poor soil fertility level, which further exacerbates the vulnerability levels of households in terms of farmland. Location of farmlands in a very flood-prone terrain with the resultant accelerated intense soil erosion in the upper parts and poor soil fertility level has created significant vulnerability levels of households. This has led to more vulnerability levels of the households as they become more sensitive to climate change impact (see Fig. 7). This result is in line with the hazard-of-place model which argues that places located nearer to sources of a natural hazard are more vulnerable to hazard impacts (Cutter et al. 2003).

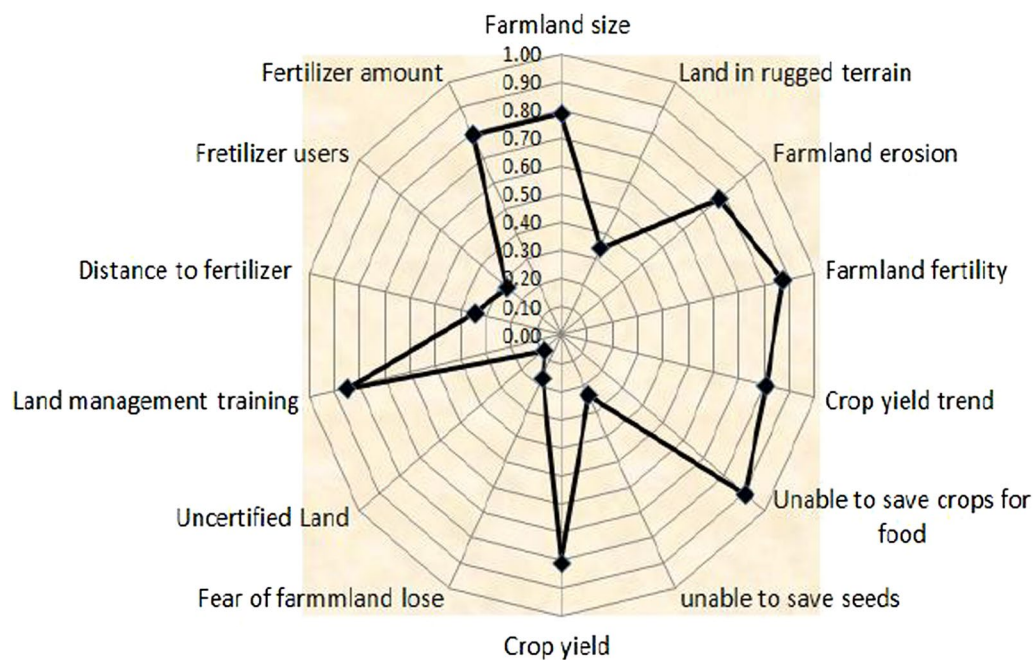
The assessment result indicated that the composite vulnerability score for households' land vulnerability was found much higher. Crop yield per hectare including its long-term declining trend is an important measure of farmland quality and vulnerability to climatic risks. The results on these indicators indicated that the surveyed households are highly vulnerable to climate change impacts by crop yield produced per hectare. The reasons are severe soil erosion resulting from flood-prone topography, intense rainfall with short duration and poor quality land management practices (see Fig. 7). Some authors argued that soil erosion is a major problem with the estimated erosion rates of 16–50 tones/hectare per year in Amhara Region accounting for more than 50 % of estimated annual soil loss in Ethiopia (Desta et al. 2000).

Figure 8 and Table 4 illustrate that, the households' agricultural lands are found to be increasingly vulnerable at 0.58 vulnerability index. Field observation asserts that the biophysical contexts have already made the

**Table 4 Normalized vulnerability indices for selected indicators [Household survey, March to April 2014 and Meteorology data]**

Natural capital	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 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	100corr	0	0.85
Distance to fertilizer market center	%	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	No.	36.89	175	0	0.79
Average farmland vulnerability index					0.58
STDEV of mean maximum temperature by year	0C	3.86	4.86	3.07	0.44
STDEV of mean maximum temperature by month	0C	1.48	1.91	0.95	0.55
STDEV of mean minimum temperature by year	0C	1.88	2.36	1.39	0.51
STDEV mean of minimum temperature by month	0C	0.71	1.01	0.42	0.49
Average exposure index by temperature					0.50
Average STDEV of RF (1979–2010) by month	MM	45.69	100.44	2.99	0.44
Average STDEV of RF (1979–2010) by year	MM	550.37	569.98	535.26	0.44
Average exposure to rainfall variability					0.44
Frequency of major hazards	Frequency	4.57	9	0	0.51
Average hazard frequency					0.40
Climate change/variability and hazards					0.46

**Fig. 7** Example landscapes for Dembia woreda being affected by flooding and severe soil erosion [Author's Field Photo, 2013]



**Fig. 8** Vulnerability radar diagram of agricultural land indicators. Index value of 0 means no or very low vulnerability and vulnerability increases as LVI values increase in the radar diagram outwards from the center [Household survey data, March–May 2014]

households more vulnerable in terms of this livelihood resource. Moreover, officials were asked questions (1) “What are the manifestations of climate change?” (2) “What are the observed impacts on farmers’ agricultural lands?” Farmers and officials of both governmental and non-governmental offices are observing massive impact of extreme weather-related events such as flood, erosion and drought, pests, diseases and weeds on natural resources such as farmlands, pastureland, water sources, and vegetation. In relation to this, Wisner et al. (2004) argue that although they may experience greater losses (in absolute terms) than the poor, resource-rich households are more resilient in that they can recover more quickly from a climatic stress/stimulus.

Although agricultural land is highly valued by the society, it has experienced persistent pressure and stresses from a range of direct and indirect socio-economic driving forces. Indeed, they are severely affected by climatic and environmental changes, leading the studied households dependent on these resources, more vulnerable to poverty and food insecurity. The impacts of future changes will be felt particularly by these communities given that our environment has faced with risks from climate change.

The results on land size indicators also showed that the total vulnerability level of the households to climate change impact was found to be higher. Several empirical works indicated that owning larger farmlands provide

more opportunities to cultivate more crops and yield though it is noted that labor availability and financial capital affect the reality of how much land can be cultivated. Barungi and Maonga (2011) found out that less farmland area is often attributed to increased vulnerability of farming households to climatic risks.

### Conclusions

This study provides ample evidence about farmers’ agricultural land vulnerability to climate change risks. The analysis found out more unfavorable biophysical contexts in the woreda having increasing exposure and sensitivity of the community to climate change. The changing patterns of rainfall, increasing temperatures, recurring floods, droughts and massive land degradation have terrible effects for the poor people who depend upon rain-fed agriculture. Likewise, the livelihood vulnerability indices (LVI) have put the households to the most vulnerable position in almost all agricultural land indicators and climatic variables. Most of the results of this study are in line with the findings of several empirical works. However, although the Amhara Regional Government has grouped Dembia woreda under the most resilient and surplus producing areas, the agricultural land LVI has put it in the vulnerable position in terms of climatic exposure indicators. This again, indicated that dividing any geographical area into high-low-potential dichotomies require integrated assessment of



biophysical characteristics and socio-economic capacities of that particular area.

Agricultural land is the main measurement of vulnerability situations of the rural households in this study. All the indicators chosen have impact on the vulnerability of the households in the woreda. The average vulnerability indices calculated using all the indicators of vulnerability are going to measure households' vulnerability levels, which are influenced by each indicator. Recurrent floods, crop pests, weeds and droughts have been a major issue throughout history in the woreda like elsewhere in Ethiopia. The scientific observations show that the climate is changing in the study area. Recent evidence includes increasing temperatures, drought frequency and unpredictable rains that fall in shorter but more intense episodes. The magnitude and rate of current climate change, combined with additional environmental, social and political issues, are making many traditional coping strategies ineffective and/or unsustainable, amplifying environmental degradation and flood-displacement.

There should be urgent needs for addressing the farmers' problems to enhance community resilience through supporting them for the choice of better adaptation strategies. In this regard, this study suggests multitude and multi-level policy, education and research interventions for enhancing community-based participatory watershed management approach supported with best indigenous knowledge and practices of farmers. Adaptation interventions should also consider local farmers' resource capacity (low-cost investment in sound agricultural land and soil management techniques).

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#### Competing interests

The author declares that there are no competing interests.

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#### 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
- Adger WN (2006) Vulnerability. *Glob Environ Change* 16:268–281
- Barungi M, Maonga BB (2011) Adoption of soil management technologies by smallholder farmers in Central and Southern Malawi. *J Sustain Dev Afr* 12(3):28–38
- Bryan E, Ringer C, Okoba B, Roncoli C, Silvestri S, Herrero M (2011) Adapting agriculture to climate change in Kenya: household and community strategies and determinants. World Bank, Nairobi
- Coltman T, Devinney T, Midgley D, Veniak S (2008) Formative versus reflective measurement models: two applications of formative measurement. *J Bus Res* 61(12):1250–1262
- Creswell JW (2012) Educational research: planning, conduction and evaluating quantitative and qualitative research. Pearson's Educational Inc, New York
- Cutter SL (1996) Vulnerability to environmental hazards. *Prog Hum Geogr* 20(4):529–539
- Cutter SL, Boruff BJ, Shirley WL (2003) Social vulnerability to environmental hazards. *Soc Sci Quarterly*, Vol 84, No. 2, Southwestern Social Science Association, pp 242–262
- Desta L, Kessie M, Benin S, Pender J (2000) Land degradation and strategies for sustainable development in the Ethiopian highlands: Amhara Region. International Livestock Research Institute, Nairobi
- Ellis F (2000) Rural livelihoods and diversity in developing countries. Oxford University Press, New York
- Feige S, Marr MA (2012) Sampling manual: a guide to sampling under the CDM with special focus to POAs, 1st edn. Frankfurt: KfW
- Fussler H (2006) Vulnerability: a generally applicable conceptual framework for climate change research. *Global Environmental Change*, Stanford
- Fussler H, Klein R (2005) Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic Change* xxx, 1–29
- Gallopín GC (2006) linkages between vulnerability, resilience, and adaptive capacity. *Glob Environ Change* 16:293–303
- Gbetibouou GA (2009) Understanding farmers' perceptions and adaptations to climate change and variability: the case of the Limpopo Basin, South Africa. IFPRI discussion paper 00849, University of Pretoria
- Global weather data for SWAT. (1979–2010). <http://globalweather.tamu.edu/>. Retrieved March 6, 2013, from [eco.web.tamu.edu](http://eco.web.tamu.edu)
- Hahn MB, Riederer AM, Foster SO (2009) The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change: a case study in Mozambique. *Global Environmental Change*, Elsevier Ltd, 1–15
- ICRISAT/International Crops Research Institute for the Semi-Arid Tropics. (2006). [www.icrisat.org/what-we-do/](http://www.icrisat.org/what-we-do/). Retrieved January 12, 2013, from the ICRISAT website:
- IPCC/Intergovernmental Panel on Climate Change (2001) Intergovernmental panel on climate change 2001: impacts, adaptation and vulnerability. Cambridge University Press, Cambridge
- IPCC/International Panel on Climate Change (2013). Working group I contribution to the IPCC fifth assessment report climate change 2013: the physical science basis summary for policymakers
- IPCC/Intergovernmental Panel on Climate Change (2007) Adaptation to climate change in the context of sustainable development, background paper. UNFCCC Secretariat, Bonn
- Israel GD (1992) Determining sample size. University of Florida, IFAS Extension, pp 1–7
- Iyengar N, Sudarshan P (1982). A method of classifying regions from multivariate Ddata. *Economic and Political Weekly*, Special article, pp 1–5
- Leichenko K, O'Brien G, Aandahl H, Tompkins, Javed A (2004) Mapping vulnerability to multiple stressors: a technical memorandum. Oslo, CICERO
- Luers A, Lobella DB, Sklar LS, Addamsa CL, Matson PA (2003) a method for quantifying vulnerability, applied to the agricultural system of the Yaqui valley, Mexico. *Glob Environ Change* 13:255–267
- Maddison D (2006). The perception of and adaptation to climate change in Africa. Policy Research Working Paper 4308. University of Pretoria: Centre for Environmental, economics and Policy in Africa
- Mamo G, Getachew F (2010). Climate change projections for Ethiopia, Ethiopian J Agric Sci. Addis Ababa, Ethiopia
- McKee TB, Doesken NJ, Kleist J (1993) The relationship of drought frequency and duration to time scales. In: Proceedings of the 8th conference on applied climatology. Colorado State University, Anaheim, California, pp 1–6
- Mertz O, Mbow C, Reenberg A, Diouf A (2008) Farmers' perceptions of climate change and agricultural adaptation strategies in Rural Sahel. *Environ Manag* 43:804–816. doi:10.1007/s00267-008-9197-0

- MoFED/Ministry of Finance and Economic Development (2007) "Ethiopia: Building on Progress: A Plan for Accelerated and Sustained Development to End Poverty (PASDEP)," Annual Progress Report 2005/06: Addis Ababa
- Molla M (2008) climate change and crop agriculture in Nile basin of Ethiopia: measuring impacts and adaptation options. Addis Ababa University, Addis Ababa
- Mongi H, Majule AE, Lyimo J (2010) Vulnerability and adaptation of rain-fed agriculture to climate change and variability in semi-arid Tanzania. *Afr J Environ Sci Technol* 4(6):371–381
- Moss RH, Brenkert AL, Malone EL (2001) Vulnerability to climate change: a quantitative approach. The US Department of Energy, Washington, DC
- NMA/National Meteorological Agency (2007) Climate Change National Adaptation Program of Action (NAPA) of Ethiopia. NMA, Addis Ababa
- O'Brien K, Leichebko R, Kelkar U, Venema H, Aandahl G, Tompkins H et al (2004) Mapping vulnerability to multiple stressors: climate change and globalization in india. *Glob Environ Change* 14:303–313
- Schroter D, Polsky C, Patt A (2004) Assessing vulnerabilities to the effects of global change: an eight step approach. *J Mitig Strategies Glob Chang* 30:1–23
- Sullivan C (2002) Calculating water poverty index. *World Dev* 30(7):1195–1210
- Sullivan CA, Meigh DJ, Fedwi MT (2002) Derivation and testing of the water poverty index phase1. Final Report May 2002 Vol 1 Overview. Wallingford and London: Center for Ecology and Hydrology, Natural Environment Research Council
- Tarling R (2009) Statistical modelling for social researchers: principles and practices. Routledge, New York
- Temesgen D (2006) Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach, Centre for Environmental Economics and Policy in Africa. University of Pretoria, South Africa
- Temesgen T (2010) Assessment of the vulnerability of Ethiopian agriculture to climate change and farmers adaptation strategies. PhD. Thesis. Pretoria: University of Pretoria
- Temesgen D, Hassan RM, Alemu T, Yesuf M, Ringler C (2008) Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. IFPRI Discussion Paper 00798. Washington, DC. Environment and Production Technology Division
- Teshome M (2015) Farmers' vulnerability to climate change-induced water poverty in spatially different agro-ecological areas of Northwest Ethiopia. *J Water Clim Change*, in Press, IWA Publishing
- Turner BL II, Kasperson RE, Matsone PA, McCarthy JJ, Corellg RW, Lindsey Christensene NE et al (2003) A framework for vulnerability analysis in sustainability science. *PNAS* 100:8074–8079
- UNDP/United Nations Development Program (2010) Human Development Index Trends, 1980–2010, Table 2, Statistical Annex 151. UNDP, New York
- UNFCCC/United Nations Framework Convention on Climate Change (2007) Climate change: impacts, vulnerabilities, and adaptation in developing countries. United Nations Framework Convention on Climate Change Secretariat, Bonn
- Vincent C (2004) Creating an index of social vulnerability to climate change for Africa. Norwich, East Anglia: Tyndall Center for Climate Change Research, Working Paper 56
- Wisner B, Blaikie P, Cannon T, Davis I (2004) At risk: natural hazards, people's vulnerability and disasters. Routledge, Francis Group, London
- Woldeamlak B (2009) Rainfall variability and crop production in Ethiopia: case study in Amhara region. In: Ege S, Aspen H, Teferra B, Bekele S (eds) Proceedings of the 16th International Conference of Ethiopian Studies, Trondheim, pp 823–836
- World Bank (2010) Africa rainfall and temperature evaluation system (ARTES). World Bank, Washington, DC
- Yohannes A (2012) Perceptions of climate change among members of the House of Peoples' Representatives, Ethiopia. *J Risk Res*. doi:10.1080/13669877.2012.657219
- Zhai F (2009) A general equilibrium analysis of the impact of climate change on agriculture in the PEOPLE'S Republic of China, Asian Development Review, pp 206–225
- Zhai F, Zhuang J (2009) Agricultural impact of climate change: a general equilibrium analysis with special reference to Southeast Asia. Asian Development Bank Institute, Tokyo

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