ORIGINAL ARTICLE

PERCEIVED HUMAN HEALTH VULNERABILITY TO CLIMATE CHANGE IN DEMBIA *WOREDA* OF TANA BASIN, NORTHWEST ETHIOPIA

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ABSTRACT

Climate change is one of the most challenging environmental concerns of the globe in the 21st Century though its visibility is much less than other environmental problems, like deforestation, land degradation, air pollution, etc. The aim of this paper is to assess perceived relative human health vulnerability to climate change-induced risks by creating empirical indices in Dembia woreda (district) of Northwest Ethiopia. Primary data were collected from 372 household heads using questionnaire. The selection of the participants was made using simple random sampling technique. Thirty -two-years meteorological data (1979 – 2010) were gathered from global weather data website. Theory-driven aggregate indices of temperature, rainfall, frequency of extreme weather events and health sensitivity were formed through the equal weighting approach of four composite sub-indices. The Intergovernmental Panel on Climate Change (IPCC) vulnerability assessment framework was used to measure human health components to see differential vulnerability of communities by indicators. The outcome of this relative study puts the rural households of Dembia woreda to the most vulnerable position (0.47 score) to climate change-induced health effects. Component-wise, the households were found to be the most exposed and sensitive social groups by temperature (0.50), rainfall variability (0.44), frequency of extreme weather events (0.51) and levels of access to health-care infrastructure (0.44). It should not imply that the other household groups are entirely resilient. Although the majority of the households have access to health institutions, they reported traveling long distance to reach to health institutions. This, in turn, has likely increased the vulnerability of rural households to health risks in the woreda. This suggests that resources that may have been spent on health sector development might be reallocated to the most vulnerable rural households.

Keywords: Climate change, exposure, Ethiopia, health vulnerability, sensitivity, Tana Basin, vulnerability index

INTRODUCTION

The long-term good health of the population depends on the continued stability and functions of the biophysical life-support systems. However, we often ignore and overlook this long-established historical truth at the expense of humanity. The world's climate system is an integral part of this complex life-support processes, one of many large natural systems that are now coming under pressure from increasing human population and economic activities [World Health Organization[(WHO), 2003].

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There is scientific agreement that human-induced greenhouse gas emissions have changed the Earth's climate. 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 scholars define it as the alteration of the earth's climate that is attributed directly or indirectly to human activity (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 its properties and that persists for an extended period, typically decades or longer (Fussel & Klein, 2005; IPCC, 2007). The recent average global warming by 0·6°C is partly attributed to anthropogenic emissions (WHO, 2003; McMichael et al., 2006; IPCC, 2007, 2013;). Climate is changing in response to numerous human activities that transfer gases into the atmosphere. Magnification of the greenhouse effect results in the observed warming that in turn brings changes in other climatic and weather variables. Apart from an increase in the natural greenhouse effect, some of these gases also deplete the stratospheric ozone layer, producing a net increase in the Ultraviolet (UV) Radiation reaching the ground. For millennia, the greenhouse effect has facilitated a balance between incoming solar radiation and outgoing terrestrial radiation; a change in either incoming or outgoing radiation modifies the surface temperature of the Earth (WHO, 2003; IPCC, 2007, 2013). By increasing concentration of heat-trapping gases in the lower atmosphere, human actions have begun to amplify Earth's natural greenhouse effect. Hence, the primary challenge facing the world is garnering mechanisms of sufficient greenhouse gas emissions reduction to avoid dangerous interference in the climate system (WHO, 2003).

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The unprecedented human-induced climate change has prompted a large international scientific effort to find the evidence. The Intergovernmental Panel on Climate Change (IPCC), established within the UN framework in 1988, was charged with advising national governments on the causes and processes of climate change; likely impacts with their associated costs; and ways to lessen the impacts (WHO, 2003; UNFCCC, 2007). The studies conducted by the IPCC have found an increasing body of observations giving a collective picture of a warming world, and is experiencing colossal changes in the climate system. This exceptional warming has taken place in a time span far shorter than the spans paleoclimatic studies have shown for geological periods with similar changes (WHO, 2003; IPCC, 2007, 2013).

All these geophysical processes influence human health (WHO, 2003; IPCC, 2007, 2013). Empirical evidence asserts that global climate has profound effects on the health and well-being of citizens. The associated changes in temperature and precipitation adversely affect human health (Ebi et al., 2006). Indeed, the changing climate is linked to increases in a wide range of infectious and non-communicable diseases. Climatic factors can directly or indirectly affect the prevalence of disease in a complex ways. Identification of communities and places sensitive and vulnerable to these changes can help health departments assess and prevent associated adverse health impacts of climate change (WHO, 2003; IPCC, 2007; Global Health Action, 2009).

The most common climate variables that people would be aware of are: air temperature, rainfall, humidity, wind speed, wind direction, and extreme weather events. In addition, a meteorologist could add cloud cover, solar radiation intensity, air pressure and other more specialized variables. Several of these variables link to human health via the basic physiological mechanisms that balance core body temperature at approximately 37^0C for all human beings. A very small range of temperatures around this value is associated with maintaining good health. Serious heat stroke and even death occurs after a relatively short time if core body temperature goes above 42^0C (Global Health Action, 2009). As the climate changes in Ethiopia, we may experience more extreme weather events, an increase in contamination of air, water and food and a greater number of emerging infectious diseases. As a result, we need to have a better understanding of the health effects of climate change and identify the most vulnerable communities so as to manage the risks (WHO, 2003).

Climate change and health have been given increasing attention during recent years, largely initiated and triggered by the insightful report by McMichael and colleagues published a decade ago (Global Health Action, 2009). National governments, via the UN Framework Convention on Climate Change (UNFCC), are committed in principle to seeking this outcome. In practice, it is proving difficult to find a politically acceptable course of action because of worries about short-term economic consequences (WHO, 2003).

Many studies have been carried out on climate change and human health at global and regional levels. Studies at global and regional levels indicated that increasing temperature and declining precipitation significantly affect human and environmental health (WHO, 2003; Patz et al., 2005; Ebi et al., 2006; McMichael et al., 2006; Global Health Action, 2009). As far as the author's knowledge is concerned, there are no local studies in Ethiopia. The results of global and regional level studies were highly aggregated over larger geographical areas, and the parameters have limited value to analyze country-specific health vulnerability and adaptation strategies, given the heterogeneity of the countries. Decisions for different scales with varied contexts require different evidence because an indicator developed to measure households' health vulnerability in South Africa or Egypt may not be relevant to Ethiopian context. Therefore, this study assessed human health vulnerability to climate change in the local setting of Dembia *woreda*, Tana Basin of northwest Ethiopia.

2. Conceptual Frameworks of Vulnerability

The most complex and debatable term for various scholarly communities is 'vulnerability', which 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 II et al., 2003; Fusel and Klein, 2005). Vulnerability has its origins in the natural hazards and food security literature (Cutter, 1996). The term is now a central concept in the livelihood, food security, sustainability science, land-use change, disaster risks management, public health, global environment and climate change research communities (Schroter et al., 2004; Fussel, 2006).

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 ontology. 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).

IPCC (2001, 2007) 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. From the natural standpoint, the IPCC defines vulnerability as "a function of the character, magnitude and rate of climate variability 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, Houghton and Khandker (2009) explain vulnerability 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 II et al., 2003).

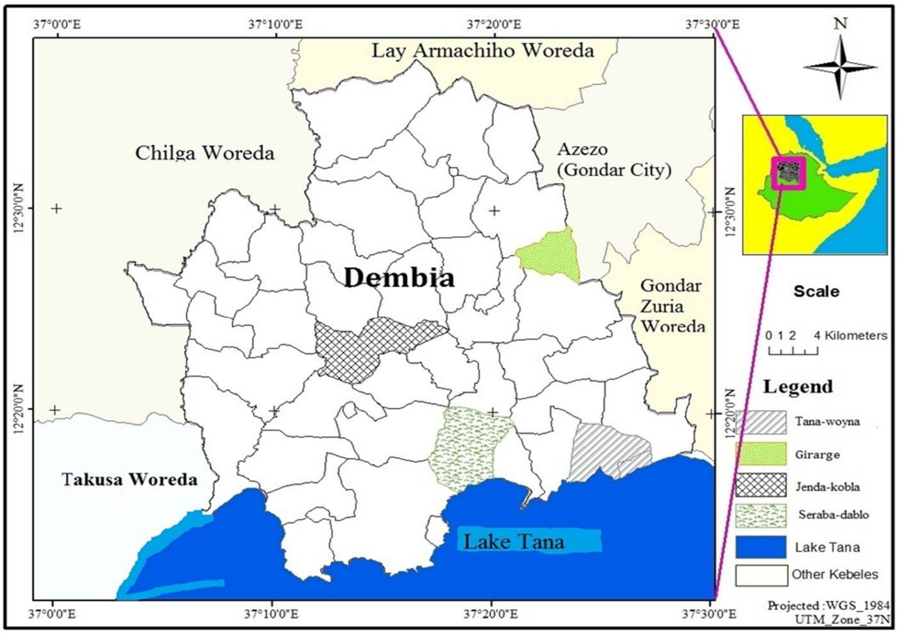
Exposure is the magnitude, frequency, intensity, and duration of climate-related hazards such as hurricanes, droughts, floods, and storms, heat-waves (high temperature), changing distribution of temperature and rainfall, which expose rural households' livelihood assets, including human health (IPCC, 2007). Sensitivity is the degree to which the rural household is adversely affected by the exposure to the changing climatic variables. It can be measured by the proportion of people who have faced with climate variability and low access to different health 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 II et al., 2003; IPCC, 2007). In line with this, Schroter et al. (2004) noted that vulnerability to climate change in terms of not only exposure to higher temperatures, but also system's sensitivity to high temperatures and peoples' ability to adapt to the effects of that sensitivity by planting trees, heat-tolerant cultivars or different crops. Thus, one can conclude that exposure, sensitivity, and adaptive capacity are inherently interlinked (Gallopin, 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 occur chronologically, but they play a continuous role in enhancing or diminishing each other. Consequently, many studies combine sensitivity with exposure or combine sensitivity with adaptive capacity depending on the indicator under consideration.

3. Study Area

Lake Tana is located on the headwater of the Blue Nile River. The Blue Nile is the major river that affects the water availability in the lower Nile catchment. Dembia *woreda* (district) is located in the Lake Tana Basin, and administratively in North Gondar Zone of the Amhara Regional State, Ethiopia. It is bounded with Gondar City and Lay Armachiho to the north, Gondar Zuria *woreda* to the east, Chilga and Alefa *woredas* to the west and part of Lake Tana to the south. The *woreda* capital, Koladiba, is located 750 Km North of Addis Ababa which is branched to west from Addis-Gondar highway at Azezo about 35km from Gondar city.

The *woreda* is mainly categorized into *woyna-dega* (midland) agro-ecological setting. Elevation varies from 1700 to 2600 m above sea level characterized mostly by flat landscape, flood plain, and wetlands. According to the data obtained from the *woreda* Agriculture Office, the topography of the area comprised of plain (87%), mountainous (5%), valleys (4.8%) and wetlands (3.2%). The land use pattern of the *woreda* comprised of a mixture of categories. Out of the total area 32.97% is used for annual

Figure 1: Location Map of Dembia woreda in the national and sub-national setting.



cropping, 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%.

The land is gradually degrading due to uncontrolled deforestation for fuel and construction purposes resulting in severe soil degradation. Population growth further aggravates deforestation and the removal of top soil from cultivated lands through erosion leading to the decline of agricultural land productivity (Dembia *Woreda* Office of Agriculture, 2014).This situation also aggravates the problem of food insecurity in the *woreda*. Even though the *woreda* is considered to have good potential for agricultural production, it is found to be vulnerable to climate change and associated extreme weather events (Teshome, 2016). As such, the *woreda* is heavily affected by flood, malaria and other water-borne diseases, and livestock diseases (Dembia *Woreda* Office of Agriculture, 2014).

4. Research Methods

Various disciplines address the study of vulnerability and human adjustment to climate change. This study is based on an interdisciplinary approach to explore global climate change and as such the research does not emerge from any single discipline. The study of vulnerability to climate change, therefore, requires an inherently eclectic approach (Schipper, 2004). The reason is mainly attributed to the fact that climate change is a complex problem interacting with a range of natural and socio-economic processes (Schipper, 2004; Adger et al., 2004). Accordingly, this study approached the households' health vulnerability to climate change in the local areas with awareness that such a study requires both an examination of biophysical, socio-economic indicators and climatic hazards. From this, we can understand that the study of vulnerability and adaptation to climate change requires multiple approaches derived from numerous disciplines so as to attain a holistic understanding of the various dimensions of the problem (Schipper, 2004; Hahn et al., 2009; Temesgen, 2010; Luk, 2011).

Conducting research includes designing and writing the research in one of the three major tracks: quantitative research or qualitative research or mixed research. Based on the nature of the research problem and the questions that will be asked to address the problem, the author chose the mixed research method. The problem, the questions, and the literature reviews help to steer towards this method. These, in turn, inform the specific research design to be used and the procedures involved in them, such as sampling, data collection instruments, the procedures, the data analysis, and the final interpretation of results (Creswell, 2012).

4.1. Sampling

Four *kebeles*, namely Gerarge, Jenda, Seraba Dablo and Tana woyena 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* (Yemane, 1967 cited in Israel, 1992) as there are different household sizes in different *Kebele* Administrations (KAs). The PPS method provided larger number of household heads for Tana-woyna (112), Seraba-dablo (208) and Jenda (206) while the smallest sample size was determined for Gerarge (46) (See Table 1).

Table 1: *Number of total and sample households of study areas*

Kebele	Total population	Total household	Sample Size
Gerargie	3,311	659	46
Jenda	7,395	1,525	106
Seraba dablo	6,882	1,560	108
Tana woyna	7,475	1,618	112
Total	25,063	5362	372

Source: Dembia Woreda Administration office, 2013

Sample households were selected using systematic random sampling technique. In 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 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.

4.2. Methods of Data Collection

This study used both primary and secondary data. Primary data were collected using household survey, field observation, and in-depth interview, which have brought the study to fruition. The household survey collected a range of quantitative data on perception of households on human communities' vulnerability to climate change-related health risks. The data sets are important for calculating health vulnerability indices; frequency counts, percentage, maximum and minimum values used for comparison among vulnerability indicators.

In order to maintain data validity and reliability, the questions were reviewed by experts from different disciplines, working in the Offices of Agriculture, Health, Food Security and Disaster Prevention. A pretest was also made by distributing questionnaires to 10 households who were not involved in the actual survey to assess whether the instruments were appropriate and suited to the study, and to delete or modify confusing and sensitive question and ideas. Necessary amendments were made based on the comments obtained from experts and responses from farmers. Pretesting of the questions was also used to determine the mean interview length and mean time required for covering the samples in order to plan the time and days required for the field survey and the number of data collectors. The author trained data collectors with respect to the survey techniques and confidentiality protocol. For example, in case survey questions contained ambiguous language that might lead to different answers depending on respondents' interpretation, data collectors were told to have common understanding. After the training, the data collectors acquired practical experience while the author made face-to-face interview during the data collection in the field.

Trained data collectors administered the household survey with close supervision of the author in April and June 2014. Household heads were approached, but if he/she were not available, the spouses were contacted. When there were difficulties to meet the selected households due to absenteeism (after repeated visits) or when they became involuntary to take part, the household head listed next to him, or her, replaced them. Most of the farmers were contacted on the homesteads and a few of them were consulted on Saturdays, Sundays, and other holidays around churches and community gathering places. The author's former students at the university had played paramount role in the process of data collection. They also played an important role in choosing the data collectors who have been working in the community in the areas of agriculture, health and teaching. They are living in the community for many years, so they better know the area and easily approach and handle respondents.

The 32 years meteorological (rainfall and temperature) data were gathered from Global weather data for soil and water assessment tool/SWAT/ [*globalweather.tamu.edu*] at a satellite station of 12.333 North latitude and 37.1875 East longitude and at elevation of 1836 m above sea level. The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) was completed over the 32-year period from 1979 to 2010. The CFSR was designed as a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system to provide the best estimate of the state of these coupled domains over this period. The current CFSR will be extended as an operational, real time product into the future. This website allows us to download daily precipitation, wind, relative humidity, and solar data for a given location and time period [*globalweather.tamu.edu*]. Population data were gathered from the respective *kebele* administration offices in the process of determining the sample size.

4.3. Methods of Data Analysis

This study used both quantitative and qualitative data analysis methods. The quantitative methods include simple regression, standardized temperature anomalies, standardized precipitation index and Health Exposure (HE) and Health Sensitivity (HS) indices complemented with descriptive statistics like mean, percentage, maximum and minimum values.

(1) Simple regression: to examine the relationship between quantitative outcome and single quantitative explanatory variable, simple linear regression is the most common method. The method is important to detect and characterize the long-term trend and variability of temperature and rainfall values at annual time scale. The parametric test considers the simple linear regression of the random variable Y on time X. The regression coefficient a (or the Pearson correlation coefficient) is the interpolated regression line slope coefficient computed from the data. The statistic as was used by Mongi et al. (2010) is:

$$Y = \beta x + c \qquad [1]$$

Where: Y represents physical factor (changes in rainfall and temperature) during the period; β represents slope of the regression equation; x refers to number of years from 1979 to 2010; c is regression constant.

(2) Standardized Precipitation Index (SPI):The SPI was used to identify droughts (duration, magnitude and intensity) across the years from 1979 to 2010. It is a statistical measure indicating how unusual an event is, 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 one year to another. It can be calculated as:

$$SPI = \frac{x_i - \bar{x}}{\delta} \qquad [2]$$

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 annual rainfall; and σ represents the standard deviation of rainfall over the period of observation (McKee et al., 1993; Woldeamlak, 2009 as cited from Agnew and Chappel, 1999). Accordingly, 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).

(3) **Health Vulnerability Index (HVI)**: HVI provides a measurement of values, which represent human vulnerability to water and food poverty as well as limited health-care facilities. High values of the HVI (which ranges from 0 to 1) indicate a greater risk of being vulnerable to changing climate conditions (Sullivan and Huntingford, 2009).

Table 2: *Health assessment indicators and hypothesized relationships to vulnerability in Dembia woreda*

Indicators	Explanation of specific vulnerability indicators	Hypothesized Relationships with vulnerability
Climate variability	Standard deviation of mean maximum temperature by year	Exposure ↑ as maximum Tσ↑ vulnerability ↑
	Standard deviation of mean minimum temperature by month	Exposure↑ as minimum Tσ↑ vulnerability ↑
	Average monthly standard deviation of rainfall (1979-2010)	Exposure ↑ as rainfall variability↑ vulnerability ↑
	Average number of hazards occurred in the past 10 years	Exposure ↑ as frequency of droughts ↑ vulnerability↑
	Family member faced injury/death due to climate change	Health Sensitivity ↑as injury and death ↑ vulnerability↑
	Percent of HHs reported at least 1 chronic illness in a family	Health Sensitivity ↑ as distance ↑ vulnerability ↑
	HHs members who missed work/school by climatic illness	Health Sensitivity ↑ as absenteeism ↑ vulnerability ↑
Health services	HHs who reported malaria incidence in their locality	Health Exposure ↑as frequency ↑ vulnerability ↑
	HHs who were not beneficiaries of health extension package	Health Sensitivity ↑as non-beneficiaries↑ vulnerability↑
	HHs who do not have/use toilet facility	Health Sensitivity ↑ as non-users ↑ then vulnerability ↑
	Average time a HH take to reach health center/hospital	Health Sensitivity ↑ as distance ↑ then vulnerability ↑

Notes: [1] Households Tσ = Standard deviation of temperature

Accordingly, an assessment of vulnerability levels of rural households to measure their access to water, food and health-care services was done using HVI. Indices were constructed using equal weighting method (Hahn et al. 2009) and the indicators were normalized as indices using the equation adapted by UNDP to calculate life expectancy index and Sullivan et al. (2002) to analyze water poverty index (See Equations (3) – (4)).

The indicators listed in Table 2 were converted into standardized index by Equation 3:

$$HHV_i = \frac{X_i - \text{Min } X_i}{\text{Max } X_1 - \text{Min } X_i} \quad [3]$$

For example, when the average time taken to reach to nearest health institution ranges from 1 to 140 minutes in the households surveyed, these minimum and maximum values were used to transform this indicator into a standardized index value to be integrated into the physical assets of the HVI.

Where: HHV_i = measure of human health vulnerability contributed by the i[th] indicator in the study area, X_i = numerical value of the i[th] indicator, Min and Max X_i = minimum and maximum values of the i[th] indicator being compared with other variables.

For variables that measure frequencies such as percent of households who were not health package services beneficiaries, the minimum value is set at 0 and the maximum at 100.

Every score for each indicator is expressed in the same standardized unit (on a 0 to 1 scale); 0 denotes least vulnerable or no vulnerability and 1 denotes most vulnerable. This allows calculating the average scores which can be done in two ways: by attaching equal importance (simple average of the standardized scores of each criterion for a given indicator) or by attaching different weights to each indicator. In this study, simple averages of standardized scores were calculated for the sub-components using Equation 4:

$$MHV_i = \frac{\sum_{i=1}^{n} V_i}{n} \quad [4]$$

Where: Mean health vulnerability index is one of the components, temperature change (Tc), rainfall variability (Rv), Hazard frequency (Hf); health sensitivity (Hs); index represents the sub-components, indexed by i, that make up each component, and n is the number of indicators in each component. Climate vulnerability index equals the weighted average of the three major components. This analysis was done by using SPSS-16 and MS-excel worksheet.

The qualitative data analysis methods supplemented the quantitative methods. The qualitative method analyzed the collected qualitative text or word information obtained through in-depth interview and field notes written during observations. The collected information was converted into word processing documents during data processing.Transcription - converting interview and field notes into text data and then translated from local language (Amharic) to English was done and analysis was made through narrating and interpreting the issues.

5. Results and Discussion

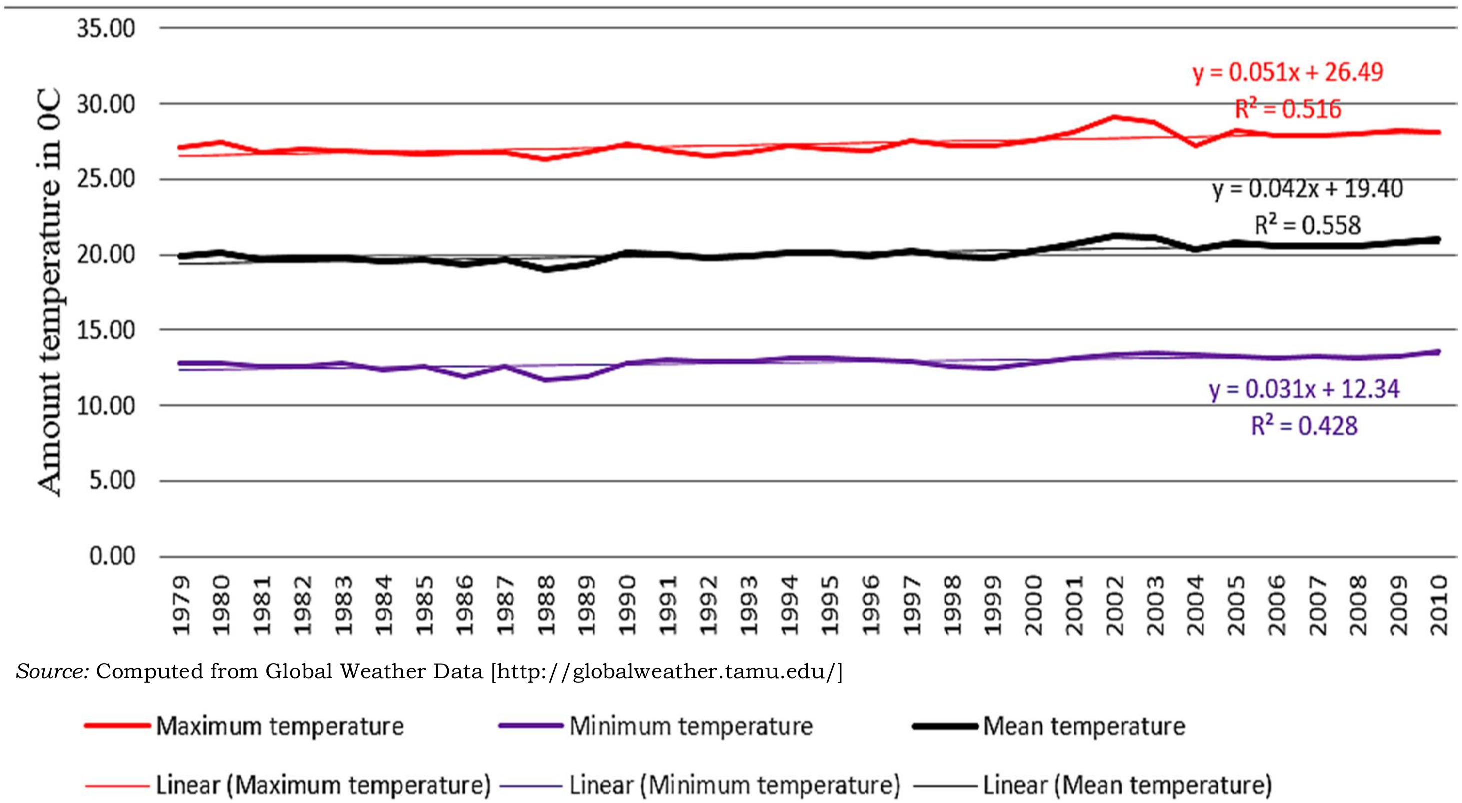
The households' health is influenced by the exposure and sensitivity to biophysical and socio-economic vulnerability contexts. Therefore, the major components to measure rural households' levels of health vulnerability to climate change are climatic exposures (temperature change, rainfall anomalies and extreme weather events) and health-care facilities measured by several indicators. These are important to inform the need for local context-specific adaptation interventions for enhancing the rural health conditions. The vulnerability levels of the households vary by these indicators.

5.1. Temperature change

Temperature is a very important climatic variable in the study of human health vulnerability to climate change risks. Evidences indicate that the mean temperatures have changed through time in Ethiopia (NMSA, 2001, 2007). The same temperature trend was detected in Dembia *woreda* (Tana Basin) of Northwest Ethiopia over the past 32 years. Figure 2 presents the average temperature trends of the *woreda* over 1979 to 2010 period. The estimated trend line for average annual temperature in y = 0.042+26.49 (R^2 = 0.558). The trend line has a positive slope indicating that the average temperature has increased by 1.3^{0}C over 32 years. On decadal time scales, it rose by 0.41^{0}C. This indicates that there was faster rate of temperature increase in the study area. The rate of increase in the *woreda* was also faster than the national level temperature rise (0.2^{0}C -3^{0}C per decade) 1 observed over the past 55 years (NMA, 2007).

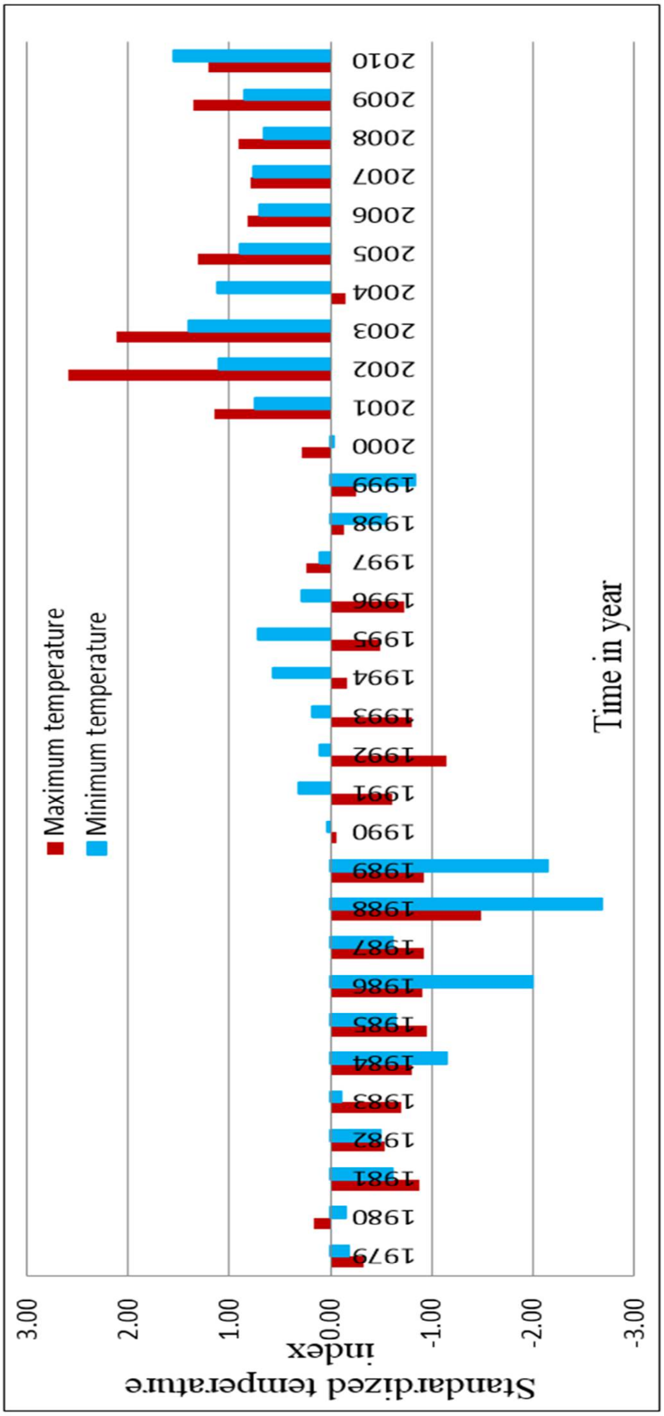
Both maximum and minimum temperatures over the past 32 years (1979-2010) increased in the Tana Basin of Dembia *woreda*. Maximum temperature increased faster than the minimum temperature. For example, the maximum temperature increased by 1.58^{0}C while the minimum temperature increased by 0.96^{0}C. In decadal time scale, the maximum temperature rose by 0.49^{0}C and the minimum by 0.3^{0}C. However, when we look at the temperature values and their correlation with years there was no statistically significant trend in annual average temperature of Dembia *woreda*. This increasing trend is also supported by 95% of the surveyed households who observed increasing temperature trend over the past 20 years. Only 2% of the households noticed a decrease in temperature, and only 1.5% of them have not noticed any temperature change.

Figure 2: *Inter-annual temperature variability and trends of Dembia woreda*



Source: Computed from Global Weather Data [http://globalweather.tamu.edu/]

Figure 3: *Maximum and minimum temperature deviations from the long-term average*



Source: Computed from Meteorology data of Global Weather Data [http://globalweather.tamu.edu/]

In addition to inter-annual temperature variability and trend, increasing deviation from the long-term average was observed in the study area over the same period (1979-2010) with immense potential human health risks. The average temperature was taken for Dembia and compared with the hottest and coldest temperature event of each year by calculating the temperature deviation using SPI formula based on Mongi et al. (2010) as observed in the *woreda*.

Figure 3 demonstrates the maximum and minimum temperature deviations from the long-term average temperatures for the *woreda*. The figure shows that until 1989 the deviation of both maximum and minimum temperatures was almost in similar pattern and below the long-term average temperature. From 1990 to 2000, increasing trend of temperature deviation was detected with greater fluctuations from time to time. Since 2001 both maximum and minimum temperature deviation were higher than the long-term average temperatures. Analysis of temperature trend showed similar trends as the one reported by IPCC (2007) and Mongi et al. (2010) both of which, pointed out that increasing temperature trend in the tropical and sub-tropical regions of the world is very high (IPCC, 2007) with adverse human health impacts.

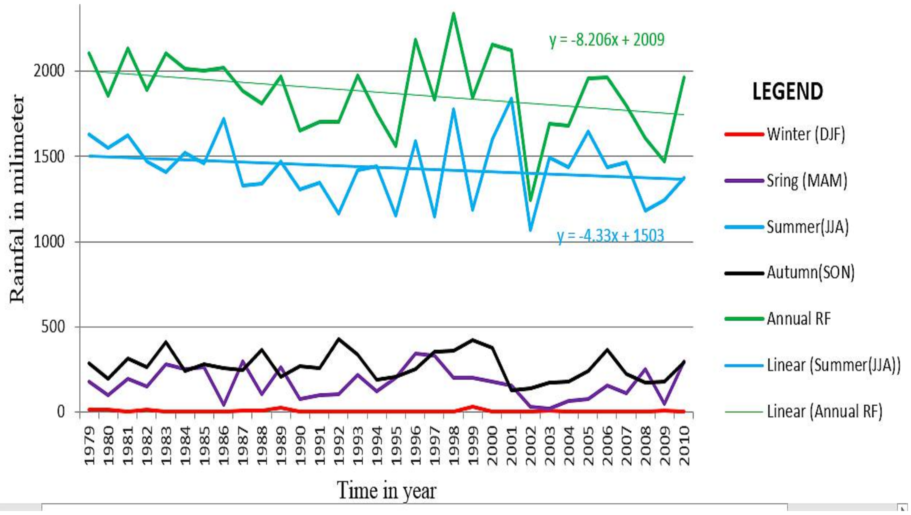
The direction of the temperature trend is consistent with the findings of Mongi et al. (2010) for Tanzania, which found out that both minimum and maximum temperatures showed increasing trends. However, in Tabora Urban and Uyui Districts of Tanzania minimum temperature increased faster while maximum temperature increased gradually. This increasing temperature trend has paramount impact on water, land, food production through worsening negative consequences on human health and productive capacities the community.

With regard to long-term temperature deviation and anomaly, the results in this study are in line with the findings of several other empirical works (Mongi et al., 2010; IPCC, 2013). The recent IPCC (2013) report stated that in addition to multi-decadal warming, global mean surface temperature exhibits substantial decadal and inter-annual variability. However, due to natural variability, trends based on short records are very sensitive to the beginning and end dates and do not in general reflect long-term climate trends.

5.2. Rainfall change and anomalies

For computing the long-term inter-annual rainfall change and anomalies, simple regression (Equation 1), was used as was used by Mongi et al. (2010) and Gbetibouo (2009). The result indicated that there is large inter-annual variability of rainfall and rate of decline in the *woreda*. Figure 4 illustrates the long-term pattern and rates of change in rainfall in the *woreda* from the years 1979 to 2010. It is clear from the figure that the total annual rainfall is declining from time to time. However, long-term rainfall change from 1979 to 2010 appeared to decrease at statistically non-significant rates (R^2 = 0.066). The main problem is the timing (late onset and early cessation) and failing in intense episodes in very short

Figure 4: *Long-term trends of rainfall (1979 – 2010) by season*



Source: Computed from Global Weather Data [http:// globalweath er.tamu.edu/]

duration.

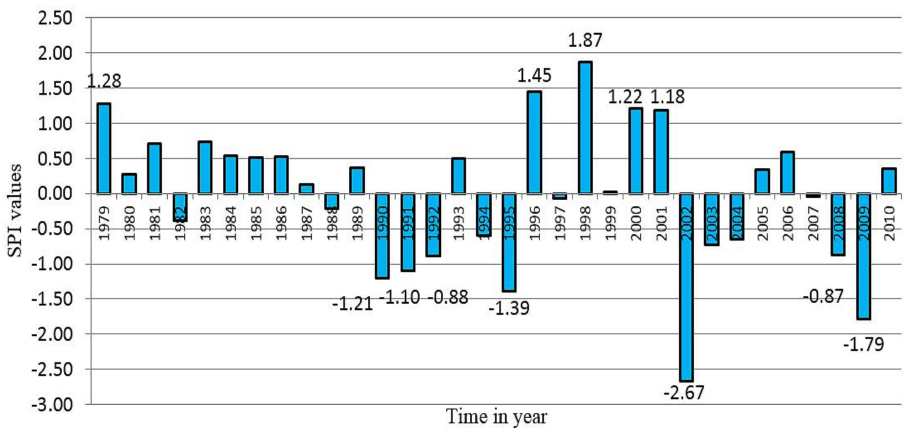
The long-term reduced amount of rainfall calculated using simple regression for the observation period indicates that the rainfall declined by 254.39 mm over the past 32 years (79.50 mm per decade). The rainfall data clearly reveal the prevalence of rainfall variation across different seasons [refer to fig 4].This result is in line with several empirical research findings. For example, the ACCRA (2011) assessment report indicates that the rainfall has shown a decreasing trend around Debark *woreda*. The study made in Tanzania by Mongi et al. (2010) also supported this finding, which declared decreasing trends of rainfall for the last 35 seasons from 1973/74 to 2007/08. Similarly, in other regions of Africa, Gbetibouo (2009) in South Africa and Mentez et al. (2008) in the Sahel Region of Africa also found decreasing rainfall trends over the past decades.

As it can be seen from Figure 4 the highest rainfall was recorded in summer (June, July and August ¬JJA) season, while the lowest was received in winter (December, January and February – DJF). Almost similar pattern and amount of rainfall was detected in autumn (September, October and November – SON) and spring (March, April and May – MAM) seasons.

Drought is a natural hazard, which can be marked, by precipitation deficiency that threats human health among other livelihood resources through exacerbating water shortage and food insecurity. Therefore, analysis of drought frequency, pattern, duration, magnitude and severity is highly demanded for designing appropriate mitigation measures. The standardized precipitation index (SPI) results illustrated in Figures 5 show the long-term drought patterns of the *woreda*.

The standardized precipitation index (inter-annual rainfall variability) for Dembia *woreda* is shown in figure 5. Rainfall is characterized by alteration of wet and dry years in a periodic pattern with adverse health effects. Out of 32 years, 14 (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

Figure 5: *Standardized precipitation index for the woreda*



Source: Computed from Global Weather Data [http:// globalweath er.tamu.edu/]

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, with varying severity. There were one extreme (2002), and four moderate (1990, 1991, 1992 and 2008) drought years, and one severe drought, 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). This wettest year may be associated with the probability of flood incidences with SPI values of 1.87 and 1.45 in the years 1998 and 1996 respectively.

5.3. Human Health Exposure and Vulnerability to Climate Change

5.3.1. Households' health exposure to climate change

Table 3: *Human health exposure, sensitivity and vulnerability indicators*

Exposure/Sensitivity/Vulnerability indicators	Unit	observed	Maximum value	Minimum value	HVI
Standard deviation of mean maximum temperature by year	0C	3.86	4.86	3.07	0.44
Standard deviation of mean maximum temperature by month	0C	1.48	1.91	0.95	0.55
Standard deviation of mean minimum temperature by year	0C	1.88	2.36	1.39	0.51
Standard deviation mean of minimum temperature by month	0C	0.71	1.01	0.42	0.49
Temperature change					**0.50**
Average Standard deviation of rainfall (1979-2010) by month	Mm	45.69	100.44	2.99	0.44
Average Standard deviation of rainfall (1979-2010) by year	Mm	550.37	569.98	535.26	0.44
Rainfall variability					**0.44**
Drought	Frequency	3.00	6	0	**0.50**
Flooding	Frequency	5.00	10	0	**0.50**
Hailstorm	Frequency	4.00	10	0	**0.40**
crop pests	Frequency	6	10	0	**0.60**
crop diseases	Frequency	6	10	0	**0.60**
Human diseases	Frequency	4	10	0	**0.40**
animal diseases	Frequency	4	7	0	**0.57**
Frequency of climate-induced hazards in the past 10 years	Freq.	4.57	9	0	**0.51**
HHs reported family member faced injury/death by climate hazards	Percent	45.1	100	0	0.45
Hazard frequency					**0.48**

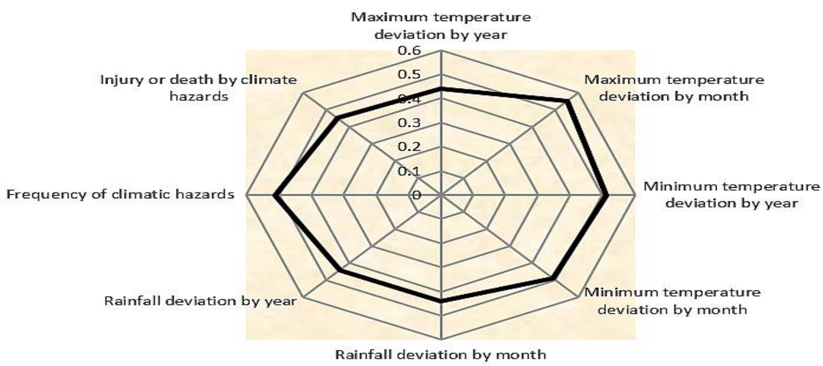
Table 3: (Continued)

Distance to the nearest health post or center	Minute	100.9	550	2.00	0.18
Average distance to the nearest hospital	KM.	51.57	250	8	0.18
HHs reported at least one chronically ill member due to climate hazards	Percent	20.3	100	0	0.20
Households whose member missed work/school due to climatic illness	Percent	31.6	100	0	0.32
Households who reported malaria incidence in their locality	Percent	91	100	0	0.91
Households who are not health package beneficiaries	Percent	36.1	100	0	0.36
Proportion of households who do not use toilet facility	Percent	91.7	100	0	0.92
Health care infrastructure					**0.44**

Source: Household survey, March to April 2014

Exposure of climate change needs to be analyzed first from the natural science perspective where models provide insights in the potential exposure of a system and resulting adverse effects. From this perspective, IPCC defines vulnerability as a function of the character, probability of occurrence, magnitude and rate of climate variation to which a system is

Figure 6: *Human health exposure radar diagram for climatic indicators*



Source: Author's computation from meteorology and household survey data

exposed, its sensitivity and its adaptive capacity (IPCC, 2001). In addition, this perspective looks at the magnitude of impacts determined by weather and other climate related events (Brooks, 2003).

The exposure of a system is determined by the amount of stress that impacts the unit of analysis. Exposure can be represented by a change in magnitude, frequency and duration of an extreme climatic event (such as droughts, floods, storms, etc), climate variability or long-term climate patterns such as increasing temperature and decreasing precipitation to which farmers' livelihood assets like water are exposed (IPCC, 2007). Accordingly, exposure indices were constructed using changes in temperature, rainfall, and frequency of climate change-induced hazards for the study area.

Figure 6 demonstrates the households' health exposure levels to climate variability and other related extreme weather events in the study area. It is clear from the spider diagram that there are three main indicators: temperature, rainfall and hazard frequency (weather related extreme events). In terms of aggregate climate exposure indices, the *woreda* is found to be more exposed to climate change at 0.48 score. This means that the surveyed households will have a 48% probability of getting into climate change-induced health risks. According to Christiansen and Subbarao, (2004) vulnerability is considered as the prospect of a person to become at risk in the future if now not at risk, or the prospect of a person continuing at risk if now in risk situations.

5.3.2. Health sensitivity to climate change

According to United Nations Environment Program/UNEP (1998), access to basic health care service, in terms of geographical proximity/isolation and economic capacity, is often important to human health vulnerability to climate-sensitive diseases. With some effort, this can be derived from scenarios on per capita incomes. Thus, this study examined relative human health vulnerability to climate change as part of sensitivity analysis from human health-care services perspectives. The important indicators for this analysis are: distance households travel to reach the nearest health facilities, reported chronic illness, injury and death in the family caused by climate change, and missing work or school by a family member because of climate-change-induced illness, malaria incidence in the respondents' locality, health package services, and toilet facilities regarding their functional relationships with health vulnerability.

The results are comparable with vulnerability indicators (refer to table 3). The average health-care vulnerability scores indicate that households in Tana Basin of Dembia *woreda* were highly sensitive to climate change impacts with a score of 0.44. Absence of toilet facilities took the lion's share for health sensitivity (0.92 score) where households were found to be more sensitive to malaria incidence (0.91 score). These findings suggest that diseases like malaria may have a negative impact on household income by limiting the number of healthy work days. This result is consistent with the report regarding incidences of different tropical diseases in tropical lowlands while no or less diseases prevalence in the highlands. It is also supported by the IPCC (2007, 2013) report, which states that human diseases are prevalent in the hot-moist regions against the cold highland environments.

Several empirical findings and literatures assert that better access to different services reduces sensitivity of human health to climate change through increasing adaptive capacities of a household (World Bank, 1997;

UNEP, 1998; Hahn et al., 2009). In the light of this, the surveyed households in Dembia *woreda* were found to be less accessed to quality government initiated health package services (0.36 index score). Although the households in Dembia are found to be less vulnerable to climate change -induced health risks (at 0.18 score) by the distance to health facilities, they were found to be more sensitive to its risks by the remaining health sensitivity indicators. For example, over 92% of the households indicated that their primary sources of health care are public health institutions,

Figure 7: *Human health sensitivity radar diagram for health service indicators*

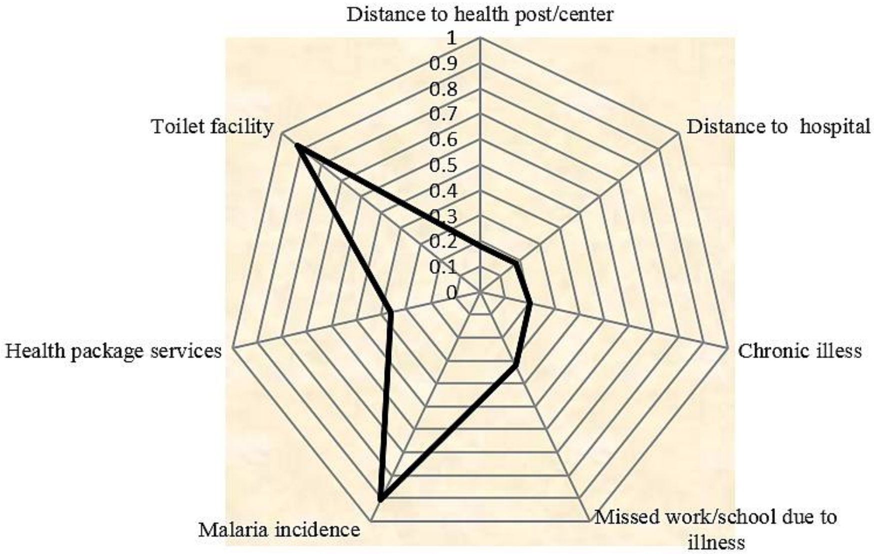
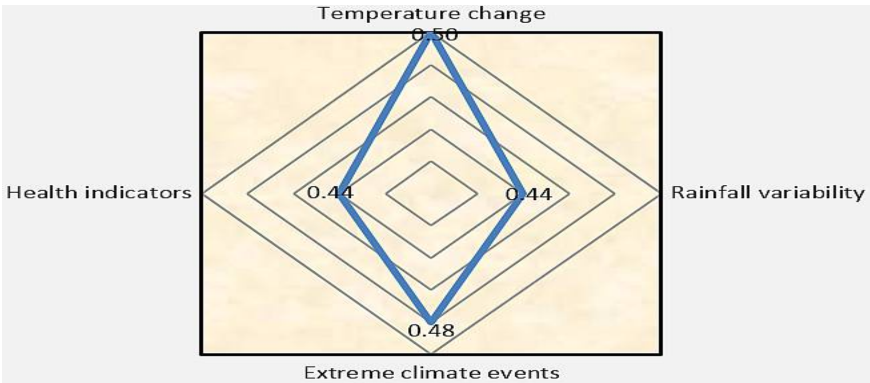


Figure 8*: Human health vulnerability radar diagram summarizing major components*



Source: Author's Computation from meteorology data and household survey such as health posts, health centers and hospitals. A very small percentage (3.8%) of households visits the traditional health healers. Only 3.8% of the households claimed they never sought out health care (refer to Figure 7).

The majority of the surveyed households (63.6 %) who did not get any treatment from health institutions reported high treatment cost requested by health institutions as the first reason. This capacity issue for accessing services is associated with poverty for most of the households. Eighteen percent of the households reported longer distance to health facilities and a higher prevalence of chronic illness. Further analysis of location and quality of health facilities might help uncover reasons why households reported long traveling times to seek health care. The rest 9.1% in the households mentioned lack of money and lack of awareness about modern medical services. Luk (2011) acknowledge awareness to be one of the important instruments to reduce vulnerability of people through providing knowledge and skill and relevant information to the public thereby enhance adaptive capacity of vulnerable households against climate change-induced health risks. Compared with other remote areas of the country, there were no households that claimed lack of skilled medical staff in the health institutions as the major reason for not visiting public health institutions for medical purposes.

When the exposure indices are compared indicator-wise, temperature variability is higher in the *woreda* with the index score of 0.50 (Refer to Table 3 and Figure 8). This finding is supported by many other empirical works. For example, increases in the frequency and severity of regional heat -waves-likely outcomes of climate change—have the potential to harm a lot of people (Interagency Working Group on Climate Change and Human Health (IWGCCH), 2009). The exposure index which shows the extent of rainfall variability is 0.44 indicating high level of exposure. Again, extreme weather events are found to be more frequent with an exposure index score of 0.48. The higher the index score, the greater the health vulnerability to climate change risks.

The different health indicators have contributed to lower human capital in Dembia *woreda*. The reason would be explained to the fact that the area has limited access to toilet facilities, health package services and prevailing of different diseases like maralia and other waterborne diseases. These in turn affect productive labor force and divert productive resources to family health treatments. In line with this, Barungi and Maonga (2011) argue that households with health problems have lower human capital as they may allocate their scarce resources to treating illnesses and household daily consumptions, thereby reducing their capacity to withstand the adverse impact of climate change.

Luk (2011) asserted that information available from different sources helps households to be aware of their own health vulnerability to climate variability and change. For instance, access to weather information is crucial for the day-to-day healthcare activities. However, the mere availability of information is not enough to measure the vulnerability levels of households to the impact of climate variability and change. Interview results indicate that some people have not changed their attitudes positively towards toilet facility, vaccination and family planning. Reports from interviews indicate that failure to construct toilet rooms brings punishment. Some people also prefer more free health treatment from the government health facilities than using their own capacities, particularly in areas where they experienced food aid for the past couple of decades in times of flood episodes. Eleven *kebele* administrations (e.g. Achera, Tanawoyna, Serabadablo, Jarjar Abanor, Adisgie Dingie, Aberjah, Mangie …) located around the shores of Lake Tana have been displaced almost every year in July and August leading their lives with support of governmental and non-governmental organizations like World Vision Ethiopia and others. Such extreme weather conditions as flooding on the unprecedented scale witnessed in recent months creates displacement which is another amplifying factor for the spread of AWD. The author has images taken from displaced people settled in temporary shelter, tents in the summers of 2012, 2013, 2014.

In the light of this finding, the UN Office for Coordination of Humanitarian Affairs/ OCHA(2006) reported that the worst flood affected population remains in Amhara Region where the disease has migrated from Metema *woreda* on the periphery with Sudan to the resettlement sites hosting the flood-induced displaced on the shores of Lake Tana. The report added that heavy rains and floods enhance diarrheal diseases outbreaks with usual occurrence of outbreaks during rainy seasons. Historically, excessive rain and flooding has created conditions conducive to the spread of diseases such as Acute Watery Diarrhea (AWD) and cholera, as flood waters flush pathogens and pollutants into water supplies leading to contamination. The OCHA (2006) report shows that the most worrying thing is the speed at which AWD can spread in temporary resettlement camps hosting displaced populations.

The OCHA report further added that the devastating nationwide flood crisis which includes property damage and displacement and the outbreak of Acute Watery Diarrhea (AWD) has severely affected the Amhara Regional State. More than 97,000 people are affected by the floods including 37, 000 displaced and approximately 68,000 people in need of immediate food assistance. Dembia *woreda* in North Gondar Zone was among the areas that have suffered from severe flooding. The displaced people in Dembia were being hosted in six temporary shelter sites accessible only by boat (OCHA, 2006).

Attitudinal problems resulting from limited awareness on the advantages of adaptation strategies obviously deter the efforts to reduce health vulnerability to climate change impacts. On the contrary, some farmers who have brought attitudinal change have increased their adaptive capacity against climate change-induced extreme events using family planning, toilets facilities, using mosquito tent, diversifying food varieties and doing income-generating activities to improve their food security status.

6. Conclusions

Climate change has become one of the most challenging environmental concerns of the 21st century. Although climate change endangers human health, most climate change research has focused on environmental effects, not on health effects. The aim of this study is to assess rural households' relative health vulnerability to climate change risks in Dembia *woreda* of Northwest Ethiopia by creating empirical indices based on the household survey and the meteorology data. Theory-driven aggregate indices of health vulnerability were formed through the equal weighting approach of four sub -indices: temperature, rainfall variability, frequency of extreme weather events, and health-care service facilities (refer Table 3 and Figure 5). Vulnerability assessment provides a framework for identifying and measuring these very important components of human capital, which may create differential vulnerability situations of the studied community (World Bank, 1997; UNEP, 1998; Hahn et al.; 2009).

The outcome of this relative health vulnerability study categorizes the rural households of Dembia *woreda* to the most vulnerable position to climate change impact. The vulnerability components provide information on indicators contribute most households' vulnerability to climate change-induced health-risks in the woreda. The studied households were found to be the most exposed social groups to climate change by temperature change(0.50), rainfall variability (0.44), frequency of extreme weather-related hazards (0.51) and health-care infrastructure (0.44) measured in terms of access to health services and other indicators (Refer to Table 3). Although it is important to remember that this is a relative scale and should not imply that the other proportion of the households are entirely resilient to climate change impact.

The result indicates that the the majority of the surveyed households have access to health institutions. Field observation noted limited functional health institutions and lack of necessary facilites and human resources throughout the communities visited. This might help explain the longer time that the households reported traveling to a health institutionfor getting better treatment. These poor health facilities have likely increased the vulnerability of the the peoples health in the *woreda* and are reflected in its high health vulnerability scores in most indicators. This suggests that resources need to be spent and reallocated on healthsector development in those more vulnerable areas.

The health vulnerability indices are grounded in existing literature on vulnerability and used the most important local level data sets. Thus, this study marks the first robust assessment of relative households' levels of health vulnerability to climate change in the Tana Basin of Dembia *woreda*, Northwest Ethiopia. Since human capital is so imperative in reducing climate change-induced health risks during and after human health disaster [(illness such as acute watery diarrhea, cholera and malaria) injury, death, displacement and safety disruption)] it is required to consider it when designing adaptation and mitigation policy measures. The government should try to maintain intact of human capital and try to make best use of existing health infrastructure. Moreover, interventions should be taken to bring behavioral changes on rural households to cope with a different climate change-induced health risks by encouraging and teaching them to construct and use toilet facilities.

Acknowledgements
The author thanks the farmers for their cooperation, the enumerators who patiently carried out the household surveys, the experts at Dembia *woreda* district Health Office, and Health Extension Workers (HEWs) at the specific study sites. The author also thanks University of Gondar for supporting this study financially.

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