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Impact of climate variability on household food availability in Tigray, Ethiopia

Shishay Kahsay Weldearegay* and Dawit Gebremichael Tedla

Abstract

Background: Currently, climate variability is a hot issue across the globe, especially in countries where rain-fed agriculture is a means of livelihood. Climate variability increases the risks of hunger in the region as it affects all four components of food security: *food availability*, *food accessibility*, *food utilization and food stability*. Rainfall shortage or excess hampers food production in the region, causing food insecurity and escalating famine. Extreme weather is affecting people indirectly through the sequential rather direct depletion of their assets. Therefore, looking on the impact of climate on food security is crucial to build a sustainable production system.

Results: Randomized data from 150 households were collected and analyzed using SPSS software. Household Food Balance Model analysis indicates that 15.7% of the households met the recommended daily calorie intake of 2100 kcal per adult equivalent/day, while 84.3% of the households fell below the daily recommended calorie intake. The average calorie intake of the households covers only 56.2%. Female-headed households are found to be more food insecure than their male counterpart. Those food insecure households use different coping mechanism to avert the shortage like daily laborer, reducing meal, borrowing, selling productive asset and switching meals. Moreover, the annual rainfall of a 20-year record averaged 725 ml (with a standard deviation of 6.7), with the minimum and maximum records at 354.5 and 1037 ml, respectively. Similarly, the average precipitation concentration index (PCI) stood at about 24.4 ml, recording a minimum and maximum PCI of 15.6 ml and 41.7, respectively. Finally, the coefficient of variability of rainfall variability is 0.16, which indicates the variation in inter-annual rainfall distribution is medium.

Conclusions: The result shows a high prevalence of food insecurity in the rural community with high prevalence in female-headed household. Therefore, strong intervention is required by the government and should exhaustively work on promoting irrigation, providing credit to farmers and subsidizing farm inputs to improve food security in rural Tigray.

Keywords: Food security, Climate variability, Coping strategies, Rural Tigray

Background

Climate-induced extremities like drought, intermittent rainfall and flood compromise the ability of households to meet their food requirements [1]. Food availability is diminished by change in agricultural productivity, and the land devoted for crop production, however, decreasing in rainfall quantity leads also to deterioration of food availability and health [2]. According to the Food Available Decline (FAD) Theory/Approach, failure in physical availability of food causes food insecurity, which is emanated mainly from the impact of natural hazards through increasing burden on the available natural resources [3]. Besides, [4] as cited in [3].

> *In case of the bad weather people are not directly victim of famine but their assets depletes sequentially. If drought occurred they cannot produce enough food then producer becomes net buyers by selling their assets especially livestock at distress value as livestock are thin and they become die due*

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to shortage of feed. At last, victim people are fleeing to market due to failure of self sufficiency, break of formal system support, no employment opportunities then famine will happen.

Food availability decline is an attribute of environmental tribulations, population growth, political instabilities, poorly conceived developmental policies and fluctuation in food prices. It is also caused by natural disasters, and other socioeconomic factors, which emaciate household food security situation coupled with weak household asset accumulation [5–7]. However, a community where their livelihood is subsistence farming, rainfall is the dominant determinant of food production. This is due to Wetter years are generally associated with higher food production; conversely, dry years are linked to lower production [8–11]. Basically, in mid-latitude, high-latitude and higher-income countries climate change has positive impact on agricultural production or crop yield, and on the other hand, lower-latitude and lower-income countries experience a negative effect on agricultural production [12]. Developing countries are, however, most vulnerable compared to developed countries. There are many conditions, which enhance the vulnerabilities for developing countries, such as low level of technological progress, lack of resources to mitigate the adverse effect of climate change on agriculture. Additional conditions include a greater dependence of their large population on agriculture for their livelihood [13]. This would increase the severity of disparities in cereal yields between developed and developing countries [14].

Generally, climate variability is not a recent situation to Ethiopia because of the numerous and frequent droughts occurrences over the years: 1889–1892, 1972–1974, 1984–1985, 2002–2003 and 2015–16, which are due to the climate variability. Climate variability increases the risks of hunger in the region as it affects all four components of food security: *food availability*, *food accessibility*, *food utilization and food stability.* Rainfall shortage or excess hampers food production, causing food insecurity and escalation of famine in the region. Bad weather also affects people indirectly through the sequential rather than direct depletion of their assets. When drought occurs, the people cannot produce enough food to meet their needs, whereas livestock suffer from the shortage of pasture. Rural farmers, therefore, revert to coping strategies, such as livestock sale to generate income and purchase food. Livestock serves as a buffer in times of hardship, with farmers disinvesting in them to buy food [15]. Therefore, governmental and non-governmental organizations should device policies in favor of improving climate risk management, strengthening resilience community-based development, building advanced weather forecasting, strong risk reduction structure and enhancing social protection to hamper the prevalence of food insecurity, particularly in vulnerable segment of the community [16].

In Ethiopia, several empirical studies have been conducted to identify the impact of social and economic factors on household food security. For example, studies [17–20], conducted in Oromia, Amhara, Tigray and South Nation Nationalities and Peoples, are few among the studies.

The Tigray region, where the study area is located, is a drought- and famine-prone area. The people mainly derive their livelihood from subsistence agriculture, which is characterized by mixed farming system on fragmented land, over utilized land and affected by erratic rainfall [17]. Although the *woreda* is food insecure and persistently benefiting from safety net program [21], there is difference in the degree of food insecurity among households. So, considering this issue is also imperative as previous study conducted [20] in the area has a methodological gap where the researcher employed safety net graduation benchmark as food security/insecurity measurement. This method involves measuring of wealth in terms of money. Such methodology does not show clear picture of household food security. The extended civil war carried out in the study area during the socialist period and Ethio–Eritrea border conflict led many women to become heads of households. Given the reasons above, this study aims to measure household food security status and to see the disparity of food insecurity between female- and men-headed households. This study will further identify the coping strategies employed in the study area determine the temperature and rainfall trends and their implication to household food security.

Research

Study location/description of study site

The study was conducted in Aksum National Regional State of Tigray, located 1024 km north of Addis Ababa. It has both urban and rural *Woredas*. The study focuses in the rural *Woreda* of Laelay Maichew. It is one of the eleven *Woredas* of central zone. It is bounded by Merelbeke in the North, Adwa in the East, Werileke and Naeder Adiet in the South and Tahtay Maichew in the West. It is located at an elevation of 1200–2050 m above sea level with an average annual rainfall and temperature of between 650 mm and 23.5 °C, respectively [21]. According to the *Woreda* Plan and Finance [22] of the rural *Woreda*, has a total population of 84,682, of which 50.2% of female. The Woreda has a total household of 19,246 (27% are female-headed), with an average family size of five people. The total area of the *woreda* is about 5,383,300 hectares; of which 1,455,200 ha is arable land, the rest is covered with forest, grazing land and mountain. It is home to rugged and gentle slope arable lands. It has two climatic zones occupied by 15 peasant associations.

Like other parts of Ethiopia livelihood of the *woreda* is dominated by subsistence agriculture. In addition to the subsistence agriculture, they also generate some extra income from petty trading, working as daily laborer, mining and other sources of income. According to *Woreda* Bureau of Agriculture [21], average size of cultivated land owned by household with five family sizes is about 0.75 ha. Teff, barely, wheat, horse bean, sorghum, finger millet and chickpea are the major crops grown in the area. Due to the small land holding per household, lack of improved agricultural technologies and inadequate extension services, as well as recurrent drought, the area is exposed repeatedly to food shortage. A map indicating the study location is presented in Fig. 1.

Research techniques

A mixed of quantitative and qualitative method approach is used, because according to [23] the use of a combination of qualitative and quantitative research techniques is better than the use of one of them to address and assess impacts and food security status.

Sampling techniques

Both probability and non-probability sampling systems were used. Study area was purposively selected, because the *woreda* is either seasonally or chronically food insecure and rarity of studies conducted in food security. At last but not least, we grew up in the area and have valuable information about the life experience of the community, topography of the *woreda* and can entertain the regional language, which helps us to communicate easily. Rural households are the unit of analysis. The *woreda*

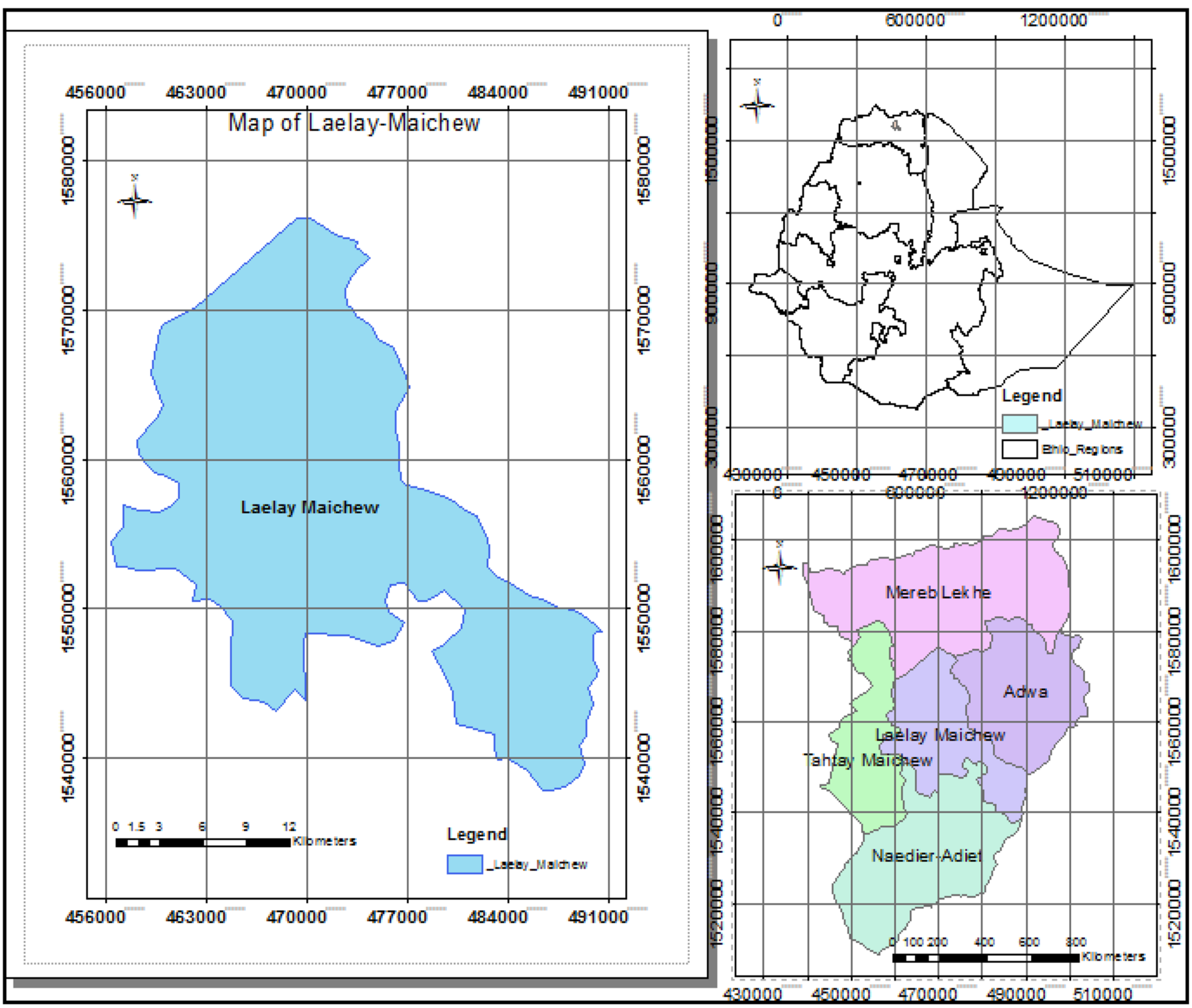

Fig. 1 Study area location. *Source*: Adapted from Kahsay and Mulugeta (2013)

has 15,785 households. A multistage random sampling method was employed to select respective agroecologies, kebeles and respondents. The *woreda* was clustered into two agroecological zone *kolla* and *woinadega*. One kebele from *kolla* and two kebeles from *woinadega* representative kebeles were selected. Accordingly, Miha, Lesalso and Dura were selected using simple random sampling. This sample is representative, because the households are living in similar agroecological setups, have similar livelihoods and are believed to be homogeneous. Since the study considered both female-headed and male-headed households. It is also stratified into female-headed and male-headed households to take representative samples from each household. Respondents were taken from a list of alphabetical order of latest tax registration document from each kebele. The first household was selected by simple random sampling; then, subsequent households were selected using systematic random sampling after n interval of the first selected household.

Sample size is determined by a formula developed by [24] for the determination of sample size.

$$n = 385/((1 + (385/N);$$

where $n =$ sample size and $N =$ population size. Accordingly, 150 respondents were selected (Table 1).

Data sources and collection procedures

Data were derived from primary and secondary sources. Primary data were collected by household survey questionnaires and interviews.

Household survey

One hundred and fifty questionnaires were distributed to collect data regarding the households.

Focus group discussion

Focus group discussants were selected purposively, and two focus group discussions were held in each kebele with ten to twelve participants in each focus group discussion, and a total of six focus group discussants from different economic status, different age groups, different religions, different educational levels, different sex and different positions were participated. To minimize dominance and biasness, equal chances were provided to each participant to express their feelings.

Observation

Observing the environment and life of the community.

Secondary data were collected from published books, journals, articles, maps and proceedings from various institutions, organizations and websites, *woreda* bureau of agriculture, *Woreda* plan and finance and Regional Meteorology Service Agency (RMSA).

Data analysis

Measuring food security

Food security has four basic dimensions, namely availability, access, utilization and stability. However, for this study food availability was measured using Household Food Balance Model (HFBM). Since the focus of the title is on food availability. Accordingly, total food production of each household was divided by the number of families' adult equivalent to get the per capita food availability of household in kg. This kg was converted into their respective kilo calorie using the FAO and EHNRI food composition tables (Additional file 1). Finally, it was calculated as daily calorie requirement/adult equivalent/day. According to the Ethiopian government, 2100 kcal/adult equivalent/day or 225 kg of cereals per person per annum set as minimum acceptable weighted average requirement [25, 26]. Based on this minimum daily calorie intake requirement, food secure and food insecure households were identified.

In Eq. (1), HFBM is calculated using the equation below adapted from [27, 28];

$$\begin{aligned} \mathrm{NGA} =& [\mathrm{GP} + \mathrm{GB} + \mathrm{FA} + \mathrm{GG} + \mathrm{FW} + \mathrm{MP} + \mathrm{DP}] \\ & - [\mathrm{HL} + \mathrm{GP} + \mathrm{GU} + \mathrm{GS} + \mathrm{GSE}] \end{aligned} \tag{1}$$

NGA: Net grain availability (quintal/household/year), GP: Total grain production (quintal/household/year), GB: Total grain bought (quintal/household/year), FA: Quantity of food aid obtained (quintal/household/year), GG: Total grain obtained (quintal/household/year), FW: Food for work (quintal/household/year), MP: Total meat products (kilogram/household/year), DP: Total dairy products

Table 1 Selected kebele and sampled households. *Source*: *Woreda* Plan and Finance Office (WPF 2012)

PA	Year of study	Total households of the PA			Sampled households from Each PA		
		M	F	Total	M	F	Total
Miha	2013	492	182	674	24	9	33
Lesalso	2013	997	369	1366	44	16	60
Dura	2013	899	333	1231	39	18	57
Total	–	2388	884	3272	107	43	150

Source: *Woreda* Plan and Finance Office (WPF 2012) (kilogram/household/year), HL: Postharvest losses (quintal/household/year), GU: Quantity of grain reserved for seed (quintal/household/year), GS: Amount of grain sold (quintal/household/year), GV: Grain given to others (quintal/household/year), GSE: Grain used for social events (quintal/household/year).

Analysis of climate variability

A two decade of meteorological data of rainfall and temperature was gathered from the RMSA. From these data, PCI, CV of the rainfall values at different timescales and annual temperature were calculated and presented in tables and graphs. According to [29], precipitation concentration index is calculated using formula (2).

$$\mathrm{PCI} = 100 \times \frac{\left(\sum \mathrm{pi}^2\right)}{\left(\sum \mathrm{pi}\right)^2} \tag{2}$$

where $p_i =$ is the rainfall amount of the ith month of a year and $\sum =$ summation over the 12 months. According to Oliver, PCI values of less than 10 indicate uniform monthly distribution of rainfall, values between 11 and 20 indicate high concentration and above 21 indicate very high temporal rainfall concentration as in indicated in Woldeamlak [29]. Rainfall variability over a period of time was also analyzed by calculating the CV of the rainfall values at different timescales using formula (3).

$$\mathrm{CV} = \frac{\sqrt{\sum f\,(xi - x)^2}}{n/x} \tag{3}$$

where $x =$ mean annual rainfall in mm, $n =$ number of years for which the rainfall data are available for a given station, $xi =$ annual rainfall (mm) of the year ith of a given station.

Result and discussion

Food security status of the households

Household Food Balance Model was used to measure food security though there are many approaches to measure food security. The result showed that 15.7% were food secure and the rest 84.3% were food insecure. This indicates that more than three-fourth of the households was exposed to critical shortage of food, which falls to meet the minimum calorie requirement. For the purpose of lucid understanding of food security and to have good picture of households' food gap, households were grouped into three categories based on their calorie availability/adult equivalent/day. Food secure ($\geq$ 2100 kcal/adult equivalent/day), moderately food insecure ($\geq$ 1050 to < 2100 kcal/adult equivalent/day) and severely food insecure (< 1050 kcal/adult equivalent/day). The mean daily calorie intake of the households was 1181.3 cal, which only meets 56.2% of the minimum daily requirement (2100 kcal). The minimum and maximum calorie intake was 103 and 3000 kcal, respectively, which shows a great variation in the availability of food across households. So, the mean value falls under the category of moderately food insecure with incredible minimum and maximum daily calorie intake value. Table 2 indicates female-headed households were heavenly exposed to food insecurity than their counterpart male ship. Studies conducted [30] in Zimbabwe, Malawi and Zambia founds that female-headed households were more vulnerable to food insecurity than male-headed households where their means of livelihood is casual agricultural labor which complements with this finding. Similarly, anthropometrics measurement also verified that children from female-headed households show more stunting (low height-for-age) as compared to those from male-headed households [31]. In addition, findings of [32–34] in Pakistan, South Africa and Ethiopia showed female-headed households are more food insecure than male-headed households. This is mainly related to lack of access to financial, social, human, natural and physical assets.

Honey was not included directly in computing total annual grain availability and was not converted into its respective calorie equivalent, because it was not incorporated in the food composition table and contributes insignificant amount in their daily consumption. Generally, all animal products were not included when calculating the total grain availability and not converted to their respective calories as they contribute insignificant in the daily household food consumption. Most of the time households sell life animals and buy grains to fill the gap in grain requirements of their families as the focus group discussants implied.

Moreover, postharvest losses were considered as negligible and are not included in calculating the total grain availability of households. This is due to the introduction of different types of pesticides, good awareness in postharvest losses prevention, control and traditional knowledge of the community; therefore, postharvest losses are considered as insignificant. Except the aforementioned

Table 2 Food availability in calorie

Calorie availability/adult equivalent/day	Household head			
	Male		Female	
	Number	%	Number	%
FS ($\geq$ 2100 kcal)	26	24.4	8	18.6
MFI (1050 to < 2100 kcal)	33	30.7	17	39.5
SFI (< 1050 kcal)	48	44.9	18	41.9
Total	107	100	43	100

variables which are not included in computing total grain availability, the rest of all variables are computed using the HFBM and converted into their respective calorie equivalent using the EHNRI and FAO food composition table.

Coping strategies of the households

Coping mechanisms used by different rural households are many depending on the availability of resources they have. Respondents replied. It is not uncommon to experience different coping strategies during food shortage to minimize or avert the prevalence of asset depletion and other catastrophic impact. Result of the analysis discloses (Table 2) that daily laborer is a dominant means of coping mechanism. The key informants and focus group discussants said, although there is job opportunity in their residential area, most of the capable bodies are fled to western Tigray during the weeding and harvesting season since daily wage is better. Following daily laborer, eating less preferred foods and a combination of one or two coping strategies (selling wood, work as daily laborer, selling alcoholic beverages in village towns, mining and guarding schools, clinics, etc.), with a percent of 22 and 14.7%, respectively. Likewise, 3.3% of the respondents said reducing quantity of meals they eat, 2.7% borrowing or purchasing on credit, 2% selling productive assets, 1.3% reducing number of meals and selling woods but consuming seed stocks and getting free aid (1%) are barely practiced as listed in Table 3.

Findings of [33, 35] in Ghana, Bangladesh, also showed that eating less preferred foods commonly practiced coping mechanism, which has quite close similarity. However, study conducted [36] in Malaysia indicated that selling valuable materials and borrowing money are the most practiced coping strategies, which is less practiced in the study area. In general a review [37] in Ethiopia, household employ seasonal labor migration, consume less preferred foods, borrow grain to be returned double at the next harvesting season, send their children to relatives, rent their economic assets like land, and children are forced to drop from their school.

Table 3 Coping strategies

Coping strategies	Frequency	%
Eating less preferred foods	33	22.0
Borrowing or purchasing on credit	4	2.7
Consuming stock seeds	1	0.7
Reducing number of meals	2	1.3
Reducing quantity of meals	5	3.3
Selling household assets	3	2.0
Selling woods and charcoal	2	1.3
Daily laborer	77	51.3
Aid	1	0.7
A combination of different coping strategies	22	14.7
Total	150	100.0

Analysis of climate variability

The objective of this analysis is not to show sophisticated model analysis and correlations using rigorous analytical model, rather to focus on general implication of temperature and rainfall, and their implication to food availability/production. If there is increasing/decreasing trend so what will be the fate of agricultural production or food availability. Food production in a given years is mostly related to optimum level of temperature, precipitation and radiation. Therefore, extreme events are a cause to failure of food availability as a result of inter-annual climate variability. Profound investigation of climate variability is crucial in Ethiopia, as large portion of the population means of living is rain-fed agriculture.

Temperature trend

Generally in tropical countries and subtropical countries, crop and crop productivity decrease as temperature increases from 2 to 3 °C and the forecast indicates that a significant reduction in crop productivity will be observed in 2020 [38]. Studies [29] implied differences in precipitation have a higher explanatory power than temperature in describing changes in crop yields: correlation between precipitation and yields is higher than temperature. This suggests that wetter years are associated with higher crop production. While higher temperature could be generally associated with lower yields.

The result showed that temperature is increasing from time to time; it increases from the year 1992–2003 and falls in the consecutive years after 2003. This fall in temperature might be due to some conservation practices. Basically, a little rise in temperature leads to the dwindling of plants and animals performance directly or indirectly. Figure 2 shows that there is fluctuation of temperature every year. This has impacts on their production according to the focus discussants. The variance analysis shows every year there is a variation of 0.65 °C. Even this variation is not undermined; its impact on the biological system is not overstated.

Rainfall trend

Report [39, 40] indicates that annual rainfall is significantly changed across Ethiopia and suggesting high inter-annual variability with a slight but statistically significant negative trend. This is in line with previous analyses, which highlight the importance of inter- and intra-seasonal rainfall variability over total annual rainfall in determining livelihood and food security

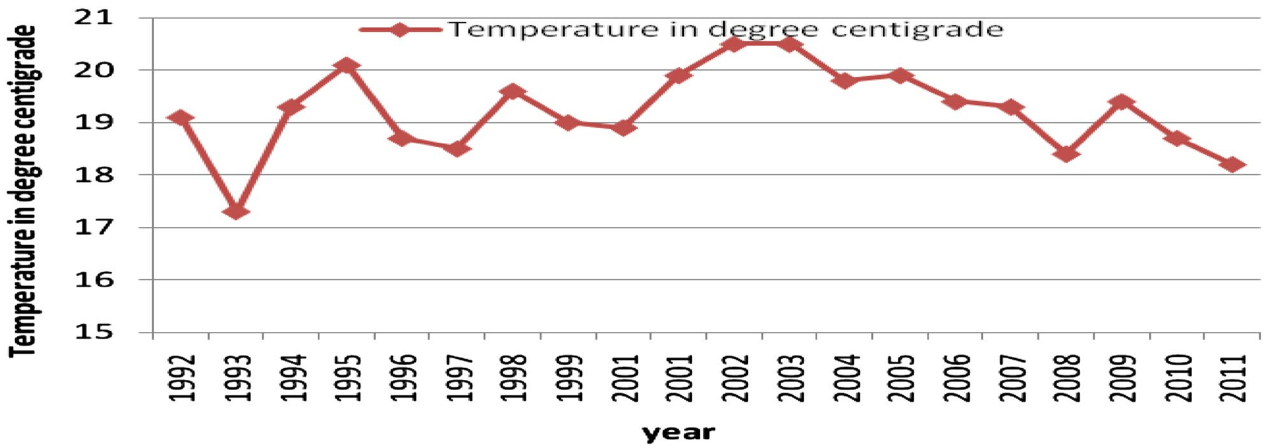

Fig. 2 Temperature trend. *Source*: Own compilation based on RMSA (2013)

outcomes [41]. The result indicates the minimum and maximum annual rainfall is 354.5 and 1037 ml, respectively, with mean annual rainfall of 725 ml. Besides, the minimum and maximum PCI is 15.6 and 41.7 ml, respectively, with average PCI of 24.4 ml (Table 4). It is clear that optimum rainfall is necessary for increased crop productivity and food security. However, high concentration of rainfall has a serious consequence on crop production and food security. According to [29], PCI is classified into three: < 10 uniform monthly distribution, 11–20 high concentration and > 21 very high concentration of rainfall. Therefore, the result showed high concentration rainfall variability, which is similar to the finding of [42]; this implies that food availability is in question, because high concentration of rainfall exposes arable and non-arable land to severe soil erosion and environmental degradation. According to [43] PCI greater than 21 ml is a challenge for water and soil conservation. So this implies that food availability of rural people who dominantly depend on rain-fed agriculture is extremely suffered by food shortage. Generally, the PCI indicates heavy rain mixed with hails every year in one or more than one of the kebeles will be happened. As a result crop, production or availability will be declined; then, this leads to mass poverty and food insecurity. However, the inter-annual rainfall variation is medium with rainfall variability of 0.16, which has not significant effect in crop production (Fig. 3).

Table 4 PCI and CV. *Source*: Own compilation based on RMSA (2013)

Station	PCI %	CV
Aksum	24.4	0.16

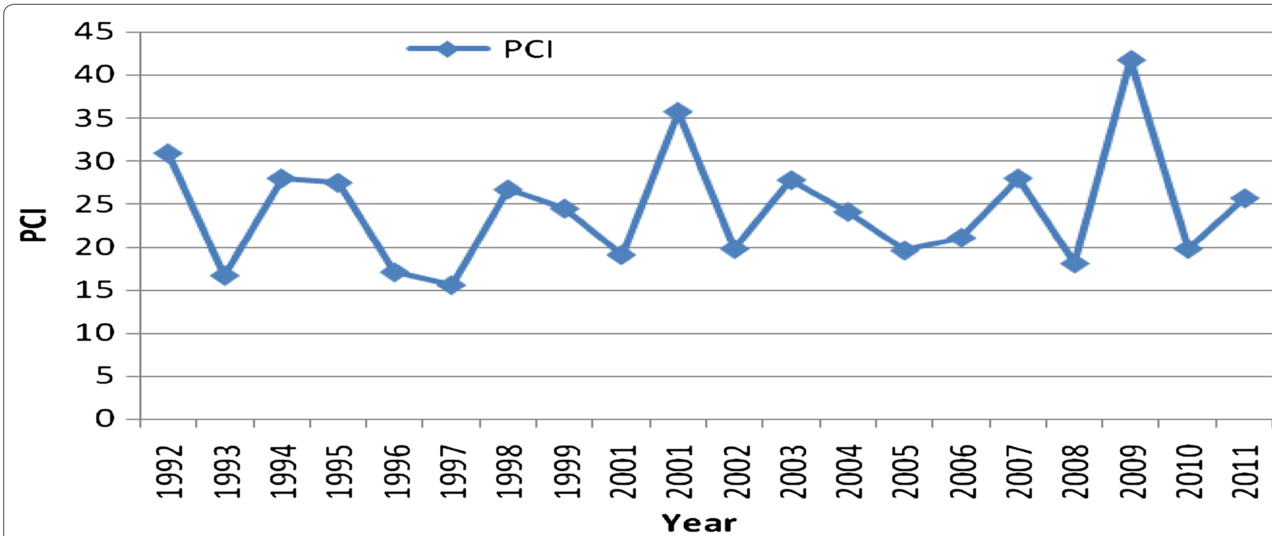

Fig. 3 Precipitation concentration index (PCI). *Source*: Own compilation based on RMSA (2013)

Conclusions

Different efforts are in place to minimize the prevalence of food insecurity and poverty. However, from the sampled households more than 75% are food insecure. Besides, the prevalence of food insecurity is higher in female-headed households. This report is a bell for the government to invest aggressively in modern agriculture. Since the population is getting higher and higher, the production is lower. Therefore, appropriate development strategies should be devised, and booming agricultural production and productivity using improved seeds, fertilizers and investing on irrigation rigorously will be paramount. In addition, the community should also engaged in honey bee production, poultry production and fattening to diversify their income and to solve the problem of food shortage.

The commonly practiced coping mechanism is working as daily laborer, eating less preferred foods and combination of different strategies while consuming stock seed and getting aid are rarely practiced. Therefore, heavy investment on industries is mandatory to increase the employment opportunity, since most of the rural households are flew more than 300 km from their residential to work. The annual rainfall concentration is very high; this implies that there is a great variation in rainfall between rainy months. It may be also followed by heavy hails which damages the crop production and productivity. Therefore, building strong early warning system and rehabilitation program is crucial.

In general, food insecurity is pervasive in female-headed households, daily laborer is the mostly practiced coping mechanism and intra-month rainfall concentration is very high. Therefore, devising packages that matches with the physical capacity of female-headed households to minimize the risk of food insecurity in particular and different adapting mechanism should also developed to halt the progressive impact of rainfall variability.

In conclusion, the government and the community should give due value to a forestation, reforestation and soil and water conservations. As these practices are very important, to minimize the risk of climate variability and to boost agricultural production and to generate extra income from the conserved ecosystem.

Additional file

Additional file 1. Calorie content of foods used in the study area.

Abbreviations

UN: United Nation; IFPRI: International Food Policy Research Institute; WBoA: Woreda Bureau of Agriculture; WPF: Woreda Plan and Finance; FAO: Food and Agriculture organization; PSNP: Productive Safety Net Program; FDRE: Federal Democratic Republic of Ethiopia; MoFED: Ministry of Finance and Economic Development; HFBM: Household Food Balance Model; RMSA: Regional Meteorological Service Agency; PCI: Precipitation Concentration Index; CV: coefficient of variability; ENHRI: Ethiopian Nutrition and Health Research Institute.

Authors' contributions

SK carried out reviewing relevant materials, data gathering, analyzes the data and preparing the tables and figures. DG carried out editing, formatting and organizing the references. Both authors read and approved the final manuscript.

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Competing interests

This is our original work; there is no any competing interests in regard to this paper.

Availability of supporting data

Yes there are supporting data calculated calorie for each cereal.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Study participants were first asked whether they accept to take part in the researcher survey. No approval by an ethics committee is necessary for the applied methodology, but consent was also sought from the participants before being involved.

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