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Assessment of Climate Change Effects on rain fed crop Productions: The case of Smallholder Farmers of West Shoa Zone, Oromia, Ethiopia.

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Abstract

Rain-fed crop production is inherently susceptible to climate variations, making it a vulnerable sector in all nations. However, the impact of climate change is disproportionately felt by the poorest nations and their citizens due to their limited coping mechanisms. Therefore, the objective of this research is to gain a comprehensive understanding of the local climate trends in the west shoa zone of the Oromia region. Specifically, the study aims to investigate how these trends affect rain-fed crop production in different agro-ecologies and how smallholder farmers are adapting their farming practices to cope with the current climate variability and change.

Additionally, the study examines the typical weather patterns in the area, the significance of indigenous knowledge, and the institutional coping strategies that are currently being employed. To achieve these objectives, two research techniques were employed. Firstly, monthly time series data on temperature and precipitation from three stations (Bako, Ambo, and Holeta) within the zone were analyzed using the Mann Kendall trend test at a 95% significance level to assess temporal monotonic trends. Secondly, semi-structured questionnaire-based interviews and group discussions were conducted.

The trend evaluation at the three stations revealed relatively stable precipitation trends, with sample Z-values of 0.29, -0.27, and -0.97 for Bako, Ambo, and Holeta, respectively. In contrast, the analysis showed a significant increase in temperature, with Z-values of 3.54, 1.84, and 2.78 for the respective stations. Furthermore, the socio-economic data analysis indicated that the occurrence and frequency of weather events varied across different locations within the research area. The most prevalent events were prolonged drought, including late onset or early offset (71.2%), flood or excessive moisture (53.8%), heavy rain (32.6%), frost (20.5%), and strong winds (4.5%). These events hinder agricultural operations and have diverse impacts on rain-fed crop production, which relies on normal distribution and the timely onset and offset of the rainy season. The issue becomes more severe in areas with mid-altitude and lowland terrain. According to the survey, the main consequences include complete crop loss, reduced yield, decreased seeding area, delayed seeding and maturity, as well as an increase in crop pests. In order to adapt, smallholder farmers employ various strategies such as accepting the loss, replacing crops, diversifying their crop selection, practicing late seeding, cultivating early maturing crops, implementing zero or minimum tillage techniques, and growing tolerant crops. Additionally, these farmers rely on local knowledge, such as traditional early warning systems and tillage practices, to cope with adverse weather events. Despite their efforts, smallholder farmers face challenges due to limited resources including efficient technologies, land, labor, savings, credits, and crop insurance. Although the long-term mean values of precipitation remain stable, there is significant seasonal and inter-annual variability. Moreover, the small fluctuations in precipitation and temperature have a substantial impact on rain-fed crop production, compounded by other biophysical and socio-economic factors. Therefore, this study highlights that even minor weather shocks can have significant consequences, emphasizing the need to enhance adaptation options, allocate resources appropriately, and provide timely information on future climate change to enable farmers to take necessary preventive actions.

Key words: Climate change, climate trend, adaptation, mitigation, rainfall, impact, coping mechanisms

Chapter 1 Introduction and Background

Climate change is currently a pressing issue that is being addressed at various levels, including local, national, regional, and global. Although there is ongoing discussion regarding the extent to which human activities have contributed to climate change, there is a general consensus that its impacts are evident through changes in weather patterns, an increase in extreme weather events, and a decrease in predictability [1-3];. This increased weather variability as a result of climate change results in potentially sudden and irreversible disruptions to life and livelihood-sustaining natural systems, and the resulting economic, social and environmental dislocations [4]. Evident patterns of continuous climate change and future forecasts suggest that most countries will face more severe adverse effects, particularly impacting the poorest populations who have limited resilience to climate challenges. Moreover, climate change is having a disproportionate impact on the impoverished and marginalized communities within nations. The anticipated consequences present a significant risk to the progress and durability of the Millennium Development Goals in developing nations, as well as the effective realization of human rights in both developed and developing countries [4]. Despite global coverage of climate change, there is global variation in climate change manifestations based on geographic location and environmental factors. For instance, in Europe retreating glaciers, flash floods, wild fires and rising sea levels are some of the manifestations whereas, in Africa, climate change is manifested as drought and floods [5]. Accordingly, the climate change impacts global variation based on adaptive capacity, socioeconomic, technological and environmental factors. In developing countries like Africa will face increasing water scarcity and stress with a subsequent potential increase of water conflicts as almost all of the 50 river basins in Africa are trans-boundary [6]. Agricultural production relies mainly on rainfall for irrigation and will be severely compromised in many African countries, particularly for subsistence farmers and in sub-Saharan Africa. On the other hand, in Europe agricultural sector is believed to benefit from gradual climate change due to the carbon effect and the warming climate [7, 8];

Numerous scholars have conducted research to ascertain the influence of climate on agriculture, proposing various adaptation measures. Despite the abundance of evidence regarding the impact of climate change, smallholder farmers have struggled to effectively address and cope with climate-related hazards. Top-down approaches, such as modeling and scenario analysis, have been employed to provide valuable insights for decision-making, particularly in terms of the biophysical aspects of impacts. However, these models have limitations in representing human interactions and local capacities for adaptation. Additionally, the resolution of models utilized to assess climate change in developing nations is often inadequate and relies heavily on data from external sources. Along with the disparity in outputs from different models, this makes the use of results as a basis for adaptation action very difficult [9]. Hence, as a complement to top-down approach, bottom up which recognizes and builds upon local coping strategies and indigenous knowledge and technologies, and the capacity and coping range of communities, and local institutions is useful in developing specific strategies.

In Ethiopia, more than 85% of the people depend mainly on agriculture for their livelihoods, rendering them very vulnerable to climate variability and change. Accordingly, in recent times, a significant number of people in Ethiopia are being affected chronically by drought and/or flooding, leading to deaths and loss of assets and to an appeal for international support [10]. The ability of small holder farmers is of paramount importance to deal with adverse effect of climate related shocks with successful adaptation strategies. According to [10], Ethiopia has been marked by fluctuations in climate conditions, leading the local population to devise various methods of adaptation. These encompass early warning systems, traditional approaches to soil and water conservation, the cultivation of diverse crops and livestock, mobility, reciprocity, customary conflict resolution, and more. Although not a novel idea, the potential of these strategies in addressing agricultural climate change remains unexplored.

Small-holder farmers in the western Shoa region have also been modifying their practices in response to changing climate patterns and advancements in technology. These adjustments serve as coping mechanisms to deal with the variability in weather conditions, even though the farmers themselves may not explicitly label their actions as resilience-building. Integrating resilience-building measures into existing agricultural operations could greatly enhance the farmers' capacity to adapt to the unpredictable weather patterns associated with climate change [11]. Hence, this research aims to know the climate trend and weather events, impacts on rain fed crop production, and coping mechanisms which can be used to upgrade the perception of farmers about climate change and improve rain fed crop productions in West shoa Zone.

Chapter 2 Methodology

2.1 Research area description

2.1.1 Location

West Shoa, situated in the Oromia regional state, is one of the 18 administrative zones with coordinates between 8o 17' and 9o 56' N and 37o17' and 38o 45'E. The zone spans 174 km in its North-South extension and 183 km in its East-West extension. It shares borders with Amhara Regional state and North Shewa to the north, Addis Ababa region to the east, East Wollega to the west, and south west Shoa and Jimma Zone to the southwest. Covering a total area of 15086.15 km2, West Shoa is divided into 18 woredas and two independent urban administrative zones, namely Ambo and Holeta. Ambo, the largest urban center in the zone, serves as the capital and is located 114 km west of Addis Ababa. The map of the research area is depicted in Figure-1 below.

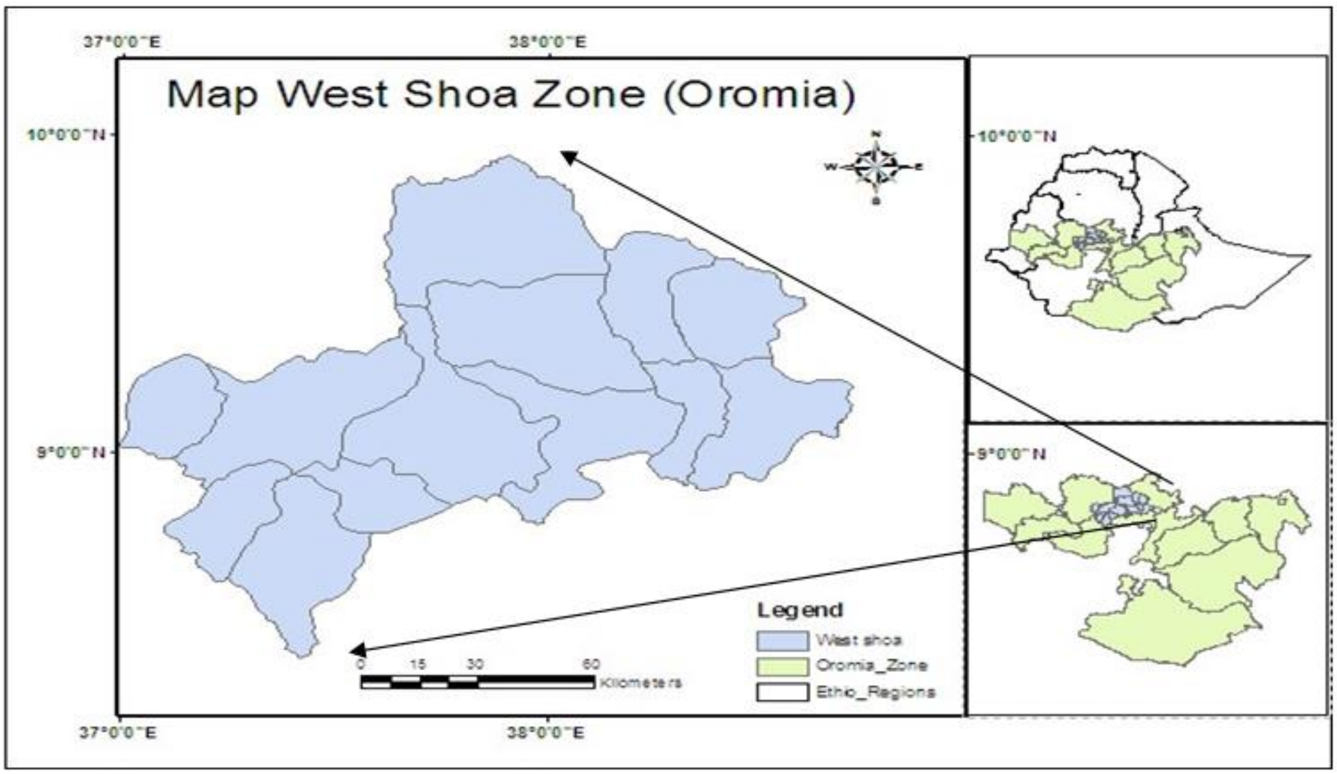

Figure 1 Study area map Source: Central statistical agency (CSA**)**

2.1.2 Population

According to [12] the total population estimated 2,080,698 out of which 1,021,484 (49.1%) are male and 1,059,214 (50.9%) are female. The zone is predominantly settled by Oromo ethnic groups, out of total population 1,845,162.9 (88.68%) are living in rural areas while the rest 235,535 (11.32%) are urban dwellers. Active and productive labor force is estimated to be at 52% while economically dependent population constitute about 48 % [12]. The population density varies from 84p/km2 to 218p/km2.

2.1.3 Topography

Topographically, West Shoa is characterized by diversified land forms consisting of mountain peaks, plateaus, plains, valleys, spurs and lowlands. Elevation varies from 900m to 3500 m asl

2.1.4 Climate

The climate in this region is predominantly influenced by altitude and latitude compared to other factors. According to the simplified agro-climatic classification of Ethiopia, it falls under three agro-climatic zones: Highland (27%), mid-altitude (56%), and lowlands (17%) (ZARDO). This zone experiences a bimodal rainfall pattern, with the main rainy season occurring in the summer months, peaking in July (from June to August), and a shorter rainy season from February to April. Rainfall levels range from 813.2 mm to 1669.1 mm. The maximum temperature in the area fluctuates between 24°C and 29°C, while the minimum temperature ranges from 11°C to 13°C.

2.1.5 Vegetation

Six percent of west shoa's area is covered with protected and dense natural forests. These include Menagesha suba forest, Jibat forest, Chilimo forest and Gura forest.

2.1.6 Land use and Agriculture

Mixed agriculture is the occupation of over 90 % of the population. The area is suitable for the production of major cereal crops such as Teff, Wheat, Barley, Maize, sorghum, and also oil seeds such as Noug, Flax and linseeds. The area is also rich in its livestock population and hence animal husbandry is practiced as supplementary to rain fed crop production. As to the land use, according to [12] out of total parcels estimated to 787,522 ha, 596325 ha (75%) covered by temporary crops (cereals, pulses, oil crops and others),16054 ha permanent crops (Such as Coffee and fruit trees), 104,863ha grazing land,46428ha fallow land,5687ha wood land and 18165 ha others such as swampy and rocky areas. The average land holding per household is estimated to1.51 ha [12].

As to the soil conditions the chromic and pellic vertisols, chromic and orthic Luvisols, Rendzinas, Halphic and luvic phaezems and distic Nitosols are the major soil types. There are three agricultural research institutions namely Ambo plant protection Research, Holeta agriculral Research center and Bako agricultural research centers, currently undertaking different agricultural research activities.

2.2 Research strategy and Site selection

The research was aimed to see the trend of major climatic variables in order to investigate the extent to which change in physical factors and socioeconomic impact faced agree with one another as a result of climate change and variability. As case study research, an exploratory question, ''what'' and ''how'' and also both qualitative and quantitative approach, is used to undertake this research. According to [13], methodological triangulation; obtaining data from different sources, such as observations, documentations and interviews, helps to harnesses diverse ideas about the same issue and assist in cross-checking the results, and consequently helps to increase the validity, reliability of the findings and eases data analysis. Impact assessment alone is subtle and may not be sufficient enough to show consequences of climate impact on different member of community [13]; hence vulnerable PAs selected from different Agro-ecologies based on past exposure to weather variability. Moreover, to assess vulnerability of rural livelihood strategy in context of shocks and other stressors used as indicators such as (Landholding, water availability, biological resources, social interconnectedness, labor availability, saving and credit availability) and asset access modifications by social relations, institutions and organizations [14]. This in turn also used to identify the resources required to cope up with the prevailing extreme weather events. The site selected based on past exposure to different climatic shocks and due to the increase in frequency unusual weather events in the area especially in mid altitude and lowland PA with Zonal Agriculture and Rural Development Office (ARDO) and Disaster Prevention and Preparedness Office (DPPO) experts. The occurrences of unusual weather events were common in mid altitude and lowland PAs of almost all Woredas with in the Zone. Beside this the number of people under food aid in the affected areas and those areas facing frequent weather events is also used as selection criteria.

2.3 Methods of Data Collection

Both primary and secondary data were used to undertake this research. The data were obtained from primary sources (field observation, household, government officials, Development agents) and secondary data (government documents, meteorological data, and crop production data).

2.3.1 Primary data

The study focused on the west Shoa zone, which consists of 18 woredas (Ambo, Bako, Toke-kutaye, Ejere, Ginchi, Holeta, Ada Berga, Meta Robi, Jeldu, Gindeberet, Ilfata, Cheliya, Mida-kegn, Ilu-Gelan, Tikur-inchini, Jibat, Nono, and Dano). These woredas were classified into different categories based on factors such as crop diversity, altitude, rainfall, and temperature, according to the traditional classification by the Zonal Agriculture and Rural Development Office (ZARDO). The highland category includes Holeta, Jeldu, Cheliya, Mida-kegn, and Tikur Inchini, while the mid-altitude category includes Ambo, Toke-kutaye, Ejere, Ginchi, Ada Berga, Meta Robi, Gindeberet, Ilfata, Jibat, and Nono. The remaining woredas, Ilu Gelan, Dano, and Bako, are classified as lowlands. Due to the vastness of the area and the need for a comprehensive study, representative sampling was employed for the research. Three representative woredas, namely Holeta, Ambo, and Bako, were selected based on the availability of meteorological stations, agro-ecology, and accessibility. This selection aimed to examine the differences and commonalities in terms of climate-related hazards and the coping mechanisms employed.

Two Farmers Associations were chosen from each woreda, specifically Talacho and Dufa from Holeta, Senkelle and Kisose from Ambo, and Amarti-Gibe and Dembi-Gobu from Bako. The selection was based on their previous exposure to precipitation variability, involvement in food aid programs, and weather-related hazards, as indicated by Agricultural Census data. The sample farmers were randomly selected from each village, with a requirement that they have lived in the area for more than ten years. The survey design is illustrated in Figure-3 below.

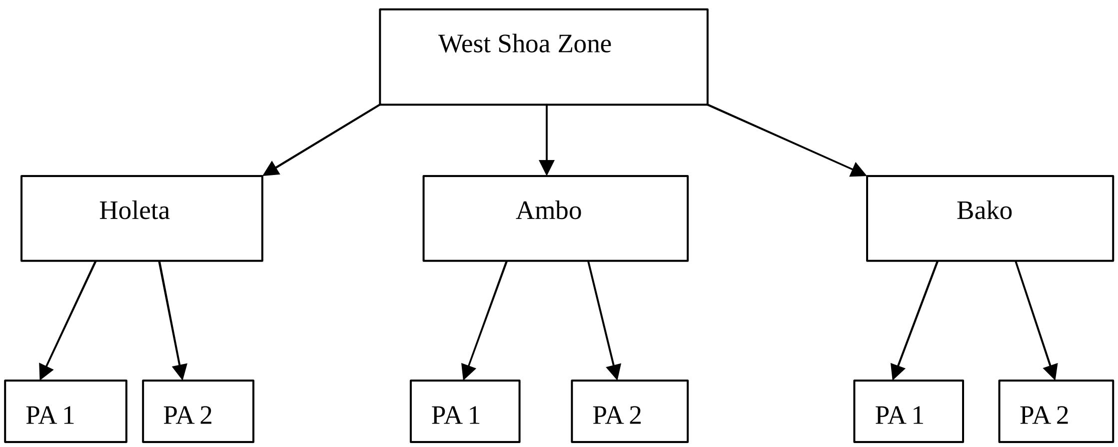

Figure-3 Survey Design

The first approach used was to conduct household interviews using *semi-structured questionnaire* in selected PAs and Primary data on impact, adaptation measures and coping mechanism employed were collected from April to May 2010. The interview was conducted on 60 lowlanders, 60 households from mid-altitude, and 32 from highlands based on proportion weather related incidents in the area; and a total of 152 key informants from three representative Woredas of the study Area. The summary of questionnaires on major findings was presented to the farmers *through focal group discussions* so that they can make comments, suggestions and approvals.

The second approach was *review of E-books, Journals and Published local researches* on response to extreme weather events and existing local innovation/ indigenous knowledge to adapt to weather shocks in study areas. Moreover, unpublished reports of some NGOs working at the grassroots level and respective government offices also reviewed to share their findings. In addition, a literature review was conducted on some global and regional issues related to climate change and local adaptation to relate and compare with the local context. Interviews and discussions also held with relevant government and NGO staff working at village, district, and zonal level (District and Zonal ARDO and DPPO). Field observation was conducted in the Bako, Ada Berga, Ambo, Tikur Inchini and Meta Robi, regarding the existing situations of the research area.

2.3.2 Secondary Data

Published and unpublished literatures were collected from different government offices. Data on crop production were collected from District and Zonal Agriculture and rural development office where as data on climate shocks and victim people were obtained from District and Zonal DPPO. Precipitation and temperature values were collected from NMSA (three sample meteorological stations namely, Holeta, Ambo, and Bako) which are found at different locations and altitudes with in the research area. Contemporary climate change was studied by records of values which have been obtained by standard equipment. Monthly total precipitation and Temperature values of 41 years, 41 years, and 15 years were used at Holeta, Bako, and Ambo respectively for the trend analysis. Only 15 years' values were used at Ambo due to the poor organization and quality of the data. Table-2 Geographical location of Meteorological Stations.

No.	Station Name	Location		Altitude(masl)
		Latitude	Longitude	
1	Holeta	09°00'N	38°30'E	2400
2	Ambo	08°58'N	37°51'E	1977
3	Bako	09°06'N	37°09' E	1650

Before the analysis, some pre-analysis activities such as filling of the missing years from Archives of the stations, adjustment of incomplete data and adjustment of outliers were employed for quality data.

3. RESULTS AND DISCUSSIONS

The result of the research in this paper presented by categorizing in to four parts based on the objectives set at the beginning. The first part includes the trend of climatic variables; rainfall and temperature. The second part comprises occurrence of usual weather events experienced by the area. The third part is about impact of weather events on rain fed crop production and the perception of farmers. The final part is the existing coping mechanisms, the resource required by small holder farmers and local indigenous technical knowledge of the farmers that contribute to cope with climate change.

3.1 Rainfall Variability and Trend

According to the Mann Kendall monotonic trend analysis the results indicate there is increasing trend at Bako whereas decreasing trend at Holeta and Ambo stations; however, the trend analysis indicates only weather the trend is increasing or decreasing over certain period of time. Hence significance test for the trend is of paramount importance in order to predict the occurrence of extreme weather events and their likely impacts. Accordingly, the trend significance tests show there is *no statistically significant trend.* Hence the trend evaluation indicates there is stable trend at the three sites (Table-3). According to Mankendall significance test at level of significance 0.05, the test hypothesis is

$H_0 = \mu = \mu_0$ (there is no significant trend/stable trend in the data

$H_A = \mu \neq \mu_0$ (there is significant trend/unstable trend in the data.

Hence $Z\ \alpha_{/2} = \pm 1.96$

If $-1.96 \leq Z \leq 1.96$ accept the hypothesis or else Reject H_0

Table-3 Values of Precipitation Trend analysis (Source: NMSA)

S.N	Sample Station	N	"S" Value	Sample Z-value	Trend Evaluation (α=0.05)
1	Bako	492	1077	0.29	*Stable*
2	Ambo	276	-423	-0.27	*Stable*
3	Holeta	492	-3553	-0.97	*Stable*

Even though there is no significant trend at the three stations the values show there is variability with in the research area. The result of Annual total rainfall and monthly rainfall analysis at the three selected stations namely Holeta, Ambo and Bako shows year to year variations. Rainfall data analyzed for Holeta and Bako is from the year 1979 to 2019 (41 years) while that of Ambo is from 1997 to 2019 (23 years). The average annual rainfall analysis in Table-4 below shows the total annual rainfall shows variability at the three sample meteorological sites and the variability is relatively high at Bako. As one goes from higher altitude to the mid altitude and low altitude areas the variability of the Rainfall also increases accordingly which also consistent with primary data obtained by survey.

Table- 4 Annual total Rainfall Variability (Source: NMSA)

Stations	N	Minimum	Maximum	Mean	Std.Deviation	Variance	CV
Bako	41	830.2	1658.8	1248.34	184.40	34005.63	0.148
Holeta	41	728.8	1261	1033.79	121.71	14814	0.118
Ambo	23	748.2	1230	995	151	22802.14	0.152

Accordingly, the results indicate that trends are not uniform with in the research area. The trend analysis of total annual rainfall shows that rainfall trend shows decreasing trend for Holeta and Ambo station while that of Bako shows increasing trend with variability (fluctuations from the base line values). The temporal variation of the total annual rainfall is displayed in the figures below.

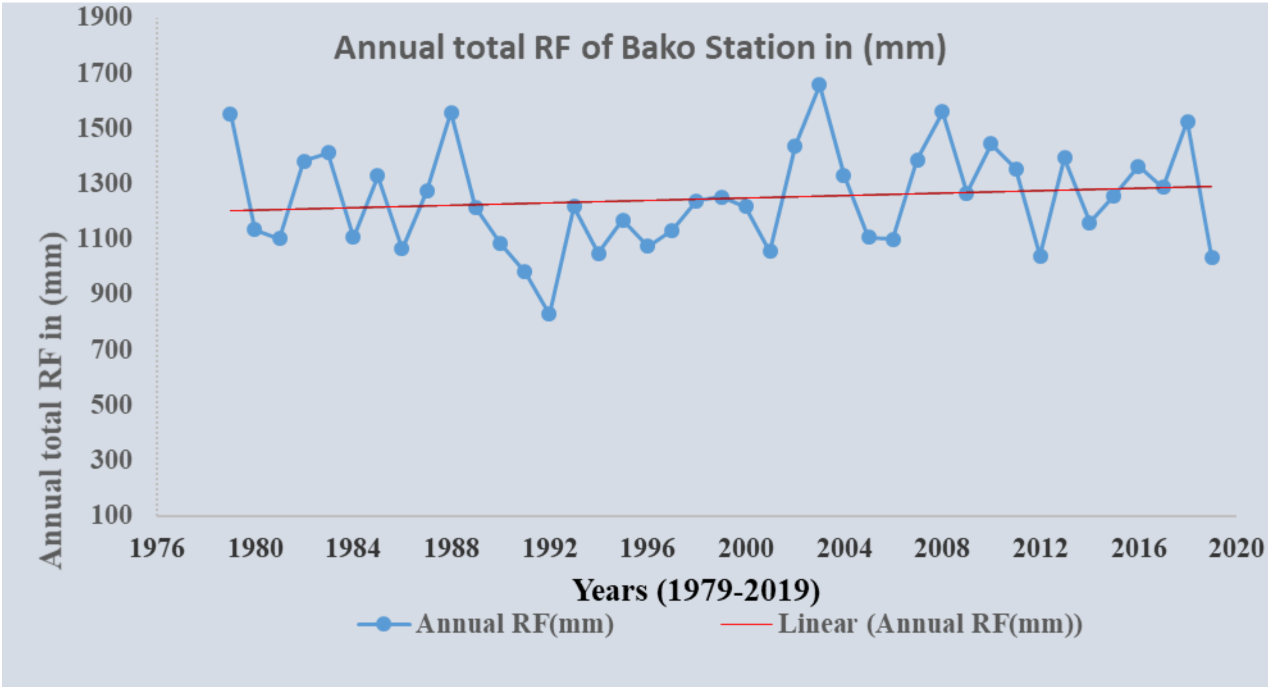

Figure-4 Trends and variability of annual total rainfall at Bako station (Source: NMSA)

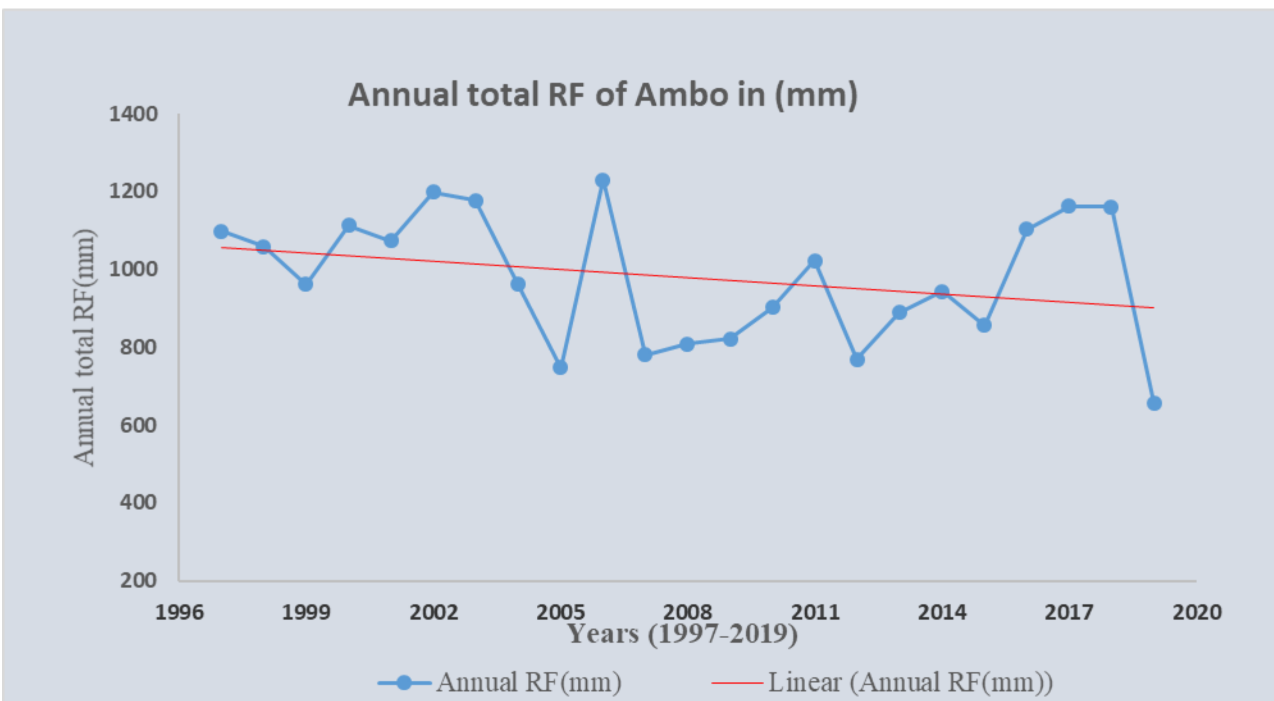

Figure-5 Trends and variability of annual total rainfall at Ambo Station (Source: NMSA)

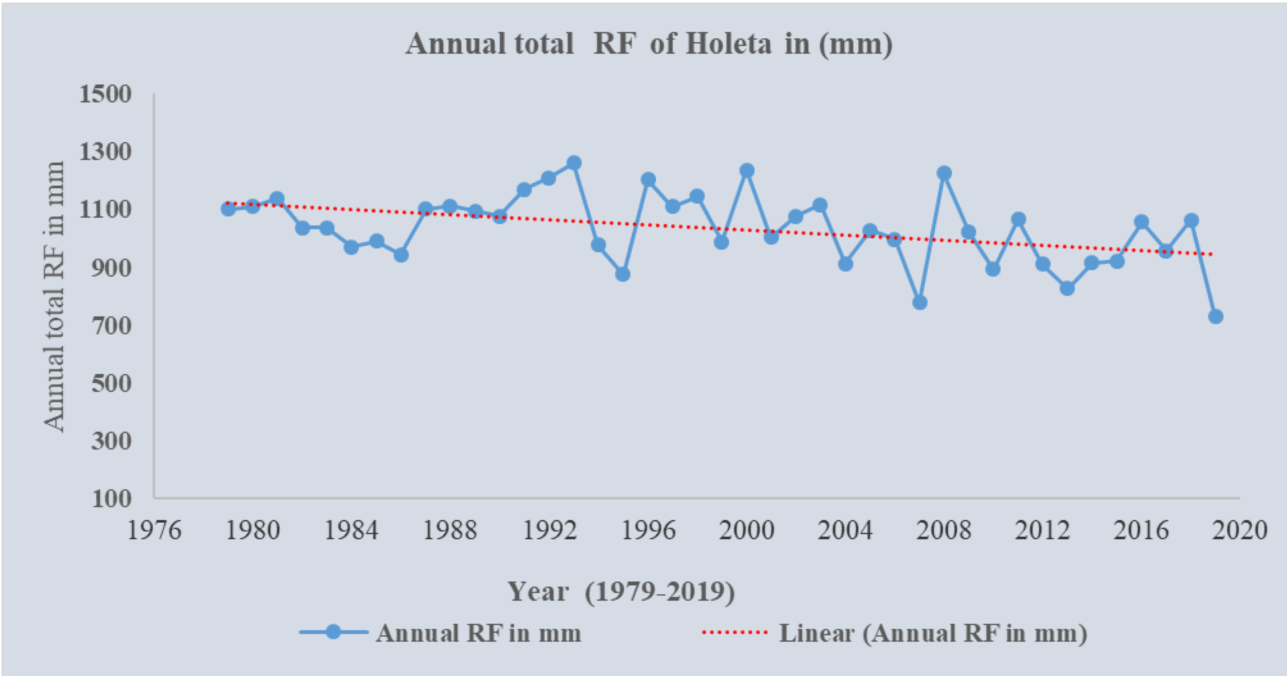

Figure-6 Trend and variability of average annual total Rainfall at Holeta Station (Source: NMSA)

There is also spatial variability in total annual amount with in the zone. Woredas found at the boundaries of south western part of the country have relatively high total annual rainfall. The altitude difference is 2400 masl at Holeta, 1977masl and 1650 masl for Ambo and Bako respectively. Figure- below shows spatial variability of rainfall within the research area.

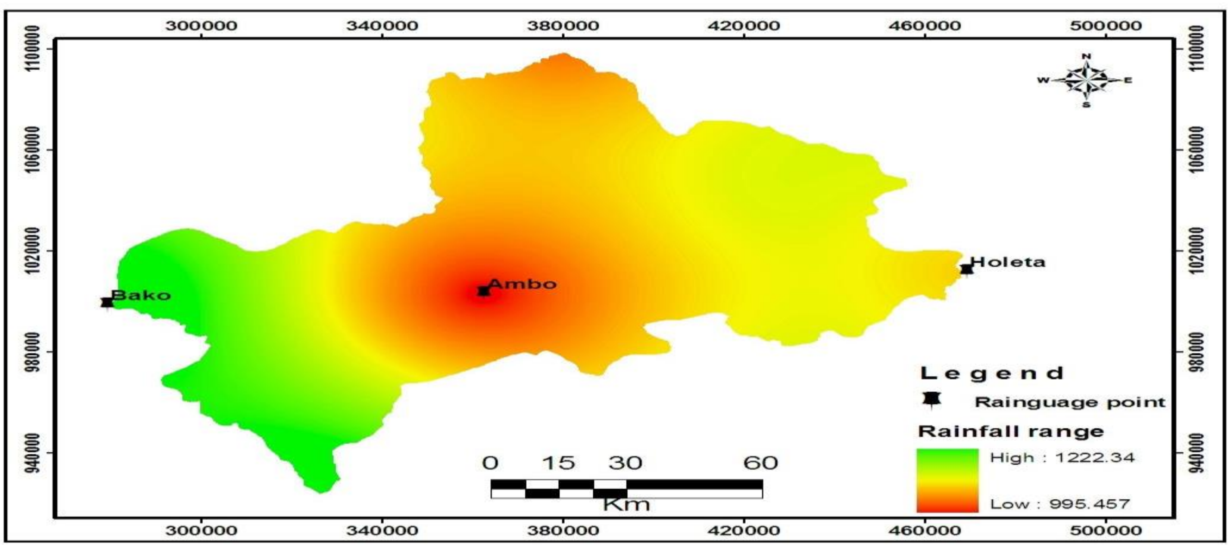

Figure-7 Spatial Variability of rainfall of west Shoa Zone (Source: NMSA)

Measurements taken from Ethiopian meteorological stations show that the annual volume of rainfall over the past fifty-five years has remained more or less constant when looking at the average for the whole country across the period 1961-2016 [15]. However, if one looks at how rainfall is distributed across the country, there is a marked difference: there is a tendency for less rain to fall in the northern part of the country where there is already massive environmental degradation. On the contrary the central highlands characterized by increasing trend; However, decreasing trend at Holeta and Ambo whereas increasing trend is observed at Bako. Hence, the frequent occurrence of flush flood, heavy rain, could be associated with its variability in distribution and the degradation of the land which lacks its capacity to store rain water as a result of excessive exploitation.

Seasonality effects also analyzed to know whether the seasonal component has a trend or not. Seasonality analysis indicates what has happened with in the year; like fluctuations in the peak rainfall time. The peak rainfall time does not occur at the same date each year the pattern of the variation is altering from year to year which also affect crop production. Accordingly, monthly values for 491 months at Holeta and Bako and 276 months at Ambo. Hence, monthly average rainfall values were used to analyze the seasonality of the rainfall and the result indicates that the pattern of the peak time shows variation where as the12 month seasonal component has no trend except for Holeta station.

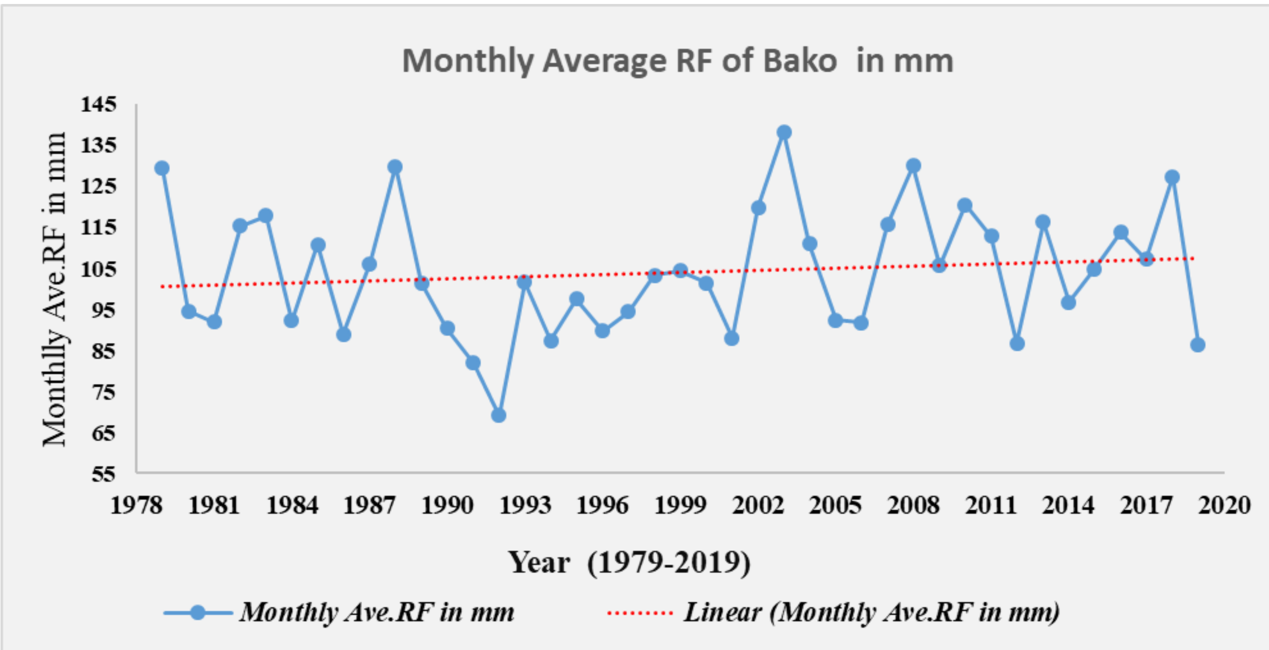

Figure 8. Trend and variability of Monthly Rainfall at Bako Station (Source: NMSA)

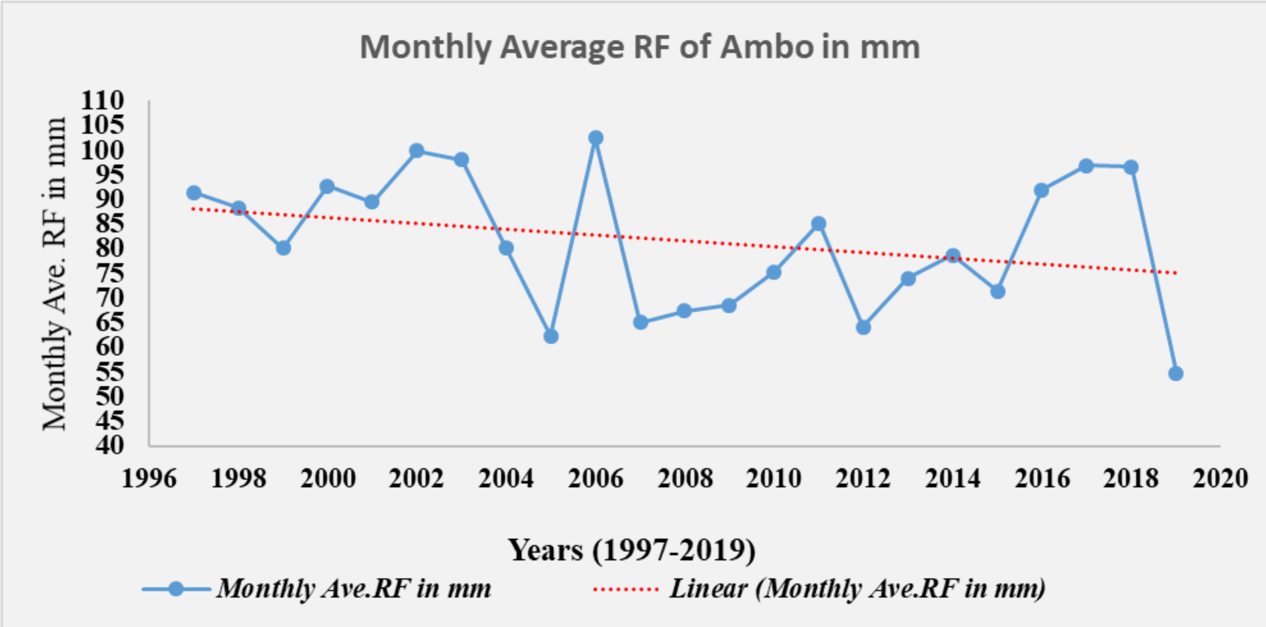

Figure 9. Trend and variability of Monthly Rainfall at Ambo Station (Source: NMSA)

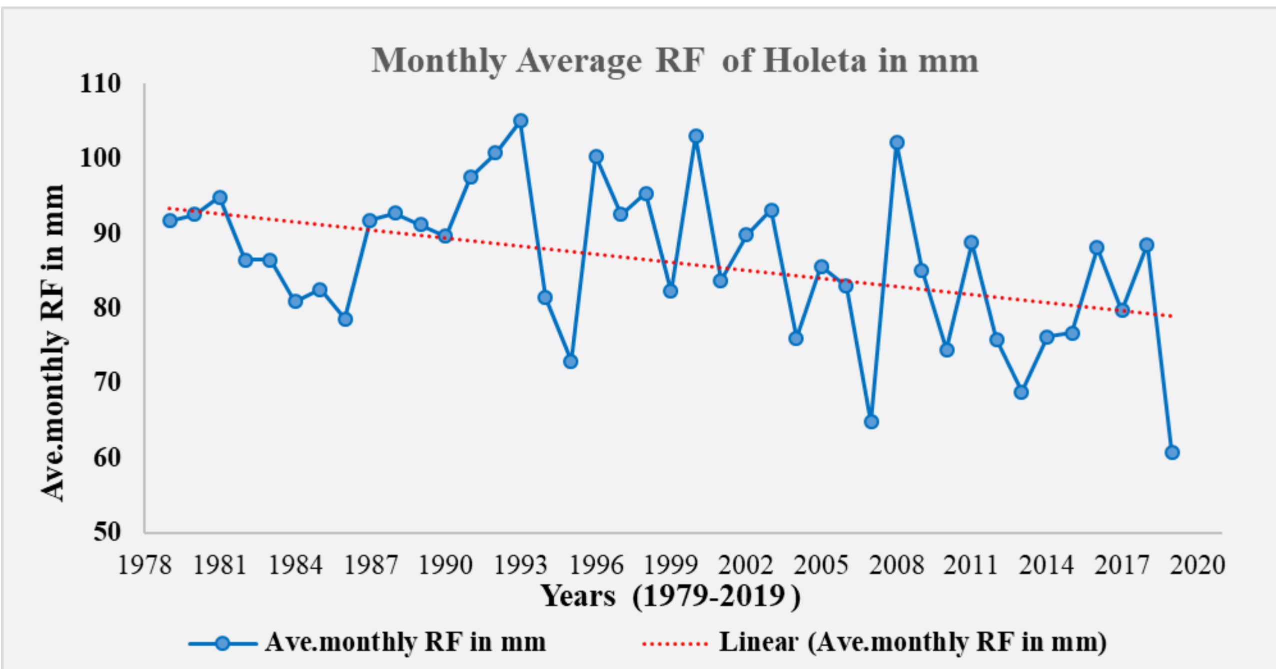

Figure 10. Trend and variability of Monthly Rainfall at Holeta Station (Source: NMSA)

The impact of rainfall on crop production can be related to its total seasonal amount or its intrapersonal distribution. In the extreme case of droughts, with very low total seasonal amounts, crop production suffers the most. But subtler intra-seasonal variations in rainfall distribution during crop growing periods, without a change in total seasonal amount, can also cause substantial reductions in yields. This means that the number of rainy days during the growing period is as important, if not more, as that of the seasonal total [16]. According to the rainfall trend analysis the change in annual total is insignificant while the impact on crop production and variation in total production is still increasing which indicates that the annual total alone is inadequate to determine impact on crop production. Hence, for better insight of impacts on crop production analysis of seasonal variation is very decisive since variation in all seasons of the year are not equally important from crop production point of view. The following tables show seasonal total rainfall and coefficient of variation of *kiremt* and *Belg* season.

Table-5 Kiremt (June- September) Rainfall and coefficient of variation

Stations	N	Minimum	Maximum	Mean	Std.Deviation	Variance	CV
Bako	41	472.8	1190	854.7	159.60	25473	0.187
Holeta	41	561.8	903.2	743.0	84.26	7101.4	0.113
Ambo	23	367.8	837.8	640.2	127.8	16333.3	0.20

Table-6 Belg (March-May) rainfall and coefficient of variation

Stations	N	Minimum	Maximum	Mean	Std.Deviation	Variance	CV
Bako	41	116.5	429.6	259.1049	74.49	5550.2	0.287
Holeta	41	46.22	435.4	199.581	71.27	5079.8	0.357
Ambo	23	0	449.4	219.8	104.06	10827.9	0.47

The seasonal rainfall shows variability as indicated by their coefficient of variation in the tables above. The *Belg* rainfall (March to May) is more variable than the *kiremt* (June to September). This is also consistent with the conclusion made by [17] which reveals that *Belg* rainfall is more variable than *kiremt* rainfall. As *Belg* rainfall is more favorable for crops and its variability also affect production by hindering agricultural activities (such as land preparation and sowing time) and crop physiology such as germination and growth of seedlings. The *Belg* the rainfall is favorable as there is no aeration problem, no cloud cover and the crops are also photo synthetically active. Moreover, the seasonal variability of rainfall also associated with late on set and early offset of the rainy season. The correlation analysis of *kiremt* and *Belg* season also shows inverse relationship at Holeta and Bako station while it is positively correlated at Ambo. The positive correlation at Ambo may be associated with short length period of rainfall data. The survey also supports that when there is good distribution in *Belg* rainfall; the *kiremt* rainfall become less in amount and more variable and vice versa. However, the relationships of seasonal rainfall are found to be statistical insignificant however small variation in rainfall has significant impact on production due high dependency on rain-fed agriculture and other compounding factors.

Table-7 correlation of *Belg* and *Kiremt* rainfall at three stations

	Stations		
Pearson's Correlation of *Belg* and *Kiremt* Rainfall	Bako(N=41)	Holeta(N=41)	Ambo(N=23)
Correlation Coefficient	-0.138	-0.021	0.174

4.2 Temperature variability and trend

Unlike that of rainfall Mann Kendall trend analysis for average monthly temperature shows statistically significant increase except Ambo stations. According to the survey the respondents of Ambo area indicate that the temperature has been increasing in the area in the past two decades; however, the statistical analysis shows non-significant. Hence the stable trend at Ambo may be due to the short length the data as Mann Kendall trend analysis become stronger depending on the length of the data. The seasonal Mankendall test for temperature also shows that there is significant trend (Annex-2). Table- below show values for temperature trend analysis.

Table-8 Values of Average Temperature Trend Analysis (Source: NMSA)

S.N	Sample Station	N	"S" Value	Sample Z-value	Trend Evaluation (α=0.05)
1	Bako	492	12932	3.54	*Unstable (increasing)*
2	Ambo	180	1493	1.84	*Stable*
3	Holeta	492	10158	2.78	*Unstable (Increasing)*

The results of average annual temperature trend analysis indicate that trends show there is variability at the three sampled stations (Bako, Ambo and Holeta). Table –9 below shows descriptive statistics of average annual temperature.

Table-9 Values of Average Annual Temperature and coefficient of variation (Source: NMSA)

Stations	Temperature	N	Minimum	Maximum	Mean	St.dev.	Variance	CV
Bako	Max	41	26.8	29.7	27.9	0.63	0.405	0.02
	Min	41	12.27	14.67	13.60	0.56	0.319	0.04
Ambo	Max	15	25.2	27.3	26.08	0.54	0.293	0.02
	Min	15	10.58	12.35	11.56	0.52	0.272	0.05
Holeta	Max	41	20.8	25	22.3	0.69	0.479	0.03
	Min	41	-2.6	12.2	6.15	2.89	8.35	0.47

The temporal variation average annual Temperature trend is displayed in the figures below.

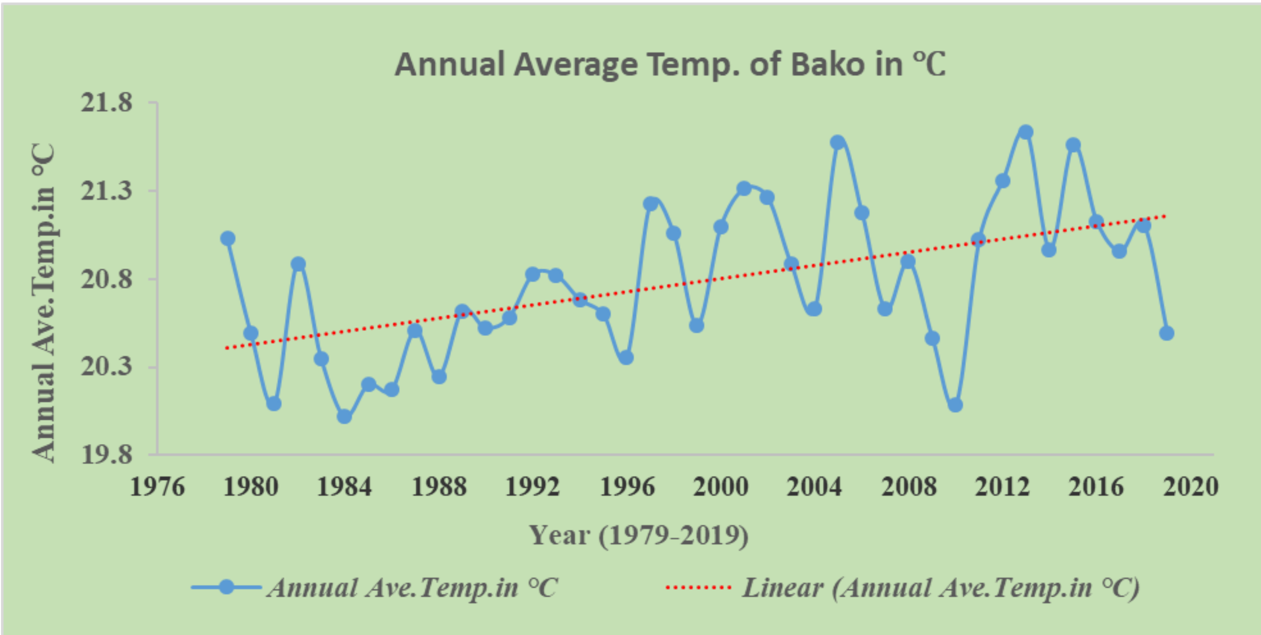

Figure 11. Trends and variability of Ave. Annual Temperature at Bako (Source: NMSA)

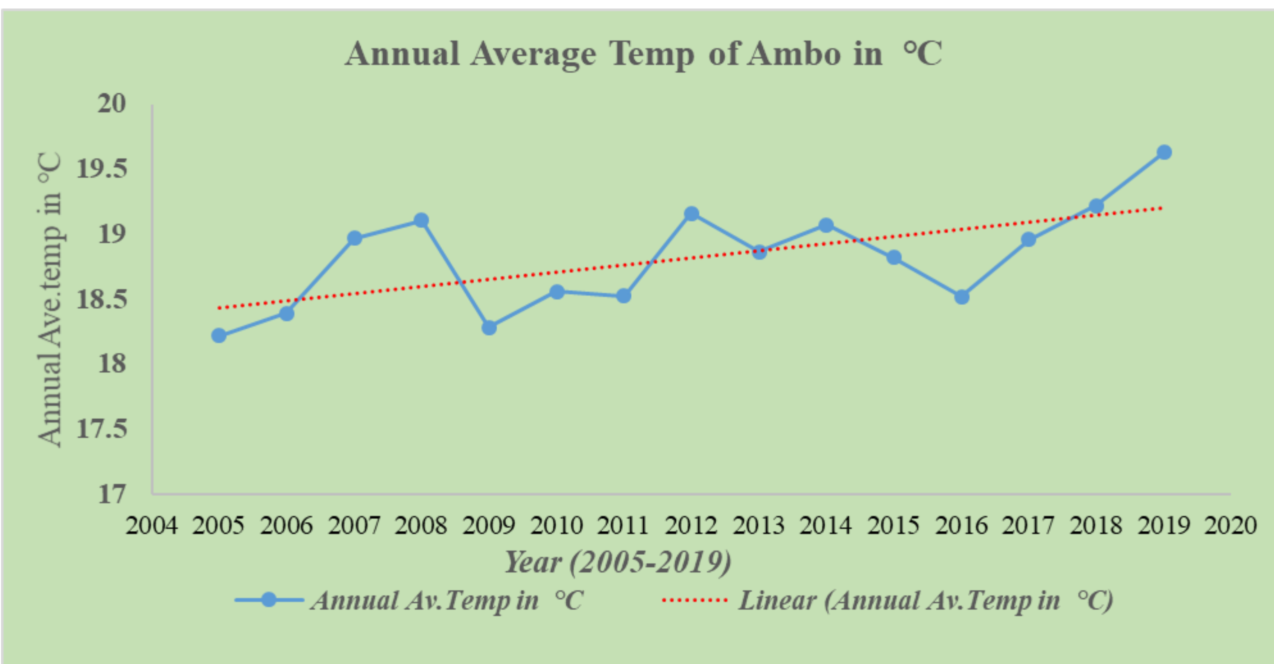

Figure 12. Trends and variability of Ave. Annual Temperature at Ambo Station (Source: NMSA)

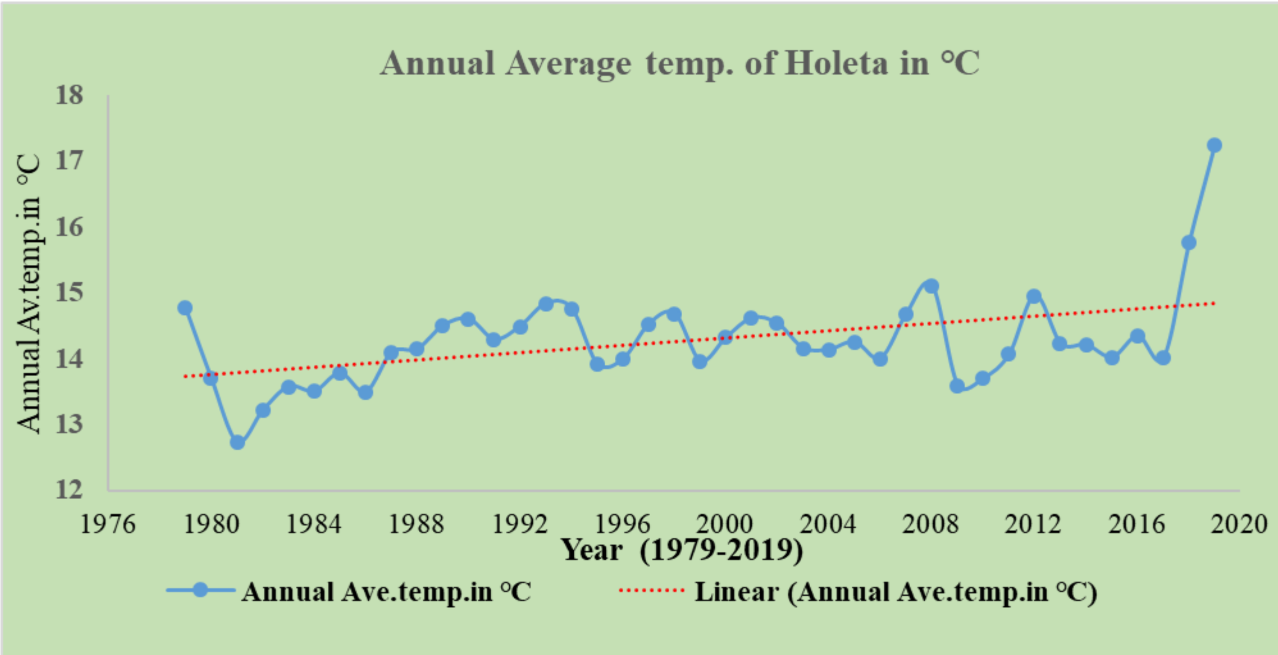

Figure 13. Trends and variability of Ave. Annual Temperature at Holeta (Source: NMSA)

According to [18] there has been a general trend of atmospheric warming in Ethiopia. Average annual minimum and maximum temperature have been increasing by 0.25 and 0.1 °C per decade respectively. The average temperature increase per decade for Holeta and Bako is o.25 and 0.2°C respectively. According to the survey, in Bako and Ambo Woredas, the respondents also indicate there is frequent soil moisture stress due to the increased temperature and farmers compelled to grow maize varieties of short growing period. Moreover, in areas around Holeta which is relatively higher altitude, the farmers have started to grow maize which was formerly limited to low altitude areas. This indicates that the soil moisture stress is not only due to meteorological drought but due to increased evaporate-transpiration due to the overlap of time of maximum temperature period (March to May) and *Belg* rain variability during the growing periods. This result would have been sounder if Aridity index of the areas is calculated but organized data on evaporate-transpiration was lacking.

4. Conclusions and Recommendations

4.1 Conclusion

The investigation into the consequences of climate change on rain-fed crop production for smallholder farmers has yielded several significant findings. By actively involving smallholder farmers in the research and data collection processes, participatory approaches have empowered them to contribute their knowledge and concerns, ensuring that assessments accurately reflect their lived experiences. The collection of localized data in the west Shoa Zone has shed light on the distinct challenges faced by farmers in different agro-ecological zones. By providing communities with access to climate information through diverse channels, informed decision-making regarding crop selection and resource management becomes possible. Capacity building programs that focus on climate-resilient farming techniques and crop diversification play a crucial role in helping farmers effectively adapt to changing climate conditions. The implementation of social protection mechanisms, such as weather-indexed insurance and safety nets, assists farmers in coping with climate-related shocks. Additionally, factors such as age, education, access to resources, and market dynamics influence the ability to adapt to the impacts of climate change. Communities residing in the woredas of Ambo, Bako, and Holeta experience various climate variability impacts, which disproportionately affect vulnerable groups such as the poor, landless individuals, disabled individuals, women, children, and the elderly.

4.2 Recommendations

Based on the outcomes of the study, the following recommendations are forwarded to local communities and government representatives.

- The local government ought to implement policies that provide support and improve market access for smallholder farmers in the research areas. Furthermore, they should promote policies that give importance to the requirements and concerns of smallholder farmers, such as investing in rural infrastructure, establishing connections to markets, implementing mechanisms for price stabilization, ensuring land tenure security, and creating regulatory frameworks that encourage sustainable agriculture and climate adaptation. Agricultural stakeholders have the ability to design specific interventions and support systems to strengthen resilience, improve livelihoods, and guarantee food security amidst the challenges posed by climate change.
- The government ought to enhance the adaptation strategies of local residents to climate change by providing various training sessions at Farmers Training Centers (FTCs) in Woredas, kebeles, and demonstration sites. To enhance their productivity and resilience, the government has introduced and mandated the community to utilize new agricultural technologies, inputs, fertilizer supplies, and various media. Furthermore, to assist smallholder farmers, the government should bolster the integration among different institutions, non-governmental organizations, and communities.
- The government should enhance the number of meteorological stations and improve infrastructures to ensure the availability of weather and climate information for the local community. Additionally, it is crucial for the government to assert the community's ownership over natural resources in order to conserve and restore them, as well as protect the environment. Furthermore, there is a need to enhance the accessibility and services of institutions to effectively address the problems faced by farmers.

In conclusion, it is suggested that further research be undertaken to thoroughly investigate the vulnerability to climate change. Additionally, it is important to assess the effectiveness of various adaptation options in order to inform policy decisions related to climate change adaptation. Developing a tailored adaptation menu specific to each locality will help account for the impacts of climate change and variability, ultimately leading to more effective adaptation strategies.

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