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Impacts of Climate Change on Crop Yields in South Gonder Zone, Ethiopia

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Abstract Agriculture is the most susceptible sector to climate change related hazards. This is due to the fact that climate change affects the two most important direct agricultural production inputs and these are precipitation and temperature. The impacts of climate change on crop production and coping mechanism differ from place to place which is situated in different agro-ecological zones. Therefore, this study analyzed the impacts of climate change on crop yields in three purposively selected woreda's of south Gonder Zone. Primary and secondary data were used for the study. In this paper, climate data were taken from Bahir Dar Meteorological Agency (BDMA) while crop yield data were obtained from South Gonder Zone Agricultural Development Office (SGZADO). The data were analyzed using SPSS version 20.0 and Microsoft Excel in order to evaluate the impact of climate change on the yields of different crops in South Gonder Zone, Ethiopia. Multiple regression, trend analysis and correlation analytical techniques were used to anlyze the data. The result showed that the annual total rainfall and mean annual temperature have been increased by an average of 126.52mm ($p<0.01$) and 0.531℃ ($P<0.01$) per year respectively for Addis Zemen Station. This confirms the occurrence of global warming at Addis Zemen station. An increasing trend of crop yield data for rice, teff and maize were observed from 2003-2012 for Addis Zemen station while an increasing trend of crop yield data for teff, wheat, barley, maize, bean and pea have been observed from 2003-2012 for Mekane Eyesus stations. The result obtained from the analysis carried out indicated that the impact of rainfall, minimum and maximum temperature have been statistically insignificant except rainfall against teff, minimum temperature for teff and chickpea crops and maximum temperature for wheat, barley and pea cereal crops at 95% and 99% probability level whereas the impact of climate on the yield of rice, maize,sorghum, bean and cowpea have been statistically insignificant. Efforts should be made to increase the cultivation of crops on which the impacts of climate on their yield is insignificant.

Keywords: *agriculture, climate, crops, yield, south gonder zone*

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1. Background

Agriculture is the most susceptible sector to climate change related hazards. This is due to the fact that climate change affects the two most important direct agricultural production inputs and these are precipitation and temperature [1]. Although the effects of changes in climate on crop yields are likely to vary greatly from region to region, anticipated changes are expected to have large and far-reaching effects predominantly in tropical zones of the developing world with precipitation regimes ranging from semiarid to humid [2]. Hazards include increased flooding in low lying areas, greater frequency and severity of droughts in semiarid areas, and excessive heat conditions, all of which can limit crop growth and yields. As temperatures continue to rise, the impacts on agriculture will be significant [3]. These impacts are already being experienced by many communities in countries of the Southern hemisphere. There will also be an increase in droughts and heavy precipitation events, which will further damage crops through crop failure, flooding, soil and wind erosion [4].

Agriculture is extremely vulnerable to climate change. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. Changes in precipitation patterns increase the likelihood of short-run crop failures and long-run production declines. Although there will be gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative, threatening global food security [5]. According to [6] predict an overall reduction of 10 percent in maize production in the year 2055 in Africa and Latin America, equivalent to losses of $2 billion per year, affecting principally 40 million poor livestock keepers in mixed systems of Latin America and 130 million in those of sub-Saharan Africa.

Climate change is an important environmental, social and economic issue. It threatens the achievement of Millennium Development Goals aimed at poverty and hunger reduction, health improvement and environmental sustainability. Such issues are particularly important for Sub-Saharan Africa (SSA) where many people depend on agriculture for subsistence and income. Agriculture, and especially crop growing, is heavily dependent on weather events in SSA, where 97% of agricultural land is rainfed. The impact of climate change on crop yields is therefore a major concern in this region [7]. Ethiopia is not an exception to the adverse impacts of climate change as its economy is highly dependent upon climate sensitive rain-fed agriculture. The country is among the most vulnerable nations to climate and ecological change, given that only a small proportion of its cultivated land is irrigated and food production is dependent mainly on traditional rainfed agriculture [8]. The effects of climate change are substantial, particularly in developing world. These countries are highly dependent on climate sensitive natural resource. Sectors for livelihoods and incomes, and the challenges in climate that are projected for tropics and subtropics, where most developing countries are found, are generally adverse for agriculture [9].

Furthermore, the means and capacity in developing countries to adapt to changes in climate are scarce due to low levels of human and economic development and high rates of poverty. These conditions combine to create a state of high vulnerability to climate change in most of the developing world [10]. Developing countries have lesser capacity to adapt and are more vulnerable to climate change damages, just as they are to other stresses. This condition is extreme among the poorest people [11].

Many studies have concluded that the agriculture sector of the country is the most affected sector by climate change. According to [12] made an integrated quantitative vulnerability assessment for seven Regional States of the total eleven regions by using biophysical and social vulnerability indices of Ricardian approach. The study revealed that decline in precipitation and increase in temperature are both damaging to Ethiopian agriculture.

In the EACC study, Crop was used to assess the changes in CO_2 concentration, precipitation, and temperature from the four GCMs and was used to estimate the changes in production (yield) each year for four major crops. The yield effects reflect the reductions in yield due to either the lack of available water, or due to the overabundance of water that causes waterlogging (FAO, 2008). CO_2 fertilization is included in the analysis but does not make a significant difference. Current research is suggesting much smaller CO_2 fertilization than initially thought. Additionally, new research shows that under higher CO_2 levels, ozone will also be present and that has a negative impact on crop yields [13].

Climate impacts are significant, but variable over regions and crop type. The impact of these trends tends to grow stronger in time. The Dry2 scenario is the most damaging scenario due to the frequent occurrence of droughts [14]. The impacts of climate on yields are first-order effects that trigger direct and indirect economic impacts - such as reductions in income, employment, savings and investments [15].

Ethiopia's agricultural sector, which is dominated by small scale, mixed crop and livestock farming, is the mainstay of the country's economy. It constitutes more than half the nation's Gross Domestic Product (GDP), generates more than 85 percent of the foreign exchange earnings, and employed about 80 percent of the working population. Its dependence on agriculture makes the country particularly vulnerable to the adverse impacts of climate change on crop and livestock productions. Generally, increased frequency of droughts and floods negatively affects agricultural production, demonstrating agriculture's sensitivity to climate change [16].

Some scholars have conducted research to measure expected impacts of climate change on agriculture in developing nations [17]. For example, the studies in pastoralist are found out several adaptation mechanisms to reduce farmers' vulnerability to climate change, regarding crop production [18,19].

In different parts of Ethiopia, climate change is affecting the yield of crop production because they are exclusively dependent on rainfed agriculture with little or no adaptive strategies to cope up with climate. The magnitude of climate change related problems have been intensifying both spatial and temporally. The increase in frequency of extreme weather events such as droughts and floods accompanied by the difficulty in predicating growing seasons create a considerable endanger for the achievement of food security. This phenomenon is also the real manifestation of south Gonder zone where this investigation was conducted. Currently, of the total 777,096 population of four woreda i.e. Simada, Ebnat, Lay Gaint and Tach Gaint, 147, 188 populations i.e. 19% of the woreda population are food insecure. Therefore, the objectives of this study was to examine the trend of crop production under the prevailing environmental condition and the relationship between precipitation and temperature elements on the yield of major crops produced in the study area.

2. Methods

2.1. Description of the Study Area

Geographically the South Gonder zone is located between 11° 02' -12° 33' N latitude and 37° 25' -38° 43'E longitudes. The zone is bordered on the south by east Gojjam, on the southwest by west Gojjam and Bahir Dar, on the west by Lake Tana, on the north by north Gondar, on the northeast by Wag Hemra, on the east by north Wollo, and on the southeast by south Wollo; the Abbay River separates south Gondar from the two Gojjam Zones (see Figure 1) [20].

The climate of the zone is more influenced by altitude and latitude than others. Based on the simplified agro climatic classification of Ethiopia, it lies within four agro climatic zones. Wurch (Alpine) and Kola (tropical) accounts for 2.5% and 16% respectively whereas Woina Dega (Sub tropical) and Dega (temperate) account 27% and 54% of the zone. The zone has bimodal rainfall pattern, summer is the main rainy season with its peak in July (June to August) and the short rainy season from February to April. Rainfall varies from 900 mm to1599mm. The average annual rainfall in the zone is 1300mm. The average temperature in the zone is 17℃ [20]. The farming system in the zoneis characterized by mixed farming. Hence, more than 85% of the farm households engage in mixed farming systems and more than 93% of the farm households plough their land using traditional farming technology [21].

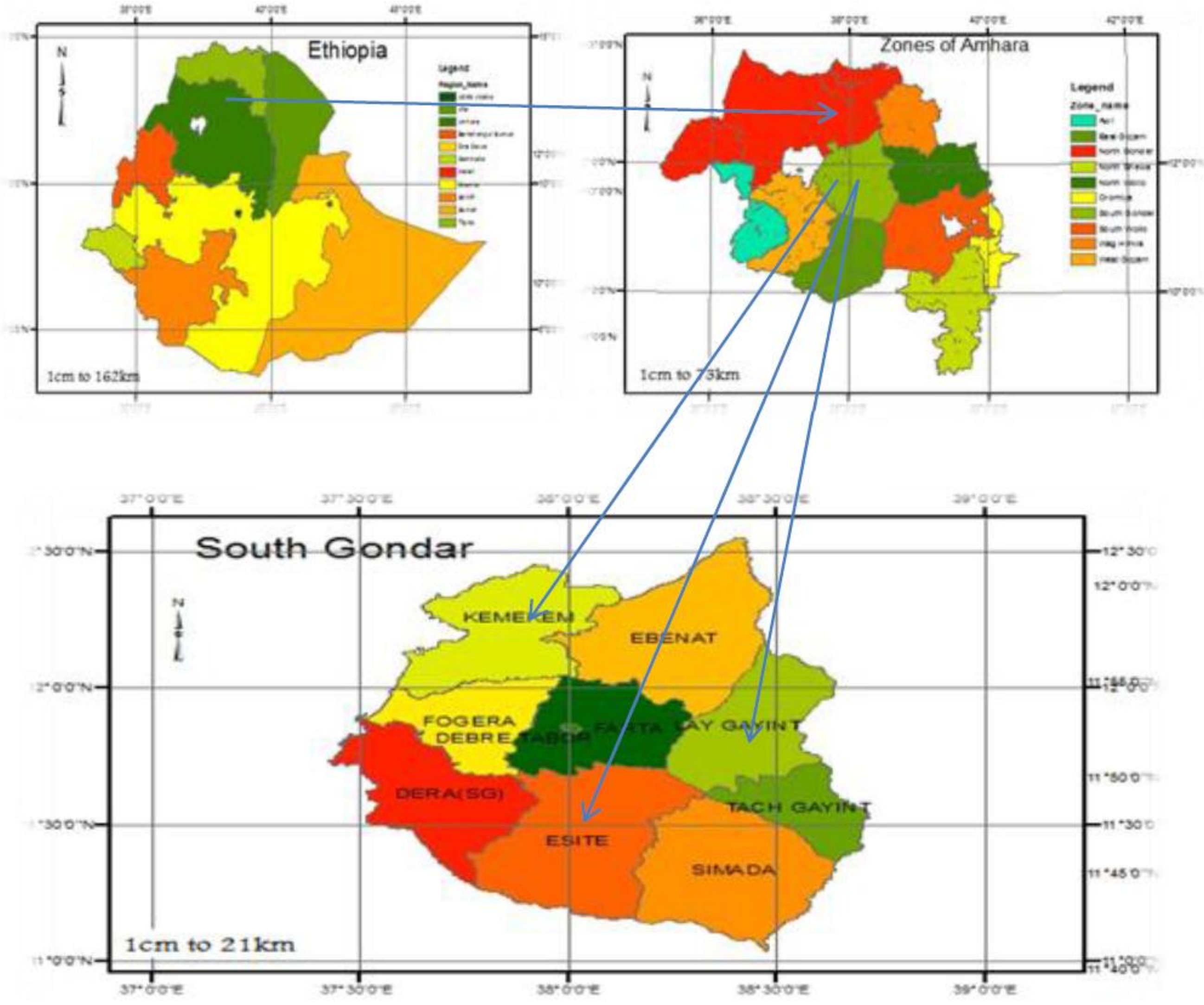

Figure 1. Map of the study area

2.2. Methods and Procedures

This study is designed as survey that assesses impacts of climate change on crop yields of local people in south Gonder zone. Therefore, to accomplish the proposed research with respect to the objectives and the nature of the research questions of the study, both qualitative and quantitative data collection and analytical techniques were employed. In the quantitative aspect, household survey were used to collect relevant data with respect to impacts of climate change on crop production and coping mechanisms of local people. A qualitative technique was used to analyze data collected through focus group discussion, key informant interview and observation. Furthermore, qualitative approaches were used in conjunction with quantitative approaches to strengthen quantitative data.

Both primary and secondary data sources were used in the study. The primary data sources were questionnaire, interview, discussion, and observation while secondary data sources were government documents, Metrological data and crop production data.

To examine the impacts of climate change on crop production, agricultural product yields data with climatic parameters (i.e. Temperature and Rainfall) were employed in this research. Ten years climate data (rainfall, maximum temperature and minimum temperature) were obtained from Bahir Dar Meteorological Agency (BDMA) while crop yield data such as rice, barley teff, wheat, maize, sorghum, bean, pea, chickpea and cowpea were obtained from South Gonder Zone Agricultural Development Office (SGZADO). The choice of these three climatic parameters was based on their influential role on agriculture sector.

2.3. Data Analysis

Data obtained from the meteoroidal agency and agricultural development office was analyzed using version 20.0 Statistical Package for Social Science (SPSS) and Microsoft Excel 2010. Both descriptive and inferential statistical techniques were employed in data analysis. Hence, using descriptive statistical techniques such as mean, standard deviation, median and variance were computed whereas using inferential statistical technique such as multiple regression, correlation analysis and analysis of variance (ANOVA) were computed to see the relationship between climatic parameters with crop yield data.In general, descriptive, trend and regression analysis were all used to analyze the data.

The trend model is of the implicit form C_i=f(T,e) and was subjected to linear, quadratic, cubic power, semi-log,

exponential functional forms to determine the best based on the value of the adjusted R^2
Ci=climate variables
T=time, e= error term
The regression model is of the implicit form $Y=f(X_1, X_2, X_3, e)$
Y= Annual crop yield (Qun/Ha)
X_1=Total Annual Rainfall/precipitation (mm)
X_2=Mean Annual Temperature (°C)
X_3=Time Period.

3. Results and Discussion

3.1. Trend of Annual Rainfall

Statistical record of rainfall in Addis Zemen stations of south Gonder zone between 2003 and 2012 shows statistically significant ($p<0.05$, 0.002) an increasing trend with the highest value in 2011 and lowest in 2003 for Addis Zemen station while statistical record of rainfall in Nefas Mewcha and Mekane Eyesus stations of south Gonder zone between 2003 and 2012 shows statistically insignificant as the computed p-value is greater than 0.05 but shows an increasing trend in 2011and 2010 and lowest in 2004 and 2009 for Nefas Mewcha and Mekane Eyesus stations respectively. The value of highest volume of rainfall which was recorded in 2011 and 2010 was 2446.8 mm, 1221 mm and 1538.1mm while the lowest was recorded in 2003, 2004 and 2009 with value of 1162.1 mm, 741.6 mm and 759.8 mm and the mean of the rainfall data in the stations from 2003-2012 are 1617.49mm, 1013.56mm and 1268.41mm whereas the standard deviation of the rainfall data are 452.7708mm, 165.241mm and 233.8701mm for Addis Zemen, Nefas Mewcha and Mekane Eyesus stations respectively. The highest value of standard deviation shows that there is a large variability of rainfall amount from year to year. The coefficients of variation of annual rainfall are 27.99%, 16.3% and 18.43% for Addis Zemen, Nefas Mewcha and Mekane Eyesus stations respectively. According to a study made by [17] indicates that CV is used to classify the degree of rainfall variability when CV<20 it is less variable, CV <30 moderate and high CV>30. Therefore, rainfall in Addis Zemen station is more variable than the other two stations. According to [19] the annual average rainfall in the Amhara region is 1194 mm, with a standard deviation of 124 mm and coefficient of variability of 10.4%. However, both standard deviation as well as coefficient of variation of rainfall in the study area shows higher value compared to the regional rainfall. Therefore, rainfall is more variable in the study area. The coefficient of correlation between rainfall and time has a value of 0.846, 0.553 and 0.247, implying that there is a strong positive relationship between rainfall and time for Addis Zemen and Nefas Mewcha stations while there is a week positive relationship between rainfall and time for Mekane Eyesus station respectively. The correlation is statistically significant for Addis Zemen station.

In this study, trends of total annual rainfall data for 10 years in Addis Zemen, Nefas Mewcha and Mekane Eyesus stations have been analyzed during the period 2003-2012. Total annual rainfall data has shown an increasing trend of 126.52mm, 30.178mm and 19.096mm per years for Addis Zemen, Nefas Mewcha and Mekane Eyesus stations respectively (see Figure 2. a,b and c).

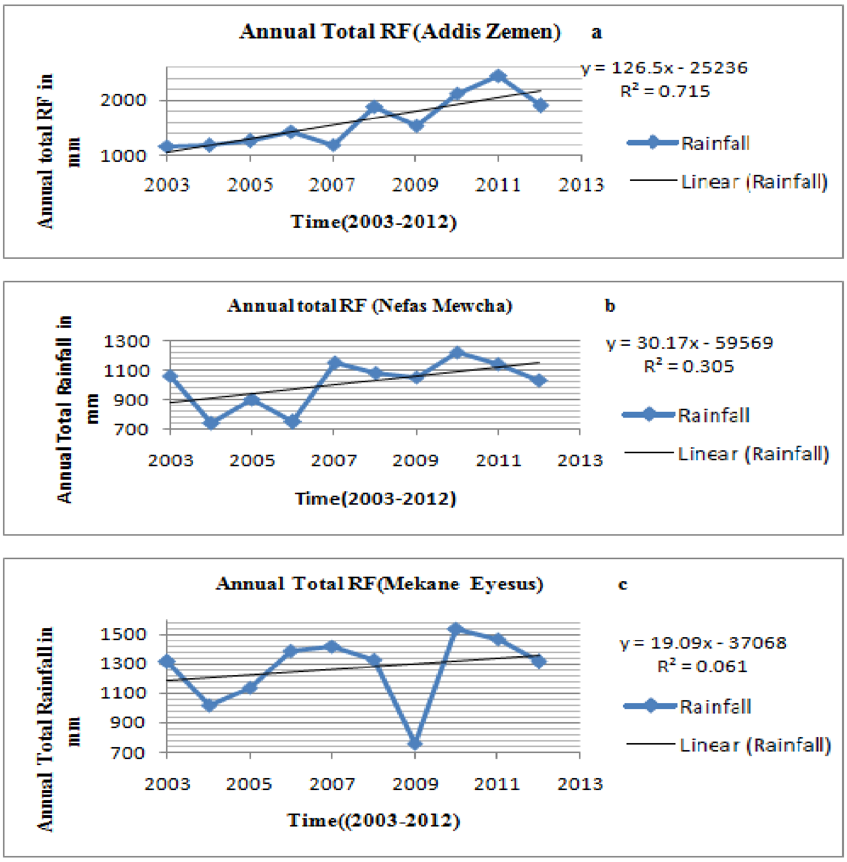

Figure 2. Trends of Annual Total Rainfall for (a) Addis Zemen, (b) Nefas Mewcha and (c) Mekane Eyesus Stations respectively

Table 1. Descriptive and Trend Analysis of Rainfall Data from 2003-2012

Stations	N	Minimum	Maximum	Mean	Std.Deviation	Correlation coefficient	CV
Addis Zemen	10	1162.1	2446.8	1617.49	452.7708	0.846**	0.2799
Nefas Mewcha	10	741.6	1221	1013.56	165.241	0.553	0.163
Mekane Eyesus	10	759.8	1538.1	1268.41	233.8701	0.247	0.1843

**.Correlation is significant at the 0.01 level (2-tailed).

Table 2. Descriptive and Trend Analysis of Temperature Data from 2003-2012

Stations	N	Minimum	Maximum	Mean	Std.Deviation	Correlation coefficient	CV
Addis Zemen	10	17.83	22.62	20.6083	1.78423	0.903**	0.086
Nefas Mewcha	10	12.12	14.71	13.1802	0.65902	-0.294	0.048
Mekane Eyesus	10	15.65	18.7	17.315	0.82059	-0.612	0.047

**.Correlation is significant at the 0.01 level (2-tailed).

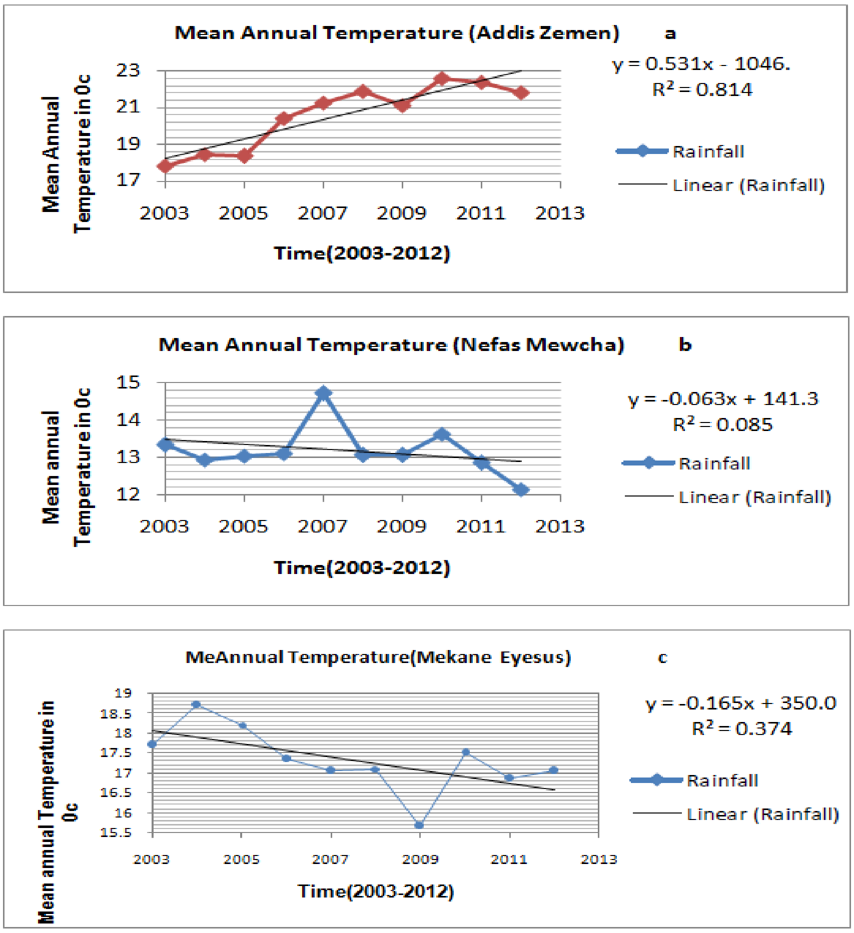

Figure 3. (a) Addis Zemen, (b) Nefas Mewcha and (c) Mekane Eyesus Mean Annual Temperature Respectively

3.2. Trend of Annual Temperature Mean

Data on temperature from 2003-2012 shows an increasing trend with minimum temperature (17.83℃) recorded in 2003 and maximum temperature (22.62℃) recorded in 2010 for Addis Zemen station whereas data on temperature from 2003-2012 shows a decreasing trend with minimum temperature (12.1℃ and 15.65℃) recorded in 2012 and 2009 and maximum temperature (14.71℃ and 18.70℃) recorded in 2007 and 2004) for Nefas Mewcha and Mekane Eyesus stations respectively The mean value of temperature is 20.6℃, 13.2℃ and 17.32℃ while the value of standard deviation is 1.7℃, 0.65℃ and 0.82℃ for Addis Zemen, Nefas Mewcha and Mekane Eyesus stations respectively. This value of standard deviation and coefficient of variation of temperature indicates that variability of temperature is lowest compared to rainfall variability. The coefficient of correlation of temperature and time for Addis Zemen station is 0.903 and is statistically significant at 1%, implying that temperature has significant positive relationship with time. Therefore, temperature changes with time significant. The warming is real and significant. On the other hand, the coefficient of temperature and time is -0.294 and -0.612, implying that temperature has insignificant negative relationship with time for Nefas Mewcha and Mekane Eyesus stations respectively (see Table 2).

Figure 3 (a, b and c) represents the mean annual temperature and its trend in the period of under examination. Using a linear regression model, the rate of change is defined by the slope of regression line which in this case is about 0.5318℃ per year,-0.0638℃ per year and -0.1658℃ per 10 year for Addis Zemen, Nefas Mewcha and Mekane Eyesus stations respectively.

3.3. Trend of Crop Yield

Rice, teff, maize, sorghum and chickpea yield show an increasing trend with a trend coefficient of 2.9618, 1.5812, 2.153, 1.366 and 2.844 quintals per hectare per year respectively for Addis Zemen station while cowpea yield show a decreasing trend with a trend coefficient of 0.7 quintals per hectare per year. Trend of rice, teff and maize yield are statistically significant at 1% and 5% while trend of sorghum, chickpea and cowpea are not statistically significant. Out of the total selected crops, teff has the lowest mean yield value 11.78 quintals per hectare while rice has the highest mean yield value 45.7 quintals per hectare for Addis Zemen station (see Table 3). The maximum value for rice yield (77.0 qun/ha), teff (18.6 qua/ha), maize(40.2qun/ha), sorghum (26 qun/ha), chickpea (51.6 qun/ha) and cowpea (61.4 qun/ha) were recorded in 2009, 2012, 2012, 2009, 2009, 2011 and 2007 respectively while the minimum values for rice yield (0 qun/ha), teff (5 qun/ha), maize (14.7 qun/ha), sorghum (1.6 qun/ha), chickpea (5 qun/ha) and cowpea (3.9 qun/ha) were recorded in 2010, 2003, 2004, 2006, 2006, 2003 and 2004 respectively for Addis Zemen station.

Teff, wheat, maize and sorghum yield show an increasing trend with a trend coefficient of 0.389, 10.62, 1.129, and 0.343 quintals per hectare per year respectively for Nefas Mewcha while barley, bean and pea yield show a decreasing trend with a trend coefficient of 0.175, 0.489 and 135 quintals per hectare per year. Trend of teff, wheat, barley, maize, sorghum, bean and pea yield are not statistically significant (see Table 4). Pea has the lowest mean yield value 6.2 quintals per hectare whereas maize has the highest mean yield value 12.57 quintals per hectare for Nefas Mewcha station (see Table 4).

Teff, wheat, barely, maize, sorghum, bean and pea shows an increasing trend while the coefficient of correlation between teff, wheat, maize and sorghum showing a weak positive relationship with time; also it is statistically insignificant. The Maximum value for teff yield (11 qun/ha), wheat (20.5 qun/ha), barley (14.6 qun/ha), maize (28.9 qun/ha), sorghum (18.6 qun/ha), bean (12 qun/ ha/) and pea (9.5 qun/ha) were recorded in 2012, 2011, 2007, 2011, 2009, 2003 and 2003 respectively for Nefas Mewcha station while the minimum value for teff yield (4.6 Qun/ha), wheat (7.5 qun/ha) , barley (8.9 qun/ha), maize (5.9 qun/ha), sorghum (2.3 qun/ha), bean (2.6 qun/ ha/) and pea (1.9 qun/ha) were recorded in 2007, 2004, 2008, 2008, 2008, 2010 and 2010 respectively for Nefas Mewcha stations.

Teff, wheat, barley, maize, sorghum, bean and pea yield show an increasing trend with a trend coefficient of 1.958, 3.718, 3.347, 4.380, 0.732, 1.630 and 0.887 quintals per hectare per year respectively for Mekane Eyes us station. Trend of teff, wheat, barley, maize, bean and pea yield are statisticallysignificant at 1% and 5% while trend of sorghum yield is not statistically significant (see Table 4).

Pea and maize has the lowest and highest mean yield value of 11.82 and 30.18 quintals per hectare for Mekane Eyesus station respectively (see Table 5). The coefficient of correlation between teff, wheat, maize and sorghum showing a strong positive relationship with time; also it is statistically significant except sorghum. The Maximum value for teff yield (26.9 qun/ha), wheat (43.2 qun/ha) , barley (47.9 qun/ha), maize (61.5 qun/ha), sorghum (25.9 qun/ha), bean (26.2 qun/ ha/) and pea (19.9 qun/ha) were recorded in 2011, 2008, 2009, 2011, 2011, 2012 and 2012 respectively for Mekane Eyesus station while the minimum value for teff yield (7.1 qun/ha), wheat (11.8 qun/ha), barley (7.5 qun/ha), maize (2.7 qun/ha), sorghum (0 qun/ha), bean (7.4qun/ha/) and pea (8.5 qun/ha) were recorded in 2003, 2003, 2003, 2008, 2008, 2003 and 2003 respectively for Mekane Eyesus station.

Table 3. Descriptive and Trend Analysis of Crop Yield Data for Addis Zemen station from 2003-2012

Stations	Types of Crop	Minimum	Maximum	Mean	Std.Deviation	Correlation coefficient	Trend coefficient
Addis Zemen	Rice	0.00	77.00	45.6500	22.68530	0.511*	2.9618
	Teff	5.00	18.60	11.7700	4.92861	0.854**	1.5812
	Maize	14.70	40.20	26.6450	7.93874	0.629*	2.153
	Sorghum	1.60	25.90	17.7200	7.53345	0.378	1.366
	Chickpea	5.00	51.60	26.7600	17.54994	0.467	2.844
	Cowpea	3.90	61.40	24.2100	18.84177	0.27	-0.7

*.correlation is significant at the 0.05 level (2-tailed).
**.Correlation is significant at the 0.01 level (2-tailed).

Table 4. Descriptive and Trend Analysis of Crop Yield Data for Nefas Mewcha station from 2003-2012

Stations	Types of Crop	Minimum	Maximum	Mean	Std.Deviation	Correlation coefficient	Trend coefficient
Nefas Mewcha	Teff	4.6	11	7.24	2.23418	0.289	0.3891
	Wheat	7.5	20.5	11.99	3.65345	0.378	0.62
	Barley	8.9	14.6	12	1.7062	-0.156	-0.175
	Maize	5.9	28.9	12.57	6.68897	0.333	1.129
	Sorghum	2.3	18.6	11.28	4.69084	0.244	0.543
	Bean	2.6	12	6.8	3.15947	-0.333	-0.489
	Pea	1.9	9.5	6.19	2.31922	-0.111	-0.135

Table 5. Descriptive and trend analysis of crop yield data for Mekane Eyesus station from 2003-2012

Stations	Types of Crop	Minimum	Maximum	Mean	Std.Deviation	Correlation coefficient	Trend coefficient
Mekane Eyesus (c)	Teff	7.1	26.9	15.33	7.03484	0.778**	1.958
	Wheat	11.8	43.2	27.38	13.37658	0.600*	3.718
	Barley	7.5	47.9	24.89	12.94917	0.689**	3.347
	Maize	2.7	61.5	30.18	19.64981	0.600*	4.380
	Sorghum	0	25.9	16.03	7.48154	0.289	0.732
	Bean	7.4	26.2	14.89	5.6349	0.778**	1.630
	Pea	8.5	19.9	11.82	3.53107	0.644**	0.887

*.Correlation is significant at the 0.05 level (2-tailed).
**.Correlation is significant at the 0.01 level (2-tailed).

Table 6. Regression analysis

Stations	Crop	R	R^2	Adjusted R	F	Significance
Addis Zemen Nefas Mewcha Mekane Eyesus	Rice	0.626	0.392	0.088	7.289	0.0361*
	Teff	0.767	0.589	0.383	2.862	0.126
	Wheat	0.862	0.743	0.614	5.777	0.033*
	Barley	0.832	0.693	0.539	4.506	0.056***
	Maize	0.573	0.328	-0.007	0.978	0.463
	Sorghum	0.228	0.052	-0.422	0.109	0.952
	Bean	0.312	0.098	-0.354	0.216	0.882
	Pea	0.909	0.826	0.739	9.495	0.011*
	Chickpea	0.797	0.635	0.453	3.486	0.09***
	cowpea	0.736	0.541	0.312	2.359	0.171

*.Correlation is significant at the 0.05 level (2-tailed).
***.Correlation is significant at the 0.1 level (2-tailed).

3.4. Regression Analysis

The multiple linear regression analysis of crops produced in the study area with rainfall and temperature parameters of climate is presented in Table 6. The results shows that the adjusted Rof this model 0.088, 0.383, 0.614, 0.539, -0.007, 0.42, -0.422, -0.354, 0.739,0.453 and 0.312 with the R^2=0.392, 0.589, 0.743, 0.693, 0.328, 0.0.052, 0.098,0.826,0.625 and 0.541 shows that the multiple linear regression explains 39.2%,58.9%, 74.3%, 69.3%, 32.8%, 5.2%, 9.8%, 82.6%, 63.5%, 54.1 % of the variation of the rice, teff, wheat, barley, maize, sorghum, bean, pea, chickpea and horsepea yield respectively can be as a result of the impact of rainfall, minimum and maximum temperature. The F-ratio which determines the overall significance of regression is statistically significant at 5% level of probability as F-calculated value (7.289, 5.777 and 9.495) is greater than F-tabulated value. Therefore, it is concluded that climate change significantly affected rice, wheat and sorghum yield. Besides, the F-ratio which determines the overall significance of the regression is statistically significant at the 10% level as F-calculated value (4.506 and 3.486) is greater than F- tabulated value. To this effect, it is concluded that climate change significantly affected barley and chickpea yield. On the other hand, the F-ratio which determines the overall significance of the regression is not statistically significant at the 10% level as F-calculated value (2.862, 0.978, 0.109, 0.216 and 2.359) is less than F- tabulated value. To this effect, it will be conclude that there is no significant relationship between climate change and rice, teff, maize, sorghum, bean and cowpea yield. Teff, maize, sorghum, bean and cowpea is not affected by climate change as shown in the result. Therefore, teff, maize, sorghum, bean and cowpea planting can serve as a viable alternative for farmers living in areas prone to climate change.

3.5. Prediction Model

The model of multiple regression analysis predicts that an increase in rainfall will cause an increase in yield of rice, teff, wheat and maize crop production and where an increase rainfall will cause a decrease in yield of barley, sorghum, bean, pea, chickpea and cowpea (see Table 7).

On the other hand, an increase in minimum temperature will cause an increase in yield of rice, maize, sorghum, pea, chickpea and horse bean crop production whereas an increase in minimum temperature will cause a decrease in yield of teff, wheat, barley and bean crop production. However, an increase in maximum temperature will cause an increase in yield of rice, chickpea and horse bean crop production whereas an increase in maximum temperature will cause a decrease in yield of teff, wheat, barley, maize, sorghum, bean and pea crop production (see Table 7).

3.6. Correlation Analysis

The Pearson correlation coefficient between the climatic parameters and the selected crop yields were computed and the result is as presented in Table 8. This analysis indicates that the correlation value of rainfall against teff is greater than 0.5 and statistically significant at 0.05 significance level and shows positive correlation exists between rice crop and rainfall. On the other hand, the correlation value of rainfall against rice, wheat, maize and sorghum are less than 0.5 and this portrays positive correlation occur between these particular crops. The correlation between barely and rainfall is approximately zero shows barely crop yields and rainfall have week correlation means whether rainfall amount increase or decrease do not influence its yields. Besides, the correlation value of rainfall against bean, pea, chickpea and Horsebean are less than 0.5 as well as negative. Hence, the increasing amount of rainfall leads to declining the yields of these particular crops.

The correlation value of minimum temperature against teff and chickpea are greater than 0.5 and this indicates positive correlation exists between these crops and minimum temperature. As it indicated in the table below the correlation between teff and chickpea with minimum temperature is statically significant at 0.05 significance level. On the other extreme, the correlation value of minimum temperature against rice, wheat, barely, maize, sorghum and Horsebean are less than 0.5 and positive correlations between these crops under this climate parameter whereas the correlation between bean and pea against minimum temperature are less than 0.5 and this shows negative correlation relationships exist Table 8.

The last column of the table indicates the correlation between the common crops growing in the study area and maximum temperature. Therefore, the correlation value of maximum temperature against chickpea is greater than 0.5 (i.e. 0.628) and have positive correlation relationships between them, the correlation value of maximum temperature against rice and horsebean are less than 0.5 (i.e.0.493 and 0.229) but have positive correlations. On the other hand, the correlation value of maximum temperature against teff, wheat, barely, maize, sorghum, bean and pea are negative but the correlation value is statistically significant at 0.01 significance level for wheat, barley and pea crops, whereas for the other negatively correlated crops the value is less than 0.5. In general the analysis shows that the impact of rainfall, minimum and maximum temperature on these particular crops in the study are statistically insignificant except rainfall against teff, minimum temperature for teff and chickpea crops and maximum temperature for wheat, barley and pea cereal crops Table 8. According to Intergovernmental Panel on Climate Change (IPCC) Report, Climate Change 2014 – Impacts, Adaptation and Vulnerability, rise of global temperature and increasing food demand would pose large risk to food security globally and regionally. It finds that even at just 1 degree Celsius of warming, a negative impact for major crops like wheat, rice and corn would be seen [22].

For instance, in India, It is predicted that with only 1 degree celsius rise in temperature, annual wheat production could go down by 6 million tones [23]. During February-March 2003-04, night temperature was recorded 3 degree celsius above normal in Haryana. Subsequently, wheat production declined from 4106 kg/ha to 3,937 kg/ha at this time. If temperature increases by 1 to 4 degree celsius, the grain yield of rice is going to reduce by 10% for each degree. Basmati varieties, a very important cash crop, has already shown vulnerability to temperature induced pollen sterility leading to lower grain formation [24].

Table 7. Prediction model

Stations	Parameter	Rice	Teff	Wheat	Barley	Maize	Sorghum	Bean	Pea	Chickpea	Horse bean
		Unstandardized Coefficients									
		B	B	B	B	B	B	B	B	B	B
Addis Zemen, Nefas Mewcha Mekane Eyes us	Constant	-299.491	44.418	95.232	165.099	94.302	40.106	9.488	86.893	-167.891	-136.194
	Rainfall	0.029	0.009	0.003	-0.004	0.017	0.002	-0.009	-0.002	-0.012	-0.039
	Minimum T^0c	3.103	1.019	-1.255	-4.853	0.747	0.45	2.353	-4.967	5.412	6.672
	Maximum T^0c	11.99	-2.148	-3.465	-4.989	-4.035	-1.254	-0.292	-1.792	5.197	5.043

Table 8. Correlation analysis

Stations	Crop	Rainfall	Minimum Temperature	Maximum Temperature
Addis Zemen Nefas Mewcha Mekane Eyes us	Rice	0.11	0.365	0.493
	Teff	0.649*	0.671*	-0.457
	Wheat	0.132	0.192	-0.856**
	Barley	0.008	0.013	-0.807**
	Maize	0.489	0.474	-0.346
	Sorghum	0.137	0.18	-0.19
	Bean	-0.255	-0.023	-0.093
	Pea	-0.21	-0.412	-0.676*
	Chickpea	-0.435	0.745*	0.628
	Horsebean	-0.142	0.401	0.229

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

4. Conclusions

This study investigated rainfall and temperature trend analysis in the case of south Gonder zone, Amhara, Ethiopia. The duration of the study period of rainfall data analysis was chosen as (2003-2012) 10 years. From the study, it can be concluded that both rainfall and temperature shows positive trends but it is statistically significant only for Addis Zemen station while it is statistically insignificant for Nefas Mewcha and Mekane Eyesus stations. The increasing trend of rainfall also puts the area at the risk of flooding in the future if proper environmental protection practices are not implemented.

It can also be concluded that rice, wheat, barley, pea and chickpea yield is much more affected by climate change in contrast with teff, maize, sorghum, bean and cowpea.

5. Recommendations

Local government of the study area should enforce environmental laws that will encourage citizens to plant tree which helps to regulate the local climate change through absorbing the excess amount of carbon dioxide in the atmosphere which contribute for the occurrence of excess heat waves as well as to reduce the risk of flooding which will be occurred due to heavy rainfall.

It is also recommended that efforts should be made to increase the cultivation of crops on which the impacts of climate on their yield is insignificant. Research should be conducted on the reproduction of more improved seeds that that will tolerate heat waves in the study area which is likely to occur in the near future.

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Competing Interests

The Authors declares that there are no competing interests.

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