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Keywords: climate change, climate variability, productivity trend, impact, risks.

I. Introduction

The key source and means of livelihood of most Ethiopians is agriculture. Though agriculture remains the most important sector in the Ethiopian economy, the contribution to speeding up its overall socio-economic development is becoming less and less. Declining land productivity and crop yield resulted from farm size fragmentation coupled with high population growth; subsistence farming with weak agricultural technologies and extension service; land degradation problems; inappropriate policies, and the prevailing climate change and its variability are the prime challenges facing the agricultural sector (Temesgen & Hassan, 2009, Welde gebriel and Prowse, 2013).

The agricultural system of Ethiopia is known as a subsistence mixed farming system comprising of crop and livestock farming with a low supply of agricultural technologies and extension services (Belete *et al*., 1991). In a mixed farming system, the farming community in rural and peri-urban areas practiced cultivation of crops, rearing of livestock, exploiting of the natural resource endowments, and few of them involved in off-farm and non-farm income-generating activities for their livelihood. The choice for crop production explicitly depends on the agro ecological conditions of the area, such as soil type, moisture availability, agro climatic conditions, institutional accessibility, and socio-demographic conditions. Akin to crop production, agro-climatic conditions such as rainfall, temperature, and humidity are deterministic factors for livestock production.

The natural environment in which the human being is living and the overall socio-economic development is affected by climate. Climate is a long-term summary of weather conditions, taking accounts of the average conditions and their variability(IPCC, 2007). The long-term variability of weather conditions over time and space is climate change. The variability in weather conditions includes the change in temperature, rainfall pattern and precipitation. Climate change is an emerging global challenge in the 21st century that explicitly affects the socio-economic development of nations in which Ethiopia is the one that has been adversely affected. In Ethiopia it has imposed some adverse impacts on the agriculture exacerbating the food insecurity problem of the country (Weldegebriel and Prowse, 2013). The climate change adverse effects in developing countries are more drastic than in developed countries because of the fact that developing countries' population depends on agriculture for their livelihood, have limited capacity to adapt, and mitigate the changes and have a high poverty level(Pereira, 2017;Sejian, 2013). It has a substantial impact on agricultural production of both crop and livestock productivity and aggravates the poverty level of countries of which developing countries, including Ethiopia, are severely affected (Shumetie *et al*., 2017). In the climate variability, there is severe moisture stress, drought, rainfall patterns variability, atmospheric

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temperature change, high sunshine intensity, and low precipitation affecting agricultural productivity.

The change in climate variability posed crop loss, livestock productivity decline, pest infestation, disease outbreak on livestock and crops, human displacement, life loss, and an overall socio-economic disturbance and tension of the entire society. To reduce and mitigate the negative impact of climate change and variability, countries adopt and implement various climate abating mechanisms. Unless the negative impact of climate change is abated through adaptation mechanisms, the damage it posed increases with time increment(Pereira, 2017;Temesgen &Hassan, 2009).

In the South Nation Nationalities and Peoples' Region (SNNPR), climate variability, mainly rainfall pattern, temperature, and relative humidity have affected agricultural productivity, mainly crop production. For the last two decades, i.e., 1994 to 2017, climatological data in rainfall, temperature, and relative humidity obtained from the weather stations of the central zones of SNNPR showed different patterns responding differently to crop production. The crop production data obtained from the Central Statistical Agency (CSA) of Ethiopia in cereals, pulses, root crops, and coffee showed different productivity trends.

Given the agricultural technologies availability, extension services, input availability, high market price for food grains, and the policy environment functioning in the region, the agricultural yield of the major crops have not shown significant change over the years. Based on a review of literature, secondary data obtained from CSA, and time series climatological data of the National Meteorological Service Agency (NMSA), this paper tries to address and synthesized the crop productivity trend and the likely impacts of climate variability on crop production. The in-depth empirical analysis of climate change on agriculture and its simulation on crop yield and productivity is out of the scope of this paper that need further empirical research.

II. Literature Review

a) Climate Change and Variability

Climate change in Intergovernmental Panel on Climate Change (IPCC) usage refers to a change in the state of the climate that can be identify by changes in the mean and the variability of its properties that persists for an extended period, typically decades or longer period (IPCC, 2007). IPCC further defined climate change as any change in climate over time, whether due to natural variability or human activity. Climate change may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or land use(IPCC, 2012). Other scholars define climate change as a process of global warming, in part attributable to the 'greenhouse gases' generated by human activities and the likely changes are both global such as rising sea levels attributable to ice -melt and local such as changes in rainfall patterns (Slateret al., 2007). It is also define as the fluctuations in the patterns of climate over long periods(Ngaira, 2007).

Plausible climate change scenarios include higher temperature, change in precipitation, and higher atmospheric CO_2 concentrations (Adamset al., 1998). On the other hand, the greenhouse gases such as carbon-di-oxide (CO_2) lead to changes in climate conditions such as a change in temperature, precipitation, soil moisture, and sea levels (Kelbore, 2013). If the changes in climate parameters such as a change in temperature, precipitations, sea levels, and soil moisture show year-to-year variations or cyclical trends, it is known as climate variability (IPCC, 2007).Weather is the set of meteorological conditions such as temperature, rainfall, wind, humidity, sunshine intensity, snow, and others observed at a particular time and place. Usually, the weather condition of a specific place at a specified period recorded in meteorological stations. The climate, on the contrary, describes the long-period summary of weather conditions taking account of the average as well as the variability of the climatic conditions experienced at a place (IPCC, 2007). The fluctuations that occurred from year to year and the statistics of extreme conditions such as storms, floods, rise in temperature, and any other extreme weather conditions are consider as part of climate variability (ibid).

b) Impacts of Climate Change on Agriculture

Globally, climate change and variability become debating issues and political agendas of both developed and developing countries. Climate change and fluctuation have become a global and real issue (Ngaira, 2007), affecting billions of people, including the natural environment. The presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social or cultural assets in places can be exposed and could be adversely affected by climate change (IPCC, 2012). It causes wide-ranging impacts and effects on the natural and environmental resources, ecology, human and animal health and socioeconomic status of citizens of every country.

The change in climate parameters such as a change in temperature, precipitation, or rainfall patterns affects crop yield and productivity. Although temperature increase has both positive and negative effects on crop yield, it has adverse effects in reducing yield and quality (Adams et al., 1998). Temperature increase leads to higher respiration rates, shortens the period of seed formation and grain filling period, lowers biomass production, and finally reduces the required crop yield or its productivity. Equally important, the change in temperature also has imposed a negative impact on livestock production. It lowers forage production which limits feed supply to animals (Adams et al., 1998); change in temperature, specially heat stress, adversely affects the livestock production and threatens the survival of animals (Sejian, 2013).

Agricultural activities, mainly crop, and livestock productivity, is primarily dependent on climate (Adams et al., 1998). Climate change has imposed a negative impact on the agriculture, affecting crop and livestock production (Pereira, 2017). The possible physical and economic effects of climate change on agriculture are changes in crop and livestock yields as well as the economic consequences resulted from these potential yield changes (Adams et al., 1998). Increased temperature, precipitation, erratic rainfall, recurrent drought, flooding, and frost are the main climatic variables affecting agricultural activities. As witnessed from Ethiopian Central statistical Agency, climate-related events such as drought, excessive rainfall, high temperature, frost, etc. affect specific crop yields negatively and to different degrees (Berger *et al*., 2017).

Climate change influences crop and animal production, hydrologic balances, input supplies, and other components of the economy(Adams *et al*., 1998). Moreover, climate change has adverse impacts on plant and animal health (Pereira, 2017); it creates negative pressure on crops and livestock by aggravating pest, weeds, and disease infestation; it entails series damage on crop production and productivity (Shumetie et al., 2017); it reduces net crop revenue per unit area during summer and winter season (Temesgen & Hassan, 2009). A study made in Nigeria by Ngaira (2007) reported that reduced agricultural land use, increased aridity, increased incidences of farm pests and diseases, over-cultivation including marginalized land, food insecurity, and poverty are some of the effects of climate change occurring in Africa.

The major climate attributes such as the rise in temperature, the change in frequency and intensity of precipitation, the increase in the level of CO_2 available for photosynthesis have direct impact on agricultural productivity (Nastiset al., 2012). High soil and atmospheric temperature, low rainfall or precipitation, and high level of CO_2 result in severe drought occurrence that lowers agricultural productivity, which ultimately affects the farming community whose livelihood and employment directly depend on agriculture. As the farming community is adversely affected by climate change and variability, the food supply to the market, raw material requirement of agro industry, foreign exchange earnings, and other income-generating activities gained from the sector will be dramatically affected negatively, which ultimately impose significant loss to the entire economy of a given country.

c) Risks of Climate change and Variability on Agriculture

Agricultural production variability is a main risk that is manifested in loss of crop yield and reduction of livestock, deterioration of product quality, and dramatic change of market price in crop and livestock products. The major sources of production risks in agriculture are variation in complex weather conditions such as erratic and variable rainfall, rise in temperature, change in humidity and precipitation patterns; pests and disease occurrence; application of outdated technology and practices; inefficiency of farm machinery and low quality of agricultural inputs. At the same time, marketing, financial, human resource risk caused by improper operation and application of production systems, and legal risks caused by inappropriate rule and policy are important sources that need focuses in managing and mitigating the consequences in agricultural production. Ethiopia is frequently reported as the most vulnerable country in climate change and variability risks imposed on its rain-fed and subsistence agriculture (Tessema and Simane, 2019). It has imposed adverse effects on the agricultural sector (Weldegebriel and Prowse, 2013); smallholder farmers are highly vulnerable to climate change and variability ((Tessema and Simane, 2019) resulted in low agricultural production and consequently in food insecurity. All the climate change and variability attributes have imposed deterministic effects in crop and livestock production in lowering the amount produced and the expected quality.

Sub-Saharan African countries including Ethiopia are experienced by climate change and variability mainly by the rise in mean temperature and erratic rainfall. The climate change and variability risks have resulted in the occurrence of frequent drought, floods, pests and disease, and other risk extremes (Weldegebriel and Prowse, 2013). On the other hand, the heavy dependency of the economy on subsistence and undeveloped agriculture; low level of transfer, and adoption of improved agricultural technologies and practices have exposed the farming community to a high level of vulnerability and risk (Tessema and Simane, 2019). African countries including Ethiopia are more exposed to the risks of climate change and variability not only to their exposure to climate change but also due to the lack of their capacity to respond or adapt to the impacts of climate change (Berger *et al*, 2017).

d) Adaptation and Mitigation of Climate Change

Adaptation measures and mitigation of climate change are vital in countries whose economy is dependent on rain-fed type of agriculture ((Weldegebriel and Prowse, 2013). Climate change is not only the determinant of agriculture, but on the contrary, agriculture is also one of the drivers for climate change. Countries whose economy largely depends on agriculture are more vulnerable to climate change risks. To overcome the short and long-run climate risks, countries stand differently. For example, Ethiopia stands 7th among the first ten worst performing countries to climate change risk in 2015, next to the four severely attacked African countries, namely Sierra Leone, South Sudan, Nigeria, and Chad (Maplecroft, 2015). The vulnerability in Ethiopia and other African countries emanates from the underdeveloped agricultural system and low level of economic development. The susceptibility in African's agriculture to climate change is high due to the facts that its agriculture system is commonly rain-fed and underdeveloped with low technological inputs, majority of African farmers are small-scale farmers or at subsistence level with few financial resources, limited access to infrastructure, and information (Pereira, 2017).

Climate change and variability impacts and effects differ from nation to nation *(Shumetie* et al., 2017). In those countries whose livelihood and employment directly depend on agriculture, the effects, and impacts of climate change and variability are much more drastic than the developed countries whose economy is largely dependent on other sectors (Sejian, 2013). To overcome such vulnerability and climate change risk on agriculture and socio-economic development of countries, different coping mechanisms and adaptation strategies have been implemented. Ethiopia, including the SNNPR has implemented community-based watershed development as a green economy strategy to rehabilitate, conserve and protect the land resources (MoARD, 2005). Since 2011, SNNPR in implementing community-based participatory watershed development, farm-level soil and water conservation (terracing, contouring, bunds), communal land rehabilitation and conservation, agro forestry practices, on-farm agricultural technologies introduction and adaptation (improved crop varieties, livestock breeds, management practices), the introduction of off-farm and non-farm income generating schemes as climate adaptation strategies to cope with climate changes(SARI, 2018).

Climate adaptation to overcome or mitigate the short-run climate variability and extreme weather or climate events (climate extremes) can serve as the basis for reducing the vulnerability of long-term climate change (IPCC, 2012). In the agricultural sector, switching towards using improved crop varieties, agronomic and plant protection practices, use of improved animal species, diversifying crop types and animal species, use of animal husbandry practices, use of irrigation, access to financial resources, market and agro-climatic information are climate adaptation strategies that the farming communities should practice and implement (Weldegebriel & Prowse, 2017). In SNNPR, productive safety net program (PSNP) has introduced as a climate-change adaptation strategy as livelihood diversification for food-insecure, poor households (ibid). From a policy perspective, the government should consider and respond to the likely impacts of climate change on the economy as a whole and the agriculture sector in particular. Responding to climate variability sooner, incorporating agricultural practices into mitigation policies, strengthening research and development (R&D) to enable the farming community livelihoods to be more resilient are some of the measures that need to be considered by policymakers (Slater et al., 2007).

III. Research Methodology

a) Geographical and Socioeconomic Description

The Southern Nations, Nationalities, and Peoples' Region located in the south and south-western part. Geographically it is situated between the coordinates of 4^0 27'' to $8^0$30''N, and 34^0 21''to 39^0 11''E with altitude ranging from 376 to 4207 m asl and with mean annual temperature from 15^0c to 30^0c. It covers a total area of 110931.9 km^2 divided into 17 zones.

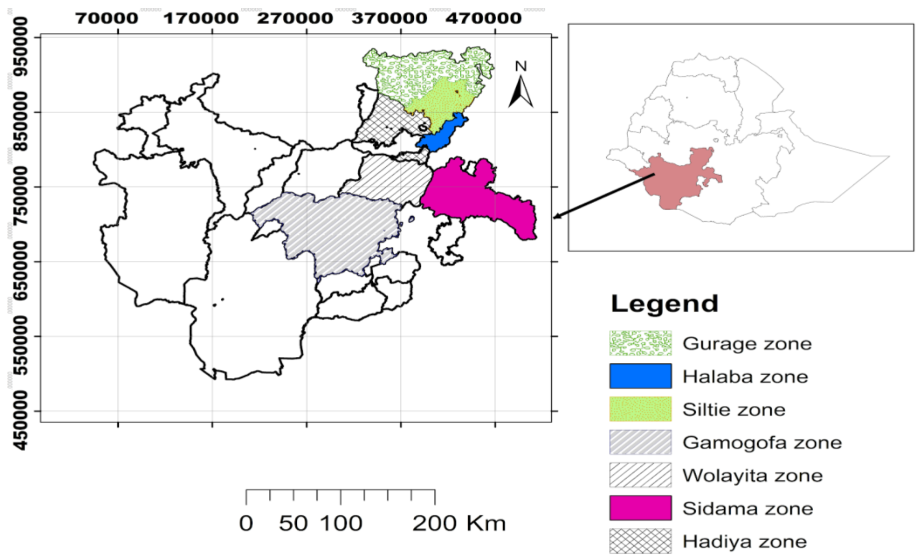

Fig. 1: Geographical location of the study areas

The study covered the central areas of the southern Ethiopia, namely Sidama, Walaita, Gurage, Hadiya, GamoGofa, and Halaba where there arehigh agricultural activities mainly crop production. Theseareas are known for their high population density, andtheir main livelihood is derived from agriculture, mainly from crop production. The area covered by crops in central zones of SNNPR is estimated to be 50.7% of the total regional cropland of which Sidama, Gurage, Waliata, Hadiya, GamoGofa, and Halaba accounts for 6.91%, 9.87%, 6.49%, 10.84%, 12.94% and 3.65% of the regional total respectively (CSA, 2017).

b) Data Type and its Source

The data from CSA's annual rainy season agricultural sample survey report and climatological time series data collected from weather stations of NMSA. The secondary data obtained from CSA includes the private peasant holding the main season area and production of major crops. Time series data from NMSA comprises the seasonal (*Kiremt*[1], *Bega*[2] *and Belg*[3]) and annual rainfall, the temperature of the nearby weather stations located in central zones of SNNPR.

c) Crop Yield Data

Area, crop yield, and crop yield per unit area of major cereals, pulses, root crops, coffee, and red pepper were taken for this study. For this study, only crop productivity for 12 crop types, namely maize, *tef*, wheat, barley, sorghum, finger millet, faba bean, common bean, sweet potato, taro, coffee, and red pepper was considered for the years 1998 to 2017. Due to the missed data reported in CSA's sample survey, the yield data for some crops, for example, sorghum and finger millet, were not available for 1998 to 2004, and yield data for sweet potato, taro, coffee, and red pepper for the years 1998 to 2001 was not included.

d) Climate Data

A time series rainfall data for *belg*, *kirmet* and *bega seasons* and annual total rainfall collected from NMSA. The rainfall data of all six stations, including rainfall and annual total rainfall computed for 1994 to 2017, was organized and tabulated into two periods (Annex Table 1). For simplicity, the seasonal and total rainfall amount is convert to the natural logarithm (ln). Similarly, the average minimum, maximum and average temperature value for 1994 to 2017 was taken from the weather stations and organized into two periods (see annex table 2).

e) The Econometric Model

The impact of climate change and variability on crop yield was analyzed using a stochastic production function developed by Just & Pope (1979). In the model, the dependent variables specified were the mean and variance of the yield of crops. The independent variables included were the average seasonal rainfall and annual average temperature for over 19 years for maize, *tef*, wheat, barley, faba bean, and common bean yield. For the root crops and coffee, 15 and for red pepper 14years considered. The production function allowed the effect and impacts of climate element on the mean yield of the major crops, and the variability of the yield of each crop were measured by the variance. The estimation was done based on the maximum likelihood estimation procedure.

[1] Kiremt is the Ethiopian local language term indicating 'main rains' season stays from June to September

[2] Bega indicates the dry season with high temperature and little rainfall extends from October to January

[3] Belgexpress the short or small rains season starts from February/March and extends to May

The stochastic production function for crop (i) and year (t) specified as:

$$y_{it} = f[X_{it}, \beta] + h^{1/2}[Z_{it}, \sigma] + \varepsilon_{it}$$

E(y) = F(X), V(y)=h(X), so that the effect of mean and variance on crop yield are independent.

y_{it} is the dependent variable, where the first function is the effect of the regressors on the mean yield, and the second part is the effects of independent variables on crop yield variance. In the stochastic production function, t denotes the production years (1998 to 2017), ε_{it} is the stochastic term with $E(\varepsilon) = 0$, $V(\varepsilon) = \sigma^2$, X_{it} is the independent variables affecting crop i in the year t, β and σ are estimate coefficient providing the effect of each X on mean and variance of crop yield.

IV. Results

a) *Rainfall Trends*

The inter-seasonal rainfall in six weather stations from 1994 to 2017 years showed fluctuating trend going up and down that the variations affect crop yield and productively differently (Fig.2). Except for *belg* in Hossana, and k*irmet* in Arbaminch, the mean difference test for *Kiremt*, *bega* and *belg* seasons, and annual rainfall in all stations for the periods 1994 to 2005 and 2006 to 2017 showed insignificant effect (Annex Table 1). The rainfall mean difference for the two periods showed little increment in Hawassa, Woliata Sodo, and Arbaminch weather stations figured to 13.67 mm, 23.93 mm, and 54.19 mm, respectively. On the contrary, at Hossana, Buie, and Halaba weather stations the mean difference showed a decrement and was found to be insignificant (Annex Table 1).

The mean difference and the statistical test for the main season (*Kiremt*) rainfall of the two periods showed increasing and decreasing trends. The mean difference for four meteorological weather stations, namely at WalaitaSodo, Hawassa, Arbaminch, and Hossana, showed an increasing trend of 36.67 mm, 40.61 mm, 74.52 mm, and 77.58 mm, respectively and found insignificant. At HalabaKulito and Buie weather stations, the mean difference showed a decreasing trend reaching 75.43 mm for both stations (Annex Table 1).

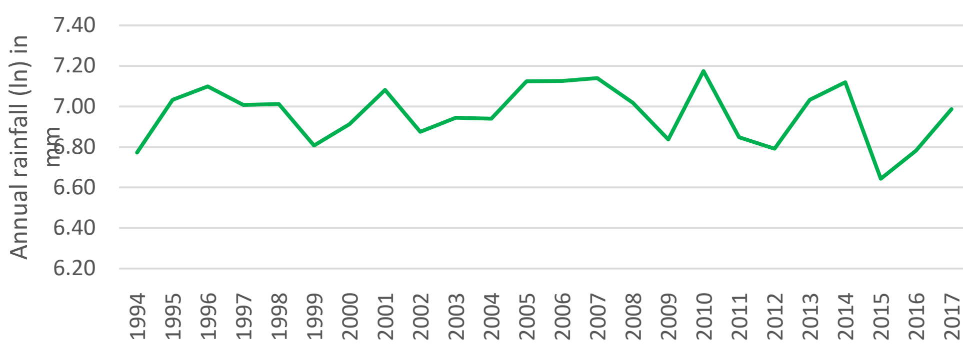

Fig. 2: Annual rainfall trend (1994-2017)

b) *Temperature Trends*

The observed and recorded average minimum, maximum, and annual temperature in 5 weather stations of the central zones of SNNPR for the years 1994 to 2005 and 2006 to 2017 showed an increasing trend (Fig3).The annual average temperature means difference for the two periods in Hossana, Arbaminch, Wolita Sodo, Hawassa, and Halaba Kulito was found to be 0.34 ℃, 0.42℃, 0.45℃, 0.91℃ and 1.53℃ respectively and showed significant difference (Annex Table 2). Similarly, the average maximum temperature for all stations showed an increasing trend, and with the exception of Hossana, the average minimum temperature for the rest weather stations also showed an increasing trend. The lowest minimum average temperature was ranging from 19.89 to 21.01℃.

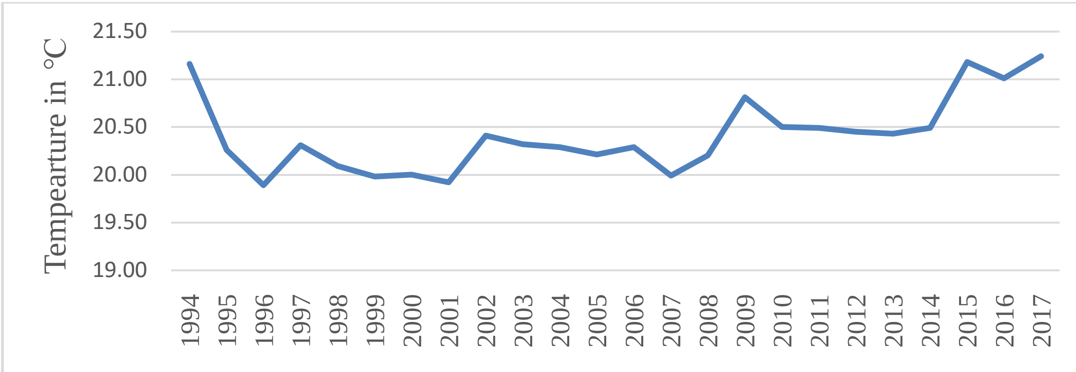

Fig. 3: Average annual temperature trend (1994-2017)

c) Productivity Trend of Cereal Crops

The productivity trend of cereals in 1998 to 2017 showed different trends(Fig.4). Maize average productivity showed the lowest in 2001 (13.68 Qt Ha-1), and the highest in 2017 (35.07 Qtha-1) and the productivity was lower than the national average (36.75 Qtha-1) in 2017 (CSA, 2017). Tef productivity ranged from 6.22 Qtha-1 in 2004 (CSA, 2004) to 13.91 Qt ha-1in 2017 and lay below the national average (16.64 Qtha-1) reported in 2017 (CSA, 2017). Similarly, the productivity of bread wheat ranged from 11.40 Qt ha-1 in 2000 (CSA, 2000) to 24.39 Qtha-1, and yet it was lower than the national average (26.75 Qtha-1) (CSA, 2017). Food barley productivity ranged from 11.26 in 2002 to 20.66 Qtha-1 in 2017 and it was below the national average reported in 2017 (21.11 Qtha-1).Sorghum productivity ranged from 8.32 Qtha-1 in 2006(CSA, 2006)to 20.17Qt ha-1 in 2017, and was lower than the national average (26.10Qt ha-1)(CSA, 2016). Halaba is the major finger millet producing area, where the lower productivity was 9 Qtha-1 in 2006(CSA, 2006)and the highest was recorded in 2015 (16.9 Qtha-1), and was lower than the national average reported in 2017 (22.30 Qtha-1).

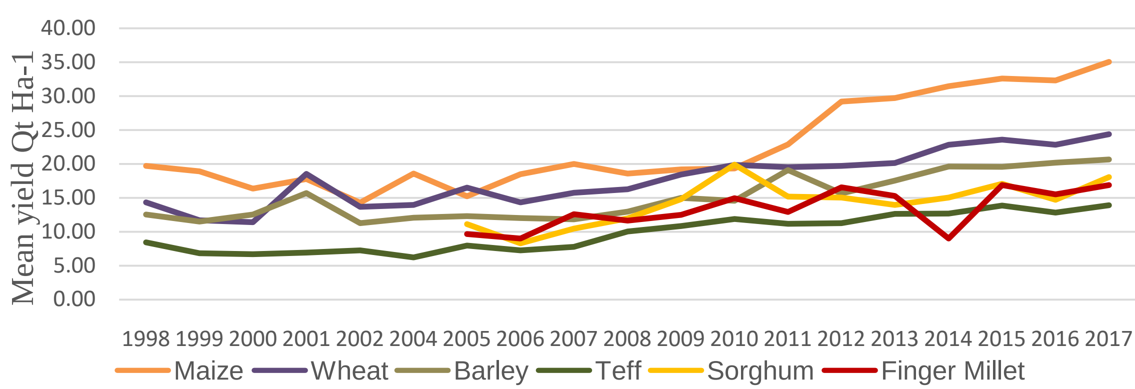

Fig. 4: Cereal crops productivity trend (1998-2017)

d) Productivity Trend of Pulse Crops

The productivity trend of major pulse crops, namely faba bean and common bean, showed an increasing trend(Fig 5). For the period 1998 to 2017, the lowest productivity of faba bean was observed in 2001 (9.04 Qtha-1) (CSA, 2001) and the highest yield in the year 2017 (22.07 Qtha-1) and was higher than the national average (20.53 Qtha-1) in 2017 (CSA, 2017). The mean yield productivity of common beans ranged from 6.65 Qt ha-1 in 1998 (CSA, 1998)to 16.09 Qt ha-1(CSA, 2017).

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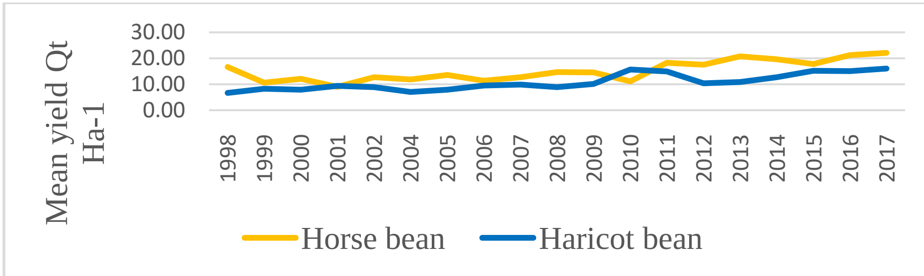

Fig. 4: Pulse crops productivity trend (1998-2017)

e) Productivity Trend of Root Crops

The productivity of taro and sweet potato showed a constant trend from the year 2002 to 2012, showing an average yield of 92Qtha^{-1}(CSA, 2012) and an increasing trend right from 2013and reached 336.4 Qt ha^{-1} of taro and 378 Qt ha^{-1} of sweet potato in 2015(CSA, 2015).

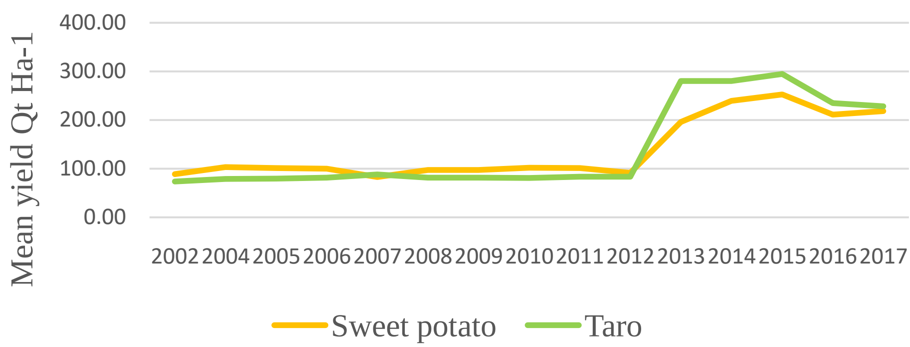

Fig. 5: Sweet potato and taro productivity trend (2002 - 2017)

f) Productivity Trend of Coffee

From 2002 to 2017, the productivity trend of coffee showed up and down with little change in productivity (Fig. 7). The highest productivity reached 6.94 Qtha^{-1} of clean coffee in 2013(CSA, 2013), and the lowest was 4.38 Qt ha^{-1}(CSA, 2004).

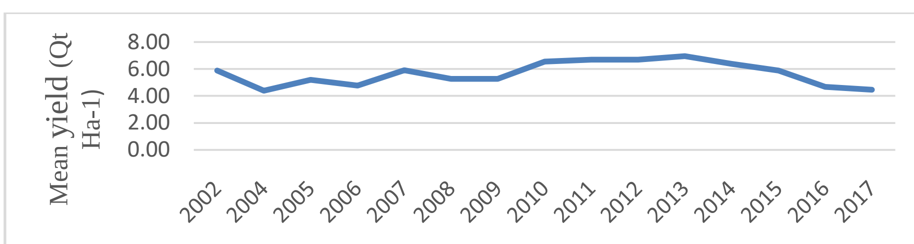

Fig. 6: Coffee productivity trend (2002-2017)

g) Productivity Trend of Red Pepper

Nationally, Marko, Meskan, and Halaba are known as the potential producer of red pepper. Due to the data unavailability in CSA's report, only Halaba was considered. The productivity trend in the first four years showed a sharp increasing trend up to 2007, and then it started to decline down to 17.4 Qtha^{-1} in the consequent years (Fig. 8). The productivity of red pepper reached its maximum (39.8 Qtha^{-1}) in 2007 (CSA, 2007) and the minimum (16.48 Qtha^{-1}) in 2016.

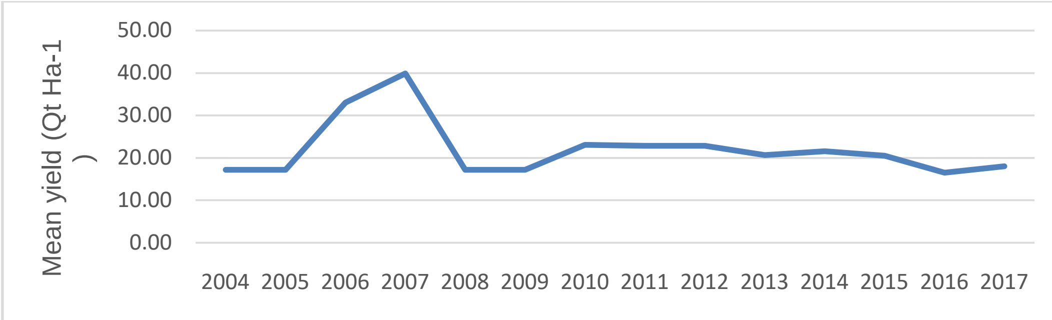

Fig. 7: Red pepper productivity trend (2004-2017)

h) Climate Variability Impact on Crop Production

The rainy season average rainfall has negative and insignificant impacts on maize and wheat yield; positive, and significant effects on *tef;* positive and insignificant effects on barley, sorghum and finger millet yield in the specified years. Similarly, the short season (*Belg*) rainfall has positive effects on the mean yield of major cereals. On the other hand, it imposed a negative and insignificant result on finger millet yield. The annual average temperature has also showed a positive effect on wheat, and other small cereals growing in the central zones of SNNPR (Table 1). The estimated variance coefficient of the rainy season rainfall for maize, wheat, and barley was negative and insignificant, while for *tef*, sorghum, and finger millet found to be positive, and insignificant (Table 2). The estimated coefficient in *Belg* season has positive impacts on the yield variance of all crops except finger millet. Lastly, except for the yield of barley, annual temperature showed a positive and significant effect on the yield variance of other cereal crops.

Table 1: Estimated coefficient of mean of cereal crops yield (Qt)

Description	Maize		*Tef*		Wheat		Barley		Sorghum		Finger millet	
	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE
Kirmet rainfall (ln)	-0.100	0.402	0.796*	0.404	-0.372	0.382	0.334	0.358	0.560	0.495	0.576	0.512
Belg rainfall (ln)	0.077	0.208	0.082	0.208	0.197	0.196	0.315	0.185	0.393	0.245	-0.055	0.254
Average temp	0.523**	0.196	0.902***	0.197	0.148	0.186	0.566***	0.174	1.064***	0.291	1.056***	0.301
Constant	3.661	5.642	-11.688*	5.663	10.659*	5.347	-3.506	5.016	-16.242*	8.604	-15.024*	8.896
N	19		19		19		19		14		14	
R^2	0.385		0.584		0.167		0.452		0.605		0.601	
Adjusted R^2	0.263		0.501		0.001		0.342		0.487		0.482	

*Notes: ***, ** and * are significant at 1%, 5% and 10% probability level, SE stands for standard error.*

Table 2: Estimated coefficient of variance of cereal crops yield (Qt)

Description	Maize		*Tef*		Wheat		Barley		Sorghum	
	β	SE	β	SE	β	SE	β	SE	β	SE
Kirmet rainfall (ln)	-0.045	(0.929)	0.380	(0.703)	-0.162	(0.722)	-0.479	(0.758)	0.779	(2.328)
Belg rainfall (ln)	-0.605	(0.478)	0.071	(0.363)	0.473	(0.372)	-0.171	(0.391)	2.746**	(1.153)
Average temperature	0.994*	(0.452)	0.753**	(0.343)	1.022**	(0.352)	-1.222***	(0.369)	3.312**	(1.366)
Constant	8.489	(12.486)	5.375	(9.854)	2.418	(10.113)	51.665***	(10.618)	-67.50	(40.44)
N	19		19		19		19		14	
R^2	0.356		0.246		0.421		0.429		0.516	
Adjusted R^2	0.227		0.095		0.305		0.315		0.371	

*Notes: ***, ** and * are significant at 1%, 5% and 10% probability level, SE stands for standard error.*

The seasonal average rainfall observed during the periods 1998 to 2017 has imposed positive and insignificant impacts on the mean yield of faba bean, and common bean. On the other hand, the average temperature in the area has a positive and significant impact on both crop's mean yields (Table 3).The estimated variance coefficient of the rainy, and short season's rainfall for faba bean yield found to be positive and insignificant. On the other hand, it was a positive and significant for common be an yield. Lastly, annual temperature showed a positive and insignificant effect on the variance of faba bean and a positive and significant effect on the variance of haricot bean yield.

Table 3: Estimated coefficient of mean of pulse crops yield (Qt)

Description	Faba bean		Common bean	
	β	SE	β	SE
Kirmet rainfall (ln)	0.460	(0.343)	0.861	(0.721)
Belg rainfall (ln)	0.145	(0.177)	0.598	(0.372)
Average temperature	0.675***	(0.167)	1.708***	(0.352)
Constant	-6.473	(4.809)	-32.608***	(10.099)
N	19		19	
R^2	0.522		0.625	
Adjusted R^2	0.426		0.550	

, *, indicates significant level at 10% and 1% probability level respectively*

Table 4: Estimated coefficient of variance of pulse crops yield (Qt)

Description	Faba bean		Common bean	
	β	SE	β	SE
Kirmet rainfall (ln)	-0.203	(1.507)	1.955	(1.431)
Belg rainfall (ln)	-0.563	(0.778)	1.498*	(0.738)
Average temperature	1.051	(0.735)	3.271***	(0.698)
Constant	3.521	(21.12)	-65.782***	(20.052)
N	19		19	
R^2	0.188		0.618	
Adjusted R^2	0.025		0.543	

** and ***, indicates significant level at 10 and 1% probability level respectively*

A part from the technological availability of the crops, the regression coefficient also revealed that the seasonal rainfall and temperature imposed positive effects on the mean yield of taro, sweet potato, coffee, and red pepper from 2002 to 2017 (Table 5). Synonymously, the seasonal rainfall and annual temperature showed a positive effect on the variance of sweet potato, taro, coffee, and red pepper growing in central zones of SNNPR over 19 years (1998 to 2017).

Table 5: Estimate of coefficient of mean root crops and coffee yield (Qt)

Description	Taro		Sweet potato		Coffee		Red pepper	
	β	SE	β	SE	β	SE	β	SE
Kirmet rainfall (ln)	0.919	(1.201)	0.807	(0.803)	0.985	(0.697)	0.649	(0.627)
Belg rainfall (ln)	0.250	(0.631)	0.379	(0.422)	0.116	(0.367)	0.079	(0.312)
Aver.temp.	2.393***	(0.719)	1.148**	(0.481)	1.044**	(0.418)	0.898**	(0.369)
Constant	-43.178*	(20.903)	-17.062	(13,97)	-17.09*	(12.14)	-11.71*	(10.929)
N	15		15		15		14	
R^2	0.538		0.350		0.364		0.386	
Adjusted R^2	0.412		0.173		0.190		0.202	

****, ** and * indicates significant level at 1%, 5% and 10% probability level respectively*

Table 6: Estimated coefficient of variance of root crops and coffee yield (Qt)

Description	Taro		Sweet potato		Coffee	
	β	SE	β	SE	β	SE
Kirmet rainfall (ln)	3.487	(5.213)	0.829	(2.483)	2.512	(1.846)
Belg rainfall (ln)	2.161	(2.740)	0.862	(1.305)	0.266	(0.970)
Average temperature	7.154**	(3.126)	1.914	(1.489)	2.811**	(1.107)
Constant	-157.001	(90.753)	-22.889	(43.224)	-51.96	(32.202)
N	15		15		15	
R^2	0.343		0.151		0.373	
Adjusted R^2	0.164		0.081		0.202	

***, indicates significant at 5% probability level*

V. Discussions

a) *Climate Variability Trends*

Climate change refers to a change in the state of the climate that can be identify by changes in the mean and the variability of its properties that persists for decades (IPCC, 2007). It is the fluctuations in the patterns of climate over long periods (Ngaira, 2007). If the changes in climate parameters such as a change in temperature, precipitations, sea levels, and soil moisture show year-to-year variations or cyclical trends, it is known as climate variability (IPCC, 2007). Given other non-climatic drivers of environmental and human-made conditions, the change in climate parameters such as a change in temperature, precipitation, or rainfall patterns affects crop yield and productivity. The climate attributes such as the rise in temperature, the variation in frequency and intensity of precipitation, the increase in the level of CO_2 available for photosynthesis have a direct impact on agricultural productivity (Nastis et al., 2012).

The rainfall in most Ethiopian parts is characterize by seasonal and inter-annual variability (Seleshi & Zanke, 2004). In rain-fed agriculture, rainfall is the most important climatic factor influencing the growth of crops. Crops need water for their growth, photosynthesis of making their food, and to their overall performance. Rainfall provides water that serves as a medium through which nutrients transport for crop development (Ndamani & Watanabe, 2015). In Ethiopian agricultural activity, rainfall is the prime and important source of water to grow crops. The year-to-year variations and the aggregate long-run rainfall variability have imposed an impact on crop yield. Excessive rainfall condition such as flooding has a negative and devastating consequences on crop production. On the other hand, low rainfall or precipitation results in severe drought occurrence that results in crop failure by lowering its productivity that ultimately affects the farming community. The climatic condition of the central zones indicates that the variability in seasonal rainfall is higher in the short rainy than the rainy season and results in low crop yield.

Similar to the change in rainfall pattern, high temperature is likely to reduce crop productivity that a high-value perennial crops are starting to be negatively affected by the rise in temperature (Pereira, 2017). Temperature increase posed positive and negative effects on crop yields; it has adverse effects in reducing the yield and quality of crops (Adams et al., 1998). Temperature increases lead to higher respiration rates, shorten seed formation and grain filling period and lowers biomass production, and finally reduces crop yield. The increased temperature for the last two decades in all weather stations of SNNPR has shown a signal to a climate change as a whole. The fluctuations in average minimum, maximum, annual temperature, and average sunshine duration showed the climate variability scenarios of the areas. During the periods 1994 to 2017, the overall average temperature ranged from 20.26 to 21.24 ℃ for the highest peak characterized by adverse weather conditions resulted in low crop yield. The change in average temperature from 19.89 to 21.24 ℃ amounted to 1.35 ℃ has imposed a negative impacts on crop yield.

b) *Productivity Trend of Crops*

The productivity of crops depends on soil fertility, management practices, agro climatic conditions, and other practices applied in the area. The commonly grown cereals in the central zones of SNNPR are maize, *tef*, wheat, barley, sorghum, and finger millet. Sorghum and finger millet grow at low land parts where the relative humidity is less and physiologically demanded short rains. Typically, from the central zones of SNNPR, the whole Halaba and part of Gamo Gofa dominantly cultivate sorghum and finger millet as an adaptation strategy to overcome the excessive heat and moisture stress. Faba bean, and common bean are the dominant pulse crops growing in central zones. The productivity of faba bean and common bean showed an increasing trend and, in some years, when the climatic conditions were not favorable, it showed a declining trend. The lowest yield productivity of common bean was 6.65 Qt ha^{-1} in 1998 (CSA, 1998) and showed an increment of threefold in 2017(CSA, 2017).

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Due to the favorable agro-ecological conditions, soil type, indigenous practices, and improved technology availability of root crops, southern Ethiopia leads to in producing and consuming root crops. *Enset* (false banana), taro, sweet potato, cassava, and yam are the dominant root crops utilized as stable food sources, and supplied to the local and national markets. Due to the introduction of high yield varieties, improved agronomic practices, and consumer preferences to taro and sweet potato as substitute food against high priced cereals crops, the productivity has increased dramatically from an average of 83.4 and 101 Qt ha^{-1} to 336.4 and 378 Qt ha^{-1} for taro and sweet potato respectively (CSA, 2015). The mean productivity of taro in central zones is higher than the national average recorded in 2015 (297.76 Qt ha^{-1}), and the productivity of sweet potato is approximately equivalent to the national average, i.e. 455.8 Qt ha^{-1}. Most of the zones in southern Ethiopia are coffee producing, supplying, and exporting coffee. Apart from the non-climatic factors, the possible reason for low yield is the climatic effect that aggravates the coffee berry borer disease that adversely affects its productivity.

c) *Climate Variability Impact on Crop Production*

The IPCC report revealed that climate change and variability have multifaceted effects and impacts on people and the natural environment (IPCC, 2007). Climate change and fluctuations become a global issue(Pereira, 2017; Ngaira, 2007), affecting billions of people, including the natural environment. Climate variability has posed positive and negative impacts on agriculture by lowering and increasing production, productivity and affecting product quality. A study made in Rwanda noted that climate variability is one of the factors affecting year-to-year crop production (Mikovaet al., 2015). In the farming community whose agricultural activities are rainfed type, the change in climate element, mainly the change in temperature and precipitation level, affect production and productivity of crops (Shumetie et al., 2017).

High temperatures and changes in rainfall patterns impose negative impacts on cereal crop productivity (Pereira, 2017). Main season average rainfall has a negative consequences on maize and wheat yield; positive effects on *tef,* barley, sorghum, and finger millet yield. The negative impacts of rainfall patterns on maize and wheat yield were associated with the prevalence of vast rust and viral diseases that lowered the productivity of both crops in SNNPR. Moreover, maize water requirement for its growth and physiological maturity depends on the seasons that the major maize producing areas of SNNPR plant it during the onset of the short rainy season (usually from March to April). The negative estimated coefficient of mean yield of finger millet witnessed that it is usually plant at the end of the rainy season due to its low requirement of moisture and high soil temperature.

The seasonal change in rainfall showing positive coefficients of variance on the yield of cereal crops revealed an increase in covariates whose effects on crop yield lead to a higher yield variance or vice versa holds. Thus, the estimated variance coefficient of the rainy season rainfall on maize, wheat, and barley were negative resulted in lower yield variance. While for *tef*, sorghum, and finger millet it was positive and hence higher yield variance. The estimated coefficient in *belg* season has positive and insignificant impacts on the mean yield and variance of all crops except finger millet. Lastly, except for the production of barley, annual temperature showed a positive association and significant effect on the yield variance of other cereal crops.

Inter-seasonal rainfall and change in temperature have impacts on pulse crops, coffee, and on the yield of bi-annual crops such as taro and sweet potato. Faba bean and common bean yield hada positive association with seasonal rainfall patterns and to the average temperature. The coefficient estimation of mean yield was synonymous with the increasing productivity trend of both crops during the specified periods. When, there is an adverse climatic condition like low precipitation and excessive heat, it adversely affects crop yield and quality. For the periods 1994 to 2017, given other technological and input supply conditions, the productivity of coffee in study areas has not shown significant change, ranging between 4.38 and 6.94 Qt Ha^{-1}(CSA, 2013). The estimated coefficient in the stochastic production function also verified that the inter-seasonal climate variability showed an insignificant effect on the mean yield of coffee.

d) *Adaptation and Mitigation of Climate Change*

The farming community living in the different agro-ecological system have different climate resilience-building strategies to cope up the risks. A study made by Tessema and Simane (2019) in Fincha'a sub-basin of the upper Blue Nile basin in Ethiopia reported that farmers living in agroecology to high exposure to climate change with low adaptive capacity have exercised high vulnerability and conversely those living in low exposure with higher adaptive capacity have experienced low vulnerability shocks. Countries whose economy is largely dependent on subsistence rainfed agriculture are more vulnerable to climate change risks(Pereira, 2017). To overcome the short and long-run climate risks, countries stands differently. Apart from climate change, vulnerability in Ethiopia and other African countries emanates from limited capacity to abate or adapt against the change (ibid). The climate vulnerability is high in Ethiopia and many African countries due to the facts that, weak agricultural technological services (Belete *et al*., 1991); low supply of inputs, and few financial resources (Pereira, 2017) and limited access to infrastructure and information (Mekonnen, 2013).

Cognizant of the facts, to adapt to climate change variability and its impacts, Ethiopia developed and has implemented various strategies and initiatives. Climate Resilient Green Economy Strategy (CRG-I) in 2011(FDRE, 2011),Adaptation and Resilience Strategy (CRG-II) in 2014, the first Growth and Transformation Plan (GTP-I) and the second Growth and Transformation Plan (GTP -II) or Ethiopian five-year development plan for 2015 to 2020 are the major strategies and initiatives. These are national adaptation strategies to overcome climate change and variability in the country and different economic sectors.

In Africa in general and in Ethiopia in particular, different climate change adaptation and mitigation measures have been implemented. For example, African farmers are increasingly adopting a variety of conservation and agroecological practices such as agroforestry, contouring, terracing, mulching, and minimum tillage or no-till (Pereira Laura, 2017). Introducing and promotion of new agricultural technologies, for example, new varieties of maize and wheat accompanied by policy intervention for example credit and fertilizer subsidy is recommended as an effective adaptation option (Berger *et al*., 2017). In Ethiopia, in highly degraded and food-insecure areas including the southern region 'adaptive social protection' framework, for example, Productive Safety-Net Programme (PSNP) have been implemented to restore the productive land through different land scape measures like integrated soil and water conservation measures as climate adaptation strategies (Weldegebriel and Prowse, 2013). All climate change adaptation practices will be expected to have twin benefits of lowering carbon emissions as well as diversifying the sources of livelihoods and it reduces the vulnerability to livelihood shocks for poor farmers who depend on agriculture (Weldegebriel and Prowse, 2013; Pereira Laura, 2017).

In the agricultural sector, there are climate adaptation strategies recommended for the farming communities to practice(Weldegebriel & Prowse, 2017). To overcome the challenges of climate change and variability, the research system of the country in general and that of the regional research system developed crop suitability maps as adaptation and mitigation strategies. The South Agricultural Research Institute (SARI) released a number of disease-resistant, drought-tolerant high yielding, and early maturing taro and sweet potato cultivars. After the intervention, right from 2013, the yield and productivity of taro and sweet potato increase nearly by four folds and reached its maximum productivity in 2015 (i.e., 33.6ton Ha^{-1} taro and 37.8 ton Ha^{-1}sweet potato) (CSA, 2015). In SNNPR, taro and sweet potato have twin benefits that in one hand, it boosts agricultural productivity, and on the other hand, acts as climate-smart crops growing in the moisture stress areas.

VI. Conclusion and Recommendation

The agricultural system in SNNPR is largely rainfed and underdeveloped type that uses low technological inputs and traditional practices. Due to these facts, it has been affected by climate change, mainly by change in rainfall patterns, humidity patterns and rises in temperature. Climate change and variability reduce yield, lower the quality of agricultural products, aggravate pests and diseases, endure health, affect the natural and environmental resources, and ultimately it affects livelihood of people. The climate variability in terms of change in temperature and inter-seasonal rainfall for 1994 to 2017 showed an increasing trend imposing effects on crop yield and livestock production. On the other hand, the yield productivity trend of major crops showed very little change in yield per unit area. Akin to climate variability, the crop productivity trend for major crops showed fluctuating type in years of the favorable climatic condition it resulted in better productivity and in worst seasons it showed a decreasing trend. The stochastic production function revealed that rainfall variability on mean yield showed a positive and insignificant association, and the change in temperature indicated a positive association and significant effect for most of the major crops grown in the central zones of SNNPR.

Different adaptation measures and climate resilience-building strategies are paramount importance measures to cope with climate change and variability. Before any physical interventions, the perception level of the community about impacts on the livelihood of people, assets, and environmental resources should be raise. Introduction and use of improved crop varieties, improved practices, and land enhancing practices, irrigation, and livelihood diversification, institutional services like credit, social protection and information access are some of the adaptation strategies to climate change, and its variability. From the policy perspective, R&D should be strengthen that enable the agricultural sector and the farming community to be more climate-resilient. In conclusion, policymakers and development practitioners should give due emphasis and take sooner developmental and policy actions to manage the risks associated with climate change and variability by incorporating climate change adaptation strategies.

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Annex table 1: Rainfall mean difference test between 1994 - 2005 and 2006 - 2017

Weather station	Season	1994 – 2005		2006 -2017		MD	Test statistics	
		Mean (mm)	SD(mm)	Mean (mm)	SD (mm)		t	f
Hossana	*Belg*	430.90	91.87	397.01	112.24	33.89	0.809**	0.48
	Kiremt	562.56	47.55	640.14	94.17	-77.58	-2.548	5.125
	Bega	157.68	107.74	113.84	95.50	43.84	1.055	.009
	Annual RF	1151.14	140.05	1151.00	149.52	0.14	0.049	0.002
Hawassa	*Belg*	327.58	80.56	340.90	113.60	-13.34	-0.332	1.094
	Kiremt	458.90	80.76	499.51	117.63	-40.61	-0.986	1.737
	Bega	175.52	74.76	135.24	52.91	40.27	1.523	0.448
	Annual RF	961.99	127.69	975.67	180.16	-13.67	-0.215	1.591
HalabaKulito	*Belg*	279.93	151.39	306.38	176.55	-26.46	-0.394	0.296
	Kiremt	660.12	95.92	584.69	186.17	75.43	1.248	2.036
	Bega	92.50	50.42	55.63	62.30	36.87	1.593	0.208
	Annual RF	1032.54	201.00	946.70	289.96	85.84	0.843	0.970
WalaitaSodo	*Belg*	452.46	127.76	451.48	141.57	0.97	0.018	1.415
	Kiremt	601.50	152.84	638.18	176.24	-36.67	-0.545	0.343
	Bega	238.15	135.98	226.39	120.09	11.77	0.225	0.168
	Annual RF	1292.12	204.48	1316.05	222.61	-23.93	-0.274	0.100
GurageBuie	*Belg*	279.93	151.38	306.38	176.55	-26.45	-0.394	0.296
	Kiremt	660.12	95.92	584.69	186.17	75.43	1.248	2.036
	Bega	92.50	50.42	55.63	62.30	36.87	1.593	0.208
	Annual RF	1032.54	201.01	946.71	289.96	85.83	0.843	0.970
Arbaminch	*Belg*	412.07	105.04	387.11	105.67	24.96	0.581	0.204
	Kiremt	209.41	40.59	283.93	114.27	-74.52	-2.129*	4.179**
	Bega	269.05	137.93	273.69	111.31	-4.64	-0.091	0.005
	Annual RF	890.54	146.93	944.73	165.73	-54.19	-0.847	0.943
All stations	*Belg*	363.81	136.88	364.88	145.68	-1.07	-0.045	0.060
	Kiremt	525.43	181.82	538.52	190.92	-13.09	-0.421	0.030
	Bega	170.90	117.24	143.40	118,32	27.49	1.401	0.563
	Annual RF	1060.14	212.48	1046.81	258.01	13.33	0.339	0.658

Source: Computed from NMSA, 1994 to 2017

****, ** and * indicate the significance level at 1%, 5% and 1% probability level, SD is standard deviation*

Annex table 2: Temperature mean difference test between 1994 - 2005 and 2006 - 2017

Weather station	Temperature in ℃	1994 - 2005		2006 -2017		Mean	Test statics	
		Mean	SD	Mean	SD	difference	t	f
Hossana	Average Max. Temp	22.58	0.27	23.31	0.41	-0.73	-4.999***	2.836
	Average Min. Temp	10.8	0.31	10.79	0.69	0.01	0.037	8.887***
	Average Temp	16.70	0.23	17.04	0.45	-0.34	-2.270**	3.204*
Hawassa	Average Max. Temp	27.42	0.33	27.73	0.53	-0.32	-1.766*	2.893
	Average Min. Temp	12.83	0.40	13.73	0.58	-0.91	-4.462***	1.482
	Average Temp	20.11	0.22	20.73	0.44	-0.62	-4.309***	3.170*
HalabaKulito	Average Max. Temp	27.78	0.34	29.13	0.79	-1.35	-5.409***	2.284
	Average Min. Temp	13.53	0.42	15.25	2.40	-1.72	-2.437**	20.277***
	Average Temp	20.66	0.29	22.19	1.44	-1.53	-3.622***	13.243***
WalaitaSodo	Average Max. Temp	25.38	0.32	25.63	0.52	-0.25	-1.404	2.329
	Average Min. Temp	14.46	0.30	15.09	0.66	-0.63	-3.022***	3.381*
	Average Temp	19.92	0.22	20.36	0.48	-0.45	-2.938***	3.441*
Arbaminch	Average Max. Temp	30.53	0.31	30.83	0.56	-0.30	-1.606	3.377*
	Average Min. Temp	17.06	0.46	17,60	0.56	-0.54	-2.586**	0.665
	Average Temp	23.80	0.29	24.22	0.43	-0.42	-2.765**	3.215*
All stations	Average Max. Temp	26.81	2.65	27.33	2.71	-0.52	-1.053	0.295
	Average Min. Temp	13.78	2.08	14.49	2.53	-0.71	-1.664*	2.387
	Average Temp	20.29	2.26	20.91	2.49	-0.61	-1.400	1.134

Source: Computed from NMSA, 1994-2017 weather station data

****, **and * indicates significant at 1%, 5% and 10% probability level respectively*

Annex table 3: Crop productivity mean difference test between 1998 - 2005 and 2006 - 2017

Crops type	1998-2005		2006-2017		Mean	Test statistics	
	Mean	SD	Mean	SD	difference	t	f
Maize	16.98	4.35	25.80	7.22	-8.82	-7.518***	17.547***
Tef	7.18	1.65	11.23	2.24	-4.05	-9.848***	4.036**
Wheat	14.40	3.4	19.52	4.63	-5.11	-5.881***	2.824*
Barley	12.47	3.19	16.56	5.08	-4.09	-4.168***	4.457**
Sorghum	10.19	3.69	14.56	3.74	-4.37	-2.401*	0.062
Finger millet	11.20	2.14	13.65	2.82	-2.45	-1.421	0.734
Faba bean	11.66	2.3	16.81	4.61	-5.15	-5.591***	43.589***
Common bean	7.93	1.92	12.46	3.37	-4.53	-7.581***	7.782***
Potato	83.22	15.13	133.62	64.14	-50.40	-2.034*	35.279***
Sweet potato	97.79	13.14	149.15	85.06	-51.36	-3.461***	10.220***
Taro	77.53	2.90	158.42	96.13	-80.89	-2.034*	35.279***
Coffee	5.14	1.01	5.78	2.29	-0.63	-1.602	5.768**
Red pepper	17.14	0.00	23.08	7.57	-5.94	-2.716**	1.705

Source: Agricultural sample survey of CSA (1998-2017)

****, ** and * indicates significant at 1%, 5% and 10%probability level respectively*

Annex table 4: Crop productivity mean difference test (zonal) between 1998-2005 & 2006-2017

Zone	Crops type	1998-2005		2006-2017		Mean difference	Test statistics	
		Mean	SD	Mean	SD		t	f
Sidama	Maize	17.63	2.05	27.83	6.37	-10.21	-5.109***	22.796***
	Tef	6.17	1.20	9.98	2.48	-3.81	-3.651***	2.840
	Wheat	13.28	1.39	17.10	3.92	-3.82	-2.517**	8.434**
	Barley	11.06	1.73	14.66	3.23	-3.60	-3.16***	2.435
	Faba bean	10.50	2.19	14.83	4.22	-4.33	-2.932***	2.111
	Haricot bean	8.15	2.24	13.18	3.01	-5.03	-4.149***	0.031
	Sweet potato	101.2	7.24	110.96	23.58	-9.76	-1.222	4.168*
	Coffee	5.45	1.19	8.01	2.47	-2.56	-2.576**	1.301
Gurage	Maize	21.13	2.67	30.17	7.77	-9.04	-3.674***	22.98***
	Tef	7.39	1.25	11.79	2.12	-4.39	-5.668***	2.825
	Wheat	14.33	4.29	21.33	2.59	-6.99	-3.886***	2.644
	Barley	15.74	2.13	21.73	5.07	-5.99	-3.581***	14.271***
	Faba bean	13.32	2.67	17.89	4.91	-4.57	-2.627**	5.20**
	Potato	83.22	15.13	133.62	64.14	-50.40	-2.282**	4.685*
	Coffee	3.95	0.74	3.15	1.29	0.80	1.421	0.467
Hadiya	Maize	16.01	1.09	24.91	7.32	-8.89	-4.127***	22.764***
	Tef	8.50	1.43	11.64	2.26	-3.13	-3.694***	0.989
	Wheat	16.55	3.06	22.76	3.82	-6.21	-3.886***	1.764
	Barley	11.54	3.62	16.99	4.16	-5.46	-2.997***	0.517
	Faba bean	11.16	0.98	17.71	4.39	-6.55	-4.959***	13.211
	Haricot bean	8.47	1.57	11.74	2.72	-3.27	-3.315***	1.506
	Coffee	5.34	0.67	5.71	0.83	-0.36	-0.804	0.238
Walaita	Maize	15.70	5.39	22.46	4.54	-6.76	-1.998	0.006
	Tef	5.7	0.29	10.93	2.11	-5.19	-8.218***	6.48**
	Wheat	13.61	2.31	17.32	4.15	-3.72	-2.071*	1.715
	Haricot bean	7.62	1.48	11.37	31.8	-3.74	-2.69**	6.017**
	Taro	78.13	3.23	175.50	113.6	-97.37	-2.965**	31.956***
	Sweet potato	100.9	22.21	195.76	121.3	-94.82	-2.542**	16.913***
	Coffee	6.17	0.62	7.35	1.40	-1.18	-2.203*	2.124
GamoGofa	Maize	8.59	4.34	23.43	8.69	-14.84	-4.185***	5.117**
	Tef	6.2	0.79	11.63	2.36	-5.43	-6.602***	0.977
	Wheat	10.68	1.73	16.08	3.92	-5.40	-3.582***	0.938
	Barley	10.32	0.94	12.86	2.93	-2.54	-2.523**	2.227
	Sorghum	7.66	1.77	12.92	3.37	-5.26	-3.722***	0.884
	Haricot bean	5.99	1.49	11.70	3.11	-5.70	-4.595***	4.651**
	Taro	76.92	3.08	141.35	76.04	-64.43	-2.925**	40.836***
	Sweet potato	91.25	6.91	140.74	60.91	-49.49	-2.744**	25.912***
	Coffee	4.83	0.51	4.68	0.90	0.15	0.389	1.247
Halaba	Maize	18.12	2.99	26.00	6.42	-7.88	-2.801*	1.845
	Tef	8.91	3.13	10.89	2.29	-1.98	-0.856	0.252
	Wheat	16.74	4.68	21.85	4.75	-5.11	-1.426	0.123
	Sorghum	13.99	0.45	16.21	3.47	-2.22	-2.108*	2.297
	Finger millet	11.20	2.15	13.65	2.82	-2.45	-1.421	0.734
	Haricot bean	8.60	3.01	14.32	3.68	-5.72	-2.062*	1.138
	Red pepper	17.14	00	23.08	7.57	-5.94	-2.716**	1.705

Source: Agricultural sample survey of CSA (1998-2017)

****, **, * indicates significant at 1%, 5% and 10% probability level respectively*

The t-test indicates for equality of means and f-test for equality of variances