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Impacts and Challenges of Seasonal Variabilities of El Niño and La Niña on Crop and Livestock Production in The Central Rift Valley of Ethiopia: A Review

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Abstract

In the view of seasonal climate variabilities, climate is the primary determinant of agricultural productivity. The El-Niño-Southern Oscillation (ENSO) is the most important coupled ocean atmosphere phenomenon to cause global climate variability on inter-annual time scale. Furthermore, El-Niño and La-Niño would create severe reduction of rainfall and severe drought, leading to reduction of pasture and water availability that cannot support the livestock population, as a result of this phenomenon, the livestock population showed a decreasing trend drought. The El Niño and La Niña phase are marked by a deep layer of warm ocean water and of cooler than average ocean temperatures across the eastern and central equatorial Pacific region respectively. More than half of the El-Niño and La-Nina events coincided with lower rainfall distribution and reducing livestock population and higher mortality and off-take rate of cattle and sheep over the area. Drought following El Niño caused 50 to 90% crop failure, in the eastern parts of Ethiopia.

Key words: Climate variability; Crop production; El-Niño; La-Niño; Livestock production

Introduction

The El-Niño-Southern Oscillation (ENSO) is the most important coupled ocean atmosphere phenomenon to cause global climate variability on inter-annual time scale. Basically, the phenomenon is related to the quasi periodic redistribution of heat across tropical Pacific region. ENSO is characterized by a varying shift between a neutral phase and two extreme phases such as El Niño and La Niña. The El Niño phase is marked by a deep layer of warm ocean water across the eastern and central equatorial Pacific region. La Niña related condition is opposed to those of El Niño a deep layer of cooler than average ocean temperatures across the east-central equatorial Pacific region. Monthly and spatially Sea Surface Temperature anomaly (SSTa) and the index values of each month has been considered over the tropical Pacific region of 5°S - 5°N and 150°W - 90°W. If the SSTa index values are 0.5 or greater, between -0.5 and 0.5, and -0.5 or less for consecutive months over central and eastern and Pacific Ocean, ENSO phase is categorized as El Niño, Neutral, and La Niña, respectively [1].

Climate is the primary determinant of agricultural productivity [2]. Major economic sectors in sub-Saharan Africa are highly vulnerable to climate change and climate variability, with huge economic impacts. Agriculture remains the economic mainstay of many countries in sub-Saharan Africa, employing about 60% of the workforce and contributing approximately 30% of gross domestic product (GDP) [3]. Climate change can occur through natural physical and chemical processes and through human activities. Global atmospheric concentrations of CO2, CH4, and N2O have increased since 1750. Changes in the atmospheric concentrations of GHGs and aerosols, land cover and solar radiation alter the energy balance of the climate system; leading to climate change on the Earth. Global total annual anthropogenic GHG emissions have grown by 70% between 1970 and 2004 [4]. Application of suitable climate change adaptation and mitigation practices have played a great role in reducing the impacts of climate change on natural resources, crop production and food security. Climate change is expected to influence crop and livestock production, hydrologic balances, input supplies and other components of agricultural systems [2].

In East Africa, the agricultural sector provides livelihoods to 80% of the population and contributes about 40% of the GDP. Consequently, climate change and variability and the increasing frequency of extreme climatic events such as floods and drought in the region are threatening the food production systems, livelihoods and food security of hundreds of millions of people. Therefore, El Nino has been the most important natural calamity causing crop loss, shortage of water, food and feed for animals, and human beings and livestock in Ethiopia. In Ethiopia, the first public report on El Nino was on August 5, 1997, experts from the NMA had interview on Ethiopian TV explaining the role of El Nino in drought [5]. On the contrary, La Nina phenomena also affected agricultural production, food security causing death of human beings and livestock as a result of flooding and excess rainfall which can harm crop production. So, understanding the importance of El Nino in the Ethiopian climate and livelihood of the population; this paper has been reviewed to assess all-inclusive scientific literatures on the impact of El Nino and la Nina on crop production in Ethiopia, and to prospects climate adaptation strategies to confirm food security.

The Ethiopian Rift Valley seems attractive as a location for such evaluation, because of its ease of access and range of climates and soils, it was first necessary to establish of which areas of Africa it is representative in terms of plant environments. Ethiopia is among the most vulnerable countries in Africa due to its great reliance on climate-sensitive industries, particularly agriculture [6-10]. Furthermore, in the millennia, people have tried to understand, predict, forecast, and guess what might be the natural variations of local and regional climate

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on seasonal and on year-to-year time scales. Intra seasonal to inter annual climate variability impacts the agriculture sector and, therefore, many agricultural decisions can benefit from high-quality, reliable predictions. Emphasized that intra seasonal forecasts are considered essential for making appropriate decisions to modify strategies that reduce vulnerability for smallholder farmers. El Niño conditions are closely monitored by major meteorological institutes and forecasts are updated accordingly. The early warning provided by climate scientists each year enables governments throughout the region to discuss and implement El Niño-related contingency plans. The aim of this study was to briefly review the impacts and challenges in the seasonal variabilities of El Niño and La Niña on crop and livestock production in the central rift valley of Ethiopia.

Review of Related Literature

Concepts and definition of frameworks

La Niña is a weather pattern that occurs in the Pacific Ocean. In this pattern, strong winds blow warm water at the ocean's surface from South America to Indonesia. As the warm water moves west, cold water from the deep rises to the surface near the coast of South America. During a La Niña period, the sea surface temperature across the eastern equatorial part of the central Pacific Ocean will be lower than normal by 3 to 5 °C (5.4 to 9 °F). La Niña is a complex weather pattern that occurs every few years, as a result of variations in ocean temperatures in the equatorial band of the Pacific Ocean [11].

El Niño is severe drought and associated food insecurity, flooding, rains, and temperature rises due to El Niño are causing a wide range of health problems, including disease outbreaks, malnutrition, heat stress and respiratory diseases. Both El Niño and La Niña, the two phases of ENSO, influence rainfall, floods, dynamics and their implications for agriculture and food security. As the (Figure 1) depicted that, El Niño is a local warming of surface waters that take place in the entire equatorial zone of the central and eastern Pacific Ocean of the Peruvian coast and which affects the atmospheric circulation worldwide [12].

Generalized Walker Circulation (December-February) anomaly during El Niño events, overlaid on map of average sea surface temperature anomalies. Anomalous ocean warming in the central and eastern Pacific (orange) help to shift a rising branch of the Walker Circulation to east of 180°, while sinking branches shift to over the Maritime continent and northern South America (NOAA Climate.gov drawing by Fiona Martin).

El Niño of Southern Oscillation (ENSO); the Southern Oscillation is an East-West balancing movement of air masses between the Pacific and the Indo-Australian areas. It is associated (roughly synchronized) with typical wind patterns and El Niño, and measured by the Southern Oscillation Index (SOI) [13]. El Niño is the oceanic component, while the Southern Oscillation is the atmospheric one. This combination gives rise to the term ENSO (El Niño – Southern Oscillation). Although there is no perfect correlation between El Niño and the Southern Oscillation as regards minor variations, large negative values of the SOI are associated with warm events. Between the warm phase (El Niño) and cool phase (La Niña), scientists describe conditions as "ENSO-neutral." Neutral means that the temperatures, winds, convection (rising air), and rainfall across the tropical Pacific are near their long-term averages (Figure 2).

The overview of parts of Ethiopian Rift Valley

The Central Rift Valley (CRV) in Ethiopia located between 38°00'-39°30' E and 7°00'-8°30' N covers about one million ha and is part of the Great African Rift Valley. The Central Rift Valley in Ethiopia is a closed river basin where poverty and natural resource degradation are firmly intertwined. The rapidly growing population increasingly over-exploits the scarce natural resources in their struggle for survival. There are three major vegetation zones are found in the Rift Valley namely; the sub-humid zone, the semi-arid zone and the arid zone. Moreover, the expansion of cropland at the expense of forest, woodlands, grasslands, and water in the Central Rift Valley [14,15]. The Rift Valley of Ethiopia, like its extension in East and central Africa, was formed by extensive down faulting of the earth's crust at the end of the Tertiary and at the beginning of the Pleistocene period. It forms part of a series of fractures in the earth's crust extending from the Dead Sea in the north, via the Red Sea and the rifts of East and central Africa, to Mozambique in the south. In Ethiopia it has a general northeast to southwest trend and extends over approximately 750 km.

The climate of the Ethiopian rift valley: Ethiopia is one of the country's most vulnerable to the impacts of climate variability and change on agriculture. The present study aims to understand and characterize agro-climatic variability and changes and associated risks with respect to implications for rained crop production in the Central Rift Valley (CRV). The rainfall distribution from November to February northeast winds prevail, giving settled dry weather throughout most of the valley. During this period there is little cloud, diurnal temperatures are high and relative humidifies low. Between March and May more

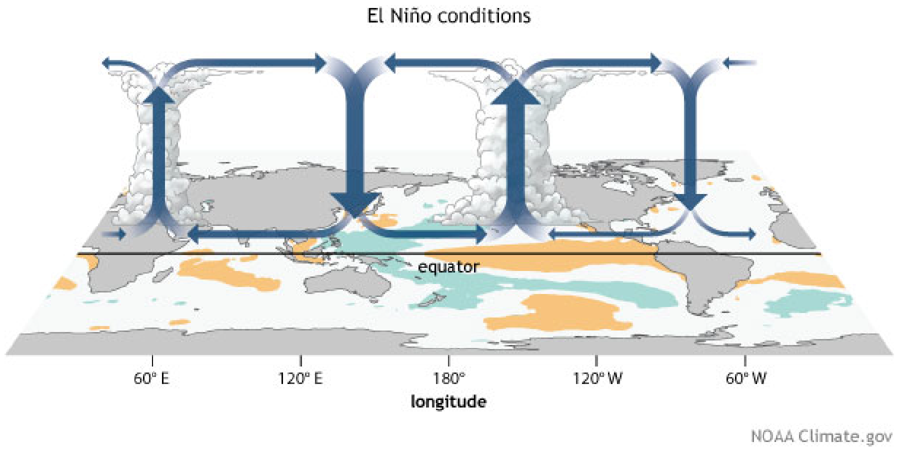

Figure 1: The overview of El Niño condition on the sea surface tempearature occurrence (NOAA Climate.gov drawing by Fiona Martin).

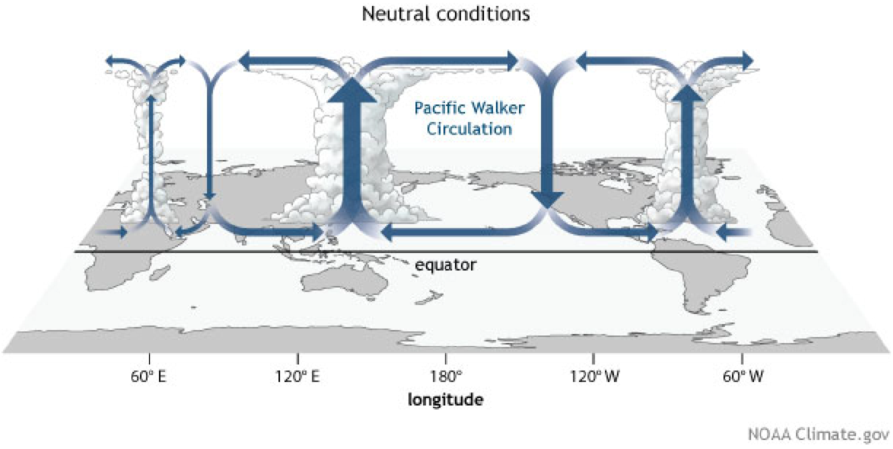

Figure 2: El Niño of Southern Oscillation between the warm phase (El Niño) and cool phase (La Niña) over the sea surface temperature.

unsettled weather is experienced due to the convergence of moist southeast winds from the Indian Ocean with the northeast airstream. There is also an emerging consensus that Eastern Africa, and particularly Ethiopia, is one of the most vulnerable regions regarding the impacts of climate variability and change [16-19]. Currently, natural climate variability is one of many factors already pushing people below the poverty trap threshold [20]. In the southern part of the valley, however, there is little rainfall between June and August and a secondary peak in September and October. Rainfall increases with altitude along the Rift Valley escarpment to an approximate annual average of 1600 mm at the 3000 m contour. However above about 1800 m the correlation of rainfall with altitude is particularly poor due to orographic effects. (Table 1) showed that, the records for temperatures from stations in the Rift Valley are even fewer and more fragmentary than those for rainfall, and to date data have been obtained for only 13 stations. There is a reasonable correlation between temperature and altitude: on average mean annual temperatures decrease by approximately 1.55°C for every 100 m increase in altitude.

Highest monthly temperatures are normally recorded in the dry season between November and March. Lowest monthly minimum temperatures are also recorded during the dry season when night skies are clear. The incidence of low temperatures may influence the growth of plants at altitudes above 1400 m. It is known that many tropical legumes cease to grow at temperatures between 10 and 12°C and that some show considerable limitation in growth at around 15°C [21].

Role of climate in the trend and variability of Ethiopia's cereal crop yields: Climate variability and change are among the major environmental challenges of the 21st century. The atmospheric concentration of greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxide has substantially increased over time. Climate variability and change impacts directly or indirectly on all economic sectors to some degree, but agriculture is among the sectors most sensitive and inherently vulnerable to climate variability, and climate change is most likely to increase this vulnerability [7,22-27]. The impacts of increased temperature from global warming and changes in rainfall patterns resulting from climate change are expected to reduce agricultural production and put further pressure on marginal land [28,29].

Ethiopian agriculture and in general the economy, and climate are highly intertwined. (Figure 3) shows the correlation between rainfall variability and the overall performance of the country´s GDP: years of poor rainfall were associated with low, whereas years with high rainfall were associated with high country ‘s total and agricultural GDP [7]. Climate variability, particularly rainfall variability and associated droughts have been causes for food insecurity in Ethiopia [30,31]. Climate change is expected to pose more challenges and to further reduce the performance of the economy [32]. A study on mapping poverty and vulnerability in Africa identified Ethiopia as one of the country’s most vulnerable to climate variability and change [33].

The characterization of seasonal climate variability in central rift valley of Ethiopia

The Upper Awash River rises from the high plateau of central Ethiopia near Ginchi town, west of Addis Ababa and extends to Koka dam. Upper Awash Basin (UAB) is part of lands where all digital elevation maps are located about 1500 m above sea level [34]. The major agricultural crops grown in the area are cereals, pulses, and oil seeds [35]. In the UAB, the rainfall is highly characterized by inter annual and inter seasonal variation. The rainfall type of UAB is bimodal type, which are two rainy seasons and one dry season. The belg (FMAM) rainy season extends from February to May. Major rain bearing systems during the belg season are the development of thermal low over South Sudan, generation and propagation of disturbances over the Mediterranean Sea, sometimes coupled with easterly waves, development of high pressure over the Arabian Sea, the interaction between mid-latitude depressions and tropical systems accompanied by troughs and the subtropical jet and occasional development of the Red Sea Convergence Zone (RSCZ) [36,37].

Kiremt (JJAS) main rainy season covers the period from June to September. Major rain producing systems during kiremt season includes northward migration of ITCZ, development and persistence of the Arabian and South Sudan thermal low along 20oN latitude, development of quasi-permanent high pressure systems over south Atlantic and south Indian Oceans, development of tropical easterly jet and the generation of low level Somali jet that enhance low level south westerly flow [36,38]. Under such circumstances, crop yield values of each year in Upper Awash Basin (UAB) and associated ENSO phase is needed into a simple tool that allows users to customize the output of its specific situations. Therefore, the research study was conducted with the objectives of determining the influences of ENSO on the local areal rainfall pattern, and determining impacts of ENSO phase on major cereal crop productivity.

Station	Altitude (m)	No. of years	Ann. mean (Min.°C)	Ann. mean (Max.°C)	Ann. mean (°C)
Asela	1700	10	12.7	28.4	20.6
Alaba Colito	1800	10	11.5	26.4	18.9
Awassa	1680	12	11.5	26.8	19.1
Bekewle (Conso)	1380	6	16.9	27.3	22.1
Gato	1320	3	18.6	31.1	24.9
Mega	1700	6	14.2	23.1	18.6
Melka Guba	not known	3	18.6	32.0	25.3
Miereb Abaya	1290	4	17.1	31.2	24.1
Moyale	1200	2	19.1	29.8	24.5
Neghelli	1480	20	12.7	25.7	19.2
Tertele	1460	2	16.9	26.9	21.9
Wondo Chabicha	1800	11	11.3	26.3	18.9
Yavello	1740	13	13.1	25.2	19.1

Table 1: Mean annual temperatures for some stations in the Rift Valley.

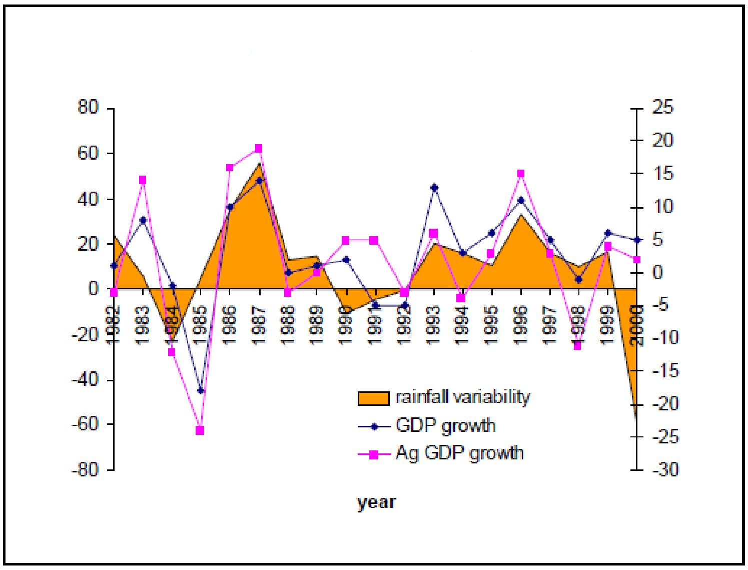

Figure 3: Effect of rainfall variability on total and agricultural GDP in Ethiopia (Adapted from World Bank, 2006).

The climate of Africa is warmer than it was 100 years ago and model-based predictions of future GHG induced climate change for the continent clearly suggest that this warming will continue and, in most scenarios, accelerate [39,40]. Observational records show that during the 20th century the continent of Africa has been warming at a rate of about 0.05°C per decade with slightly larger warming in the June–November seasons than in December–May [39]. By 2000, the five warmest years in Africa had all occurred since 1988, with 1988 and 1995 being the two warmest years. This rate of warming is not dissimilar to that experienced globally, and the periods of most rapid warming the 1910s to 1930s and the post-1970s occur simultaneously in Africa and the rest of the world [41]. The long rains (March–May) are less variable, so inter-annual variability is related primarily to fluctuations in the short rains. These are also linked more closely to large-scale, as opposed to local, atmospheric and oceanic factors. Rainfall fluctuations show strong links to ENSO phenomenon, with rainfall tending to be above average during ENSO years [42]. The importance of short rains for inter-annual variability is underscored in (Figure 4) which compares annual time series of rainfall for the region as a whole with the corresponding time series for four seasons. A visual comparison shows that the similarity is strongest with October–November rainfall. This is confirmed by linear correlation coefficients: the correlation between October–November departures and annual departures is 0.71, compared to 0.53 between April–May and annual rainfall departures [42]. DJFM = December, January, February and March; JJAS = June, July, August, and September; AM = April, May; ON = October, November.

Impact of El niño and la niña on agriculture in Ethiopia

El Nino and La Nina result from interaction between the ocean and the atmosphere in the tropical Pacific. The increase in the temperature of the surface water bodies is part of the oceanic response to the altered atmospheric conditions, especially the changes in the trade winds over the Pacific Ocean El Nino has been the most important natural calamity causing crop loss, shortage of water, food and feed for animals, and human beings and livestock in Ethiopia [43]. On the contrary, La Nina phenomena also affected agricultural production, food security causing death of human beings and livestock as a result of flooding and excess rainfall which can harm crop production. However, El Niño could produce other climatic impacts, including flash floods or intense hurricanes that could influence the crop season, disrupting agricultural activities and damaging crops (Figure 5).

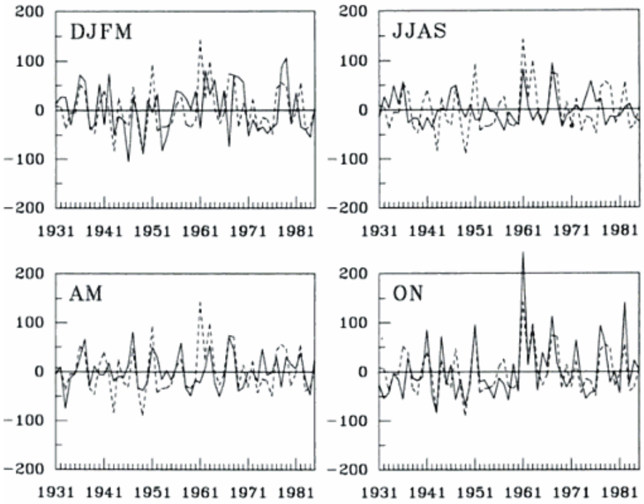

Figure 4: Time series of rainfall departures for individual seasons (solid lines) compared with the annual rainfall departure series [42].

Reduction of rainfall during El-Niño and La-Niño would create severe drought, leading to reduction of pasture and water availability that cannot support the livestock population, as a result of this phenomenon, the livestock population showed a decreasing trend. In this study, more than half of the El-Niño and La-Nina events coincided with lower rainfall distribution and reducing livestock population and higher mortality and off-take rate of cattle and sheep. Livestock mainly depends on long rainy season as the short rainy season is not mostly reliable. El-Niño events were more severe than La-Niño on livestock population and mortality in the study areas. Cattle and sheep population was lower during ENSO period of the study area, while the pastoralists were forced to diversify drought tolerant species such as goats and camels. Previous studies in Afar and Borana pastoral communities testified that herd diversification were the results of shifts in vegetation from grassland to woodland [44-46].

Cereal crop yield reduction due to various ENSO phases: In the course of ENSO phase changes from normal situation, the major cereal crop productivity has decreased for overall cereal crop yield in regionalized area of the Upper Awash Basin by 10.1% and 9.1% due to El Niño and La Niña episode, respectively (Table 2). Previous studies also suggested that drought have mostly occurred due to the failure of long rainy season [47-49]. The results showed that cereal crop production in regionalized area three was more vulnerable to El Niño episode while reduction during La Niña episode is less in regionalized area three than regionalized area.

Relationships between rainfall variability and livestock population: Cattle and sheep are more affected by rainfall variability than goats and camels. The cattle and sheep population was positively correlated to sheep population (r=0.74, P<0.05). Moreover, El-Niño reduces the amount of rainfall during the long rainy season as a result of which the livestock population during this time was declined (Figure 6) whereas La-Niño suppresses the short rainy season and enhances the long rainy season rainfall distribution; as a result, reduced cattle and sheep population (Figure 7). The rain-fed agricultural production system is vulnerable to seasonal variability which affects the livelihood outcomes of farmers and landless laborers who depend on this system of agricultural production [50].

Pastoral communities mostly depend on the rainfall during the main rainy season for availability of pasture and water resources. Cattle and sheep population was lower (P<0.05) during most El-Niño and La-Niño events in the study area. In addition, the population of goat and camel were also lower during ENSO events (p>0.05). The rainfall variability is expected to limit the availability of water and feed supply. This result results are consistent with Lobell et al., 2008 who indicated rainfall variability is the cause for increase intensity and frequency of droughts that would affect the productivity of feed resources and livestock. Based on adaptability to the current rainfall variability due to ENSO events, the livestock species we studied had the following rankings: camel>goat>sheep>cattle under pastoral communities of Shingle Zone of Ethiopia.

Cattle mortality rate increased with decreasing mean annual rainfall lower than normal distribution during most ENSO events (P<0.05) in pastoral communities (Figure 8). Similarly showed the consequence of decreasing rainfall on reduction of pasture, leading to sudden decline of livestock performance and condition due to health related problems [51-53].

The El-Niño-Southern Oscillation (ENSO) and Sea Surface Temperature Variability (SSTa)

The most important feature of sea surface temperature variability that can cause large scale weather disruptions is El Niño and its counterpart La Niña [54]. According ENSO and local rainfall relationship has been made of correlation and regression methods in attempting to establish evidence of “teleconnections” that affects local rainfall patterns to [55]. According to in Ethiopia ENSO events have strongly linked with various atmospheric system and rainfall distribution [56]. The principal cause of drought in Ethiopia is asserted to be the fluctuation of the global atmospheric circulation, which is triggered by SSTa, occurring according to ENSO events.

The phenomena have significant impact on displacement and weakening of the rain producing system in the seasons. ENSO episodes and other regional systems have impact on seasonal rainfall performance and rainfall variability over Ethiopia due to remote teleconnections system (36,56-58). Hence, most of the drought years were recorded during kiremt season’s El Niño episode. Since agriculture

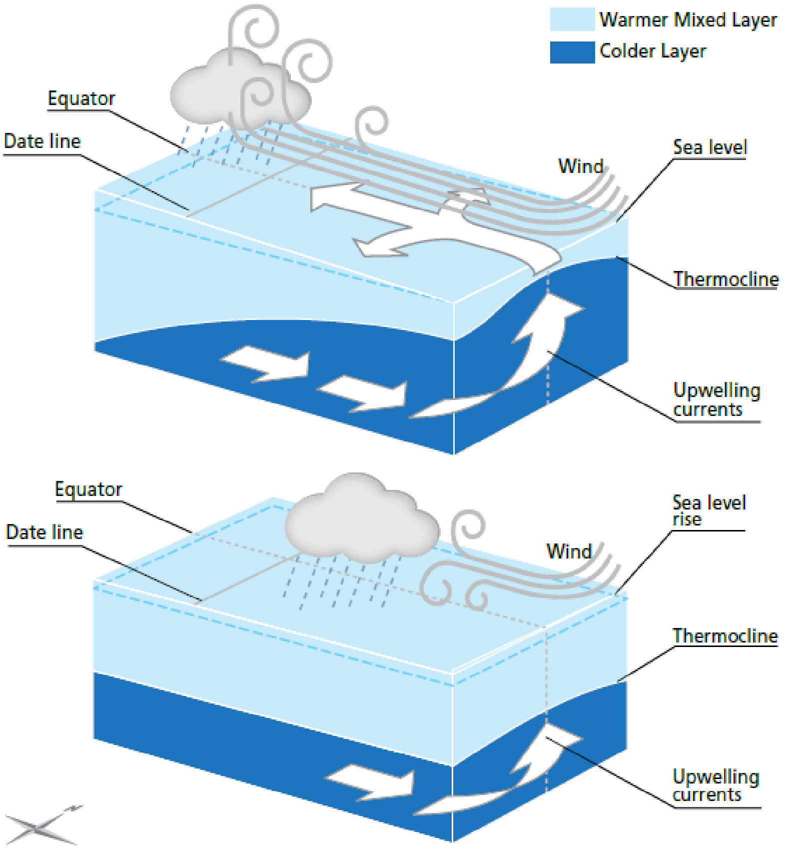

Figure 5: Normal conditions (upper part) compared with El Niño conditions (lower part) (NOAA).

Cereal crop	Average productivity (Qt/ha)	El Niño Δproductivity (Qt/ha)	Percentage change (%)	La Niña Δproductivity (Qt/ha)	Percentage change (%)
Teff	12.17	-2.0	-16.49	-0.96	-7.90
Wheat	17.9	-2.47	-13.77	-4.12	-23.02
Maize	22.2	-2.60	-11.72	1.46	+6.56
Sorghum	16.13	+0.26	+1.64	-1.97	-12.19

Table 2: Impact of ENSO events on crop productivity in regionalized area.

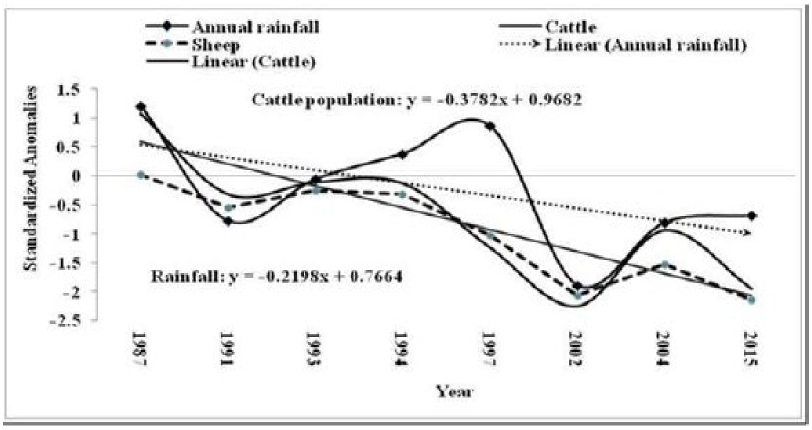

Figure 6: Trends of standardized livestock population (cattle, sheep) and rainfall anomalies observed during El-Niño episodes in Shinile Zones of Somali Region, Ethiopia, 1987 – 2015.

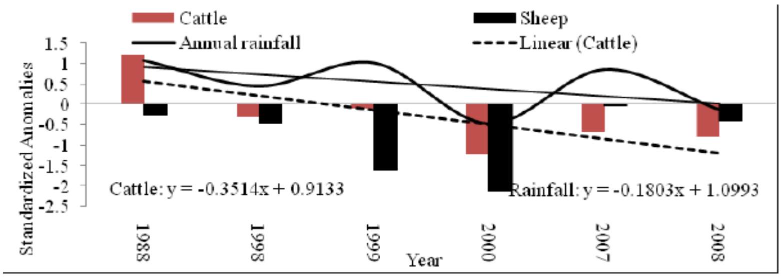

Figure 7: Trends of standardized cattle, sheep and rainfall anomalies observed during La-Niño episodes in Shinile Zones of Somali Region, Ethiopia, 1988- 2008.

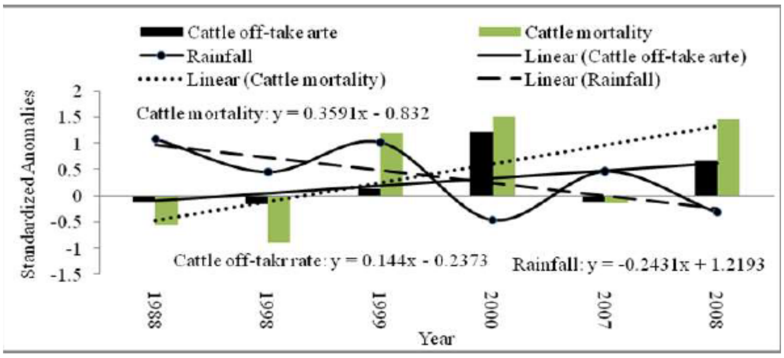

Figure 8: Trends of standardized rainfall, cattle mortality and off-take rate anomalies observed during La-Niño episodes in Shinile Zone, eastern Ethiopia.

is heavily dependent on rainfall, productivity and production are strongly influenced by climatic and hydrological variability due to ENSO phases. In Ethiopia, the degree of crop yield variability over time is determined by the amount, pattern, and frequency of rainfall [59]. Showed that ENSO-based seasonal climate reduces crop yield [60].

El nino and la nina adaptation strategies in Ethiopia

El Nino phenomenon is a natural climate calamity, disrupting the tropical climate and triggering severe drought and flood and it occurs two to seven years. The climate variability in Africa has been linked to global climate oscillating systems [61,62]. The North Atlantic Oscillations (NAO), El Lx o – Southern Oscillations (ENSO) and sea surface temperatures (SSTs) are major factors responsible for interannual variability in African rainfall (Friede richs, 2004).The government of Ethiopia is has been taking the initiative in providing adaptation and mitigation strategies and settle the livelihood of vulnerable communities in different areas around the country. Food aid, feed for animals, water, health and hygienic tools have been distributed and agriculture related interventions were distributed to Afar, Somalia, Oromia, Amhara, Tigray and other impacted areas by the government and humanitarian organizations.

Drought insurance in Ethiopia: The agricultural sector in Ethiopia is highly vulnerable to climate variability. Crop production is predominantly based on rain-fed conditions. Drought is among the major climate related natural hazards affecting crop production and livelihood of millions of people in Ethiopia. More than 85% of the population in Ethiopia depends on agriculture. However, climate variability affects crop production, animal husbandry, natural resources and food security. El Nino is one of the most negatively affecting natural calamities in Ethiopia. On the other hand, recurrent drought causes loss of crop yield, animal feed and water for animals and human beings. Therefore, as adaptation strategies for these circumstances, the government of Ethiopia provides a new insurance policy 'weather insurance' as an important risk minimization strategy for farmers reduce the impact of crop loss. Therefore, understanding the influence of global climate oscillating systems on regional rainfall variability and livestock population dynamics will significantly contribute towards development of effective pastoral management strategies to cope with drought [62].

The impacts of climate variability (El Nino and La Nina) on food security: Extreme flooding, drought, lack of potable water for livestock and domestic use, food insecurity and market imbalance are associated with El Niño and La Niña in Ethiopia. Drought following El Niño caused 50 to 90% crop failure, in the eastern parts of Ethiopia. An El Niño event increases the risk of heavy rainfall and flooding in some parts of the world, while in others, it increases the risk of drought through reduced rainfall. Climate variability, such as periods of drought and flood as well as longer-term change, may either directly or indirectly profoundly impact on all these three components in shaping food security were shown in (Figure 9). However, there are a number of significant differences regarding the circumstances and presentation of La Niña and ElNiño over the study area [63]. Firstly, due to the continuously evolving predictions concerning the likelihood and intensity of La Niña conditions in the Pacific Ocean, the scenario presented here should not be considered as definitive. Secondly, if significant La Niña conditions do develop, the impact will be felt on the back of the most intensive El Niño event on record, from which affected communities across Ethiopia have not yet recovered. According to Food security trends, both the number of undernourished people and the prevalence of undernourishment have declined steadily since 1990 (FAO/WFP, 2010) were depicted in (Figure 10). Despite significant progress in reducing undernourishment by 28 per cent in the period 1990-2005, Ethiopia is considered a least developed country and is ranked 174 out

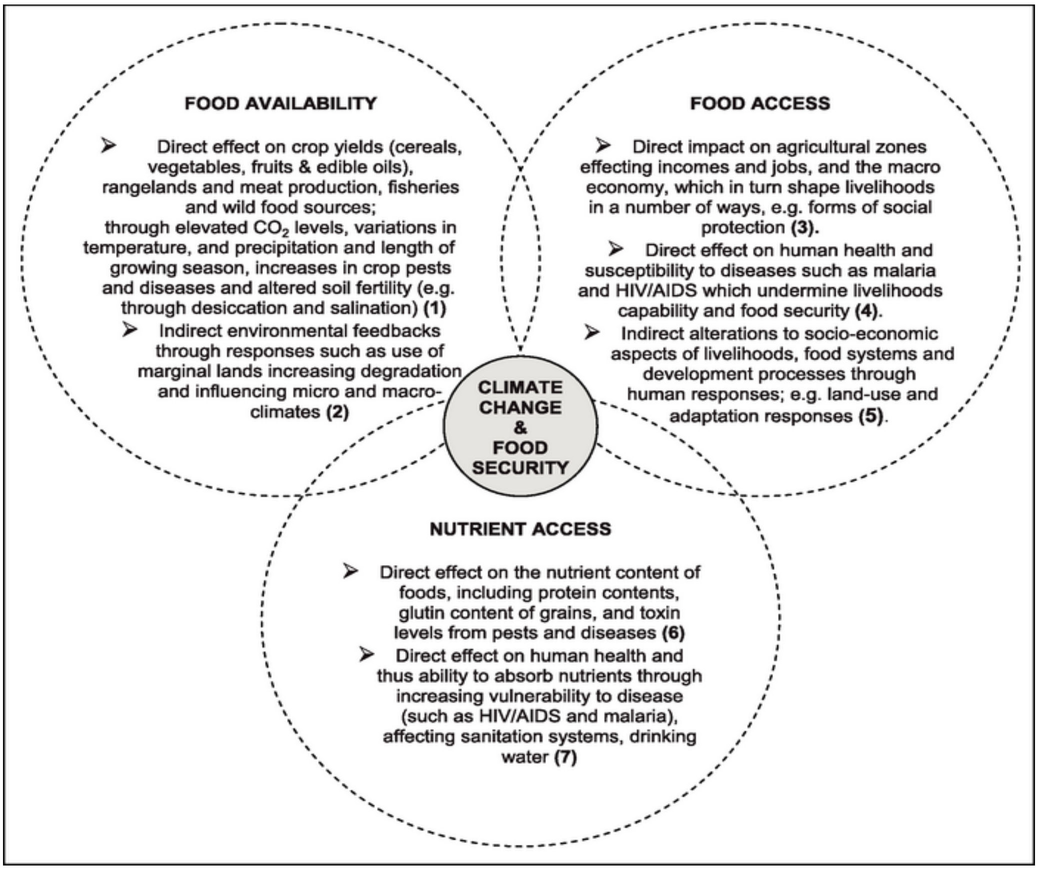

Figure 9: Linkages identified between climate change in Africa and three major components of food security Gommes et al. and Slingo et al.,[16].

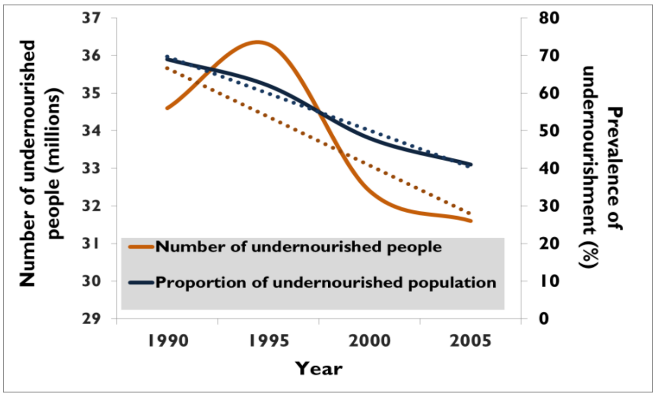

Figure 10: Trends in undernourishment as per FAO/WFP 2010.

of 187 on the Human Development Index [64]. While the 2015-2016 El Niño weather event is now over, humanitarian needs continue to grow, and are not expected to peak until early 2017 as food security continues to deteriorate in many regions. El Niño-related drought continues to affect Ethiopia, and food insecurity and malnutrition rates remain high with millions of people requiring humanitarian assistance. Humanitarian needs have tripled since early 2015 as severe drought has caused successive harvest failures. Climate impacts on food production is the predominantly rain-fed agricultural system, rainfall is one of the main climatic determinants of food production in Ethiopia. Wetter years are generally associated with higher food production; conversely dry years are linked to lower production. Furthermore, climate impacts on livelihoods across most of Ethiopia, households report lack of/erratic rainfall as the main risk contributing to their food insecurity and overall vulnerability. The poorest farmers rely especially on food-based coping strategies such as reducing the quantity or quality of meals. Similarly, they rely on livestock sales often selling their last productive female or temporary labour migration. In recent years, however, there has been limited capacity of host areas to offer employment due to increasingly erratic rainfall which is reducing labour availability. According the

the findings of the [8,23,65]. Confirm that, climate-induced risks, and in particular rainfall-related risks, are the most important causes for uncertainty in crop production in most regions of Sub-Saharan Africa.

Mainstreaming climate risk management into development and food security strategies: Integrating climate risk management structures into broader development pathways offers a cost-effective manner to address multiple development challenges, while accounting for the emerging risks posed by climate variability and change. Disaster risk reduction structure, social protection and safety nets offer critical platforms and vehicles for investing in risk management for the most vulnerable and should become a policy priority. Scaling up risk management is critical in view of a changing risk environment characterized by increasing risks as well as larger numbers of people exposed to these risks. Successful scaling up should be implemented at the community level, as well as at the national, regional and global levels by adapting successful experiences and best practices in resilience building. Therefore, adaptation to increasing climate variability is now imperative to sustain crop production in the CRV. Climate-proof strategies including better seasonal climate forecasts improved cultivars and efficient rain-water management are critical for improving rainfed agriculture [66].

Explore the adaption of agriculture to climate variability and change

Agro-climatic indices are mostly used to characterize current climate variability and extreme events as indicators for climate induced risks. Optimum planting dates which provided maximum yields occurred between end of May (day of year 141) to mid-June (day of year 169) for the baseline climate while maximum yields were simulated with planting dates between mid-June (day of year 162) and end of June (day of year 183) in climate change scenarios with slight differences between the two crop model simulations (WOFOST shows stronger response to planting dates than DSSAT) (Figure 11). This indicated that optimum planting dates will be delayed by approximately three weeks in future climate relative to the baseline climate. It should be noted that the early possible planting dates, which are dictated by the start of the rainfall season, did not shift much in the climate change scenarios because rainfall increased during April and May by 20.8 and 4.9 % (averaged over climate change scenarios), respectively (data not shown). However, rainfall in June and July was reduced by 5.9 and 5.4% (averaged over climate change scenarios), respectively, which in combination with the increased temperature reduced yields for the earliest planting dates. On the other hand, rainfall during August, September and October increased by 2.2, 3.8 and 16.8% in the future scenarios, respectively, which favored maize growth with the late planting dates. Furthermore, an integrated assessment of climate change at farm level allows accounting for resource heterogeneity and differences in socio-economic contexts to come to farm-scale adaptations [67].

The impacts of climate change and it's implication on ethiopian agriculture

According to IPCC, 2012 revealed that, the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase in the twenty-first century over many areas of the globe. Consistently, there is medium confidence that droughts will intensify in the twenty-first century in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration. The atmosphere fluctuates across different time-scales, which may range from daily weather to long-term climate change. Climate variability refers to time-scales ranging from months to decades. Climate is extremely variable particularly over the arid and semi-arid parts of Ethiopia. The annual rainfall variation is mostly associated with variation in sea surface temperature (SST) over the tropical Pacific. Warm SST (El Niño) leads to reduction in the summer rains, while the cold phase (La Niña) has the opposite effect. (Figure 12) shows an example for Kombolcha station in north-eastern Ethiopia, a region frequented by droughts. The major droughts of the 1970s, 1980s, and 1990s demonstrate the extreme climate fluctuations over this part of the country.

Climate variability also means fluctuation in crop production, whether this is due to drought or flooding. As a result, climate extremes have their most profound impact on agricultural production, which

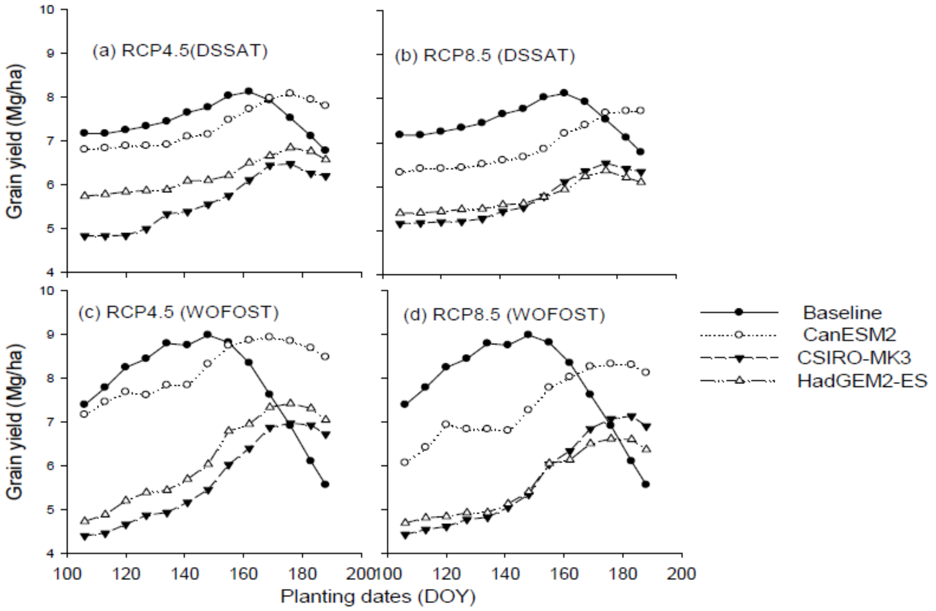

Figure 11: Effects of planting dates on maize grain yield under the baseline and future climate change scenarios in the Central Rift Valley, Ethiopia.

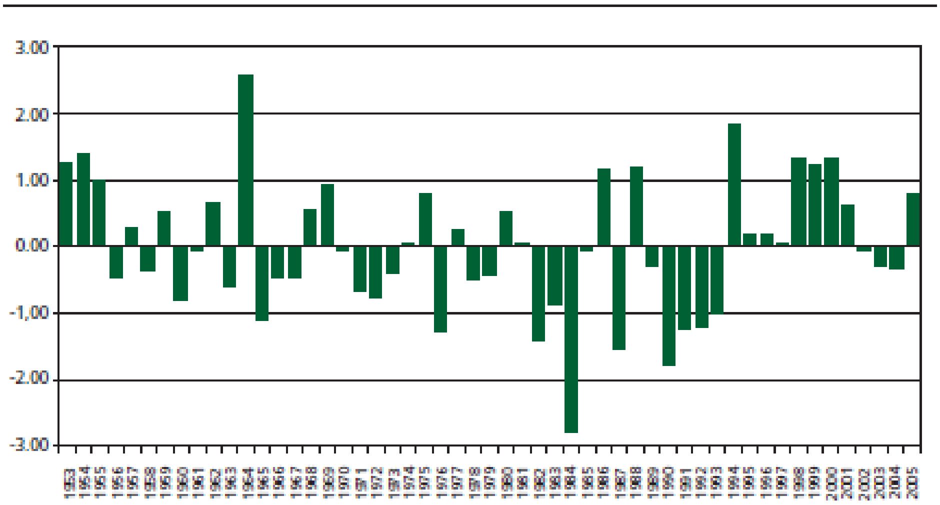

Figure 12: Standardized anomaly of June to August rainfall for Kombolcha station Ethiopia (NMA).

have been a big hindrance to the country's economic development. In addition to the seasonal rainfall totals and their season-to season variability, the distribution of the rainfall within a season is also very critical to agriculture. The occurrence of droughts and floods has been found to reduce Ethiopia's annual growth potential by more than one third [68]. It is estimated that the 1984-85 drought reduced Ethiopia's agricultural production by 21 percent, which led to a 9.7 percent fall in the GDP [7].

Crop and livestock losses over North-Eastern Ethiopia, associated with droughts during 1998-2000, were estimated at US$266 per household, which is greater than the average annual income for 75 percent of the households in this region [69]. The effect of climate variability is, of course, felt more at household levels. This is particularly true for the very poor, whose livelihood depends totally on rainfall as the sole source of moisture for crop or pasture growth. For such communities, variability in seasonal rainfall will inevitably result in highly variable production levels.

Climate risk management: Sustainable development in Ethiopia needs to take the challenge of climate variability and change into account. There should be interventions to reduce the sensitivity of the systems (household to national) to climate variability and/or improve the capacities of households and the country to cope with this impact on development. Climate risk management (CRM) is a useful approach for dealing with the effects of climate variability today, while building capacity for adaptation to climate change [70,26]. CRM informs decision-making through the application of climate knowledge and information. Effective CRM deals with the full range of variability, balancing hazard management with efforts to capitalize on opportunities [70]. CRM thereby increases resilience to short-term climate variability while increasing adaptive capacity to deal with the longer-term climate change. (Figure 13) depicted that shows the impact of drought on GDP growth during 1998 and 2002, while the impact on agriculture relative to the other economic sectors [71].

Hansen et al. (2007) describe three components of CRM:

- ➢ Effective rural climate information services that will enable farmers to adopt technology, intensify production and invest in more profitable livelihoods when conditions are favorable; to protect families and farms against the long-term consequences of adverse extremes. Systematic use of the climate information will help to reduce the uncertainty that impacts planning and decision-making.

- ➢ Information and decision support systems synthesize historic, monitored and forecast climate information into forms that are directly relevant to institutional decisions (planning, trade, food crisis response) that impact farmer livelihoods. Innovations in index-based insurance and credit to overcome some of the limitations of traditional insurance and are being applied to pre-financing food crisis response and to removing credit constraints to adopting improved technology.

Conclusion

As concluded this paper review, climate is the primary determinant of agricultural productivity. The El-Niño-Southern Oscillation is the most important coupled ocean atmosphere phenomenon to cause global climate variability on inter-annual time scale. The El Niño phase is marked by a deep layer of warm ocean water across the eastern and central equatorial Pacific region while, La Niña related condition is opposed to those of El Niño a deep layer of cooler than average ocean temperatures across the east-central equatorial Pacific region. Therefore, El Nino has been the most important natural calamity causing crop loss, shortage of water, food and feed for animals, and human beings and livestock in Ethiopia. Furthermore, La Nina phenomena also affected agricultural production, food security causing death of human beings and livestock as a result of flooding and excess rainfall which can harm crop production. Ethiopia is among the most vulnerable countries in Africa due to its great reliance on climate-sensitive industries, particularly agriculture.

The Central Rift Valley in Ethiopia is a closed river basin where poverty and natural resource degradation are firmly intertwined. In the northern rift valley, on July to October is the main rains come to the wet winds from the Indian and Atlantic oceans converging over the highlands. However, in the southern part of the valley, there is little rainfall between June and August and a secondary peak in September and October. As the results, the impacts of increased temperature from global warming and changes in rainfall patterns resulting from climate change are expected to reduce agricultural production and pressure on marginal land. Reduction of rainfall during El-Niño and La-Niño would create severe drought, leading to reduction of pasture and water

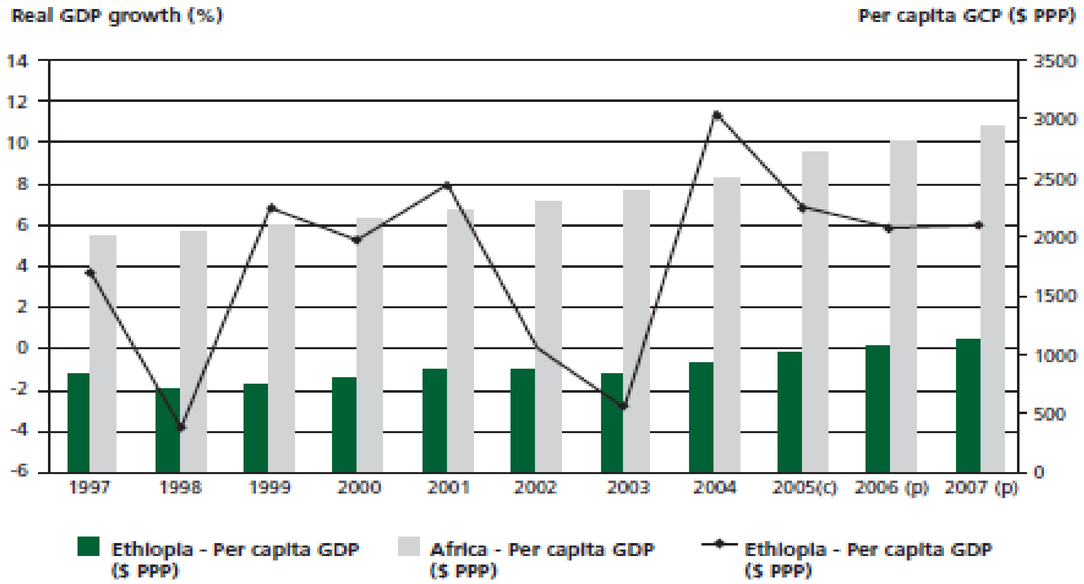

Figure 13: Real GDP Growth and Per Capita GDP [71].

availability that cannot support the livestock population, as a result of this phenomenon, the livestock population showed a decreasing trend. Moreover, in this review, more than half of the El-Niño and La-Nina events coincided with lower rainfall distribution and reducing livestock population and higher mortality and off-take rate of cattle and sheep over the area. Hence, declining of rainfall during this period has resulted in severe livestock reduction. Cattle and sheep population was lower ($P<0.05$) during most El-Niño and La-Niño events in the study area.

The principal cause of drought in Ethiopia is asserted to be the fluctuation of the global atmospheric circulation, which is triggered by sea surface temperature, occurring according to ENSO events. ENSO episodes and other regional systems have impact on seasonal rainfall performance and rainfall variability over Ethiopia due to remote teleconnections system. Therefore, extreme flooding, drought, lack of potable water for livestock and domestic use, food insecurity and market imbalance are associated with El Niño and La Niña in Ethiopia. Drought following El Niño caused 50 to 90% crop failure, in the eastern parts of Ethiopia. Climate impacts on food production is the predominantly rain-fed agricultural system, rainfall is one of the main climatic determinants of food production in Ethiopia. Disaster risk reduction structure, social protection and safety nets offer critical platforms and vehicles for investing in risk management for the most vulnerable and should become a policy priority. Finally, warm sea surface temperature (El Niño) leads to reduction in the summer rains, while the cold phase (La Niña) has the opposite effect over the environmental condition. This is particularly true for the very poor, whose livelihood depends totally on rainfall as the sole source of moisture for crop or pasture growth. Climate risk management thereby increases resilience to short-term climate variability while increasing adaptive capacity to deal with the longer-term climate change.

Recommendations

Based on the integrate aspect of introduction and review of related literature focused the following recommendation were forwarded;

- ➢ Decision-support frameworks and training that provide a medium-term strategic understanding of the temporal and spatial distribution of El Niño and La Niña impacts were deeply concerned on the inputs of agricultural practices.
- ➢ Short-term seasonal climate and agricultural forecasting to enable farmers knowledge on climate variability computable with going crop production.
- ➢ Complain and extend longer term information on the current and future extent on the impact of climate change on the nature of climate variability.

Further review were incorporate SWAT and APSIM model analysis is better to understand moisture and drought capacity before and after the occurrence of El Niño and La Niña impacts.

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