ASSESSMENT OF CLIMATIC VARIABILITY AND DEVELOPMENT OF LOCALIZED CLIMATE PREDICTION METHOD FOR LIVESTOCK PRODUCTION IN BORANA AREA, SOUTHERN ETHIOPIA

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By

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APPROVAL SHEET

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DEDICATION

This thesis is heartily dedicated to my child Phebe, my beloved wife, **Meskerem Terefe** and all my **family** for their moral support and encouragement during my work at Haramaya University.

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this thesis is my own work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis and completion of this thesis. Any scholarly matter that is included in the thesis has been given recognition through citation.

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ACROYNMS AND ABBREVIATIONS

ABM	Austrian Bureau of Meteorology
AM	April-May
ANOVA	Analysis of Variance
ASAL	Arid and Semi-Arid Lands
CCA	Canonical Correlation Analysis
CCAFS	Climate Change, Agriculture and Food Security
CGIAR	Consortium Group on International Agriculture Research
CPT	Climate Prediction Tool
CSA	Central Statistics Agency
CV	Coefficient of Variation
DEM	Digital Elevation of Model
DOY	Day of Year
ENSO	El-Nino and Southern Oscillation
EWS	Early Warning System
FGD	Focus Group Discussion
GIS	Geographical Information System
GGA	Gumi Gayo Assembly
IK	Indigenous Knowledge
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institution of Climate for society
ITCZ	Inter Tropical Convergence Zone
JF	January-February
JJAS	June-July-August-September
LLJ	Low Level Jet
MAM	March-April-May
MLR	Multi-Linear Regression
NATL	North Atlantic
NPAC	North Pacific
NAO	North Atlantic Ocean
NMA	National Meteorological Agency
NMSA	National Meteorological Service Agency

NOAA	National Ocean and Atmosphere Administration
OND	October-November-December
PCA	Principal Component Analysis
PC	Principal Component
PNA	Pacific- North America
RSCZ	Red Sea Convergence Zone
SATL	South Atlantic
SCI	Score of Confidence Interval
SD	Standard Deviation
SPAC	South Pacific
SON	September-October-November
SPI	Standardized Precipitation Index
SST	Sea Surface Temperature
TEJ	Tropical Easterly Jet
TK	Traditional Knowledge
WP	West Pacific

BIOGRAPHICAL SKETCH

The author was born in January 27, 1984 in West Shewa Zone of Oromia National Regional State, Jeldu District. He attended his elementary education at Gojjo elementary and secondary education at Ginchi Senior secondary school in 2004. After successfully accomplished the Ethiopian School Leaving Certificate Examination, he joined Arba Minch University. He graduated with a BSc degree in Meteorology Science in July 2007.

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ASSESSMENT OF CLIMATIC VARIABILITY AND DEVELOPMENT OF LOCALIZED CLIMATE PREDICTION METHOD FOR LIVESTOCK PRODUCTION IN BORANA AREA, SOUTHERN ETHIOPIA

ABSTRACT

This study examines seasonal climate prediction method and evaluates its social and economic values in reducing climate-related hazards on livestock productivity over Borana Zone using monthly rainfall and temperature data recorded over Borana Zone for the period of 1983-2014 as well as regional and global oceanic and atmospheric indices. The predictive potential of March-May, June-August and September-November rainfall in Borana Zone also examined using mainly statistical methods and identified traditional climate prediction indicators. Multivariate statistical techniques would have applied to analyze and predict seasonal rainfall. Global and regional processes have distinct impact long rainy (MAM) and short rainy (SON) climate patterns over Borana Zone. This is also reflected in a relatively in regional and local climate drivers. Result indicates that two to three distinct homogenous rainfall zones in the region. In addition, the study shows that long rainy (MAM) has declined and while temperature over all season has risen throughout the past consecutive decades. ENSO predictability skill for JJA season has less potential to provide seasonal rainfall forecasts one or two months in advance. Altogether, the results as generated from this study indicates a prevailing of recurrent droughts, particularly during the main rainy season, which has been predicted in advance using integrating scientific climate prediction and a wisdom of indigenous knowledge of Borana Community. Seasonal climate prediction is a promising tool to enhance societal exposure to climate-relate calamities by availing timely and local-specific weather and climate forecasts.

Keywords: ENSO, Homogeneous zone, Indigenous knowledge, Predictability skill, Rainy season

1. INTODUCTION

1.1. Background

Arid and semi-arid lands (ASAL) cover nearly two-thirds of the African continent (Galvin *et al*., 2001). Galvin *et al*., (2001) further indicated that the majority of African livestock and more than 50 million people who are dependent on livestock and dry land agriculture reside in these dry zones. For instance, Ethiopia is home to the largest cattle population in East Africa with approximately 29.5 million heads, which represents almost 30 percent of the total population of cattle in East Africa of roughly 90 million heads (CSA, 2013; ILRI, 2000; Tilahun and Schmidt, 2012). Solomon *et al*. (2003) also documented that Ethiopia has the largest livestock population in Africa. Close to 60% of the land, area in Ethiopia is pastoral. Pastoral communities are the most vulnerable communities to climatic shocks in Ethiopia. However, traditional pastoral cattle production is the major livelihood strategy for the Borana community of East Africa (Cossins and Upton, 1987; Coppock, 1994). The possession of cattle, therefore, constitutes an integral part of social, economic and ritual life for the people. An individual without cattle may not qualify to fulfill the requirements of certain social standards or to execute certain social obligations (Tache and Sjaastad, 2010).Comparison to other pastoral livestock, the Borana cattle herd productivity wasfound to be higher due to their remarkable production and reproductive performances, low mortality rates, and suitability for arid environments (Cossins and Upton, 1988b).

At present, however, the Borana livestock production system is coming under increasing pressure from various stresses, including human population growth, degrading and shrinking rangelands, insecure communal land rights, market failures, and recurrent climatic shocks (Desta and Coppock 2004; Angassa and Oba, 2007; Homann *et al.,* 2008; Tache and Sjaastad, 2010).Climate variability, especially increasing frequency and intensity of droughts, accentuates the impacts of these stressors, undermining the traditional coping strategies and deepening the vulnerability of the Borana pastoralists. Cattle are the livestock species most susceptible to water and feed shortages produced by climate change (Seo *et al*., 2010). Prolonged drought including a shortage of an erratic rainfall can cause serious range of degradation. What rainfalls during a drought is mostly hardly adequate to allow grasses to grow (Helland, 19980) and unable to fill the surface water ponds (Cossins and Upton, 1987). This means that the Borana have had to over utilize the areas around permanent water points or wells even during the rainy season. Heat distresses on animals also reduce the rate of animal feed intake and causes poor performance growth (Rowlinson, 2008).Lack of water and increased frequency of drought in certain countries will cause a loss of resources. As a result, the Borana herders who have historically been cattle pastoralists are reportedly responding to environmental changes by adjusting their herd composition and keeping more drought tolerant species such as, camels and goats (Zander, 2011 and Faye *et al*., 2012).

The main hazards faced by households' livelihood in the Borana Zone are drought, livestock diseases and conflict with neighboring areas and tribes. Apparently, drought is a function of a shortage in the required amount of rainfall as well as its erratic distribution. The severity of droughts indeed can lead to herd depletion through increased mortalities, forced off-takes, and emergency slaughter (Cossins and Upton, 1988b). Desta and Coppock (2002) have suggested that drought occurrences cause massive cattle losses every 5 to 6years on the Borana Plateau. Furthermore, drought affects the availability of pasture and water for the livestock, and is a hazard that occurs nearly every year. Livestock diseases such as pasteurellosis, internal and external parasites, and blackleg are, commonly occurring every year and affect cattle, sheep and goats. The effect of these diseases ranges in severity, resulting in some serious cases in the death of livestock (Thornton *et al.,* 2009).

The pastoralist of Borana relied on the traditional climate forecast knowledge particularly, reading livestock intestine and stars, cattle body condition and cross with *Gada* System for many years to forecast the climatic shock such as drought and flood to manage livestock (Hurst *et al.*, 2012). The subject of traditional knowledge has acquired importance in recent times. Traditional knowledge has generally defined as the knowledge of a people of a particular area based on their interactions and experiences within that area, their traditions, and their incorporation of knowledge originating from elsewhere into their production and economic systems (Boef *et al*., 1993). Recently, an increasing variability in climate reduced the pastoralist's confidence on his or her own predictors and increasingly looking for modern science-based weather forecast. However, the challenge is to provide reliable forecast through appropriate methods based on the needs of the farmers. According to Luseno *et al.* (2003), recently traditional methods (as in the past 20 years) seemed to be less predictable.

In recent years however, as localized meteorological monitoring systems have expanded, pastoralists are willing to utilize climate-based early warning for early action. Climate prediction is one of the most important means to minimize climate-related hazards, such as droughts in order to increase both quantity and quality of livestock production. For example, WHO (2004) noted that climate prediction plays great role to control drought and diseases, which are highly sensitive to climate variability. With increasing demand for operational drought and disease early warning systems (EWS), recent advances in the availability of climate and environmental data and increased use of geographical information systems (GIS) and remote sensing make climate-based EWS increasingly feasible from a technical point of view.

1.2. Statement of the Problem

Drought is one of extreme weather events, which usually results when rainfall is far below average (failure of rainfall). Droughts have frequently hit Borana region of Southern Ethiopia, causing heavy livestock mortalities, particularly of cattle (Desta and Coppock, 2002; Angassa and Oba, 2007). In Borana area, droughts occur due to either failure of the long rains or below average of both the short and the long rains. Between 1980 and 2000, Borana zone experienced three major droughts in which pastoralists lost about 35-67% of their livestock inventory with a monetary value of hundreds of millions of USD (Shibru, 2001; Desta and Coppock, 2002). In 2001-2002, another drought hit the region, which was followed by the 2005-2006droughts. The 2005-06, droughts chiefly had exacerbated livestock mortality, though severe impacts on human water supply mentioned in many communities. Recent increases in human and livestock populations, decrease in availability of grazing lands, and a decline in adherence to social mores, however, have eroded the effectiveness of traditional means to stem risks of livestock asset losses during drought (Coppock, 1994).

The pastoralist of Borana relied on the traditional climate forecast knowledge particularly, reading livestock intestine and stars, cattle body condition and cross with *Gada* System for many years to forecast the climatic shock such as drought and flood. Other problem of Borana elders faced is lack of interpretation and understandings of early warnings issued from governments and NGOs. Dekadal, monthly and seasonal climate predictions released by National Meteorological Agency (NMA) and other international centers usually cover large-scale spatial resolution.

As results, it is less reliable in predicting weather for localized area. This study is therefore designed to investigate and develop localized climate prediction methods and identify traditional weather/climate prediction method that enable to manage climate-related risks mostly that affect livestock productivity in the Borana Zone of Southern Ethiopia.

1.3. Significance of the Study

The study is designed to develop localized climate prediction method in order to monitor climate-related hazards on livestock productivity over Borana Zone of Southern Ethiopia. It also enables to provide valuable information and scientific knowledge that used to develop local climate forecast and to mitigate climatic shocks such as drought and flood. The study is expected to contribute to enduring preparedness and efforts of climate resilient for Borana livestock productivity systems as well as to enhance the livelihood of the people. In addition, it examines and documents the climatic features of the region, which plays significant role by enhancing and facilitating exchange of climate knowledge and information among local communities, field experts, policy makers and researchers. A livelihood approach is the means of potential role that seasonal climate forecasts might play in increasing adaptive capacity particularly in response to climate variability. This ,research therefore helps decision makers, local communities and NGOS to plan economic activities in advance by reducing the harmful effects of, drought, manage livestock, water resources and agricultural activities.

1.4. Objectives of the Study

1.4.1. General objective

An overall objective of this study is to develop localized climate prediction method, for reducing climate-related hazards on livestock productivity over Borana Zone.

1.4.2. Specific objectives

The specific objectives of the study area;

1. To develop and examine localized climate prediction methods for monitoring seasonal climate under livestock production system.
2. To develop user-interface climate package for the pastoral community of Borana Zone.

2. LITERATURE REVIEW

2.1. Climate Variability and Livestock Production

Climate variability is the way climate fluctuates yearly as above or below of a long-term average value (NOAA, 2009). It is one of the pervasive stresses that individuals and communities in rural areas are entitled to coping with. Human-being recognized millennia ago the importance of climate variability to the sustenance of life, whether that variability was expressed in the form of droughts, floods, heat, cold, or wind (Troccoli *et al*., 2007). Seasonal climate forecasts provide an indication of how variable the rainfall might be compared to past years and is therefore considered as information that could help to prepare for and adapt to climate variability (Goddard *et al*., 2001). Similarly, the most important feature of sea surface temperature variability that can cause large-scale weather disruptions is El Niño and its counterpart La Niña, a near basin-wide warming and cooling of the equatorial Pacific Ocean, known as ENSO (Goddard *et al.,* 2001). According to IPCC (2013),climate variability refers to shorter term (daily, seasonal, annual, inter-annual, several years) variations in climate, including fluctuations associated with, for example tele-connection systems, *El Niño* (warming) or *La Niña* (cool) events, which is spatial and season specific. As Galvin *et al.* (1994) have documented it, it is characteristic of all dry lands, but in Africa, it is particularly potent. This precipitation variability influences ecosystem dynamics and thus exerts a major influence on human lifestyles and land use patterns. Climate variability, which affects ecosystem structure and function, always influences African livestock production and rain-fed agriculture production (Galvin, 1988; Galvin *et al*., 1994).

The cattle populations, which are mostly sensitive to climate variability, are located in arid regions (IPCC, 2007). Pastoralists and agro-pastoralists depend directly and indirectly on the products of their livestock, so they have developed multiple coping mechanisms to deal with drought. These include keeping diverse species of livestock, movements of species-specific and production- specific livestock herds over large areas, emigration out of the pastoral system until the perturbation passes, economic diversity, and even allocating seasonal and drought-induced nutritional stress among those community members better able to cope with it (Galvin, 1988 and 1992; Galvin *et al*., 1994). As documented in Hoffmann (2010), the cattle have been, influenced directly through climate variability, and indirectly through parasites and vector borne diseases, which is still uncertain.

Climate change that observed over the region has resulted in diminished quantity and quality of local water and forage resources, thereby severely and negatively affecting the region's livestock and in turn jeopardizing pastoralists' mode of living, such as Borana, who depends on these animals for livelihoods and subsistence. Lower than average rainfall recorded during 1999-2005 (Conway and Schipper, 2010) and again in 2011 caused mass die-offs of livestock, and hence forced Borana pastoralists to adopt new coping mechanisms to manage increased risks associated with climate-related catastrophes. Although new coping strategies may enable the Borana to better adapt to new or more severe climate-related events, stress and hardship for Borana pastoralists are likely to continue, or even increase, as climate scientists projecting increasingly frequent and severe drought and other climatic extremes in the Borana region of southern Ethiopia (Ellis and Gavin, 1994).

At present, NMA issues seasonal rainfall prediction information for February-May (FMAM), June-September (JJAS) and October–January (ONDJ) seasons. During the JJAS (long rainy season),most parts of the country receive substantial rains, except the Southern and Southeastern lowlands, where March-May (MAM) constitutes the main rainy season and October-December (OND) forms the short rain season (Korecha, 1999). Accordingly, NMA classifies Ethiopia in seven homogeneous rainfall zones for JJAS (Korecha, 1999), eight zones for MAM (Amedie, 2000; Korecha, 2002a) OND seasons (Korecha, 2002b). During JJAS, the major rainfall producing systems are the northward progression and establishment of the Inter Tropical Convergence Zone (ITCZ), the formation of low level jet (LLJ), the strengthening of the Mascarene High pressure, the strengthening of St. Helena High pressure, the strengthening and frequent emergence of the Tropical Easterly Jet (TEJ) and the associated monsoon systems (NMSA, 1996a & b).

Borana Zone receives rainfall on average between 238 to 896mm, where variability is high and hence with CV ranging from 18% to 69% (Angassa and Oba, 2007). Erratic rainfall and its general declining in southern Ethiopia, during both February–May and June–September (Viste *et al*., 2013) are the most recent climatic extremes. Decreasing rainfall reduces the primary production and forage quality (Beier *et al.,* 2008 and Kassahun *et al*., 2008).). Because of this, the pastoralists are risk-averse livestock producers, and then stock densities will be lower the higher is rainfall variability (Sandler and Sterbenz, 1990; McCarthy, 1999).

Borana Zone is characterized by a bimodal rainfall distribution leading to very short growing seasons. Under these conditions, it is likely that crop output is more variable than livestock output, since livestock production is more mobile and flexible (Ellis *et al.,* 1993; Niamir-Fuller, 2000).Rainfall seasonality affects livestock production and the livelihoods of these people. It has been documented that East African rainfall is bimodal with short rains occurring in October and November and long rains beginning in February or March and ending in May (Nicholson 1993, 1994; Ellis & Galvin, 1994). Changing patterns in precipitation, a rise in global mean temperature, and increasing frequencies of extreme events such as flooding, drought and heat waves are, among others climatic extremes, so far evidenced (IPCC, 2013). Also Viste *et al*. (2013) documented that in southern Ethiopia, there has been a general decline in rainfall during MAM period. This pattern varies across the region; with uncertainty of the rains, increasing in drier zones. IPCC (2013) concluded that changes in rain-fed livestock numbers in any African region would be directly proportional to changes in annual precipitation.

The major problems to addressing livestock feeding during the dry seasons and drought periods are lack of adequate information on the climatic condition and low adoption of improved feed production; conservation processing and feeding technologies have promoted. In addition, traditional dry seasons and drought periods livestock feeding strategies are becoming ineffective due to changing production environments (Galvin *et al.,* 2004). Dry seasons and drought periods livestock feeding strategies should start with a better understanding of the dry land climatic conditions and currently practiced livestock feeding strategies (Lema and Majole, 2009). However, grazing lands are being lost due to drought, increasing population pressure and restricted access to land. This forces more and more pastoralists to settle and grow crops, resulting in considerable reduction in grazing lands (ILRI, 2005).According to Megersa (2013), the perceptions of flooding would have dominated by two divergent viewpoints. He documented that 46.7% of the respondents felt that the frequency of flooding had decreased due to a general decline in precipitation, whereas 44.6% of them claimed that flooding had actually become more frequent, as rainfall became more erratic and intense with short-lasting storms.

As the livestock population is often beyond carrying capacity of the grazing land shock in rainfall leads to acute food and water shortage (Rufael *et al*., 2008).On the other hand, declining of precipitation in southern has been documented, most strongly for the spring season (Seleshi and Camberlin, 2006; Seleshi and Zanke, 2004). This leads to sudden decline of livestock production, mainly milk, and deterioration of livestock body condition. The consequences of acute feed and water shortages could be severe if the drought period is prolonged might see mass death of livestock. Shortage of rain and the frequently recurring drought in the area is a major cause for reduced forage production and quality. These fodder and water and the harsh climatic condition of the area seriously affect the health and productivity of animals. Besides, the prolonged dry season and drought are the causes for high mortality rate and diseases such as foot and mouth disease (FMD), black leg and anthrax; parasites such as ticks and manage mites; have a significant effect on the health and productivity of animals (Rufael *et al*., 2008).

2.2. Temperature Variation and Livestock Production

There is new scientific consensus revealing that the global climate is changing (IPCC, 2013).Global mean temperature increased by 0.6 degree C in the last century, with the hottest years ever in record occurring after 1990. This warming of the world climate has been linked to a higher concentration of greenhouse gases (GHGs) in the atmosphere, the consequences of which can be manifested in the higher frequency of extremes such as floods, droughts and cyclones (IPCC, 2013). The impacts of rising average temperature, high rainfall variability and increase in the frequency and intensity of droughts are undeniably more severe in the tropics than temperate regions. Increases in temperature directly pose thermal stresses on animals, impair feed intake, metabolic activities and defense mechanisms, thereby hindering their production and reproductive performances (Nardone *et al.,* 2010).Rises in temperature also adversely affect pastoral livestock production through indirect impacts on pasture growth, water availability and disease distributions (Kassahun *et al*., 2008 and Thornton *et al*., 2009).

2.3. Importance of Climate Prediction for Managing Livestock

Throughout recorded history, fluctuation of weather has played a major role in human life (Seleshi, 1996) and attempts always been made to predict how the future weather will behave. The earliest prediction is the biblical reference to Joseph's interpretation of the Pharaoh's dream: "Behold, there come seven years of great plenty throughout the land of Egypt and there shall arise after them seven years of famine" (Genesis 41: 29-30 King James Version). In fact, what Joseph forecast was the fluctuation of the flow of the Nile River that comes mainly from the Ethiopian highlands and is dependent on an abundance of the rainfall of this area.

Today, after a passage of over 4000 years since Josephs' forecast, the issue of having a valuable rainfall forecast is still a challenge. However, with the advent of reliable instrumentation, monitoring of the oceans, space and the atmosphere, more information on basic characteristics of climate is becoming available. Particularly, in the second half of the 20th century, the spatial and temporal coverage of such information has expanded (Seleshi, 1996). According to Troccoli *et al*. (2007)*,* climate prediction, at least that covering the next few seasons, is one of the oldest professions, with known examples stretching back millennia. Life depends on climate, and decision making to sustain life requires methods of foreseeing climate abnormalities that threaten life.

Those managing drought must, to the extent to which it is practical equip them with the best available knowledge of the likelihood of future drought and major impact of drought. This knowledge can come from various sources. Increasingly, international technological capacity in remote sensing and climate modeling can provide useful seasonal forecasts of drought (Swift, 2001). Large-scale quantitative surveys of the availability and price of food in markets can pick up economic impacts of drought at an early stage. Community-based early warning can relay to drought managers peoples' own perceptions of the progress of drought and its impacts. Livestock keepers' knowledge, of their own environment and their experiences to cope with drought will be invaluable in designing and implementing systems that can detect severe drought in its onset phase. Such knowledge will be local-specific, and needs therefore thoroughgoing participation of livestock keepers in early warning systems, by the use of "participatory rural appraisal methods, including semi-structured interviews, social mapping, and food ranking and seasonal calendars, to produce mainly qualitative information (Swift, 2001). As documented by Morton and Barton (2002) documented early warning, play a great role for pastoralist to, de-stock during severe drought. On the other hand, according to Heffernan *et al*. (2004), it may be useful to restock and restore people to their “normal” livelihoods or, as was an increasingly realized, improved and less vulnerable livelihoods after the end of the droughts and as rainfall returns climatic information play imperative role.

2.4. Importance of Indigenous Knowledge

Since historic past, local communities in different parts of the world have continued to rely on Indigenous Knowledge (IK) to conserve the environment and deal with natural disasters. Communities, particularly those who are vulnerable to droughts and floods prone areas have generated a vast body of IK on disaster prevention and mitigation through early warning and preparedness (Anandaraja *et al*., 2008; Svotwa *et al*., 2007).The global scientific community has acknowledged the importance of IK. In addition, it was endorsed and recommended at the World Conference on Science held in Budapest, Hungary in 1999, that IK have must been integrated into science, particularly in the fields of environment and development (Warren, 1999).

In order to achieve the full potential of participatory approaches to sustainable development, it is important that there should be greater recognition for the immense value of IK for development activities. An increasing number of formally established IK resource centers are that active. At present, there are eight such centers located in Netherlands, United States, Sri Lanka, Mexico, Nigeria, Philippines, Ghana and Indonesia (Larson, 1998).

3. MATERAIALS AND METHODS

3.1. Description of Study Area

The Borana Zone locates in the south-most part of the Ethiopian lowlands occupying a total land area of about 95,000 km^2. It is located between $3^0$36'N-$6^0$38'N and $33^0$43'E-$39^0$30'E, sloping gently from 2702 meters in the northeast to about 496 meters in the extreme south that borders northern Kenya.

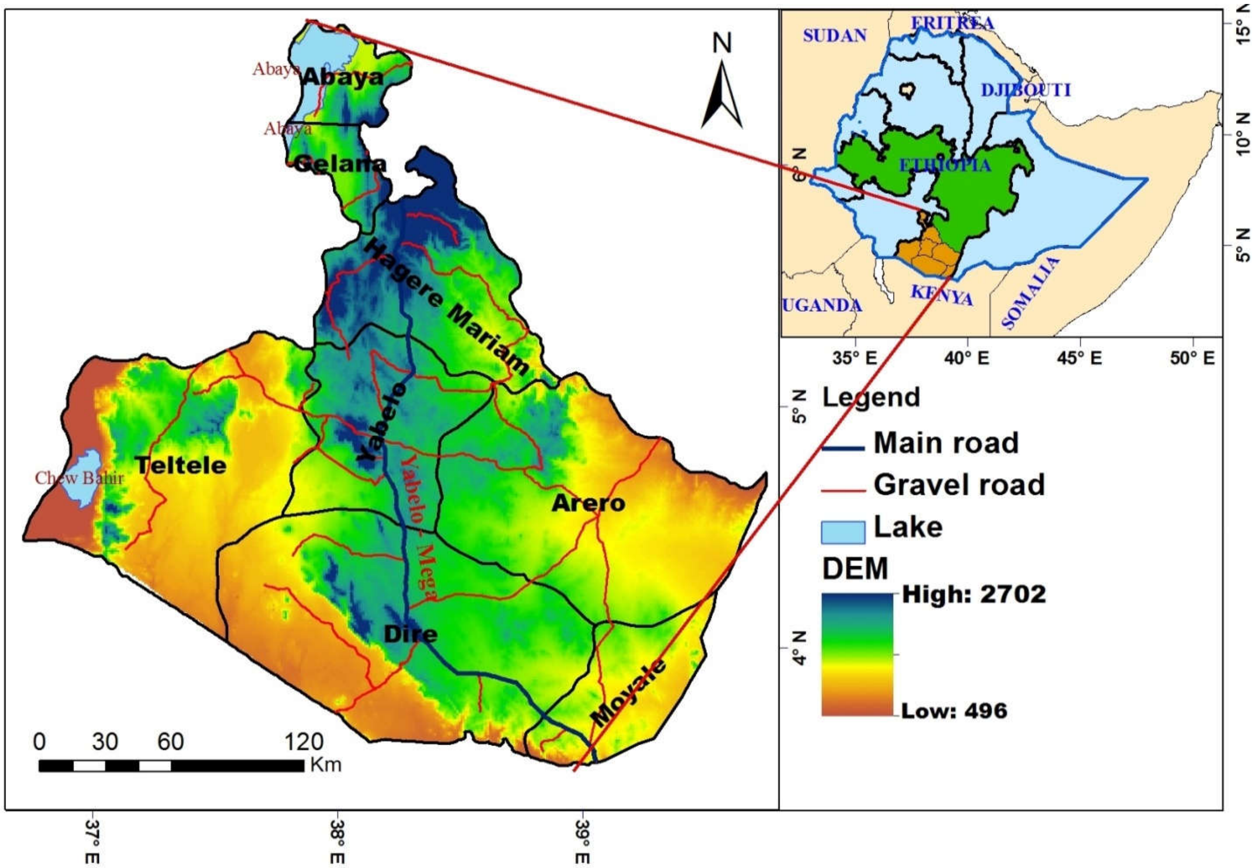


Fig. 1.Map of Study Area

The Borana rangelands divided into four ecological zones based on soil types, natural vegetation, primary productivity, and duration of growing seasons. The rangelands are dominated by tropical savannah vegetation with varying proportions of open grasslands and perennial woody vegetation (in Homann *et al.*, 2007). These include the savannah in the north, which has the potential to carry relatively high numbers of livestock, the bush land with high shrub cover in the central zone, the medium-potential grassland in the east, and the volcanic areas in the west (Kamara, 2001).

The area is still predominantly in pastures comprised of flat plains forming the main parts of the range. Cattle is by far the most important livestock species held by the Borana pastoralists and accounts for about 90 percent of the total livestock holdings in the area (McCarthy *et al*., 2004).The area is classified as arid and semi-arid with mean average of annual rainfall 238-896mm, with mean daily air temperatures ranging between 19^0C and 26^0C.

Annual rainfall regime ranges on average from 300 mm in the South to 900 mm in the North per annual (Kamara *et al.*, 2005) and is bimodal pattern of rainfall, with the long rainyseason (*Ganna*) between March and May, and the short rainy season (*Hagayya*) between September and November followed by two dry seasons. The long dry-warm season (*Bona hagayya*) occurs from December to February, and the short dry-cold season (*Adoolessa*) occurs from June to August. In normal years, the zone receives maximum rains between March and May, and the short rainy between September and October. During the two rainy seasons, the onset and cessation of the rains are often irregular, but the *Ganna* rains are more reliable than the *Hagayya* rain in its amount, temporal and spatial coverage. The former rains account for 60% of the total annual rainfall, while the latter rains contribute about 30% (Sutter, 1995). The remaining 10% usually prevails from the occasional rains (*furmaata)*, which provide sporadic relief by punctuating the progress of the dry season stress and making inter-seasonal transition easier for human and livestock populations. Variable rainfall results in great variability in forage and range production. To cope with variable range production, communities in Borana area often combine mobility and sedentary livestock management.

3.2. Method of Data Collection

3.2.1. Sources of data

The climatic data of the study area obtained both from local and international climate centers. The observed and gridded (10km x 10km) rainfall data (covering 1983-2014) and surface air temperatures data (1980-2011) at stations level were obtained from 13 National Meteorological Agency of Ethiopian (NMA) stations. Similarly, oceanic sea surface temperatures (SST) data used for the study extracted from NOAA/NCEP and International Research Institute for Climate Society (IRI) website as well as other international forecast centers (https://www.ncdc.noaa.gov/ and http://www.ncep.noaa.gov/. The remaining data, noticeably livestock populations obtained from Yabello Agricultural Research Center, Yabello Pastoralist Development Office and Ethiopian Central Statistics Agency (CSA).

On other hand, localized data on traditional climate forecast collected from key informants and traditional weather forecasters (elders) group discussion. The four "*Gada*" periods, Jilo Aga (1976-1984), Boru Guyo (1984-1992), Boru Madha (1992-2000), Liben Jeldesa (2000-2008) and five years (2009, 2010, 2011, 2012,2013 and 2014) from the "*Gada*" of Guyo Goba (2008-2016), been used to generate historical data. Key informants and Focus Group Discussion (FGD) detail explained regarding to trends in rainfall, temperature, drought frequency, pasture availability, rangeland cover, water availability and livestock production depending on the *Gada* cycle. In addition, key informants and FGD, were tried to explain indictors that used for traditional weather/climate forecast. Similarly, local knowledge on seasonal climate prediction methods obtained from traditional weather forecasters /elders (*ayantu*) of the Borana society. They have been using these methods for many years. Missed data were filled according to WMO (1988), which recommended that normal or period averages was calculated only when values are available for at least 80% of the years of record, with no more than three consecutive missing years.

Purposively two stations were selected from North and South parts of the region clearly fall under bimodal type of rainfall. In order to characterize monthly and seasonal rainfall patterns at northern and southern parts of the Zone. The purpose of selecting these two stations was to compare the climatic condition of the region from both the northern and southern parts of the region. Hagere Mariam district is commonly known for its agro-pastoralist and is one of the highland districts among the Borana Zone, whereas Moyale is confined in the lowland area.

3.3. Method of Localized Homogenous Rainfall Zones

The climatic features of Borana zone is categorized into homogenous rainfall regimes using ground meteorological observations and gridded data. As the rainfall over Borana Zone arid and semi-arid parts exhibits high spatial variability, it is useful to divide the zone into zones of homogeneous rainfall climate. There are different ways of doing this. Many studies (e.g. Dyer 1975; Ehrendorfer 1987) use principal component analysis. However, when the spatial variation of rainfall is complex and the first few principal components account for only small percentage of the variance, the method does not work well (Gadgil *et al*., 1993). By using principal component that depicted in Statistics package for social Science (SPSS) the Borana Zone main rainy season (MAM), short rainy season (SON) and short cold season (JJA) has divided into three, three and two homogeneous regions, respectively. The classifications were focus on determination of data of standardized rainfall anomalies that represent the study area by using principal component of analysis (PCAs) in SPSSsoftware20, (2011).

The map produced with close analysis of various combinations of the principal components and zones. Out of thirteen such combinations, the first PCs have total variance greater 1 case would have selected as the least noise involved in it. The stations whose monthly rainfall pattern is well correlated and in close proximity to each other tended to be clustered together forming three homogeneous rainfall zones. Past records of SSTs over 1983-2004 are used to develop the model. Mean of JF, AM and JA SSTs have used to predict MAM, JJA and SON rainfall at Borana Zone. Stepwise multiple linear regressions have applied to select predictors that have potential predictive and leave when extra predictors no longer significantly enhance predictive skill. All coefficients are statistically significant at the 95% level, and the overall model "goodness of fit" is significant at 99%. The regression forecasts are shown both within the training period (1983-2004) and for an independent (2005-2014) verification period.

3.3.1. KMO and Bartlett's Test

Kaiser-Meyer-Olkin measure of sampling adequacy statistics were used to test factor analysis, which varies between 0 and 1that a value of close to 0 indicate inappropriate factor analysis and a value close to 1 indicates appropriate factor analysis. Alternative criteria recommend acceptable values greater than 0.5 as acceptable. The Kaiser Criteria classification were mediocre (0.5-0.7), good (0.7-0.8), great (0.8-0.9) and Superb (>0.9). Criteria of Bartlett's significance test were used ($p<0.001$). The Kaiser Criterion communalities after extract are greater than 0.7 and the variable is less than 30. In addition, F-test was used for appropriate factor analysis. The hypothesis for one-way ANOVA: The hypotheses for one-way ANOVA: H0; $\mu1=\mu2=\mu3$ (all means are equal) and H1; $\mu1\neq\mu2\neq\mu3$ (not all means are equal).

3.4. Seasonal Climate Prediction Methods

3.4.1.Statistical climate prediction method

Nowadays, there are many seasonal climate prediction methods among which, statistical climate prediction is one of the most familiar (Ogallo *et al*., 2008). One month-lead statistical prediction model that relates the monthly SSTs values to the rainfall anomaly prediction was developed using the canonical correlation analysis (CCA) technique, a subroutine that is embedded in Climate Predictability Tool (CPT) of the International Research Institute for Climate Prediction and Society (IRI) (Mason and Tippet, 2005). One-month lead prediction implies the prediction is made for the target month that begins 1 month after the end of the predictor's month, for instance using January SSTs to predict rainfall of March and so on. Canonical correlation analysis is an extension of a multiple regression technique to the case of the vector-valued predictor-predictands relationship (Landman and Goddard, 2002). Hotelling (1936) first defined CCA using the singular value decomposition of a matrix *C* where:

$C = Ryy^{-1} Ryx\ Rxx^{-1} Rxy$

Where: C = matrix of singular value decomposition

Ryy = Correlations between Y variables

Ryx = Correlations between Y and X variables

Rxx = Correlations between X variables

Rxy = Correlations between X and Y variables

According to Van den Doon (2007) standardized long year rainfall anomalies selected from each zones are used in this CCA technique that relates patterns in monthly SSTs anomaly of the pre seasonal months used as predictors. While observed rainfall anomaly data used as predictands, provides a good overview of empirical seasonal prediction methods. Under CCA principles, the predictors which have significant correlation with seasonal rainfall anomaly is identified by those oceanic areas having a strong relationship with the respective rainfall zones for a target month, in which a threshold correlation (r) value of $\geq |0.3|$ was taken into account, which amounts to a minimum 10% of the variance being explained (Tanco and Berri, 2000).

3.4.2. Selection of the best predictors

After standardized rainfall anomalies of each zone replaced with all selected potential predictors (NINO 3.4, NAO, IOD etc.), the predictors having F-ratio with 95%, P-value <0.05, R^2 and R> 50% significant level were selected to develop the models. The selected predictors would be identified as the candidates which normally be tested for inclusion in the model that should be used to make predictions. The standard approach is to include only those predictors in the final regression equation that contribute to a significant reduction in the size of the errors by using SYSTAT version 8 software (Korecha and Barnston, 2007). Finally, develop statistical Multiple Linear Regression (MLR) model along with performing appropriate trend analysis.

3.4.3. Calibration of seasonal climate prediction model

Real-time seasonal forecasts need to be complemented by an extensive set of retrospective forecasts (often referred to as hindcasts).Calibration depends on the comparison of past observations against the corresponding hind casts, so that, long-year data can be arranged accordingly in the format of seasonal climate prediction model. Half of the total year, available rainfall data were used for model construction and the rest data have been used for verification. Therefore, more years were available for producing retroactive forecasts. Model calibration perform as follows; first, check seasonal forecasts required an estimate of skill and reliability of the forecast system, and hindcasts were necessary to provide such skill assessments. Secondly, values generated from the model were then calibrated against the observations and remove biases that are often part of the dynamical prediction systems (Van den Doon, 2007).

3.4.4. Evaluation of model performance

Developed model was subjected to skill performance evaluation. Some of evaluation techniques use in order to compare pairs of predicted and the observations to which they pertain. One of the categorical forecast measure used is the hit score (HS) or the ‘proportion correct’ and is the most direct measure of the accuracy of categorical forecasts. Hit score is simply a fraction of the *n* forecasting occasions when the categorical forecast correctly anticipated the subsequent event or non-event (Wilks, 1995).

$$HS = \frac{(a + e + i)*100}{p} \quad (1)$$

Where: a, is correct forecast of below normal rainfall (B)

e, is correct forecast of near normal rainfall (N),

i, is correct forecast of above normal rainfall (A),

p is a total count of forecasting occasions.

When seasonal rainfall anomaly lies between -0.5 and 0.5 it is normal, when it exceeds 0.5 it is classified as above normal. In addition, when the anomaly lies below -0.5 it termed as below normal. HS receives the score of one for perfect prediction, while the forecasts equivalent to the reference forecast receives a zero score (Wilks, 1995).

3.5. Traditional Weather/Climate Prediction Method

Borana communities are looking own environment and search the indictors to predict future weather/climate. They based on the traditional climate forecast knowledge particularly, reading livestock intestine and observing stars, cattle body condition and cross with *Gada* System for many years to forecast the climatic shock such as drought and flood (Legesse, 1973; Luseno *et al.*, 2003).

3.6. Methods of Data Analysis

3.6.1. Rainfall and temperature anomaly analysis

The nature of the trends of rainfall and temperature were examined by the Standardized precipitation Index (SPI). It provides an area average index of relative rainfall based on the standardization of rainfall totals. Rainfall data was calculated as monthly, seasonally, annual averages and the CV. According to McKee *et al*., (1993), the standardized anomalies (Z) of inter-annual variability in rainfall, sea surface temperature (SST) and surface air temperature are calculated as,

$$Z = \frac{x - \bar{x}}{SD} \tag{2}$$

Where, X is an annual average

$\bar{X}$ is long-term mean and

SD is standard deviation. This statistic would be enabled to determine the dry (-ve values) and wet (+ve values) years in the record. The degree of drought is classified as extreme drought (Z<-2), severe drought (-1.5>Z>-1.99), moderate drought (-1.0>Z>-1.49), Near Normal (-0.99<Z<0.99), moderately wet (1.0<Z<1.49), very wet (1.5<Z<1.99) and extreme wet (Z>2+). Annual rainfall variability has been calculated using the coefficient of variation (CV), which expressed as

$$CV = \frac{SD}{\bar{X}} * 100 \tag{3}$$

Where, CV, is coefficient variation,

SD, is standard deviation and

$\bar{X}$ is the long-term rainfall mean.

The degree of variability of CV is classified as less, moderate and high. For total rainfall CV, <20% is classified as less variable, CV from 20% to 30% as moderately variable, and CV> 30% is classified as highly variable and vulnerable to drought as indicated in ABM (2010).

3.5.2. Relationship between rainfall and livestock population

Correlation and regression are used to examine relationships between monthly, seasonal and annual rainfall and livestock population (cattle, camel and goats).The patterns of inter-annual rainfall variability and fluctuations in livestock population also presented graphically to gain a better understanding into rainfall-livestock population relationships in the Borana Zone. Similarly, the simple correlation and multi regression analysis is used between rainfall, sea surfaces temperature (SST), and surface air temperature and cattle herds is analyzed with appropriate statistical software such as Statistical Package for Social Science (SPSS) version 20, (2011) and INSTAT+ 3.37 (Stern *et al.*, 2006) using the following formulas, respectively.

$$r = \frac{\sum xy}{\sqrt{\sum [(\sum x2)\ (\sum y2)]}}, \qquad (4)$$

Where, r is correlation coefficient,

X is independent and

Y is dependent variables.

Multiple regression models is expressed as,

$$Y = \alpha + \beta 1X1 + \beta 2X2 + \beta kXK + e, \qquad (5)$$

Where, Y is the value of the dependent variable,

α is the intercept, β1,β2..., βk, are regression coefficient variable,

β is represents the amount of change in Y for one unit change in the corresponding x-value when the other x values are held constant; x_1, x_2,... x_n, are the independent variables and, *e* is the error of estimate or residuals of the regression.

A spatial distribution of rainfall and temperatures are analyzed by using Geographical Information System software (ArcGIS) version 10.0 (ArcGIS, 1999-2005 Inc.). Most of the time, the aforementioned software are frequently used during data analysis and summarizes.

4. RESULTS AND DISCUSSION

4.1. Monthly and Seasonal Rainfall Distribution at Borana Zone

In Borana Zone,during the main rainy season, the rain pattern starts from the west side and slightly propagate to north, southwest and slowly covers central parts of the Zone (Fig.2). According to Cossins (1987a) documented that seasonal disribution of rainfall is more important than total quantity in determining primary Productivity.

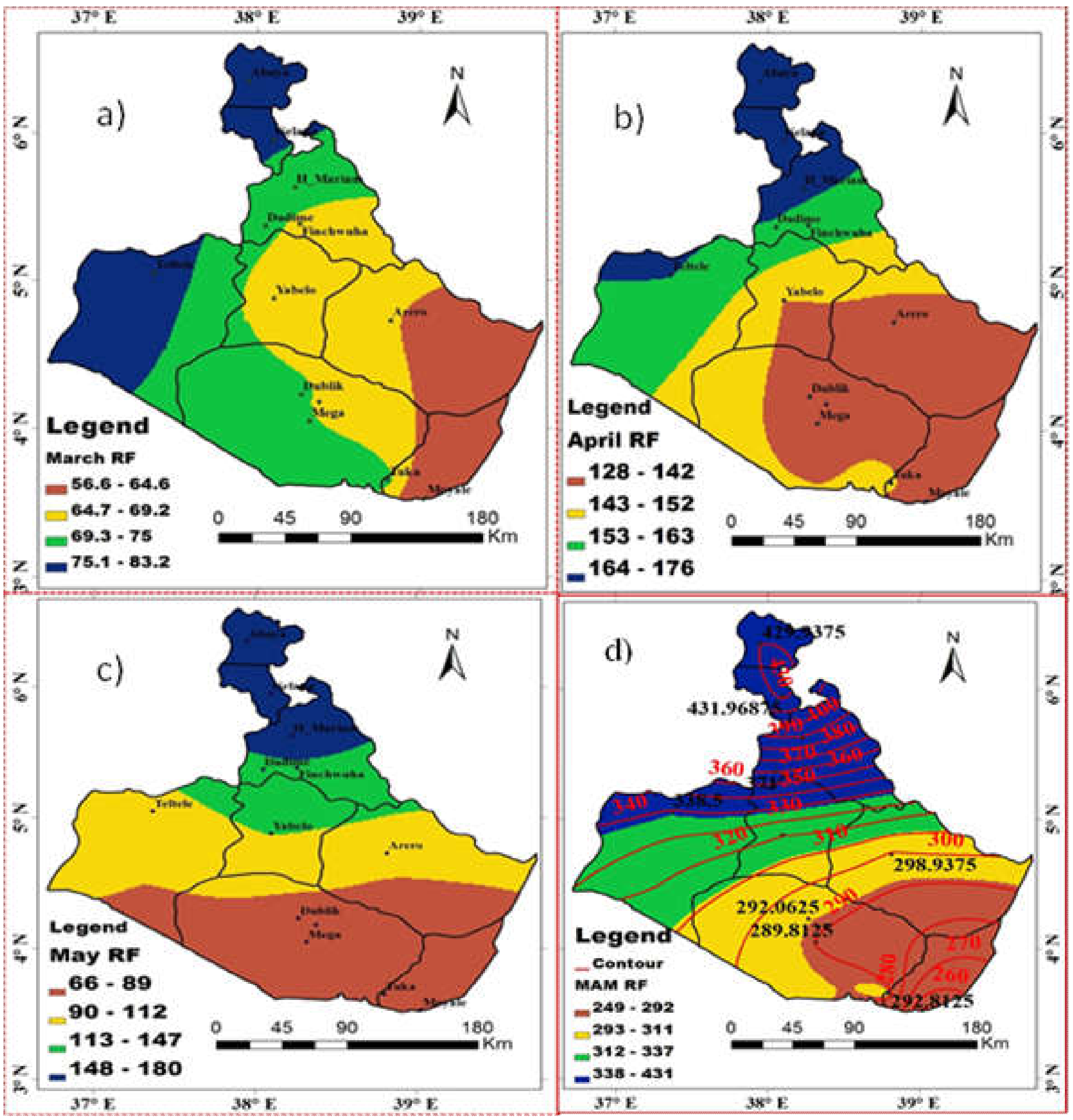


Fig. 2. Mean rainfall distribution over Borana Zone for month a) March, b) April, c) May, and d) MAM

Rainfall analysis was based on annual rainfall anomalies which may not show its seasonal patterns. Particularlyan erratic nature of rainfall of the aridregions in which a large share of the annual rainfall totals fall in a few days and lost rapidly through runoff and evaporation, seasonal amount and distribution is much more suggestive of rainfall deficits than the annual total (Ellis and Galvin, 1994).These authers also indicated that total annual rainfall is not a good indicator as compared to the seasonal distribution pattern in identifying deficits in rainfall that resulted from limited distribution. Hence, paying attention to the seasonal distribution of rainfall, especially in areas receiving bimodal rains, is virtually important in relating deficits to their negative effects.

As revealed from Fig.2a, during the first month of the season,which is March good rainfall distributions were observed in the west and southwest parts of the Zone. In contrast, east and southeast portion of the Zone received less rainfall amount. In this month, west, southwest and edge of north parts of the Zone received better rainfall. Throughout this month, the rainfall was extended from 56 to 83 mm, but the less rainfall amount observedat southeastern part of the Zone. During April and May, more or less similar patterns of rainfall were observed through the Zone (Fig. 2b and 2c). As showed in Fig.2d, good rainfall patterns during MAM season were observed over the northern parts of the Zone while the amount was not as better of rainfall distribution over the southern parts of the Zone. Mostly,maximum magnitude of rainfall was recorded over the northern parts of the Zone, which is accounted for mild highland while less rainfall was observed over southern parts of the Zone, which perhaps dominates pastoral communities.

In generally, the northern parts of the Borana Zone, which ismild highland experience the better rainfall pattern whereas southern parts of Zone possesses similar and but limitedrainfall distribution. For instance, southern Borana receives rains only for a few days in September when ITCZ retreats southward and remains upto the first dekade of November.The second rainy season is short,erractic and less in amount as compared to the main rainy season (Fig.3).

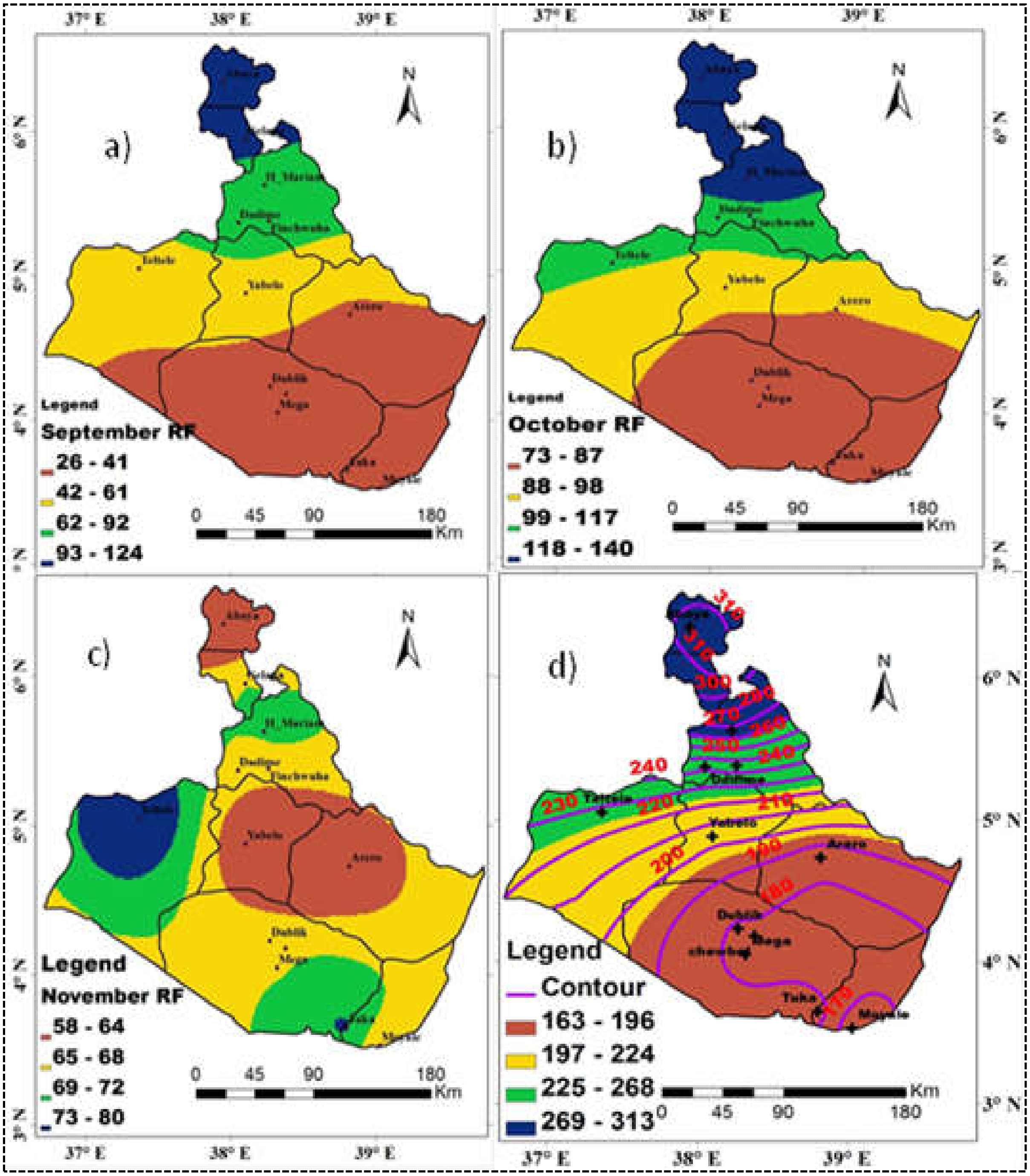


Fig.3. Mean rainfall distribution over Borana Zone in a) September, b) October, c) November, and d) SON

4.2. Rainfall Variability at the Study Area

4.2.1. Monthly rainfall variability and trend analysis

Like, Borana Zone's rainfall condition shows high spatial and temporal variability. The results of the linear trend analysis for the period of the study (1983-2014) at different seasons clearly demonstrate a general tendency of decreasing in monthly rainfall (Fig.4). Rainfall is one of the key indicator and element of climate system. In addition, changes and variations succeeded rainfall variations have adverse influence on ecosystem. Climate variability is the characteristic of arid and semi-arid of East Africa specially rainfall (Galvin *et al*., 1994).

Borana Zone experiences the long rainy season, which starts around March and runs through to May, with the peak centered between March and May while the short rainy season runs from September to November (coinciding with the Southward retreating of the Inter-Tropical Convergence Zone). As indicated in Table 1, the maximum and minimum rainfall in the first month of main rainy season (March) is 83.5 and 55 (mm), respectively. The coefficient variation of the month is about 10%, which lies within less variable category. Therefore, the coefficient variation for the month of March is less and its increment has shown to be insignificant (Fig.2a).In April, the region gets the highest rainfall amount as compared to the rest of the year. During the past thirty-two years, April rainfall extended from 175.9mm to 128 mm, with standard deviation and coefficient of variation 14.7 and 9.7%, respectively. On Fig.4b, the trend line clearly indicated decline pattern in rainfall amount. The declining of April rain could be the main cause for weakening of MAM rainy season. May is the last month for main rainy season, which experiences high rainfall variability compared to March and April. May rainfall extended from 65.87 mm to 179.9 mm, with SD and CV 40.6 mm and 35.3%, respectively. The CV of the month was about 35.3%, which lies within high variable category.

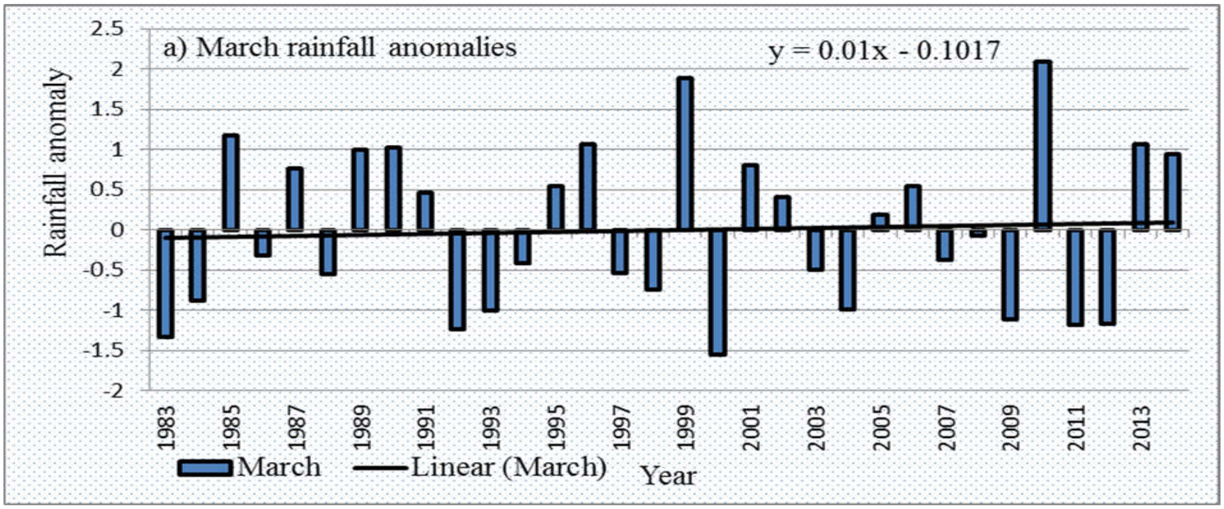
Several other studies showed that declining trends in rainfall, particularly in the major rainy seasons, have substantiated the existence of a strong link between a downward trend in rainfall as a result of climate change in the region (Funk and Verdin, 2010; Williams and Funk 2010; Rao *et al*., 2011; Omondi *et al.,*2012). As it can be seen from (Fig. 4b and 4c), the main rainy season

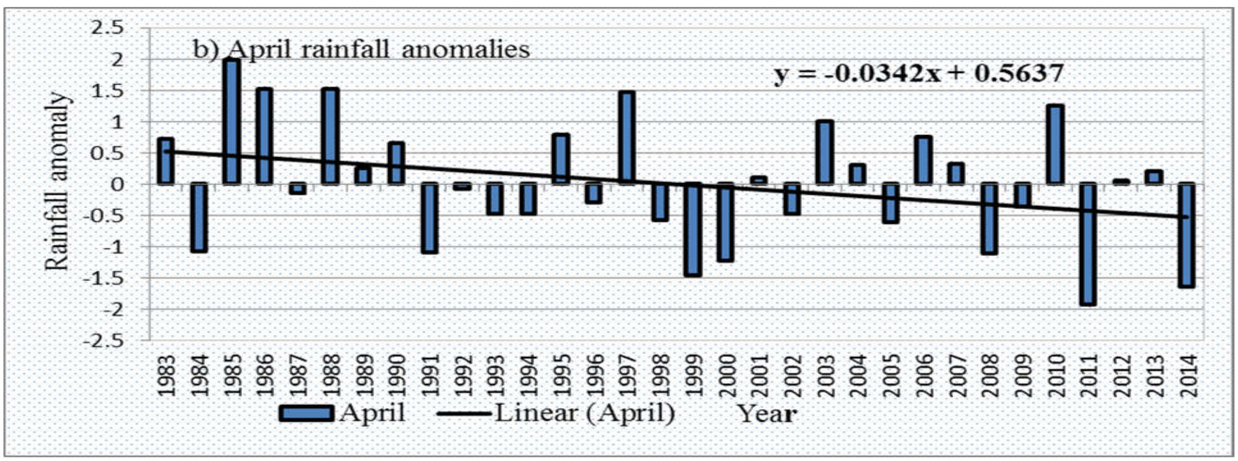
(MAM) rainfall has been continued to be declined. Similarly Viste *et al*. (2013) documented that in southern Ethiopia there has been a general declining in precipitation during this period.
This pattern varies across the region, with uncertainty of the rains increasing in drier zones. The decline of the main rainy season could be the main cause of cattle mortality and loss of livestock production.

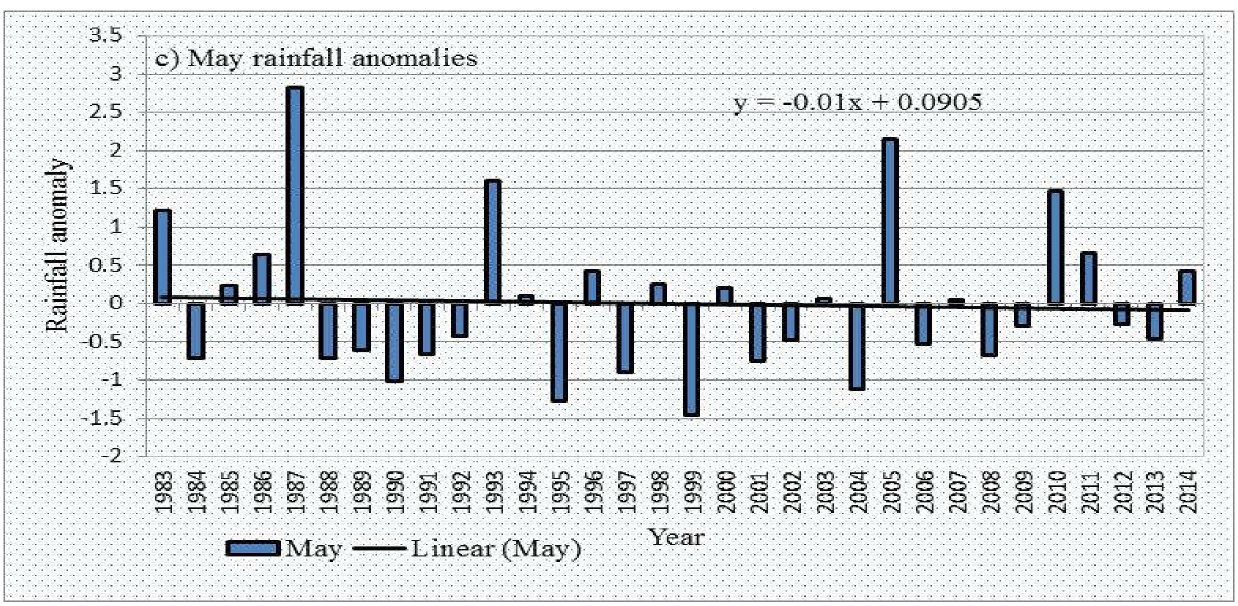
Table 1: Descriptive statistics of monthly rainfall at Borana Zone

	Monthly rainfall in (mm) at Borana Zone					
Descriptive statistics	Mar	Apr	May	Sep	Oct	Nov
Maximum	83.5	175.9	179.9	124.3	140.0	80.0
Minimum	55.0	128.4	65.9	25.5	73.4	57.5
Mean	70.3	151.0	115.0	56.6	99.3	66.0
Std. Deviation	7.0	14.7	40.6	31.0	22.6	6.0
Range	28.5	47.8	114.0	98.8	66.6	22.5
CV	10	9.7	35.3	54.8	22.7	9.0

In Borana Zone pastoralist and agro-pastoralist areas, the second rainy season starts from September and extended until of the November. During the past thirty-two years, September rainfall extended from 25.5mm to 124.3mm, with SD and CV 31 and 54.8%, respectively. May is the last month for main rainy season, which experiences high rainfall variability as compare to March and April. During the second rainy season received in the month October, which rainfall extended from 99.3mm to 140mm, with SD and CV about 22.6 and 22.7%, respectively. November is the last month of for second rainy season, are rainfall extended from 57.5mm to 80mm with SD and CV 6.0 and 9%, respectively. On (Fig.4e and 4f), the trend analysis indicated that second rainy season an increasing pattern in rainfall amount.


a) March rainfall anomalies
y = 0.01x - 0.1017
Rainfall anomaly
Year
March
Linear (March)


b) April rainfall anomalies
y = -0.0342x + 0.5637
Rainfall anomaly
Year
April
Linear (April)


c) May rainfall anomalies
y = -0.01x + 0.0905
Rainfall anomaly
Year
May
Linear (May)

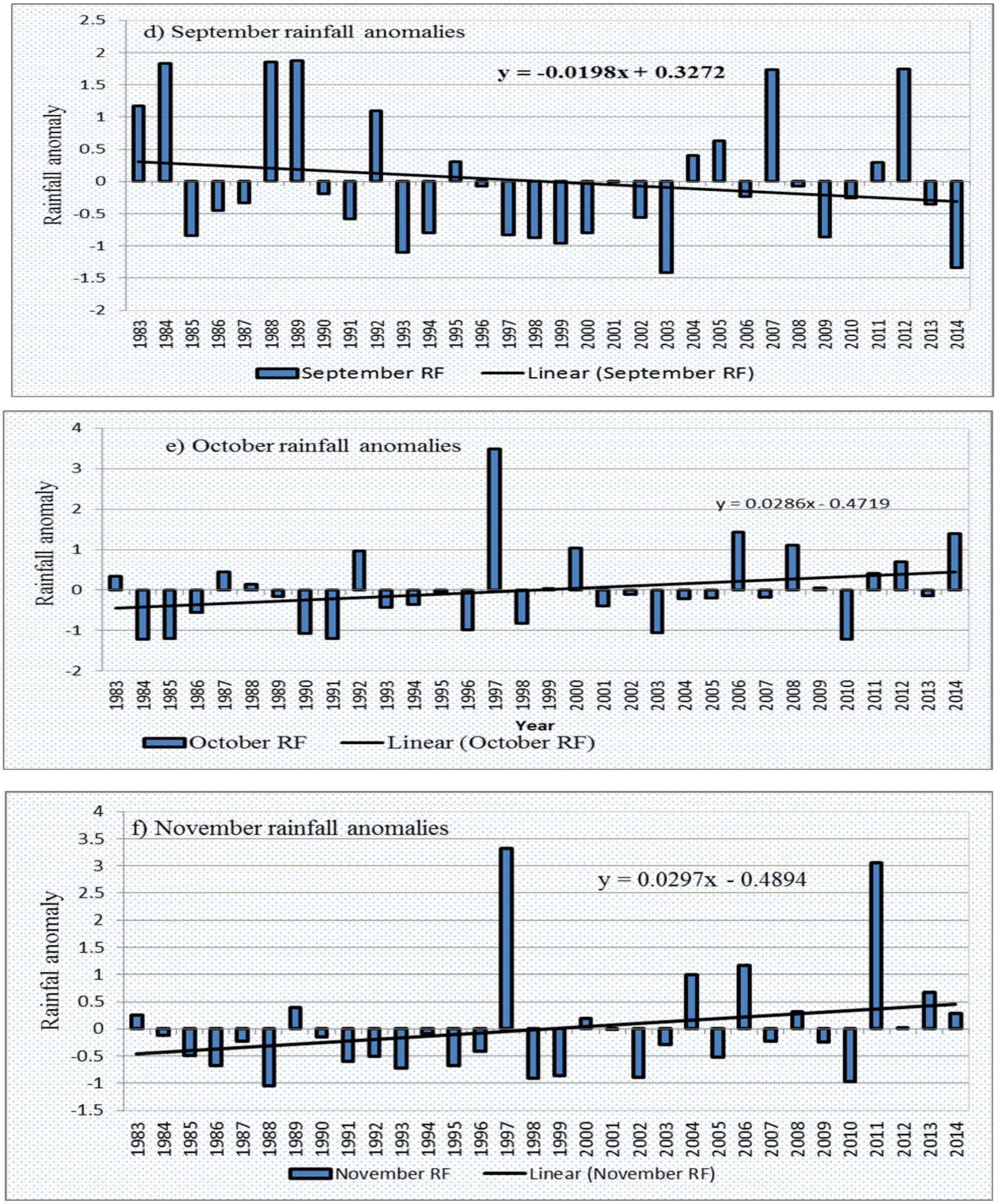
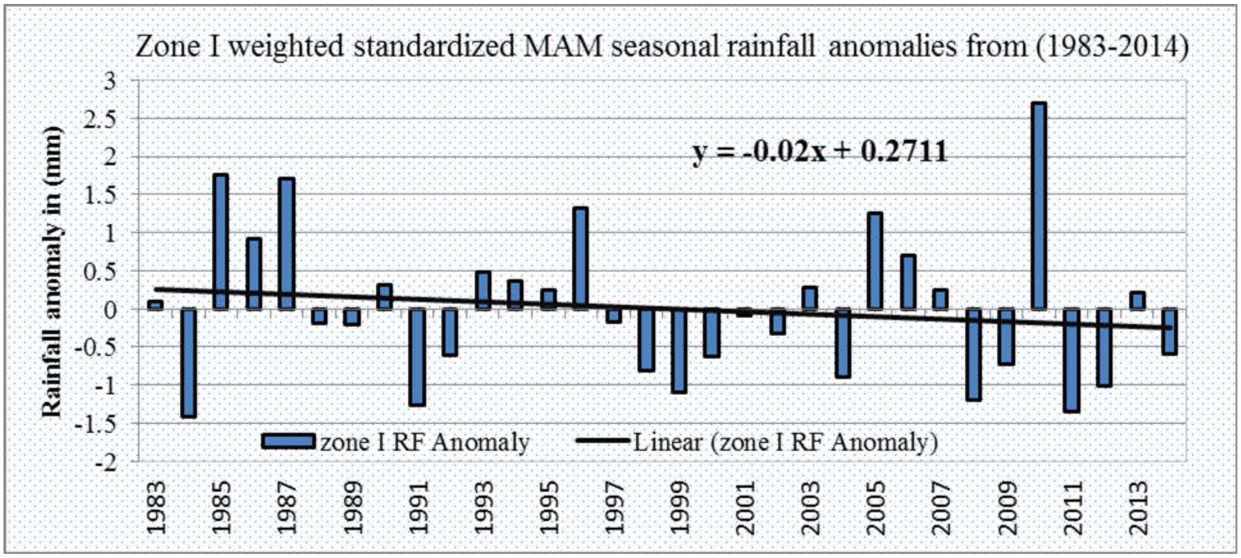
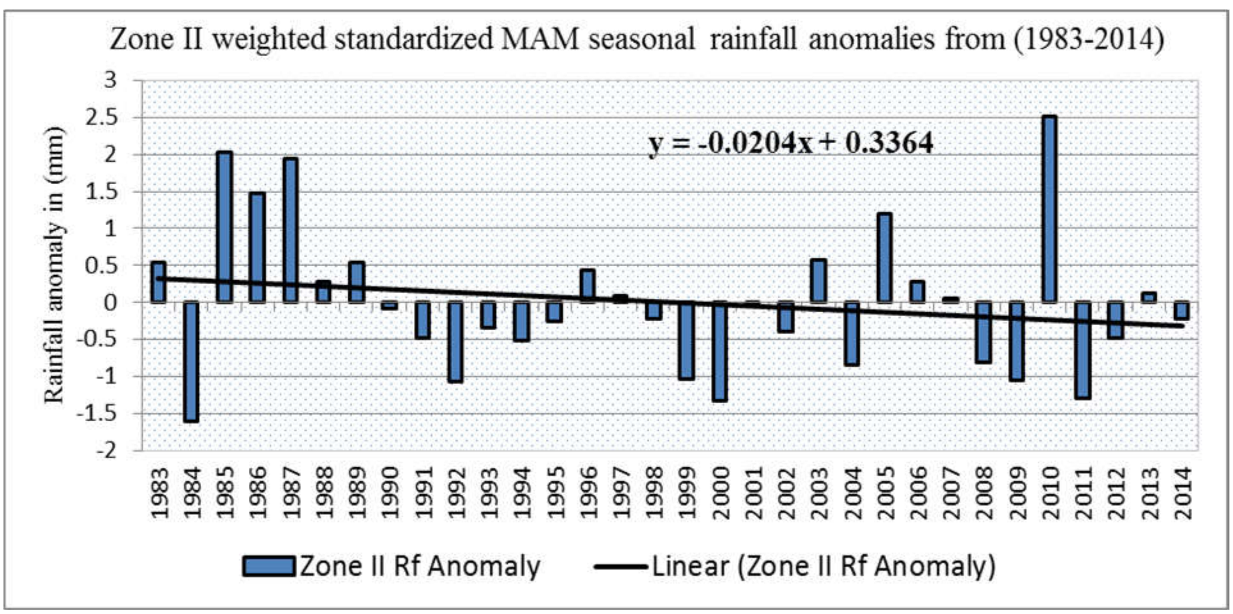


Fig. 4.Time series showing rainfall anomalies and trend over Borana Zone during a) March, b) April, c) May, d) September, e) October and f) November

4.2.2. Seasonal rainfall variability and trend analysis

Estimation of changes in the seasonal rainfall during the last three dekades was weakening due to decreasing pattern in rainfall amount during in April and May. However, the seasonal rainfall during (SON) revealed an increasing from time to time over the past thirty-two years due to increasing during October and November (Fig.4e and 4f). In addition, NMSA (1996a) confirmed that the seasonal rainfall during MAM is erratic and its pattern highly variably in amount.





Zone III weighted standardized MAM seasonal rainfall anomaly from (1983-2014)

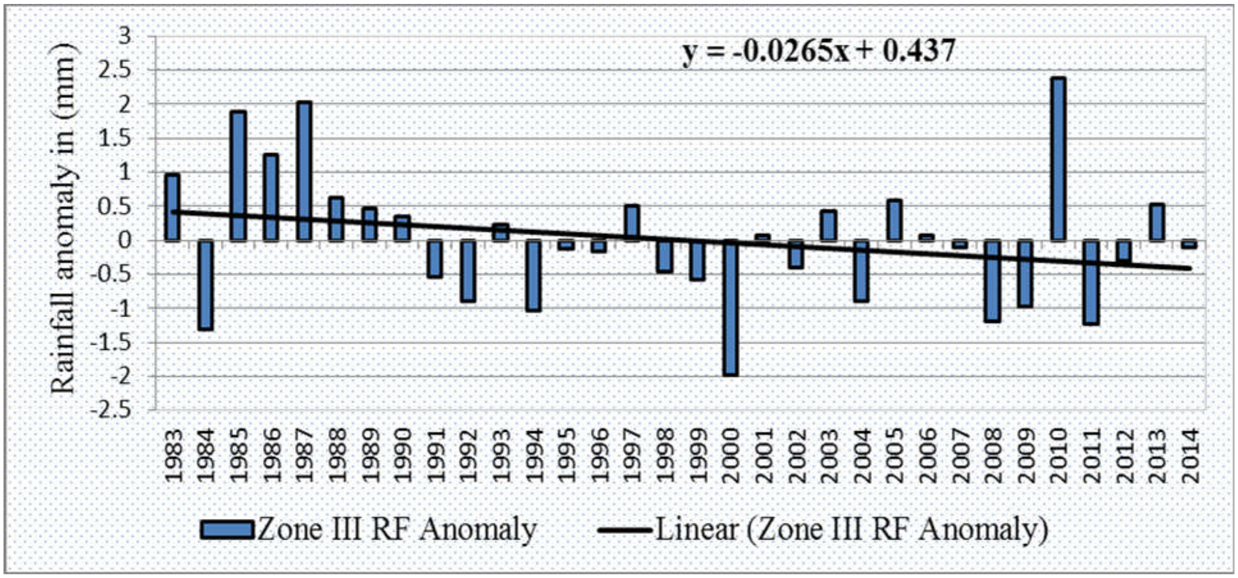
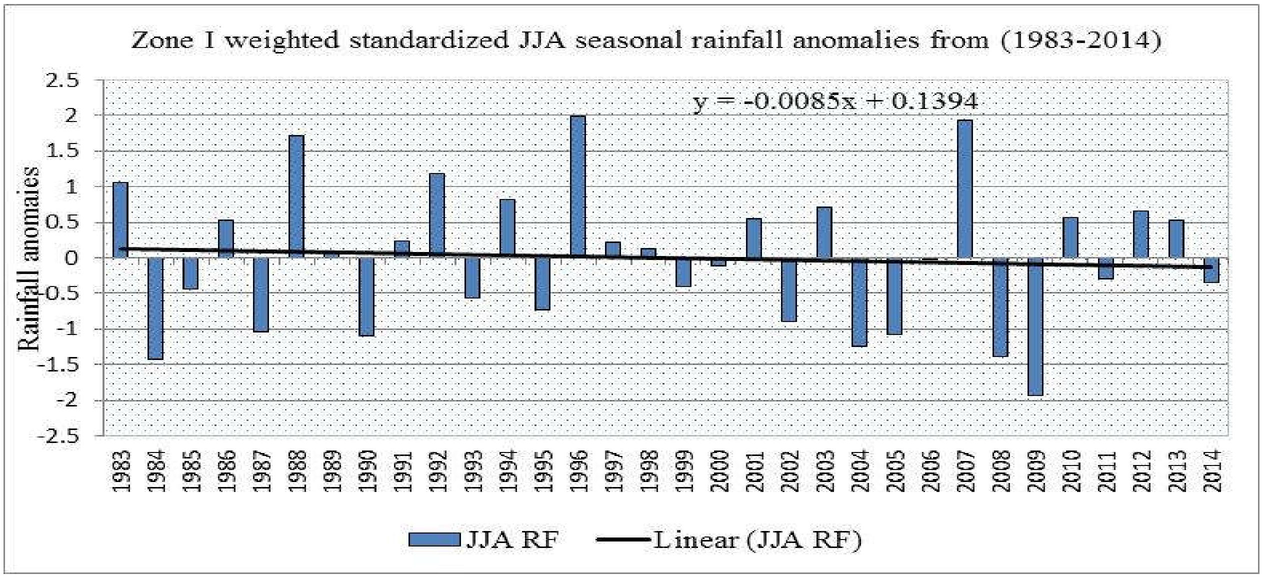
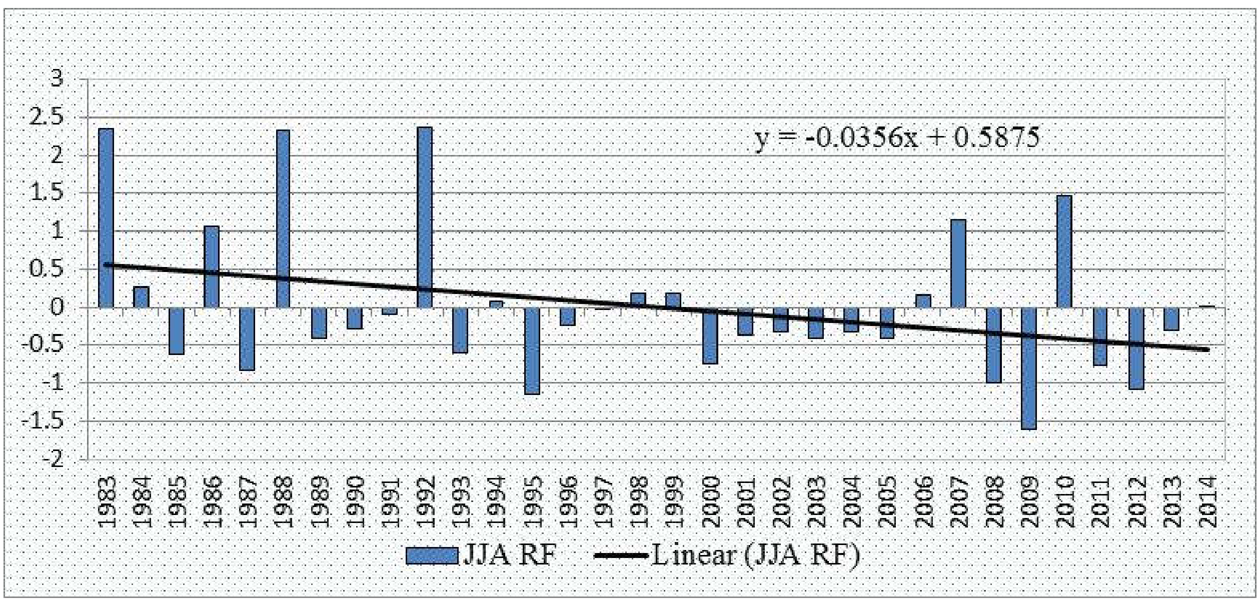


Fig.5. Time series showing rainfall anomalies and trend over Borana Zone during MAM for Zone I, Zone II and Zone III.

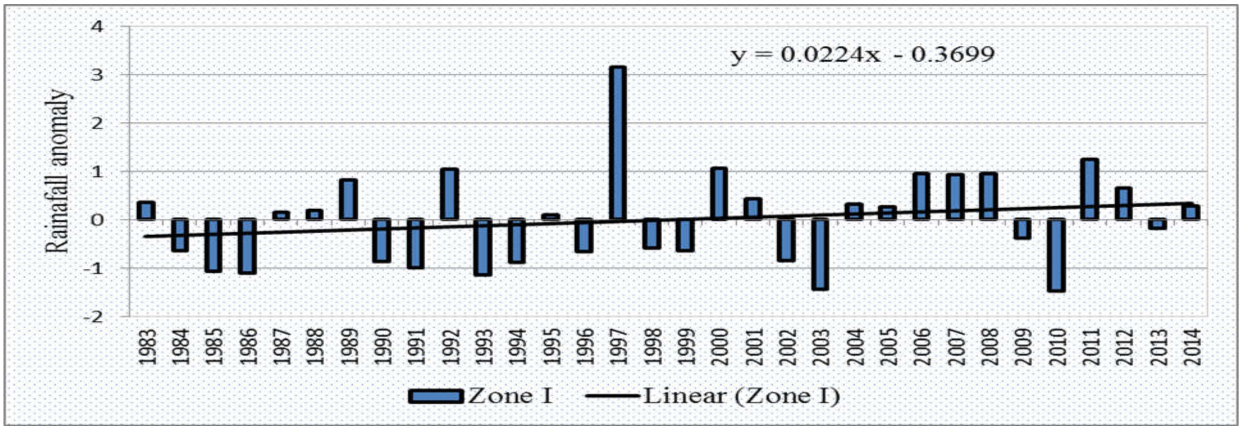
Fig.5 revealed that rainfall totals during the main rainy season has decreased in the study area. Inversely in case of short rainy season (SON), the trend analysis of the standardized seasonal rainfall showed an increase in rainfall amounts over time at Zone (Fig.7).Compared with the long-term average total; it means that the annual rainfall was decreasing at a rate of 0.17 per ten year. It is also clear from the results of the linear trend analysis that the decline in the annual rainfall yield is predominantly because of the substantial decline in April and May rainfall, due to this the (MAM) season reduced over the time (Fig.5). Similar result has been observed is the main cause of the livestock death (Fig. 13). As computed to the second season, pastoralist and agropastoralists depends highly on the main season rainfall. Hence, decrease the amount of rainfall during season has resulted in tremendous death of livestock population.



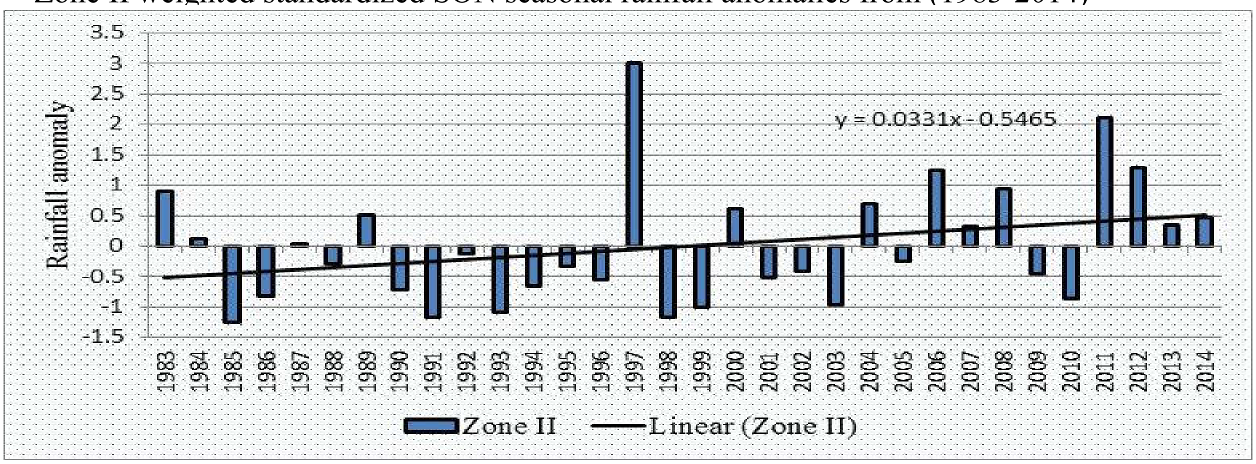
Zone II weighted standardized JJA seasonal rainfall anomalies from (1983-2014)



Zone I weighted standardized SON seasonal rainfall anomalies from (1983-2014)



Zone II weighted standardized SON seasonal rainfall anomalies from (1983-2014)



Zone III weighted standardized SON seasonal rainfall anomalies from (1983-2014)

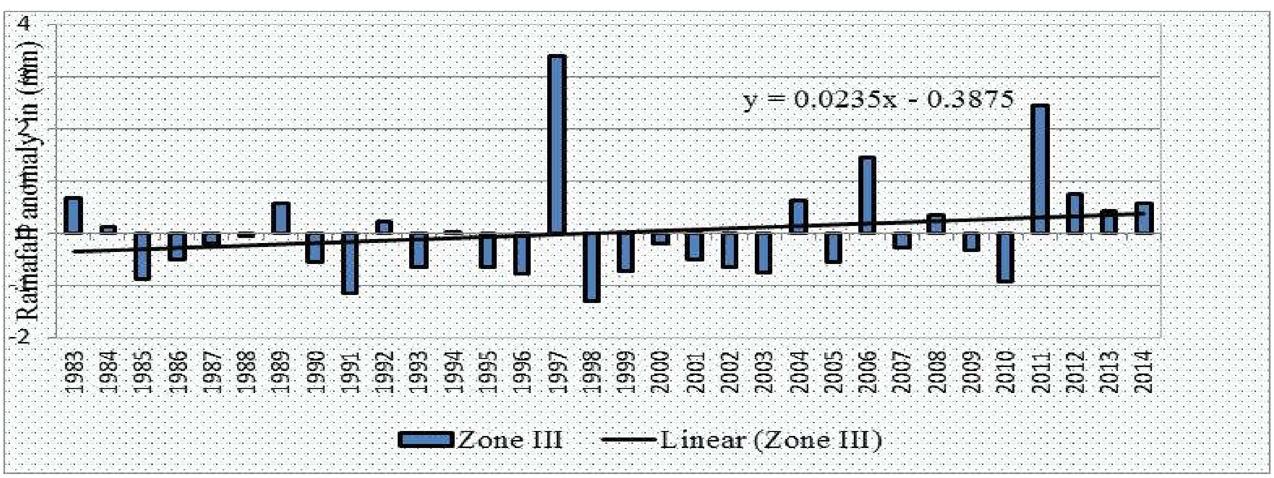
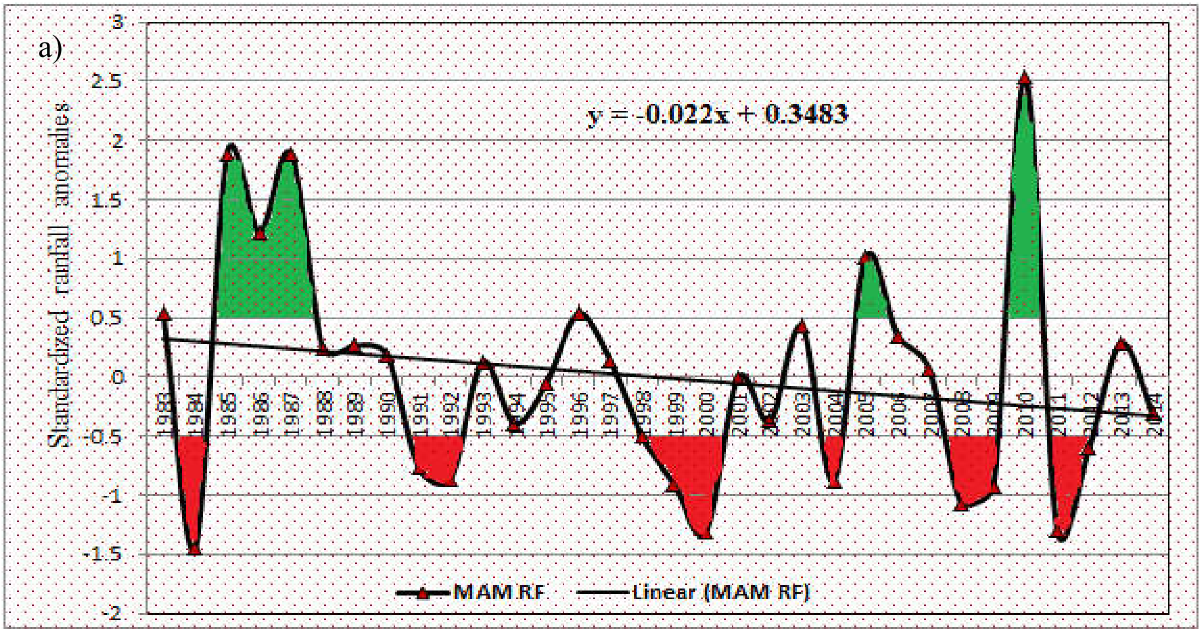
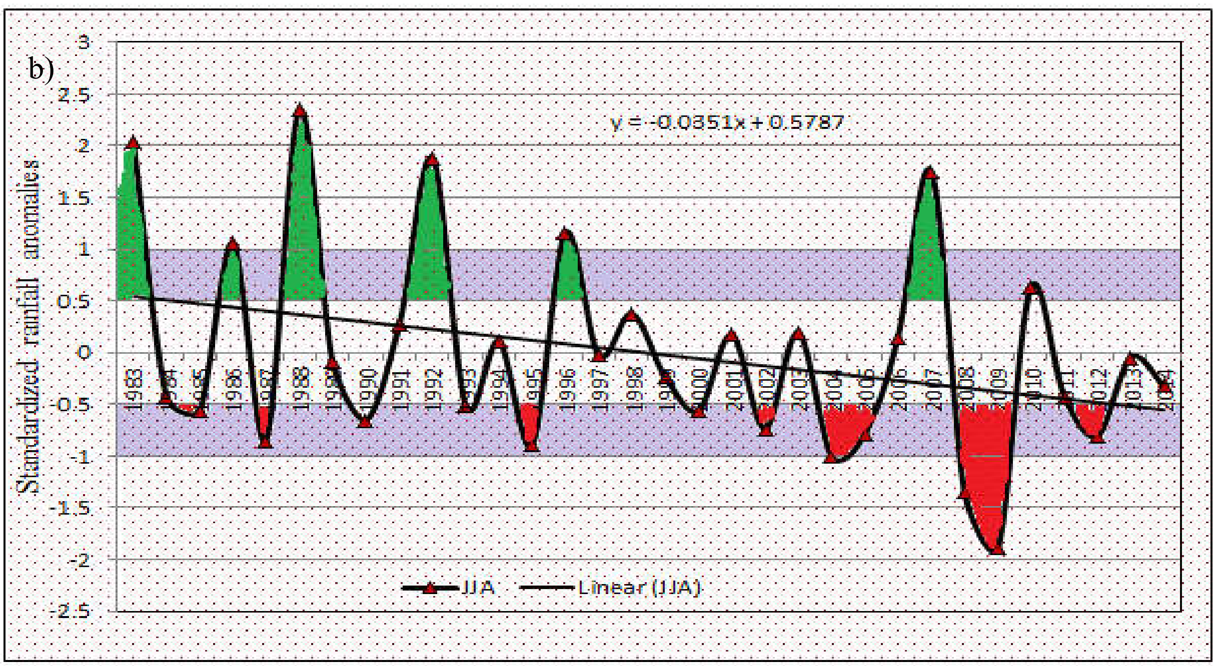


Fig. 7. Time series of rainfall anomalies and trend over Borana Zone for SON Zone I, Zone II and Zone III.


a)
Standardized rainfall anomalies
y = -0.022x + 0.3483
MAM RF
Linear (MAM RF)


b)
Standardized rainfall anomalies
y = -0.0351x + 0.5787
JJA
Linear (JJA)

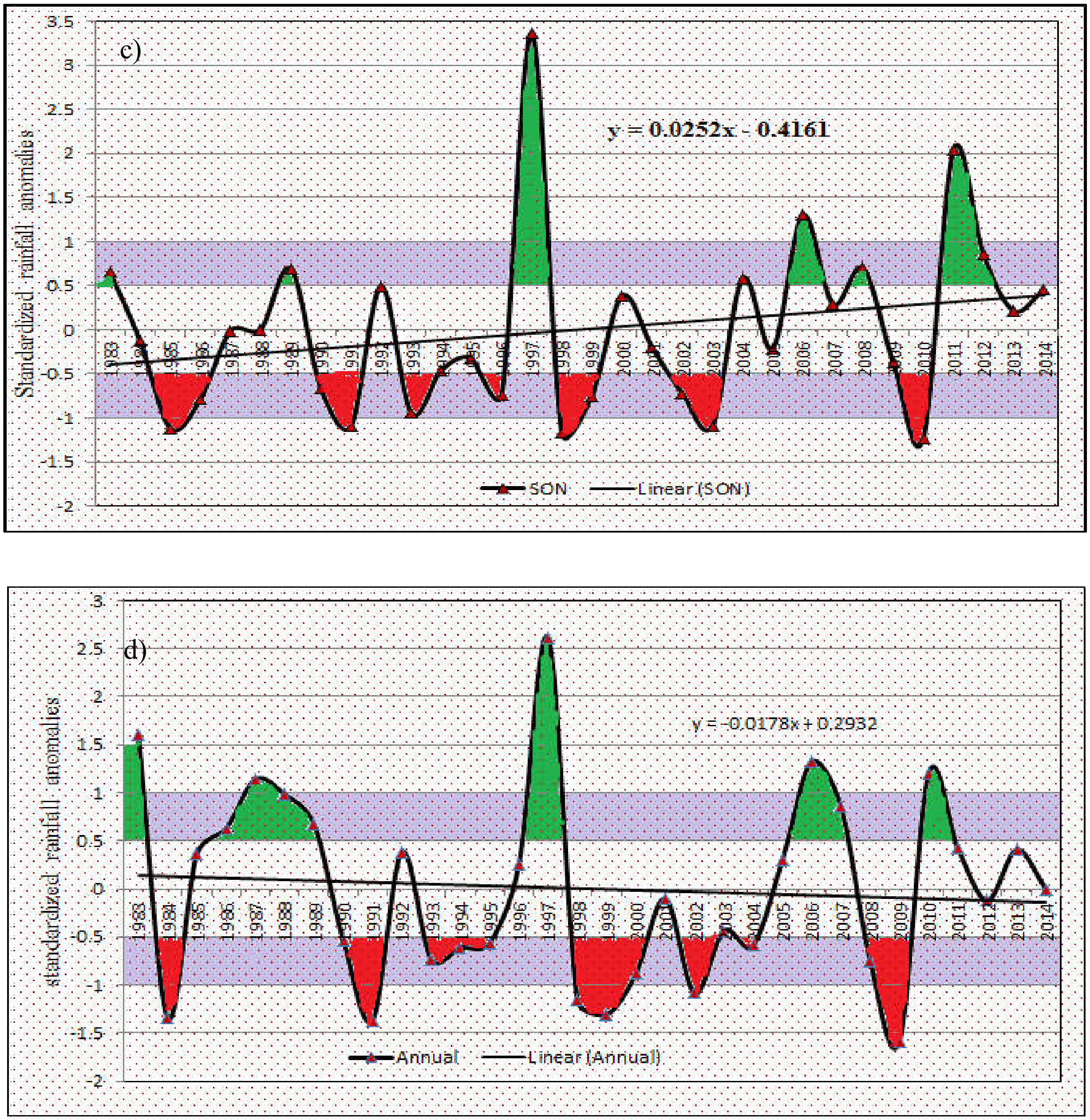


Fig. 8.Time series of a) MAM, b) JJA, c) SON and d) annual standardized rainfall anomalies and trend over Borana Zone

As shown from Fig.8a, from 1983 until 2014, the Zone received below and above normal rainfall during (MAM) season. The red colour indicated the year that of rainfall declined moderate to extreme dry (1984, 1991, 1992,1998,1999,2004,2008,2009,2011 and 2012), whereas the green is show the year that rainfall is moderate to extreme wet (1985, 1986, 2005 and 2010).

Obviously as the graph shown, the Zone was moderate for 10 years out of thirty-two years and moderate to extreme wet for 4 years out of thirty-two years during MAM season. The Borana Zone arid and semi-arid was consequently for sixty (17) years (from 1988-2004) were near normal to moderate dry (Fig. 8a).Among these sixty years, four-drought years had occurred (1991, 1992, 1999 and 2000) and serious affected massive of cattle mortality.

Fig.8c, shows year-to-year variation of (SON) season rainfall over the Zone expressed in terms of standardized rainfall anomaly averaged which clear shown the rainfall increased. As the trend, analysis shown years like (1983,1997,2006,2008,2011 and 2012) were moderate to extreme wet, however years like (1985,1986, 1990,1991,1993,1998,1999,2003 and 2010) were received moderate to extreme dry. Among, the above normal years during the short rainy season, 1997 year is the year serious flood occurred. As Fig. 8c indicated, the Zone had moderate to extreme wet almost for 5 years while for 11 years it were received moderate to extreme dry out of thirty-two years. As observed from Fig. 8a, 1997 little rainfall in amount during the long rainy season. As it seen from Fig.8c, the trend line indicates that SON season rainfall shows increment. In case of annual rainfall, as trend analysis could have seen from the Fig.8d, the Zone received 7 years moderate to extreme wet and 8 years moderate to extreme wet out of thirty-two years. Note that rainfall standardized anomalies in seasonal or annual less than negative one (<-1) indicates severe and extreme drought.

4.2.3. Pattern of annual rainfall at Borana Zone

Borana Zone experiences a bimodal seasonal pattern as it lies astride the equator: the long rainy seasons starts from March and runs through to May, with the peak centered on April; the short rainy seasons run from September to November (coinciding with the shifting of the Inter-Tropical Convergence Zone) with peak rainfall October (Fig. 9 and Fig.10). The source of ITCZ is the development of thermal low over south Sudan, generation and propagation of disturbances over the Mediterranean Sea, sometimes coupled with easterly waves and development of high pressure over Arabian Sea. These interactions between mid-latitude depressions and tropical systems accompanied by toughs and the subtropical jet and occasional development of the Red Sea Convergence Zone (RSCZ) (NMSA, 1996; Gonfa, 1996). For the reason that the Sun is over the equator on 21st March, the tropic of Cancer on 22nd June, the equator again on 23rd

September, and the tropic of Capricorn on 22nd December. The interdependence between the Sun and Earth as the Sun's heat causes a low pressure zone that encircles the earth roughly parallel to the equator, and that moves north and south following the sun, usually with a lag of 4 to 6 weeks (Donohe *et al*., 2012). The ITCZ is the result of the convergence of the northern and southern hemisphere trade winds and is characterized by relatively low-pressure zone. Over these ITCZ areas, the weather is quite disturbed, consisting of widespread cloudiness, occasional thunderstorms and precipitation and moderate to strong winds (Aida, 1999). Therefore, seasonal climate characteristic of tropic regions are depending on the movement of ITCZ, which enhance the movement of air masses.

The annual rainfall associated to topography and global SST phase, over the highest elevation regimes receive up to 1107 mm per year whilst the low plateau receives only 534 mm (Table 2). The entire Zone receives less than 432 mm of rainfall per season, particularly areas around the southern parts of the Zone. The (Fig.8d) shows as well that annual rainfall is highly variable, especially in the arid and semi-arid regions, and unreliable for rain-fed agriculture and livestock production.

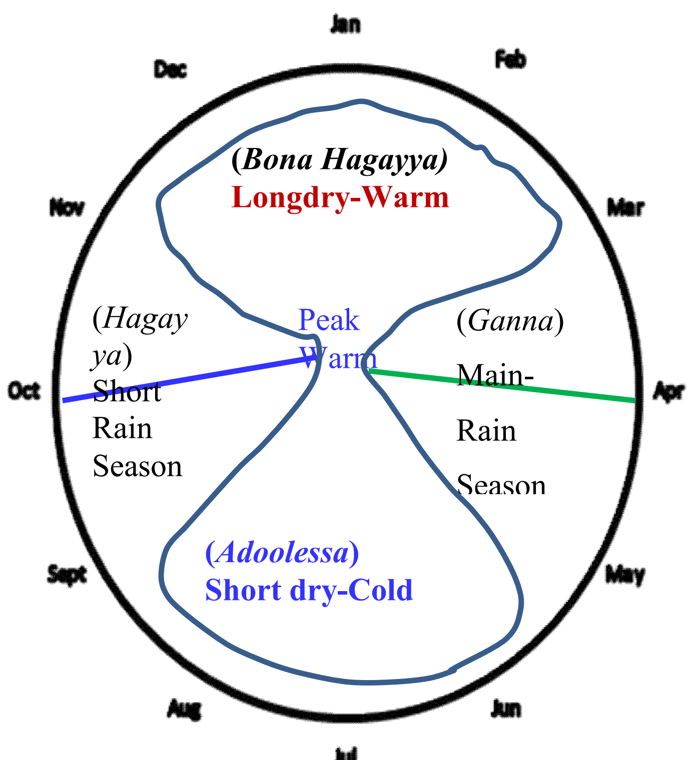


Fig. 9. Borana Zone annual rainfall cycle

The entire of the districts experienced mean annual rainfall of 738 mm in the period of observation, with a standard deviation coefficient of variation 184 mm and 24.7%, respectively.

According to ABM (2010), the variation could be taken as moderate. Therefore, the annual rainfall variability was taking as moderate variability. Generally, below average rainfall years occurred 16 out of the 32 years (Fig.8a). During the major drought years of 1984, 1991-1992,1999, 2000,2004 and 2011 the mean MAM seasonal rainfall declined by 37.8%, 22%, 23%, 34% , 24% and 34%, respectively. The MAM season total rainfall of Borana Zone also varies temporally and spatial, extended 248 mm to 432 mm, with standard deviation and coefficient of variation 58.8 mm and 17.5%, respectively. This season is the main rainy season of the Zone, which the Borana communities accomplished many activities.

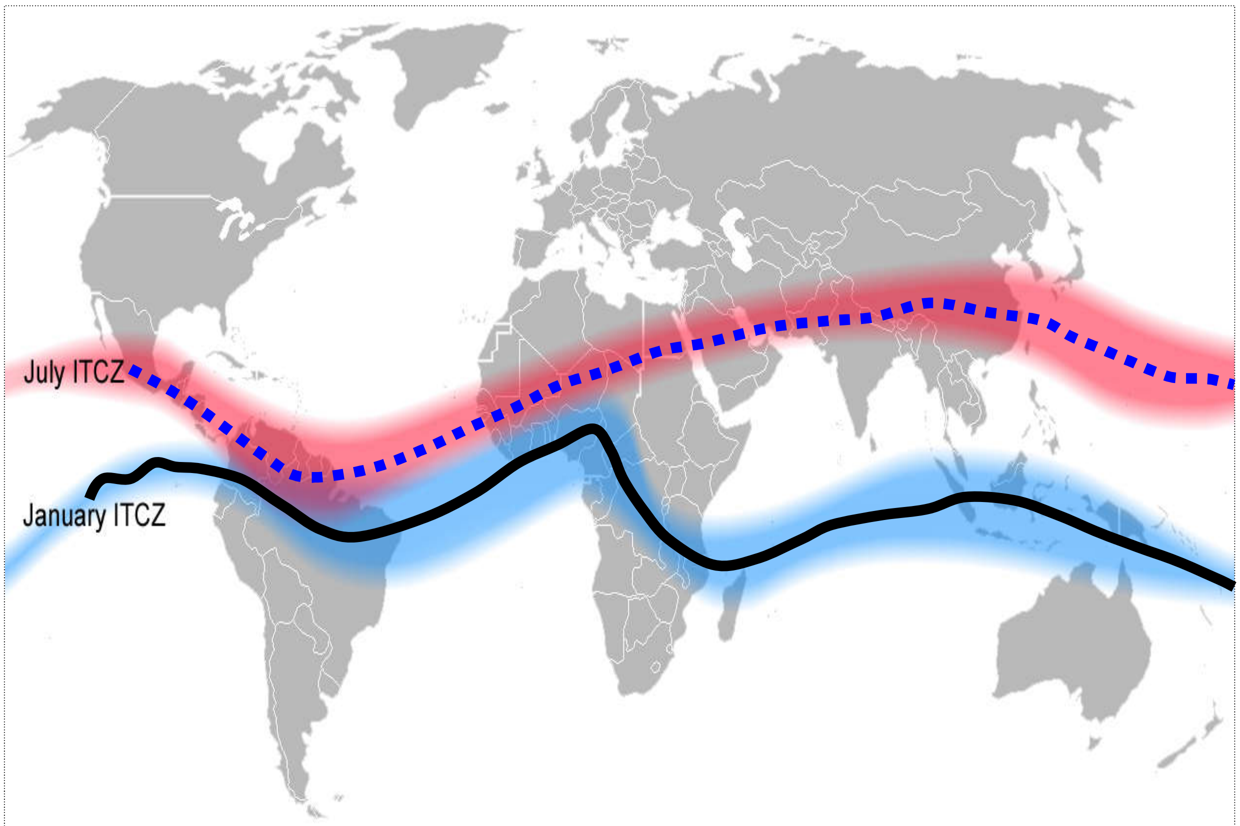


Fig. 10. Position of Inter Tropical Convergence Zone (ITCZ) during January and July months

Table 2: Descriptive statistics of annual and seasonal Rainfall at Borana Zone

Descriptive statistics	Annual Rainfall (mm)	Total Seasonal Rainfall (mm)			
	Rainfall	MAM	JJA	SON	DJF
Minimum	534.4	248.9	47.9	162.8	52.0
Maximum	1107.2	432.0	270.5	313.4	95.0
Mean	738.6	336.3	106.7	221.9	73.6
Range	572.8	183.1	222.6	150.6	43.1
SD	184.1	58.8	69.3	52.0	12.6
CV	24.9	17.5	65.0	23.4	17.1
25^{th}	591.9	291.2	50.7	179.2	66.7
50^{th}	681.2	320.6	75.5	203.7	70.7
75^{th}	857.6	385.0	142.0	261.7	83.8

MAM=March, April, May, JJA= Jun, July, August, SON= September, October, November, DJF= December, January, February

4.4. Effects of Rainfall Variability on Cattle Mortality

Seasonal patterns in the standardized anomalies of rainfall revealed that the droughts would have revealed by sequential failures in the long and short rains (Fig.11). In addition, a time series indicates clearly that drought that occurred during 1984, 1992, 2000, 2004, 2009 and 2010/11directly associated with the failure of long rainy season (Fig.11). However, drought events that occurred in 1991, 1999 and 2002 were associated with shortening and poor performance of long and short rainy seasons. In recent years, droughts have become severe and recurrent, which occur once in every four to six years. The trend lines obviously indicate that recently cattle population decline with the decline of long rain season (Fig.14a). From 1983-2014, for instance, among droughts years occurring in Borana Zone,70% of the events occurred due to declining of long rainy season whereas 30% associated to declining of both rainy seasons. Among drought events that occurred in Borana Zone 1983/84 and 2010/11 were found to be worst incidences that widely affect the Zone.

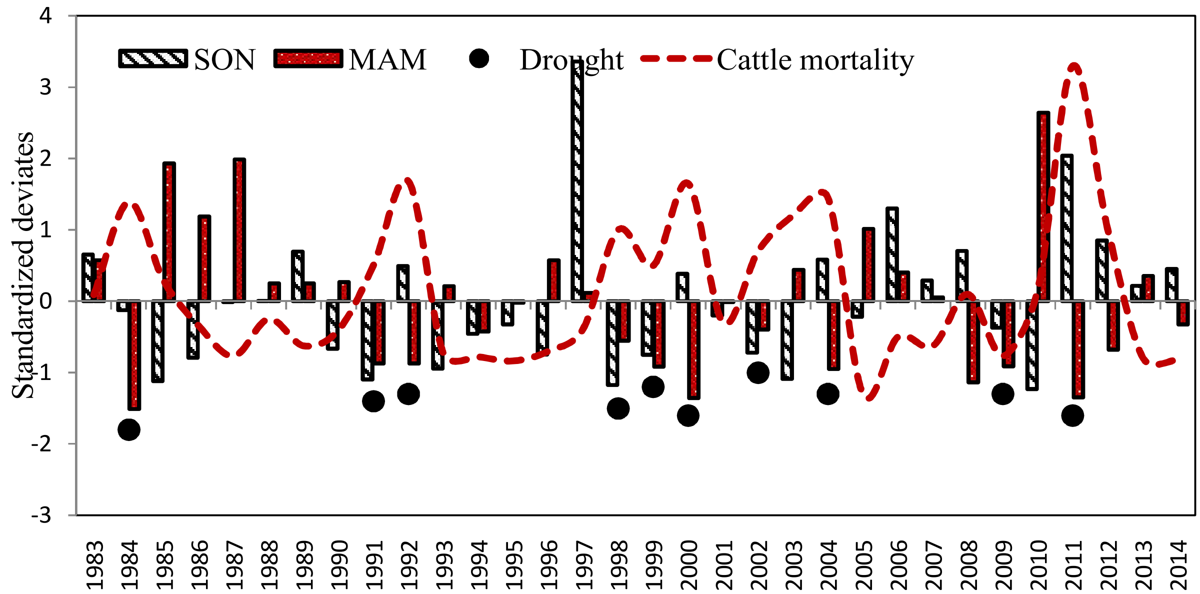


Fig.11.Standardized Seasonal rainfall anomalies and cattle mortality in Borana Zone

4.4.1. Standardized rainfall anomalies and percentiles as a measure of drought

In Borana Zone, droughts occur due to either failure of the long rains or below average of both the short and the long rains. As indicated in (Fig. 11) that among thirty-two years (1983-2014) the long rains and short rains were below average for 10 and 9 years, respectively. However, failure of the short rains alone may not result in drought if the long rains resume timely. Drought indicators based purely on precipitation give a good overall view of the situation. Correspondingly McKee *et al. (*1993) used standardized rainfall anomalies to classify degree of drought. Ntale and Gan (2003) compared different drought indices for East Africa, concluding that a modified SPI was the best indicator for monitoring East African droughts. Droughts have frequently hit the Borana area, causing heavy livestock mortalities, particularly of cattle (Desta and Coppock, 2002; Angassa and Oba, 2007). The risk of heavy livestock losses suffered during recurrent severe droughts associated with rainfall variability presents one of the most serious threats to pastoral livestock keepers. Drought is an extreme weather event, which results when rainfall is far below average (failure of rainfall).

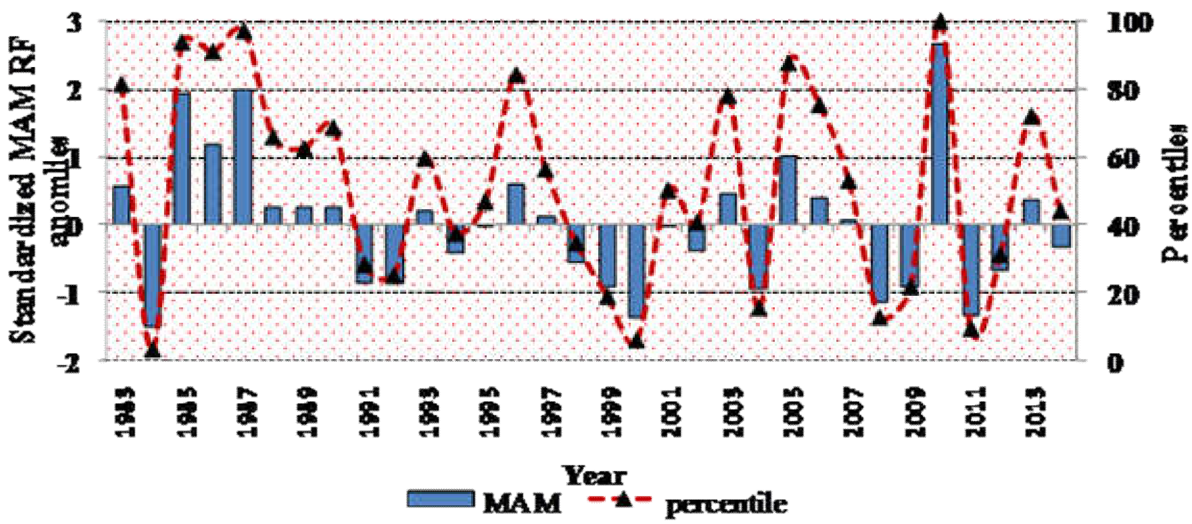


Fig. 12. Standardized seasonal rainfall anomalies and percentile, were plotted x and y axes, respectively

Drought begins when the standardized rainfall anomaly first falls below zero and ends with the first positive value (McKee *et al.,* 1993). In addition, drought measured that precipitation below 30 to 20th percentile may indicate mild drought (dry year), 20 to 10th percentile: moderate drought and less than 10thpercentile severe drought (Megersa *et al*., 2013). As the Fig.12 indicated the droughts of 1984, 2000 and 2011 categorized as severe drought their percentiles (3, 6 and 9), respectively. Moreover, drought of 1999, 2004 and 2008 were categorized as moderate drought, their percentiles (19, 16 and 13), respectively. The mild droughts (dry years) were occurred in 1991, 1992 and 2009 years with their percentiles of (28, 25, and 22), respectively. Generally, from 1983 to 2014 three class of droughts were occurred, which is known as mild (dry year), moderate and severe droughts. Similar to rainfall percentiles also rainfall anomalies clearly, strongly associated with drought events. For instances, the standardized rainfall anomalies values during severe drought years in 1984, 2000, and 2011 was (-1.5,-1.4 and -1.34), respectively.

4.4.2. Cattle herd dynamics in Borana Zone

The seasonal patterns of rainfall revealed that cattle herds were associated with the long rains. In most cases, it was the sequential rain failures of long rain (Fig.13).

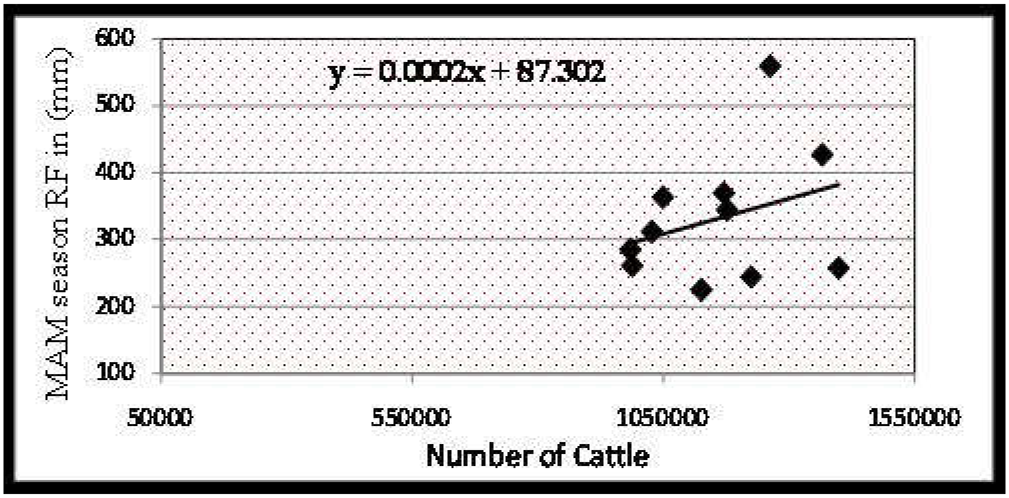


Fig.13. Relationship between cattle herds and MAM seasonal rainfall

As indicted in scatter plot of Fig.13, increase the amount of total rainfall during MAM increases cattle herd. As discussed in different angles, in Borana Zone pastoralist area the cattle herds are mainly depend on long rainy season rather than short rainy season because second rainy season (SON) is not reliable. As suggested in many studies (Coppack, 2004; Megersa *et al*., 2013 and Viste *et al.,* 2013), drought occurred due to failure of long rain (MAM) season. Likewise, from Fig.6 it was confirmed that 1983/84 and 2010/11droughts were occurred as mild to severe due to declining long rainy (MAM) season. A downward trend in cattle population mirrored a similar underlying trend in inter-annual rainfall variation. Accordingly, changes in cattle number were significantly linked with changes in rainfall (Fig.14a).

Table 3: Time series multivariate cross correlation matrix

Variables	Cattle	Goat	Camel	MAM	SON	Temp
Cattle	1	-0.133	-0.282	0.629*	0.002	-0.417
Goat		1	0.312	-0.282	0.187	0.762**
Camel			1	-0.455	-0.035	0.623*
MAM[a]				1	-0.218	-0.479
SON[b]					1	-0.071
Temp[c]						1

**. Correlation is significant at the 0.01 level (1 tailed), *. Correlation is significant at the 0.05 level (1-tailed), [a] MAM: long rain (March-April-May) season, [b] SON: Short rains (September-October-November) season and [c] Temp: Mean Temperature

A correlation analysis was used to measure impacts of temperature and rainfall on livestock population dynamics. The analyses revealed that cattle with long rainy (MAM) season (r =0.629, P < 0.05) and goat(r =0.0.762, P < 0.01) were positively correlated with temperature. Whereas camel were having positive relationship with temperature (r = 0.623, p < 0.05) (Table 4). The long and short rains had positively correlated with the seasonal changes in cattle numbers, but the correlation is significant with long rain (Table 4).The annual mean temperature had a negative but insignificant correlation with cattle numbers. The goat and camel numbers were positively correlated with the mean annual temperature and significant (Table 4). Inversely, both goat and camel were negatively correlated with long rain, which is insignificant. In Borana Zone, performance of cattle mainly depends on the long rainy season rather the short rainy season.

Table 4: Relationship between climate variability and ruminant livestock population dynamics in Borana pastoralist area

		Un standardized Coefficients		Standardized Coefficients	t		Correlation
Species		B	Std. Error	Beta	value	Sig.	Partial
cattle	(Constant)	824352.76	143192.5		5.757	0.000	
	Rainfall	948.6	391	0.629	2.43	0.038	0.629
Camel	(Constant)	-407468.4	196665.6		-2.072	0.068	
	Temperature	21090.66	8834.56	0.623	2.387	0.041	0.623
Goats	(Constant)	-2937971.7	1051707.6	0.762	-2.79	0.021	
	Temperature	166775.3	47244.5	0.762	3.53	0.006	0.762

Table 5: Correlations among dependent variables (cattle, goat and camels) and the predictors (rainfall and temperature)

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Variation Statistics			
					F Change	df_1	df_2	Sig. F
Cattle	0.629[a]	0.395	0.328	117669.2	5.88	1	9	0.038
Goats	0.762[a]	0.58	0.534	104741.1	12.46	1	9	0.006
Camel	0.623[a]	0.39	0.32	19586.2	5.70	1	9	0.041

a. Correlation of predictors: rainfall and temperature and dependent variable: Cattle, Camel and Goats whereas correlation is significant at (P is at 0.01 and 0.05). Method: Stepwise

4.4.3. Trends of ruminant livestock population in recent decade

In Borana Zone, rainfall variability greatly influence herd dynamics under different year by herd die-offs and lower birth rates. The 2010/2011 drought was associated with a substantial decline in cattle herd sizes due to heightened mortality (26%) and forced off-take (19%). Death occurrences and mortality rates varied significantly by district, herd size and feed supplementation (Megersa *et al.,* 2013). Likewise, Abdeta and Oba (2007) documented that cattle herd dynamics is strongly determined by rainfall variability in southern Ethiopia. As shown in Fig.13a number cattle revealed decrease with decline of long rainy season. In other word, the standardized deviation of cattle number appeared to mirror the inter-annual rainfall variability in rainfall.

The association between rainfall amount and the population of goat and camel were depicted in Fig.14b and 14c; the result revealed that rainfall amount has no strong relationship with population of goat and camel. Increased drought recurrences and bush encroachments have cited as major factors behind growing interest in camel production (Megersa *et al*., 2013). Consequently, there is a progressive shift from centuries old socio-cultural cattle pastoralist to multi-species herding with an increasing tendency to keep more drought tolerant animal species. Due to differences in their tolerance to water and feed shortage, and resistance to drought among species, multi-species herding is of vital importance in minimizing climate related risks.

Increased in climate variability and drought recurrence reinforce the Borana society's livestock diversification from cattle to more drought tolerant species like Goat Sheep and Camel (Faye *et al.*, 2012; Megersa *et al.,* 2013). The failure of short (September to November) and long rains (March to May) led to the 2010/2011drought, which consequently resulted in household food insecurity following the drought event.

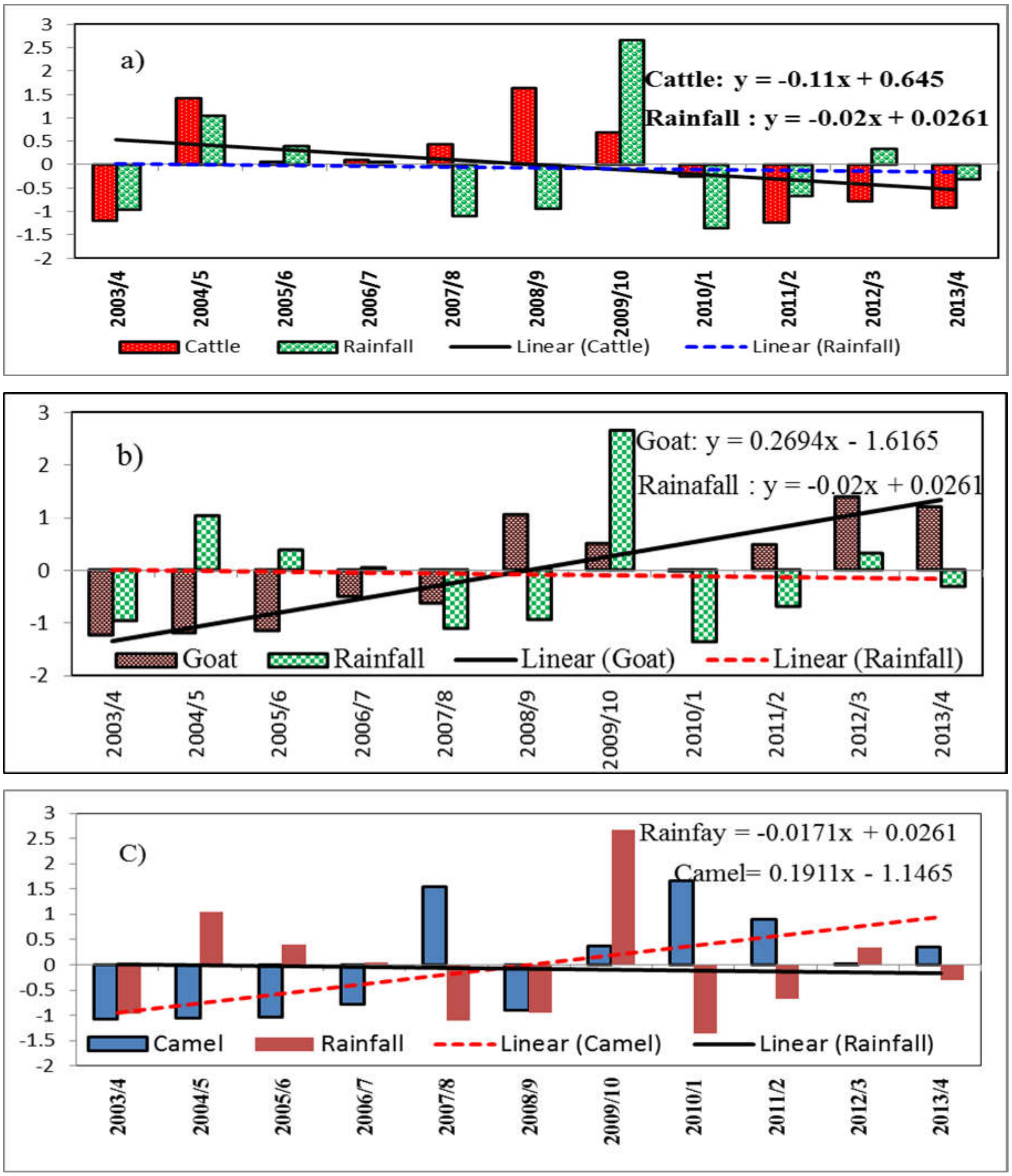


Fig.14. Trends of standardized ruminant livestock population and rainfall a) cattle and RF, b) Goat and RF and c) Camel and RF

	Month						
Year	Mar	Apr	May	Sep	Oct	Nov	All
1984	16	122	145	95	74	43	495
1991	90	80	106	77	64	42	459
2000	16	128	214	65	251	90	764
2011	4	72	181	73	81	228	639
1985	199	303	160	59	50	54	825
1986	23	245	237	88	62	15	670
1987	120	141	298	71	179	64	873
2010	158	210	257	60	70	11	766

Fig.15. Monthly rainfall during eight special years (Four drier and four wettest years)

As depicted in Fig.15, among these eight special years, like 1984, 1991, 2000 and 2011 were severe droughts years that massive of cattle mortality in Borana Zone whereas the years like 1985, 1986, 1987 and 2010 wettest year especially during the long rainy season. Mostly the droughts observed during the mentioned years have caused cattle death (Fig.11) due to decline of long rainy season. During these years, the decline of rainfall became less failure of the March rainfall (Fig.15).For instance, during drought 2011, the amount of rainfall observed in March month is 4mm. Likewise during March 1984 and 2000 were severe drought. This indicates that strong relationship between livestock population dynamics and rainfall. The long rainy seasons are more essential for forage production, crop cultivation and replenishment of water resources, and hence the declining trend is detrimental to pastoral livestock production.

4.4.4. Consequence of drought1983/1984 and 2010/11 on livestock species in Borana Zone

In Borana Zone, severe drought that occurred in 1983/84 and 2010/11 seriously affected societies. Seasonal rainfall patterns revealed that sequential failures of the short and long rains were often associated with droughts. The main cause for 1983/84 and 2010/11 droughts were due to the failure of MAM rainfall (Fig.8a). In contrast (SON) rainfall that observed in 1983/84 and 2010/11 exceeded climatologically norms. As the data obtained from Pastoralist Development Office indicated, the a massive of livestock mortality from in the dry and cold short season

(JJA).The 2010/2011 drought caused massive cattle losses, with mortalities varying significantly by district, herd size and feed supplementation. In general, the analyses exhibited that rainfall variability were having impacts on cattle production, portending a precarious future for the sustainability of cattle pastoralist in Borana Zone of southern Ethiopia.

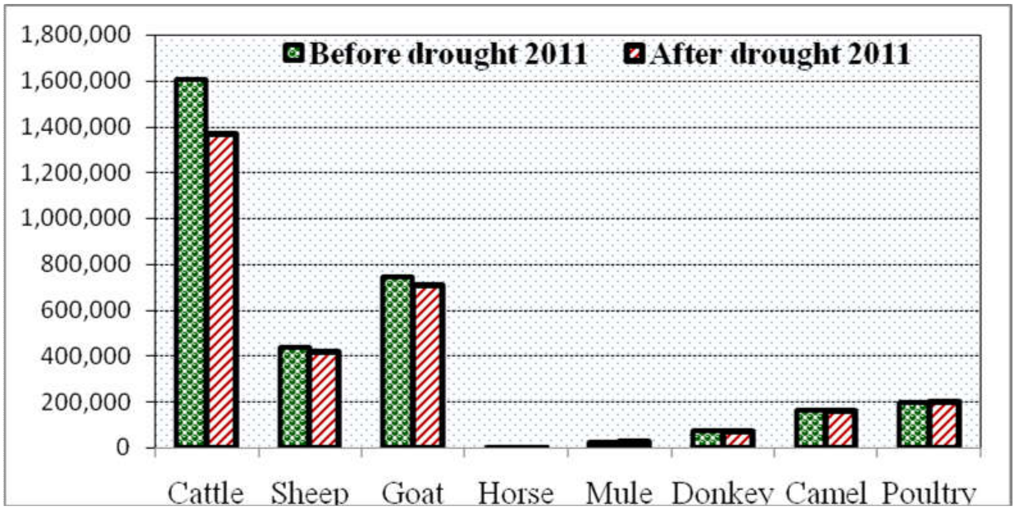
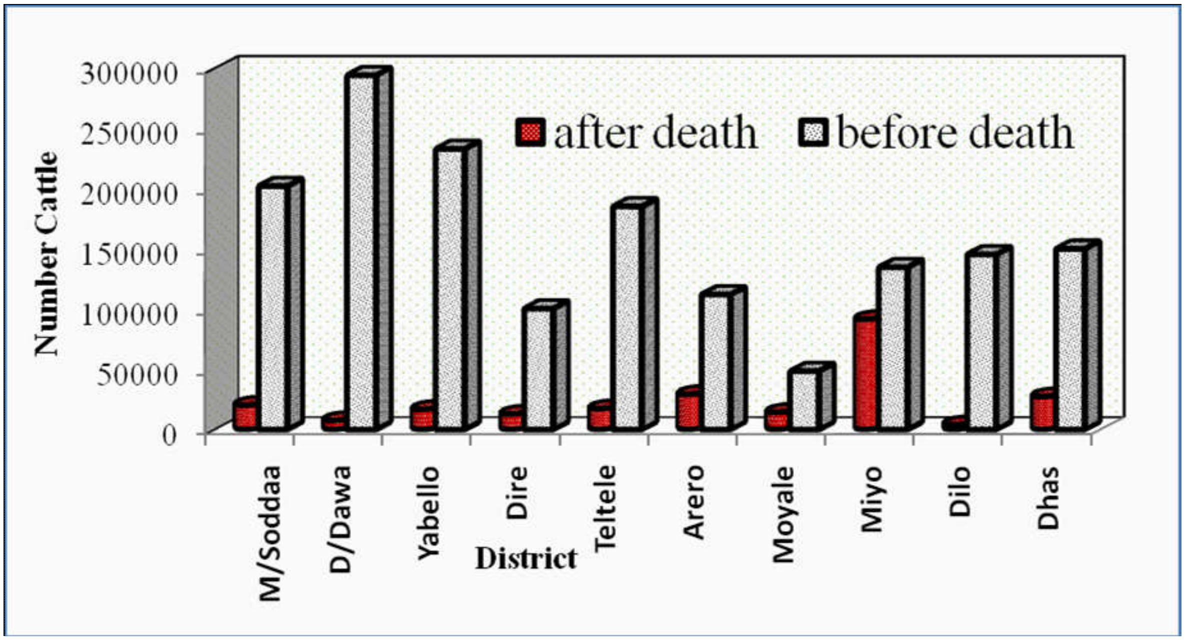


Fig.16. Livestock species before and after 2010/11drought incidence

Climatic variations have a major influence on calving percentage and calf mortality (Cossins, 1987a). A bad drought not only causes high calf mortality but also results in low calving rates in the following year. A decline in calving rate, together with high calf mortality, results in a shortage of replacements and a consequent reduction in animal numbers (Cossins, 1987a). Other studies confirmed that droughts have repeatedly hit the Borana plateau, causing huge mortality in livestock and heightening hardships in humans (Cossins and Upton, 1988; Desta and Coppock, 2004).

Particularly, recurrent droughts evidenced to be the most destructive to the asset basis of pastoral people like the Borana of East Africa. Droughts can lead to herd depletion through increased mortalities, forced off-takes, and emergency slaughter (Cossins and Upton, 1988). Desta and Coppock (2002) have anticipated that drought occurrences cause massive cattle losses every 5 to 6 years on the Borana Plateau. Such quasi-periodic shocks have been evidenced to cause substantial declines in cattle herds, such as by 43% in 1983/1984 (Cossins and Upton 1988), 42% in1991/1992, 25% in 1996 (Tache 2008) and 53% in 1999/2000 (Angassa and Oba 2007). As a result, a total of 45 million dollars asset losses have been estimated for a target population of 7000 households between 1980 and 1997 (Desta and Coppock, 2002).



Source: Borana Zone Pastoralist Development Office

Fig.17. Cattle population before and after drought of 2010/11 by districts

As shown in Fig. 17, during 2010/11 among livestock species massive cattle were lost whereas less mortality has observed over camel, sheep and goat, respectively. However, as the data shown drought 2010/11 were not affected livestock species such as horse, mule and poultry. Also Care Ethiopia (2009) documented that drought 2010/11 impacts include decreased pasture availability, water availability, leading to water shortages and travel over long distances by women in search of water; decreased livestock disease resistance; decreased livestock productivity. For instance, in terms of milk and meat, emaciation and death of livestock, decreased livestock prices and household incomes, crop failure in agro-pastoral areas.

4.4.5. Onset of rainfall at Borana Zone

Like East African arid and semi-arid areas, Borana Zone rainfall is characterized as erratic and highly variable. Erratic onset and distribution of rainfall have resulted in livestock and crop production failure that has led to acute food shortage in Borana Zone. The onset and distribution of rainfall highly associated with the northward migration of Inter-Tropical Convergence zone (ITCZ). The ITCZ which drives the bimodal rainfall pattern during its seasonal North-South movements (Ellis and Galvin, 1994) is highly susceptible to the atmospheric and oceanic factors such as rising sea surface temperatures and the El Niño-Southern Oscillation (Omondi *et al.,*2012).This subsequently, affects the onset and cessation of the regional rainfall as shown in Table 6.

According to the criteria of start of rainy season that embedded in the INSTAT plus version (3.37) software, the start of seasonal rain declared when as total rainfall of more than 20mm recorded in three consecutive days (Stern *et al*., 2006). These criteria normally fulfilled after fist March or first April and no drier spell exceeding 10 day within the next 30 days. No drier spell exceeding 10 days within the 30 days taken as extra criteria that embedded in INSTAT plus version (3.37) helps to avoid false onset. In the Borana zone, for instance, at Hagere Mariam station, March is identified as the starting of rain for 38 years. Rainfall early starts for 18 years and late- onset for 21 years whereas at the Southern part of Zone at Moyale station among 33 years the rainfall early onset for 16 years and late onset for 17 years. As Fig.18a, time series indicated, at Hagere Mariam station clearly last decade the onset of rainfall shift from March to the April. However, when both months take as initial condition start of rain, it is fluctuated not clear at Moyale station. When the April month take as the initial condition for start of rainfall at Hagere Mariam station among 38 years early start for 34 years and late onset for 4 years whereas at Moyale station early onset for 31 and late onset for 2 years. As shown from Fig.21, the early onset associated with high amount rainfall and late onset with less rainfall amount.

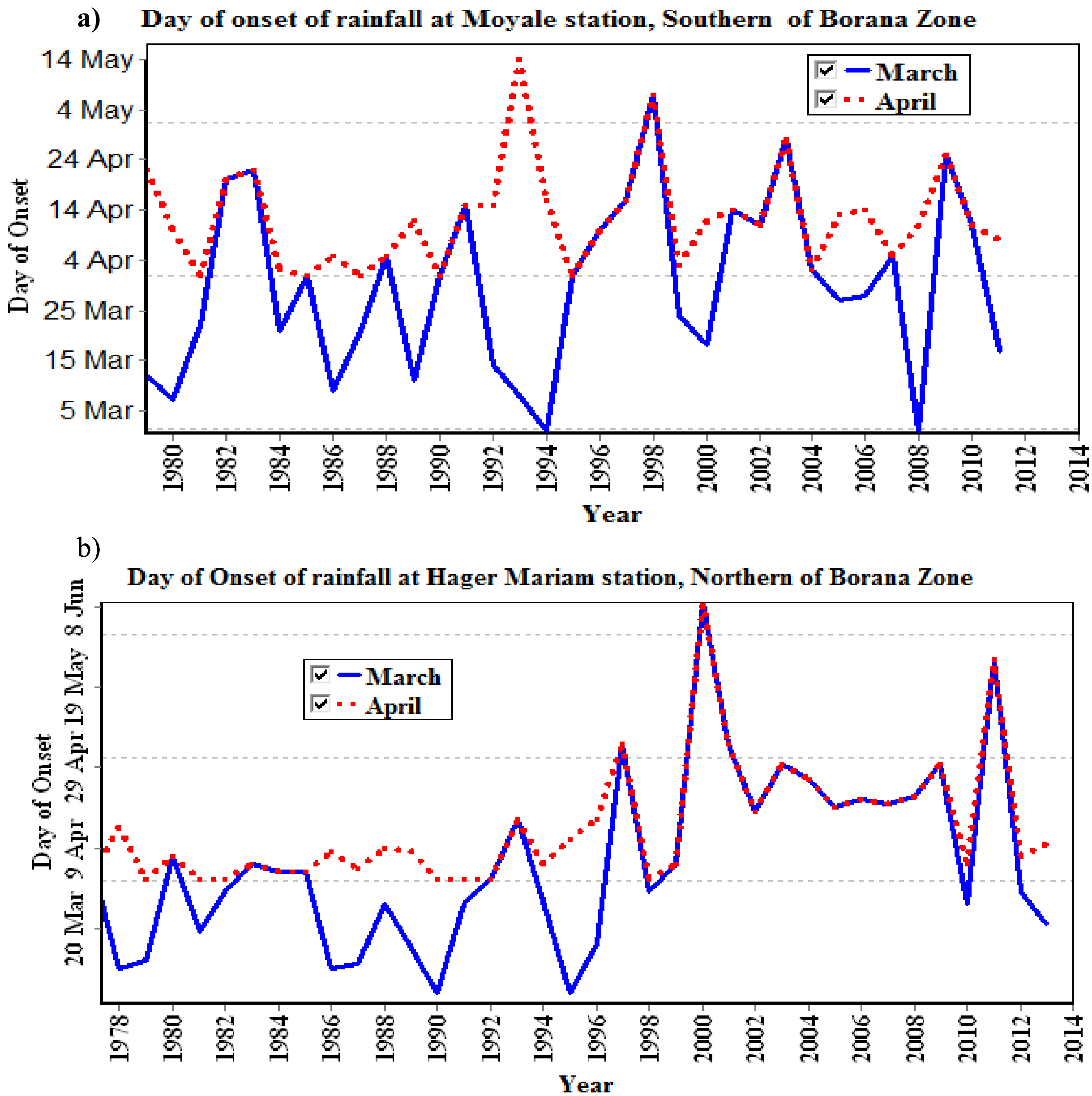


Fig.18. Day of onset of rainy season at Hagere Mariam and Moyale stations, considered start of rain is first March and first April for comparision.

Many scholars documented that the study area is commonly known by the persistence of bimodal type of rainfall (NMSA, 1996 a, b). Clearly understanding of the variability of key MAM characteristics is crucial for Borana pastoralist and agro-pastoralist to manage livestock, to have agricultural planning in general, and especially mitigate the adverse effects of recurring drought and there by fully capitalize when more rains that are abundant occur.

Intended for Pastoralist and agro-pastoralist communities of Borana region first week of March is to be the potential of planting date. Fig. 21 shows how early onset date is associated with increased rainfall totals at both Hagere Mariam and Moyale. Early onset dates in this case, implies the start of rainfall sometimes before February or before the end of DJF season. From the linear regression line, onset date explained about 45% and 40% of total rainfall variance during the main rainy season over Moyale and Hagere Mariam, respectively. Accordingly, Moyale and Hagere Mariam receive maximum rainfall 857 and 1035 mm, respectively, from which one can be deduce a reduction of rainfall totals by 3 mm for a day delay an onset of rainy season (Fig. 21)

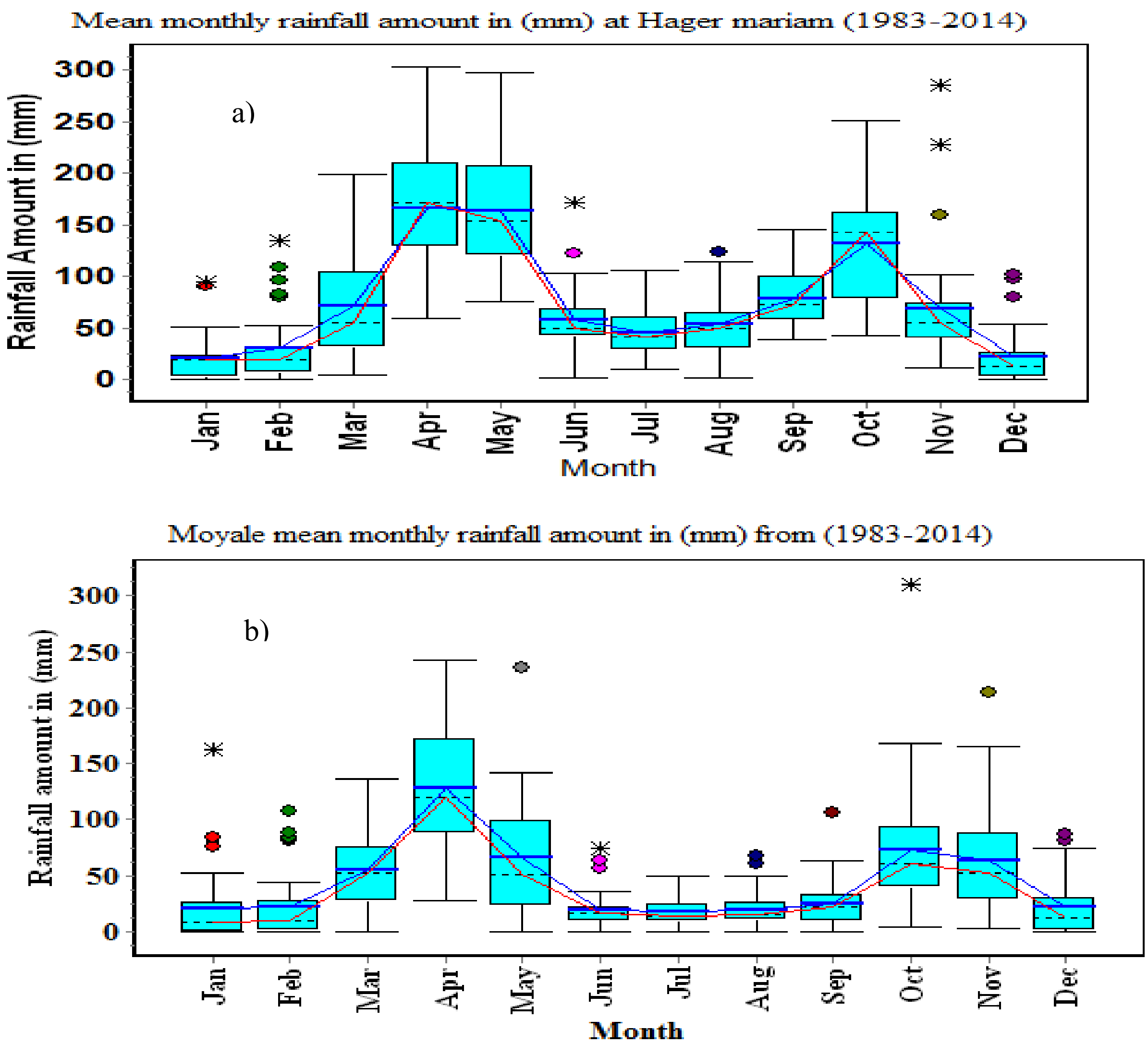


Fig.19. Mean monthly rainfall of a) Hagere Mariam and b) Moyale, where solid blue line represents is mean and solid red line represents Median

The distribution of operationally useful rainfall features listed in Table 6 reflected a suitable starting point in order to examine the time series manners. The lower (25 percentile), median (50 percentile) and upper quartile (75 percentile) caps of the whiskers shown in Fig. 20a and Fig. 20b provide a complete and useful explanation of the existing variability in the rainfall features. For instance, in Fig.20a, the variability in onset date reflected on the two meteorological stations dictated significance difference as well as showed that Hagere Mariam, which usually receives higher rainfall, experienced higher variability than Moyale. Onset date observed lower and upper quartiles at Hagere Mariam fall between 54 and 117 DOY (two months) with 35.0% CV and between 61 and 104 DOY (around one and a half months) with the 19.5% CV for Moyale. In case of cessation of rainy season, less variability shown at Hagere Mariam with 6% CV as compared to Moyale, which is 10.5% CV. Therefore, planting date at Hagere Mariam is earlier than 25 March (85 DOY) and 15 March (75DOY), while this circumstances possibly happened only once in every four years (Table 6). Furthermore, at Hagere Mariam the upper quartile (75 percentile) statistic extends up to the 117 DOY (last days of April), while it seems and the date would be 15 April (104 DOY) in the case of Moyale.

Table 6: Descriptive statistics of important rainfall features for Hagere Mariam and Moyale stations

Seasonal Rainfall features	Minimum	Quartile 1 (25%)	Quartile 2 (Median)	Quartile 3 (75%)	Maximum	Average	SD (±)	CV (%)
	Hagere Mariam							
Onset date (DOY)	54	85	96	117	234	105	37	35
End date (DOY)	306	306	307	326	365	319	20	6
Duration(No. days)	91	191	220	247	264	214	40	19
MAM total (mm)	215	346	383	456	662	399	105	26
SON total (mm)	141	196	284	344	581	278	95	34
Moyale								
Onset date (DOY)	61	76	92	104	128	90	18	20
End date (DOY)	122	122	133	146	168	135	14	11
Duration(No. days)	6	26	47	61	99	45	24	53
MAM total (mm)	88	195	243	290	462	249	85	34
SON total (mm)	58	97	121	210	538	163	104	64

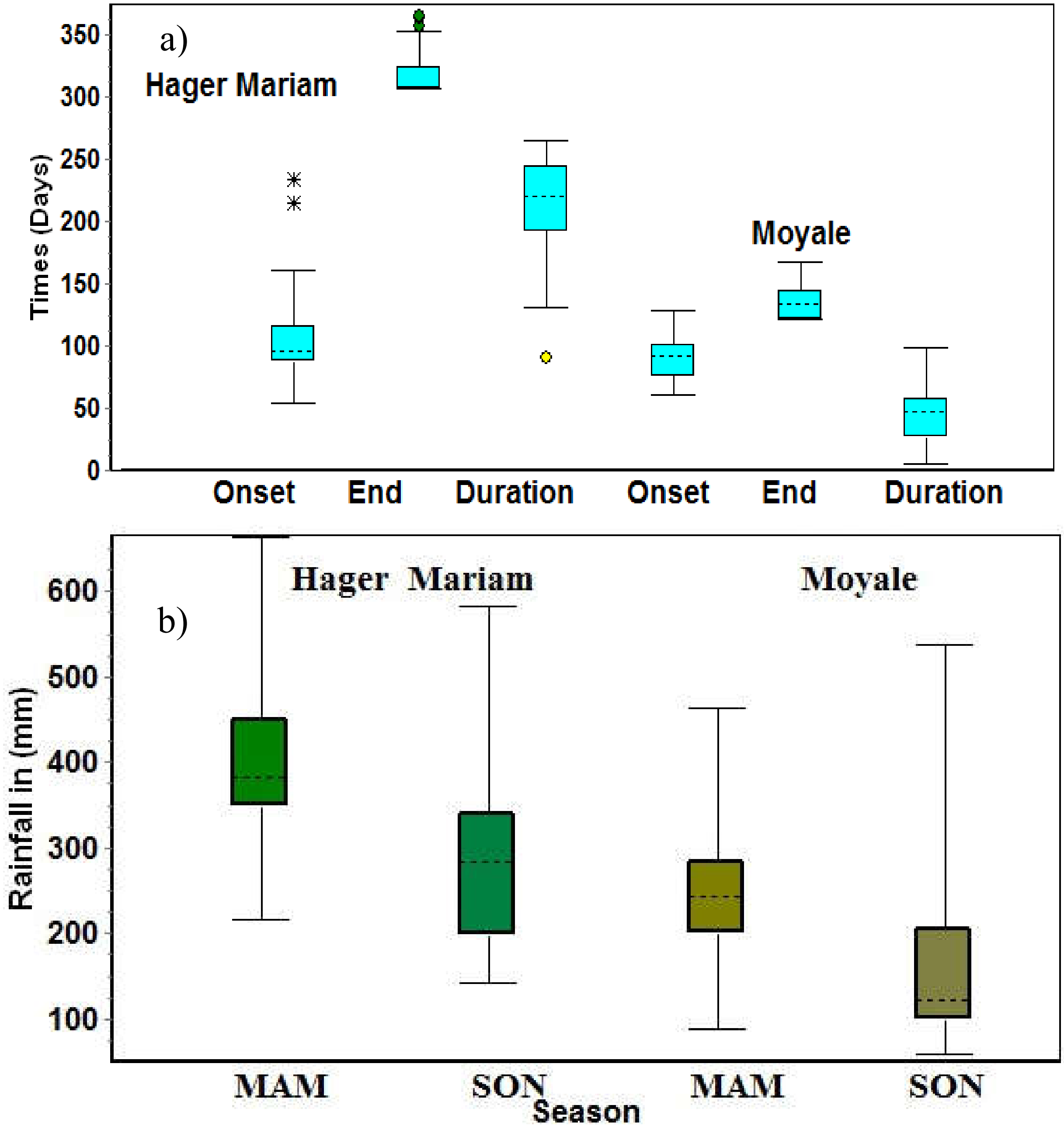


Fig.20. Important seasonal rainfall features at Hagere Mariam (1983 - 2014) and Moyale (1983-2014) of Borana Zone, Southern of Ethiopia (a) onset date, end date and duration of rainy season ; (b) MAM and SON rainfall totals.

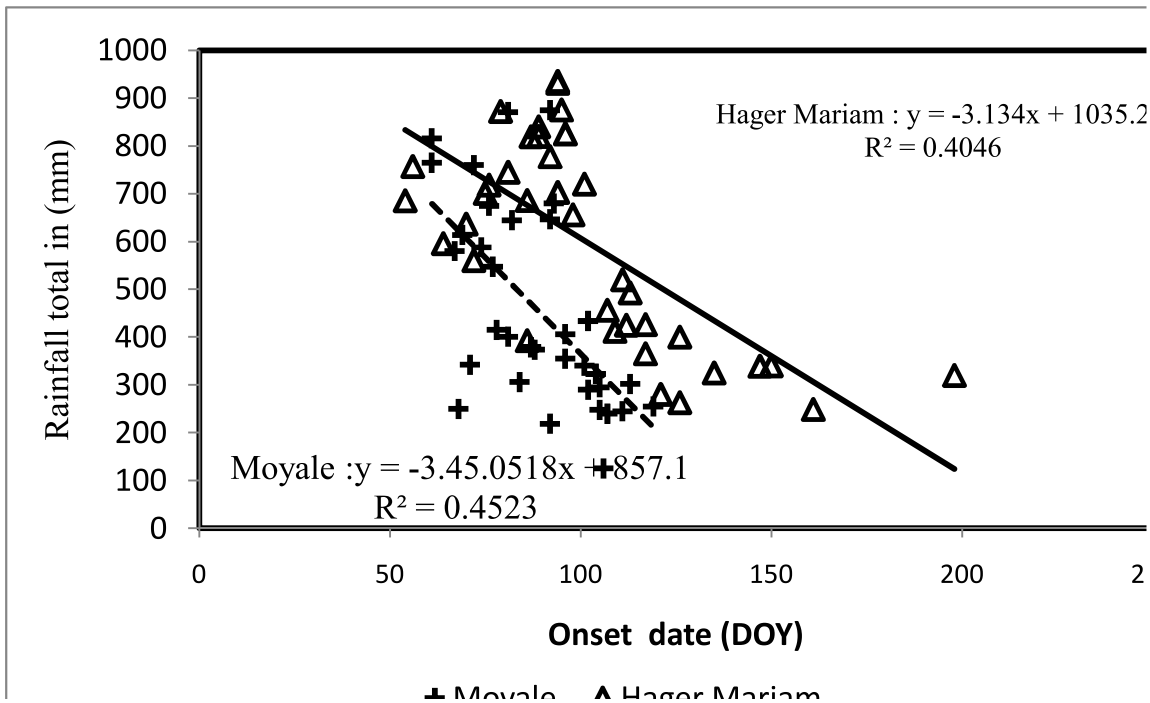


Fig.21. Rainfall onset date versus MAMSON rainfall total at Hagere Mariam (Δ) and Moyale (+) (the broken line represents Moyale and the solid trend line represents Hagere Mariam).

4.4.6. Cessation of rainfall at Borana Zone

In determining the end date, a fixed 5mm of evapo-transpiration per day and 100 mm of plant available soil water were considered (Stern *et al*., 2006).The end of the main rainy season extended to June, which followed by the start of short, dry and cold rainy season before September. This circumstance implies sometimes MAM rainy season merge with SON seasons. As seen from Fig.18, the break period that exists between the two rainy seasons that prevails in the southern parts of Borana Zone, whereas the break point is mild in the case of the northern parts of the Zone. The variation of cessation is less compared to onset.

4.4.7. Probability of length of dry spells

In rain-fed farming, the recurrent dry spell becomes critical, particularly for the seedling establishment during the first 30 days or so after planting. In fact, a dry spell of any length could occur at any stage of crop growth; however, it is potentially damaging if it coincides with the most sensitive stages such as flowering and grain filling (Stern and Coe, 1984). For Agro-pastoralist, who practices agricultural activities in arid and semi-arid it is very important to know the recurrent of dry spell for managing crop production. Therefore, to provide a viable decision aid to various practitioners, different dry spell lengths had examined as documented by (Mamo, 2005). Accordingly, given a condition that first week of March is a potential planting date, the probability of dry spells longer than 5, 7, 10 and 15 days were analyzed (Fig. 22). This sheds insight into the risks related to a range of dry spell lengths during the entire rainy season. In addition, the reason behind including the 'dry spell length' conditions into the later months of the growing season is to provide a complete picture of how the dry spell length of various magnitudes are distributed during the entire growing season as well as to examine the associated risk that might prevails at each location.

The 'W -shape' curves portrayed in Fig. 22 explain, for instance, the probability of dry spells longer than 15 days within the 30 days after planting on the first day of any month that forms part of the rainy season (March-May). For both Hagere Mariam and Moyale stations, the probability of dry spells longer than 15 days in March is less than 40% and 25% whereas it shows a certain degree of down zero at the end of third and start of second March, respectively. All the dry spell length probability curves converge to their minimum only during the peak rain period (April and May or DOY 92-153) over Hagere Mariam and turn upward again around June (153-261 DOY).Whereas over Moyale, it turned upward again around May (122-271), signaling the end of the growing season. In the case of short rainy season (SON), all the dry spell length probability curves converge to their minimum at Hagere Mariam and Moyale only during the peak rain period (Mid-September and mid-October or 261-291) and October or 275-306), respectively. Between the two rainy seasons, the length of growing period prevails at Moyale is relatively shorter in the second rainy season. In case of the probability of dry spell greater than 10 days is around 0.8 during the start of rain at Hagere Mariam and 0.7 at Moyale (Fig.22).

a) Hager-Mariam b) Moyale

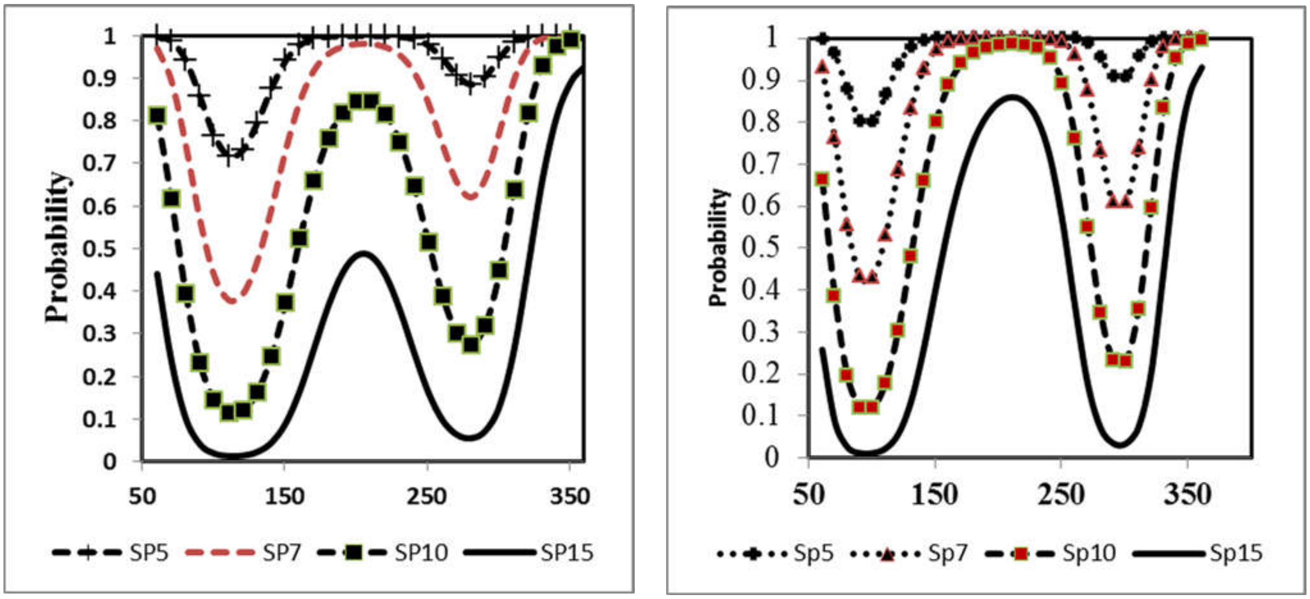


Fig.22. Probability of dry spell longer than 5, 7, 10 and 15 days, given first of March as potential planting date at (a) Hagere Mariam and (b) Moyale(On the figure,SP5= Greater than 5 days, SP7=Greater than 7 days, SP10= Greater than 10 days and Greater than 15 days)

Information on the probability of such a range of dry spell lengths is useful for different groups of agro-pastoralist who work under different capability or resource endowments. The case of Moyale agricultural activities, it seems very difficult to undertake stable agricultural practices throughout the rainy seasons. The situation is even worsened especially during the short rainy season (SON) as rain is unreliable.

Generally, dry spells and the associated probability information can serve different farming groups working under different practical settings for setting tactical decisions and take appropriate actions within their own 'real life', particularly to combat or avoid fate of drought that would have negative consequences on farming practices. In addition, knowing the dry spell lengths and probability of occurrence of rain enables meteorologist to give monthly and seasonal climate prediction. Likewise, information of dry spell lengthshelp decision makers, local communities and NGOs to plan economic activities in advance while reducing the harmful effects of drought, manage livestock, water resources and agricultural activities.

4.5. Temperature Variability and Its Trend over the Borana Zone

4.5.1. Pattern of seasonal mean minimum and maximum temperature Borana Zone

As depicted in Fig.23 in Borana arid and semi-arid regions, temperature patterns is varying from district to district. For instance, the lowest minimum temperature distribution was observed over Yabello and Dire districts. However, the highest minimum temperature distributed over edge of northern part and southern part of the Zone.

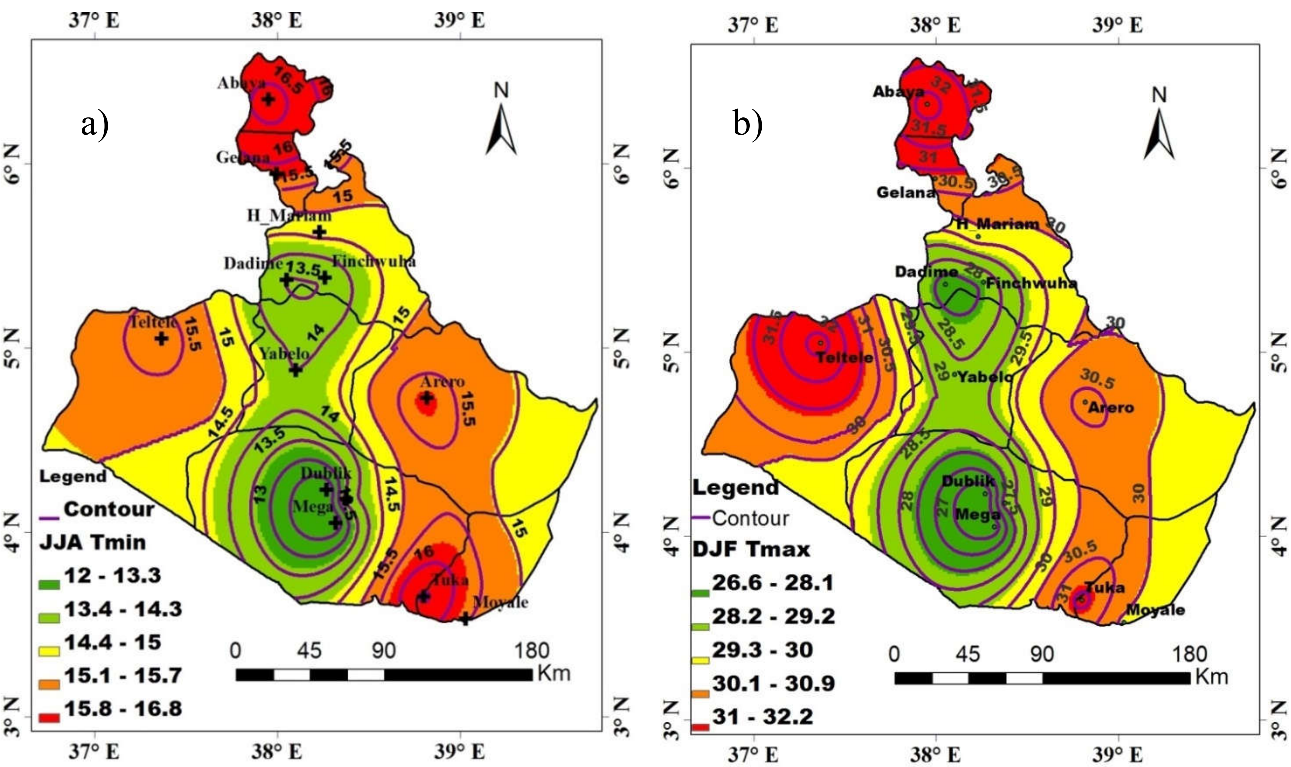


Fig.23.Graph showing mean minimum and maximum temperature distribution over Borana Zone for a) JJA Tmin and b) DJF Tmax

In Borana Zone, the lowest mean minimum temperature commonly observed during the June-July-August whereas the highest maximum temperature observed during the long dry (December-January-February) season. As observed from Fig.23a, the lowest minimum temperature was recorded at Dire district while the highest minimum temperature was recorded at Moyale and Abaya. Among the four seasons, JJA season is very cold and dry potentially varying in minimum temperature. The highest maximum temperature has been identified during

December-January-February among the four seasons, which adversely affect the livestock production. Rising in temperatures, coupled with declined precipitation reduce crude protein and digestible organic matter contents of the plants, thereby posing nutritional stresses to grazing animals (Craine *et al*., 2010).

4.5.2. Month, seasonal and annual temperature variability and trends

Global warming has considered being the major threat for life on our planet. Observations show that global mean temperature at the earth's surface has substantially increased over the twentieth century [IPCC, 2013]. Many low-income countries are located in tropical, sub-tropical region, or in semi-arid zones, that are particularly vulnerable to shifting weather patterns and rising temperature (Joachim, 2008). Likewise, temperature of Borana zone is rising from time to time. The year-to-year variation of annual minimum temperatures expressed in terms of temperature-standardized average has increased significantly (Fig.24). As it could have seen from the Fig.24, the Zone has experienced both warm and cool years over the last 31 years. However, the recent years are the warmest as compared to earlier years. As it shown in Fig.24, the trend analysis clearly reveals that there has been a warming trend in the annual minimum temperature over the past three decades and it has been increasing by about 0.7 ^{0}C in every ten years.

During the transitional period, short, cold and dry season (JJA) obviously revealed that minimum temperature has substantially increased (Fig.25). During the JJA season the ITCZ, which associated with low pressure, migrates to the northern parts of Ethiopia. Therefore, during this period Borana Zone became cold, cloudy and dry. In addition, as it seen from the box plot (Fig. 27), the seasonal minimum temperature is more fluctuated during JJA, which is the main cause for disease outbreak such as foot and mouth.

The JJA seasonal minimum temperature is extended from 14.61 ^{0}C to 16.78 ^{0}C, with standard deviation of 1.58 and coefficient variation 10.81% (see Table 7). It has been increasing by about 0.56 ^{0}C per ten year when it compared to annual minimum temperature. In generally, the observed monthly, seasonal and annual temperature at Borana zone show increasing from time to time, which directly and indirectly affects the livestock production. Many studies (e.g. Nardone *et al.,* 2010; Thornton *et al.,* 2009) confirmed that an increase in temperature directly posed thermal stresses on animals; impair feed intake, metabolic activities and defense mechanisms, thereby hindering their production and reproductive performances. Rises in temperature also adversely affect pastoral livestock production through indirect impacts on pasture growth, water availability and disease distributions.

Table 7: Descriptive Statistics for monthly and seasonal minimum temperature (^{0}C) at Borana Zone

Descriptive statistics	Jun	Jul	Aug	JJA
Maximum	17.10	16.70	16.87	16.78
Minimum	12.45	11.78	11.85	12.02
Mean	14.95	14.35	14.54	14.61
Std. Deviation	1.55	1.60	1.61	1.58
CV	10.37	11.15	11.07	10.81

CV= Coefficient Variation, JJA= June-July-August

Table 8: Descriptive Statistics for monthly and seasonal maximum temperature (^{0}C) at Borana Zone

Descriptive statistics	Jan	Feb	Dec	DJF
Maximum	32.39	33.03	31.69	32.26
Minimum	27.04	27.22	25.61	26.63
Mean	29.68	30.21	28.44	29.44
Std. Deviation	1.87	1.96	1.98	1.93
CV	6.30	6.49	6.96	6.56

CV=Coefficient Variation, DJF= December-January-February

In Borana Zone, the highest maximum temperature always documented during the DJF season (Fig.26). In addition, the trend line well indicated year-to-year seasonal maximum temperature with the tendency of an increasing trend. The long dry season maximum temperature extends from 29.44^{0}C to 32.26^{0}C with standard deviation and coefficient variation of 1.93 and 6.56%, respectively (Table 8).The variability of maximum temperature of DJF season was less compared to the variability of JJA minimum temperature. Rising temperatures exacerbate the influence of moisture stress on plant growth and thermal stress on animals by decrease the crude protein and digestible organic matter contents of plants (Craine *et al*., 2010).

Zone average annual minimum temperature standardized from (1981-2011)

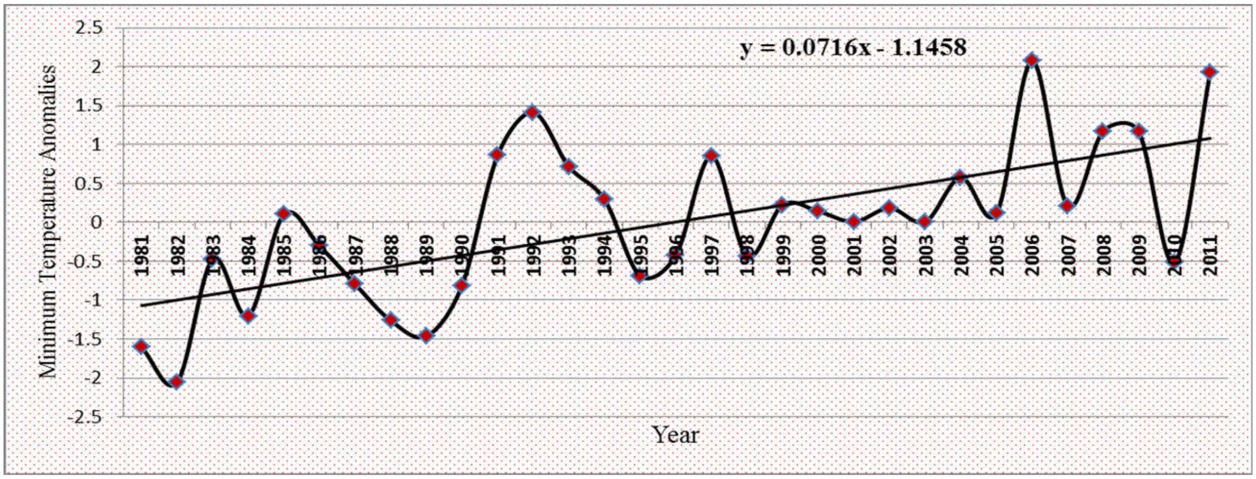


Fig.24.Year to year variability of annual minimum temperature and trend over Borana Zone expressed in temperature.

Zone average JJA seasonal minimum temperature standardized from (1981-

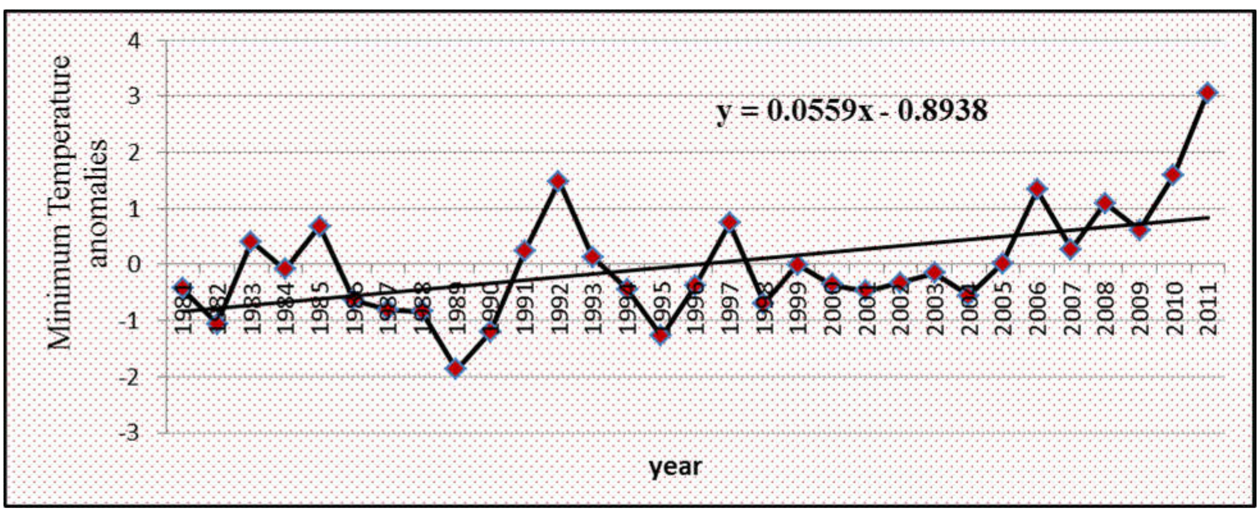


Fig.25. Year to year variability of JJA seasonal minimum temperature and trend over Borana Zone expressed in temperature

Zone average DJF seasonal maximum temperature standardized from (1981-2011)

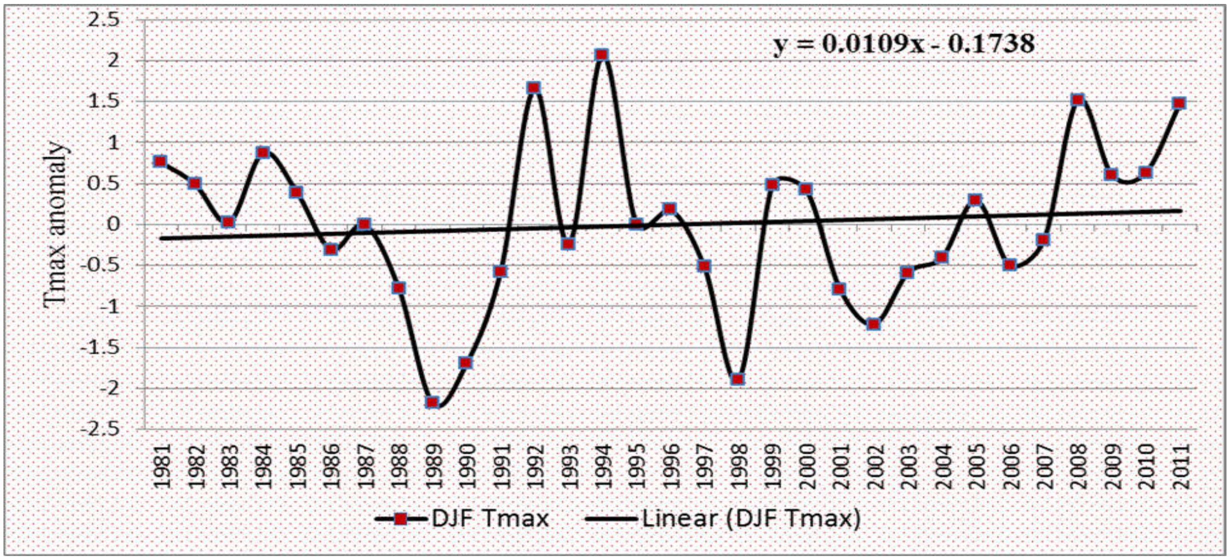


Fig.26.Year to year variability of DJF seasonal maximum temperature and trend over Borana Zone expressed in temperature

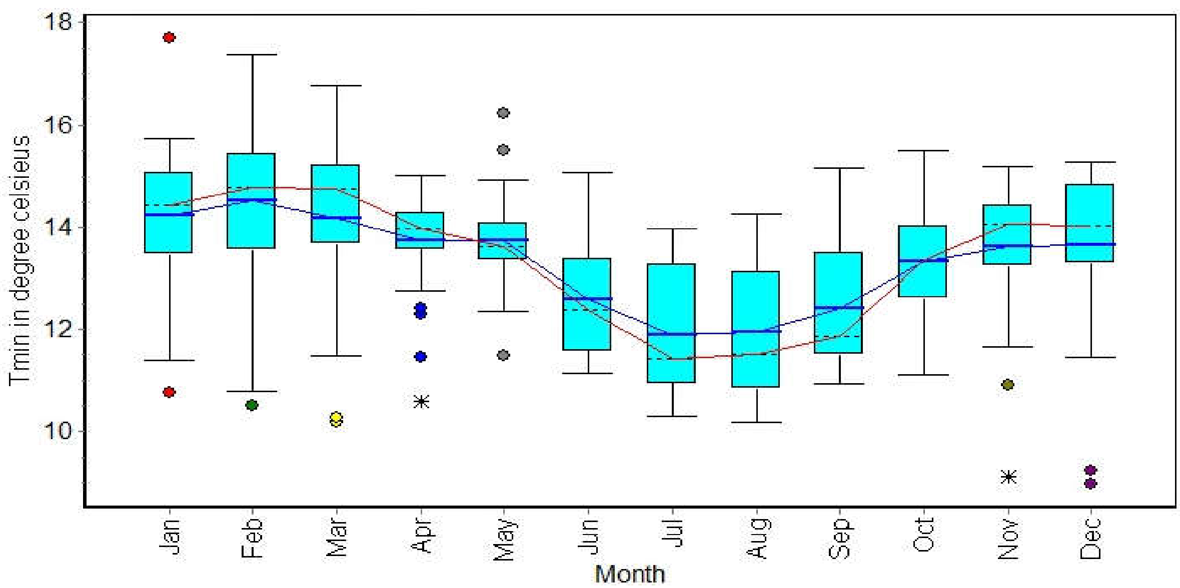


Fig.27. Box plot of mean monthly minimum temperature of Borana Zone where, blue line represents mean and red line represents median

The JJA season minimum temperature showed remarkable temporal variability whereas the steady increase in the maximum temperature from 2004 to 2011 showed evidence of warming and hence progressive habitat dryness. This season is commonly known as dry and cold season that hindering cattle production. Weak negative correlation that emerged between cattle numbers and rising temperatures could also indicate the effect of reduced water availability due to increased evaporative water loss and ultimately reduced forage availability as well as its quality. This seldom happened due to a reduced retention of green leaves by plants during the dry season. Hence, the elevated temperatures during droughts are likely to exacerbate the declining in number of cattle by accentuating water and forage shortages as well as thermal stresses. A warming and drying trend in climate negatively affects the rangeland productivity by lowering the quantity and nutritional quality of forages besides causing water scarcity (Thornton *et al*., 2009). In addition, the spread of tick diseases increases associated with increment temperature in long dry season which seriously reduction livestock production (Personal communication, Olana Jira).

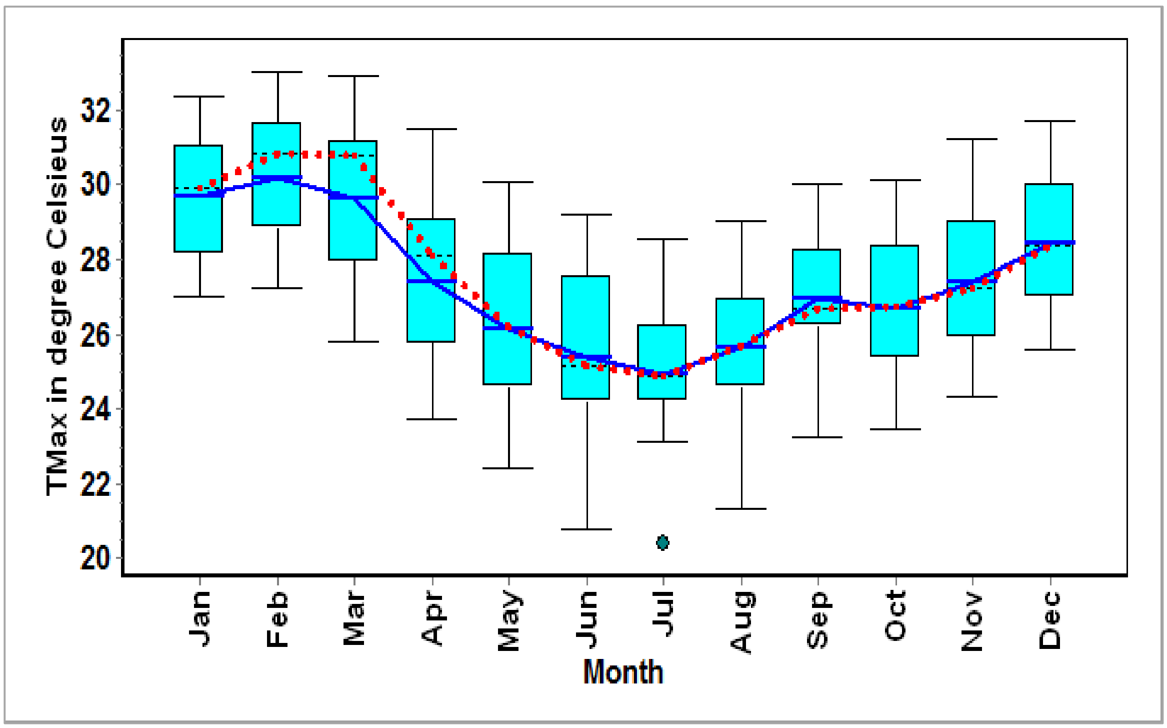


Fig.28. Box plot mean monthly maximum temperature of Borana Zone where blue solid line represents mean and red dot line represents Median

As it can be seen from Fig.28, after the second rainy season the mean maximum temperature increased in amount and covered wide area. Rises in temperature also adversely affect pastoral livestock production through indirect impacts on pasture growth, water availability and disease distributions (Thornton *et al*., 2009). Moreover Craine *et al*. (2010) documented that rising temperatures, coupled with declined precipitation reduce the crude protein and digestible organic matter contents of the plants, thereby posing nutritional stresses to grazing animals. In Borana Zone, therefore, the rising maximum temperature is the most characteristics of long dry season and more persist in the edge of north and west part of the Zone (Fig. 23b).

4.6. Classification of Borana Zone Rainfall into Homogeneous Regime

From the global oceans coarse scale of influence and particularly from the rainfall climatology point of view, it is often challenging to define such small areas into further homogeneous zones, without taking account of the interaction between the atmospheric circulation and detailed topography (Olsen *et al*., 1995; Dent *et al*., 1990). However, given the complexity of the climatic patterns in East Africa in general and Ethiopia in particular, it is not surprising to find large spatial variations in rainfall patterns in the study area.

The Eigen values associated with each component represent the variance explained by that particular linear component. In addition, these values display the Eigen value in terms of the percentage of variance explained (so, component 1 explains 81.969% and component 2 explains 7.68% of total variance). The remaining 11 components explain only 10.351%. The Eigen values associated with these components were again displayed (and the percentage of variance explained) in the columns labeled extraction sums of squared loadings. In the final part of the table (rotation sums of squared loadings), the Eigen values of the components after rotation are displayed. Rotation has the effect of optimized the component structure and one consequence for these data is the relative importance of the two factors is equalized. Before rotation, component 1 accounted for considerably more variance than the remaining one (81.969% compared to 7.68%), however after extraction it accounts for only 56.474% of variance compared to 33.175% of variance. The factors extracted accounted for 89.649% of cumulative whereas remain one covered 10.351% (Table 9).

Table 9: MAM season total variance explained by each component of PCA

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.656	81.969	81.969	10.656	81.969	81.969	7.342	56.474	56.474
2	0.998	7.680	89.649	0.998	7.680	89.649	4.313	33.175	89.649

Table 10: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.883
Bartlett's Test of Sphericity	Approx. Chi-Square	740.992
	df	78
	Sig.	0.000

In addition, the Borana Zone classified into three homogenous rainfall regimes during the main rainy season statistically confirmed by F-test (Table 11).

Table 11: One way ANOVA: SCI mean of MAM rainfall between Zones

Source of Variation	Degree of Freedom	Sum of Squares	Mean of Square	Computed ***Fb***	Tabular F **5%**	**1%**
Between groups (Treatment)	2	238,483.41	119,241.7	15.6**	3.09	4.82
Within groups (Treatment Error)	93	709,019.91	7,623.87			
Total	95	947,503.32				

[a]CV= 25.8% , [b]** = Significant at 1% level

The computed Fc value of 15.6 is larger than the tabular F $\propto$value at the 1% level of significance of 4.82 and at the 5% level of significance of 3.09. Hence, the mean difference MAM season rainfall said to be highly significant. The Ho null hypothesis is rejected and alternative hypothesis true so that acceptable. This means that 25.2% of the variation in SCI scores explained by membership in the groups. The other 74.8% of the variation is due to Zone-to-Zone variation within each of the groups. So that there is a statistically significant difference among three homogenous rainfall regimes classified during main rainy season.

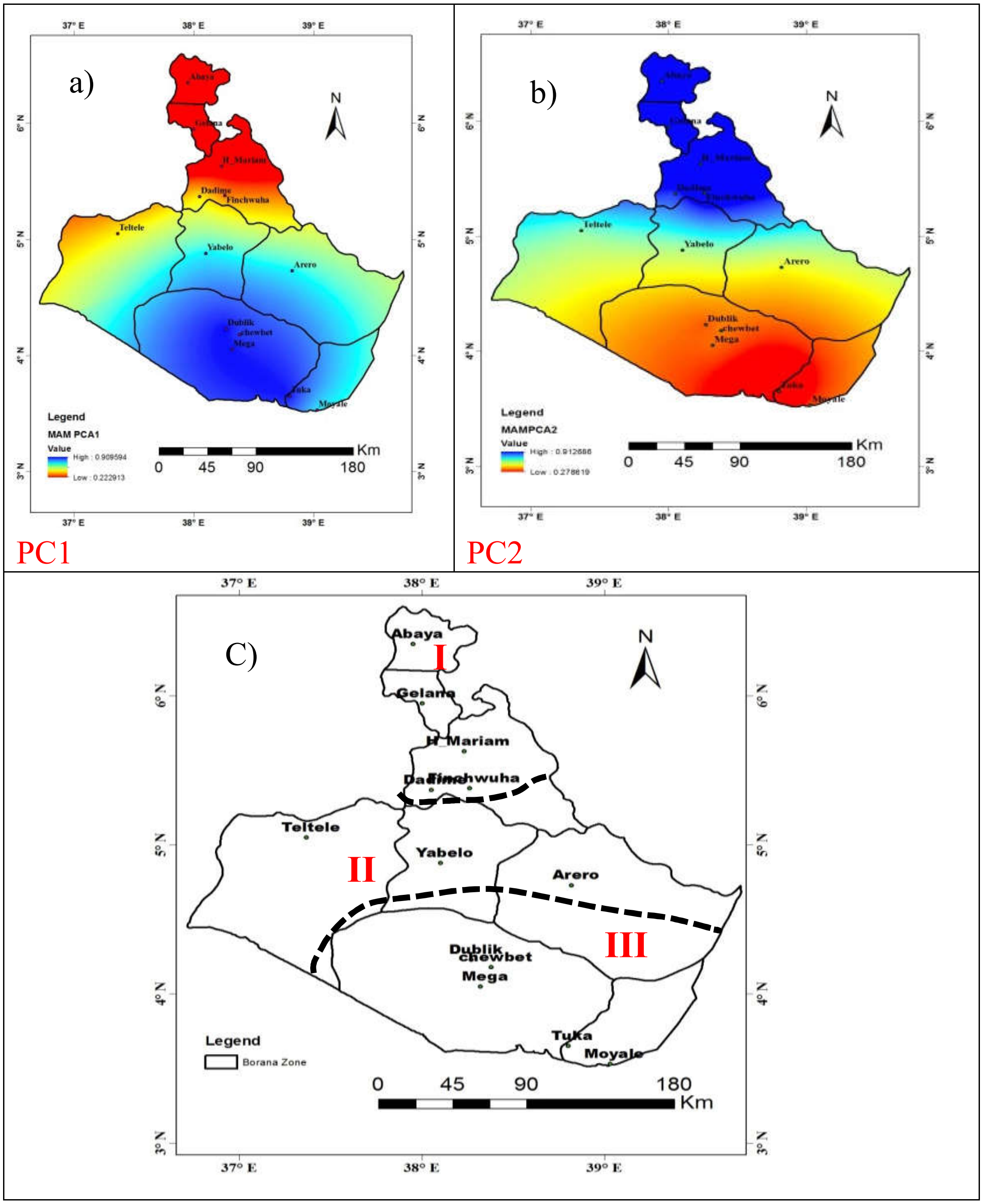


Fig.29. Three homogeneous rainfall zones in Borana Zone of Southern Ethiopia during MAM as defined by the principal component analyses

To study in detail temporal and spatial variability of rainfall in JJA season, it is necessary divided the Zone into homogenous rain Zone. Therefore, the JJA has divided into two homogenous rainfall regime by using principal component analysis method that depicted in statistical package for social science (SPSS). The Eigen values associated with each component represent the variance explained by that particular linear component. In addition, these values display the Eigen value in terms of the percentage of variance explained. In this case, 3 components contain 89.333% of the variation of the 13 original variables. Component 1 explains 65.579%, component 2 explains 12.574%, and component 3 explains 11.18% of total variance. The remaining 10 components explain only 10.667%. The Eigen values associated with these components are again displayed (and the percentage of variance explained) in the columns labeled extraction sums of squared loadings. In the final part of the table (rotation sums of squared loadings), the Eigen values of the components after rotation are displayed. Rotation has the effect of optimized the component structure and one consequence for these data is the relative importance of the two factors is equalized. Before rotation, component 1 accounted for considerably more variance than the remaining two (65.579% compared to 12.579% and 11.18%), however after extracted it accounts for only 35.485% of variance compared to 31.984% and 21.864% of variance. The components extracted accounted for 89.333% of cumulative whereas remain one covered 10.667% (Table 12).

Table 12: JJA season total variance explained by each component of PCA

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.525	65.579	65.579	8.525	65.579	65.579	4.613	35.485	35.485
2	1.635	12.574	78.153	1.635	12.574	78.153	4.158	31.984	67.469
3	1.453	11.180	89.333	1.453	11.180	89.333	2.842	21.864	89.333

Table 13: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.827
Bartlett's Test of Sphericity	Approx. Chi-Square	594.440
	df	78
	Sig.	0.000

According to KMO and Barlett's test, the classification of Borana Zone rainfall into homogenous regime during JJA, this indicates appropriate factor analysis (Table 13). In addition, analysis of variance (ANOVA) was used to test the statistical significance between two Zones (Table 14).

Table 14: One way ANOVA: SCI mean of JJA rainfall between Zones.

Source of Variation	Degree of Freedom	Sum of Squares	Mean of Square	Computed ***Fb***	Tabular *F* **5%**	**1%**
Between groups (Treatment)	1	17,956.0	17,956.0	9.29**	4.00	7.08
Within groups (Treatment Error)	62	119,875.76	1,933.48			
Total	63	137,831.76				

[a]Cv= 26.25%, [b]** = Significant at 1% level

The computed *Fc* value of 9.29 is larger than the tabular *F* ∝ value at the 1% level of significance of 7.08 and at the 5% level of significance of 4.00. Hence, the mean difference said to be highly significant. The Ho null hypothesis is rejected and alternative hypothesis true so that acceptable. The computed coefficient of determination is 13%, which dictates that 13% of the variation in SCI scores explained by membership in the zones. The other 87 % of the variation is due to Zone-to-Zone variation within each of the zones. Therefore, homogenous rainfall regime classification is statistically significant.

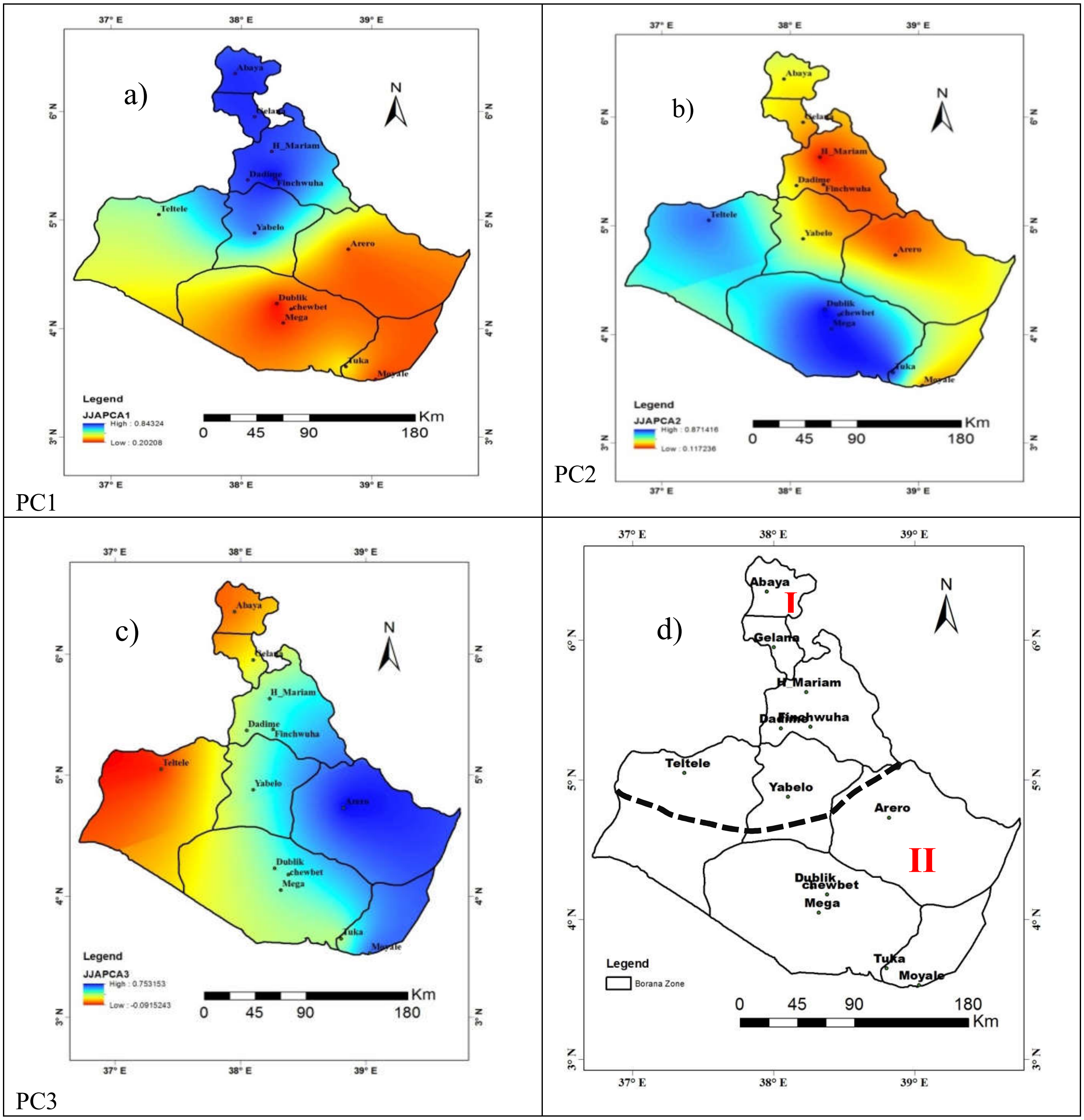


Fig.30.Two homogeneous rainfall zones in Borana Zone of Southern Ethiopia during JJA as defined by the principal component analysis

The Eigen values associated with each factor represent the variance explained by that particular linear component. Furthermore, these values display the Eigen value in terms of the percentage of variance explained. In this case, 2 components contain 92.746% of the variation of the 13 original variables. Component 1 explains 84.92% and component 2 explains 7.826% of total variance. The remaining 11 components explain only 7.254%. The Eigen values associated with these components are again displayed (and the percentage of variance explained) in the columns labeled extraction sums of squared loadings. In the final part of the table (rotation sums of squared loadings), the eigen values of the components after rotation are displayed. Rotation has effect on optimized the component structure and one consequence for these data is the relative importance of the two factors is equalized. Before rotation, component 1 accounted for considerably more variance than component 2 (84.92% compared to 7.826%), however after extracted it accounts for only 51.152% of variance as compared to 41.595% of total variance. The components extracted accounted for 92.746% of cumulative whereas remain one covered 7.254% (Table 15).

Table 15:SON season total variance explained by each component of PCA

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.04	84.920	84.920	11.04	84.920	84.920	6.65	51.151	51.151
2	1.017	7.826	92.746	1.017	7.826	92.746	5.40	41.595	92.746

Table 16: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.911
Bartlett's Test of Sphericity	Approx. Chi-Square	806.967
	df	78
	Sig.	0.000

As Table 16, indicated factor analysis was highly appropriate and significant Kaiser Meyer is located in a superb category. As well, the analysis was statistically confirmed by F-test (Table 17).

Table 17: One way ANOVA: SCI mean of SON rainfall between Zones

Source of Variation	Degree of Freedom	Sum of Squares	Mean of Square	Computed *Fb*	Tabular *F* 5%	1%
Between groups (Treatment)	2	170,848.44	85,424.22	10.1**	3.09	4.82
Within groups (Treatment Error)	93	785847.70	8,449.98			
Total	95	956,696.14				

[a]Cv= 40.27%, b** = Significant at 1% level

F calculated is 10.1 and F tabulated is at 0.05 and 0.01 are 3.09 and 4.82, respectively. F calculated is greater than F tabulated, therefore the null hypothesis is rejected and alternative hypothesis accepted. At 5% and 1% significance level, statistical evidence indicated that mean different in SON seasonal rainfall achievement for the three zones.

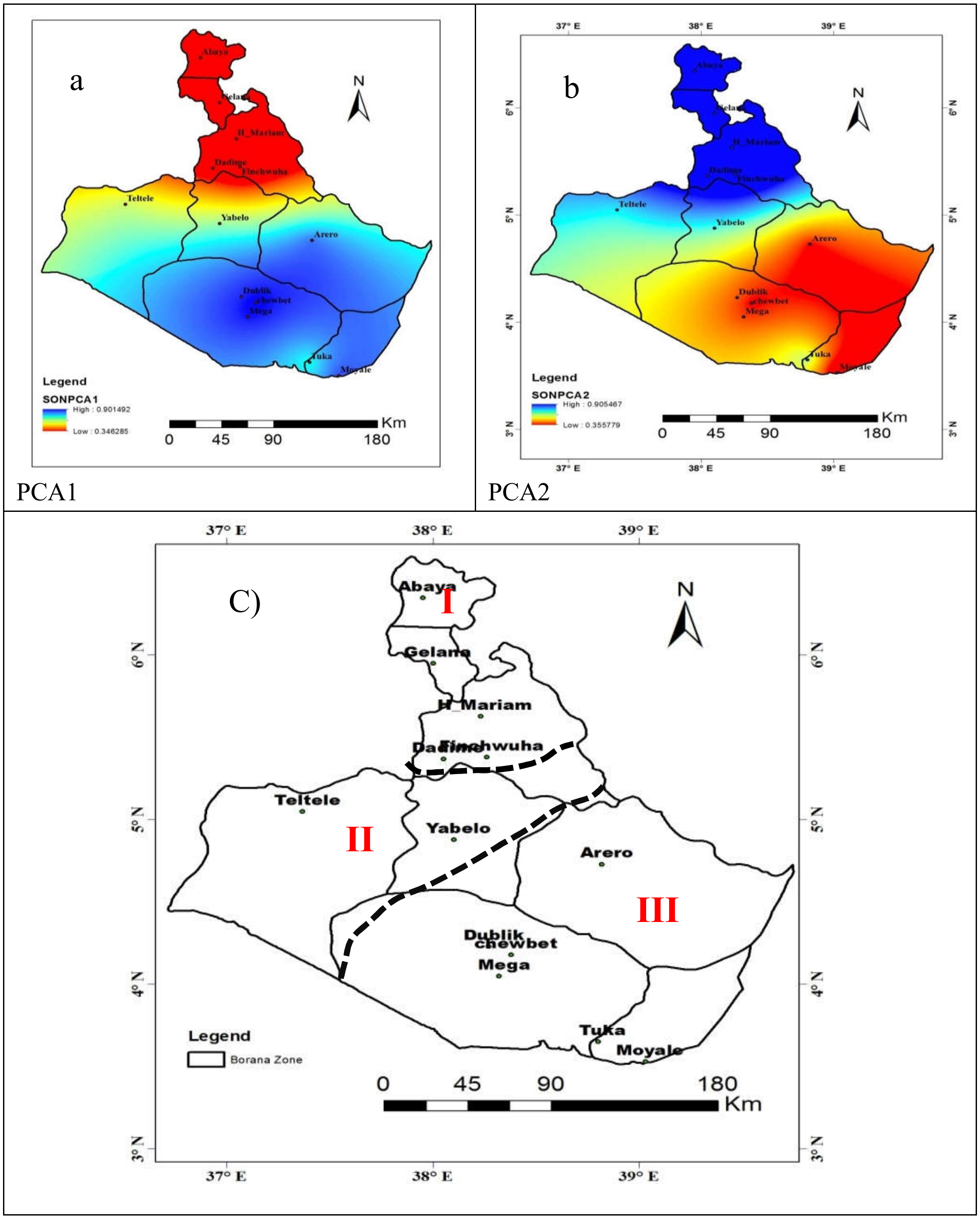


Fig.31.Three homogeneous rainfall zones in Borana Zone of Southern Ethiopia during SON as defined by the principal component analyses

4.6.1. Relationship between ENSO and rainfall at Borana Zone

In recent decades, there has been a proliferation of statistical models for making extended-range forecasts of the state of the El Niño–Southern Oscillation (ENSO) phenomenon over lead times of several seasons (Landman and Mason, 2001). Because ENSO variability is to a large extent the result of ocean–atmosphere variability internal to the tropical Pacific (Neelin *et al*.,1998), skillful forecasts of central equatorial Pacific sea surface temperature anomalies, for example, can be developed relatively using only prior temperatures in the region as predictors (Landman and Mason, 2001). Correspondingly, Korecha and Barnston (2007) documented that ENSO predictability led to potential predictability of seasonal climate over many tropical and some extra-tropical regions. Although the importance of ENSO to Ethiopian rainfall is being accepted and incorporated in the NMA's operational forecasting policy more now than previously, it continues to be somewhat underweighted despite widespread documentation of its importance (NMSA 1996 and Gissila *et al*., 2004). The study aims to quantify the statistical relations between ENSO, and other oceanic and atmospheric phenomena, and MAM, JJA, and SON rainfall, a practical objective being to develop models that skillfully anticipate rainfall anomalies prior an onset of rainy season, allowing for societal mitigation measures.

Table 18: Correlation between rainfall of(Zone I, Zone II, Zone III and MAM RF) and JFSST (Nino 3.4, Nino 4, Nino 3 and Nino 1+2) the same year (1983-2014)

	Zone I	Zone II	Zone III	MAM	NIN3.4	NINO4	NINO3	NINO1+2
Zone1	1	0.890**	0.811**	0.939**	0.262	0.327	0.157	0.002
Zone2		1	0.946**	0.984**	0.283	0.299	0.205	0.096
Zone3			1	0.956**	0.341	0.348	0.257	0.115
MAM				1	**0.307**	**0.338**	0.214	0.073
NIN3.4					1	0.848**	0.958**	0.725**
NINO4						1	0.701**	0.360*
NINO3							1	0.873**
NINO1+2								1

In Borana Zone, during long rainy season La Nina event suppresses the main rainy season of the zone whereas El Nino enhanced the main rainy season of Borana Zone (Fig.32 and 33). Among ENSO regions Nino 3.4 and 4 indices have significant correlation with long rain over Borana Zone (Table 18). As indicated in Table 18, all Nino region indices had shown better correlation with Zone III during MAM season than Zone I and Zone II while among Nino indices Nino 1+2 was not showed significant correlation with all three Zones during main rainy season. The association of MAM rainfall with ENSO in early pre-MAM month January is strong, and increases as the time of the ENSO state approaches the beginning of the rainfall season. In particular, positive correlations are found between MAM total rainfall and Nino 3.4 SST over all Borana Zone. However, better positive correlation were found between MAM total rainfall and Nino 4, which is statistically significant ($\geq$0.338). For instance, Table 18 showed that all Nino indices were positively correlated with Zone I, Zone II and Zone III homogenous rainfall of Borana Zone. All Nino indices better positively correlated with Zone III homogenous rainfall regime as compared to rest (Table 18).

The high Niño-3.4 and 4 SSTs in January could be due to an El Niño that had matured earlier and would likely dissipate before March tend to start opposite phase of El Nino, La Nina. However, the emerging of El Nino phase in January usually strengths and persists during preseason and in-season enhance the Borana Zone rainfall whereas persistence of La Nina prolong rain and concurrent causes declining of Borana Zone rainfall (Fig.32 and 33). A time series of the Borana Zone MAM rainfall average, which was computed for 1983-2014 and standardized by 1983–2012 rainfall statistics, has shown in Fig.35. Overall, abundant rainfall tends to occur during La Niña (El Niño) long rain season (MAM). For instance, around 60% decline in Borana rainfall during long rain season is associated with La Nina whereas 40% of rainfall deficient associated during El Nino and Neutral years (Fig.35). However, El Nino events enhance long rain of Borana during MAM season whereas La Nina events suppressed the main rainy season of the Zone (Fig. 34a, b and c). The strengths of linear relationship between Zone I, Zone II, Zone III MAM rainfalls and the Niño-3.4 SST index for individual months from January, February and mean JF was shown in Table 19 and the correlations are about 0.33, 0.28 and 0.31, respectively during the preceding months of the long rainy season. January SST during El Niño, have strong association with long rainy season (MAM) over Borana Zone while as the prior months approaches to the predicted season the relation become very weak.

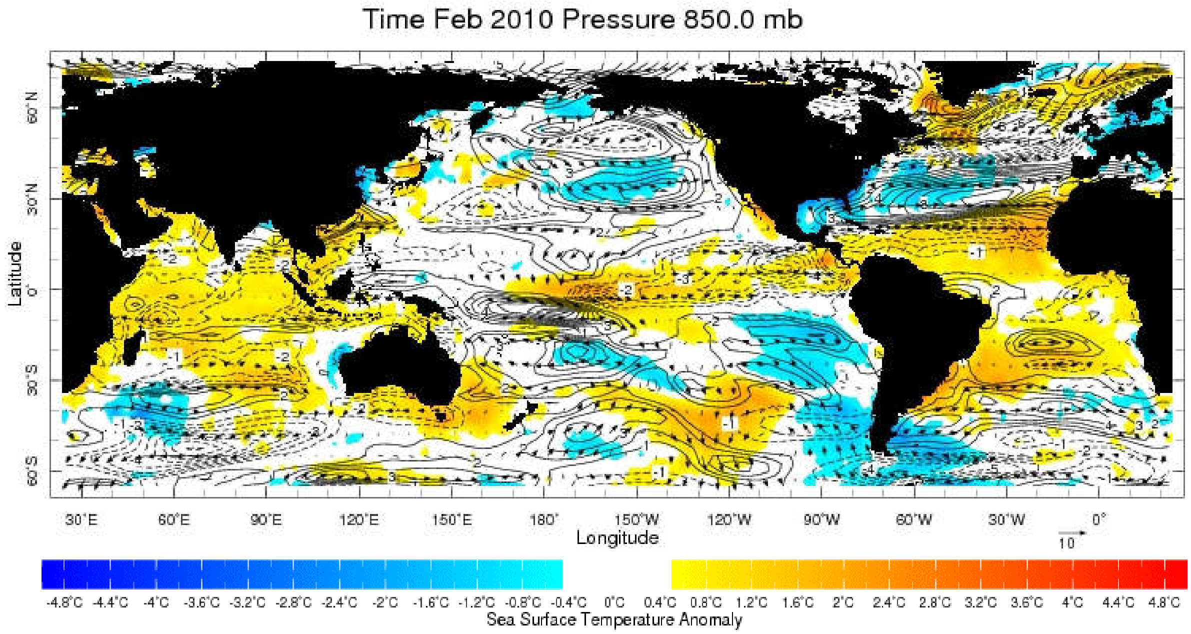
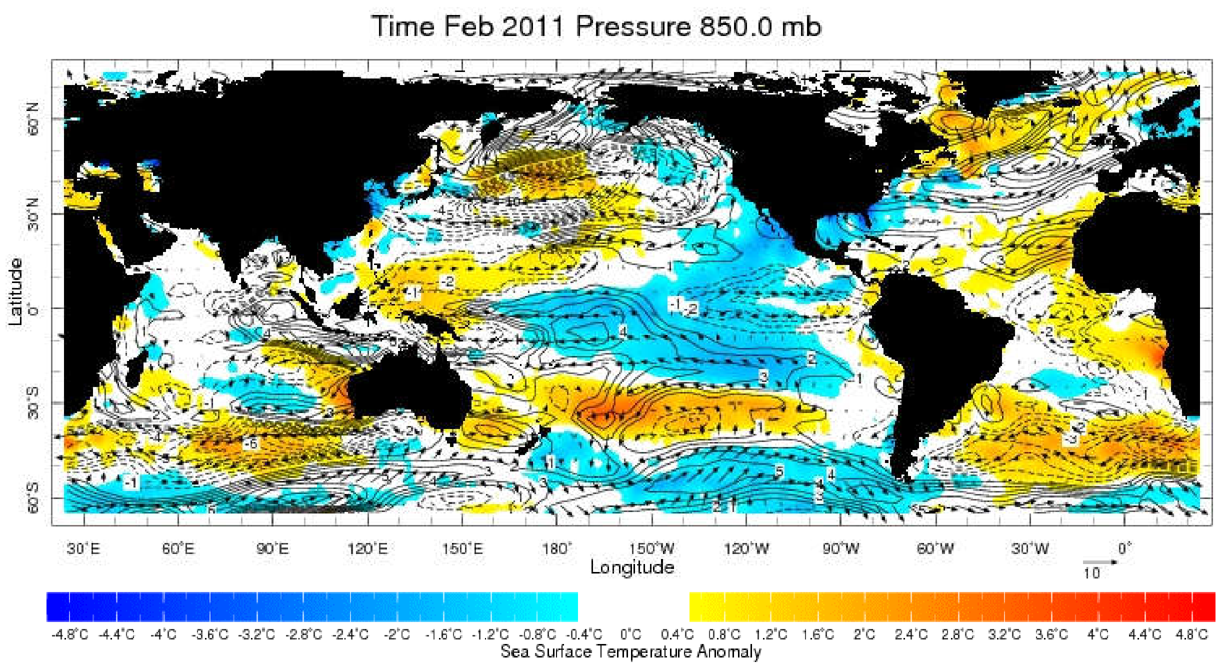


Fig.32.El Nino phase during preseason of long rainy season (MAM) associated with Borana Zone rainfall totals



http://iridl.ldeo.columbia.edu/maproom/Global/Atm_Circulation/Wind_SST_Anom.html

Fig.33.La- Nina phase during preseason of long rainy season (MAM) associated with Borana Zone rainfall totals

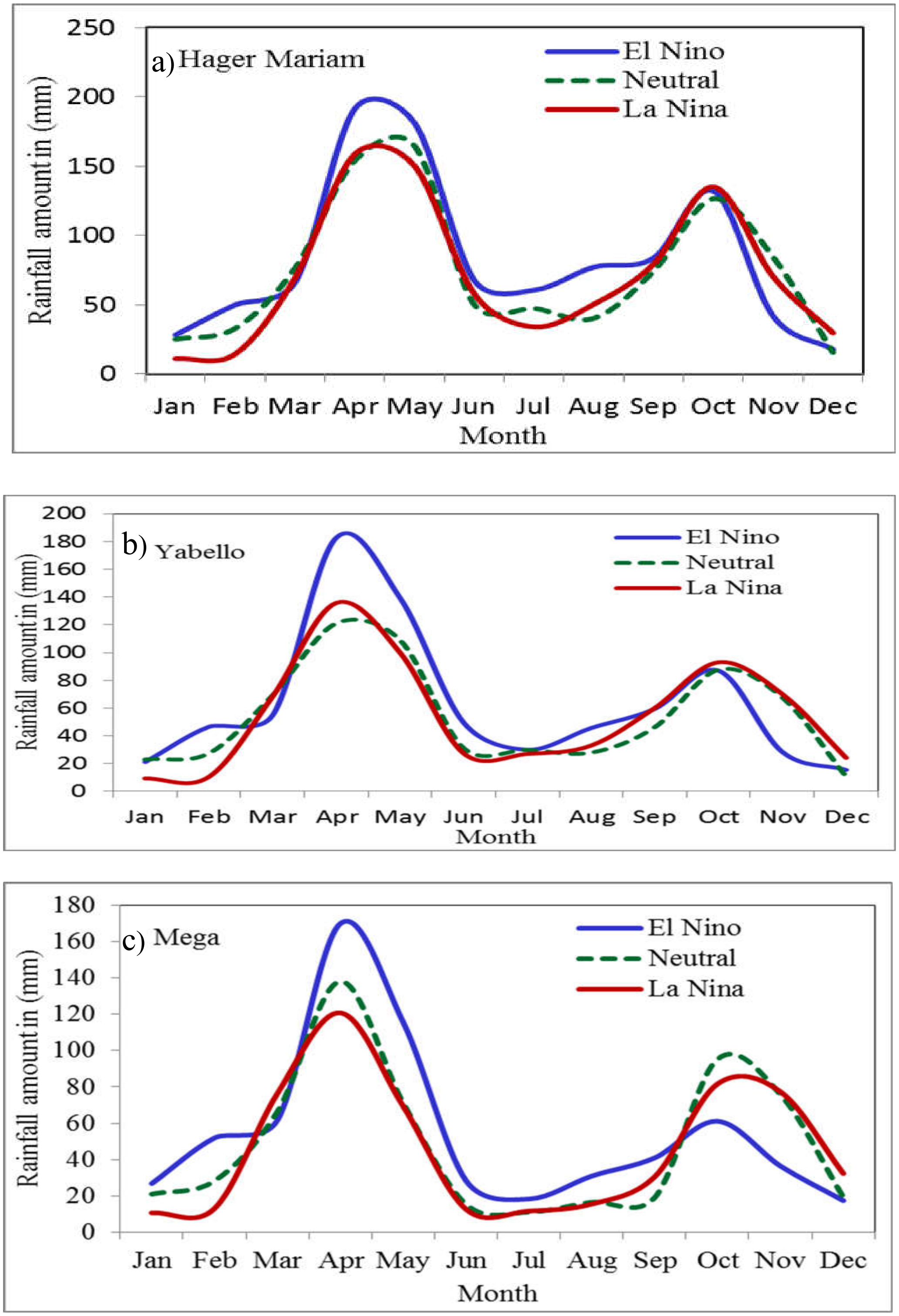


Fig.34. Seasonal march of mean monthly rainfall amount (mm) composited when MAM season is classified as El Niño, La Niña, or neutral, for three stations located in the north, central, and southern portions of Borana Zone

Table 19:Correlation between Zone I, Zone II, Zone III, MAM rainfall and preceded monthly Nino 3.4SST

	Jan	Feb	JF	Zone1	Zone2	Zone3	MAM
Preseason							
Jan	1	0.980**	0.996**	0.282	0.306	0.350*	0.325
Feb		1	0.994**	0.234	0.251	0.327	0.281
JF			1	0.262	.283	0.341	0.307
Zone1				1	0.890**	0.811**	0.939**
Zone2					1	0.946**	0.984**
Zone3						1	0.956**
MAM							1

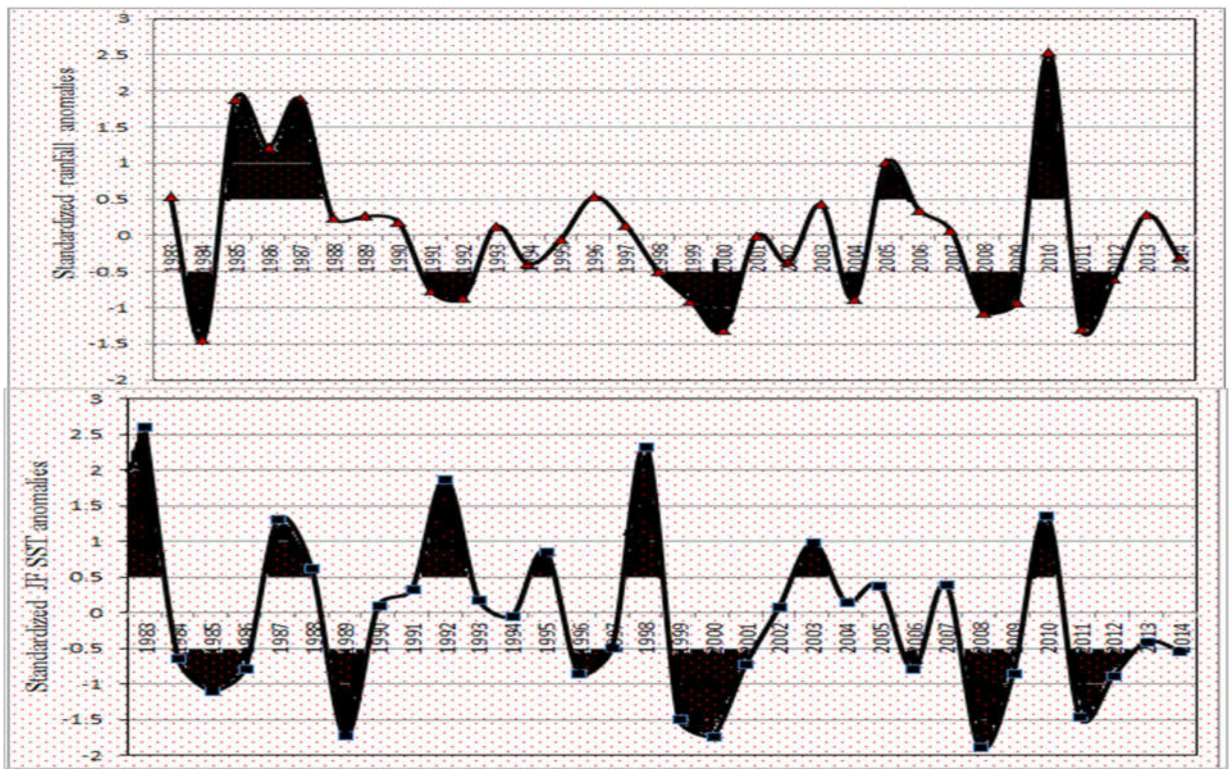


Fig.35. Standardized MAM rainfall anomalies of (top) all Borana Zone rainfalls and (bottom) those of Niño-3.4 SST for 1983–2014. Correlation among the two is 0.31

4.6.2. Canonical Correlation Analysis (CCA)

A comparison between matched pairs of observed rainfall anomaly and the cross-validated anomaly prediction values have been made by CCA was employed to develop skillful seasonal rainfall model. It is assumed that, once sound a prediction model has been developed and cross-validated giving high forecast skill, then the candidate model can be operationally used in forecasting future values of the predictands, based on the future observations of the predictor variable (Wilks, 1995). As depicted Table 20, different oceans SSTs were strongly related to the rainfall patterns of the different months, as well as different zones. The tropical SST predictors were used to train seasonal-rainfall models for different zones for different seasons in Borana Zone. For instance, mean JF, AM and JA SST's were selected for developing suitable prediction models for MAM, JJA and SON seasons. For clarity, the prediction results would be discussed zone wise as follows:

Table 20: Prediction models for MAM, JJA and SON rainy season for Borana Zone

Prediction Model	R	R^2	P ≤
Zone I_{MAM} = -0.145*PNA- 0.597*NAO+ 0.162*Nino 3.4	0.76	0.57	0.05
Zone II_{MAM}=-0.731*NINO4-0.252*WPAC-0.903*NAO +0.490*NPAC	0.85	0.73	0.01
Zone III_{MAM}= -1.036*NATL -0.165*WP-0.652*NAO	0.73	0.53	0.05
Zone I_{JJA} = -0.371*SATL +0.53*SPAC+0.653*QBO	0.72	0.52	0.05
Zone II_{JJA}= -0.498*NPAC-0.832*SIN+1* SPAC	0.70	0.49	0.05
Zone I_{SON}= 0.626*NINO12+1.216*NATL -0.613*ESPAC1	0.72	0.52	0.05
Zone II_{SON}=-0.731*NINO4-0.252*WP-0.903*NAO+0.441* EASTPAC	0.79	0.63	0.05
Zone III_{SON}=0.537*NINO12+1.423*NATL-0.523*WP+0.448*CPAC	0.90	0.81	0.01

Historical records of SSTs over 1983-2004 are used to develop the model. The resulting model used three predictors such as Pacific North America (PNA), North Atlantic Oscillation (NAO) and Nino 3.4 SST. This model results in a highly significant multiple R^2 of 0.57. The model equation, with standardized variables are for Zone I, Zone II and Zone III during MAM season see model equation in the (Table 20). The model explains 57% of the total variance of Zone I seasonal rainfall (R = 0.76) and (R^2=0.57). The time series of hindcasts from Zone I rainfall and the multiple regression model has shown in Fig.39a. The regression forecasts are shown both within the training period (1983-2004) and for an independent (2005-2014) verification period.

The resulting model used three predictors such as South Atlantic (SATL) during JJA, South Pacific (SPAC) and Quasi Biennial Oscillation (QBO). This model results in highly significant multiple R^2 of 0.52. The model equations, with standardized variables, are for Zone I and Zone II during JJA season sees model equation in the (Table 20). The model explains 52% of the total variance of Zone I seasonal rainfall (R = 0.72) and (R^2=0.52). The time series of hindcasts from Zone I rainfall and the multiple regression model has shown in Fig.40a.

The resulting model used three predictors during SON such as Nino12, North Atlantic (NATL) and Eastern Pacific (ESPAC). This model results in highly significant multiple R^2 of 0.52. The model equations, with standardized variables, are for Zone II and Zone III during SON season sees model equation in the (Table 20). The model explains 53% of the total variance of Zone I seasonal rainfall (R = 0.72) and (R^2=0.52). The time series of hindcasts from Zone I rainfall and the multiple regression model has shown in Fig.40a.

The distribution of spatial correlation with mean of JF SSTs affect the MAM season. During this season, strongest feature in Fig. 36, mean of JF SSTs is ENSO related with the positive (negative) ENSO phase associated with low (high) seasonal rainfall. The correlation patterns over Nino 3.4, Pacific North America and North Atlantic Oscillation were showing strong relationship with Zone I rainfall during MAM season whereas central Atlantic and Indian Oceans do not show strong features. More or less positive correlation between rainfall and JFSSTs appear in the over South Atlantic and East Indian Ocean (Fig. 36).The correlation patterns over the Nino 4, West Pacific (WP), North Atlantic Oscillation and North Atlantic have shown strong relationship between Zone II rainfall in MAM Season and JF SST rather than January and February. Negative values in the North pacific, East Indonesia and South Atlantic Ocean have shown strong correlation with Zone II during in the MAM season. Correspondingly, from Fig.36 correlation patterns over the North Atlantic (NATL), West Pacific (WP) and North Atlantic Oscillation (NAO) have revealed strong relationship between JF SST and Zone III rainfall during MAM season. A weak positive correlation was shown over Indian Ocean while the weak negatives over seen over South Pacific Ocean.

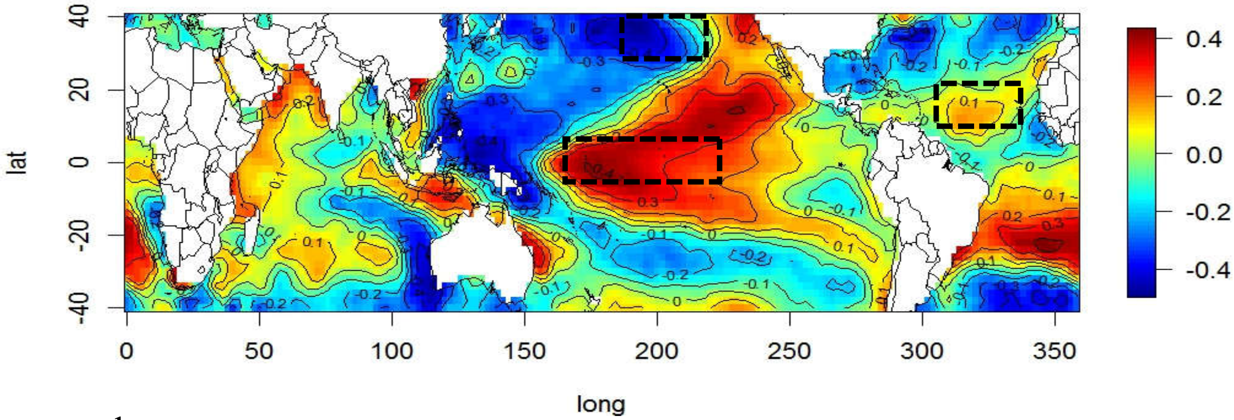
The distribution of correlation of mean of AM SST influence the short temporary (JJA) season for Borana Zone. During this season, the correlation patterns AM SST over the South Atlantic (SATL), South Pacific (SPAC) and Quasi Biennial Oscillation have indicated strong relationship with Zone I Rainfall. However, the correlation patterns over the North Pacific (NPAC), South Indonesia (SIN) and South Pacific (SPAC) have revealed strong connection of AM SST with Zone II rainfall (Fig.37b). Also extra correlations seen over the Indian and more parts of Pacific Ocean have weak positive (negative) values with Zone I rainfall. Strong positive correlation patterns shown over the Madagascar and Southeast India while strong correlation patterns clear seen over the North and South Pacific Ocean which affect the Zone II rainfall during short temporary rainy (JJA) season.

The distribution of correlation with mean of July and August SST mark the SON season, which strong features related with positive (negative) ENSO phase associated with low (high) seasonal rainfall (Fig. 38). The correlation patterns over the Nino 1+2, North Atlantic and East Pacific were showed strong relationship with Zone I rainfall during SON season (Fig. 38a). The correlation patterns over the central Atlantic and west tropical Pacific revealed negative values whereas over the West Indian Oceans and Southeast shown positive correlation that enhance the Zone I rainfall in the SON season. More or less positive correlation between rainfall and JA SSTs appear in the over South and North Pacific Ocean.

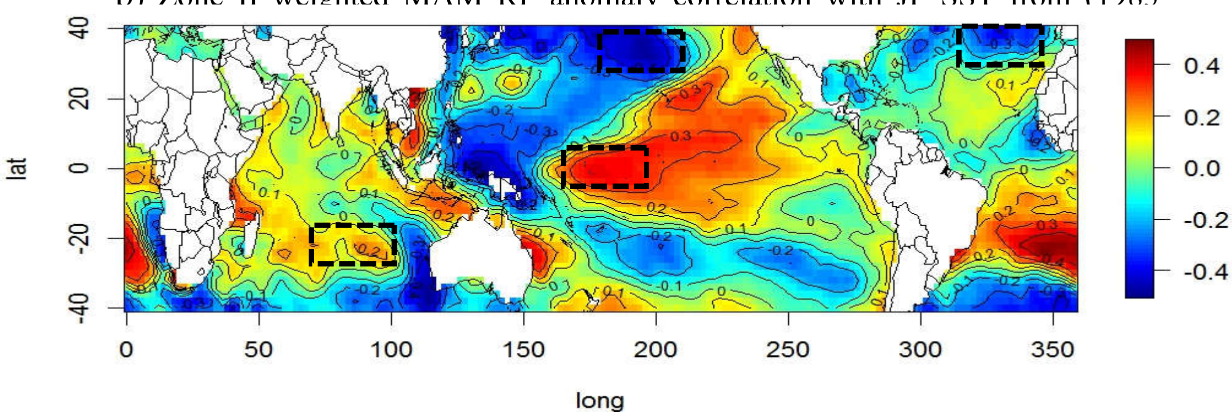
As depicted in Fig.38b, the correlation patterns over the Nino 4, West Pacific, North Atlantic Oscillation and East Pacific have shown strong association of JA SST with Zone II rainfall during SON season. High correlation have seen over the Nino 1+2 region that directly affect the Borana Zone rainfall during SON especially Zone II rainfall. In addition, medium strong correlation between zone II rainfall and JA have observed over the West Indian, south Pacific and South Atlantic during SON that has high contribution. The correlation patterns over the Nino1+2, West Pacific, North Atlantic and central Pacific obvious revealed strong association between JA SST and Zone III rainfall in the SON. A weak negative correlations were seen over the central and East of Atlantic ocean whereas weak positive correlation shown over the North Pacific and some parts of central Pacific (Fig.38c).

Generally, as described in (Fig.36) North Atlantic Ocean has highly negative correlation with MAM rainfall for all three homogenous rainfall regimes. While, JF Nino 3.4 and 4 SST are positively correlated with MAM rainfall, which enhances the rainfall for Borana Zone. Beside, JJA South Pacific SST has strong positive correlation. For second rainy season, JA Nino 1+2 SST positively correlated all homogenous rainfall regimes while central Atlantic and West Pacific ocean negatively correlated.

a) Zone I weighted MAM RF anomaly correlation with JF SST from (1983-2014)



b) Zone II weighted MAM RF anomaly correlation with JF SST from (1983-



c) Zone III weighted MAM RF anomaly with JF SST from (1983-2014)

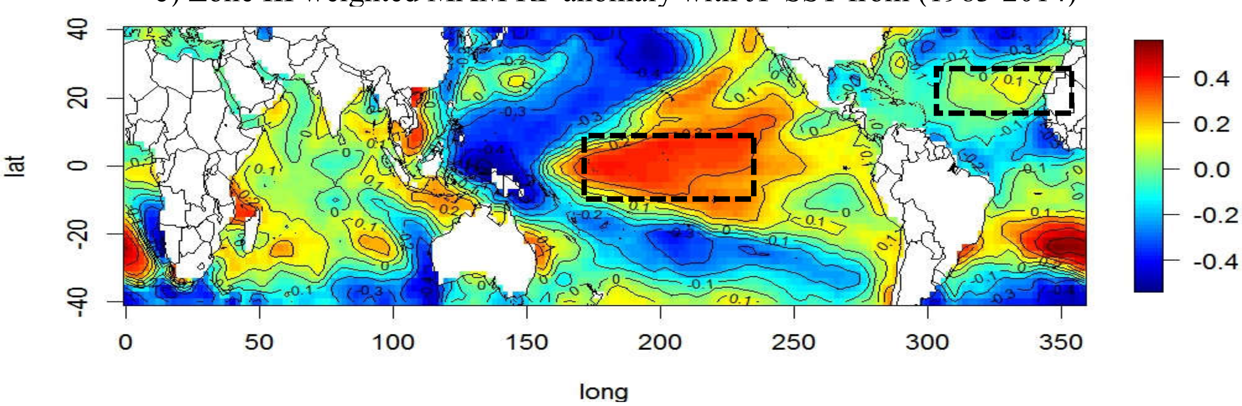
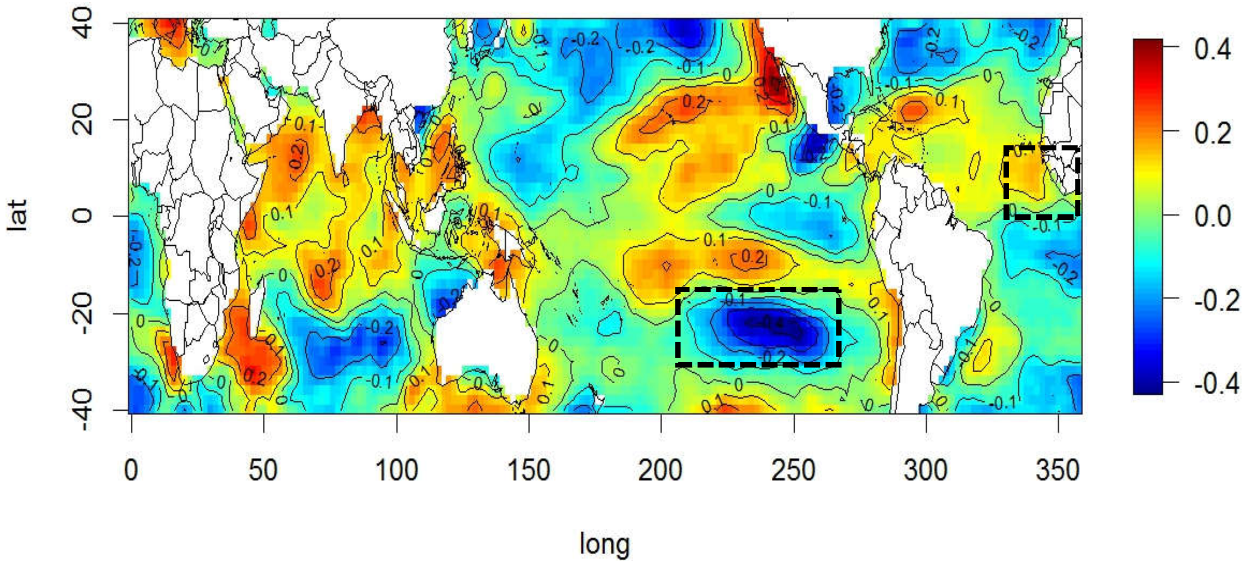


Fig.36.Spatial correlation between MAM seasonal rainfall and sea surface temperature (SST)

a) Zone I weighted JJA RF anomaly correlation with AM SST from (1983-2014)



b) Zone II weighted JJA RF anomaly correlation with AM SST from (1983-2014)

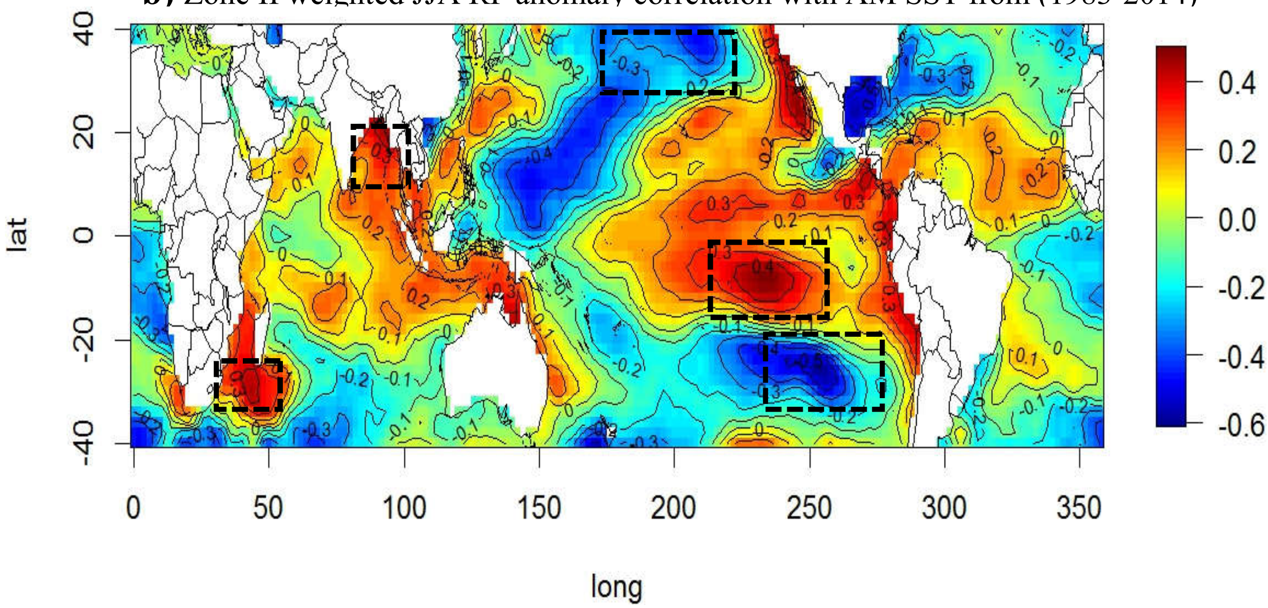
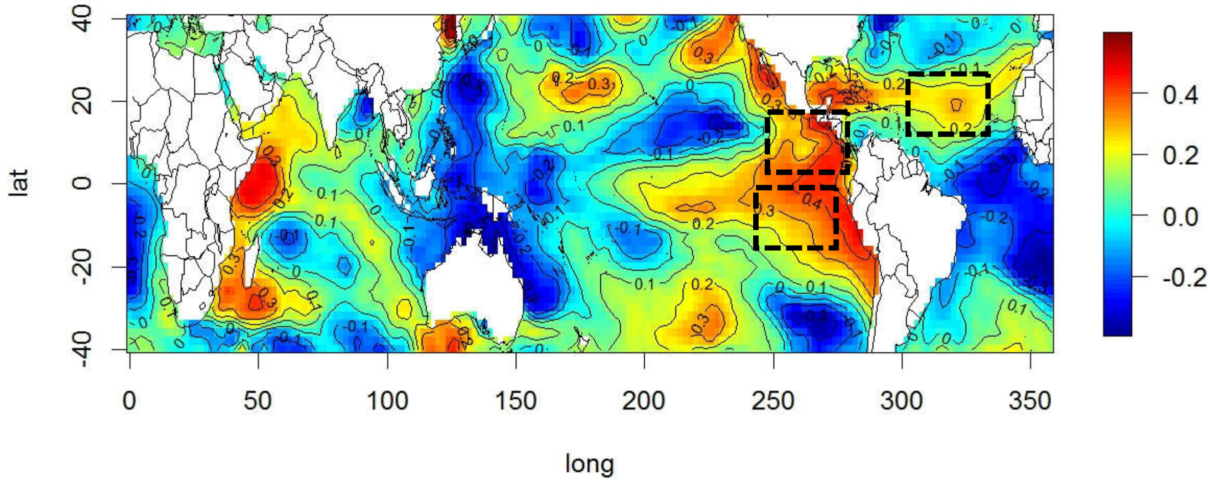
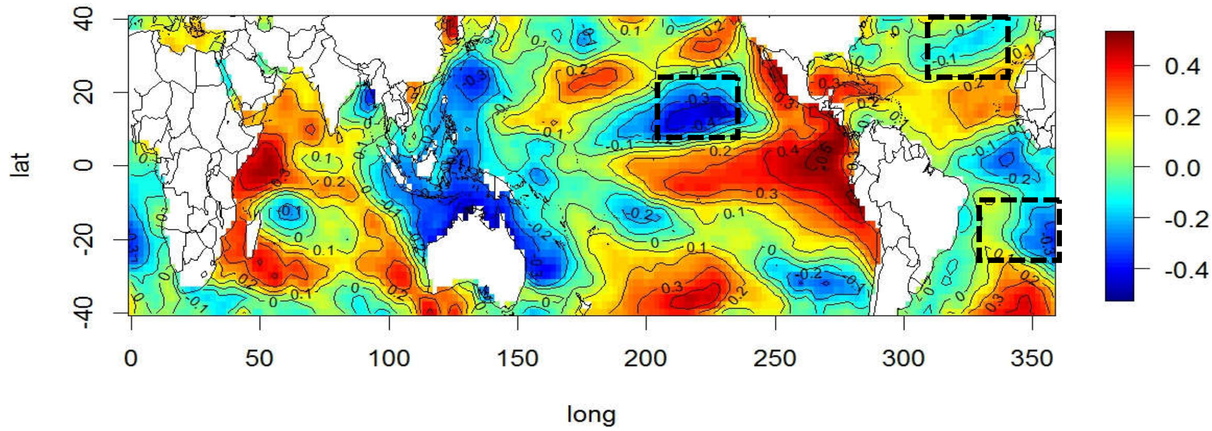


Fig.37. Spatial correlation between JJA seasonal rainfall and sea surface temperature (SST)

a) Zone I weighted SON RF anomaly correlation with JA SST from (1983-2014)



b) Zone II weighted SON RF anomaly correlation with JA SST from (1983-2014)



c) Zone III weighted SON RF anomaly correlation with JA SST from (1983-2014)

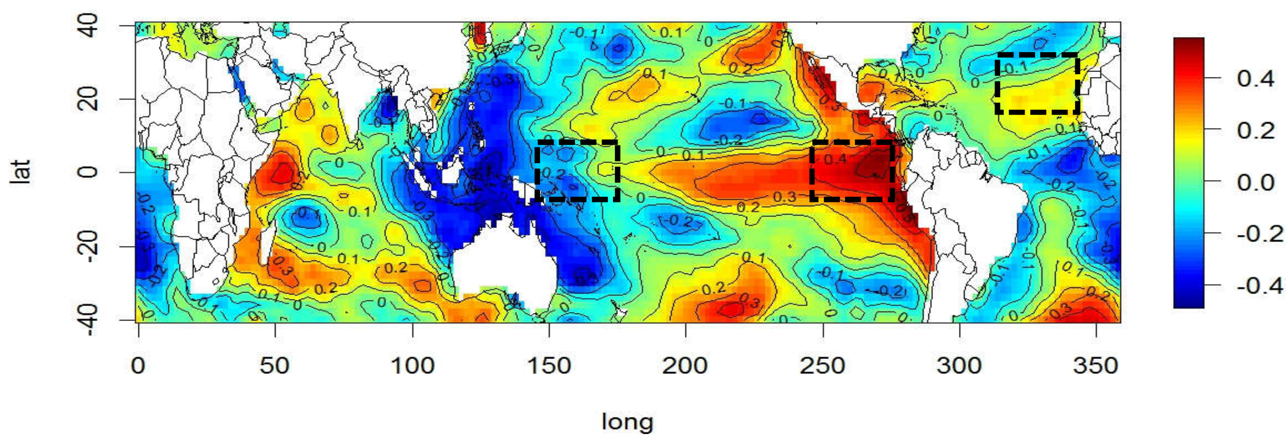


Fig.38. Spatial correlation between SON seasonal rainfall and sea surface temperature (SST)

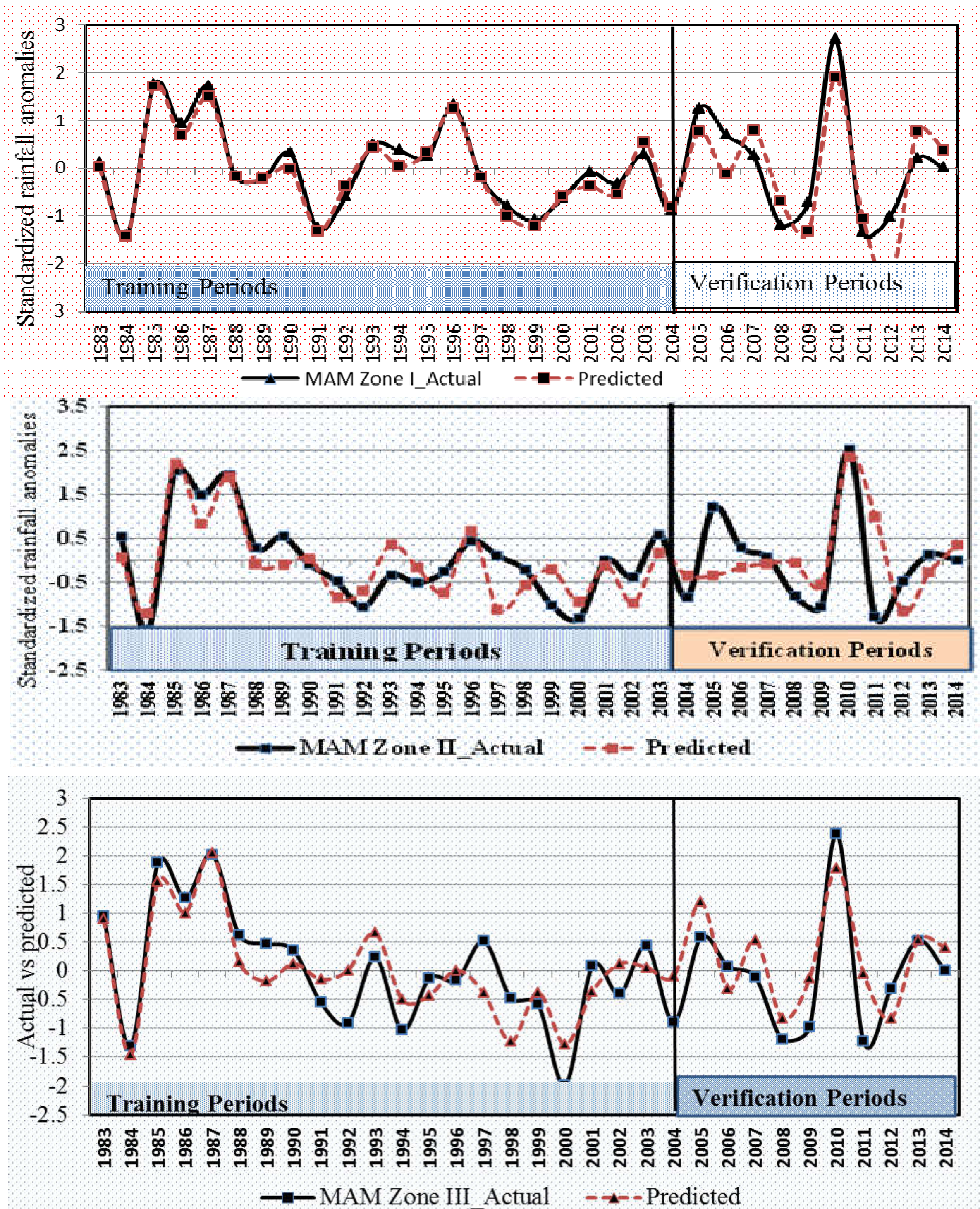


Fig.39. Time series of mean JFSST anomalies (°C) as observed for the periods 1983–2004 and MAM predicted rainfall were available for 1983-2014, whereas the multiple linear regression models is built based on 1983-2004 and validated for the remaining period

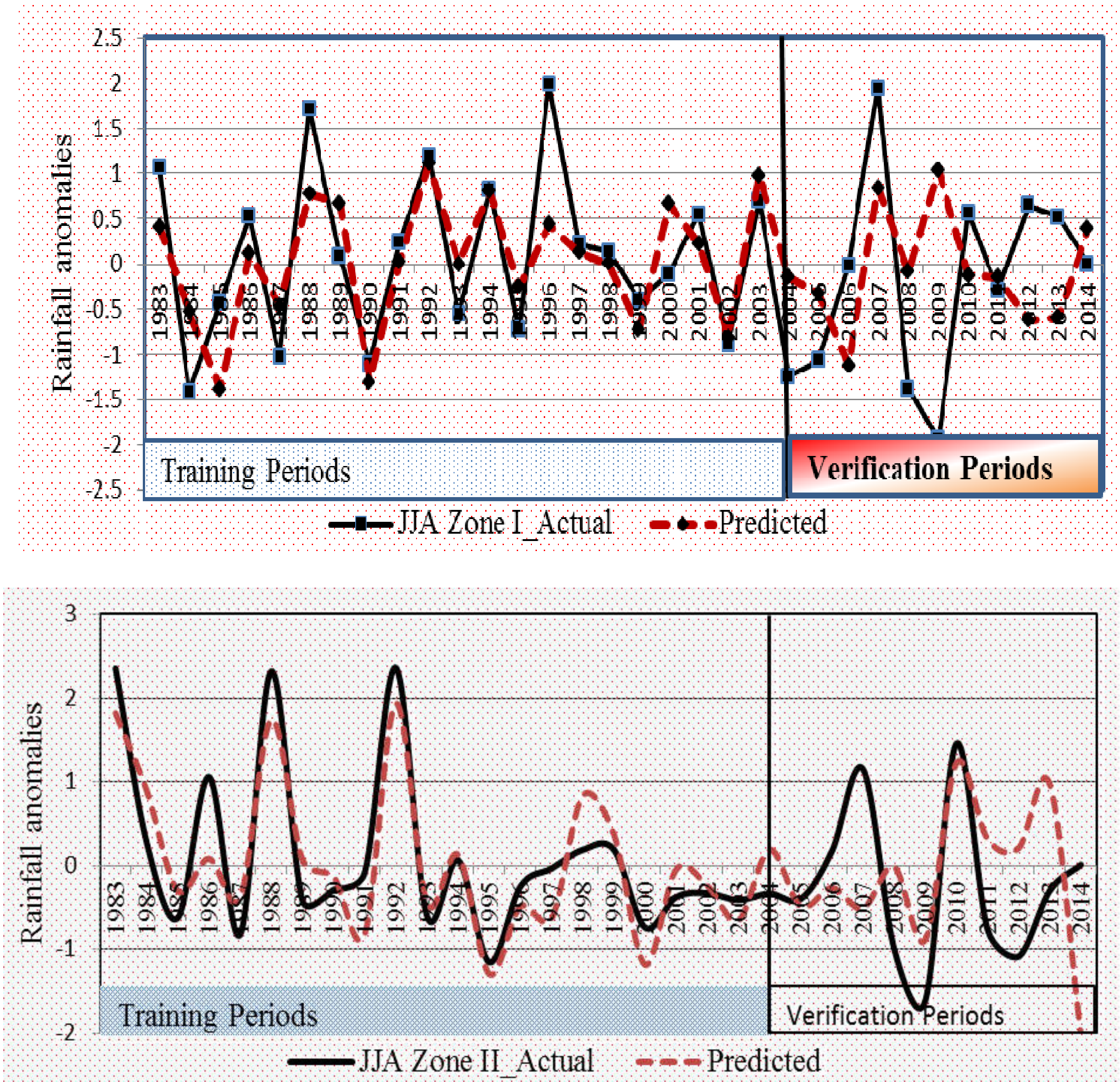


Fig.40. Time series of mean AMSST anomalies (°C) as observed for the periods 1983–2004 and JJA predicted rainfall were available for 1983-2014, whereas the multiple linear regression model is built based on 1983-2004 and validated for the remaining period

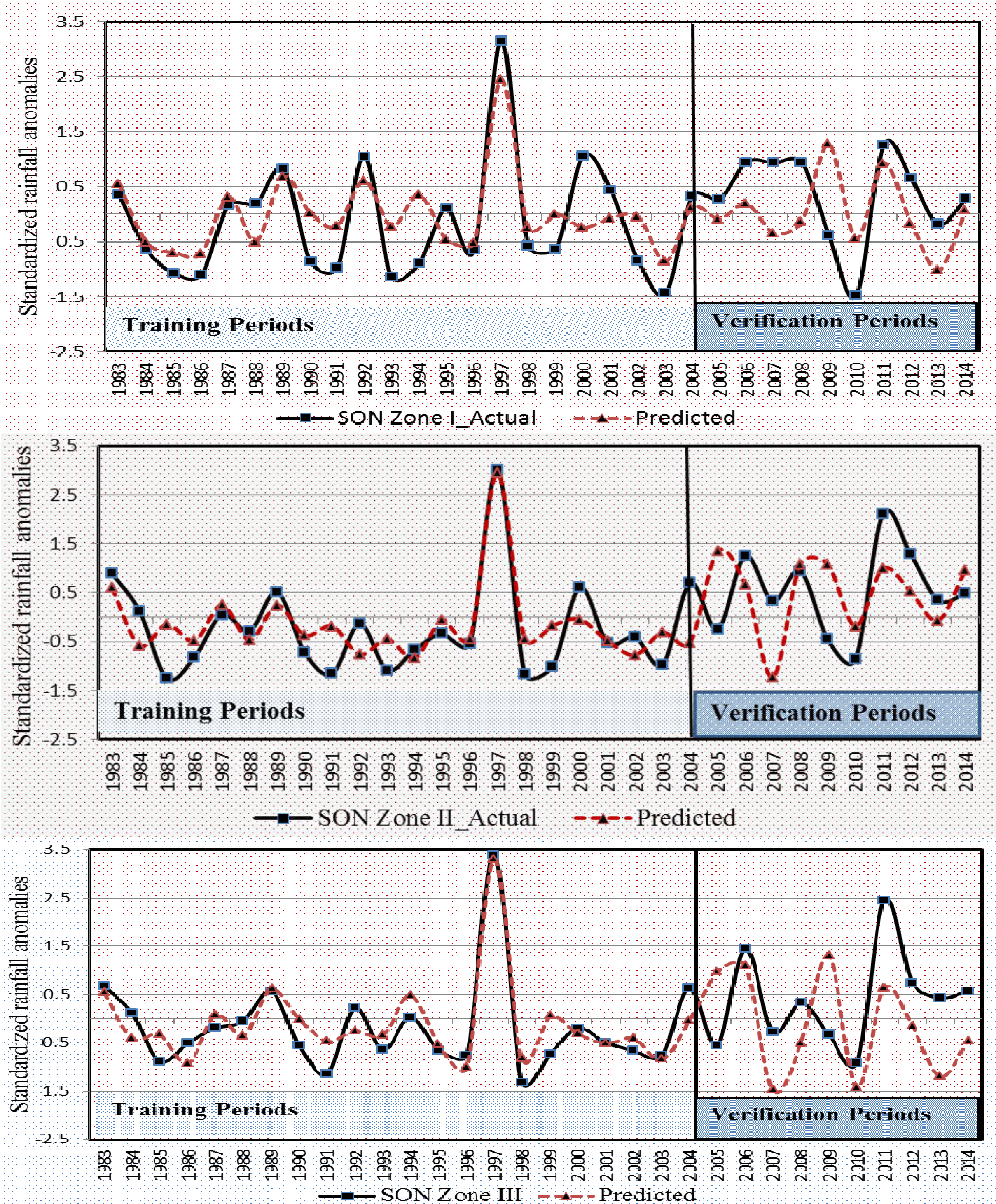


Fig.41. Time series of mean JA SST anomalies (°C) as observed for the periods 1983–2004 and SON predicted rainfall were available for 1983-2014, whereas the multiple linear regression model is built based on 1983-2004 and validated for the remaining period

4.7. Traditional Weather/Climate Prediction Method at Borana Zone

During the field trip of November 2014, as the information derived from the traditional climate prediction elders (*ayantu*) shown, similar to local communities in different parts of the world, enrich in IK in the field of weather and climate prediction in Borana Zone for more than half of millennium.

Studies revealed that Borana pastoralist communities locally adopted indicators for traditional climate forecast knowledge. These include, reading livestock intestine and stars, cattle body condition and cross with *Gada* System for many years. These indicators have been used to predict climatic shock such as drought and flood (Legesse, 1973; Luseno *et al.*, 2003). Among Borana communities, pastoralism built very stable ancient tradition that historically proved as a system that can foretell the adverse effect of extreme climatic variation and disseminate valuable information so that the local communities are capable of adapting to frequent and often-dramatic climatic variation (Boku, 2000). In recent decades, however, this lifestyle has come under enormous pressure, which undermined the ability to maintain the standard of living of a large sector of the pastoralists (Boku, 2000). Survey showed that pastoralists of Borana Oromo have used traditional weather/climate prediction in managing the performance of livestock during past centuries. However, in Ethiopia until now this usefulness TK method would have no documented well and integrated with scientific climate prediction method. The importance of integrating both the scientific and indigenous climate forecasts information for farm level decision is gaining momentum as also documented in Mozambique and Kenya by Lucio (1999) and Ngugi (1999), respectively.

The evidence derived from Focus Group Discussion (FGD) has shown that traditional climate prediction declined due to climate variability and deforestation and hence it was linked to the weakening of local attributes. Likewise, Luseno *et al.* (2003) recognized traditional methods (as in the past 20 years) seemed to have poor performance in predicting local climate.

The elders also mentioned other reason for the declining of the role of Traditional knowledge (TK) in weather and climate prediction in Borana Zone. Up to now, TK has transferred from generation to generation through oral from *ayantu* and village elders. Office of Borana Zone disaster and preparedness confirmed that in spite of all the usefulness of TK in weather and climate prediction, the art is under threat of endangered due to lack of systematic documentation of the knowledge and lack of coordinated research to investigate the accuracy and reliability of TK forecasts (Olana Jira, Personal communication in Nov 2014). In spite of the numerous problems that the pastoralists have to overcome daily, they continue to survive in a harsh environment with extreme and unpredictable weather conditions (Solomon, 2003). Therefore, any attempt that enable to improving the living conditions of Borana community should first incorporate a thorough understanding of the pastoralists' TK including traditional practices, goals and strategies.

4.7.1. Local climatic and conflict prediction indictors at Borana Zone

The Borana people are using enormous type of climate prediction indicators. Among the community members, the majorities were tried document in this paper. Tables provide details of other local climatic indicators as follow (Table 21). In Borana Zone, morning star and livestock intestine are the most widely used indicators in predicting rainfall and conflict events. Other indicators mentioned include animal behaviors and movement of ants, insects and animals. As indicated by the elders among plants phenology acacia is widely used for seasonal climate prediction. Likewise, flowering of *Oda* (the sycamore trees) also good indicator of onset while the opposite is true when it dropout leaves it indicates extreme drought. This tree is not simply dropout its leaves due to extreme drought. As weather-related indicators, wind patterns, direction and variation also found to be used in monitoring rainfall.

Table 21:Traditional weather forecasting and climate prediction indicators related to rainfall conditions as derived from group discussion with indigenous elders (*ayantu*)

Indicator	Signs	Time of Event	Forecast/Prediction
Morning star	Normally, morning star has seen for 240 days without hide. Small in size, hid for one hundred (100) days in the East.	Before main rainy Season	Indicate lack of rainfall in the coming season.
	Hid for sixty - (60) days and come again	Before main rainy season	Normal and above normal rainfall is expected in the coming season.
Stars assemblage	Star pattern and the movement of stars from west to east at night under clear skies	Preseason and at cessation of the season	Indicate onset of rainfall in short day and patterns are also used to predict cessation of rainfall
Livestock intestine	Entire white of intestine after reading by traditional forecaster		Indicates lack of rain in the coming season
	The dark tendency to black vein of the intestine		Shows above normal rainfall followed flood
	Quit white and contradiction of intestine and when try to stretch back to its origin size.		Indicates war/conflict
	When read by traditional forecaster dark have tendency to black of intestine and simple stretch		Shows peace and flood occur

Table 21 (Continued)

Indicators	Signs	Time of Event	Forecast/Prediction
Animal behavior	-Well-fed calves jumping around happily in the veld and on their way home from grazing area and unwilling to graze the following morning		Indicates good rain on the way and have continuity
	-Rose libido and goat and sheep frequent mating		Indicates of good rain in the next season
	-At morning after leave fence, if cattle return say Moo		Shows Lack of rain for in the future
	After drink water at river unwilling to go grass area and want to stand for a long time		Indicates the coming season/year lack of rain
	Cattle urinated at sleep		Shows next drought season
Moon Phase	Born of new moon following lightning and thunder in next ten days	January	Indicate good rain upcoming season
	After born of new moon next absence of lightning and thunder and no clouds	January	Lack of rain and drought forthcoming season
	Appear of new moon, after five days and morning star shown ten day,	November	Indicate the season is good and extend
Insects	Appearance of many Termites	January-February	Indicate near rainfall onset
	Appearance of ants and rapidly increasing size of anthill	January-February	Indicate near rainfall onset and good rainfall
Appearance of plants	-Flowering and budding of acacia -Flowering of wild lilies in the veld like *Oda*		Both indicates near rainfall onset and good rainfall
Wind	Wind swirls	February	Shows approaching of rain onset
	If strong wind from east to west	February	It is good because of bearing rainfall

The most common traditional indicators across the Borana Zone were documented in Tables 21, which indicators zone were used, what they forecast/predict, the time of occurrence at that particular time. As evidence in the FGD shown above, the pastoralists divided rainfall prediction into good rains and lack of rain. The Borana pastoralist uses terminology, “good rain” when rain resulting in a good pasture of rangeland, abundance of water for livestock and good crop.

Conversely, the terminology “lack of” rain means when rains do not result in good crop, pasture of rangeland and abundance of water, particularly associated with medium and extreme drought.

As evidence of derived from FGD shown the indictors used by Borana pastoralists were composited of traditional, astronomical and meteorological indictors to predict the rainfall, conflict, floods, drought, and so forth (Fig.1 in Appendix). In seasonal climate prediction pastoralists, use meteorological indicators such as wind swirl, direction, lightning and thunder, which primarily used in scientific forecast to develop model. However, the challenge is to provide reliable forecast through appropriate methods based on the needs of the pastoralists. The pastoralists use the indictors to predict rainfall onset, cessation, flood, and war/conflict. As elders (*Ayantu)* underpinned, TK is playing a major role within the Borana societies. Based on TK, the communities are able to anticipate most of the disasters that seldom affect them. Disaster prediction and early warning leads to preparedness and other responses, and when disaster impacts controlled, recovery starts after.

4.7.2. *Gada* system as a climatic shocks recording system

“*Gada*” is a system of classes that attributes, almost all human aspects, such as military, political, economic and ritual” (Halake, 2010:36). The *Gad* generation of Borana has five-generation classes that succeed each other after eight-year of a *Gada* period (Halake, 2010).The Borana *Gada* has three fundamental elements such as legislative, executive and judiciary organs, which play political, economic, judicial and social roles. According to Halake (2010) “It is through the existence of these organs that the Borana customary laws for natural resource management and other community affairs are made, practiced and protected by the members of community in general and customary leaders in particular. This Borana oral tradition suggests that drought is cyclic and they remember regional droughts with the *Gada* cycle (Oba, 1998b:73). According to Golicha Guyo, one of the known oral historians of Borana, drought (Oola) started in history of Borana during *Gada* period of Bule Dadacha (1776-1783). Then other droughts have remembered during Gada periods of Saqqo Dadacha (1814-1821), and Guyo Boru (1885-1891) which has locally remembered by Oola *qolajii*. During those *Gada* periods drought had occurred once in eight years. According to Golicha Guyo, it was during Gada period of Goba Bule (1968-1976) drought occurred more than two times within one *Gada* period. Starting from this *Gada* period drought becomes recurrent in nature even if the frequencies and magnitudes varied. The recent *Gada* cycles and climatic shocks and others events were discussed in detail (Table 22).

As Wario Hunda among key informants explained, the *Gada* system regulates the management of natural resources and play pivotal role in political, social, economic and judicial processes. Still now, rather than scientific climate forecast Borana pastoralists and agro-pastoralists apply this local/ indigenous climate forecast cross with *Gada* system. According to key informants and FGD reason of Borana pastoralist relied on local weather/climate forecast/predict, traditional weather/climate it is simple to understand, locally available (not expected from external) and already this knowledge known by elders and societies. However, the scientific weather/climate is not locally available and difficult to interpret due to lack of knowledge. Owing to the climate variability, time to time the confidence level of elders has declined. The evidences that derived from key informants and FGD, indicate pastoralists' shows willing to use scientific weather/climate prediction output, but are not accessibility at local (Fig.1 in Appendix).

Table 22: During *Gada* cycles climatic shocks, conflicts and diseases outbreak evidence derived from traditional forecasters (ayantu).

Gada cycle	During power taking (*gaafa baallii fuudhe*)	During Gumi Gayo Assembly (GGA)	During power transfer (*Gaafa baallii kenne*)
Gada Jilo Aga (1976-1984)			During transfer power the absence of rainfall (*Oola*) In this Gada period the Sun covered for one day
Gada Boru Guyyo (1984-1992)	- Absence of rainfall in both season (*Oola*) was existed and extreme drought	-	Before two year left absence of rainfall (Oo*la*) in both rainy season, conflict , foot and mouth were appeared
Gada Boru Madha (1992-2000)			Before one year left foot and mouth and drought
Gada Liban Jaldessa (2000-2008)			No (*Oola*) occur but medium drought conflict were existed
Gada Guyyo Gobbaa (2008-2016)		Complete (*Oola*) were not existed and extreme drought occurred specially drought of 2011	

As observed from Table 22, the drought recurrent and absence of rainfall (*Oola*) almost existed before one or two years before Aba *Gada* transfer power to his successor. This drought recurring every six to seven years and both their frequency and severity may be rising. The rainy season March to May, (MAM) rainfall declining is strongly associated with transfer of power in *Gada* cycle. From the empirical analyzed data drought of (1984, 1991, 1992, 1999/2000 and 2011) has occurred during transfer of power except 2011 drought, which occurred during Gumi Gayo Assembly (GGA).

4.7.3. Drawback of both traditional and scientific seasonal weather/climate prediction

The pastoralists are willing to learn about and confidently accept science-based knowledge and wished to make open discussion on the advantages and disadvantages of using traditional as well as science-based weather/climate forecasts/predictions indicators/knowledge. The traditional forecasters (*ayantu*) mentioned in detail the problems regarding to traditional and scientific weather and climate prediction. As the traditional forecasters FGD evidence indicated, traditional weather/climate prediction problems such as, culture-based and interpreted differently for different areas, cannot predict mid-season dry spells or their probabilities, do not indicate rainfall distributions but only when to prepare for the onset and sometimes something on the quality of the season to come etc. In addition, the FGD commented that drawback of seasonal climate prediction. For instance, it is not easily available and accessible for use in agriculture, advantages has not documented in ways that farmers can understand, difficult to interpret and it is not easy to make decisions based on the probabilistic information given, not point specific and there is a need for trustable downscaled weather/climate forecasts/predictions.

There are many noble ideas that the scientists can learn from traditional weather/climate forecasters (*ayantu*). In view of this, there is a need for follow-up research to look more deeply at local indicators against climate change and possible integration of scientific knowledge and local knowledge. Pastoralists use weather and climate related indicators in their traditional forecasts/predictions, mostly for seasonal rains and droughts monitoring purposes. Decision of pastoralists and agro-pastoralists are making according to traditional knowledge and understanding of these environmental conditions of their local area, obtained through years of experience. Understanding of the traditional knowledge on weather and climate is a critical phase to facilitate effective communication on science-based agrometeorological knowledge.

Traditional weather forecasters (*ayantu*) have substantially benefited the community in providing direction on the possible occurrence of climate related disasters or other civil unrest for many years before modern scientific methods for weather forecasting and climate prediction became apparent. It was noted that mobility of pastoralists and seldom farming with relatively low yields continued successfully with the exception of regular disasters.

4.7.4. Decentralized seasonal weather /climate prediction at local level

As Olana Jira among key informants explained, Borana pastoralists and agro-pastoralists time-to-time have become very vulnerable to rainfall variability and climatic shocks like droughts and floods. There is also lack of timely weather forecasts at local village or district levels. In addition, from traditional weather/climate forecasters (elders) discussion it was confirmed that the main problems regarding to both traditional climate and scientific climate output is that both of them are less accessible and distributed timely. Moreover, the traditional weather/climate forecast information is not released from particular area as it was not been well organized. Still know there is no systematized ways purposively transfer traditional climate forecast information as well as techniques. Owing to this, only some clans, who live together in a particular village mostly benefited from such traditional ways of weather/climate information released by *ayantus*.

As TK has predominantly embedded in practices and experiences, it most commonly exchanged through personal communication and demonstration, from master to apprentice, from parents to children, from neighbor to neighbor and from traditional leaders to the community (Berkes, 1999). Various communities have different ways of disseminating indigenous information. For instance, faced with an impending disaster, the clan elders in some communities in Kenya beat specific drums and sound horns to alert people to assemble at known meeting points, where specific advice or instructions are communicated and appropriate preparedness and response actions are decide upon.

Ethiopia's system for generating official early warning systems at national, regional, district, or village levels for climatic shocks management is non-existing and this puts pastoralists and agro-pastoralists and the entire population in the obstinate position of being unable to adequately prepared for extreme climatic events. Therefore, user-interface climate package for the pastoral community of Borana Zone must be designed and practiced at village center (Fig. 42). In Ethiopia still there no localized scientific and tradition, knowledge forecast integration and user-interface climate package for a pastoral and agro-pastoral community. However, to serve pastoralists and agro-pastoralists at nearby integrated scientific and traditional forecast that translated into their own language is crucial which must simply accessible and release on timeline manner at village level.

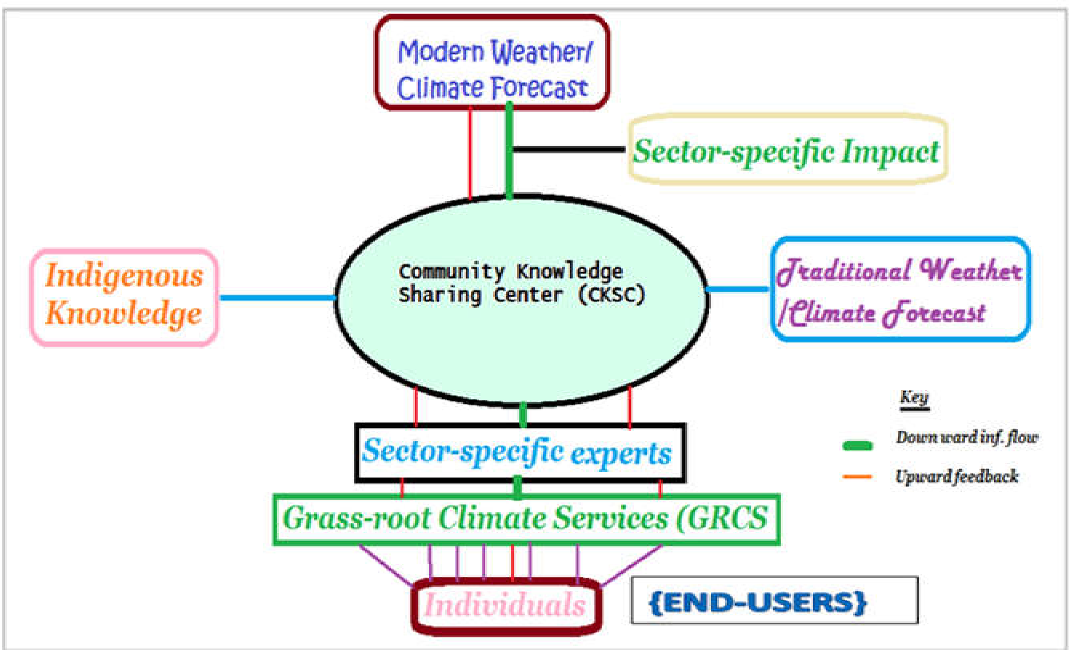


Fig.42: Conceptual framework for Grass-root Climate Services

The process indicates that concentrated interchange between the scientific knowledge providers and user groups helps to define the strategies for linking the knowledge systems (Fig. 42). The study shows that pastoralists could able to bridge the two different knowledge systems. As shown in Fig 42, it is apparent to develop decentralized system of forecasting system at the village level by linking the traditional and scientific knowledge through a participatory approach to mobilize the pastoralists and agro-pastoralists around the technology. Indeed, accessing, availability of infrastructure, skill and expertise are crucial to develop reliable region-specific scientific forecast to serve the pastoralist and agro-pastoralists societies.

Borana Zone has gifted with a wide range of natural resources and rich institutional heritage. However, nowadays pastoralists like others in Ethiopia have been facing natural and man-made problems such as recurrent droughts, rangeland deterioration, bush encroachment, erosion of traditional safety nets and weakening of traditional institutions, a narrow livelihood base, limited market for their livestock and increased conflict.

In addition, to governance structures of the modern state, a traditional institution known as the *Gada* regulates the social life and relations of the Borana. The institution is responsible for traditional governance, access to land, management of natural resources such as water and pasture, managing conflict, and relations with other institutions. Recently, due to different cases this institution has been weakening. However, traditional institutions need to be strengthened and empowered by restoring their authority through respecting their role.

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary and Conclusions

In Borana Zone of southern of Ethiopia, the long rainy (MAM) season is the main season, which is very essential for different accomplishments. As the result of rainfall and temperature trend analysis indicated, at present Borana societies faced to climate variability such as declined of rainfall in amount and raised in temperature, which also adversely affected pastoral livestock production through indirect impacts on pasture growth, water availability and disease distributions. The pastoralists of Borana used and relied on traditional climate prediction to reduce in advance climate related hazards that recently decline due to climate variability. In addition, dekadal, monthly and seasonal climate predictions released by National Meteorological Agency (NMA) and other international centers usually cover large-scale spatial resolution. In recent years however, as localized meteorological monitoring systems have expanded, pastoralists are willing to utilize climate-based early warning for early action. This study examined, localized seasonal climate prediction method and applies in proactive reducing climate-related hazards on livestock productivity over Borana Zone and plan user-interface climate package for the pastoral community of Borana Zone.

In all parts of Borana Zone, arid and semi-arid lowland and high rainfall variability are strong inducing prolonged droughts. This study examines the monthly, seasonal and annual rainfall analysis by using thirty-two years data. The study findings revealed that a declining trend and a high inter annual variability in long rainy season rainfall strongly associated with drought occurring almost recurring every around *Gada* cycle years. The recent declining in the long seasonal rainfall happened predominantly because of the substantial decline in April to May rainfall over Borana Zone. Inter annual variation in seasonal rainfall was better indicator of drought occurrences than variation in the total annual rainfall, as droughts often resulting from sequential deficits in the long and the short rains. The study further specified that main cause of drought over Borana due to declining in both long rainy (MAM) and short temporary (JJA) seasons. However, from the finding the second rainy (SON) season conversely showed an increasing trend, which is consistent with previous studies. The results further showed as well that rainfall is highly variable, especially in the arid and semi-arid Borana Zone, and unreliable for rain-fed agriculture and livestock production.

The study in deed examinedonset, cessation and dry spells over two weather stations namely Hager Mariam and Moyale that are located in northern and southern parts of Borana Zone, respectively. Study finding were indentified thathigh variation in onset of the season became more dominnatwh while it is less variable in the case of cessation of the seasons.

Seasonal patterns as generated from the standardized anomalies of rainfall revealed that the droughts mostly occurred sequentially due to the failure in the long and short rains. As a time series of standardized rainfall indicated clearly indicated droughts occurred during 1984, 1992, 2000, 2004, 2009 and 2010/11 directly associated with failures of long rainy season. The study further showed that declining in cattle populations were associated with an analogous underlying trend in rainfall and wider range of its variability.

The result of this study revealed that zonal temperatures have shown increasing trends on monthly, seasonal and annual time scales. During short, dry and cold (JJA) season, the minimum temperature was highly variability with an increasing trend. Indeed, it has been increasing by about 0.56 ^{0}C per ten year. As the trend, line clearly revealed that there has been a warming trend in the annual minimum temperature over the past 31 years with the value of about 0.7 ^{0}C per decade.

Using principal component analysis, the main rain (MAM), short temporary rain (JJA) and second rainy (SON) seasons of Borana Zone were classified into three, two and three homogenous rainfall regimes, respectively. Wide scale global and regional atmospheric and oceanic bodies have strong link with these homogenous rainfall regimes in different seasons. This study identified that El Nino enhances while La Nina suppresses the long rain of Borana Zone.

Multivariate statistical techniques have applied to analyze and predict seasonal rainfall patterns using preceding monthly mean global sea surface temperatures and other related predictors data. Lag relationship between ENSO and Zonal rainfall revealed that ENSO has skillful predictability for long and short rainy seasons of Borana zone. Based on this analogy, is this study established possible ways to use ENSO states and its direction and rate of evolution, as a simple statistical precursor MAM rainy season. Nevertheless, ENSO has weak predictability skill for JJA season.

Focus group discussion and key informants were used to identify traditional weather/climate forecast/prediction indicators that help to providing seasonal climate prediction. In addition, system of recording climatic shocks, conflicts and diseases outbreak during *Gada* cycles evidence was derived from traditional forecasters.

In generally, statistical seasonal climate prediction method skillfully predicted seasonal rainfall of Borana Zone. It was confirmed that climate prediction is one of the most imperative proactive means to minimize climate-related hazards, such as droughts and disease in order to increase both quantity and quality of livestock production in Borana Zone. Accustomed to use of seasonal climate forecasting can in fact increase awareness, leading to recovering social, economic, and managing products within livestock production systems. In addition, seasonal climate prediction is one of many risk management tools that play an important role in managing livestock decision making. Employing the use of reliable and up-to-dated seasonal climate forecast enable communities in order to recover social and economic wellbeing, managing products with in livestock production, especially by using integrated scientific and traditional weather/climate forecast/prediction amongst Borana pastoralists in advance. As finding indicted the main problem among the Borana Communities is still regarding less accessibility and distribution of climatic information in time.

5.2. Recommendations

It is recommended that there is a need to underpin advanced study on the lag relationship between ENSO and rainy seasons over Borana. Based on the scientific exploration and prior knowledge on ENSO evolution, pastoralist communities can get valuable early warning information that enable them to destock or restock their cattle well time in advance before extreme climatic events emerges over the region. In fact, the regional SST anomalies of the Atlantic and Indian Oceans, which have strongly associated with climate and weather processed were not examined exhaustively in this study. Future research should therefore address the need of grass- root-climate services in order to sustain the productivity of cattle production under the changing climate.

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7. APPENDICES

I. List of questionnaires for Focus Group Discussion

1. What did you know about climate prediction?
2. Have you ever heard about climate prediction/weather information?
3. If yes which one? Traditional or scientific climate prediction?
4. If your answer for question number 3 is traditional, how can traditional forecast given over your region? When? Before rain start or after rain start? Verify it in detail?
5. What are the rainy seasons of your zone?
6. What time the rainfall start and cessation at Borana zone Southern of Ethiopia? A) Early B) late or C) on time
7. What is the role of traditional climate prediction for your zone? When do you give the service?
8. What types of climate related hazard exhibited in this zone? When?
9. Have you heard climate information ahead of the coming hazard?
10. What are your methods to predict the coming season?
11. What are the major constraints you have that hinder your copying mechanism?
12. Did you believe that scientific forecast would benefit you to combat the hazard?

II. List of key informants

1. Hora Tola (historian)
2. Wario Hunda (From Borana Zone Disaster and Preparedness office)
3. Olana Jira (From Yabello Agricultural Research Institution)

III. Participants of Focus Group Discussion

1. Hora Tola
2. Ilma Jarti
3. Boru Kajela
4. Wako Jabeso
5. Gift Boru

LIST OF FIGURES IN APPENDIX

Fig.1.Photo taken during Focus Group Discussion