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Inter-connection Between El-Niño-Southern Oscillation Induced Rainfall Variability, Livestock Population Dynamics and Pastoralists Adaptation Strategies in Eastern Ethiopia

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Abstract
Extreme climatic events significantly limit livestock performance in semiarid tropics. We assessed the effect of El-Niño-Southern Oscillation (ENSO) rainfall variability episodes on livestock population dynamics of pastoral communities in Shinile zone of eastern Ethiopia. Rainfall and ENSO data from 1984-2015 were collected from the National Meteorology Agency of Ethiopia and National Oceanic and Atmospheric Administration, respectively. Future rainfall trend was predicted with MarkSim (RCP 4.5 General Circulation Model). Livestock population was collected from Ethiopian Central Statistical Agency and the respective study zone. The analysis of rainfall data revealed that there was higher inter-annual rainfall variability under pastoral communities during studied years. Cattle and sheep had positively associated ($P<0.05$) with mean annual rainfall of ENSO events, whereas the population of goat and camel were also positively associated with mean annual rainfall ($P>0.05$). Cattle mortality and off-take rate had a significant negative relationship with ENSO rainfall variability. Hence, ENSO rainfall variability has affected livestock population dynamics, mortality and off-take rates. Accordingly, pastoral communities are being practicing settlement around watering points, seasonal mobility and destocking as adaptation strategies. However, the lack of climate information ahead, shortage of watering points and mobility restriction were major adaptation challenges under pastoral communities. Moreover, the predicted annual rainfall variability and increasing temperature (2020-2100) would also likely to affect the livestock potential in pastoral areas. Therefore, we recommended implementation of appropriate early warning systems and disseminate ENSO information ahead to minimize the loss of livestock that would affect the fragile livelihoods of pastoral communities.
Keywords: El-Niño; La-Niño; Livestock mortality; Off-take rate; Rainfall variability; Rainfall prediction; Trend analysis.

1. INTRODUCTION

Livestock is an essential part of the biological basis for world food security, and contribute to the livelihoods of over thousand million people. Ethiopian pastoral comprises 60% of Ethiopia's land and has large grazing areas that hold half of the nation's livestock, which account for over 90% of meat and live animal exports. The total direct economic contribution of pastoralism to the Ethiopian economy through the production of milk, meat, skin, hides, *etc*., is estimated at about 6% of the agricultural GDP per annum (Berhanu and Feyera, 2009). Moreover, the pastoral system provides various livestock products and contributes significantly to the livelihoods of the people and to the country's economy at large. However, the level of contribution is generally much lower than the potential due to different constraints including shortage of water, feed and low quality of the available feeds as the pastoral areas experience very low rainfall and frequent droughts which are closely associated with climate change and variability (Adugna, 2012).

The most important feature of sea surface temperature (SST) variability that can cause large-scale weather disruptions is El Niño and La Niña, a near basin-wide warming and cooling of the equatorial Pacific Ocean, known as El-Niño-Southern Oscillation (ENSO) (Godderd *et al.,* 2001). NOAA (2013) defines ENSO state (e.g., El Niño or La Niña) as a departure from normal of the SST in the Niño 3.4 region of magnitude 0.5°C or more. The main ENSO signal is found during the northern summer (Camberlin, 2009), depicting lower than normal rainfall in the years of higher SST in the eastern equatorial Pacific (i.e., El Niño years). El Niño episode occurs when the large scale atmospheric pressure differences between the eastern and western side of the Pacific, and is characterized by warmer than normal temperature and covering the wide central and eastern tropical pacific. As a result, the warmer waters of the western pacific begin to flow back towards the eastern pacific. This creates a large pool of the anomalously warm water that effectively cuts off the water temperature rises (by approximately 0.5^{o}C) on the eastern side (Trenberth, 1991). On the other hand, La Niña is the counterpart to El Niño and is characterized by cooler than normal temperature across much of the equatorial eastern and central pacific. During La Niña, the easterly winds are strengthened, cooler than normal water and extend westward to the central pacific. As the same time, warmer than normal water in the western pacific is accompanied by above normal rainfall in areas which normally remain dry during that particular season (Trenberth, 1991).

In recent years, the episodes of ENSO, including El Niño and La Niña becoming common phenomena in Shinile pastoral communities of Ethiopia and causing rainfall variability (Serigne *et al.,* 2006; Korecha and Sorteberg, 2013) through affecting the distribution and amount of rainfall (Segele and Lamb, 2005; Diro *et al.* 2011), which again alters livestock population and rangeland potentials. ENSO had its own impact on the wet or dry seasons, as El Niño or La Niña is a departure from normal of the SST (NOAA, 2013). The continuous rise of temperature also induced prolonged droughts in semi-arid environments, and such climatic variability affects negatively the performance and population of livestock in pastoral communities, which are dependent upon rain-fed natural resources. Rainfall is the primary important climatic element that affects the availability of feed resources and livestock performance in most parts of eastern Ethiopia and its variability becomes a problem in pastoral communities. Hence, the livestock herders are responding to climate changes by adjusting their herd composition and keeping more drought tolerant species (camels and goats) (Faya *et al.,* 2012; Megersa *et al.,* 2014).

The pastoral areas of Shinile zone in eastern Ethiopia have frequently affected by ENSO events, leading to lower production and productivity of livestock, as well as high livestock mortalities. However, information on ENSO episodes and other climate variability and how different livestock species respond to these extreme events and climatic shocks would be helpful for developing appropriate societal mitigation measures and planning strategies at national and local levels (Best *et al.,* 2007; Korecha and Barnston, 2013). Moreover, it is also critical to assess the expected future rainfall and temperature change to minimize stresses (Thornton *et al.,* 2009) and sustain livestock potential under the changing climate and global warming. However, knowledge on the effects of rainfall variability during ENSO episodes on livestock population dynamics at pastoral communities in eastern Ethiopia is either lacking or limited. Therefore, we studied the impacts of rainfall variability during ENSO events on livestock population dynamics (off-take and mortality rates), as well as the perception, challenges and adaptation strategies of pastoralists in Shinile zone of eastern Ethiopia.

2. MATERIALS AND METHODS

2.1. Description of the study area

The study was conducted in Shinile zone of the Somali region of Ethiopia, representing pastoral production system (Figure 1). We selected Shinile zone for our study due to its potential in livestock population and vulnerability to frequent climate shocks. According to constitution of the Federal Democratic Republic of Ethiopia, zone is an administrative division, lower than regional state and higher than district. Shinile zone is located between 9°47'and 11°00'N Latitude and 40°69' and 42°94'E Longitude, at an altitudinal ranges of 500 to 1600 m above sea levels. Average annual rainfall for Shinile is 447mm, ranging from 195 to 737 mm, and was highly variable among years with a coefficient of variation (CV) = 35.4% (1984 - 2015). Under normal condition, Shinile zone receives its highest rainfall amount during long rainy season (June to September) while the short rains prevail from March to May. The mean daily minimum and maximum temperatures, from 1984 to 2015, were 19°C and 32°C, respectively. The zone is dominated by pastoral production system, where livestock is the main livelihood of the people, dependent up on communal grazing systems on rangelands as feed resources. Cattle, sheep, goat and camel are the major livestock types owned by the pastoralists in Shinile zone.

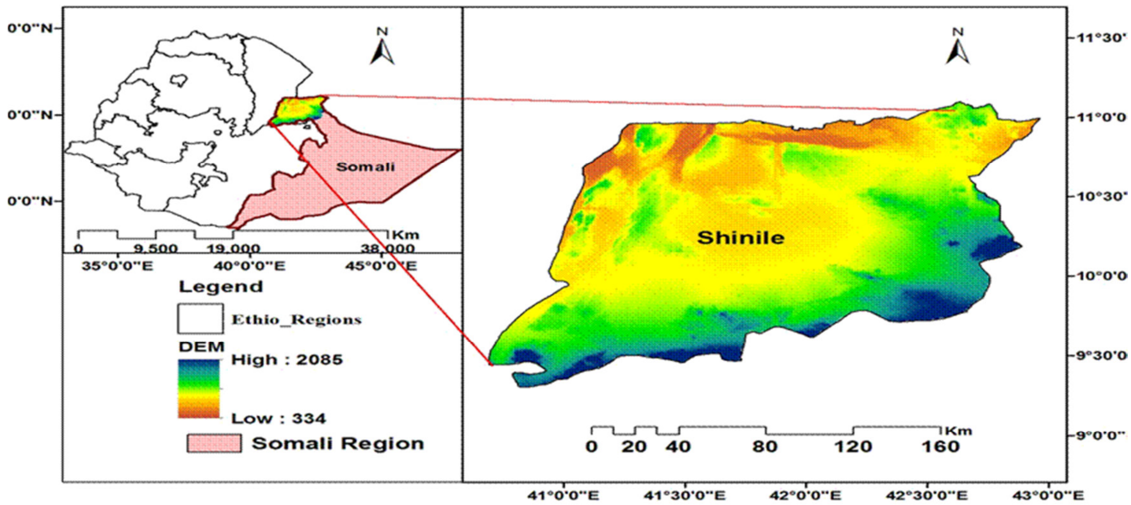

Figure 1. Location of the study area, Shinile zone in Somali region of Ethiopia

2.2. Rainfall and livestock data

We used gridded (10 km x 10 km) rainfall data obtained from National Meteorological Agency of Ethiopia (NMA), as the rain gage station available data for the study area was not enough and has a lot of discontinuity since a minimum of 30 years rainfall data is recommended for time series climatic change analyses according to the World Meteorological Organization (IPCC, 1999). Annual rainfall data were collected during the period 1984-2015. ENSO years was obtained from the (NOAA/CPC (National Oceanic and Atmospheric Administration/Climate Prediction Center, 2009, 2013) and IRI (International Research Institute for Climate Society) websites, as well as other international forecast centers (http://www.ncdc.noaa.gov/and http://www.ncep.noaa.gov/). Based on this information eight El-Nińo years (i.e., 1987, 1991, 1993, 1994, 1997, 2002, 2004, and 2015), six La-Nińa years (i.e., 1988, 1998, 1999, 2000, 2007, and 2008) were included for the study. The livestock population data (cattle, sheep, goats and camels) from 1991-2015, as well as mortality and off-take rates of livestock species (2001-2015) as production performance indicators were collected from the Central Statistical Agency of Ethiopia (CSA, 1991-2015). Furthermore, IPCC reports of 2013, as well as governmental and non-governmental organizations working on livestock production in our study areas were consulted for secondary information. There are different factors other than rainfall variability during ENSO events that affect the livestock population, productivity, mortality and off-take rate. Among other things rising temperature, feed shortage in quality and quantity, genetic potential, disease prevalence and others. However, because of the limited scope of this study all other factors are not considered.

2.3. Perception, adaptation strategies and adaptation challenges of pastoralists against rainfall variability

Survey was conducted in Shinile districts of eastern Ethiopia to study the pastoralists' perception on the effect of ENSO events. We used semi-structured questionnaires consisting of both open and close–ended questions for data collection related to pastoralists in sights and opinion, adaptation strategies and challenges about the effect of extreme weather condition on livestock population and productivity, water and feed resource availability. The questionnaire was pre-tested and used for the final interview after all adjustments were made. During the time of data collection, 260 pastoralists were selected from the two *kebeles* (the smallest administrative units under district) (*kebele* I: N =116, *kebele* II: N =144) using proportional random sampling to the overall livestock population size of each site and asked them about their strategies practiced and challenges faced to adapt and mitigate during ENSO events. Among the selected pastoralists, 72 of them were females as the engagement of women to livestock is higher under pastoral communities. Eventually, households were randomly selected from each sample *kebele* based on the list obtained from local administrators. In addition, focus group and key informant discussions, classified by sex and age groups were conducted to avoid specific group's idea dominance, as well as to include gender and household experiences. There were a total of four focus group discussions (FGD), two from each *kebele*, and each FGD accommodated 15 individuals. Moreover, household heads above 50 years were purposely selected for the interview during the FGD (Bartlett *et al.*, 2001), using unstructured interviews and direct discussion. Beside the researcher, three local enumerators, knowledgeable of the local language (Somali language) were participated to administer the household survey. Data were collected between the months of September to December, 2014. Moreover, during data collection, data related to livestock population, milk yield, sales (off-take rates) and herd history, impact of rainfall variability on livestock population, as well as their adaptation strategies and challenges against inter-annual rainfall variability during ENSO events were included.

2.4. Data analyses

2.4.1. Analysis of rainfall trend and variability anomalies

Mann-Kendall's test was used for analyzing the trend of rainfall (Partal and Kahya, 2006) by using XLSTAT software. Variability of rainfall was analyzed using coefficient of variation (CV) (AMB, 2010; Dereje *et al*. 2012; Gebre *et al.* 2013). The CV was calculated as: - $CV = \frac{SD}{X} * 100$, where SD is standard deviation of rainfall and X is the long-term rainfall mean. The CV values below 20% shows less rainfall variability, while CV values between 20-30% and >30% indicate moderate and high rainfall variability (ABM, 2010), respectively. Standardized Rainfall Anomaly (SRA) was calculated from long-term rainfall data as it indicates the status of drought frequency or inter-annual rainfall fluctuations (Table 1). It is calculated from the monthly rainfall data as the difference between annual rainfall of a particular year and the long-term rainfall average divided by the standard deviation [$Z = X - X/SD$].

Table 1 Drought categories and the corresponding standardize rainfall anomaly (SRA) values

SRA values	Drought categories
≤ -2	Extreme drought
-1.5 to – 1.99	Severe drought
-1.0 to -1.49	Moderate drought
-0.99 to 0.99	Close to normal
1.0 to 1.49	Moderate wet
1.5 to 1.99	Very wet
≥ 2	Extreme wet

Source: (http://drought.unl.edu/monitor/spi/program/spi.program. htm)

2.4.2. Analysis of future climate scenarios

The IPCC used four climate change scenarios known as the Representative Concentration Pathways (RCPs) to replace the previous scenarios of the Special Report on Emission Scenarios (SRES) (IPCC, 2013). Each of RCPs defines the trajectory of the alteration or change in the net irradiance (W/m^2) of the tropopause due to an increase in the concentration of greenhouse gases (GHGs) and other forcing agents for the year 2100. The four scenarios or RCPs include: a very low baseline emission scenario (RCP 2.6), a post-2100 emission stabilization scenario (RCP 6) and a very high baseline emission scenario (RCP 8.5). On the other hand in RCP4.5 scenario, which is selected for our downscaling, GHGs concentrations rise with increasing speed until the forcing is 4.5 Wm^{-2} in the year 2100. This is a moderate emission scenario of concentration rise. Future scenarios of indices of rainfall and temperature projections in Shinile were done by downscaling global circulation model outputs and downloaded from http://www.ccafs-climate.org/patternscaling/ MarkSim-GCM using latitude, longitude and elevation of the study area (Jones and Thornton, 2013). Future rainfall and temperature changes were analyzed for three time slot centered in 2030 (2020-2049), 2050 (2040-2069) and 2080 (2070-2099) and compared its trend and variability with the current rainfall data (1984-2015) for the study area.

2.4.3. Relationship between ENSO rainfall and livestock population

The relationship between livestock population, mortality and off-take rate of livestock with mean annual rainfall variability during ENSO years was determined by regression analysis (Mintab 15). The data on perception of the livestock herders against the inter-annual rainfall variability were analyzed using a Kruskal-Wallis rank test method (Schlotzhauer, 2009). The chi-square (X^2) test was used to compare challenges and adaptation strategies of the pastoral communities against the inter-annual rainfall variability (ENSO years).

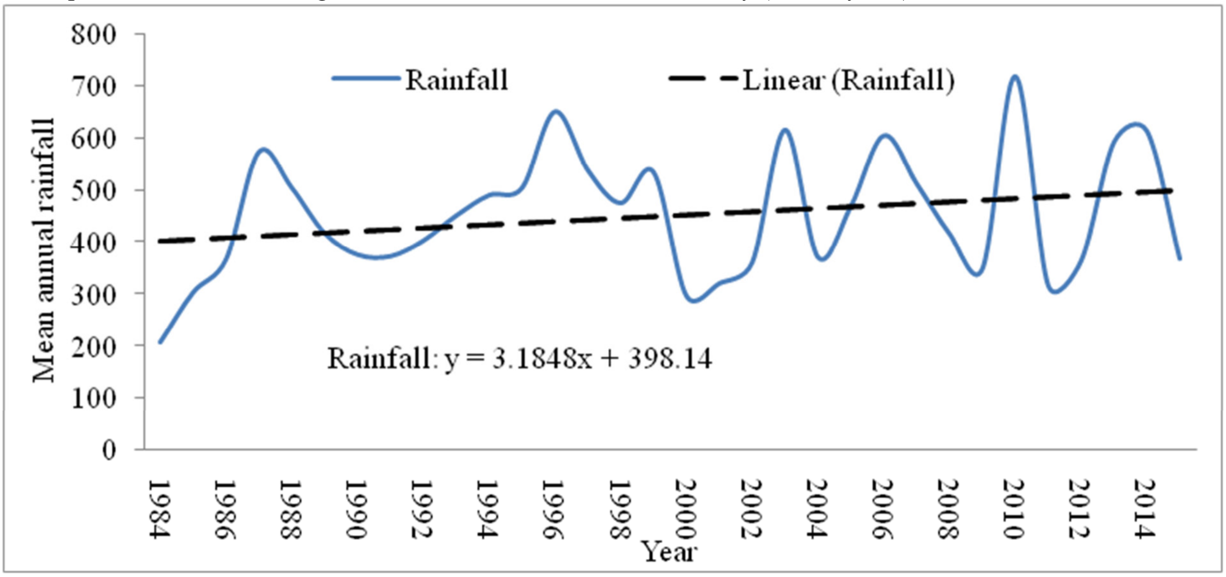

Figure 2. Trends of mean annual rainfall and its variability in Shinile zone of Somali region, Ethiopia, 1984-2014

3. RESULTS

3.1. Trends and variability of rainfall during ENSO episodes

The annual and main rainy season rainfall data showed an increasing trend (P>0.05) whereas the short rainy season indicated decreasing trend (P>0.05) in Shinile zone of Ethiopia (Figure 2; Table 2). Moreover, there was higher inter-annual rainfall variability during the study years as reflected by the high CV (35.4%) and SRA. The rainfall trend indicated that 53% of its distribution was deviate from the average rainfall amount. Among the El-Niño and La-Niño years identified, more than half of the events had below average rainfall distribution, leading to higher rainfall variability in the study areas (Figure 3). The SRA showed that 40% of rainfall was near moderate to high drought. The ENSO events rainfall analysis revealed that El-Niño reduces the amount of rainfall during the long rainy season and increases its amount during the short rainy season, whereas, La-Niño suppresses the short rainy season and enhances the long rainy season rainfall distribution in our study area (Figure 4). Furthermore, the long-term rainfall data (1984 – 2015) indicated that drought occurred during the 1984, 2000, 2002, 2009 and 2011(Figure 3), of which year 2000 and 2002 are categorized in ENSO episode and contributed to lowering of cattle and sheep population, increase of mortality and off-take rates in the study area.

Table 2 Trends of annual and seasonal rainfall for the period of 1984-2015, in Shinile zone of Somali region in eastern Ethiopia

	Annual rainfall		Long rainy season		Short rainy season	
	Z_{mk}	Slope	Z_{mk}	Slope	Z_{mk}	Slope
Pastoral	0.139ns	+3.53	0.215ns	+3.192	-0.101ns	-1.071

Z_{mk} is Mann-Kendall trend test, Slope (Sen's slope) is the change (mm)/annual; ns is non-significant at 0.05. The mean seasonal and annual rainfall trend recorded, - value is decreasing trend and + values is an indication of increasing trend

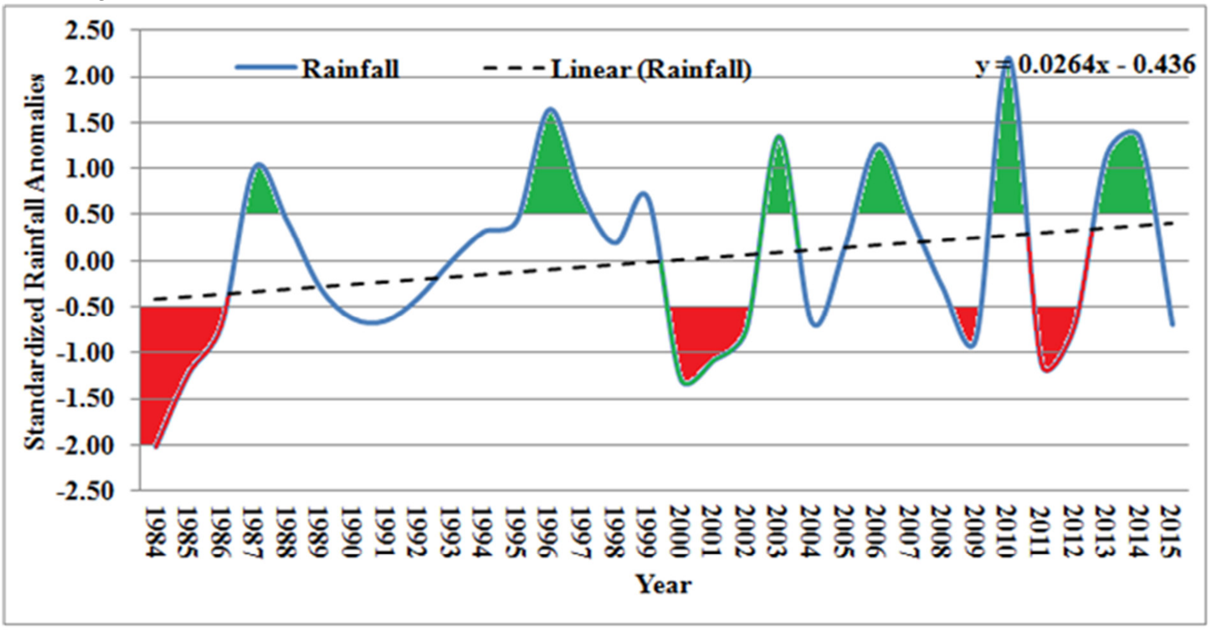

Figure 3. Standardized mean annual rainfall anomalies of Shinile zone in Somali region, Ethiopia, over the period of 1984–2015. The red colour indicated moderate to extreme drought periods, whereas the green showed moderate to extreme wet years.

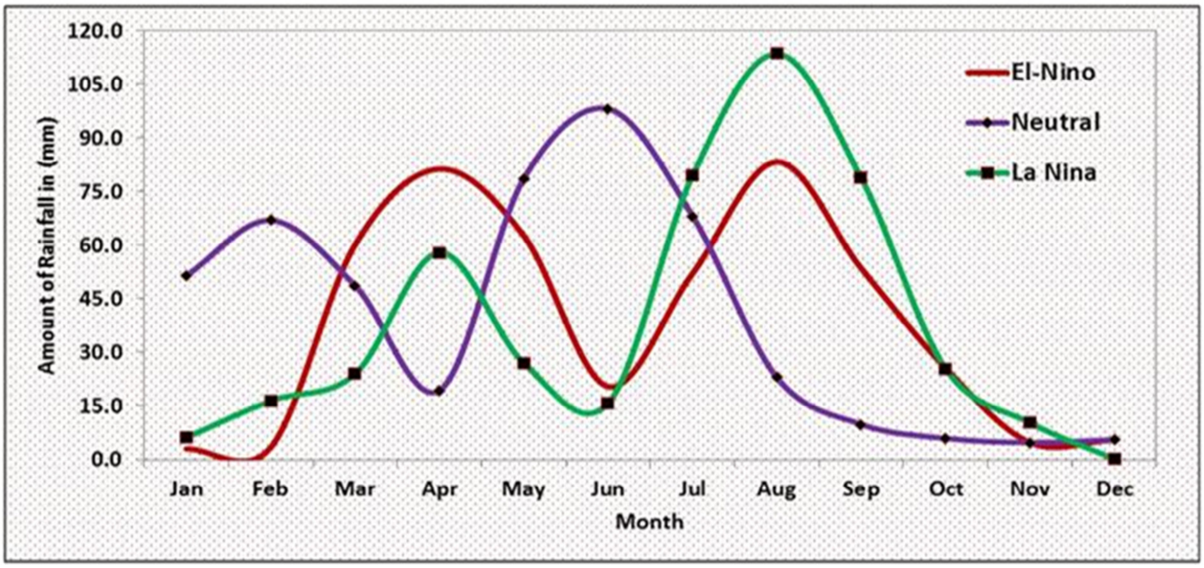

Figure 4. Mean monthly standardized rainfall anomalies observed during El-Niño, La-Niño and neutral episodes in Shinile zone of Somali region, Ethiopia during the period 1984-2015.

3.2. Relationships between rainfall variability and livestock population

According to the results of this study, cattle and sheep are more affected by rainfall variability than goats and camels. Camels are more tolerant to rainfall variability. This can be supported by a positive relationship between cattle and sheep population and mean annual rainfall in the Shinile zone (Figure 5). The cattle and sheep population was positively correlated to sheep population (r=0.74, P<0.05). Moreover, El-Niño reduces the amount of rainfall during the long rainy season as a result the livestock population during this time was declined (Figure 6), whereas La-Niño suppresses the short rainy season and enhances the long rainy season rainfall distribution; as a result reduce cattle and sheep population in the study area (Figure 7). Pastoral communities mostly depend on the rainfall during the main rainy season for availability of pasture and water resources. Hence, declining of rainfall during this period has resulted in severe livestock loss. Cattle and sheep population was lower (P<0.05) during most El-Niño and La-Niño events in the study area. In addition, the population of goat and camel were also lower during ENSO events (p>0.05). Based on adaptability to the current rainfall variability due to ENSO events, the livestock species we studied had the following rankings: camel>goat>sheep>cattle under pastoral communities of Shinile zone of Ethiopia.

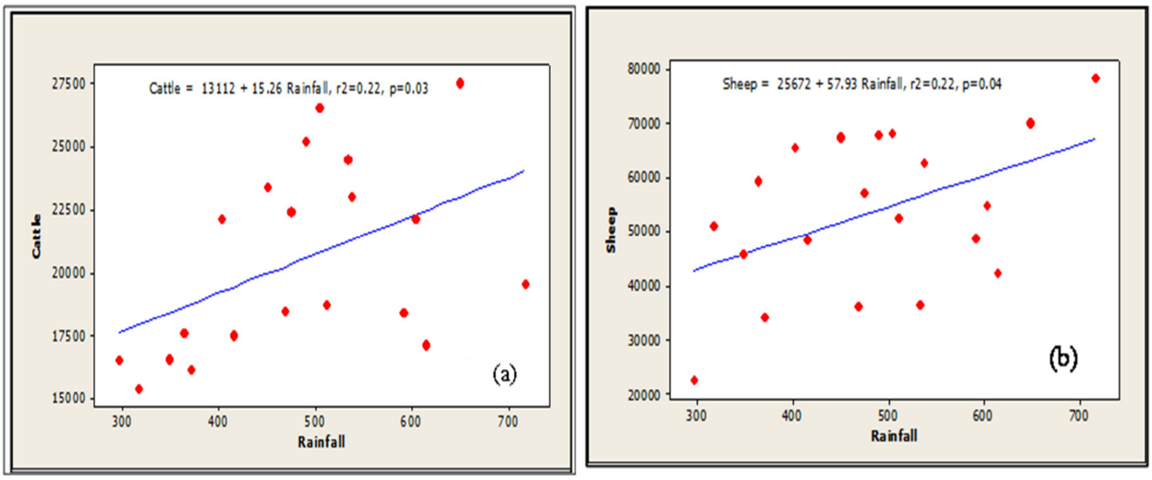

Figure 5. Relationship ofmean annual rainfall to cattle (a), sheep (b) population under pastoral communities of Shinile zone in Somali region of Ethiopia

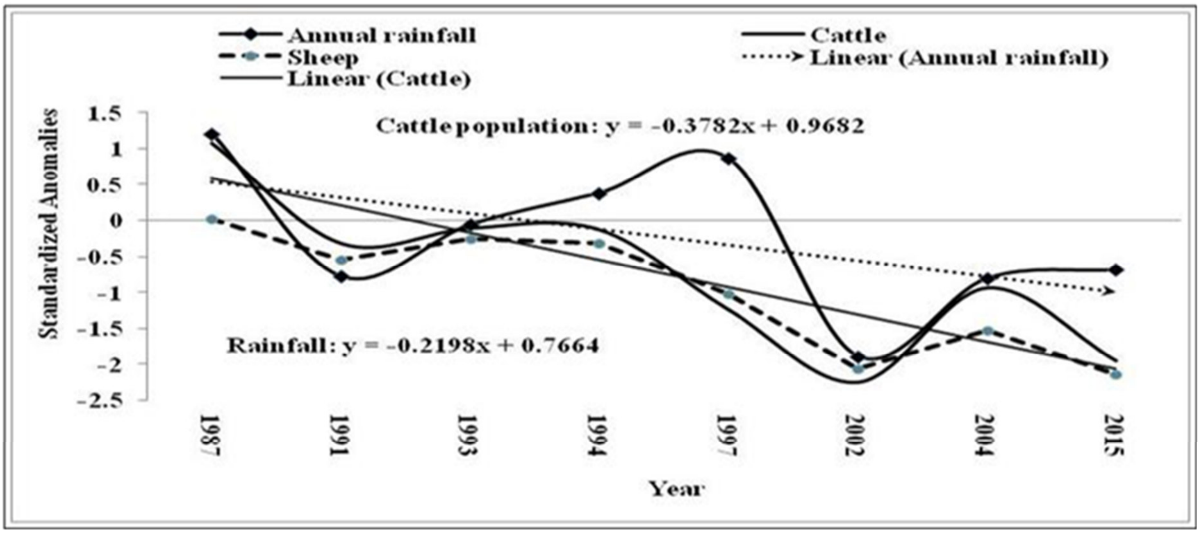

Figure 6. Trends of standardized livestock population (cattle, sheep) and rainfall anomalies observed during El-Niño episodes in Shinile zones of Somali region, Ethiopia, 1987 – 2015

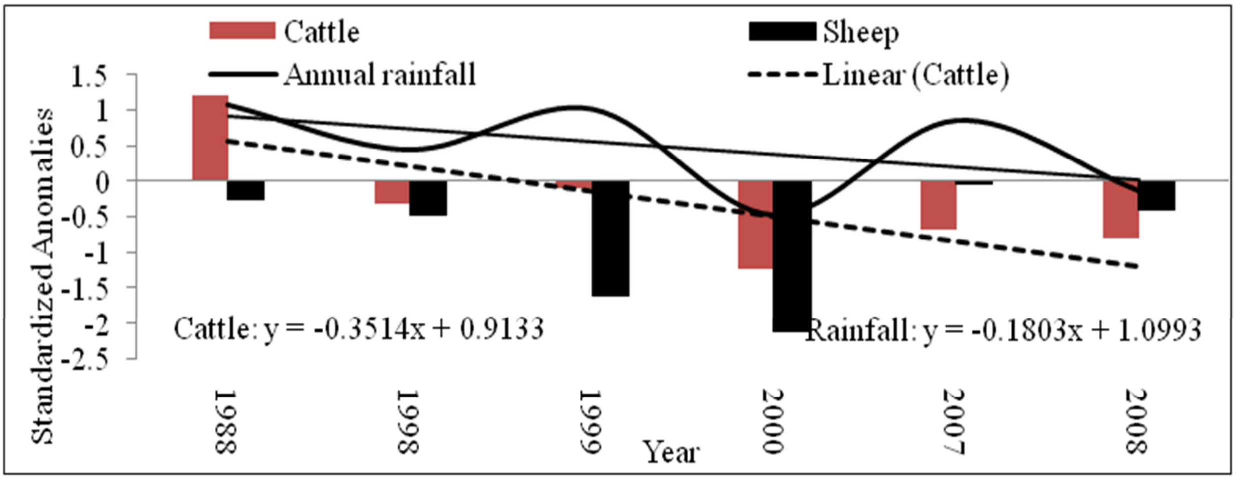

Figure 7. Trends of standardized cattle, sheep and rainfall anomalies observed during La-Niño episodes in Shinile zones of Somali region, Ethiopia, 1988- 2008

Cattle mortality rate was increased with decreasing mean annual rainfall lower than normal distribution during most ENSO events ($P<0.05$) in pastoral communities (Figure 8). Sheep, goats and camels mortality also showed negative association to low rainfall distribution ($P>0.05$). Moreover, cattle off-take rate were higher in most La Nina episodes in the study area (Figure 9). For instance, in La-Niño years 2008, cattle mortality was increased by 12.4%, sheep 26.2%, goats 6.5% in Shinile pastoral communities.

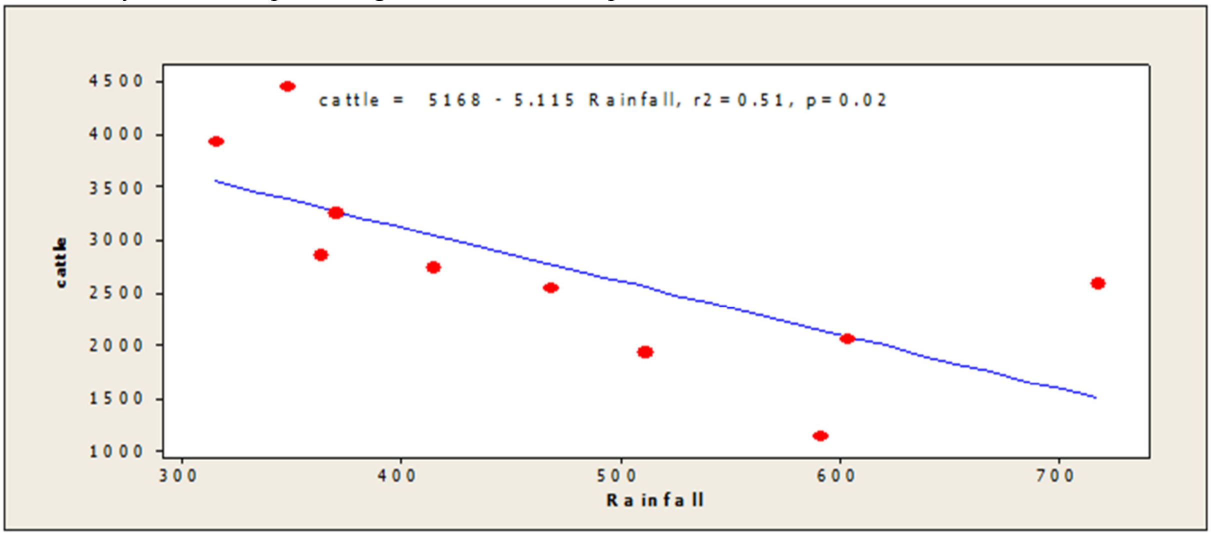

Figure 8. Relationship of mean annual rainfall to cattle mortality during El-Niño episodes under pastoral communities of Shinile zone of Somali region, Ethiopia

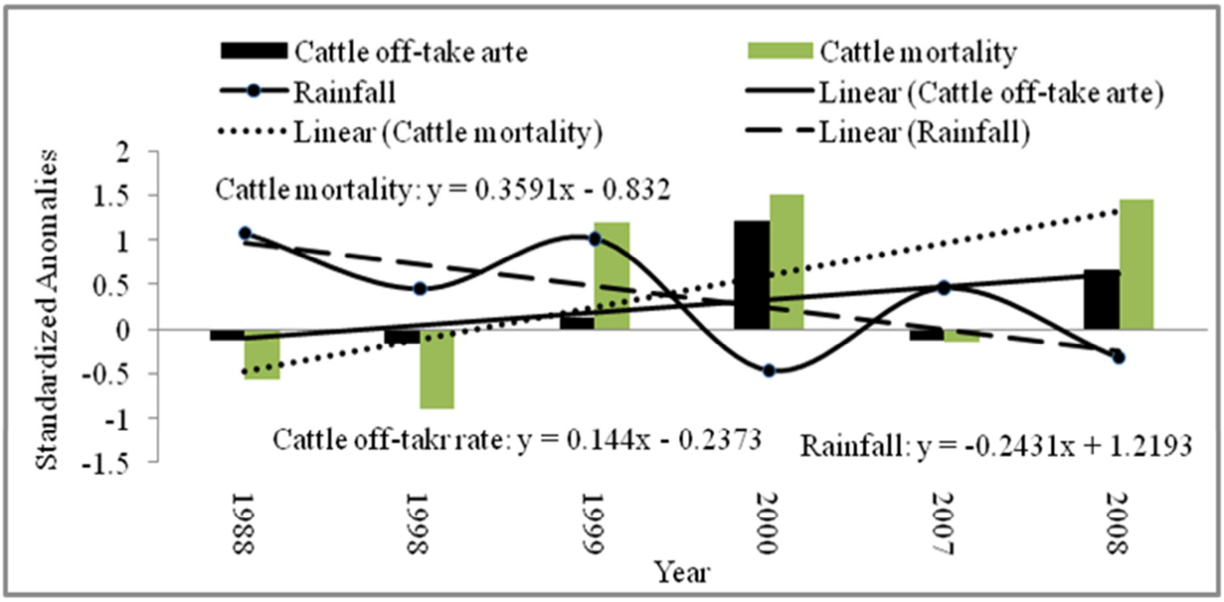

Figure 9. Trends of standardized rainfall, cattle mortality and off-take rate anomalies observed during La-Niño episodes in Shinile zones, eastern Ethiopia

3.3. Perception, adaptation strategies and adaptation challenges of pastoralists against extreme rainfall variability

Similar to the above findings, respondents' had also perceived that the patterns of rainfall distribution reduce the livestock population and increase the mortality and unwanted sales of livestock through reducing the availability of pasture and water resources (Table 3). The majority of respondents agreed that extreme climate variability were reduced the water and feed resource availability. Respondents' in the study areas had the knowledge that the condition of rangelands was deteriorated with bush encroachment leading reduced the performance of livestock. Pastoralists' adaptation strategies to wards ENSO event is indicated in Table 4. The majority of respondents (90%) applied settlement around watering points to reduce the effect of ENSO events on livestock population and its productivity. The majority of respondents (86%) also agreed that seasonal mobility was the second option to reduce the effect of rainfall variability during ENSO events. When drought appears non-lactating cattle moved over long distance in search of better grazing land and water. Such activities were used for reducing rangeland degradation problems. However, there are some adaptation challenges including, poor climate information access and knowledge, shortage of water points, and restriction of mobility that reduced the effect of adaptation strategies (Table 5). The results showed that more than 86% of respondents in the study areas realized that they didn't have extreme weather information access before happening.

Table 3. Possible impact of rainfall variability on livestock population and productivity as ranked by Kruskal-Wallis test according to the sampled respondents under pastoral communities (n = 260)

Perceived impact	Pastoralist
Serious shortage of water for livestock	1.16[a]
Reduced pasture availability, rangeland degradation, bush encroachment	1.56[b]
Animal disease, parasitic infestation and mortality	2.51[c]
Poor condition of livestock and unwanted sales	3.82[d]
Reduced livestock population and products	4.21[e]
Poor reproductive performance	5.13[f]
Probability value	0.00

Table 4 Adaptation strategies (%) of the sampled respondents in Shinile zone of eastern Ethiopiato extreme climate variability [(kebelle I (n =116) and kebelle II (n =144)].

Adaptation strategies	Pastoral community		P value (X^2)
	Kebele I	Kebele II	
Settlement around watering points	91	90	>0.05
Seasonal mobility	86	87	>0.05
Livestock destocking	83	71	>0.05
Diversification of livestock species	75	50	<0.05
Feed supplementation	69	45	< 0.05

Table 5 Adaptation challenges (%) of the sampled respondents in Shinile zone of Somali region, Ethiopia to extreme climate variability [kebelle I (n =114) and kebelle II (n=116)].

Adaptation challenges	Pastoral community		P value (X^2)
	Kebelle I	Kebelle II	
Poor access to climate information	91	85	>0.05
Shortage of water points/deep water table	86	78	>0.05
Restriction of seasonal mobility	82	67	>0.05
Bush encroachment	74	52	<0.05
Human population pressure	71	41	<0.05

3.4. Prediction of future climate scenario in Shinile pastoral areas

The prediction of future amount of annual rainfall would increase by 2030, 2050 and 2080s under RCP 4.5 scenario in Shinile pastoral communities (Figure 10). In Shinile, the annual rainfall will increase by 11.4, 9.4 and 5.9% in 2030s, 2050s and 2080s, respectively. The future annual rainfall of Shinile is also predicted to be variable (CV=30.5%). Moreover, the future temperature tends to increase as compared to the base period. The maximum temperature in the study area expected to increase by an average of 0.67, 0.57 and 0.52°C in the 2030, 2050 and 2080, respectively compared to the current maximum temperature. The minimum temperature also estimated to increase by 0.42, 0.9 and 0.63°C in the 2030, 2050 and 2080, respectively.

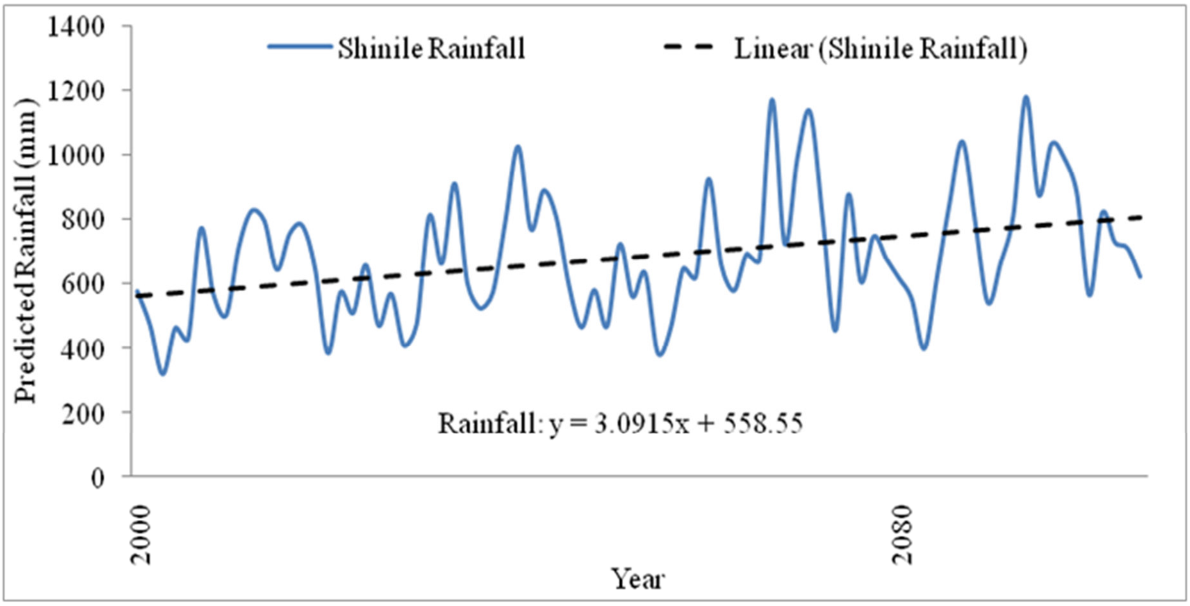

Figure 10. Trends of current mean annual rainfall and its future prediction scenarios, over the period of 1984 – 2100, for Shinile zone of the Somali region in eastern Ethiopia.

4. DISCUSSION

4.1. Trends and variability of rainfall during ENSO episodes

The rainfall characteristics from 1984 - 2015 indicated that there was a clear inter-annual and seasonal rainfall fluctuation, with a higher coefficient of variation. Consequently, this rainfall variability leads to extreme drought condition, causing to reduce the livestock population under the pastoral communities of the study area. Omondi *et al.* (2012) indicated the existence of declining in rainfall amount as a result of climate variability in most parts of the dry lands. Similarly, declining of rainfall has been documented during climate variability and change in southern Ethiopia (Viste *et al.* 2013); in Amhara region (Dereje *et al.* 2012) and in central rift valley of Ethiopia (Tsegaye *et al.* 2015). Usually, El-Niño and La-Niño episode occur when SST deviate from normal, which might be associated with the result of ocean atmosphere variability internal to tropical Pacific Ocean (Seleshi and Zanke, 2004). Moreover, based on SRA analysis, rainfall ranged between normal to high drought, which is consistent with previous studies in other African country (Sherwood 2013; Kgosikoma and Batisani, 2014). Such droughts have the potential to increase loss of livestock that would devastated the fragile livelihoods of the pastoral communities, particularly women (Sherwood, 2013), where alternative livelihood options are limited (Kgosikoma and Batisani, 2014).

4.2. Relationships between rainfall variability and livestock population

Reduction of rainfall during El-Niño and La-Niño would create severe drought, leading to reduction of pasture and water availability that cannot support all the livestock population, as a result of this phenomenon, the livestock population showed a decreasing trend. In our study, more than half of El-Niño and La-Niño events were coincided with lower rainfall distribution, and reducing livestock population and higher mortality and off-take rate of cattle and sheep. In the study area, livestock population is mainly depending on long rainy season as the short rainy season is not mostly reliable. In addition, the long rainy season is more essential for forage production and replenishment of water resources and hence the declining trends of long rainy seasons determine the livestock population and mortality. Previous studies also suggested that drought have mostly occurred due to the failure of long rainy season (Angassa and Oba, 2007; Viste *et al.* 2013; Megersa *et al.* 2014). As a result, El-Niño events were more severe than La-Niño on livestock population and mortality in the study areas. Our findings showed that cattle and sheep population was lower during ENSO period of the study area, while the pastoralists were forced to diversify drought tolerant species such as goats and camels. Previous studies in Afar (Tilahun *et al.* 2016) and Borana pastoral communities (Megersa *et al.* 2014; Brigham *et al.* 2015) observed that herd diversification were the results of shifts in vegetation from grassland to woodland. This could be due to the shortage of feed and water availability, as a result conception and birth rate of livestock is reduced, which leads to increasing mortality and unplanned livestock sales (Brigham *et al.* 2015). In addition, the population of goat and camel were not significantly reduced with ENSO annual rainfall distribution, indicating that goats and camels are more adapted to low rainfall distribution compared to cows and sheep. In addition, the replacement of grasses with less palatable woody plants due to climate variability might affect cattle and sheep population than goats and camels population (Abebe *et al.* 2012). Moreover, goats and camels are able to utilize the available browse and bushes species better than sheep and cattle under lower rainfall distribution. Moreover, similar studies have also supported the dependency of goats and camels herding rather than cattle and sheep dominancy to use the available feed resources more effectively (Teshome *et al.* 2010; Megersa *et al.* 2014). Furthermore, camel is more selected by the livestock herders during high rainfall variability due to relatively its higher milk production abilities and market price which can be easily converted into cash and income generation than other livestock population (Tilahun *et al.* 2016); as a result goats and camels used as an adaptation strategies against frequent extreme rainfall variability.

In our study, there was a high mortality of livestock during periods of El-Niño and La-Niño episodes. This could be due to traveling of long distance of pastoralists with their animals in search of better grazing and water resources under low rainfall seasons, leading to severe mortality of the livestock population. Moreover, appropriate rainfall is highly relevant for the growth and production of forages and water resources, and hence, the variability of rainfall is a serious problem to the livestock production (Desta and Coppock, 2002). A similar finding is also observed in Borana pastoral areas by Megersa *et al.* (2014) who documented that shortage of grazing lands and climate variability are the major cause of the declining of livestock population and its productivity. Similarly, the highest mortality of sheep, goat and camel was observed in year 2000 and 2002 at times of ENSO events. Most of the ENSO year in the study areas caused a higher livestock mortality due to the shortage of feed and water resources as a result of abnormal rainfall distribution. As a result the pastoral communities forced to sale large number of poor body conditions of their animals usually at lower price to purchase food grain for their family members during drought events (Brigham *et al.* 2015). The off-take rate of animals was lower during neutral years in our study, which might be associated with normal rainfall distribution that minimize mortality and off-take rate and increases births, leading to increasing livestock population (Mapiye *et al.* 2009). Hence, this could be partially explained the importance of rainfall on vegetation and water sources for livestock (Ward *et al.* 2004). According to Lobell *et al.* (2008) rainfall variability causes increase intensity and frequency of droughts, which affect the productivity of livestock. Moreover, Thornton *et al.* (2009) also reported that climate change affects livestock productivity by altering the quantity and quality of feed available for animals especially, in area where extreme rainfall variability occurred. Outbreak of El-Niño event in 1997 has led to a death of up to 80% of the livestock population in Somalia and northern Kenya (World Bank, 2010). Moreover, in Borana pastoralists who depend on animals for their subsistence livelihoods, lower than average rainfall recorded during 1999-2005 caused massive die-offs of livestock (Conway and Schipper, 2010). Most of the drought years, especially years 1984, 2000, 2002, 2009 and 2011, caused a higher livestock mortality due to the shortage of feed and water resources. However, lowest mortality and off-take rates of cattle, sheep, goat and camel was observed in wet year such as 1996, 2003, 2006, 2010 and 2014, especially during the long rainy seasons, indicating that there is a strong relationship between livestock population and rainfall distribution (Desta and Coppock, 2002; Angassa and Oba, 2007; Tache and Sjaastad, 2010).

4.3. Perception, adaptation strategies and adaptation challenges of pastoralists against extreme rainfall variability

Pastoralists had already understood a declined trend of rainfall amount as opposed to meteorology data and leading to reducing water and pasture availability, and livestock population and applied different strategies to reduce the impact of climate variability. In Shinile zone, pastoralists use settlement around watering points and look for feed supplement to save their livestock. Moreover, pastoralists use browse trees during periods of low rainfall distribution, and supplying of crop residues and hay by government and non-governmental organization to reduce drought impacts. Mobility and splitting of herds in to different places was practiced to get water and pasture for their animals. In addition, pastoralists also practiced destocking some of their cattle, sheep, and goats with low price during ENSO events. Although, most pastoralists practiced various adaptation strategies, some pastoralists did not practice due to several challenges. Seasonal mobility of pastoralists together with their livestock was necessary in the study areas under the changing climate, but these days, mobility become the second option because intra and inter-ethnic conflicts due to shortage of pasture and water resources in most parts of neighboring rangelands in the study areas. Moreover, the local government encourages settlement of pastoralists for introducing better interventions. However, such activities might lead to high human population (Berhanu *et al.,* 2013), affecting the traditional resource use and management, reduce livestock per household and cause fragmentation of communal rangelands (Tilahun *et al.* 2016). Similar findings were also observed in Borana pastoral communities, in that mobility is an adaptive mechanism to reduce feed and water shortage in arid environment (Feye, 2007; Abebe *et al.* 2011). Although the importance of ENSO events to Ethiopian rainfall distribution pattern is being accepted and incorporated in the National Meteorology Agency's operational forecasting policy more at present than before, the intention to aware the impact and get ready the pastoral communities beforehand to reduce the impact of drought incidence is somewhat underestimated. This results the loss of livestock and destocking with low price during El-Niño events. For instance, recent El-Niño year in 2015 lost 63.6% of the sheep, 48.4% of the goat, 31% of the cattle, and 19% of the camel population in pastoral areas of Shinile district in eastern Ethiopia (personal communication).

4.4. Prediction of future climate scenario in Shinile pastoral areas

Expected future rainfall scenarios revealed that the annual rainfall most likely to increase in Shinile pastoral area in the predicted years, and coincide with the IPCC (2007) projection, which reported an increased rainfall in parts of eastern Africa. In contrast, decreasing trend of future annual rainfall was reported by Tsegaye *et al.* (2015) in the rift valley of Ethiopia, which might be due to differences in topography, altitude, and atmospheric interactions. Although the future rainfall prediction indicated increment, the variability likely to limit the availability of water and feed supply in the study areas. Our results are consistent with Lobell *et al.* (2008) indicating rainfall variability is the cause for increase intensity and frequency of droughts that would affect the productivity of feed resources and livestock. Similarly, Beier *et al.* (2008) and Kassahun *et al.* (2008) showed the consequence of decreasing rainfall on reduction of pasture, leading to sudden decline of livestock performance and condition due to health related problems (Rufael *et al.* 2008). Prediction of rising in temperature is also expected as a major cause for reduction of livestock performance. Nardone *et al.* (2010) argue that rising in temperature may directly affect thermal stresses on animals, reduce feed intake, and impairs metabolic activities, thereby hindering their performance. Moreover, Thornton *et al.* (2009) also indicated that higher temperature affect the population and productivity of livestock in the pastoral and agro-pastoral production systems through indirect impacts on feed and water availability and disease distribution. Thus, the annually predicted rainfall variability and increasing temperature may affect the future livestock population, mortality and off-take rates in Shinile pastoral areas of Ethiopia.

CONCLUSIONS

The present study revealed that extreme drought events greatly affected the number and productivity of livestock and leads to camels and goats herding than cattle and sheep dominance as an adaptation strategy. The mortality and off-take rate was also affected by ENSO events. Though, the future rainfall trend showed an increase in annual rainfall, its variability could result in extreme drought and could be a sign of threat to the existence of enough water and grazing resources to the livestock. The increase in future minimum and maximum temperature projection expected to increase water requirement by animals and pasture that would likely exacerbate the water, feed shortage and biodiversity of plant species in the study areas. Currently, pastoralist perceived the impact of rainfall variability on livestock population and mortality, which includes shortage of water, feed resources and livestock products. On the other hand, they practiced settlement around water points, seasonal mobility and destocking as their adaptation strategies. In contrast, poor climate information and knowledge on ENSO and mobility restriction are the major adaptation challenges and put the system under pressure in the study areas. Although, mobility restriction aimed at improving the livelihood of Shinile pastoral communities by the local governments, that could not bring satisfactory changes in improving feed and water resources (e.g., Berhanu et al. 2013). Hence, there is a need to design long term climate early warning systems with the participation of local community at ground level to minimize the severity of extreme drought episodes on livestock population dynamics and their productivity. Proper land management, and implementing basic conservation mechanisms would be also crucial to minimize risks related to climate variability and changes, and sustain rangeland productivity under the changing climate as much of the rangelands are in degraded state and difficult to achieve considerable total soil carbon stock which determine the ecosystem function.

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