CARIAA
Collaborative Adaptation Research Initiative in Africa and Asia

ASSAR
Adaptation at Scale in Semi-Arid Regions

Climate variability and impact in ASSAR's East African region

CARIAA-ASSAR Working Paper

Mekonnen Adnew Degefu, Mohammed Assen and Daniel McGahey

Degefu, MA., Assen, M., McGahey, D. 2018. Climate variability and impact in ASSAR's East African region. CARIAA-ASSAR Working Paper. International Development Research Centre, Ottawa, Canada and UK Aid, London, United Kingdom. Available online at: www.assar.uct.ac.za

About CARIAA Working Papers

This series is based on work funded by Canada's International Development Research Centre (IDRC) and the UK's Department for International Development (DFID) through the **Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA)**. CARIAA aims to build the resilience of vulnerable populations and their livelihoods in three climate change hot spots in Africa and Asia. The program supports collaborative research to inform adaptation policy and practice.

Titles in this series are intended to share initial findings and lessons from research and background studies commissioned by the program. Papers are intended to foster exchange and dialogue within science and policy circles concerned with climate change adaptation in vulnerability hotspots. As an interim output of the CARIAA program, they have not undergone an external review process. Opinions stated are those of the author(s) and do not necessarily reflect the policies or opinions of IDRC, DFID, or partners. Feedback is welcomed as a means to strengthen these works: some may later be revised for peer-reviewed publication.

Contact

Collaborative Adaptation Research Initiative in Africa and Asia,
c/o International Development Research Centre
PO Box 8500, Ottawa, ON
Canada K1G 3H9
Tel: (+1) 613-236-6163; Email: cariaa@idrc.ca

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About ASSAR

All authors of this working paper are team members in the ASSAR (Adaptation at Scale in Semi-Arid Regions) project, one of four hotspot research projects in CARIAA. The international and interdisciplinary ASSAR team comprises a mix of research and practitioner organisations, and includes groups with global reach as well as those deeply embedded in their communities. The ASSAR consortium is a partnership between five lead managing institutions - the University of Cape Town (South Africa), the University of East Anglia (United Kingdom), START (United States of America), Oxfam GB (United Kingdom) and the Indian Institute for Human Settlements (India) – and 12 partners – the University of Botswana, University of Namibia, Desert Research Foundation of Namibia, Reos Partners, the Red Cross/Crescent Climate Centre, University of Ghana, ICRISAT, University of Nairobi, University of Addis Ababa, Watershed Organisation Trust, Indian Institute for Tropical Meteorology, and the Ashoka Trust for Ecology and the Environment.

Working in seven countries in semi-arid regions, ASSAR seeks to understand the factors that have prevented climate change adaptation from being more widespread and successful. At the same time, ASSAR is investigating the processes – particularly in governance – that can facilitate a shift from ad-hoc adaptation to large-scale adaptation. ASSAR is especially interested in understanding people's vulnerability, both in relation to climatic impacts that are becoming more severe, and to general development challenges. Through participatory work from 2014-2018, ASSAR aims to meet the needs of government and practitioner stakeholders, to help shape more effective policy frameworks, and to develop more lasting adaptation responses.

Why focus on semi-arid regions?

Semi-arid regions (SARs) are highly dynamic systems that experience extreme climates, adverse environmental change, and a relative paucity of natural resources. People here are further marginalised by high levels of poverty, inequality and rapidly changing socio-economic, governance and development contexts. Climate change intersects with these existing structural vulnerabilities and can potentially accentuate or shift the balance between winners and losers. Although many people in these regions already display remarkable resilience, these multiple and often interlocking pressures are expected to amplify in the coming decades. Therefore, it is essential to understand what facilitates the empowerment of people, local organisations and governments to adapt to climate change in a way that minimises vulnerability and promotes long-term resilience.

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About the authors

Mekonnen Adnew Degefu *is a researcher at Addis Ababa University.*

Contact: mekonnenadnew@gmail.com

Mohammed Assen *is a researcher at Addis Ababa University and the AAU lead for ASSAR.*

Contact: moh_assen@yahoo.com

Daniel McGahey *is Senior Environmental and Social Scientist at Earth Systems, a consultancy company specialising in social and environmental impact assessments, water management, carbon accounting, energy and climate change. He holds a PhD in Geography from the University of Oxford.*

Contact: daniel.mcgahey@earthsystemseurope.com

Contents

List of Figures

1. Introduction

Rural livelihoods within East Africa depend on rain-fed agricultural systems and fragile natural resources (Schreck and Semazzi, 2004; Bowden and Semazzi, 2007). Geographically, Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Uganda, and Tanzania are grouped as East and Horn of African countries. Agriculture in these countries is characterized by smallholder contributions to agricultural production of up to 90% accounting for about 40% of national gross domestic product (Adhikari *et al.*, 2015). About 60% of the total land area in the region is classified as dryland, characterized by an arid and semi-arid climate receiving less than 500 mm mean annual rainfall (Funk *et al.*, 2008). The drylands of East and Horn of Africa are home to several million people, where livelihoods predominantly rely on pastoral farming and related activities. In recent years, the drylands of East and Horn of Africa have been exposed to multiple and complex climatic shocks particularly recurrent drought which underlie chronic poverty, food insecurity, and rangeland degradation (Fitzgibbon and Crosskey, 2013). The economic, social and environmental impacts of climate variability upon dryland inhabitants are extreme, and expected to be worsened by global climate change (Funk *et al.*, 2008).

Climate variability in East Africa is related to the complex topography, latitudinal location and effects from regional and global atmospheric circulation (Bowden and Semazzi, 2007). Rainfall and temperature are the two most important climatic variables that display high levels of variability across a range of spatial and temporal scales, and exert significant impacts on human livelihoods, socioeconomic development and ecosystems of East and Horn of Africa (Omondi *et al.*, 2014). Climate-related shocks such as droughts and floods are not only common, but are also increasing environmental risks in East Africa (Funk *et al.*, 2008). Over the past four or five decades, the prevalence of drought and flood hazards have cost numerous human lives, caused a series of famines (Funk *et al.*, 2008; Bezabih and Di Falco, 2012), human displacement (Meze-Hausken, 2000; Comenetz and Caviedes, 2002; Mulugeta *et al.*, 2007) and environmental degradation (Biazin and Sterk, 2013). The prevalence of drought and flood events also affects the Gross National Product (GNP) of many African countries (World Bank, 2006; Conway and Schipper, 2011). For example in Ethiopia, a 10% decrease in seasonal rainfall from the long-term average translates into a 4.4% decrease in the country's food production (World Bank, 2006).

Global climate change is expected to worsen the prevalence of spatio-temporal climate variability in East and Horn of Africa. Evidences from General Circulation Model (GCMs) and Regional Climate Models (RCMs) projections indicate the future incidence of significant temperature increases across East and Horn of Africa provide insufficient evidence about the future rainfall shift, due to the presence of challenges for simulating and projecting rainfall variability (Endris, 2013; Buontempo *et al.*, 2014). Thus, studies reported the probability of both drying and wetting conditions in coming decades (Conway and Schipper, 2011). Despite our improved understanding of likely GCC stressors and impacts on environmental resources and socioeconomic activities, relatively less attention has been placed on implications for adaptation planning and intervention.

The objective of this working paper is to review the available information and literature on the current and future climate variability, risks and vulnerabilities across East Africa, and reflect on possible implications for climate adaptation planning and intervention. This paper assessed major climate elements (rainfall and temperature) variability and trends with emphasis on extreme rainfall variability, drought and flood events, which are the major climate related risks in the region. The paper also deals with environmental and socioeconomic vulnerability and the implications for climate related disaster risk management and climate change adaptation planning efforts in the region.

2. Methods

This working paper aims to demonstrate the current state, and future nature of climate variability through a literature review of current knowledge relating to climate-related risks, impacts and vulnerability across the semi-arid regions of Eastern and Horn of Africa, with a particular focus on Ethiopia, Kenya and Uganda. This review was conducted as part of a series of Regional Diagnostic Studies (RDS) undertaken by the Adaptation at Scale in Semi-Arid Region (ASSAR) research project to provide more detailed information on climate variability and related risks over East Africa. The main sources of data for this working paper were academic and grey literature searched using the Google scholar search engine for new and additional literature that covers a range of documents on rainfall and temperature variability, drought and flood events, risks and vulnerability issues for East and Horn of Africa. The search included Web of Science/ Web of Knowledge bibliographic database, using a range of potentially applicable keywords and their combinations including: 'climate variability in East Africa, Ethiopia, Kenya, Uganda'; 'drought and flood events in Ethiopia,'; 'drought and flood events in Kenya'; 'drought and flood events in Uganda'; 'drivers of climate variability in East Africa'; 'impacts and vulnerability to climate variability in East and Horn of Africa and in the three countries-Ethiopia, Kenya and Uganda'; 'climate change in East Africa'; 'climate change in Ethiopia'; 'climate change in Kenya'; 'climate change in Uganda'; 'effects of climate variability in East Africa'; ' climate variability in semi-arid areas of East Africa'.

The literature collected through the Google search focused on three Eastern Africa countries (namely Kenya, Uganda and Ethiopia). Some articles referring to other parts of eastern Africa (e.g. South Sudan, Somalia, and Tanzania) or other parts of sub-Saharan Africa were also reviewed. The review also drew on broader articles related to the themes of climate change, vulnerability and development that do not have a regional focus. Although we collected literature from various published, peer and non-peer reviewed and unpublished sources, emphasis was given to articles published in peer-reviewed scientific journals. More than 100 literature sources were studied in detail, after initially skimming over 500 articles searched from relevant international journals (individual journals and search engines), African journals, and donor reports (e.g. DFID, USAID, World Bank, UNEP) published between 2000 and 2015. The search produced an initial listing of identified documents and their major highlights.

Additional searches were also conducted on broader themes of East Africa's climate characteristics, climate (temperature and rainfall) variability and drivers, drought and flood incidents, and climate related risks and vulnerability.

3. Climate Characteristics

Eastern and Horn of Africa is characterized by great topographical diversity with elevation that ranges below sea level in the northeast part of the rift valley system to high and rugged and dissected mountains and flat-topped plateaus. This complex topography has created many local climatic conditions that range from hot deserts over the lowlands to very cold mountain ranges like the Simien Mountains and Arsi-Bale Highlands in Ethiopia and Eastern Arc Mountains in Kenya and Tanzania. About 60% of the total land area is of the region classified as dryland and as arid and semi-arid, receiving less than 500 mm of rainfall annually and also frequently affected by drought hazards (Schreck and Semazzi, 2004; Bowden and Semazzi, 2007). Moreover, this area is generally warmer than the highlands and mountains, and is inherently an area of low and erratic precipitation not suitable for reliable rainfed crop production and therefore historically used for extensive pastoral livestock production (Amsalu and Adem, 2009).

The north-south oscillation of the Inter-Tropical Convergence Zone (ITCZ) is responsible for seasonal changes, and has created complex annual rainfall cycles in the region (Mutai and Ward, 2000; Gissila *et al.*, 2004; Bowden and Semazzi, 2007). Annual oscillation of the ITCZ results in a bimodal rainfall pattern for the greatest part of the Eastern and Horn of African region. The extreme northward movement of the ITCZ provides the June-September rainfall season (the main rainfall season) over the highlands of Ethiopia, as air masses carrying moisture from various oceanic sources (Atlantic, Indian and Pacific) and dry air from continental sources converge and ascend above the Ethiopian highlands (Korecha and Barnston, 2007; Segele *et al.*, 2009; Viste and Sorteberg, 2013). This main rain during June–September accounts for 50%–80% of the annual rainfall totals over the Ethiopian highlands resulting in the major cropping season and water reservoirs in the country (Korecha and Barnston, 2007; Viste and Sorteberg, 2013). The location of the ITCZ over the extreme north of Ethiopia (150 N) and the development of the monsoon trough across much of the northern two-thirds of Ethiopia at 850 hPa allows moist westerly winds originating from tropical Atlantic and sometimes from southern Indian Ocean via recurvature (shift to westerlies wind after crossing the Equator) to deliver rainfall over much of the Ethiopian highlands (Segele *et al.*, 2009). The temperature over all of the highlands of Eastern and Horn Africa appears lower during the main rainy season due to the effects of cloud cover (NMA, 2007). In contrast, the equatorial and southern part of East Africa falls under the influence of the dry southwest monsoon wind system that is diverted from continental land areas of Madagascar and the East African coast (Mutai and Ward, 2000; Black *et al.*, 2003).

The southward migration and location of ITCZ around the equator provides two rainy seasons for the equatorial and southern East African region, which are driven by the migration of the ITCZ back and forth across the equator (Mutai and Ward, 2000). The timing of maximum rainfall lags the position of the overhead sun by approximately one month. The first, occurs between April and May, is known locally as the ''long rains'' and the second, in October and November, as the ''short rains.'' The East African long rains (March to May) contribute a large part (up to 45%) of the annual rainfall over Kenya and Tanzania and strongly affects their agricultural activities (Pohl and Camberlin, 2006). During the short rains, the ITCZ migrates rapidly southward and the heavy rainfall is of relatively short duration. In contrast, during the long rains, the ITCZ moves more slowly and heavy rainfall for several weeks in the region could be recorded (Mutai and Ward, 2000; Black et al, 2003). These rainfall seasons also extend northward to the equator and provide some rainfall over some parts of

Ethiopia. The March-May rainfall season (long rains), provides rainfall over the southern, eastern and north eastern part of Ethiopia (Gissila *et al.*, 2004), while the short rains have a duration from September to November and provide secondary rainfall over the southern part of the country (Degefu and Bewket, 2014a). Moist westerly wind from Atlantic and the southern Indian Ocean that cross equatorial Africa around March and September allows the equatorial East and Horn African countries (Kenya, Tanzania, Uganda and southern Ethiopia) to receive their main rainfall during March-May and reduced rainfall in the September/October-November/December season (Dinku *et al.*, 2008; Omondi *et al.*, 2014). The extreme southern location of the ITCZ between December and March, and the northeast monsoon brings dry continental air into East Africa, and consequently, the rainfall during these months is far lower resulting in dry conditions over a large part of East and Horn of Africa (Mutai and Ward, 2000; Black *et al.*, 2003; Segele *et al.*, 2009).

The climate, particularly rainfall in Eastern and Horn of Africa is largely known for its inter-annual and inter-decadal variability (Black *et al.*, 2003; Segele *et al.*, 2009). The inter-annual variability over some parts of Kenya, Tanzania and Uganda is significant during the short rain season in comparison to the long rainy season (Camberlin and Philippon, 2002), while it is the *belg* rains that show higher inter-annual variability than *kiremt* over Ethiopia (NMA, 2007). The inter-annual variability during *kiremt* rainfall over Ethiopia and short rains over equatorial East Africa is mainly associated with the SST anomaly forcing, of which the El Niño–Southern Oscillation (ENSO) and Indian Ocean dipole (IOD) are the dominant sources of inter-annual variability across the region (Black *et al.* 2003; Gissila *et al.*, 2004; Christensen *et al.*, 2007; Korecha and Barnston, 2007; Seitz and Nyangena, 2009; Segele *et al.*, 2009; Ummenhofer *et al.*, 2009; Kansiime *et al.*, 2013; Segele *et al.*, 2009; Diro *et al.*, 2011). Limited research has been conducted on drivers for rainfall variability during the March-May rainfall season. Exceptions include Pohl and Camberlin (2006) whose study indicated that the Madden–Julian Oscillation is responsible for inter-annual rainfall variability during this season. More detailed explanations regarding inter-annual rainfall variability and causalities are presented in section 4.2.

4. Climate variability across East Africa

4.1. Temperature variability

Different from other tropical regions, East Africa experiences complex temperature conditions due to the effects of its varying topography. Temperature in the region ranges from very hot (>40°C) at the Afar depression, Ethiopia (Awulachew *et al.*, 2010) to very cold at the peak of Mount Kilimanjaro (Omondi *et al.*, 2014). In Ethiopia, the mean annual temperature varies between less than 10°C over the Northwest, Central and Southeast highlands to about 40°C in the lowlands of Afar, eastern and southeastern regions (NMA, 2007; Awulachew *et al.*, 2010). In Kenya the central highland regions are substantially cooler than the coast, with the coolest (highest altitude) regions at 15°C compared with 29°C at the coast. There is also year-to-year variation of the annual maximum and minimum temperatures in the region. This variation in temperature conditions across East and Horn of Africa determines evaporation and hence available soil moisture at any point of the region. This has created many vegetation types, fauna and agroecological zones across the region. Using normalized temperature anomalies, the NMA (2007) identified very warm years (1957, 1958, 1973, 1987 and

1995) and very cold years (1964, 1967, 1968, 1975, 1977 and 1989) during the last five decades. Temperatures vary little throughout the year, but drop by around two degrees in the coolest season of the high altitudes which occurs in the months of June to September (McSweeney *et al.*, 2010; Awulachew *et al.*, 2010; Omondi *et al.*, 2014).

Figure 1 shows the historical time series averaged seasonal temperature changes over East and Horn of Africa between 1963 and 2012, for the four seasons: DJF, MAM, JJA and SON. Trend analysis for the last four to five decades has shown the presence of increasing trends in temperature from climate baselines. Several studies have reported a warming trend across the region at a rate broadly consistent with wider African and global trends (Christy *et al.*, 2009; Conway and Schipper, 2011; Mengistu *et al.*, 2013). For example, for Ethiopia the NMA (2007) reported that the average annual minimum and maximum temperatures increased at rates of 0.25°C and 0.1°C per decade during 1950-2000 respectively. Meikle (2010) has also reported a warming trend on minimum temperature at 0.37°C per decade in Ethiopia for the period 1951-2006. In the Ethiopian Blue Nile Basin, Mengistu *et al.* (2013) reported the presence of statistically significant increasing trend for minimum temperature, while contrasting trends for maximum temperatures at the annual and seasonal time scales. In Ethiopia, compared to the national average as well as data from the highland regions in the country, the temperature increase in the semi-arid lowland regions has been more pronounced. For example, in the southern lowland regions of Borena, Guji and South Omo temperature has increased by 0.4°C per decade during 1950-2000 (Amsalu and Adem, 2009). In Kenya, mean annual temperatures have increased by 1.0°C since 1960, at an average rate of 0.21°C per decade (McSweeny *et al.*, 2009). Omumbo *et al.* (2011) also reported warming trends in maximum, minimum and mean temperatures at Kericho in Kenya during the period 1979–2009. Using data from 60 stations, Christy *et al.* (2009) reported the presence of statistically significant upward trends in minimum temperature in the Kenyan highlands. In Uganda, seasonal temperature has shown increasing trends at the rate of 0.9°C during March to May and September to October and 0.3°C during dry season (June to August; Nandozi *et al.*, 2012).

There is also evidence of increasing changes in extreme temperature events such as extreme maximum temperature, warm days, warm nights and the duration of warm spells across the region (Mekasha *et al.*, 2013; Omondi *et al.*, 2014). The greatest increases were observed in central regions, particularly in South Sudan where increases in the March to August period have exceeded 3°C (Omondi *et al.*, 2014). Although most of them were not statistically significant, Mekasha *et al.* (2013) reported the presence of positive trends for the maximum temperature value, warm days, warm nights and warm spell duration indicators, and decreasing trends for cool days, cool nights and cold spell duration indicators in more than 8 of the 11 stations they studied.

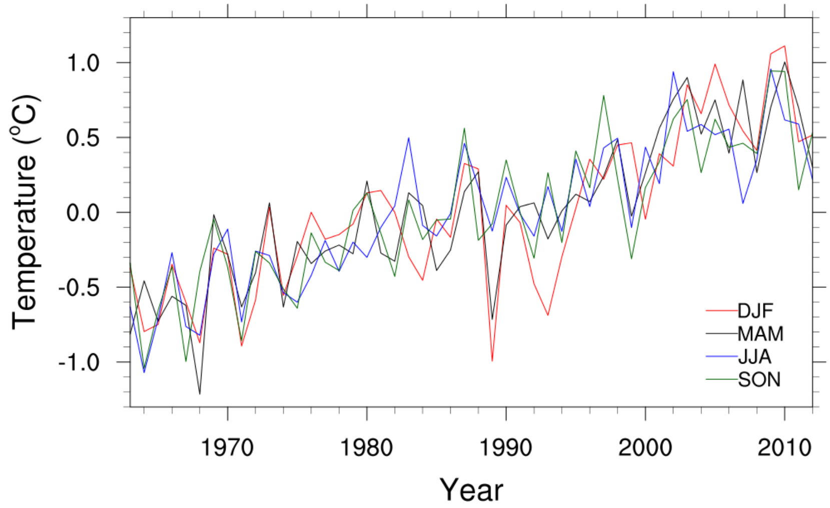

Figure 1: Time series of the land area averaged seasonal temperature changes for East Africa between 1963 and 2012, for the four seasons: DJF, MAM, JJA and SON. Source: Daron (2014), using data from the CRU TS3.22 dataset.

Almost all the General Circulation Model (GCMs) and Regional Climate Models (RCMs) projections for the region (Conway and Schipper, 2011Nikulin *et al.*, 2012; Endris, 2013; Buontempo *et al.*, 2014) indicate the future incidence of significant temperature increases across East and Horn of Africa. Though model projections are subject to uncertainties, the projected increases in average annual temperatures range from no change to 4°C by 2050. Temperatures in the central and northern regions are projected to experience the largest increases (Daron, 2014). Higher increases are more likely under a higher greenhouse gas emissions scenario and vice versa. The IPCC on the other hand, projects a warming of 0.2° C (low scenario) to more than 0.5°C (high scenario) over East Africa (IPCC, 2014).

The Kenyan plateaus and mountain ranges may remain much cooler than the lowlands (Funk *et al.*, 2010). By 2025, western Kenya is projected to see temperature increases ranging from 0.9°C to 1.1°C, while temperatures in the southern coastal area could increase by an average of 0.5°C and in northeastern Kenya temperatures could rise by 1.1°C (Funk *et al.*, 2010). Climate projections generated by UNDP (cited in DFID, 2009) for Ethiopia, highlight the likelihood of mean temperature increases of 1°C in 2020s and up to 3.9°C to 2080s. Using a multi-model dataset, the National Meteorological Agency (NMA) of Ethiopia also indicates that the mean annual temperature is likely to rise significantly when compared with the 1961-90 level by a maximum of 1.1°C by 2030, 2.1°C by 2050 and 3.4°C by 2080 (NMA, 2007).

4.2. Rainfall variability

Due to the complex topography and effects from regional and global SSTs, there is greater spatio-temporal rainfall variability over East and Horn of Africa. This has profound impacts on human livelihood, food security, water availability and environmental resources (Schreck and Semazzi, 2004; Bowden and Semazzi, 2007; Conway and Schipper, 2011). Rainfall shows major spatial variability in its amount, seasonality and year-to-year variation across the region. East African rainfall is characterized by greater inter-annual and inter-decadal variability attributed to sea surface temperature (SST) anomalies. The ENSO (El Niño and La Niña) events over the equatorial east Pacific and SST anomalies over Indian Ocean are the dominant sources of inter-annual and inter-decadal rainfall variability across East and Horn of Africa (Black *et al.*, 2003; Ummenhofer *et al.*, 2009). The periodic circulation of ENSO is a major SST model that has been linked to most of the rainfall variability over East and Horn of Africa (Amissah-Arthur *et al.*, 2002; Gissila *et al.*, 2004) and the impacts vary in different seasons and regions. The warming (El Niño) and cooling (La Niña) phases of ENSO affect the northern part of the region (Ethiopia) and southern part of the region (Kenya, Tanzania and Uganda) differently. Over the northern parts of East Africa (much of the central, eastern and northern Ethiopia), the warming phase of ENSO and Indian Ocean SST tend to be associated with under normal Kiremt (June-September) rainfall, while the cooling phase is associated with above normal rainfall events (Gissila *et al.*, 2004; Segele and Lamb, 2005; Korecha and Barnston, 2007; Segele *et al.*, 2009; Diro *et al.*, 2011; Viste and Sorteberg, 2013). Contrary to this, the warming/cooling phases of ENSO and the IOD are associated with enhanced/reduced small rains (October-December) over equatorial East Africa (Amissah-Arthur *et al.*, 2002; Schreck and Semazzi, 2004; McHugh, 2006; Bowden and Semazzi, 2007). On the other hand, the inter-annual rainfall variability during March–May season reported as the Madden–Julian Oscillation (MJO) amplitude (Pohl and Camberlin, 2006) and the temperature anomalies over West Indian Ocean (Gissila *et al.*, 2004). The inter-annual rainfall variability is pronounced during belg in Ethiopia (Conway and Schipper, 2011) and small rainfall season over equatorial East African countries (Hastenrath, 2001; Christensen *et al.*, 2007; Seitz and Nyangena, 2009; Ummenhofer *et al.*, 2009; Kansiime *et al.*, 2013). All these imply that eastern and Horn of African rainfall variability is a result of complex alignment and interplay with regional and global SSTs anomalies. This inter-annual rainfall variability is responsible for the occurrence of frequent drought and flood hazards in the region (Bowden and Semazzi, 2007; Korecha and Barnston, 2007; Ummenhofer *et al.*, 2009). These SSTs anomalies also determine rainfall onset, cessation and length of growing period in the region (Segele and Lamb, 2005). Understanding this complexity therefore has a particular importance for the application of seasonal climate forecasts in targeting and presenting the information within a time frame consistent with operational requirements and at a spatial scale appropriate to the users' needs (Amissah-Arthur *et al.*, 2002).

Rainfall trends over the past 50 years are less evident than for temperature, and there are large variations in the direction and magnitude of changes across the region. An increase in rainfall in some locations for some seasons is observed but a decrease in rainfall is observed in other parts of the regions and overall trends are weak and hard to detect. Some studies such as Hastenrath (2000); Bewket and Conway (2007) reported the observed patterns over East and Horn of Africa are affected by the presence of higher inter-decadal rainfall variability observed during the indicated period. For example, the highlands of Ethiopia experienced wetter conditions during the 1970s and drier condition during 1980s and 1990s (Bewket and Conway, 2007; Cheung *et al.*, 2008; Jury and Funk, 2012; Degefu and Bewket, 2014a).

Figure 2 shows trends of seasonal rainfall condition over East Africa for the period 1963 to 2012. Notable rainfall change appears to have occurred during the main rainfall (March to May) season over large parts of the region, specifically Tanzania, Kenya and southeast Ethiopia, which have seen decreases in rainfall exceeding 100 mm. Some highland regions of Ethiopia show drying in the JJA (summer) season, whereas areas of South Sudan show increasing rainfall in this season. In general, these patterns of change are not consistent across the region and therefore signals indicating systematic changes are weak.

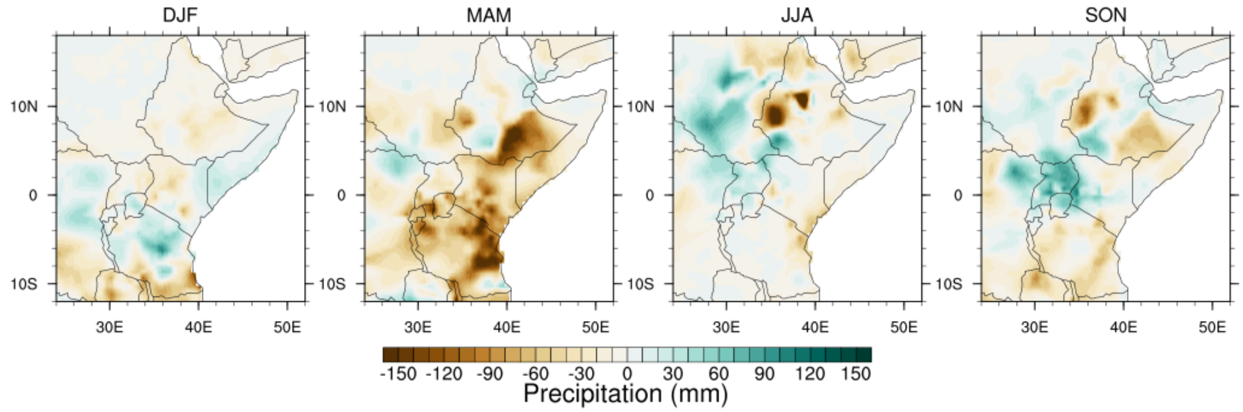

Figure 2: The change in rainfall for East Africa between 1963 and 2012 at each grid cell, according to a linear trend, for the four seasons: DJF, MAM, JJA and SON. Source: Daron (2014), using data from the CRU TS3.22 dataset.

Country level studies have shown similar complex and weak trend results for all rainfall parameters. Some studies in Ethiopia have identified downward trends in some parts of the country - mainly in the eastern, southern and southeastern regions (Seleshi and Camberlin, 2006; Cheung *et al.*, 2008; Jury and Funk, 2012). Similarly, Conway and Schipper (2011) reported a tendency of downward trends for the belg rainfall, particularly over the eastern part of Ethiopia. However, other studies (Bewket and Conway, 2007; NMA, 2007; Mengistu *et al.*, 2013; Mekasha *et al.*, 2013) reported the absence of statistically significant upward or downward trends over central and northern parts of Ethiopia. In Uganda the annual and seasonal rainfall trends showed statistically significant increasing trends over the highland areas and negative, but non-significant trends for low lying areas for the period 1971-2010 (Kansiime *et al.*, 2013).

Trend tests on extreme rainfall events have shown similar patterns to the seasonal and annual rainfall totals, the absence of systematic evidence for consistent changes in the amount, frequency or intensity of extreme events in Ethiopia (Seleshi and Zanke, 2004; Seleshi and Camberlin, 2006; Bewket and Conwy, 2007; Mekasha *et al.*, 2013; Degefu and Bewket, 2014a), except Omondi *et al.* (2014) reported the presence of statistically significant decreasing trends in total precipitation in wet days greater than one mm over the greater Horn of Africa Region.

At present there is insufficient evidence about the future rainfall shift from climate model projections for East Africa region, due to the presence of challenges for simulating and projecting rainfall variability (Conway and Schipper, 2011). Thus, studies reported the probability of both drying and wetting conditions in coming decades. IPCC projections indicated that a 5-20% increase in precipitation amount during December-February and 5-10% decrease during the June-August season (IPCC, 2014). Another study by Christensen *et al.* (2007) reported a range of projections from a decline of 3% to an increase of 25% and a mean increasing precipitation trend by 7% by the decade of 2080 to 2090. Daron (2014) reported the likelihood of drying condition in most locations of East and Horn of African region for October to March period. The number of extreme wet seasons in East and Horn of Africa expected to increase by 5 to 20 per cent (Seitz and Nyangena, 2009).

Almost all country and regional level studies were reported the same complex and nonsystematic trend for future rainfall. For example, Abdo *et al.* (2009) examine changes to rainfall in the Blue Nile Region of Ethiopia using the single HadCM3 GCM, and reported decreasing trends at the beginning of the kiremt rainfall season (May and June) and an increasing trend towards the end of this rainy season (September and October). Dile *et al.* (2013) reported a decrease rainfall of up to 30% in the near decades for the same region, but an increase in rainfall of 30% in the latter half of the century. Using multi modal projections, Conway and Schipper (2011) showed different projections of annual rainfall over Ethiopia, with some models projecting more rain, others less, but with a tendency for slightly wetter conditions. There are very small changes in multi-model average annual rainfall for the 2020s (+0.4%) and 2050s (+1%). The seasonal changes are slightly larger but still modest when averaged across all models. There are some fairly marked sub-national differences in the size and direction of rainfall change.

On the other hand, Funk *et al.* (2010) reported the likely decline of annual average precipitation by 50 to 150 mm throughout most of Kenya's interior by 2025, while a large part of Kenya is expected to have declining precipitation by more than 100 mm during the long rains. Wetter conditions are likely to occur during the short rains of October to December, particularly in northern Kenya, where projections based on general circulation models (GCM) suggest that rainfall could increase by as much as 40 per cent by the end of this century (AEA Group, 2008). Another study (Nandozi *et al.*, 2012) reported the presence of increasing rainfall during March to May (0.2 mm per day), and a decreasing trend for September to October (SON) rainy season (0.7 mm per day) and June to August (0.4 mm per day).

4.3. Drought

Climate variability over the last few decades resulted in frequent drought hazards over East African countries (Schreck and Semazzi, 2004; Bowden and Semazzi, 2007). Principal causes of drought events over East Africa are associated with ENSO-South Oscillation climate variability (Gissila *et al.*, 2004; Black *et al.*, 2003; Korecha and Barnston, 2007) and SST anomalies over the Indian Ocean (Amissah-Arthur *et al.*, 2002; Schreck and Semazzi, 2004; McHugh, 2006; Bowden and Semazzi, 2007). The warming phase of ENSO/ El Niño and Indian Ocean cause below normal rainfall/ drought events over the northern part of East and Horn of African region (Ethiopia) during Kiremt (June to September) season (Gissila *et al.*, 2004; Korecha and Barnston, 2007; Segele and Lamb, 2005). Over the southern part of East Africa (Kenya, Tanzania and Uganda) below normal rainfall and drought is associated with the cooling phase of ENSO/ La Niña and IOD and occurs during the short rainfall season (November to December) (Black *et al.*, 2003; Schreck and Semazzi, 2004; McHugh, 2006; Bowden and Semazzi, 2007; Ummenhofer *et al.*, 2009). Currently, drought is very common during the belg rainfall season (short rainfall period) over eastern and north eastern and main rainfall over southern Ethiopia due to warming SST over West Indian Ocean (Korecha and Barnston, 2007).

Ethiopia is one of the East and Horn of African countries severely affected by drought during the past decades. Drought is a common environmental problem in Ethiopia, and this has been documented since 250 BC (Block, 2008; Viste *et al.*, 2013). The drought hazard in 1888 was remembered for its severe effects, a significant proportion of the Ethiopian population died because of famine resulting from crop failure, and 90% of the animals perished due to drought and drought related impacts (Edossa *et al.*, 2010). On the other hand, during the last five decades drought has occurred in 1965, 1972, 1973, 1978, 1984, 1991, 1994, 1999 and 2002, 2004, 2009 and 2011 (Mulugeta *et al.*, 2007). Of these the 1984 drought hazard that occurred over the larger part of Ethiopia affected over 8 million people; resulting in an estimated 1 million deaths and significant livestock loss (Amsalu and Adem, 2009). The drought in 2002/03 also affected over 14.5 million people across the country (Mulugeta *et al.*, 2007). Similarly, Kenya has experienced many drought hazards during the last five decades. In Kenya, drought has occurred in 1980, 1983/84, 1991/92, 1995/96, 1999-2001, 2004, 2005, 2006, 2007/08, 2009 and 2011 (Huho and Kosonei, 2014). According to this source, the worst drought in the last one hundred years occurred in 1999-2001 that killed approximately 60-70% of livestock in the arid and semi-arid areas, caused massive crop failures, drying up of water resources, and caused severe environmental degradation and loss of goods and services. Drought studies in Ethiopia (Edossa *et al.*, 2010; Viste *et al.*, 2013; Degefu and Bewket, 2014b) indicated that drought prevalence in the region shows quite complex spatial patterns and most drought incidences occurred at local scales.

Empirical studies confirm that the frequency, geographical coverage and magnitude of drought hazards increase in the second half of the 20th Century across the East African region (World Bank, 2006; Edossa *et al.*, 2010; Viste *et al.*, 2013; Huho and Kosonei, 2014). World Bank (2006) identified about 16 drought incidences in Ethiopia, 10 drought events in Kenya and Tanzania, and 9 in Somalia and Uganda for the period 1980-2004. On the other hand, Huho and Kosonei (2014) reported the prevalence of 12 drought incidences in Kenya during 1980-2012, and indicated that about 60-70% of the 1980, 1990 and 2000 decades were characterized by drought events. Drought is becoming more frequent. For example, in Kenya the drought frequency increased from once in every 10 years in the 1970s to once in every 5 years in the 1980s, once in every 2-3 years in the 1990s and every year since 2000 (Huho and Kosonei, 2014). Similarly, in Ethiopia, the prevalence of drought increased from once per decade between the1950s and 1980s to once every three years in the 1990s and 2000s (Block, 2008).

Scenarios show that droughts will become more frequent and severe over the arid and semi-arid parts of the region, where there is chronic water shortage and high temperatures (Amsalu and Adem, 2009; Degefu and Bewket, 2014b; Huho and Kosonei, 2014). In Ethiopia, the arid and semi-arid areas in the northeast, east and southern parts of the country are now frequently affected by drought and its associated impacts (NMA, 2007). In Kenya, Huho and Kosonei (2014) reported that it is in arid and semi-arid counties such as Machakos, Laikipia, Turkana and Isiolo where frequent drought events have been experienced during the last five decades. In Uganda, drought is concentrated in eastern sub-regions such as Karamoja and Teso area (Kristjanson *et al.*, 2012; Egeru, 2012).

4.4. Flood

Flooding is a growing environmental and socioeconomic problem in East Africa particularly within lowland regions (World Bank, 2006; NMA, 2007; Amsalu and Adem, 2009; Haile *et al.*, 2014; Huho and Kosonei, 2014). This can take the form of flash floods or riverine floods and originates from highland areas, where there is high rainfall (World Bank, 2006; Degefu and Asfaw, 2006). In Ethiopia, flood hazards are most associated with major river basins: Awash, Wabesheble, Genale and Omo-Ghibe Rivers (World Bank, 2006; Block, 2008). Flood events are very common during the Kiremt season (July, August and September). During the last five decades, widespread flood hazards were observed in 1961, 1964, 1967, 1968, 1977, 1993, 1996, 1998, 2005 and 2006 (NMA, 2007). Flooding occurred in August 2006 affecting all regions of the country, except Benihsngul Gumuz (northwestern Ethiopia), and killed more than 700 people and displaced thousands (Mulugeta *et al.*, 2007). During 2004-2006, flooding afflicted several areas of eastern and southern Ethiopia, Somalia, and Kenya, killing and displacing hundreds of people. The Shebelle and Juba Rivers in the region have both flooded their banks, affecting towns and villages in an area stretching across hundreds of kilometers (Mulugeta *et al.*, 2007). Similarly, Haile *et al.* (2014) reported the prevalence of frequent flood hazards along the lower part of Baro-Akobo River basin in Gambela area in Ethiopia.

In Kenya, floods are the most common climatic disaster, and with a prevalence rate of 27% per year (Otiende, 2009). Flooding affects low lying areas of the country within the five drainage basins of the Lake Victoria Basin. According to Huho and Kosonei (2014), Bunyala sub-county, which is located within this basin experiences perennial floods that occur during March to May every year and September to October. By and large, most floods in Kenya occur immediately after droughts causing devastating impacts. In the last two decades, major floods have occurred in 1997-98, 2002, 2003, 2006, 2008, 2010 and 2012. The 1997-98 and 2003 floods were declared as national disasters. Flash flooding that occurred in 2010 claimed 73 lives and 1,864 livestock mortalities in the country. Over 3,375 households were displaced and 14,585 people were affected. It destroyed 16 bridges in the Rift Valley of Ethiopia. Similarly, in 2012 about 84 people lost their lives and 30,000 people were displaced due to flash flooding. Flooding has also been observed in Uganda from extreme rainfall events (Conway *et al.*, 2005), and is often combined with landslides (Kansiime, 2012).

The magnitude and frequency of hazards are key factors in determining the amount of damage caused by a disaster. The prevalence and impact of flood hazards show increasing trends over East and Horn of Africa (Mulugeta *et al.*, 2007; Huho and Kosonei, 2014). These all have important implications for the increasing prevalence of flood hazards in the region, and the need for enhanced flood management planning and intervention.

5. Impact of climate variability

East Africa is a highly vulnerable region to climate variability and change. A drastic climatic dislocation took place during the last two decades of the 20th century, which manifested in a drop of lake levels, onset of high mountains glacier recession, and acceleration of regional atmospheric circulation (Westerlies and Eastward Equatorial Jet (EEJ) in the upper hydrosphere of the equatorial Indian Ocean) (Hastenrath , 2001; Verdin *et al.*, 2005; Funk *et al.*, 2008). There are many climatic, environmental and socio-economic evidences/indicators for the high vulnerability of the East and Horn African region to current and future climate variability. One of the most significant evidence is the sensitivity of human livelihood and economic system as there is a strong link between climate and human livelihood and the economy in the region. In East and Horn of Africa the link between climate and livelihood is very strong, as the majority of East African community largely depends on rain-fed agriculture and other natural resource based livelihoods (World Bank, 2006; Demeke, et al, 2011; Adhikari *et al.*, 2015). Climate variability mainly of rainfall (e.g. drought, flood, erratic rainfall and change in rainfall season) has brought much damage and challenges to agricultural production and water resources, which leads to scarcity of food, water and other environmental resources for human consumption (Funk *et al.*, 2008).

It is widely recognized that East and Horn of African countries are largely vulnerable to repeated occurrence of drought and flood hazards (Hastenrath, 2001; Funk *et al.*, 2008; Conway and Schipper, 2011), increase in drylands (Biazin and Sterk, 2013) and intensified climate-sensitive diseases (Stern *et al.*, 2011). The prevalence of droughts is the number one environmental problem in East and Horn of Africa, and caused major economic and humanitarian impacts during the last four to five decades by severely affecting rain-fed agriculture and pastoralism, which is the backbone of East and Horn of Africa economies (Viste *et al.*, 2013). Over the last five decades, East and Horn of Africa region has experienced at least one major drought per decade and there is a tendency for increasing frequency and intensity of these events due to climate change (Funk *et al.*, 2008). Damage to the agricultural sector leaves the region exposed to the risk of famine, as demonstrated by the widespread famine and humanitarian crises caused by several series of droughts in the last few decades (2008/2009 and 2010/2011) (Viste *et al.*, 2013; Huho and Kosonei, 2014). Arid and semi-arid regions are particularly vulnerable to the negative effects of drought events as they are already water stressed due to lower, more erratic rainfall, and high rates of evapotranspiration (Degefu and Bewket, 2014b; Huho and Kosonei, 2014). Flooding has become a growing environmental and socioeconomic problem in East and Horn of Africa during recent decades, particularly among the lowland communities (World Bank, 2006; NMA, 2007; Amsalu and Adem, 2009; Huho and Kosonei, 2014). The prevalence and impact of flood hazards show increasing trends over East and Horn of Africa during the recent past (Mulugeta *et al.*, 2007; Huho and Kosonei, 2014). These climate variabilities have also brought many other environmental problems in the region such as soil erosion, forest degradation, spread of invasive species and water shortage (NMA, 2007; Funk *et al.*, 2008; Conway and Schipper, 2011). Climate variability is a key source of conflict between communities (Fjelde and von Uexkull, 2012). Currently the rangeland and water resources in arid and semi-arid areas are under multiple pressures and become scarce for the pastoral community. The shortage of these resources is severe during drought times; therefore increasing fodder and water shortages during drought times are sources of conflicts.

Although there is high level of scientific evidences that confirms the presence of future climate change across the world (IPCC, 2007), climate model projections of climate over East and Horn of Africa show warming in all four seasons across the region but a wide range of rainfall patterns, with no clear direction of change (Christensen *et al.*, 2007; Seitz and Nyangena, 2009; Daron, 2014; IPCC, 2014). This high level of uncertainty in the future behaviour of rainfall is a significant challenge to understanding and acting upon the risks posed by climate change (Conway and Schipper, 2011), hence is another source of vulnerability to East and Horn of African countries since there are difficulties planning with high uncertainty. This study also indicated that climate impact studies in the region to date have been rather ad hoc and tend to reflect the underlying uncertainties in climate model projections (Nandozi *et al.*, 2012; Nikulin *et al.*, 2012; Endris *et al.*, 2013; Buontempo *et al.*, 2014) and therefore have not contributed greatly to the understanding of risk significance to decision-makers.

The ongoing temperature variability over East Africa may have multiple impacts. Over high altitude regions such as mountainous lands in Uganda, Rwanda, Ethiopia and Kenya, where temperature is the limiting factor for plant growth, a rise in temperature possibly will increase crop yield (Thornton *et al.*, 2009). However, over the lowland areas, where there is warmer temperature and severe water scarcity a further increase in temperature will have negative impacts on crop production, pasture growth and increase the risk of water stress (Funk *et al.*, 2010). Water stress is frequently accompanied by heat stress, as dehydration of the plant tissue leads to overheating. Increases in temperature also increase saturation vapor pressure of air, thereby increasing evaporative demand which will lead to severe water stress in the region. Thus, climate change is projected to overall decrease the yields of cereal crop in East and Horn of Africa through shortening growing season length, amplifying water and heat stresses and increasing incidence of diseases, pests and weeds outbreaks (Funk *et al.*, 2010; Demeke *et al.*, 2011). There are also evidences for growing incidence of malaria over the highland regions of East and Horn of Africa. Temperature over the highlands of the region show increasing trends and created favorable conditions for the incidence of malaria (Hay *et al.*, 2002; Stern *et al.*, 2011; Omumbo *et al.*, 2011). Heat stress is another health risk particularly over the lowland areas, which already had warmer climate. Thus, future climate change will aggravate the incidence of heat and the risk of heat stress among the lowland community.

Climate variability is also expected to severely impact certain environmental and economic sectors. The rain-fed agriculture is an important economic sector that is highly vulnerable to the impacts of climate change in East and Horn of Africa (Adhikari *et al.*, 2015). The region has a largely agrarian political economy, with high dependence of the local communities on crop production and pastoralism for their livelihood and employment. Agriculture is a major source of food and contributor to the regional economy, contributing to 40% of GDP in the region as a whole (Nyasimi *et al.*, 2013), and over 75% of labour force across East and Horn of Africa is engaged in agriculture (Salami *et al.*, 2010). Apart from this, the pastoralism economic system and livelihood now is under multiple pressures, in addition to climate related risks (drought, floods and erratic rainfall). This area is affected by invasive plant species, rangeland and soil degradation, political and social marginalization and poor governance (Biazin and Sterk, 2013; Huho and Kosonei, 2014). Drought frequency and erratic rainfall are the major climate related problems that largely affects the rangeland and water resources in drylands of East Africa and affects the livestock sector (Edossa *et al.*, 2010; Kristjanson *et al.*, 2012; Egeru, 2012; Viste *et al.*, 2013; Huho and Kosonei, 2014). Although there are many uncertainties, global warming is expected to exert additional challenges to East and Horn of African rain-fed agricultural system. There are a growing evidences for the effects of projected climate change and future climate variability on the regional agricultural production and agricultural livelihoods (Fraser, 2007; Deressa and Hassan, 2009b; Demeke *et al.*, 2011; Evangelista *et al.*, 2013; Nyasimi *et al.*, 2013). Thus, both the pastoral and crop farming rain-fed systems are highly vulnerable to the effects of climate variability mainly of drought, flood and erratic rainfall.

There are ample empirical evidences that past and current climate variability significantly affected the primary human needs, food and water (Fraser, 2007; Mulugeta *et al.*, 2007; Funk *et al.*, 2008; Conway and Schipper, 2011). Climate variability accompanied with environmental degradation (e.g. soil erosion, water shortage, invasive species, etc.) are major drivers for the increasing food insecurity and poverty development in East and Horn of Africa (NMA, 2007; Funk *et al.*, 2008; Conway and Schipper, 2011). East and Horn of Africa is one the most food insecure regions in the world, mainly due to rainfall variability and the prevalence of prolonged drought and flood hazards (Mulugeta *et al.*, 2007; Slegers and Stroosnijder, 2008; Demeke *et al.*, 2011). The strong dependence on rain-fed agriculture in these areas results in a direct relationship between rainfall condition and grain yields, food deficits, and domestic gross national products (World Bank, 2006; Funk *et al.*, 2008). For example, in Ethiopia, chronic food insecurity affects 10% of the population; even in average rainfall years, where these households cannot meet their food needs and rely partly on food assistance (Fraser, 2007; Demeke *et al.*, 2011). It is estimated that over 10 million people suffer from chronic food insecurity and poor nutrition in Kenya, and one to two million people are annually reliant on emergency food assistance and about 30% of children aged 5 years and below are still classified as undernourished (Gok, 2010). In the 25 years to 2006, the population of food insecure people is said to have doubled in East Africa, while per capita cropped area has declined by 33% and numbers of undernourished people has risen by 80% in the region (FAO, 2006), and this is partly due to the growing harsh climate condition in the region. These climate related hazards are increasing and expected to increase in their frequency, magnitude and geographical coverage due to global warming, which is expected to worsen food crises in East and Horn of Africa (Conway and Schipper, 2011; Daron, 2014).

Water is the other major environmental sector that is affected by climate variability over East and Horn of Africa. Due to the effects of climate variability, East and Horn of African water resource showed greater spatio-temporal variability and extreme events (drought and flood) (Conway, 2005; World Bank, 2006). Evidence from empirical studies showed the presence of many water related problems such as drying up of rivers, springs, lakes and wetlands and water shortage in rivers and reservoirs also affects economic productivity by reducing the potential for hydroelectric power production (World Bank, 2006). The pastoral communities in this area are most affected by chronic water shortages, which cause them to migrate regularly in search of pasture and water. Consequently, women, young boys and girls are usually forced to walk for an average of seven kilometres daily to obtain water for domestic uses. Overall, the existing water sources are prone to contamination from human waste as the majority of the households have no latrines, as well as animal wastes, particularly at earth dams. High diarrhea rates are mainly attributable to lack of access to safe drinking water and poor hygiene practices. The water resources sector and water dependent development plans as well as the socio-economic and political relation among the riparian countries are vulnerable to the effects of climate change (Conway, 2005; Block and Strzepek, 2010; McCartney and Girma, 2012). For example, McCartney and Girma (2012) indicated that increasing demand for water resources for irrigation and hydropower at the headstream of the Blue Nile River in Ethiopia, flow at the Ethiopia-Sudan border will decrease from 1661 m3/s to 1301 m3/s as a consequence of climate change. Thus, the impacts on downstream flow in Sudan and Egypt would, as a consequence of climate change in Ethiopia is expected to be large. However, the development of water reservoirs like hydroelectric dams at the head streams of the Nile River Basin would play a dominant role in regulating the downstream flood and drought hazards (World Bank, 2006; Block, 2008).

The other issue of vulnerability in East and Horn of Africa is the risk of conflicts on communal land resources. Researchers such as Fjelde and von Uexkull (2012) have indicated that climate variability is likely to heighten the risk of communal conflict in the arid and semi-arid areas of East Africa. In particular, erratic rainfall, which reduces the availability of water and pastureland, could be sources of conflicts between pastoral communities and the problem will be stronger in the presence of economic and political marginalization.

There are also evidences that climate variability, particularly drought (Meze-Hausken, 2000; Gray and Mueller, 2012) and flooding (Degefu and Asfaw, 2006) have caused massive human displacement and migration in Ethiopia. People have migrated from drought and flood affected areas to safer regions by traveling short or long distances. For example, in Ethiopia people, particularly males migrate to urban centers in search of work during droughts (Gray and Mueller, 2012). There are also large numbers of people who permanently migrate from drier northeastern Ethiopia (Tigray and Wello) to the west and southwest Ethiopia due to drought (Meze-Hausken, 2000).

6. Conclusion

East and Horn of Africa is characterized by great climatological and weather diversity and variability as caused by the complex topography, latitudinal location and effects from regional and global atmospheric circulation. Rainfall and temperature are the two most important climate elements displaying high levels of variability across a range of spatial and temporal scales in East and Horn of Africa, and create diverse ecological and livelihood zones. Rainfall variability is more significant than temperature over the region in terms of impacts and risks. This climate variability has pronounced impacts on spatio-temporal ecological services (e.g. surface and ground water availability, biological resources, soil resource though erosion), by affecting agricultural productivity, food security, human livelihood and countries economic development in general. Due to the complex nature of East and Horn of African climate, most of such impacts are felt at local and regional levels (Verdin et al, 2005). The available drought studies in Ethiopia (Edossa *et al.*, 2010; Viste *et al.*, 2013; Degefu and Bewket, 2014b) indicated that drought prevalence in the region show quite complex spatial patterns and most of drought incidences are felt at a local scale. All these imply the need for a range of spatial and temporal scales of climate management plans and intervention activities. To do this, first we should clearly understand and model of spatio-temporal dynamics of East and Horn of African temperature and rainfall variability (Verdin *et al.*, 2005; Conway and Schipper, 2011). A poor understanding of climate science in the region is attributed to poor data quality and quantity, limited professionals and financial and other research resources (Verdin *et al.*, 2005). It is important to note that to understand the complex East and Horn of African climate in a way suitable for climate management purposes at different spatial and temporal scales one should first address the indicated gaps in climate science in the region.

Erratic rainfall, drought and flood hazards are the major climate related problems in the region to date. There are also other climate related risks such as invasive species, soil erosion, disease outbreak, landslide and heat stress in the region affecting crop production, animal rearing, food security, human health and the conflicts. Erratic rainfall and droughts caused severe water shortage for agriculture, animals and domestic consumption, particularly over the arid and semi-arid areas. Thus, arid and semi-arid ecosystems, human livelihoods and socioeconomic developments in these areas are highly vulnerable to the impacts of this climate variability.

Vulnerability related to the poor rainfall scenario in the region could be minimized by using current climate trends for the near future planning. For practical rainfall dependent activities/sectors in Ethiopia and other sub-Saharan African countries, Conway and Schipper (2011) suggested to consider the very least recent climate variability (last 20–30 years) as a guide to planning and management. However, for the long-term decisions in the case of water infrastructures, this same study recommended considering a greater range of climate variability as a guide to planning and management activities. However, there are insufficient studies on historical and or current climate variability and trends in the region due to lack of data and other research related problems (Virdin *et al.*, 2005). Thus, East and Horn of African countries and other development partners working on the regional climate modeling, climate prediction and climate related disaster management activities should give much emphasis to enhance climate information for policy makers and development planners in the region. Special emphasis should be given to climate data generation/observation/modeling and model development that will enable us to understand, predict and tackle major climate related disasters and risks (drought, erratic rainfall, flood, etc.) that are well known in the region. Apart from this, very little has been done to understand or quantify and model the economic and social effects of climate variability or extremes, at scales beyond the household and village level (Conway and Schipper, 2011). This is another area that needs greater emphasis and intervention, model development and capacity building by government, research institute and development agents like World Bank, DFID and USIAD working in the region.

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