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Full Length Research Paper

Comparison of the spatial and temporal variability of drought indices in Somalia and Lake Chad Basin

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The science and dynamics underlying drought is complex, yet understandable if approached carefully using scientific method. In this paper, scientific perspective was applied to explain and compare drought indices in Somalia and Lake Chad Basin (LCB). Geographic information system (GIS) was used to analyze similarities and differences of locational attributes of temporal and spatial drought data in both regions. There was a similarity in the thirty-year annual precipitation, aridity index and spatial distribution of surface water bodies. Net primary production (NPP) was around -10 g carbon per square meter per year ($gcm^{-2}yr^{-1}$) in south of Somalia and -20 $gcm^{-2}yr^{-1}$ in the north in 2007. In 2009, the NPP dropped sharply to near -80 $gcm^{-2}yr^{-1}$everywhere in the Somalia. In contrast, NPP has been increasing gradually in LCB from -10 $gcm^{-2}yr^{-1}$ in 2007 to near 100 $gcm^{-2}yr^{-1}$ in 2010. Standard precipitation index (SPI) analysis indicates increase in SPI value from 0 (near normal) in 2009 to around 1.3 (moderately wet) in 2010 in LCB. In Somalia however, there was a corresponding decrease from 0 to -2 (extremely dry). Continued decrease in precipitation southwards in Somalia appears to have triggered the present drought. The threat of drought in LCB has not been given adequate coverage partly because the Sahel region today may have been receiving just enough precipitation. The lessons from the current drought in Horn of Africa are however, a reminder of the potential threat facing over 30 million inhabitants of LCB.

Key words: Somalia, Lake Chad Basin, drought, standard precipitation index, aridity, water resources.

INTRODUCTION

The tremendous importance of water in both society and nature underscores the necessity of understanding how a change in global climate is affecting the availability and variability of regional water resources. Lake Chad for instance, located in one of the poorest and most drought-prone regions of the world – the Sahel region of sub Saharan Africa - has shrunk from around 25,000 KM^2 in the early 1960s to less than 2,000 KM^2 (Grove, 1996). The threat of drought in LCB has not been given adequate coverage partly because the Sahel region today may have been receiving just enough precipitation. The lessons from the current drought in Horn of Africa is however a reminder of the potential threat facing the over 30 million inhabitants of LCB.

The LCB is part of the Sahelian semiarid transition zone between the Sahara desert and the sub-humid savanna zone, with an average annual rainfall of 200 to 600 mm. In LCB, there has been a great decrease in rainfall events (Nicholson, 1988, 2000). There seem to have been some recovery from the last mild drought of 1992 in the LCB. According to Ellis and Swift (1988) and Sullivan and Rohde (2002a) productivity of the plant cover can be restored just in a couple of years with good rainfall. Despite this recovery, the threat of drought in LCB is still a source of concern.

Because drought is dynamic in nature, its analysis requires study of the spatial and temporal extent. McKee et al. (1993) developed an effective drought index the standard precipitation index (SPI) which facilitates temporal analysis of drought. Unlike some complex drought indices like Palmer drought severity index (PDSI) (Palmer, 1965). SPI has the advantage of requiring only precipitation data and is not affected by geographical differences (Lana et al., 2001).

This analysis/comparison was made a moral imperative with the United Nations estimate that 12 million people have been affected in East Africa by the worst drought in more than half a century. The urgency of the humanitarian

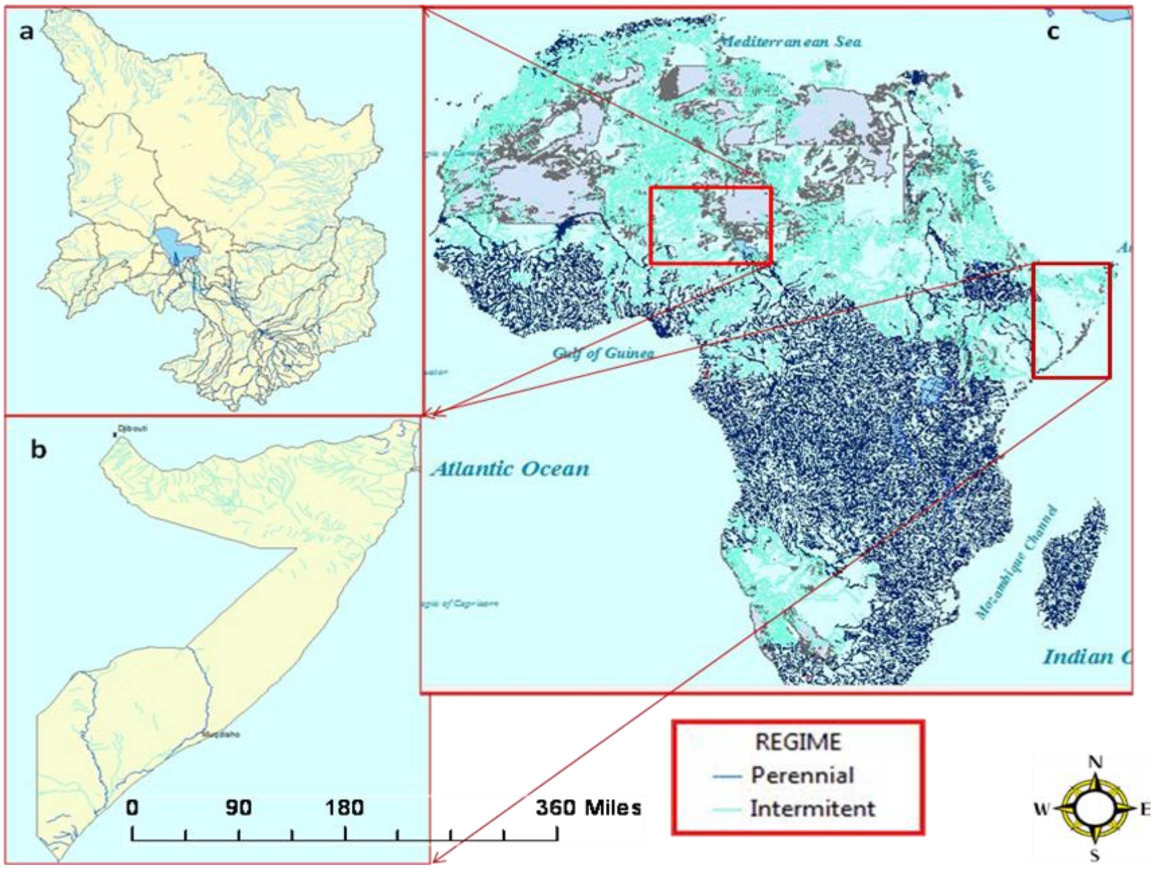

Figure 1. Study area showing perennial (dark blue) and intermittent (sky blue) rivers in (a) Lake Chad Basin, (b) Somali (c) Africa.

assistant needed to save over 3 million internally displaced and starving populations (UN, 2011) has raised the question of reliability of early warning mechanisms and water resources management question in drought prone regions of Africa.

The objective of the study is to provide a comparative analysis of spatial and temporal variability of drought indices in Somalia and LCB with the view to identifying trends and onset of drought. It will quantify the relative effectiveness of SPI, net primary production (NPP) and precipitation data as drought indices in the two regions. The result from this comparison will hopefully serve as timely scientific input for policy makers in LCB and international organizations for sustainable water resources development and management in LCB.

MATERIALS AND METHODS

Study area

Lake Chad Basin is located in one of the poorest and most drought prone regions of the world (Figure 1a). A unique and highly productive basin, Lake Chad is home to 30 million inhabitants with exceptional biodiversity. The impact of both climate and anthropogenic factors on Lake Chad Basin is substantial. Access to freshwater from both surface and groundwater resources have been hampered. Increasing pressure on groundwater resources is raising concern over long term sustainability yield of the reserves. Farmland that was once healthy has been slowly eroded to barren plains as desertification takes a heavy toll on agriculture.

Somalia which lies in the horn of Africa is located in the region bordering both the Indian Ocean and the Red Sea (Figure 1b). Somalia is also a water-scarce county, semi-arid - with an average yearly rainfall of around 250 mm and very high evaporation rate. The Juba and Shabelle Rivers in the south are the only major source of fresh water in the densely populated south.

Datasets and methodology

Geographic information system (GIS) is a good tool for analyzing spatial location, interaction, structure and processes, because hydrometeorological data are spatially distributed. In this research the (SPI) has been used as a reference index for the identification of drought events.

The CAMS-OPI technique were used to generate yearly rain gauge totals from climate anomaly monitoring systems (CAMS) (Ropelewsk et al., 1984) and estimates from outgoing longwave radiation (OLR) anomalies generated by OLR precipitation index(OPI) (Xie and Arkin 1997). The CAMS –OPI was used for the SPI analysis since it has coverage of the last four years leading to the present drought in Somalia. According to Janowiak et al.

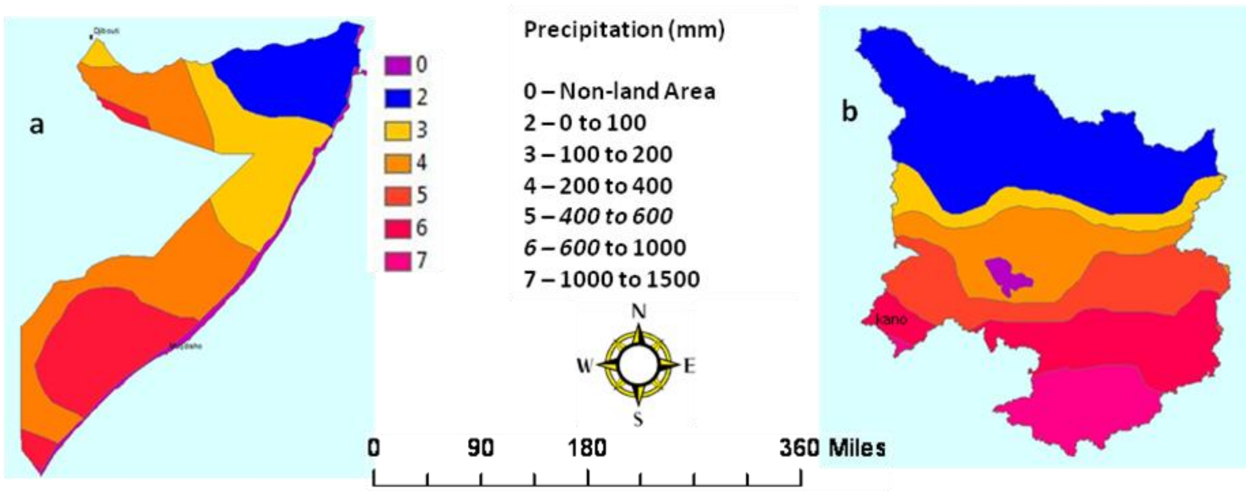

Figure 2. Mean annual precipitation (mm) 1961 to 1990: (a) Somalia (b) Lake Chad Basin: data from (CRU CL 1.0) of Climate Research Unit (CRU) of the University of East Anglia (UEA).

(1999) there is little difference between global precipitation climatology project (GPCP), climate prediction merged analysis of precipitation (CAMP) and CAMS-OPI.

The CRU CL 1.0 data-set from climate research unit (CRU) of University of East Anglia comprising monthly grids of observed mean climate from 1961 to 1990, and covering the global land surface at 0.5 degree resolution was used for precipitation analysis. The variability and trends in annual rainfall data was analyzed using data management tool in GIS. Dissolve analysis, a geoprocessing tool was used to aggregate areas based on specified attributes of annual rainfall, over a period of thirty years from 1961 to 1990.

Estimate of terrestrial net primary production (NPP) in gram carbon per square meters per year from satellite data for the two regions was obtained from global terrestrial NPP data from the University Earth and Ecosystems Science University of Montana. The technique used the global MODIS NPP algorithm to examine spatially explicit NPP changes (Zhao and Running, 2010).

RESULTS AND DISCUSSION

Similarities

The first similarity between Somalia and LCB is the spatial distribution of the thirty-year annual precipitation (Figure 2) 1961 to 1990. The minimum moisture input required for non-drought conditions in the 12 months time-step used in this analysis is crucial determined by rainfall. Rainfall which controls growing seasons in Africa swings between dry and wet seasons and this makes flood and drought a common feature. There is a general southward increase in the mean thirty-year annual precipitation in both regions/basin. LCB is wetter over the 30 years with mean total annual rainfall increasing from 200 to 400 mm in areas around the lake to 1000 and 1500 mm on the southwest and southeast of LCB respectively. The coefficient of rainfall varies from 15 to 30% and is in agreement with Fox and Rockström (2003). In Somalia on the other hand, the maximum annual rainfall was between 200 to 400 mm in the northwest and near 500 mm in the southwest edge on the country. In the northeastern edge however the mean annual precipitation is less than 100 mm. Because of the frequency of these rainfall extremes in LCB (Sahel) and Somalia (horn of Africa) some analysts have questioned the relevance of the notion for ‘normal rainfall’ in both regions (Hulme, 2001). The existence of the natural and societal systems thus depends on their capacity to adapt to this fluctuating rainfall supply (Mortimore and Adams, 2001).

Another similarity is the distribution of surface water bodies in both cases compared to the rest of the African continent (Figure 1). While the northeast and northwest regions are characterized by intermittent water bodies, the southern parts have a few perennial rivers that act as lifeline to agricultural activities and human needs. Permanent base flow sustains the perennial rivers while intermittent rivers have low seasonal flow and dry up quickly at the onset of drought. Studies by Lienou et al. (2005) in northern Cameroon show that the stream flow does not reach the large rivers. During mild and prolonged drought years, the riverbeds of these intermittent streams are desiccated, primarily as a result of substantial water abstraction for irrigation and nomadic pasturing. This led to the drilling of many uncapped boreholes and a large-scale irrigation system was constructed in the south of LCB (Lienou et al., 2005). Both schemes led to high evaporation losses and the irrigation system further failed due to the non-implementation of contingency plans during the drought periods (Isiorho and Njock-Libii, 1996). This diversion of water upstream is clearly an anthropogenic externality that reduces the amount of inflow downstream into Lake Chad.

The third similarity is the aridity index (AI) (Figure 3). It provide a simple way to express the ratio of precipitation

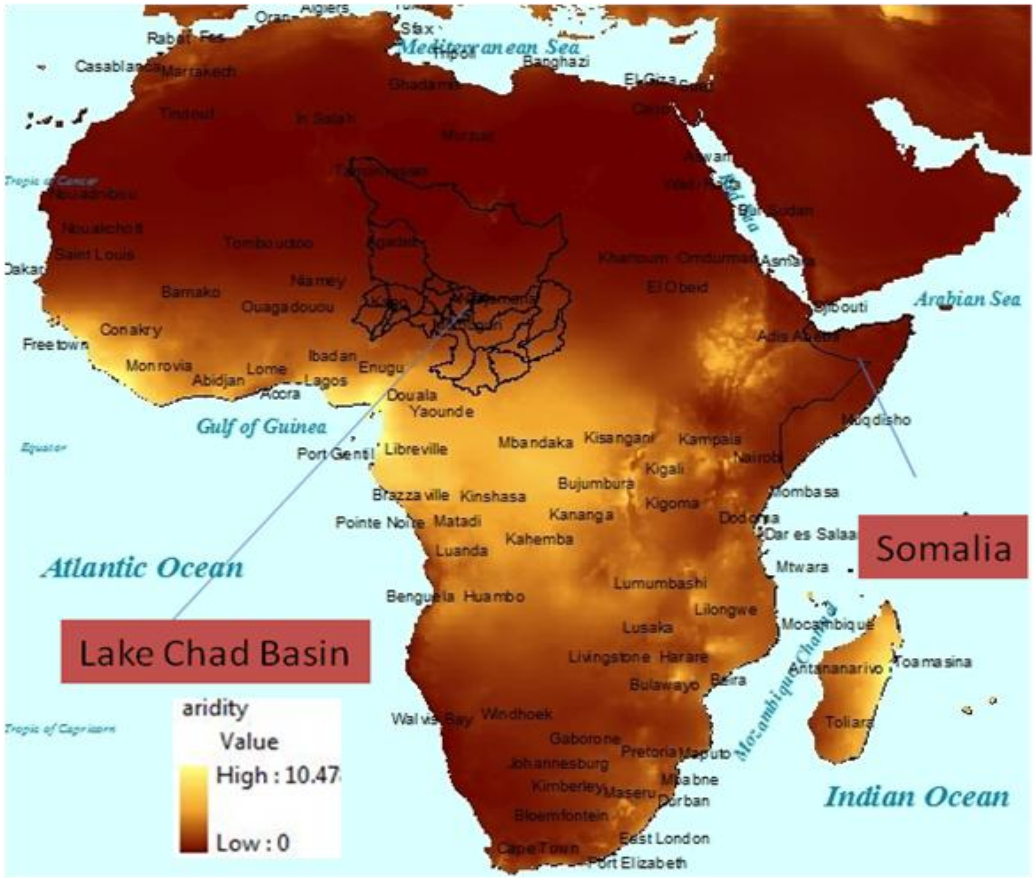

Figure 3. Aridity index for the African continent showing Lake Chad Basin (LCB) and Somalia.

to evaporation where high AI means a humid climate while a low AI means an arid climate. According to UNEP (1997) AI can be used to quantify precipitation availability over atmospheric water demand. The aridity representing the annual average over the 1950 to 2000 period was used. From Figure 3, the spatial distribution of AI is similar to that of surface water bodies. With the exception of southeastern part of LCB (with high index values), the rest of the study areas have very low AI. In LCB with low humidity and shallow lake depths (mean ~5 m), ~80% of the lake's water is lost through evaporation (Crétaux and Birkett, 2006).

This low AI means low moisture availability for potential growth of vegetation and low soil water holding capacity and subsequently high drought vulnerability. That is why Kogan (1997) suggested the possibility of integrating soil moisture measurements and vegetation indices obtained from satellite data in drought monitoring.

Differences

Drought being cyclic and regional in nature are controlled primarily by mean annual rainfall which itself depend on atmospheric circulation dynamics, sea surface temperatures (SST), latitude and mesoscale ocean currents among others. The differences between the two regions will be examined more closely with climate prediction center (CPC) merged analysis of precipitation (CMAP) of Xie and Arkin (1997). This is a data set that contains global monthly precipitation analyses from both satellite estimate and rain gauge observations.

The climate anomaly monitoring system (CAMS) outgoing longwave radiation (OLR) precipitation index ("OPI") - CAMS OPI standard precipitation index (SPI) analysis for the two regions indicates increase in SPI value from 0 (near normal) in 2009 to around 2.5 (extremely wet) in 2010 south of Lake Chad Basin. In Somalia however, there was a decrease in SPI value from 0 in 2009 in the entire country to -2 (extremely dry) in 2010 in northeast regions (Figure 4).

Because the SPI is normalized, drier and wetter climate can be represented in the same way. While 0 SPI value is classified as mild drought, -2 SPI identify an extreme drought (Table 1). Extreme drought with SPI value of -2.00 or less happen twice per century while an SPI value of 0 to -1 which is close to normal may happen up to 34 times per century. Food production in Somalia through agriculture is highly dependent on rainfall deficit. Funk (2011) found that after a period of persistent poor rains

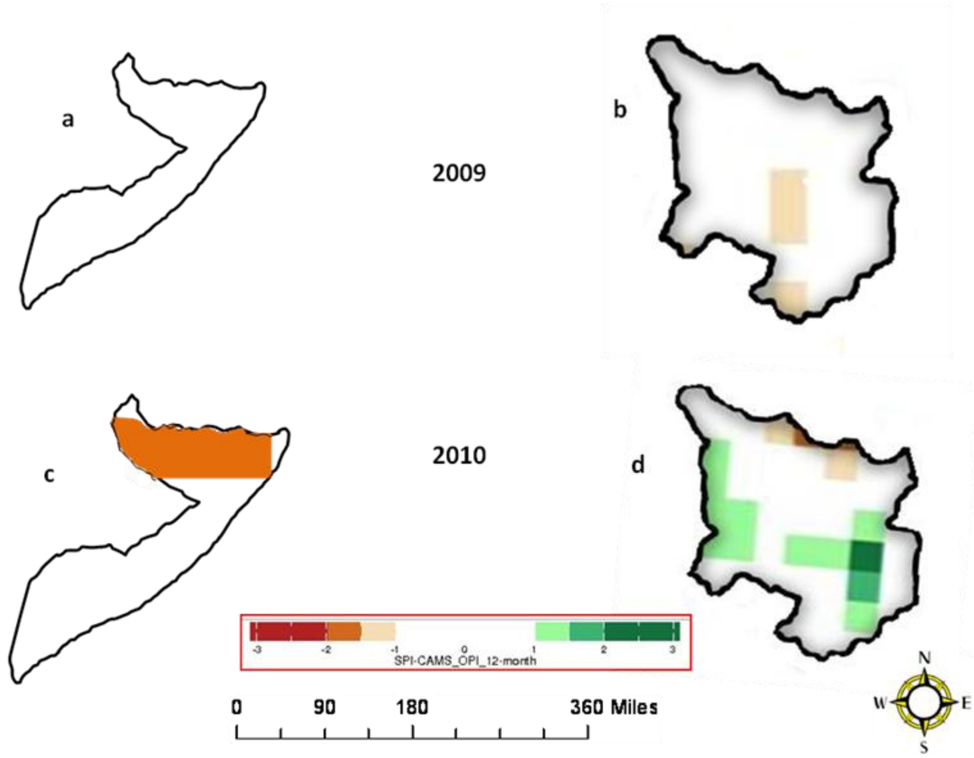

Figure 4. Climate anomaly monitoring systems CAMS OPI standard precipitation index (SPI) for Lake Chad Basin (LCB) (b. d.) and Somalia (a. c.) in 2009 and 2010.

Table 1. Standard precipitation index (SPI) Classification (Hayes et al., 1999).

SPI value	Classification
2.0 and above	Extremely wet
1.5 to 1.99	Very wet
1 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.00 to -1.49	Moderately dry
-1.50 to -1.99	Severely dry
-2.00 and less	Extremely dry

during the past decade, the autumn 2010 rains were poor. The extended drought from 2009 to 2010 (Figure 4a and c) in Somalia severely damaged the vegetation as a result of deficient moisture. Continued decreases in precipitation (2010 to 2011) southwards in Somalia appear to have triggered the present drought and famine the entire horn of Africa is currently witnessing (McKee et al., 1993, 1995; Hayes et al., 1999).

Zhao and Running (2010) reported an extremely small reduction, 0.55 petagrams of carbon (Pg C), in global terrestrial net primary production of 535.21 Pg C over a ten-year period 2000 to 2009. From Figure 5 however, the NPP has been increasing gradually in LCB since 2007, -30 ($gcm^{-2}yr^{-1}$) in southwest to about 10 ($gcm^{-2}yr^{-1}$) in 2010. The increase was more remarkable in southeast; 0 ($gcm^{-2}yr^{-1}$) - 10 ($gcm^{-2}yr^{-1}$) in 2007 to near 100 ($gcm^{-2}yr^{-1}$) in 2010 corresponding to similar increment in SPI value. In contrast however, Somalia has seen NPP hovering around -10 ($gcm^{-2}yr^{-1}$) in south of Somalia and -20 ($gcm^{-2}yr^{-1}$) in the north in 2007. 1n 2009, the NPP dropped sharply to near -80 gram carbon per square meter per year everywhere in the Somalia.

Reduction in adverse climate control on plant growth between 1982 and 1989 led to increase in Terrestrial net primary production (NPP) (Nemani et al., 2003) which makes NPP a drought indicator. The extremely dry drought in Somalia (2009) and moderately dry drought in LCB (2007) reduced annual NPP of forested ecosystems, thus the pronounced negative values.

Since the last mild drought of 1992 in LCB, there appears to be a continued recovery as shown from the temporal distribution of NPP in agreement with the findings of Ellis and Swift (1988) and Sullivan and Rohde (2002a). As expected, the spatial distribution of NPP (Figure 5) is highest in southeastern part of LCB, corresponding to 30 years average rainfall distribution (Figure 1). While Lamprey (1988) found that the southern boundary of Sahara desert vegetation had shifted southward by 90 to 100 km during the 17-year period from 1958 to 1975, Hellden (1984) in a field study in the same area found no evidence of such an expansion. The spatial distribution of NPP from this study appears to be

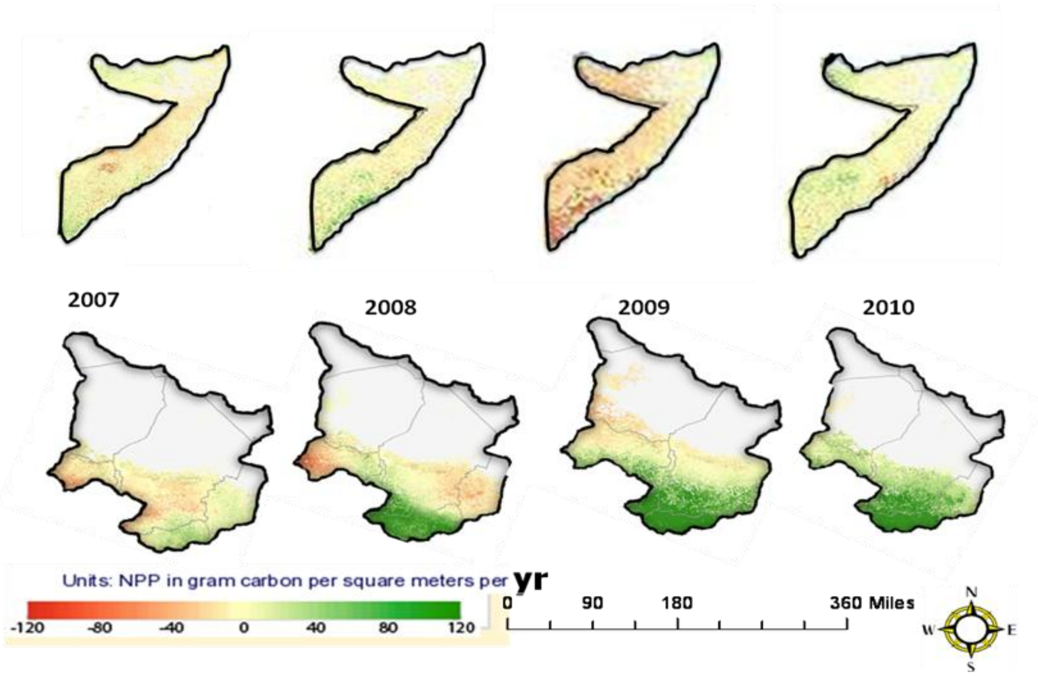

Figure 5. Terrestrial net primary production of in gram carbon per square meter per year between 2007 and 2010 (a. Somalia; b. Lake Chad Basin).

in agreement with Hellden (1984). The disagreement in the findings can be explained by the dynamic nature of drought. This clearly underscores the need for a more research on the dynamics of drought in these two regions and continuous monitoring of the spatial and temporal distribution of drought indices as an early warning mechanism.

CONCLUSIONS AND RECOMMENDATIONS

This research has provided scientific insight on the similarities and differences in drought indices in Somalia and LCB. The findings from this research suggest that LCB is not experiencing similar fate as Somalia partly because the Sahel region today may have been receiving just enough precipitation. The close hydro meteorological similarities should however serve as timely scientific input for policy makers in LCB and international organizations for sustainable water resources development and management in LCB.

The primary responsibility of providing access to safe drinking water however still lies with the local and national governments in individual countries. To date, most River basin agencies within LCB have promoted quick and cosmetic solutions that, while 'rational', have generated mixed results. Sustaining services continues to be a problem, and integrated water resources management (IWRM) by the Lake Chad Basin Commission (LCBC) remains an aspiration rather than a reality.

One reason for this is that current approaches to water resources management are missing practical realities of drought and famine. The nightmarish scenario of water-starved mothers and children currently facing severe drought in Somalia should be enough to compel action form leaders of countries within the LCB and international organizations. The famine in the Somalia has provided that missing piece and time to act in LCB is now.

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