Science of the Total Environment 610–611 (2018) 691–702

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Influence of coupled ocean-atmosphere phenomena on the Greater Horn of Africa droughts and their implications

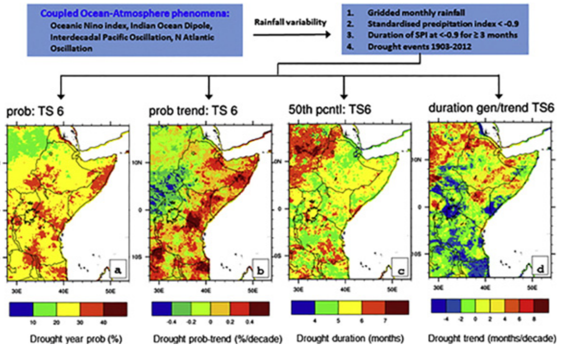
Freddie Mpelasoka [a], Joseph L. Awange [b,*], Ayalsew Zerihun [c]

[a] *Hydrometeorology Independent Researcher, Canberra, Australia*
[b] *Department of Spatial Sciences, Curtin University, Perth, Australia*
[c] *Centre for Crop and Disease Management, Department of Environment and Agriculture, Curtin University, Perth, Australia*

HIGHLIGHTS

- Zonality in drivers of drought occurrence over the GHA
- Probabilities of drought-year occurrences range from 10 to 40%.
- Most droughts last 14 and 24 months for the 12- and 24-month timescales
- Drought areal-extent decadal trends range from −0.6%, Tanzania to 3.7%, Ethiopia.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 16 May 2017
Received in revised form 21 July 2017
Accepted 11 August 2017
Available online 17 August 2017

Editor: D. Barcelo

Keywords:
Drought
Greater Horn of Africa
Climate variability
Climate shift
Drought management
Drought related humanitarian crisis

ABSTRACT

Drought-like humanitarian crises in the Greater Horn of Africa (GHA) are increasing despite recent progress in drought monitoring and prediction efforts. Notwithstanding these efforts, there remain challenges stemming from uncertainty in drought prediction, and the inflexibility and limited buffering capacity of the recurrent impacted systems. The complexity of the interactions of ENSO, IOD, IPO and NAO, arguably remains the main source of uncertainty in drought prediction. To develop practical drought risk parameters that potentially can guide investment strategies and risk-informed planning, this study quantifies, drought characteristics that underpin drought impacts management. Drought characteristics that include probability of drought-year occurrences, durations, areal-extent and their trends over 11 decades (1903–2012) were derived from the Standardized Precipitation Index (SPI).Transient probability of drought-year occurrences, modelled on Beta distribution, across the region ranges from 10 to 40%, although most fall within 20–30%. For more than half of the drought events, durations of up to 4, 7, 14 and 24 months for the 3-, 6-, 12- and 24-month timescales were evident, while 1 out of 10 events persisted for up to 18 months for the short timescales, and up to 36 months or more for the long timescales. Apparently, only drought areal-extent showed statistically significant trends of up to 3%, 1%, 3.7%, 2.4%, 0.7%, −0.3% and −0.6% per decade over Sudan, Eritrea, Ethiopia, Somalia, Kenya, Uganda and Tanzania, respectively. Since there is no evidence of significant changes in drought characteristics, the peculiarity of drought-like crises in the GHA can be attributed (at least in part) to unaccounted for systematic rainfall reduction. This highlights the importance of distinguishing drought impacts from those associated with new levels of aridity. In principle drought is a temporary phenomenon while aridity is permanent, a difference that managers and decision-makers should be more aware.

---

* Corresponding author.
E-mail address: J.awange@curtin.edu.au (J.L. Awange).

http://dx.doi.org/10.1016/j.scitotenv.2017.08.109
0048-9697/

1. Introduction

The Greater Horn of Africa (GHA) shares many common experiences with the rest of the world when it comes to impacts of drought. However, the impacts of drought in some Member States of the GHA region often appear to have more adverse effects on sustainable development than elsewhere in similar developing countries (Venton, 2012). For example, for the southern Africa region, drought in Botswana is regarded as a learning opportunity to improve/achieve water security (UN, 2017). But for the GHA region, rather than responding successfully to the frequent recurrent droughts that afflict the region, the communities are invariably devastated by famine crisis, instabilities in national economies and political tensions. For example, the Ethiopian “biblical” famines of 1973–74 and 1984–85 left about 200,000 and 400,000, people dead, respectively, with the former disaster resulting in the overthrow of Emperor Haile Selassie (Baroody, 1995; Jansson et al., 1987). The latter contributed to the end of the Marxist regime of Mengistu Haile Mariam (LAT, 1991).

Nicholson (2014) describes the relatively recent drought related crisis in the GHA region that prevailed during much of the period 2008–2011 triggering extreme food shortages and massive migration. Currently, parts of GHA are in the midst of a major drought (IGAD, 2017). The most affected areas include most of Somalia, south-eastern Ethiopia, north-eastern and coastal Kenya, and northern Uganda, with Somalia and parts of Kenya facing severe famine. It is increasingly alarming that being in dire need of food assistance in the GHA is becoming a permanent feature of the region. Almost every year, including 2014, 2015, 2016 and 2017, famine headlines appear in the news as drought related crisis (FAO, 2017).

While droughts may continue to be a major problem for some regions of the GHA, other factors such as armed conflicts and international politics are invariably responsible for propelling a situation of economic hardship caused by droughts (FAO, 2007). For example, on a long-term basis, environmental degradation, poor water resource management and poor governance are important compounding causes of severe drought impacts in the region (UN, 2014). More importantly, aridity reconstruction studies (Tierney et al., 2015) show that the region is increasingly becoming drier. This systematic persistent decline in rainfall, particularly during much of the region's primary rainy season (March-April-May) is evident in the last 30 years' rainfall record (Williams and Funk, 2011; Lyon and Dewitt, 2012). Whether this decline trend is associated with internal multi-decadal climate variability due to changes in the tropical Pacific (Yang et al., 2014; Lyon and Dewitt, 2012) or anthropogenically driven warming in the Indian Ocean or western Pacific region (Liebmann et al., 2014), its impacts are yet to be distinguished from those associated with droughts. The impact of changes in aridity levels is often hardly distinguished from that of droughts. Drought is a recurrent feature of climate variability that occurs in virtually all climate regimes, and is different from aridity which is a rather permanent feature (Mpelasoka et al., 2008). Similarly, as the underlying impoverishment of population increases, it is increasingly more difficult to distinguish between humanitarian crises triggered by drought impact and those stemming from chronic poverty (FAO, 2007).

Indeed, there are still many challenges in monitoring and prediction capabilities, as well as a perspective of the current understanding of drought and key research gaps. For example, almost all drought studies reiterate the influence of ENSO phenomenon on drought occurrences, with respect to drought prediction. However, there are other important ocean-atmosphere phenomenon such as the Indian Ocean Dipole (IOD), Inter-decadal Pacific Oscillation (IPO) and the North Atlantic Oscillation (NAO). The main challenge is to account for the interactions of different systems of climate variability and their teleconnections (Swetnam and Betancourt, 1998; Cook et al., 1999; Cordery and Mccall, 2000; Murphy and Timbal, 2008). The overall influence of climate variability drivers depends on their concurrent modes (Behera et al., 2006). Hence, this is the main source of uncertainty in predictions of climatic extremes including droughts particularly, when they are solely based on ENSO phenomenon (Kane, 1997). In addition to limited prediction skill, possibly the lack of flexibility in the impacted systems for the GHA underscore the effect of prediction. For example, currently, in Somalia and coastal Kenya cropping lands, 70% to 100% crop failure has been registered (IGAD, 2017). Livestock mortality has been particularly devastating among small ruminants with mortality rate ranging from 25% to 75% in the cross border areas of Somalia-Kenya-Ethiopia. This is happening regardless of early warnings by the Inter-Governmental Authority on Development, potentially meant to elicit early actions (preparedness and mitigation measures). Apparently, moving from crisis to risk management in the GHA requires planning that places more weight on risk assessment and the development and implementation of mitigation actions and programs as suggested in Wilhite et al. (2000).

This study has three main objectives: (1) quantification of the variation of influence among climate variability drivers across the region; (2) quantification of drought characteristics that underpin drought impacts management; and (3) examination of consistence of current increase in drought-like crises with trends in drought characteristics over the GHA region; The analyses include: (i) relating drought occurrences with climate variability drivers; (ii) modelling of transient probability of drought-year occurrences; (iii) determining drought duration; (iv) determining drought areal-extent; and (v) examining trends in rainfall.

2. Data and methodology

2.1. Data

Monthly rainfall for the 1901–2013 period on a 0.1° × 0.1° grid across the GHA region were drawn from the Centennial Trends Greater Horn of Africa precipitation dataset (Funk et al., 2015). The CenTrends data set provides a reasonably complete and accurate gridded precipitation products.

Sea Surface Temperatures (SSTs) drawn from the NCEP/NCAR Reanalysis dataset (Kalnay et al., 1996) for the 1948–2013 period were used. The SSTs were used to derive indices of four major climate variability drivers that include the Oceanic Niño *Index* (*ONI*), which represents the El Niño Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), Inter-decadal Pacific Oscillation (IPO) and the Northern Atlantic Oscillation (NAO).

2.2. Methodology

2.2.1. Identification of drought events

Monthly rainfall time series were transformed into the Standardized Precipitation Index (SPI), developed by Mckee et al. (1993) to capture rainfall variability from which occurrences of drought events were unveiled for the 1903 April–2013 March period. SPI is a probability index that gives a good representation of rainfall variability, quantifying abnormal wetness and dryness levels. Mathematically, SPI is based on the cumulative probability of a given rainfall event occurring at a location. The historic rainfall data of the location is fitted in to a gamma distribution, which fits the precipitation distribution quite well. The cumulative probability gamma function subsequently transforms into a standard normal random variable. For comparison purposes, the World Meteorological Organization (WMO) recommends the use of SPI in monitoring of dry spells (WMO, 2012).

Since much of rainfall is experienced in short rainy seasons and most of it often concentrates in a few heavy falls, small shifts in the large-scale weather patterns at different timescales significantly alter the amount and/or the distribution of rainfall. Therefore, we use SPI at four timescales to facilitate the interpretation and relevance of rainfall anomalies to different systems. For this study, we focused on the 3-month, 6-month, 12-month and 24-month timescales, which are generally relevant to a range of agricultural and hydrological systems. For a given