# Drought

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Contributor: Ephias Mugari

Droughts are an environmental challenge that often cause significant losses of livelihoods the world over. For instance, rain-fed agriculture, livestock production, biodiversity, and several ecosystem services (ES) that are fundamental to human well-being are increasingly threatened by more severe droughts [1][2].

Keywords: drought severity ; drought recurrence ; drought duration ; ecosystem products ; vegetation condition index ; remote sensing ; resilience ; semi-arid areas ; Limpopo Basin ; Botswana

## 1. Introduction

In the past 50 years, droughts alone have affected about 1.4 billion people globally [3]. In recent years, drought impacts have been particularly potent in semi-arid regions where many people uniquely depend on ecosystem products [4].

Droughts occur naturally when total annual precipitation is significantly below 650 mm, causing adverse consequences on natural vegetation and crop productivity [5]. Four types of droughts are identified in literature as meteorological, agricultural, hydrological, and socio-economic. **Meteorological droughts** occur when precipitation at any given location falls below the long-term average, spanning a period from a few months to several years. **Agricultural droughts** occur when soil moisture falls below crop requirements at any given time during or after a meteorological drought. **Hydrological droughts** are experienced when groundwater and surface water resources become insufficient as indicated by streamflow, surface, and groundwater levels. **Socio-economic drought** is experienced when a combination of the other three droughts interferes with the social, economic, and ecological systems causing undesirable consequences on human health, well-being and quality of life of indigenous communities. These definitions are well-articulated and illustrated by the National Drought Mitigation Centre at the University of Nebraska (https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx).

#### 2. Assessment of Droughts

Several methods for assessing droughts based on weather station precipitation data have emerged over the years. For instance, the Palmer drought severity index (PDSI), the standardized precipitation index and the moisture anomaly index (Z-index) all use weather station data. These techniques lack the spatial coverage and hence are only effective in assessing drought conditions in the vicinity of weather stations given the high variability of precipitation over short distances, particularly in semi-arid areas [6]. Although traditional methods to assess and monitor droughts rely on weather station precipitation, such data are often incomplete, unavailable or available for very short periods in many developing countries. Besides, the dynamism of precipitation over semi-arid regions, coupled with poorly distributed weather stations across Botswana and many other developing countries, limit more localized drought assessments and monitoring as noted by [7]. Without automated weather stations, such data are often not readily available and open to human error. Nonetheless, consistent remotely-sensed vegetation products offer an opportunity to monitor various aspects of droughts such as the onset, duration, severity, frequency and spatial distribution [8]. Moreover, in areas where weather stations are absent or sparsely distributed, remotely sensed data may be the only viable alternative data source. The vegetation condition index (VCI) based on the remotely-sensed products such as the normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI) have been used extensively to monitor drought onset, severity, duration, extent and impact the world over [7][9][10].

## 3. Effect of Droughts

Droughts drive changes in vegetation cover and consequently the delivery of those ES which depend on healthy vegetation. However, the extent to which droughts drive these changes depends on their severity, duration and recurrence [3]. While droughts are more prevalent over the semi-arid landscapes due to the adverse climate conditions experienced in these areas, they can naturally occur in any climate. In Botswana, the longest drought occurred between 1981 and 1987 lasting for seven years although widespread and devastating impacts were mostly experienced by the poor [11][12]. As the severity and recurrence of droughts are increasing globally, semi-arid areas are among the most threatened [3]. Nonetheless, the severity and duration of droughts over any area vary from one drought event to the other. For instance, some droughts occur for short periods but with severe impacts while others are mild but develop over an extended period.

Previous studies by [13][14][15][16][17][18] reveal various aspects of vegetation changes ranging from the condition and stature, to composition, in semi-arid landscapes. Considering the precipitation regimes in semi-arid and arid landscapes, droughts are among the chief drivers of vegetation degradation in these areas [15]. The consequences of vegetation change in semi-arid landscapes are varied [19][20][21]. Ref. [13] found that recurrent droughts were among the leading causes of loss of grasslands and grazing pastures by up to 86%. In Kenya, droughts were identified as being behind the decline in cultivated crop yields and conversion of woodlands to bush dominated landscapes [3][22]. With a huge dependence on the natural environment, especially among poor people in developing countries, the effects of droughts could be huge. According to [23], between 1994 and 2013, droughts accounted for 20% of the natural disasters affecting at least one billion people globally. Most of these people resided in developing countries.

A study by [24] found increasing severity and recurrence of droughts in Botswana the past two decades. Although lengthy drought periods have been recorded nationally in the early 1980s and 1990s, these were punctuated by non-drought years [25]. Since 2007, drought occurrence has been declared annually in different parts of the country showing increased frequency of droughts in recent years since the turn of the millennium [25].

**4. Implications for policy and practice**

The unchecked and drought-induced conversion of vegetation to rain-fed agriculture in Bobirwa sub-district could further expose the livelihoods of local communities. The more frequent, longer and more severe drought events in Bobirwa sub-district in the Limpopo Basin of Botswana, and possibly the entire of Botswana, which are characterized by more dynamic precipitation makes relying on poorly distributed weather station precipitation data alone inadequate. Vegetation condition index derived from remotely sensed NDVI provides a better alternative to assess spatial dynamics of droughts in data-poor regions such as Bobirwa sub-district. The variable response of vegetation to recent droughts shown in this study suggests increasing occurrence of more severe droughts and/or variable susceptibility of different vegetation types which requires more conservation measures to protect biodiversity which underpins the delivery of several essential ecosystem products. With droughts also triggering land-use changes that often cause adverse trade-offs with the delivery of several ecosystem services in Bobirwa sub-district, there exists an urgent need to increase agricultural productivity through smallholder irrigation development using groundwater in order to enhance crop yields. Higher crop yields may help curb agricultural expansions into natural vegetation, a measure used to salvage crop yields during drought periods. Smallholder irrigation development thus can effectively improve yields, reduce demand for agricultural land, increase food availability and local incomes while also providing a sustainable pathway to adaptation in semi-arid landscapes. The Meteorological Services Department needs to increase the weather stations in the sub-district and to also provide more localized seasonal forecasts in order to enhance decision-making.

## References


1. IPCC. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Cambridge University Press: Cambridge, UK, 2014.
2. Liu, W.; Sun, F.; Lim, W.H.; Zhang, J.; Wang, H.; Shiogama, H.; Zhang, Y. Global drought and severe drought-affected populations in 1.5 and 2 °C warmer worlds. Earth Syst. Dyn. 2018, 9, 267–283.
3. Kosonei, R.C.; Abuom, P.O.; Bosire, E.; Huho, J.M. Effects of Drought Dynamics on Vegetation Cover in Marigat Sub-County, Baringo County, Kenya. Int. J. Sci. Publ. 2017, 7, 89–98.
4. Bagley, J.E.; Desai, A.R.; Harding, K.J.; Snyder, P.K.; Foley, J.A. Drought and Deforestation: Has Land Cover Change Influenced Recent Precipitation Extremes in the Amazon? J. Clim. 2014, 27, 345–361.
5. Kogan, F.N. Global Drought Watch from Space. Bull. Am. Meteorol. Soc. 1997, 78, 621–636.
6. Kogan, F.N. Remote sensing of weather impacts on vegetation in non-homogeneous areas. Int. J. Remote Sens. 1990, 11, 1405–1419.
7. Quiring, S.M.; Ganesh, S. Evaluating the utility of the Vegetation Condition Index (VCI) for monitoring meteorological drought in Texas. Agric. Meteorol. 2010, 150, 330–339.
8. Singh, R.P.; Roy, S.; Kogan, F. Vegetation and temperature condition indices from NOAA AVHRR data for drought monitoring over India. Int. J. Remote Sens. 2003, 24, 4393–4402.

9. Dutta, D.; Kundu, A.; Patel, N.R.; Saha, S.K.; Siddiqui, A.R. Assessment of agricultural drought in Rajasthan (India) using remote sensing derived Vegetation Condition Index (VCI) and Standardized Precipitation Index (SPI). Egypt. J. Remote Sens. Sp. Sci. 2015, 18, 53–63.
10. Liu, W.T.; Kogan, F.N. Monitoring regional drought using the Vegetation Condition Index. Int. J. Remote Sens. 1996, 17, 2761–2782.
11. Bhalotra, Y.P.R. The Drought of 1981–87 in Botswana; Department of Meteorological Services: Gaborone, Botswana, 1987.
12. Fako, T.T.; Molamu, L. The Seven-Year Drought, Household Food Security and Vulnerable Groups in Botswana. Pula Botsw. J. Afr. Stud. 1995, 9, 48–70.
13. Abate, T.; Angassa, A. Conversion of savanna rangelands to bush dominated landscape in Borana, Southern Ethiopia. Ecol. Process. 2016, 5, 1–18.
14. Brandt, M.; Mbow, C.; Diouf, A.A.; Verger, A.; Samimi, C.; Fensholt, R. Ground- and satellite-based evidence of the biophysical mechanisms behind the greening Sahel. Glob. Chang. Biol. 2015, 21, 1610–1620.
15. Brandt, M.; Verger, A.; Diouf, A.; Baret, F.; Samimi, C. Local Vegetation Trends in the Sahel of Mali and Senegal Using Long Time Series FAPAR Satellite Products and Field Measurement (1982–2010). Remote Sens. 2014, 6, 2408–2434.
16. Leroux, L.; Begue, A.; Lo Seen, D.; Jolivot, A.; Kayitakire, F. Driving forces of recent vegetation changes in the Sahel: Lessons learned from regional and local level analyses. Remote Sens. Env. 2017, 191, 38–54.
17. Mosugelo, K.; Moe, S.; Ringrose, S.; Nellemann, C. Vegetation changes during a 36-year period in northen Chobe National Park, Botswana. Afr. J. Ecol. 2002, 40, 232–240.
18. Ringrose, S.; Matheson, W.; Wolski, P.; Huntsman-Mapila, P. Vegetation cover trends along the Botswana Kalahari transect. J. Arid Environ. 2003, 54, 297–317.
19. Winowiecki, L.; Vågen, T.-G.; Huising, J. Effects of land cover on ecosystem services in Tanzania: A spatial assessment of soil organic carbon. Geoderma 2016, 263, 274–283.
20. Dias, L.C.P.; Macedo, M.N.; Costa, M.H.; Coe, M.T.; Neill, C. Effects of land cover change on evapotranspiration and streamflow of small catchments in the Upper Xingu River Basin, Central Brazil. J. Hydrol. Reg. Stud. 2015, 4, 108–122.
21. Coe, M.T.; Costa, M.H.; Soares-Filho, B.S. The influence of historical and potential future deforestation on the stream flow of the Amazon River—Land surface processes and atmospheric feedbacks. J. Hydrol. 2009, 369, 165–174.
22. Huho, J.M.; Kosonei, R.C. Understanding Extreme Climatic Events for Economic Development in Kenya. IOSR J. Env. Sci. Toxicol. Food Technol. 2014, 8, 14–24.
23. Miyan, M.A. Droughts in Asian Least Developed Countries: Vulnerability and sustainability. Weather Clim. Extrem. 2015, 7, 8–23.
24. Mogotsi, K.; Nyangito, M.M.; Nyariki, D.M. The role of drought among agro-pastoral communities in a semi-arid environment: The case of Botswana. J. Arid Env. 2013, 91, 38–44.
25. Statistics Botswana. Botswana Environment Statistics: Natural Disaster Digest 2017; Ministry of Finance and Development Planning: Gaborone, Botswana, 2018.