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Drought risk mapping of south-western state in the Indian peninsula – A web based application

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ABSTRACT

Application of geospatial technology is very shimmering in drought monitoring. Drought severity in crops for six northern districts of Kerala has been attempted using Geospatial Techniques. Normalized Difference Vegetation Index (NDVI) is the major parameter used to measure vegetation health obtained from MODIS, Terra satellite products MOD13Q1, MOD02QKM. The mean Normalized Difference Vegetation Index (NDVI) of Kerala state over 13 years was calculated. The daily anomalies of NDVI from its long term mean NDVI over the same period was determined based on which drought risk classification was done. High negative NDVI anomaly areas are susceptible to drought and the severity of drought risk on each crop can be identified using Land Use/Land Cover data. Overlaying daily NDVI Anomaly based drought risk map on land use/land cover map gives the drought risk for different crops. Based on this, a web application has been developed for Northern districts of Kerala state in India. This web application can be used to plan for drought management measures and can also serve as a database for drought analysis.

1. Introduction

Drought is considered by many to be the most complex but least understood of all natural hazards, affecting more people than any other hazard (Hagman, 1984; Wilhite, 2000). Drought is defined as a prolonged abnormally dry period when there is not enough water for user's normal needs, resulting in extensive damage to crops and a loss of yields (Wilhite, 2005). It should be considered relative to some long term average condition rather than absolute condition (Wilhite and Svoboda, 2000). An extreme climatic condition like drought poses severe damage to crops, livestock and humans and the associated economic repercussions are huge (Al-Riffai and Breisinger, 2012; Gupta et al., 2014; Lin et al., 2013). Unlike other natural disasters, drought impacts large areas and for extended periods of time. Hence it is important to monitor the duration, frequency and spatial extent of drought using relevant indices to provide planners with useful information required to plan for disaster response measures (WMO, 2006). Since drought as a condition of precipitation deficit start as a reduction in soil moisture, agriculture is the sector that is affected first (WMO, 2006). 68% of the net sown area in India is vulnerable to drought conditions. A decrease in 17.9% of food grain production during the drought of 1987, has led to a 3.2% decline in agricultural GDP of the country (Murthy and Sesha Sai, 2010).

India Meteorological Department (IMD) defines meteorological drought as a situation when the seasonal rainfall over the area is less than 75% of its long term average. Rainfall deficits between 26% and 50% is classified as moderate drought, and that more than 50% is classified as severe drought (India Meteorological Department, n.d). On an average, 28% of the geographical area in India is considered to be vulnerable to drought (Samra, 2004). The country has witnessed worst droughts in the years 1918, 1972, 1987, 2002 and 2009 (Indian Agricultural Statistics Research Institute, 2014). There has been an increase in the area affected by moderate droughts in the country, since 1951 (Kumar et al., 2013*)*. Even with an average annual rainfall of about 3000 mm, the state of Kerala is affected by occasional localized drought events. The state has experienced drought conditions in the years 1982–83, 1983–84, 1986–87, 1987–88, 2000–01and 2008–09 (Dinesan, 2013). A total of 693 villages in the state were affected by drought in the last ten years (Government of Kerala (2012)).

Drought monitoring and its assessment are carried out using various indices; Standardized Precipitation Index (SPI), Palmer Drought Severity Index (PDSI), Surface Water Supply Index (SWSI)

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and Bhame and Mooley Drought Index (BMDI) are the ones extensively used. BMDI is drought index used in drought intensity assessment of Northern Nigeria (Francis and Kayode, 2013) and the indices SPI and PDSI is used in U.S Drought Monitoring System. Remote sensing is far superior to conventional methods (Jain et al., 2009) for drought monitoring and early warning applications. Remote sensing data, or data from satellite sensors, can provide continuous datasets that can be used to detect the onset of drought as well as its duration and magnitude (Chopra, 2006; Mu et al., 2013; Thiruvengadachari and Gopalkrishna, 1993). Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), and Temperature Condition Index (TCI) are some of the extensively used vegetation based drought indices. Among this, Normalized Difference Vegetation Index (NDVI) is the most popular satellite based vegetation index used to measure vegetation health. . Web-based drought monitoring system has been developed by many international agencies. The Global Drought Monitoring Portal (GDMP), created in April 2011 serves as a global drought information system, through which users can access interactive maps on both global and regional drought conditions (http://www.drought.gov/gdm). International Water Management Institute (IWMI) has developed a regional drought monitoring system for South West Asia, which provides information on drought onset, progression and areal extent for Afghanistan, Pakistan and Western India (http://dms.iwmi.org/). A near real time global drought monitoring based on Standardized Precipitation Evapotranspiration (SPEI) index, the SPEI Global Drought Monitor, provides drought information at 0.5^0 spatial resolution and monthly time resolution. The present study was done with an objective to develop a regional drought monitoring system for Northern Kerala. This paper explains how the drought monitoring system was developed, utilizing open source components based on the NDVI anomaly, for the near real time drought monitoring of Northern Kerala in India.

2. Material and methods

2.1. Study area

Northern Kerala encompassing the districts of Kasaragod, Kannur, Kozhikode, Malappuram, and Wayanad located between 10° 20′ and 12° 47′ North latitudes and 74° 51′ and 76° 54′ East longitudes were selected for the study (Fig. 1). Palakkad, one of the driest districts of Kerala, was also included in the study. The entire region covers an area of 17,465 km^2. Northern Kerala receives an average annual rainfall of 3379 mm (Kandiannan et al., 2008). Long-term (1871–2005) trend analysis has shown a decreasing trend (−1.7 mm/year) in Southwest monsoon and an increasing trend (+0.7 mm/year) in post monsoon rainfall over the entire state (Krishnakumar et al., 2009). Analysis of one and half century of data from 1870 to 2006 has revealed that for 21.2% of years, the onset of monsoon in Kerala was between 4th and 8th of June (Prasada Rao, 2008).

The topographical conditions marked by steep slope facilitate the fast runoff of rainwater to the Arabian Sea. Other than the natural peculiarities, anthropogenic activities like decreasing forest area/land cover due to urbanization have also contributed to this rapid runoff. Relative humidity is in general high over the state. During monsoon, the relative humidity rises to about 85%for the state. The annual range of temperature is comparatively low in Kerala. The coastal areas record a maximum temperature of 32 °C and minimum of 22 °C. The midland area records a maximum of 37 °C during summer. In the coastal area it is hot and humid during April–May while cool during December–January (Dinesan, 2013). Climate in Kerala can be divided in to four season winter, Summer, South – West monsoon, North – East monsoon.

2.2. Materials and methodology

The study area was delineated from georeferenced toposheets in Quantum GIS. Details of toposheets used are given in Table 1. The satellite data used in this study are the freely downloadable MODIS Terra Satellite products MOD13Q1 and MOD02QKM. MODIS images are used since it provides continuous daily coverage and has been widely used in drought studies. Use of MODIS images facilitate near real time monitoring of drought. Images from other sensors are not used as there might be conflicts with the pixel resolution. The monitoring period of drought for the present investigation from the year 2000–2012. In Kerala, the summer season corresponds to the months of March–May, and is severe in the month of May. Hence images for May are used for this study. The open source tools, Map Server and Open Layers are used to publish the spatial maps in the web. IRS-P6 data was collected for Land Use/Land Cover classification.

Drought monitoring using remote sensing is based on three approaches: determining drought based on a relationship between drought and soil moisture, which is obtained from remote sensing observations; vegetation index calculated from satellite images and related to drought condition; using Land Surface Temperature derived from satellite images to detect drought (Cai et al., 2011). The 16 day composite 250 m resolution Terra MODIS data [MOD13Q1] from the year 2000–2012 were downloaded and re-projected using NASA's free MRT swath Reprojection tool. The NDVI of the study area were extracted from the re-projected data. Composite value of latest 16 day MOD02QKM product is used to remove cloud from daily image. From the difference of this latest 16 day composite NDVI and the long term NDVI mean for the same period NDVI anomaly is calculated. The mean NDVI of the area over the years 2000–2012 for each 16-day period was calculated and used as reference.

NDVI is associated with various biophysical properties of crops such as its biomass, canopy cover, leaf area index etc. and hence can represent agricultural drought effectively. Tucker first suggested NDVI in 1979 as an index of vegetation health and density (Thenkabail et al., 2004). The vegetation absorbs a great part of incoming radiation in the visible portion of the electro-magnetic spectrum (VIS: 380–730 nm) and reaches maximum reflectance in the near-infrared channel (NIR: 730–1100 nm) (Propastin et al., 2008). The NDVI, defined as ratio (NIR-VIS)/(NIR + VIS), represents the absorption of photosynthetic active radiation and hence is a measurement of photosynthetic capacity of the canopy. Negative NDVI values indicate non-vegetated areas such as snow, ice and water. Positive NDVI values indicate green vegetated surfaces, and higher values indicate increase in green vegetation. NDVI itself does not reflect drought or non drought conditions (Owrangi et al., 2011). But Anomaly of NDVI from the mean values was classified to determine the agricultural drought risk (Hasan Murad and Saiful

Table 1
Toposheets used for delineating the study area.

SL. no	Districts	Toposheet No:
1	KASARAGOD	48 L/14,48 P/2,48 P/6,48 L/15,48 P/3,48 P/7,48 P/4, 48 P/8
2	KANNUR	48 P/4,48 P/7,48 P/11,48 P/8,48 P/12,48 P/16,49 M/5,49 M/9, 49 M/13,48 M/10
3	KOZHIKODE	48 M/10,49 M/9,49 M/13,49 M/14,49 M/11,49 M/15,58 A/2, 58 A/3,49 M/16
4	WAYANAD	49 M/13,58 A/1,58 A/5,49 M/14,58 A/2,58 A/6, 58 A/3
5	MALAPPURAM	58 A/2,49 M/15,58 A/3,58 A/7,58 A/11,49 M/16,58 A/4,58 B/8, 49 N/13,58 B/1,58 B/5,49 N/14,58 B/2
6	PALAKKAD	58 B/8,58 A/12,58 A/16,58 B/1,58 B/5,58 B/9,58 B/13,58 B/2, 58 B/6,58 B/10,58 B/14,58 B/7,58 B/11,58 B/15

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