

Integration of temporal satellite image analysis in development of drought indicator – Jhod Nadi, India

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Abstract – Drought events in Indian Peninsula is due to timely and inadequate monsoon (June-September) rainfall. Ground water resources sustain the agricultural practices of the marginal farmers and village level drinking water supply. Indian Remote Sensing (IRS) satellite images of March 1998 and April 2006 were used in land cover demarcation and phenology and supplemented with ground observations. Physical and bio-physical indicators were integrated in identifying spatial distribution of drought vulnerable villages for short term measures.

Key words: Drought, IRS satellite, physical, meteorological indicators, vegetation cover, vulnerability

1. INTRODUCTION

Drought is the most complex phenomenon that is yet to be understood completely, irrespective of its occurrence at a regular interval in India. Most of the Government's policy in dealing with drought has been to wait till it rains and provide some form of emergency assistance to people. Long-term impacts and management of this phenomenon are often ignored. The parameters used in drought assessment are not linearly related to one another and often have little correlation within them. It is noticed that when one drought index identifies drought at a particular place, another drought index indicates a normal condition at the same place and time (Bhuiyan 2006). Use of lack of precipitation over a region (*Meteorology drought*) for a period of time is not appropriate for regions characterized by a year-round precipitation regime. A period with inadequate surface and subsurface water resources (*hydrological drought*) is applicable only to established water uses of a given water resources management system. It takes longer for precipitation deficiencies to show up in components of the hydrological system (Mishra & Singh 2004). Cropping season with declining soil moisture and consequent crop failure without any reference to available water availability is termed as *agriculture drought*. *Socio-economic drought* is associated with supply of and demand for economic goods that arise from water resources (forage, food grains, fish, and hydroelectric power). Instead of parametric approach an integrated region based approach in characterization and drought severity would help the people. Indicators of triggering mechanism need to specify the value, the time period, the spatial scale, the drought level and whether progressing or receding conditions.

Nearly 39% of the total cultivated lands in India are frequently affected by drought. The majority of them are from the monsoon dependent rain fed agriculture areas that receive in-adequate rainfall. Hence, deficit rainfall and water stress is reported from most of the river basins in Indian Peninsular. Ground water resources sustain the agricultural practices of the marginal farmers. Irrespective of timely on-set and availability of Asian South-west monsoon clouds at the southern tip of Indian land mass do not guarantee the drought free season (Nagarajan 2009).

temperature in successive years affect the growth of the natural vegetation and crop growth. The localized amount and duration of rainfall play a crucial role in initiation of drought event.

An attempt has been made in integrating the physical indicators such as rainfall, ground water level, soil moisture and biophysical indicators such as water holding capacity of soil and plant vigor in understanding the drought process and demarcating villages that are vulnerable to drought conditions.

2. STUDY AREA - Jhod Nadi

653 sq.km area of Jhodi nadi watershed (Latitude 18⁰50' – 19⁰10'N; Longitude 77⁰00' – 75⁰ 15'E), a tributary of Godavari River, spread over monsoon semi-arid region of India, has been identified for this exercise. 80% of the rainfall (mean 800-1000mm) is received during June to September/October and rest during January-March. It has 98 revenue villages and 6 rain gauges (they are 10-20kms away from each other) are located in this watershed, in addition to seven lakes / ponds (no maintenance). There is no developed water use or resources system. No significant flow (level and duration) in the fourth order stream is observed during the monsoon season. Once in 2 or 3 years, most of the villages are declared as drought affected. Deccan volcanic group rocks and their weathered section are observed. Shallow aquifer is exploited by open dug wells and fractures at depth by bore wells. Lateritic, black and sandy soil is present. The clay content is on the top layers (70%). The open areas contain soil with cobbles and pebbles. Soil along the river banks is deep and clayey is classified as coarse shallow and medium black and deep black soils. Sugar cane and Jowar are the major crops.

Daily (10years), monthly (30year) and yearly rainfall (100years) data available from the rain gauges and sunshine and temperature information, collected from agencies were obtained. Soil type, texture and water holding capacity (60cm depth) were determined in the laboratory as found to have 7 to 10inches/inch. Crop types – Jowar & pulses. Revenue village boundary and demography and land use information of the census and revenue departments were utilized. Indian Remote sensing satellite data of Indian Space Research organization is used. ArcInfo - Geographical Information System was used in spatial integration and analysis.

3. ANALYSIS

3.1 Meteorology

The observed date of the first monsoon rain which is of concern (20 mm/day) to agriculture practices varies between 8th June and 24th June in the past 30 years. 7 to 10 days variation is noticed between rain gauges. Sunshine varies between 3.8 and 7.7; and temperature from 19.9⁰ to 35.5⁰C. Histogram showing the annual rainfall is shown in Figure 1. Mean annual rainfall (period 1901-

A continuous spell of poor rainfall in combination with high

Decadal mean varies between 626.34mm (2001-07) and 1130.64 mm (1951-60). The variation indicates the extent of reliability. Weekly (crop week) analysis of the rainfall covering June – October was carried out in understanding the rainfall support for the crops. 20mm rainfall was considered as significant in soil moisturisation. 12 weeks out of 20 weeks (June-October) reported less than 20mm of rain, indicating requirement of supplementary (groundwater) irrigation source in meeting the crop water requirement. Surface runoff condition (>100mm) is achieved only during 4 to 5 weeks. Flow in the streams can be achieved/noticed only during this period (later part of July & August).

Standardized Precipitation Index (SPI) indicates the probability of precipitation deficit of a desired time scale (McKee et al 1993). It is used to identify the beginning and end of drought conditions and to describe drought severity. It is estimated as

$$SPI = \frac{X_{i,j} - X_{i,m}}{\sigma}$$

where $X_{i,j}$ is the seasonal precipitation at i th rain gauge station and j th observation, $X_{i,m}$, the long-term seasonal mean and σ is its standard deviation. Length of precipitation and data distribution has a significant impact on SPI. Moderate drought conditions during July, mild in August, moderate to severe conditions in June and September is indicated for this watershed (Figure 2). A need for supplementary groundwater based system at place and the financial back up is further confirmed.

3.2 Hydrology

Villages that are closer to the Godavari & Manar River use lift irrigation methods, tank command facility and majority depends on the rainfall and open dug well and bore well water (goes dry from January) for cultivation of winter and summer crops).

3.3 Satellite data

Orbital satellite data is used in the demarcation of Vegetation-stress areas initiated due to adverse climatic and hydrological factors and (Kogan 2004). IRS ID LISS-3 (sensor) having 141 km swath, 23.5 m resolution in its bands - B2: 0.52 - 0.59 μ m; B3: 0.62 - 0.68 μ m; B4: 0.76 - 0.86 μ m; and B5:1.55 - 1.70 μ m was used for vegetation cover and its healthiness information. The date of pass of satellite data is 27th April 2006 & March 1998. False Color Composite of the watershed as of March 1998 is shown in Figure 3. Healthy vegetation cover is noticed along the river course. Revenue village boundary layer was overlaid in geographical identification of villages and crops.

3.4 Vegetation Response index

Water is one among the factors of production potential for crop, human and livestock in addition other in-situ growth inducing parameters and dynamic conditions. Vegetation Drought Response Index (VegDRI) was used as an agricultural drought indicator in evaluating its relationship with crop yields during the critical periods over irrigated and rain fed areas in Nebraska, USA and found to be primarily an indicator of drought intensity and not a direct indicator of crop yield. It characterizes the

2007) of a rain gauge station (Loha) is about 924.4mm; while the

agricultural drought by integrating 1) Standardized Precipitation Index; 2) Percent of Average Seasonal Greenness; Start of Season Anomaly; Land Cover; Irrigated Agriculture and 3) Soils Available Water Capacity (Brown et al 2008). Soil water holding capacity, irrigation facility and weekly rainfall are combined to demarcate the integrated Vegetation Response Index (Figure 4). Higher the index, lower the drought probability and lower the index, higher the probability. Year wise agriculture decision making (to go for agriculture or not) process use these parameters.

3.5 Normalized Difference Vegetation Index NDVI

The Vegetation Condition Index (VCI) a ratio of NDVI collected in a given period compared to its historical range for the same period during multiple years of records is used to map drought pattern (Peters et al 2002). The crop yield is also influenced by management practices, hail, flooding, and insect infestations. Normalized Difference Vegetation Index (NDVI) has been in use for many years to measure and monitor plant growth (vigor), vegetation cover, and biomass production from multispectral satellite data. Vegetation stress occurs after irrigation water deficit affects the plant growth. For vegetation monitoring, the Seasonal greenness (SG) (mean of the same period from the historical database) is expressed as percentage by the formula: PASG = (Current SG/mean SG) * 100 (Tadesse et al 2005). Channel 1 is in the red region of the electromagnetic spectrum where chlorophyll causes considerable absorption of incoming sunlight, whereas Channel 2 is in the near-infrared region of the spectrum where a plant's spongy mesophyll leaf structure creates considerable reflectance (Tucker et al 1987). Vigorously growing healthy vegetation has low red-light reflectance and high near-infrared reflectance, and hence, high NDVI values. This relatively simple algorithm produces output values in the range of -1.0 to 1.0. Increasing positive NDVI values, shown in increasing shades of green on the images, indicate increasing amounts of green vegetation. NDVI ranges 0.538 to - 0.448. The values near zero and decreasing negative values indicate non-vegetated features such as barren surfaces (rock and soil) and water and cloud. Cropped areas were grouped into high, moderate and low chlorophyll content (growth dependant) and shown in Figure 5.

4. CONCLUSION

Crop production from semi arid regions is being considered as one among ways of improving the food security. Even though regional level assessment using coarse resolution satellite information are widely available, micro level information is rare or nil. The common and pertinent problems in the region are – 1) lack of adequate and timely rain fall (assured rain) for rain fed cultivation; 2) non-availability of developed water resources system; 3) degraded or neglected tank / ponds and ground water collection and abstraction system; 4) soil fertility and water holding capacity; 5) village level resources, demand and settlement information. Planning process begins with initial assessment of existing resource potential and carrying capacity. Integrated vegetation response index methodology is being followed by people.

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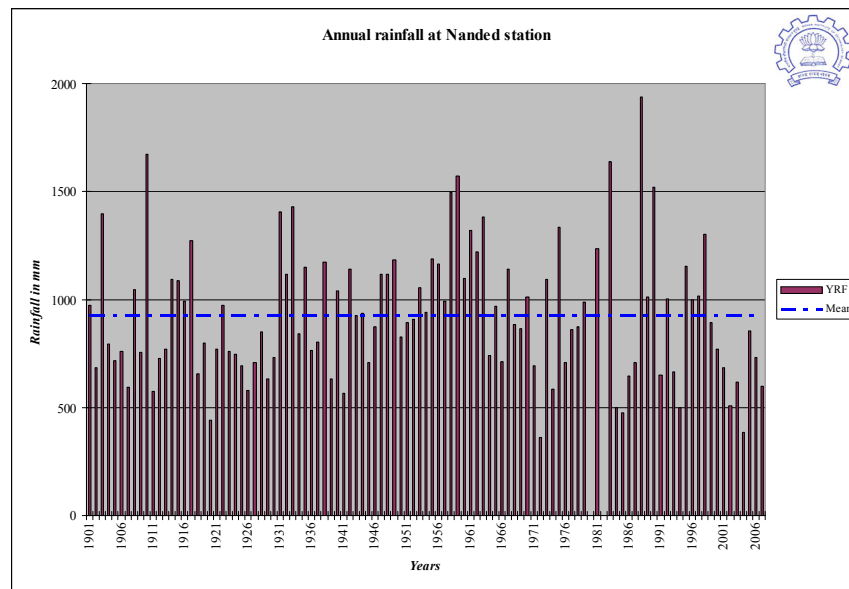
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Figure 1. Histogram showing yearly rainfall and decadal mean values



Source: Indian Meteorological department / Revenue department, Maharashtra
 Mean for: Total Years - 924.4 1901-1910 : 939.45 1911-20 : 841.23 1921-30 : 744.02 1931-40 : 1035.77 1941-50 : 939.06 1951-60 : 1130.64 1961-70 : 1024.38 1971-80 : 832.48 1981-90 : 1073.89 1991-2000 : 895.79 2001-07 : 626.34

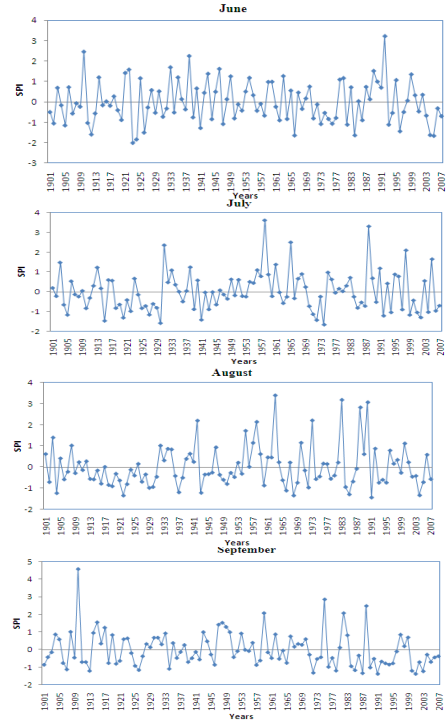
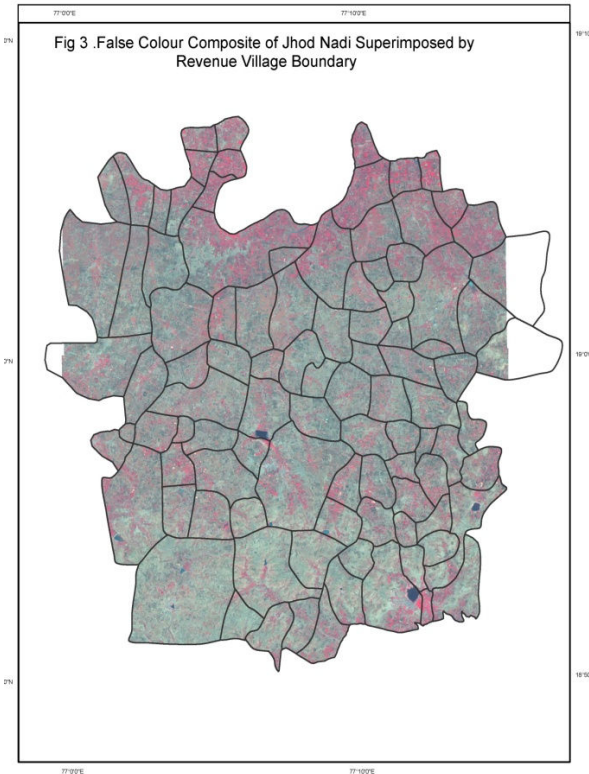


Figure 2. SPI index – Nanded station
 Mild drought (SPI: 0 to -0.99) Moderate drought (SPI: -1 to -1.49)
 Severe drought (SPI: -1.50 to -1.99) Extreme drought (>-2)

