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Analysis of Drought using NDVI and Land Surface Temperature derived indices- a Case Study of Sangareddy District

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ABSTRACT: Drought is one of the natural hazards characterized by shortage of water supply due to irregularities in the rainfall and increase in temperature rate that ultimately declines the moisture content and productivity of crops. The agriculture sector gets severely affected by these droughts impacting the livelihood of people depending on it. The present study was undertaken to estimate agriculture drought in Kandi mandal, Sangareddy district using geospatial techniques. The assessment of drought is done using indices NDVI (Normalized difference vegetation index), LST (land surface temperature), TCI (Temperature condition index), VCI (Vegetative condition index) & VHI (Vegetation condition index) for drought and normal year. The drought severity was triggered out in 2015-2016 due to the decreasing trend of vegetation identified from Normalized Difference Vegetation Index (NDVI). It was also noticed that both NDVI and LST values are inversely proportional to each other in both drought and normal year. When the temperature is more, the NDVI value found to be lesser which represents decrease in the vegetation density. The overall health of vegetation during drought and normal year monitored using Vegetation Health Index (VHI). The seasonal agricultural drought severity map block wise provides an overall idea of drought risk will help in planning the cropping pattern.

Keywords: Agriculture drought, Geospatial techniques, NDVI, LST, VHI.

INTRODUCTION

Drought in agriculture is a time of extreme dryness that affects soil moisture levels and inhibits plant development. When the amount of water needed for transpiration and evaporation exceeds the total amount of moisture available in the soil, drought occurs (Saxena *et al.,* 2019). Drought is a normal, recurring feature of climate and its characteristics as well as impacts vary from region to region. Normal rainfall during south west monsoon season is 890 mm for the country and 611 mm in north-west India, 994 mm in central India, 723 mm in southern India and 1427 mm in north east India (Sai *et al.,* 2016). In the year 2002–2003, India has faced one of the worst and exceptional drought episodes in terms of magnitude, spacing, dispersion and duration (Patel *et al.,* 2012; Dutta *et al*., 2013; Dutta *et al.,* 2015). The variability in amount of rainfall and its distribution results in delay in time of sowing and poor crop growth ultimately lead to decrease in crop production which strongly influences the livelihood opportunities. India is one of the ten countries facing substantial socio-economic risk as a result of increased drought in the changing climate scenario (Liu and Chen 2021). It is possible to reduce the impacts of drought by satellite image-based drought monitoring regularly. The satellite-based agricultural drought monitoring has become popular in recent years and widely used within various regions around the world. To attain sustainable growth in agricultural productivity and improve the livelihoods of the drought-prone people, agricultural drought monitoring is the most viable way for mitigating the problems on both local and regional scales (Sultana *et al.,* 2021). Over the past decades remote sensing has been extensively utilized to monitor agriculture drought. Various studies carried out round the globe found a strong correlation between the remotely sensed vegetation indices and soil moisture content (Dutta *et al*., 2015; Vyas *et al.,* 2015; Cong *et al.,* 2017; Ambika and Mishra 2019; Zuo *et al.,* 2019; Zou *et al*., 2020; Sandeep *et al*., 2021; Pogačar *et al.,* 2022).

Various remote sensing indices such as NDVI, VCI, TCI and VHI are available for drought monitoring, among which Normalized Difference Vegetation Index (NDVI) is the simplest and commonly used one. In India, Kulkarni *et al.* (2020); Das *et al.* (2013); Nageswara Rao *et al.* (2005), has used remote sensing techniques to assess agricultural drought. Changes in vegetation cover in an area and also the trend in occurrence of agricultural drought can be studied using the NDVI data of the region. This index is not free from defects such as error in data during rainy season and saturation effect on dense vegetation, etc. Merging with other parameters ensure more accuracy. LST is a good indicator of the energy balance at the Earth's surface which can provide important information about the surface physical properties and climate (Sruthi and Aslam 2015). A combination of NDVI and LST gives a good estimate of drought. Hence, an attempt has been made to map the agriculture drought which may help to change cropping pattern from highly water intensive crops like paddy in non-command areas to less water consuming irrigated dry (ID) crops.

MATERIALS AND METHODS

A. Description of the study area

The present study has been carried out in Kandi Mandal, Sangareddy district in Telangana. The study area is bounded between 17°58' N latitude, 78°10' E longitude and occupies the central place on Deccan plateau with 16 inhabited villages. Major crops cultivated are paddy, jowar, bajra, maize, wheat and Vegetables. The study area exhibits the semi-arid climate and the temperatures in the winter are cool ranging from 10°C to 28°C and in the summer the temperatures are hot ranging from 30°C to 45°C. The normal rainfall of the study area is 736 mm. The area receives 75 % of the rainfall through south west monsoon.

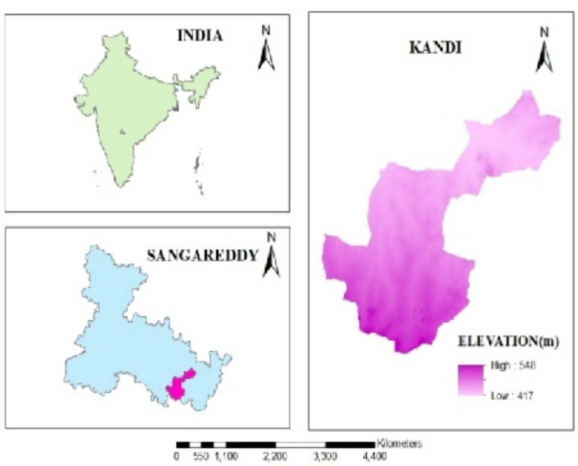

Fig. 1. Study area.

B. Generation of NDVI, VCI, TCI and VHI

The study utilized satellite images (Landsat 8 OLI/TIRS) for drought (2015-16) and non-drought year (2020-21) obtained from (https://earthexplorer.usgs.gov). The elevation map of the study area clipped from Cartosat-1. The downloaded datasets were used for the computation of remote sensing based drought indices; Normalized Difference Vegetation Index (NDVI), Vegetation condition index (VCI), Temperature Condition Index (TCI) and Vegetation Health Index (VHI). Data processing and analysis was done using Geospatial software's QGIS and Arc GIS 10.3.

(i) Normalize difference vegetation index (NDVI). NDVI is a good indicator of green biomass, pattern of production and leaf area index. The surface reflectance values of red and NIR bands of Land sat 8 used to create normalized difference vegetation index (NDVI). The spectral signature values of NDVI map varied between -1.0 and +1.0. A negative value (approaching -1) corresponds to deep water. The NDVI map generated in raster calculator was reclassified in to water bodies (-1 to 0), barren/built up/fallow (0 to 0.2) and vegetation (0.2 to 1.0).

$$\mathrm{NDVI} = \frac{\mathrm{NIR-RED}}{\mathrm{NIR+RED}} \qquad \ldots(1)$$

(ii) Vegetation condition index (VCI). Kogan (1995) established vegetation condition index to monitor local changes in ecosystem productivity. The estimation of VCI was required to retrieve another drought index VHI (Sultana *et al.*, 2021). The range of VCI varies from 0 for extremely unfavorable conditions to 100 for optimal conditions. Higher and lower values indicate good and bad vegetation state conditions, respectively. VCI was calculated using the following equation (2) (Kogan, 2004).

$$\mathrm{VCI} = 100*(\mathrm{NDVI} - \mathrm{NDVI}_{min})/\ (\mathrm{NDVI}_{max} - \mathrm{NDVI}_{min}) \qquad \ldots(2)$$

(iii) Temperature condition index (TCI). The areas with high cloud cover will be depicted wrongly as drought prone areas due to lower VCI values. To overcome such a problem the temperature-based indices can be used, which uses the thermal band derived brightness values to compute Temperature condition index, TCI (Aswathi *et al.,* 2018). The value of TCI varies from 0, for extremely unfavorable conditions to 100 for optimal conditions. TCI map generated based on LST observation from TIR remote sensing. Here, LST (Land Surface Temperature) is the radiative skin temperature of land in ºC which can be derived from thermal bands 10 and 11. The processing steps and formulas involves converting of DN (Digital number) to Satellite brightness temperature using constants K1 and K2 of satellite data (Ghaleb *et al*., 2015).

$$\mathrm{TCI} = 100*(\mathrm{LST}_{max} - \mathrm{LST})/\ (\mathrm{LST}_{max} - \mathrm{LST}_{min}) \qquad \ldots(3)$$

Where, LST = Current month LST value (˚C), LST_{max} & LST_{min} = Maximum and Minimum temperature (˚C) of multilayer. The TCI value depends on the vegetation condition of particular field. Similarly, LST based TCI is sensitive to water stresses (Patel *et al.*, 2012).

(iv) Vegetation Health Index (VHI). The index combining advantage of LST and NDVI is VHI. It has been developed using the VCI and TCI and is found to be more effective compared to other indices in monitoring vegetative drought (Kogan, 1990, 2001; Singh *et al.*, 2003, Kundu *et al.*, 2016)**.** This index integrates TCI and VCI to link the soil moisture and thermal stress in providing total vegetation health condition. The VHI can be calculated from equation given by Kogan (1997).

$$VHI = \alpha VCI + (1-\alpha) TCI \quad \ldots(4)$$

Where α is a parameter that measures the influence of individual components on the total vegetation health. The value of α is equaled to 0.5 (Kogan, 2001; Rojas *et al.*, 2011; Sultana *et al.*, 2021).

RESULTS AND DISCUSSION

The computed results of NDVI showed that vegetation is less in Feb 2016 (8.94 km^2) followed by December 2016 (12.22 km^2). Year wise comparison showed an increase in vegetation and decrease in barren/fallow/ built upland in 2021. For both drought and non-drought years February month is having less vegetation which may be due to harvesting of previous crop. The calculated NDVI value for different classes is presented in Table 1.

Temperature condition Index (TCI) map was generated using LST and are classified in to 5 classes as shown in Fig. 2. Mild to No drought observed in all the months of 2021; Extreme to moderate drought in 2016 which are 120.354 km^2 and 134 km^2 in Dec and Feb months respectively (Fig. 2). The percentage of area under drought is 90 % in 2016 and reduced to 3.6 % in 2021. Vegetation Condition Index (VCI) maps generated using NDVI for 2015-2016 and 2020-2021 years. The results revealed that most of the area under extreme drought in February 2016 (101.3 km^2) followed by Dec 2016 (52.58 km^2) and Feb 2016 (52.51 km^2). Less area is under drought in Dec 2021(24 km^2) followed by Feb 2021(78 km^2). The percentage area under drought is 63.44% and 18.07% in drought and normal year respectively (Fig. 3).

Table 1: NDVI classes and percentage of area under each class.

NDVI Density Class	2016 NDVI Class Area km^2		2021 NDVI Class Area km^2	
	Dec	Feb	Dec	Feb
Water Bodies	0.087	0.0229	1.846	2.2053
Built up/barren/fallow land	122.096	125.445	67.6168	111.534
Vegetation	12.22	8.9469	64.9124	20.6671
% area under vegetation	9.09	6.65	48.2	15.3

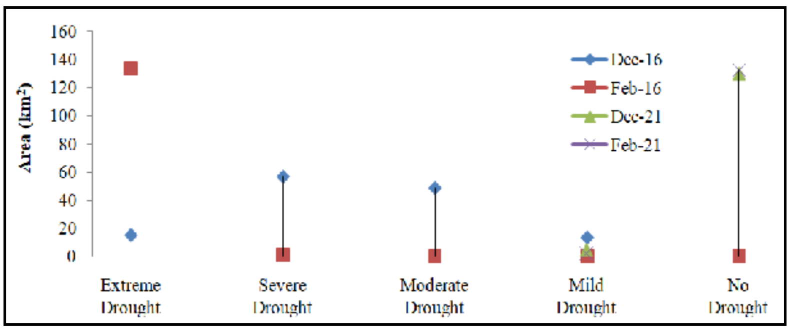

Fig. 2. Temperature Condition Index (TCI) classification.

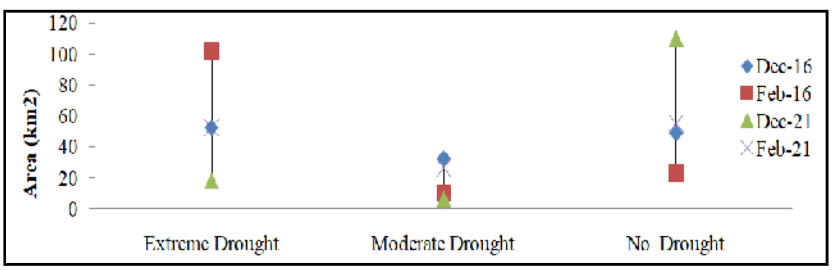

Fig. 3. Vegetation Condition Index (VCI) classification.

VHI is a combined estimate of TCI and VCI. By analyzing the results of VCI and TCI, it is observed that there are a few limitations of these indices. In case of data with excessive wetness or large cloud cover, NDVI values drops down and the VCI erroneously interprets such areas as drought. The remotely sensed indices based on TCI, takes into account the brightness temperature values. During sowing period, the LST values are very high, which indicate a low TCI value, indicating the possibility of drought. Due to these shortcomings, a combined approach of using NDVI and LST was employed. VHI basically reflects health of vegetation and is more closely related to soil moisture content than the VCI or TCI alone (Yan *et al.*, 2016). The results showed that extreme to mild drought observed in Dec 2016 followed by Feb 2016 are 13.936 km^2 and 106.579 km^2 respectively.

Table 2: Vegetation Health Index classification.

VHI density class	2016 VHI Class Area (km^2)		2021 VHI Class Area (km^2)	
	Dec	Feb	Dec	Feb
Extreme Drought	7.198	87.219	0	0
Severe Drought	4.058	11.994	0	0
Moderate Drought	2.680	7.370	0	0
Mild Drought	2.977	4.772	19.294	86.784
No Drought	117.487	23.048	115.101	47.598

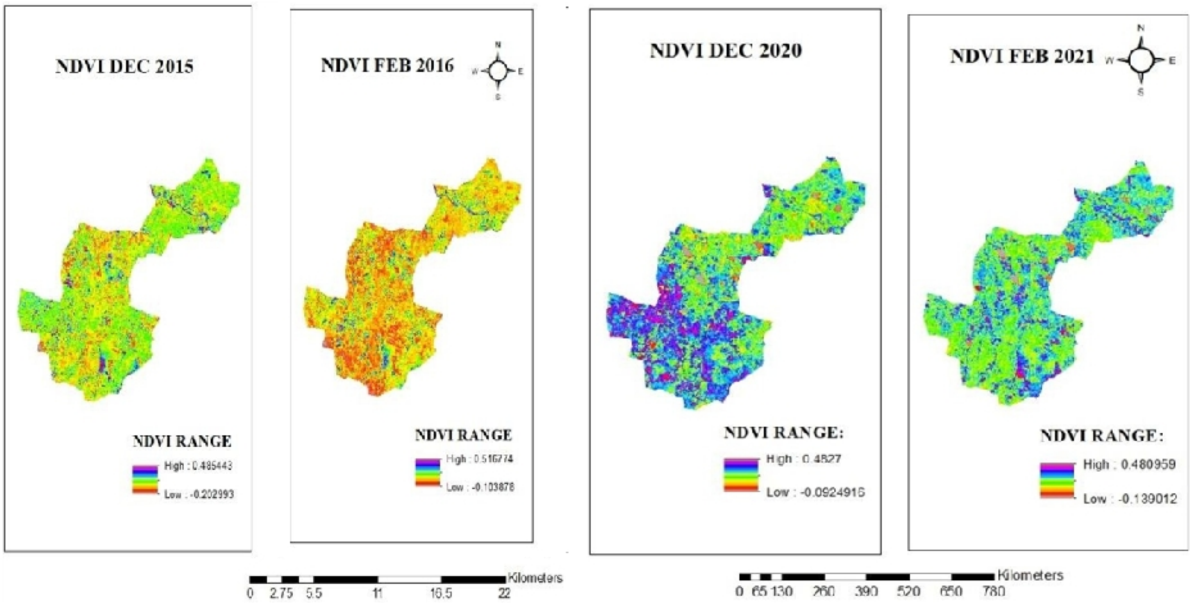

Fig. 4. Spatio-temporal pattern of Normalised Difference Vegetation index (NDVI).

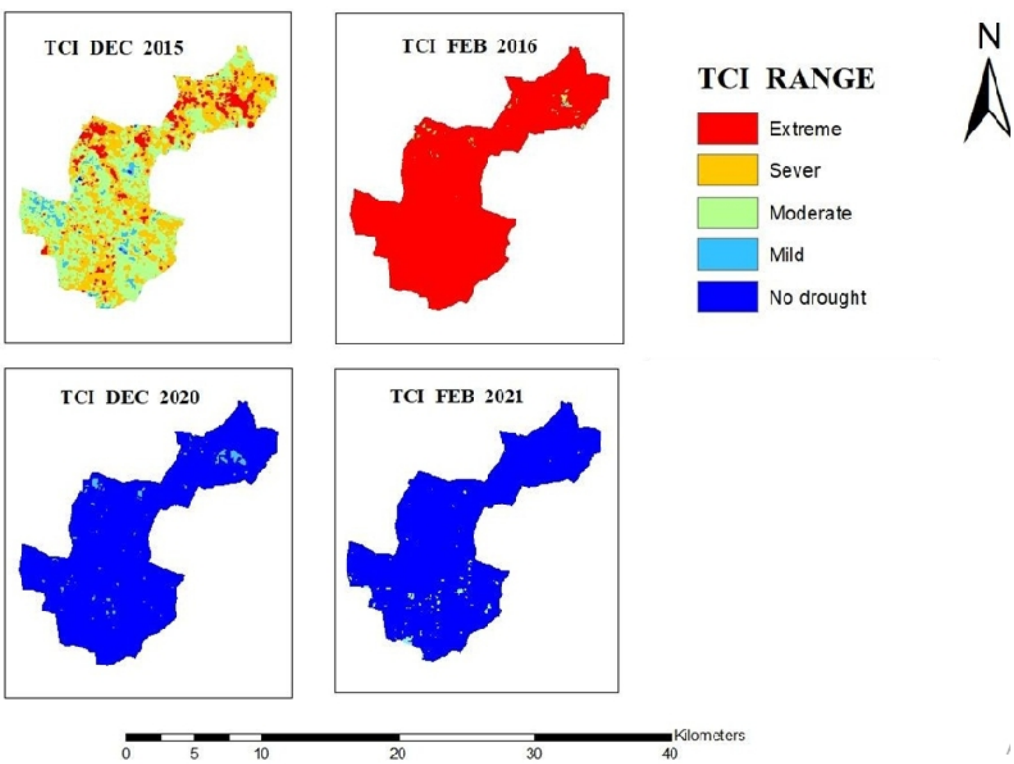

Fig. 5. Spatio-temporal pattern of Temperature Condition Index (TCI).

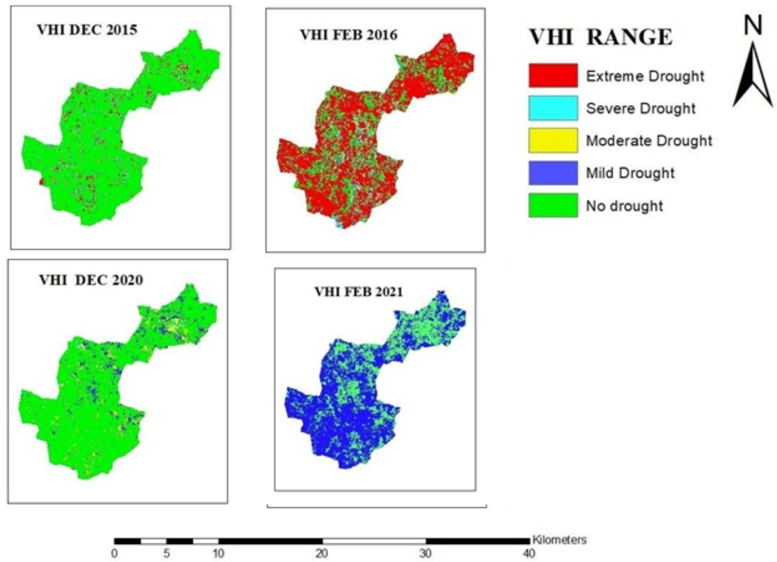

Fig. 6. Vegetation Health Index (VHI) map for drought and Non-drought year.

CONCLUSION

The objective of the work was to study agriculture drought based on remote sensing indices. The obtained area under drought from VCI, TCI was analysed for its merits and demerits. It is observed that VCI which is solely depending on vegetation index gives low values in December due to the presence of cloud cover. Similarly, TCI gives high values in February misinterpreting harvested areas as drought and over predicts. A combined approach of VCI and TCI was used to better understand and map the drought affected areas. From the generated results it was found that 12% of the total area suffered with drought in December 2016 and 84% in February 2016; mild drought observed in non drought year for both the months. Further investigations need to be done block wise for drought affected sites, available water resources and cropping pattern which will help farmers to overcome drought situations.

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Conflict of Interest. None.

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