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Research Paper

Drought severity estimation using NDWI in Parbhani district of Maharashtra

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ABSTRACT

The study was carried out to investigate the impact of drought on vegetation in Maharashtra's Parbhani district, utilizing remote sensing techniques. Analysis of Landsat 8 data for 2015 (a drought year) and 2020 (a normal year) reveals fluctuations in the Normalized Difference Water Index (NDWI) closely correlated with rainfall patterns. In 2015, NDWI indicated extreme drought conditions, while in 2020, most areas experienced mild drought. The comparison underscores NDWI's sensitivity to rainfall variability and dry spells. Meteorological factors, geographical features, and human activities influence moisture content in vegetation and soil, reflected in the distribution of drought severity classes. In 2020, a higher percentage of the area fell into the moderate drought category, shifting to extreme drought with reduced rainfall. This incremental shift highlights the susceptibility of the Parbhani district to drought conditions, emphasizing the interplay of natural and anthropogenic factors in drought assessment and management.

Keywords: Drought indices, Remote sensing, NDWI, Landsat-8, QGIS, Vegetation index

India, with approximately 18% of the world's population, faces substantial pressures on its natural resources, particularly in agriculture, where nearly 70% of the land relies on rainfall. This reliance underscores the significance of understanding and managing ecological phenomena such as droughts, which severely impact agricultural productivity and threaten food security (Hadri *et al.,* 2021). Droughts, characterized by a scarcity of water resources relative to normal conditions, manifest in various forms including meteorological, hydrological, soil or agricultural droughts and socio-economic drought (Jiang *et al.,* 2022). In the Marathwada region of India, frequent rainfall deficits contribute to meteorological droughts, while inadequate soil moisture levels exacerbate agricultural drought conditions. Historical data indicates recurring instances of severe drought, with intervals diminishing from every 4-5 years to a 3-year cycle in recent decades (Amrit *et al.,* 2020; Kulkarni and Gedam, 2018). The Parbhani district, situated within Marathwada, experiences these challenges acutely due to its predominantly rain-fed agricultural practices.

Remote sensing is one of the emerging techniques, utilizing indices like the normalized difference vegetation index (NDVI) and the normalized difference water index (NDWI), which offer valuable tools for assessing drought severity (Pandya *et al.,* 2022). NDWI, in particular, exhibits a heightened sensitivity to drought conditions, providing insights into vegetation health and water availability which has important applications in agriculture and forestry (Gao, 1995). This study aims to comprehensively evaluate drought severity in the Parbhani district using NDWI derived from Landsat-8 data which gives a quicker response to drought conditions than NDVI.

MATERIALS AND METHODS

Study area

The study area is the Parbhani district of Maharashtra situated between latitudes 18°45'N and 20°01'N, and longitudes 76°13'E and 77°26'E, covering 6511 sq. km. Erratic rainfall patterns lead to frequent droughts, affecting soil moisture and crop yields. The district experiences a hot, dry summer, and a mild winter, and relies on the south-west Monsoon for its annual average rainfall of 903.2 mm, supporting *kharif* and *rabi* cropping seasons. For study purposes, two years (2015 and 2020) were selected having extreme

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Table 1: Drought categories based on NDWI classes

NDWI values	Drought severity classes
-1 to 0.2	Extreme drought
0.2 to 0.3	Moderate drought
0.3 to 0.4	Mild drought,
0.4 to 0.5	Moderate moisture content
0.5 to 1.0	Very high moisture content

rainfall in the recent past. The year 2015 experienced the highest negative rainfall deviation (-53.7%) while the year 2020 had slightly higher rainfall (+4.07%) as a normal year.

Satellite data

This study utilized 16-day interval satellite data from the USGS Earth Explorer (NASA LPDAAC Collection) for 2015 and 2020 (NASA, 2022) and converted it into monthly by taking the mean. The analysis used LANDSAT-8 images (19 images), with cloud cover of less than 20%, and disregarding those images with more than 20% cloud cover. During August of both years (2015 and 2020), satellite imageries with more than 50 % cloud cover restricted its use for analysis due to low accuracy of analysis. Meteorological data regarding bright sunshine hours recorded were also low (7.3 and 0.0 - 1.0 hrs respectively in 2015 and 2020). Atmospheric correction was omitted due to the sensor design of Landsat 8, which minimizes atmospheric interference, ensuring reliable quantitative results without extensive correction procedures. Quantum GIS software i.e. QGIS version 3.16.6 (Lakshmi *et al.,* 2020) was used to extract and analyse satellite data. The normalized difference water index (NDWI) was calculated using a formula introduced by McFeeters (1996) in QGIS software.

NDWI values were used to classify the area into five drought classes as given in Table 1.

RESULT AND DISCUSSION

Area under different drought categories

During the year 2015, Parbhani district experienced a drought year with 417.8 mm of annual rainfall (-53.7% deviation from normal) as against normal annual rainfall (903.2 mm). Six events of dry spells within the monsoon season of 2015 with a total duration of 69 days of water stress conditions due to a gap in two successive rainfalls. Approximately normal rainfall (939.8 mm) was observed in 2020 with the occurrence of 39 days duration within 4 dry spell events. Based on NDWI values, the whole geographical area of Parbhani district was classified into drought severity classes, and class-wise percent area was estimated to study the drought severity. During both the years (2015 and 2020), the highest percent area was distributed under extreme drought severity class, followed by moderate drought and mild drought classes (Table 2). The percent area under the moderate moisture content class and very high moisture content class was low except for September 2015 and July to November 2020. The percent area of the very high moisture class was negligible throughout the year during both study years. The summer months (February to March) of both years (2015 and 2020) showed a steep decline in NDWI values which indicates the loss of moisture from vegetation.

From the satellite image processing, it was observed that water storage structures in the study area i.e. Yeldari and Sidheshwar irrigation project (dam and reservoir), exhibited higher NDWI values due to associated features of abundant vegetation, whereas the baren area showed lower values during 2015 and 2020. In the year 2020 (normal year), NDWI values were higher as compared to the NDWI values of year 2015 (drought year). This reflected higher NDWI values were obtained due to higher soil moisture and therefore the area under extreme drought severity class in 2020 was less than in 2015. Exception of higher percent area under extreme drought severity class (42.2%) in September 2020 as compared to September 2015 (21.3%). These values were obtained due to the consequent effect of the dry spell from 28th August to 6th September 2020 and evenly distributed rainfall events in August and September 2015. Though the monthly rainfall received in the months of August- September 2020 was quantitatively higher it was unevenly distributed. Therefore, the percent area under the extreme drought severity class was higher in the normal year (2020) than in the drought year (2015).

The percent area distribution of Parbhani district on the

Table 2: Comparison of month-wise percent area under different drought classes for Parbhani

Months	Rainfall (mm)		Extreme drought (%)		Moderate drought (%)		Mild drought (%)		Moderate moisture content (%)		Very high moisture content (%)	
	2015	2020	2015	2020	2015	2020	2015	2020	2015	2020	2015	2020
January	10.6	3.1	91.9	45.8	8.0	41.1	0.1	12.4	0.0	0.7	0.0	0.0
February	0.1	2.0	84.9	56.7	12.2	33.4	2.7	9.0	0.1	0.9	0.0	0.0
March	23.8	4.8	90.6	81.5	7.8	16.3	1.6	2.1	0.1	0.1	0.0	0.0
April	39.0	0.0	94.7	88.8	4.4	8.6	0.8	2.2	0.1	0.4	0.0	0.0
May	6.2	3.7	96.3	91.7	2.9	5.7	0.7	2.2	0.1	0.4	0.0	0.0
June	79.9	196.8	82.0	45.1	17.2	49.1	0.8	5.2	0.1	0.5	0.0	0.0
July	23.5	229.3	82.2	22.4	17.1	42.4	0.7	29.8	0.0	4.6	0.0	0.8
August	85.3	133.9	Not derived due to image having more than 50% cloud cover									
September	138.2	261.2	21.3	42.2	34.7	38.5	31.2	15.3	12.1	3.9	0.7	0.0
October	9.8	104.0	31.0	20.6	49.9	41.3	17.9	30.2	1.2	7.7	0.0	0.2
November	1.4	0.9	58.1	35.8	33.2	34.0	8.1	27.1	0.5	3.0	0.0	0.0
December	0.0	0.1	73.3	44.0	22.6	41.2	4.0	14.4	0.2	0.4	0.0	0.0

basis of NDWI-based drought severity classes during 2020 reflected that the percent area under the moderate drought severity class was higher in normal rainfall year 2020 (June to December) as compared to drought year 2015. Monthly variation in the moderate drought severity class was observed for both years (Table 2). The percent area under the moderate drought severity class was higher during June, July, September, November, and December of 2020 than in the same months of 2015. The exception of the higher percent area of moderate drought severity class in October 2015 was due to the rainfall immediately before the capture of the satellite image. During both the years of normal rainfall and drought, it was observed that the major area of Parbhani district comes under the extreme drought and moderate drought severity class. In deficit rainfall conditions, the area that was under moderate drought class during normal rainfall is switched to extreme drought severity class. Thus, the dry spells and drought aggravate the soil moisture deficit conditions and lead to extreme drought conditions. The area under the very high moisture content class was negligible as compared to other classes which were observed only during September 2015 (0.75) July (0.8%) and October 2020 (0.2%). NDWI is one of the indices which is used for drought severity assessments and came to the inference that these satellite indices should be used for distant locations without soil moisture measurement equipment.

CONCLUSION

The comparison of Parbhani district percent area distribution under different drought severity classes using NDWI highlights the impact of meteorological factors such as rainfall, dry spells; geographical features, and manmade structures on moisture content in vegetation and soil. The percent area under the moderate drought class was higher in the normal rainfall year (2020) whereas, the percent area under the extreme drought class was highest in the June to September months of the drought year (2015). An incremental shift in the percent area under the drought severity class was recorded with a decrement in the rainfall. The percent area classified under the moderate drought severity class during the normal year (2020) was shifted to the extreme severity drought class as a consequence of deficient rainfall and drought.

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