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Retraction

Retraction: Monitoring Drought using Multispectral Remote Sensing – A Case Study (*IOP Conf. Ser.: Mater. Sci. Eng.* 1145 012086)

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This article (and all articles in the proceedings volume relating to the same conference) has been retracted by IOP Publishing following an extensive investigation in line with the COPE guidelines. This investigation has uncovered evidence of systematic manipulation of the publication process and considerable citation manipulation.

IOP Publishing respectfully requests that readers consider all work within this volume potentially unreliable, as the volume has not been through a credible peer review process.

IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

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Monitoring Drought using Multispectral Remote Sensing – A Case Study

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Abstract. The significance of remote sensing observations in monitoring environmental phenomena is a well-established fact. High resolution satellite images acquired using multispectral sensors contribute greatly in this aspect. In the current study, an illustration of this factor is presented using high resolution multispectral data to analyse drought conditions over Solapur, India. Here, Sentinel-2 data is utilized to estimate indices like Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Vegetation condition index (VCI), which help us to infer the drought situation in the region of interest.

1. Introduction

Drought is a complex phenomenon with a significant societal impact. It becomes more complicated because it is hard to define, observe and predict. Drought occurs when a region experiences lower than normal precipitation for a period of time. Four types of drought are defined in literature, namely, meteorological, hydrological, agricultural and socioeconomic drought [1]. Drought impacts a wide spectrum of human lives like agriculture and economy. Along with impact in the food security of a region, drought adversely affects the commercial crops also, affecting farm earning [2]. The economy of countries like India is affected adversely by agricultural drought as majority of the people depend upon agricultural income and nearly about 50 million people get affected by drought annually. The sub-humid, arid and semi-arid parts of the country over the western and peninsular regions are prone to droughts. Scarcity of water due to drought result in large areas becoming unfit for cultivation throughout the year. This leads to adverse impacts on human lives and livelihood as well as on animals [3].

Monitoring is an important aspect of effective management of drought. In order to manage drought both analyses and risk assessment are essential [4]. A critical component of drought risk management is drought forecasting. Improvements in remote sensing techniques have aided monitoring of various climatic phenomena [16-19]. High resolution satellite observations are also important in disaster mitigation. Observations available from satellite-based instruments become important in regions which are sparsely monitored using traditional ground-based observatories. Remote sensing data is useful in monitoring a larger area also. Various indices are available in literature to define drought conditions using different types of parameters. There are indices utilizing meteorological variables, hydrological variables, soil parameters and remote sensing observations. The physics of interaction of electromagnetic radiation with matter form the basis of the definition of these indices.

Vegetation condition index or VCI is a popularly used index. It is defined based on the effects that drought causes to vegetation. The health of plants as indicated by the chlorophyll present in the leaves is quantified using normalized difference vegetation index (NDVI). Leaves absorb wavelengths in the red region of visible spectrum, due to the presence of pigments in them. The structure of the leaves causes radiation in the near-infrared region to be reflected from the surface. NDVI is defined based on these properties. It is a useful indicator of environmental conditions, and can be calculated using remote sensing measurements [17]. Another measure of drought, in terms of its impact on plants, is quantified using Normalized Difference Water Index (NDWI). Drought adversely affect the soil moisture of a region and the long-time soil moisture deficits lead to vegetation stress [5]. The values of NDWI depends on the plant water content. It indicates faster response to the conditions of drought, as compared with NDVI [6]. Vegetative condition index (VCI) helps us to estimate the vegetation status of a region. Vegetation cover for a specific period over a number of years is used to estimate this factor. This is why, VCI has been widely accepted for its purpose of assessment of parameters for drought analyses [3]. In the current study, the variations in VCI are used to study drought conditions. VCI reflects the variability vegetation both in space and time while allowing us to infer the impact of weather on vegetation also. This study further serves as an illustration of using high resolution multispectral satellite observations for disaster monitoring.

2. Study area

Solapur city is located in south western part of the state of Maharashtra, India. It covers an area of 180.1 kms. It has an overall height of 458 meters. It is surrounded on north by Ahmednagar district and on the east by Osmanabad district. Solapur experiences three seasons namely summer, winter and monsoon. The average rainfall received per year is 544mm [7]. The area included in this study is within 17.603 N to 17.772 N, 75.872 E to 75.963 E. The climate of Solapur district is very dry and falls under semi-arid region. The city experiences maximum temperature values ranging from 30°C to 45°C. Rainfall is uncertain and meagre. The soil types are black, coarse Gray, reddish black [8].

3. Data Used

Sentinel-2 is an Earth Observation satellite which provides multispectral observations of the Earth surface. It has a high-resolution ranging from 10m to 60m. Sentinel involves two satellites – Sentinel - 2A and Sentinel-2B.

The multispectral instruments abroad the Sentinel involves 13 spectral bands ranging from visible/near infrared (VNIR) wavelengths to short wave infrared (SWIR) wavelengths. The characteristics of the various spectral bands available in Sentinel-2 is summarised in Table 1 . The bands 5,6,7, and 8a are useful in studying vegetation and agriculture. Sentinel-2 provides the bands 1, 9 and 10 specifically for the study of aerosol, water vapour and cirrus clouds at a resolution of 60m [9]. In addition to the spatial resolution as high as 10m, Sentinel data has a temporal resolution of 5 days, which is quite high. Sentinel-2 has low radiometric calibration uncertainty [14, 15]. This assures reliability in the results when Sentinel-2 images are utilised.

Table 1. Sentinel -2A and Sentinel-2B.

Bands	*Resolution (m)*	*Sentinel-2A*		*Sentinel-2B*	
		Central wavelength(nm)	Bandwidth (nm)	Central wavelength	Bandwidth
1 – coastal aerosol	60	442.7	21	442.2	21
2- Blue	10	492.4	66	492.1	66
3- Green	10	559.8	36	559	36
4-Red	10	664.6	31	664.9	31
5-	20	704.1	15	703.8	16
6 – Red edge	20	740.5	15	739.1	15
7- Red Edge	20	782.8	20	779.7	20

8 - NIR	10	832.8	106	833.0	106
8a – Narrow NIR	20	864.7	21	864.0	22
9- Water vapour	60	945.1	20	943.2	21
10 - SWIR	60	1373.5	31	1376.9	30
11 - SWIR	20	1613.7	91	1610.4	94
12 - SWIR	20	2202.4	175	2185.7	185

4. Drought indices

Several indices are used as indicators of drought in literature. The current study utilizes the following indices.

1. Normalized vegetation index (NDVI) is defined based on the reflectance characteristics of vegetation. It further provides a means to quantify vegetation growth and biomass. NDVI can be calculated using equation (1)

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (1)$$

NDVI values fall between -1 and +1. The NDVI values closer to +1 indicates healthy vegetation. The amount of electromagnetic radiation absorbed by different plant structures differ. Healthy vegetation (photosynthetically active) will absorb more of red wavelength while it reflects much of the near infra-red region of the spectrum. Stressed vegetation having poor chlorophyll content will reflect more in the red region and less near infra-red region of the spectrum. Hence NIR and RED bands are used for estimating the properties of vegetation, in terms of NDVI. Thus, NDVI can be used to infer the vegetation profile of a region. Since vegetation is impacted by drought significantly, NDVI can be used as a basic indicator of stress on plants due to drought [11].

2. Vegetative condition index (VCI) is calculated using equation (2)

$$VCI = \frac{NDVI-NDVI_{min}}{NDVI_{max}-NDVI_{min}} \times 100 \quad (2)$$

NDVI is the average NDVI of a particular pixel. For a particular observing period, $NDVI_{min}$ and $NDVI_{max}$ represent the minimum and maximum historical NDVI values respectively. VCI is expressed as a percentage. Hence it ranges from 0 to 100. VCI can be used to study the vegetation health of an area and thus can be used to analyse the drought condition of a place. The VCI value zero corresponds to severe drought and 100 percentage corresponds to very high vegetation health. The normal condition is marked by VCI value of 50%-100%. The VCI value ranges from 20-30% indicates drought and below 20% indicates severe drought [10].

3. Normalized Difference Water Index (NDWI) is calculated using equation (3)

$$NDWI = \frac{Green-NIR}{Green+NIR} \quad (3)$$

It is also called McFeeters index defined by McFeeters in 1996. The value ranges from -1 to 1. It helps to monitor water content as it makes use of high reflectance of near infrared radiation by green leaves, while taking into account the high reflectance of green wavelength by water molecules. A high positive NDWI values indicates the area's high plant water content whereas the NDWI value going to negative side indicates very less water content [12,13].

5. Results and Discussions

The average of NDVI values over Solapur city during 2016 to 2020 is depicted in

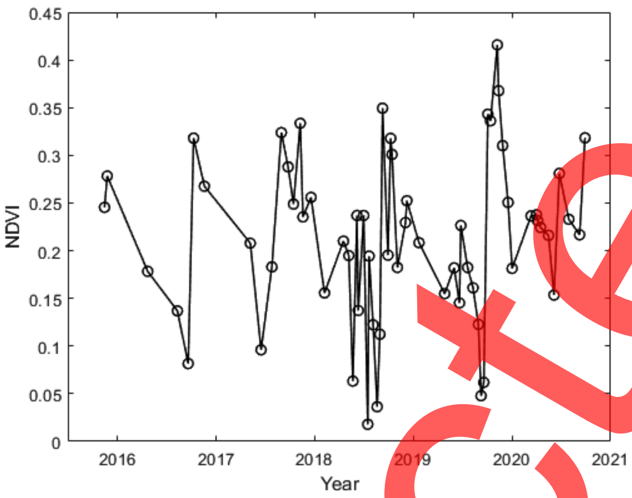

Figure 1. Variability of average NDVI over Solapur city during 2016-2020.

From the Figure1 , the yearly variability of NDVI is evident. The inter-annual variability of NDVI depends on climatic variability and the growth and variability of vegetation. The drought that impacted Solapur during 2018 and 2019 is indicated by the dip in the NDVI values as seen from

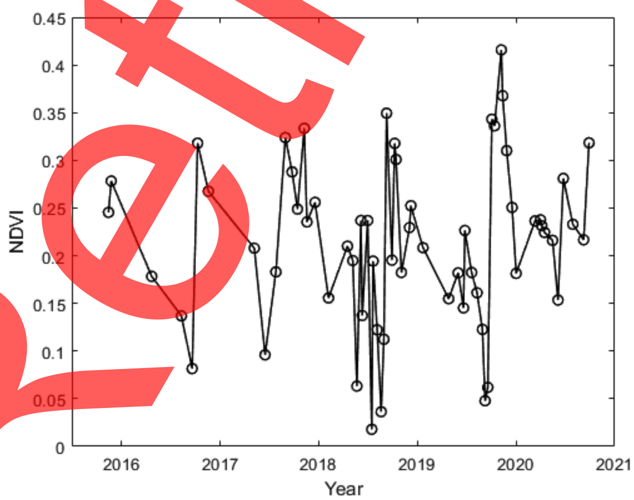

Figure **2.** Variability of average NDVI over Solapur city during 2016-2020.

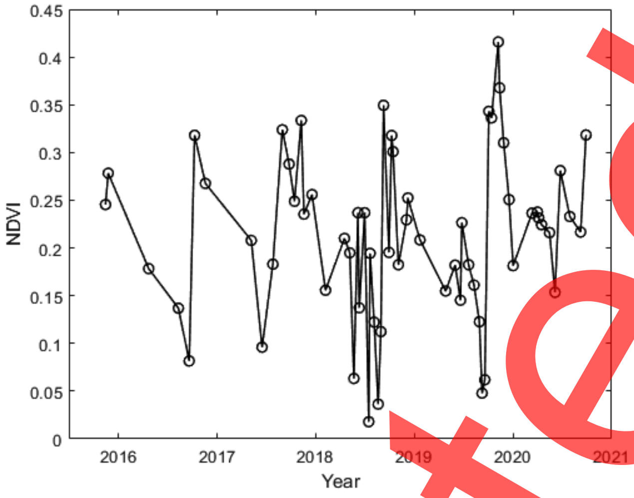

Figure 3. Variability of average NDVI over Solapur city during 2016-2020

NDWI is used to analyse water resources. Figure 2 . shows the variability of NDWI over Solapur during 2016 to 2020.

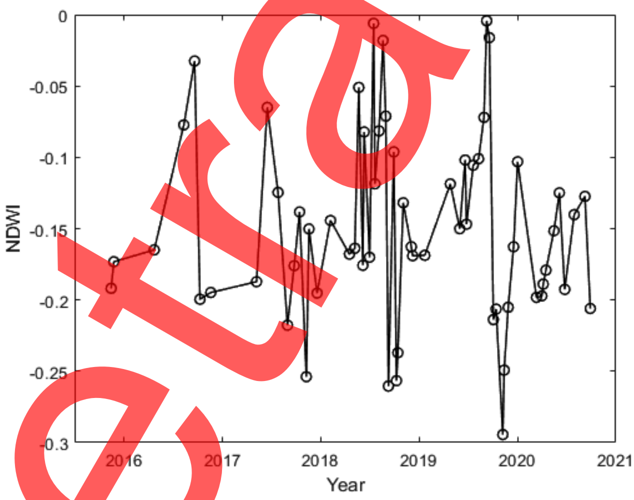

Figure 4. The time series plot of NDWI

The variability in NDWI is related to the variability in NDVI. To identify the relation between NDWI and NDVI, Pearson correlation is computed. A correlation plot is obtained between NDVI and NDWI is shown in Figure 3. The correlation coefficient is found to be -0.9482.

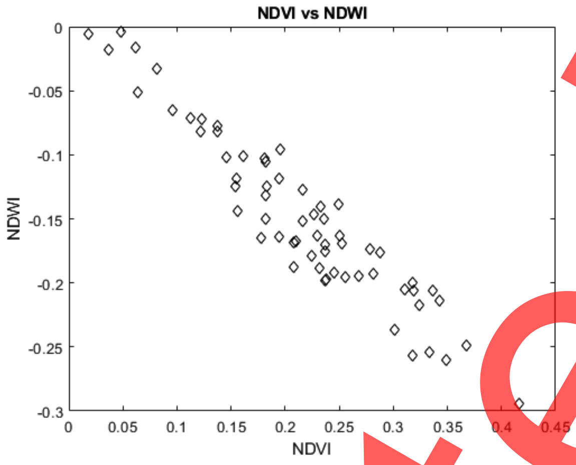

Figure 5. Correlation between NDVI and NDWI

VCI values are estimated using NDVI values for the months of April and May during the period 2016 to 2020. VCI values are the least during 2018 and 2019, which are the years when Solapur was affected by drought as indicated by Figure 4 and 5.

Figure 6. The average time series plot of VCI for the months April and May

Correlation between VCI and NDWI Figure 6 is calculated and it was found as – 0.8958.

Utilizing the VCI and NDVI indices, the drought situation over Solapur can be classified as follows IN Table 2.

Table 2. Drought classification using VCI

No	Year	VCI	Drought Class
1	2016	22.93	Moderate Drought
2	2017	26.5	Moderate Drought
3	2018	20.21	Moderate Drought

4	2019	20.07	Moderate Drought
5	2020	28.92	Moderate Drought

6. Conclusion

Sentinel-2 satellite data was used to estimate drought indices for Solapur city, Maharashtra, India. The analysis from 2016-2020 shows that the region experienced drought conditions in all five years and the intensity is almost same giving a moderate drought. By observing the VCI and NDVI values, it is clear that Solapur was affected more in 2016,2018 and 2019. The high negative correlation between NDVI and NDWI ($\rho = -0.9482$) and VCI and NDWI ($\rho = -0.8958$) shows that they are good indicators of drought and can be used as drought indices. This study is a preliminary work done for demonstrating the use of Sentinel-2 multispectral data for monitoring drought conditions of a region.

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