ECOLOGICAL PERSPECTIVE
An International Academic Journal
e-ISSN:2792-0062

ASSESSMENT & MONITORING OF AGRICULTURAL DROUGHT INDICES USING REMOTE SENSING TECHNIQUES AND THEIR INTER-COMPARISON

Pranav B. MISTRY [1], Tallavajhala M. V. SURYANARAYANA [2]
[1]The Maharaja Sayajirao University of Baroda, Faculty of Technology and Engineering Water Resources Engineering and Management Institute Samiala, /INDIA
pranav.mistry-wremi@msubaroda.ac.in, ORCID: 0000-0002-2029-4283
[2]The Maharaja Sayajirao University of Baroda, Faculty of Technology and Engineering, Water Resources Engineering and Management Institute Samiala, /INDIA
drsurya-wremi@msubaroda.ac.in, ORCID: 0000-0002-6201-5676

Doi: https://doi.org/10.53463/ecopers.20230171
Corresponding Author/İletişim yazarı: Pranav B. MISTRY
E-mail: pranav.mistry-wremi@msubaroda.ac.in
Submission Date: 28.01.2023 – **Accepted Date:** 05.07.2023

ABSTRACT

Agricultural drought is nothing but the decline in the productivity of crops due to irregularities in the rainfall as well as decrease in the soil moisture, which in turn affects the economy of the nation. As the Indian agriculture is largely dependent on the Monsoon, a slight change in it affects the production as well as the crop yield drastically. The agricultural drought monitoring, assessment as well as management can be done more accurately with the help of geospatial techniques like Remote Sensing. In present study agriculture drought is estimated in vadodara district. The purpose of the study is to analyze the vegetation stress in the Vadodara district with the calculation of NDVI, NDWI, MNDWI, WRI, NDBI and NDSI indices values. The results of NDVI values shows agricultural fields more susceptible to drought. Similarly, decreasing trend was observed in NDWI index which is 22.12% to 19.3% from 2013 to 2018.The builtup index (NDBI) is increasing by 1.85% in last 5 years. The Water ratio index is also showing decreasing trend in study area by 22.35% to 14.29%. The intercomparisions of NDVI and all other indices with rainfall data provides very useful information for agricultural drought monitoring and early warning system for the farmers. The findings of this research will be of interest to local agriculture authorities, like plantation and meteorology departments to understand drier areas in the state to evaluate water deficits severity and cloud seeding points during drought.

Key words: Agricultural drought Indices, NDVI, NDWI, MNDWI, WRI and NDBI.

1. INTRODUCTION

Drought is a natural event that occurs frequently or intermittently in almost any type of climate. It is generally the result of a natural decrease in precipitation over a period of time (Badaq Jamali et al. 2005). The drought phenomenon is recurrent in the study area that becomes the most vulnerable drought prone area of Bangladesh. Unfortunately, drought condition has received less attention and has less scientific research work compare to other calamities like flood or cyclone. The impact of drought can be much higher and can occur greater loss than flood, cyclone and storm surge (Alam et al., 2012).
Drought can be monitored effectively over large areas using remote sensing technology. Satellite-borne remote sensing data provides a synoptic view of Earth surface, and therefore can be used to evaluate drought occurrence spatially. Several remotely-sensed drought indices have been developed and applied, which include duration, intensity, severity, and spatial extent. Among those indices, the Normalized Difference Vegetation Index (NDVI) as a probe for vegetation health has been one of most commonly used approaches to drought events monitoring (Gu et al., 2007).
Remote multispectral and hyperspectral measurements have been an imperative source of data for drought and vegetation dynamics assessment. Several multispectral vegetation indices (VIs) have been employed to appraise growing vegetation attributes in recent decades (Adam et al., 2010; Yang et al., 2012). RS and GIS are features of earth observation science and have contributed an advanced system for arranging, analyzing, manipulating and storing the information about the spatial components including drought and vegetation health. Hence, remotely sensed data and GIS techniques have been utilized in recent decade to monitor urban features as well as the environmental changes (Adefisan et al., 2015)
The impacts of drought have been assessed through the estimation of green vegetation in drought-affected areas either as long or short-term dryness using vegetation indices such as Normalized Difference Water Index (NDWI), Soil Adjusted Total Vegetation Index (SATVI), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST) and Normalized Drought Dryness Index (NDDI) in the prior research, particularly in an arid or semi-arid and mild Mediterranean ecosystem where vegetation is sporadic (Gu et al., 2007).
There are many other remote-sensing-based drought indices which used for drought assessment, e.g. NDWI (Normalised Difference Water Index), VCI (Vegetation Condition Index), and VHI (Vegetation Condition Index). This research aims to compare these indices to understand the differentiation between each index, and its application for monitoring drought in vadodara district.

1.1 Objectives of the Present Study

The specific objectives of this study are to: Calculating and mapping of Normalize Difference Vegetation Index, Normalised Difference Water Index, Water Ratio Index, Normalised Difference Builtup Index, Normalised Difference Salinity Index and Soil Adjusted vegetation Index using Landsat 8 satellite image; and analyze the changes between these indices for the year of 2013 to 2018 in Vadodara district.

2. STUDY AREA AND DATA COLLECTION

The present study area is the Vadodara District in the Gujarat State of India. Total geographical Area of the district is 420 Sq. Kms. The Vadodara lies between 22°30’North, 73°19’East.The study Area is located 39 m above the Mean sea level. The important soil types encountered in the area can be broadly categorized into Loamy and clay soil. Climate condition is summer period of March, April, May, May and June reaching a maximum temperature of up to 46°C. The temperatures drop in December and the low temperatures continue up to February, touching a minimum of 13°C in January. Vadodara has an average annual rainfall of 750 to about 900 mm. This study focus on the agricultural drought assessment in Vadodara district using Landsat 8 data. Through the analysis different agricultural indices vegetation stress, percentage of water and percentage of builtup index is calculated.

3. METHODOLOGY

For the current study, methodology representing the steps and flow of work is explained in the section below. Below Table 1 shows Landsat 8 band characteristics. Landsat 8 measures different ranges of frequencies along the electromagnetic spectrum – colour, although not necessarily a colour visible to the human eye. Each range is called a band, and Landsat 8 has 11 bands. Landsat numbers its red, green, and blue sensors as 4, 3, and 2. Landsat 8 view of the Los Angeles area, May 13th, 2013. The image is rotated so north is up. All image data courtesy of the U.S. Geological Survey.

Table 1: Landsat 8 Band Characteristics

Band No.	Description	Wavelength (mm)	Band No.	Description	Wavelength (mm)
1	Coastal Aerosol	0.430 - 0.450	6	SWIR 1	1.570 – 1.650
2	Blue	0.450 - 0.510	7	SWIR 2	2.110 – 2.290
3	Green	0.530 - 0.590	8	Panchromatic	0.500 – 0.680
4	Red	0.640 - 0.670	9	Cirrus	1.360 – 1.380
5	Near Infrared	0.850 - 0.880	10	TIRS 1	10.60 – 11.19
			11	TIRS 2	11.50 – 12.51

In the present scenario, various bands were used for drought assessment and for each method offers its advantages and disadvantages. Following are some of the proposed methods to extract water bodies and estimation of vegetation stress and changes in builtup area which are considered in this study. For the current study, methodology representing the steps and flow of work is explained in the section below.

NDVI

NDVI is a widely used slope based vegetation index using red and near infrared band. It is one of the most widely used vegetation indexes. Furthermore, the measurement scale has the desirable property of ranging from -1 to 1, with 0 representing the approximate value of no vegetation, and negative values non-vegetated surfaces. Here, NDVI is calculated for mapping vulnerability of drought.

NDWI

Based on the fact that water has strongest absorption while vegetation has strongest reflectivity at near infra-red, McfeetersS.K. (1996) proposed the method of NDWI to highlight water body.

https://doi.org/10.53463/ecopers.20230171

NDWI proved to work well in separating water body and vegetation but has limitations when it comes to soil and built up area.

MNDWI

Modified Normalised Difference Water Index (MNDWI): Due to the limitations of NDWI, Xu (2006) proposed MNDWI which was found to be efficient in distinguishing water and urban areas.

NDBI

NDBI stands for Normalized Difference Built-up Index, In comparison to the other land use / land cover Surfaces, built-up lands have higher reflectance in MIR Wavelength range (1.55~ 1.75μm) than in NIR Wavelength range (0.76~ 0.90μm). NDBI is very useful for mapping the urban built-up areas and has been computed.

4. RESULT AND ANALYSIS

Multi-temporal and multi-resolution remote sensing images can provide basic data for analyzing urban spatial information and thermal environment effectively. The present study analyses the potential of LANDSAT-8 in mapping different agricultural drought indices and interprets their relationship with NDVI, NDWI, MNDWI and NDBI using ArcGIS software.

The Normalized Difference Vegetation Index (NDVI) is a Landsat derived vegetation indicator obtained from the red band and near-infrared (NIR) band ratio of vegetation reflectance in the electromagnetic radiation. Theoretically, NDVI threshold value ranges between -1 to +1. When the temperature is greater, the NDVI value is lesser which points out the decrease in the vegetation density. The decrease in soil moisture due to lack or untimely onset of rainfall along with the increased temperature causes the agricultural drought to be severe.

In the present study area, NDVI value ranges from between -0.14 to 0.58, average NDVI value is 0.23. Contrary to this, in the Normalized Difference Salinity Index (NDSI), the sand particles have higher reflectance in red band and lesser in near infrared band, so the NDSI value ranges between -0.58 to 0.15 which is also shown in below Table 2. Owing to higher NDSI value, of the area, scanty or low vegetation cover is observed. Hence, a low NDVI has been observed.

Similarly, NDWI was used in this analysis to assess the reflection of water content in the soil and on plant surfaces. The NDWI unit has no dimensions and ranges between -1 and +1 depending on the amount of surface water present. A higher NDWI value indicates a high-water content in the plant. Low NDWI values indicate low vegetation water content and thus the NDWI rate decreases during periods of water stress. As precipitation increases, the NDWI value increases. The average NDWI value representing the water content of vegetation decreases numerically, 0.41, 0.39, 0.43, 0.42 and 0.41 for the given area from 2013 to 2018.

The results of NDBI have shown the maximum surface temperature in Built-Up areas. Therefore, it have been predicted that built-up areas or urbanization is a inducing much surface temperature variations. The average value of NDBI is 0.53, 0.58, and 0.60 which is increasing year to years so builtup area of present study region is also increasing by 1% to 1.85% during study period.

https://doi.org/10.53463/ecopers.20230171

According to obtained NDVI value for the year, (Fig. 3) a total of 262.29 km^2 area had NIL vegetation, whereas scanty and low vegetation was found in 1296 km^2 and 1375 km^2 of area respectively. Generally, a declining trend was observed during 2013 to 2014 and then the trend was increasing in the area. By computing the values of NDVI and other indices of each month for the years 2013 to 2018 in a line graph, The Figures represents the line graph obtained for average rainfall and average value of all vegetation indices over study period.

Table 2: Comparisons of Average Values Drought Indices

			2013	**2014**	**2016**	**2017**	**2018**
1	NDVI	Minimum	-0.1448	-0.2079	-0.1513	-0.1685	-0.1716
		Maximum	05833	0.5413	0.5562	0.5749	0.5842
2	NDWI	Minimum	-0.5316	-0.5881	-0.6085	-0.5174	-0.5765
		Maximum	0.4160	0.3997	0.4306	0.4288	0.4134
3	MNDWI	Minimum	-0.6868	-0.7113	-0.7448	-0.6400	-0.7232
		Maximum	0.2543	0.2802	0.2503	0.2942	0.2404
4	NDBI	Minimum	-0.4160	-03990	-0.4306	-0.4288	-0.4103
		Maximum	0.5316	0.5881	0.6085	0.5174	0.5234
5	NDSI	Minimum	-0.5833	-0.5413	-0.5562	-0.5749	-0.5842
		Maximum	0.1448	0.2079	0.1513	0.1685	0.1716

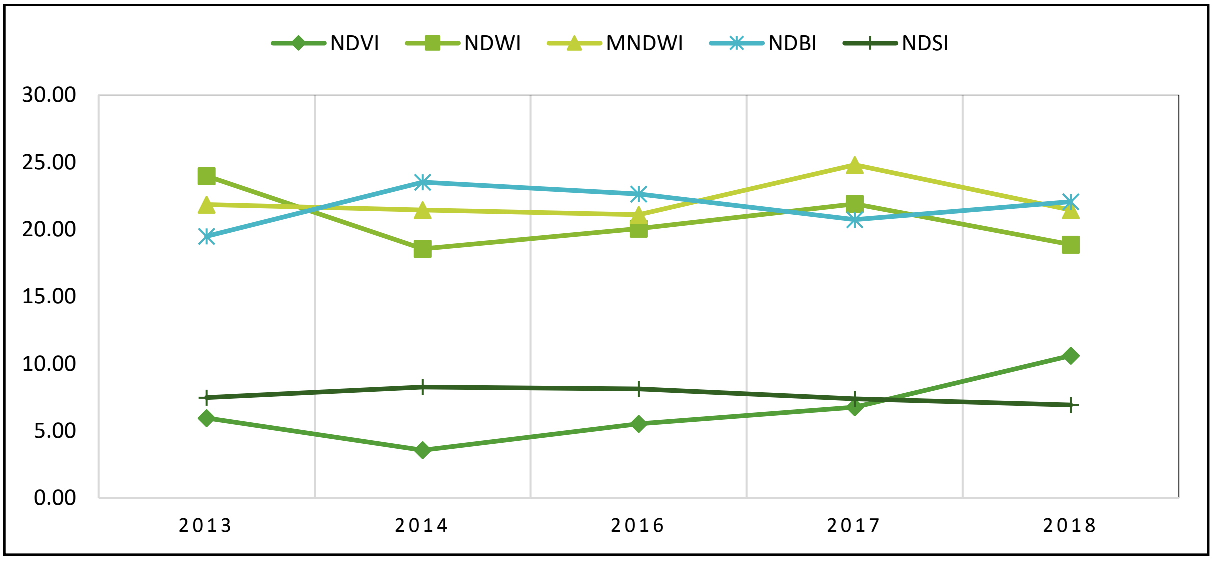
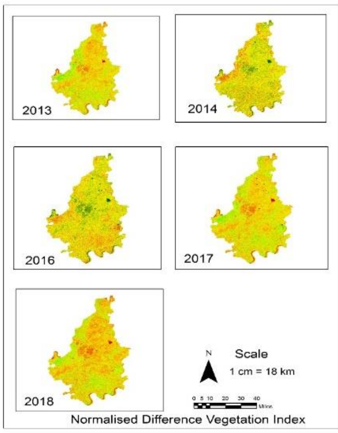
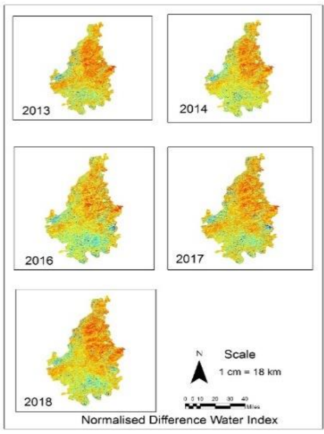
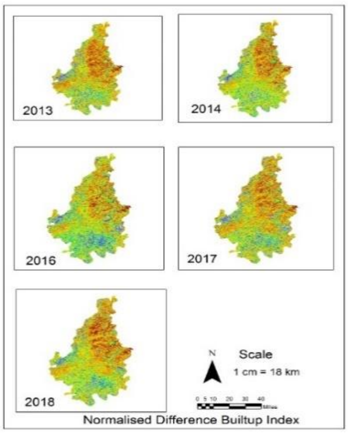


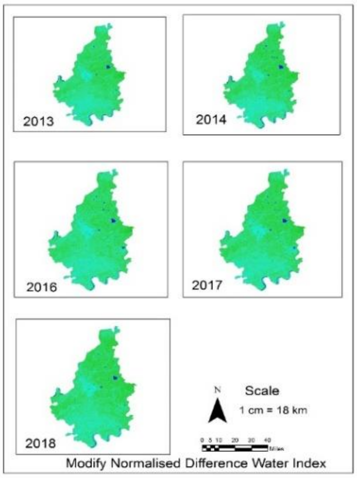
Figure 1: Comparisons of Vegetation Indices

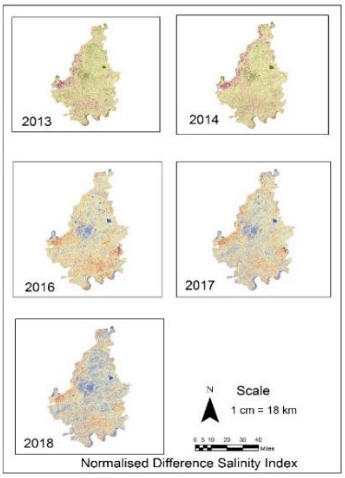
https://doi.org/10.53463/ecopers.20230171

<table>
<tr>
<td>


</td>
<td>


</td>
<td>


</td>
</tr>
<tr><td>(a)</td><td>(b)</td><td>(c)</td></tr>
<tr>
<td>


</td>
<td>


</td>
<td>a) Normalised Difference Vegetation Index

b) Normalised Difference Water Index

c) Normalised Difference Builtup Index

d) Modified Normalised Difference Water Index

e) Normalised Difference Salinity Index</td>
</tr>
<tr><td>(d)</td><td>(e)</td><td></td></tr>
</table>

5. CONCLUSİONS

Agricultural drought is one of the most frequent natural disasters in India's southern part. Remote sensing-based drought indices give advantages in terms of continuous monitoring of land surface. This study aims to compare different agriculture drought indices in vadodara district using Landsat 8 data for 2013 to 2018 years and to monitor the agricultural drought. Increasing temperature and altered precipitation patterns, leads to the extreme weather events like Drought which drastically affects the agricultural production. The average NDWI value representing the water content of vegetation decreases numerically, 0.41, 0.39, 0.43, 0.42 and 0.41 for the given area from 2013 to 2018. Similarly, decreasing trend was observed in NDWI index which is 22.12% to 19.3% from 2013 to 2018.The builtup index (NDBI) is increasing by 1.85% in last 5 years. The Water ratio index is also showing decreasing trend in study area by 22.35% to 14.29%. NDVI value shows a total of 262.29 km^2 area had NIL vegetation, whereas scanty and low vegetation was found in 1296 km2 and 1375 km^2 of area respectively. Similarly, NDSI and WRI with NDWI shows trend with increasing. The negative and positive correlation were observed between NDVI, and precipitation for different seasons due to the higher uncertainty of precipitation.

REFERENCES

A.T. Alam, M.S. Rahman, A.H. Saadat, M. Huq, (2012), "Gamma Distribution and its Application of Spatially Monitoring Meteorological Drought in Barind, Bangladesh," Journal of Environmental Science and Natural Resources 5 (2), pp. 287-293.

Adam, E., Mutanga, O., Rugege, D., (2010), Multispectral and hyperspectral remote sensing for identification and mapping of wetland vegetation: a review. Wetl. Ecol. Manag. 18 (3), 281–296.

Adefisan, E.A., Bayo, A.S., Ropo, O.I., (2015), Application of geo-spatial technology in identifying areas vulnerable to flooding in Ibadan metropolis. J. Environ. Earth Sci. 5, 153–166.

Arshad S, Morid S, Reza Mobasheri.M., and Agha Alikhani.M., (2008), Development of Agricultural Drought Risk Assessment Model for Kermanshah Province (Iran), using satellite data and intelligence methods. Option Mediterrianeennes, Series A, No: 80.

Badaq Jamali J, Asiani M, Samadi Neqab S, Javanmard S (2005), Drought Risk Management (Cognition and Strategies), 1st edn. Sokhan Gostar Publ, Tehran, Iran

Brunsell, N.A., & Gillies, R.R, (2003), Length scale analysis of surface energy fluxes derived from remote sensing. Journal of Hydrometeorology, vol 4, 1212–1219.

Gu Y, Brown JF, Verdin JP, Wardlow B.(2007), A five-years analysis of MODIS NDVI and NDWI for grassland drought assessment over the central Great Plains of the United States. Geophysical Research Letters; 34: L06407, doi: 10.1029/2006GL029127.

Gu, Y., Brown, J.F., Verdin, J.P., Wardlow, B., (2007). A five-year analysis of MODIS NDVI
Hasan Murad and A. K. M. Saiful Islam, (2011), Drought Assessment Using Remote Sensing and Gis In North-West Region Of Bangladesh, 3rd International Conference on Water & Flood Management (ICWFM-2011).

McKee, T. B., Doesken, N. J., Kleist, J. et al., (1993). The relationship of drought frequency and duration to time scales. Proceedings of the 8th Conference on Applied Climatology, 17number 22, California, 179–183.

Mishra AK, Ines AVM, Das NN, Khedun CP, Singh VP, Sivakumar B, Hansen JW. (2015), Anatomy of a local-scale drought: Application of assimilated remote sensing products, crop model, and statistical methods to an agricultural drought study. Journal of Hydrology; 526:15- 29.

Niclòs, R., Valiente, J.A., Barberà, M.J., Estrela, M.J., Galve, J.M. & Caselles, V., (2009) Preliminary results on the retrieval of land surface temperature from MSG-SEVIRI data in Eastern Spain, in EUMETSAT 2009: Proceedings of Meteorological Satellite Conference, PP 21-25.

Ravish Keshri, Sanjay K. Jain, Mahesh Kothari And A.K. Mishra, "Remote sensing satellite (NOAA AVHRR) based drought assessment and monitoring in Southern Rajasthan", International Journal of Agricultural Engineering, Vol. 2 No. 1, 2009, PP 50-57.

Yang, J., Weisberg, P.J., Bristow, N.A., 2012. Landsat remote sensing approaches for monitoring long-term tree cover dynamics in semi-arid woodlands: comparison of vegetation indices and spectral mixture analysis. Rem. Sens. Environ. 119, PP 62–71.

Ying xin Gu, Jesslyn F. Brown, James P. Verdin, and Brian Wardlow, "A five-year analysis of MODIS NDVI and NDWI for grassland drought assessment over the central Great Plains of the United States", Geophysical Research Letters, Vol. 34, 2007, L06407, doi:10.1029/2006GL029127.