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Review

NDVI: Vegetation Performance Evaluation using RS and GIS

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ABSTRACT

Vegetation is a crucial part of ecosystem and plays a key role for soothing global environment. Normalized Difference Vegetation Index (NDVI) is one such remote sensing technique which is used to compute vegetation cover change. Remote sensing and geographical information system methods are used often in examining natural resources, determination of land changes and related planning work. The methodology discussed in this study is based in association with remote sensed data about vegetation, in the form of Normalized Difference Vegetation Index (NDVI). The main application of this index is to monitor the vegetation cover. NDVI is the function of the spectral contrast between the reflected Near Infrared (NIR) and Visible (VIS) radiance from a surface. A further study is made on the calculated NDVI to evaluate the agricultural drought index in the form of Vegetation Health Index. This index is a combination of Vegetation Condition Index (VCI) and Land Surface Temperature (LST). VHI classifies vegetation health, which is suitable to indicate agricultural drought extent. A correlation is studied statistically between NDVI, VHI, precipitation and temperature. The present study is focussed on the Shirur and Khed talukas of Pune district for the years 2000,2003,2009,2012,2015 and 2018 for particular months. The use of data Landsat 7 ETM+ for year till 2012 and data Landsat 8 OLI for 2015 and 2018 was made. Data was obtained from U. S Geological Survey. The precipitation data was taken from maharain.gov.in. Thus, vegetative cover over the specified area was studied including the drought severity. A liner regression analysis is performed using the evaluated data which can be used to forecast the vegetation condition as an early warning system for agricultural drought.

Keywords: NDVI, VHI, agricultural drought, Landsat, VCI, LST

INTRODUCTION

The economy of India is dependent upon agriculture sector. Thus, agriculture can be called as a back bone of India. To develop these valuable asset-like landscapes, green open spaces is of a great concern. The way to advance in any field is to gain the knowledge of the advanced technology. With the help of advanced tools and combination of educated and skilled employees, it is possible to perform better in various fields.

Remote sensing and Geographical Information System are ways to enhance in the monitoring vegetation, determination of land changes and planning work. The satellite imagery is used for yield and production forecasting, green cover inventory and assessment of drought like catastrophe.

By studying the temporal and spatial variations in the vegetative structure, monitoring and analysis can be performed. Vegetation indices are widely used in this field. There are numerous indices in use to study the changing pattern of the vegetation. These indices are the indicators of health and greenness of vegetation and a measure of density. To compute the vegetation indices the band combination is used which mainly comprises of red, green and infrared spectral bands.

One of the most widely used index is Normalized Difference Vegetation Index (NDVI) to monitor vegetation stress. Normalized Difference Vegetation Index (NDVI) offers better

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results and is easy to understand the vegetation change. Normalized Difference Vegetation Index (NDVI) converts multi spectral data into single image band which displays vegetation distribution. To quantify the healthy green vegetation based on satellite images, NDVI a graphical indicator makes use of the differential reflection of green vegetation in the visible and near infrared-portions (NIR) portion of the spectrum thus providing condition of the vegetation. The value of NDVI ranges from -1 to +1, value leaning towards +1 denoting healthier vegetation.

Further, the remotely sensed data from satellite is used to analyse the drought risk and has become wide spread these days. Drought, a natural hazard causes noteworthy loss in the field of crop production, water supply and harness the well- being of humans. Recognition of such calamity becomes important to decrease its impact and severity in future. The way to mitigate drought effectively is to monitor such risk in advance with the help of remote sensing technology. Drought indices have been developed which comprises of spatial extent of vegetation, duration, intensity of meteorological factors. Although there are many new indices that are theoretically more reliable than the NDVI (such as soil-adjusted, transformed soil-adjusted, atmospherically resistant, and global environment monitoring indices), they are not yet widely used with satellite data [6] (Rondeaux et al., 1996). Among these indices, Normalized Difference Vegetation Index (NDVI) is one of the effective approach to monitor drought. A combination of NDVI in the form of Vegetation Condition Index (VCI) with land surface temperature (LST) delivers a strong correlation thus providing information about agricultural drought beforehand.

This study aims to examine the vegetation extent over the Shirur and Khed talukas of Pune District. The relationship between rainfall, NDVI in the context of these talukas Shirur and Khed is analysed with NDVI as a tool for drought monitoring, rainfall being the key factor in vegetative health. The use of Landsat dataset for examination of these indices is made and is explained in the methodology section.

STUDY AREA

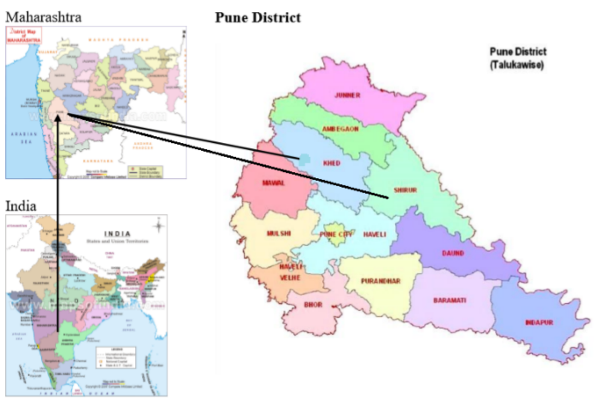

Figure 1: Location map of study area.

The study is focussed on the Shirur and Khed talukas of Pune district. Pune district lies between 17.54 to 19.24-degree North latitude and 73.19 to 75.10-degree eastern longitude located in western part of Maharashtra state, India with Shirur located at18.8250° N, 74.3776° E and Khed at 18.8405° N, 73.9072° E. In arrears to the geographical conditions of Pune district, rainfall is unevenly distributed. The Western part of the district adjacent to the West coast is hilly area having forest cover, due to which the rainfall intensity is more in this area as compared to the eastern parts. Mainly, this rain is brought by the southwest monsoon winds during the summer and about 87 percent of rainfalls during the monsoon months June to September with maximum intensity in the month of July and August. Around 73% of cropped area is cultivated under rainfed conditions. Agriculture is Rabi crop dominated in these areas and second being the Kharif Crops. Summer crop production is comparatively less Shirur is located on the east boundary of Pune District on the banks of Ghod River. Shirur is influenced by the semi-arid climate. Khed lies in the western region of Pune district with river Indrayani flowing through this taluka with somewhat cool climate.

METHODOLOGY

In this research, Vegetation condition was identified of long-term sequence for the year 2000, 2003, 2006, 2009, 2012, 2015 and 2018 of months January, May, September and December. For the analysis of Normalized Difference Vegetation Index (NDVI) and land surface temperature (LST) multispectral and thermal data from Landsat were used. The dataset used for the year 2000, 2003, 2006, 2009, 2012 was Landsat 7 ETM+ and for 2015 and 2018 was Landsat 8 OLI. The following flowchart describes the methodology briefly.

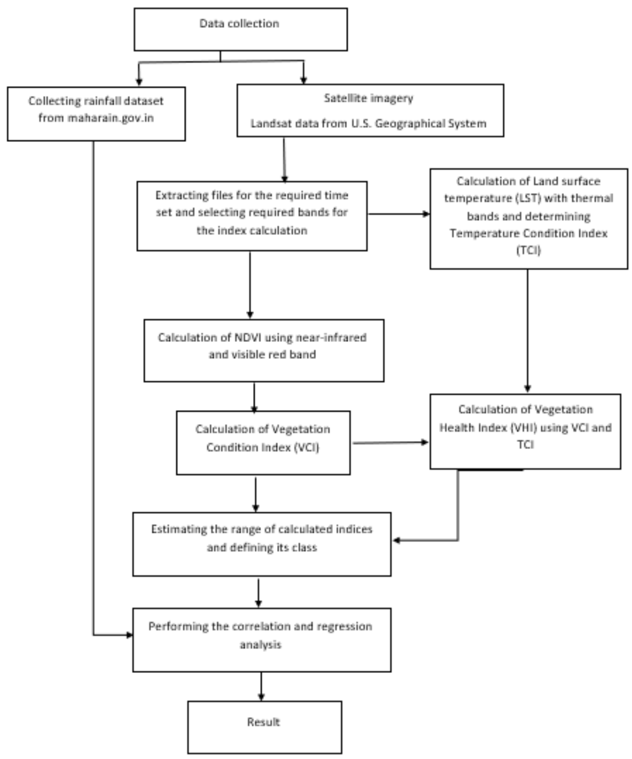

Figure 2: Methodology flowchart.

NDVI is expressed by the formula: $NDVI = \frac{NIR-Red}{NIR+Red}$

NDVI calculation for the Landsat 7 ETM+ was calculated using relation: $NDVI = \frac{band\ 4 - band\ 3}{band\ 4 + band\ 3}$

NDVI calculation for the Landsat 8 OLI was calculated using relation: $NDVI = \frac{band\ 5 - band\ 4}{band\ 5 + band\ 4}$

Provided, bands are having their usual meaning according to the data set used. The classification of vegetative cover based on the NDVI values was according to the following table [7].

Table 1: NDVI classification range.

Cover type	NDVI range
Dense green leafy vegetation	0.500-1.000
Medium green leafy vegetation	0.140-0.500
Light green leafy vegetation	0.090-0.140
Bare soil	0.025-0.090
Swampy areas/wet lands	-0.046-0.025
Water bodies	-1- -0.046

NDVI and LST time series have potential to describe the various dynamics of dry conditions [1]. The Landsat data sets were used to calculate vegetation condition index (VCI) and temperature condition (TCI), respectively. TCI is obtained from the calculated Land surface temperature which is calculated following the procedure in Landsat handbook provided by U.S Geological Survey. Combined VCI and TCI data was then employed to calculate VHI, a vegetation drought index which incorporates overall vegetation health and its severity to indicate agricultural drought extent at any time of the year. The calculation of VHI is shown by the following description. The VCI was obtained from Normalized Difference Vegetation Index (NDVI) to monitor vegetation condition [2]. The VCI data were derived by following equation.

$$VCI = \frac{(NDVIa - NDVImin)}{NDVImax - NDVImin} \times 100$$

Here, NDVIa represents NDVI value of current month, while NDVImin and NDVImax denotes the minimum and maximum NDVI values, respectively, throughout the period of observation. The VCI has been recommended as drought tool, however, using sole VCI was not enough to describe drought analysis accurately. To improve, the TCI was developed to capture different responses of vegetation to in-situ temperature as additional information. This can be achieved by employing thermal channels for drought monitoring [2]. The TCI was calculated using the following equation.

$$TCI = \frac{(LSTmax - LSTa)}{(LSTmax + LSTmin)} \times 100$$

Where, LSTa is the LST value of current month, LSTmin and LSTmax denotes the minimum and maximum LST values, respectively, calculated from multiyear time series data. The VHI was calculated to analyse vegetation stress and define the drought severity. The VHI can be expressed by following equation.

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

VHI is expressed as a combination of VCI and TCI by parameter α. Here, parameter α in equation takes a value between 0 and 1. Since normally there is no a prior knowledge of the actual contribution of the moisture and temperature conditions to the health of the vegetation in a given region, the value of α is generally taken as 0.5 [3, 4]. In this study, following classification scheme for drought monitoring was proposed based on following table. [5]

Table 2: VHI classification range.

Drought class	VHI
Extreme drought	<10
Severe drought	10-20
Moderate drought	20-30
Mild drought	30-40
No drought	>40

Further, rainfall data was obtained from Department of Agriculture, Maharashtra state for rainfall data. The annual precipitation was considered for the analysis. With the calculated data for NDVI, VHI, LST and rainfall data collected, the correlation and linear regression analysis was performed the results of which are as discussed below.

RESULTS AND DISCUSSION

Results of NDVI

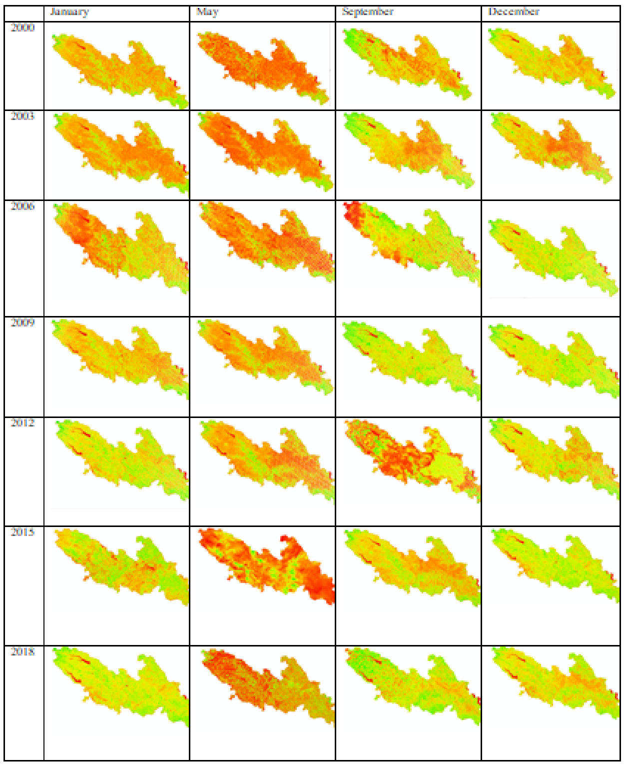

Figure 3: NDVI images.

Results of VHI

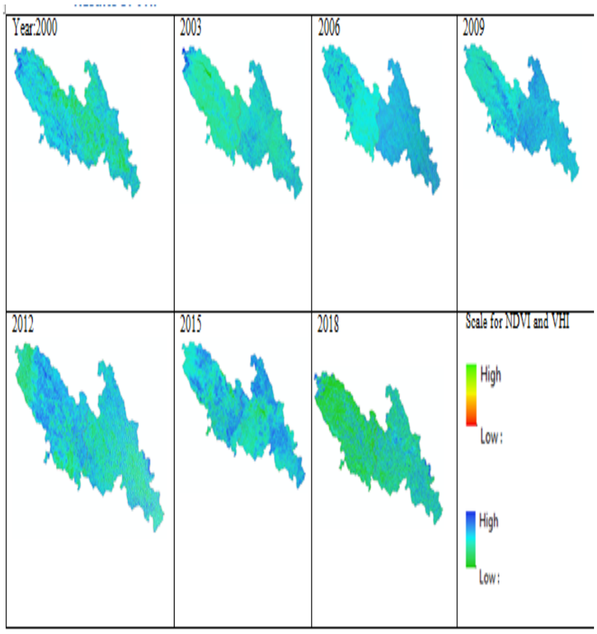

Figure 4: VHI images.

Classification

Table 3: Calculated NVDI and VHI values.

Year	Block	NDVI Class (Based on the maximum values obtained)	VHI class
2000	Shirur	Medium green vegetation (0.55)	24.3-49.3 (No drought)
	Khed	Dense green vegetation (0.83)	23.6-74.32 (No drought)
2003	Shirur	Medium green vegetation (0.31)	25.4-30.4 (Moderate drought)
	Khed	Medium green vegetation (0.61)	29.4-53.55 (No drought)
2006	Shirur	Dense green vegetation (0.890)	26.3-52.3 (No drought)
	Khed	Dense green vegetation (0.897)	25.1-89.1 (No drought)
2009	Shirur	Dense green vegetation (0.942)	25.8-54.8 (No drought)
	Khed	Dense green vegetation (0.73)	25.16–68.96 (No drought)
2012	Shirur	Medium green vegetation (0.71)	10.42-36.6 (Mild drought)
	Khed	Dense green vegetation (0.69)	13.9-49.14 (No drought)
2015	Shirur	Medium green vegetation (0.579)	25.90-39.70(Mild drought)
	Khed	Dense green vegetation (0.81)	25.6-80.19 (No drought)
2018	Shirur	Light green vegetation (0.398)	29.32-30.9 (Moderate drought)
	Khed	Dense green vegetation (0.77)	31.76-75.68 (No drought)

Here, the values tabulated clearly illustrate the class and severity of NDVI and VHI. Temperature being an important factor in the calculation of VHI, it is to be noted that in fact of having high NDVI values, its VHI value obtained can be less .In the year 2012, Shirur with NDVI value is having VHI in class of mild drought but for Khed ,NDVI is 0.69 and having VHI in the class of no drought category, as Shirur has the hot and dry climate with Khed having somewhat cool climate.

Correlation and Liner regression analysis results

Correlation between NDVI, VHI and annual Rainfall (in mm) for Shirur and Khed

Table 4: Correlation values.

Block	NDVI &VHI	NDVI & Rainfall	VHI & Rainfall
Shirur	0.838127	0.890172	0.889107
Khed	0.909356	0.778066	0.8072

It is found that these indices can be successfully used to identify the spatio-temporal extent of agricultural drought. In addition, it can also be employed to explain drought severity classes in the research areas through composite analysis of both vegetation health by vegetation condition and temperature condition of vegetation given by VHI. Thus, the variables under the study are correlated with the strength of their association for Shirur and Khed as shown above.

Correlation between NDVI and Temperature

The result obtained for correlation of NDVI and temperature are negative which is Shirur corr. factor= -0.396 and Khed corr. factor= -0.637 which denotes that the rise in temperature lowers the value of NDVI.

Regression analysis for NDVI and annual rainfall (in mm)

Table 5: Regression analysis for NDVI and annual rainfall.

Block	r 2	Significance value	Equation
Shirur	0.7924	0.0072	Y = 0.2428 + 0.000821×(X)
Khed	0.60538	0.0398	Y = 0.62179 + 0.0001998×(X)

Regression analysis for VHI and annual rainfall (in mm)

Table 6: Regression analysis for VHI and annual rainfall (in mm).

Block	r 2	Significance value	Equation
Shirur	0.7905	0.0074	Y = 25.65103 + 0.03508×(X)
Khed	0.6515	0.0281	Y = 48.0341 + 0.03163×(X)

r^2 value: The value of r2 obtained is 0.7924(for Shirur NDVI &rainfall), the value closer to the 1, better the regression line fits the data. To check the significance of result obtained statistically, significance value is observed which is 0.0072 (<0.05 Pearson coefficient) and is ok.

- Linear Regression equation: Y = 0.2428 + 0.000821×(X) (for Shirur case). Here, Y=Shirur annual rainfall and X= NDVI values. The equation illustrates that 1unit change in rainfall, changes NDVI value by 0.00821 units. Thus, these coefficients can be used to forecast the change in vegetative cover. The equations developed are useful in forecasting, crop insurance design and drought monitoring.

CONCLUSION

This study attempts to identify the spatio-temporal extent of vegetative cover and agricultural drought over Shirur and Khed talukas using satellite-borne remote sensing data based on NDVI, VHI and thus can be successfully used to identify the same. It is employed to explain drought severity classes in the research areas through composite analysis of both vegetation health by vegetation condition and temperature condition. The estimated results of VHI can contribute to monitor the commencement of agricultural drought as early warning system. The correlation and linear regression analysis can be made useful to forecast the vegetative cover condition. The results can further be useful for land use/ land cover database creation, identification of multiple crop and soil type.

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