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Feature Extraction using Normalized Difference Vegetation Index (NDVI): a Case Study of Jabalpur City

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Abstract

This paper presents an improved method for the analysis of satellite image based on Normalized Difference Vegetation Index (NDVI). The method employs the multi-spectral remote sensing data technique to find spectral signature of different objects such as vegetation index, land cover classification, concrete structure, road structure, urban areas, rocky areas and remaining areas presented in the image. For land cover classification, some band combinations of the remote sensed data are exploited and the spatial distribution such as road, urban area, agriculture land and water resources are easily interpreted by computing their normalized difference vegetation index. Different values of threshold of NDVI are used for generating the false colour composite of the classified objects. The simulation results show that the NDVI is highly useful in detecting the surface features of the visible area which are extremely beneficial for municipal planning and management. The vegetation analysis can be used for the situation of unfortunate natural disasters to provide humanitarian aid, damage assessment and furthermore to device new protection strategies.

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1. Introduction

The multispectral remote sensing images are very efficient for obtaining a better understanding of the earth

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environment [1]. It is the science and art of acquiring information and extracting the features in form of spectral, spatial and temporal about some objects, area or phenomenon, such as vegetation, land cover classification, urban area, agriculture land and water resources without coming into physical contact of these objects [2]. The remote sensing data has many application areas including: land cover classification, soil moisture measurement, forest type classification, measurement of liquid water content of vegetation, snow mapping, sea ice type classification, oceanography [2]. The multispectral remote sensing images carry essential integrating spectral and spatial features of the objects [3]. In this paper, the multispectral image of Jabalpur region is used to calculate the percentage of versatile features such as vegetation, water bodies, land cover classification, concrete structures, rocky area, urban areas, road structure and remaining area presented in this image, and to subsequently make these extracted features available to the public for further analysis in order to avoid any sort of natural disasters like flood.

Remote sensing is a technology used for obtaining information about a target through the analysis of data acquired from the target at a distance. It is composed of three parts, (a) Targets, objects or phenomena in an area; (b) Data acquisition through certain instruments; and (c) Data analysis by some devices. The derived data has been acquired by the use of Electromagnetic Radiation (EMR) in one or more regions of the electromagnetic spectrum that is reflected or emitted from the earth's surface. The information transfer is accomplished by use of EMR in its visible region [4]. EMR wave is a form of energy that reveals its presence by the observable effects it produces when it strikes the matter.

In the Indian remote sensing agency, generally two types of generic sensors are employed for the collection of information, named passive remote sensing and active remote sensing. The passive remote sensing is used for gathering the satellite information and sun is the source of energy. It consists of an array of small sensors or detectors, which is used to record the amount of electro-magnetic radiation that is reflected or emitted from the Earth's surface [5]. While in case of active remote sensing, the remote sensing system propagates its own electro-magnetic radiation and measures the intensity of the return signal. For the feature extraction, mostly passive remote sensing is applied and the active remote sensing is used for the radar imaging system [5].

The National Aeronautics and Space Administration of USA (NASA) uses 7-band data for feature extraction, and it is called as LANDSAT image. The multispectral remote sensing data image of Jabalpur region is received from the National Remote Sensing Agency and it is called INSAT image. It consist 3-band data and the information is accomplished by the help of these 3 bands named near infrared band, red band and green band. Each band contains some specific information and with the help of these three bands, the features can be extracted. On the basis of wavelength, remote sensing is classified into three types as: visible and reflective infrared remote sensing, thermal infrared remote sensing, and microwave remote sensing [6].

Digital image processing of satellite data provides tools for analyzing the image through different algorithms and mathematical indices. Features are based on reflectance characteristics, and indices have been devised to highlight the features of interest on the image [7]. There are several indices for highlighting vegetation-bearing areas on a remote sensing scene. NDVI is a common and widely used index [8]. It is an important vegetation index, widely applied in research on global environmental and climatic change [8]. The vegetation response to environment is very sensitive and not only affects the ecological balance and climate but has also been found to be effective barrier against natural disasters. NDVI is calculated as a ratio difference between measured canopy reflectance in the red and near infrared bands respectively [9]. This paper shows how the differences between the visible red and near-infrared (NIR) bands of an INSAT image can be used to identify areas containing significant vegetation and other different features.

Many researchers have reported the use of NDVI for vegetation monitoring [10, 11] assessing the crop cover [12], drought monitoring [13, 14] and agricultural drought assessment at national [15, 16] and global level [17]. Recently, the researchers have employed remote sensing techniques for estimating the vegetation status of growing crops by determining the appropriate wavelength or combination of wavelengths to characterize crop deficiency [18, 19]. Vegetation index (VI) is a simple and effective measurement parameter, which is used to

indicate the earth surface vegetation covers and crops growth status in remote sensing field [20]. In addition, many researchers [21, 22] have widely used NDVI. While other researchers explored remote sensing techniques for estimating the nitrogen status of growing crops by determining the appropriate wavelength or combination of wavelengths to characterize crop N deficiency [21, 19, 20, 22].

Several different techniques have been reported in literature for analysis of satellite image such as NDVI [23], Artificial Neural Network (ANN) [24] and Satellite Image Contrast Enhancement using Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) [25]. In artificial neural network technique, the performance parameters of feed-forward neural network are the weights [24]. They are varied so that the predicted output is close to true output value corresponding to the input values. This technique is based on two types of learning algorithm: supervised and unsupervised learning [24]. Another technique has been proposed by H. Demirel, Ozcinar and Anbarjafari named DWT and SVD [25]. In all such method, the objective function is feature extraction from the multiband data.

2. Study Area and Site Description

The investigations were performed as a case study on Jabalpur region, which is located in center of India. Jabalpur situated in Madhya Pradesh, India and its geographical coordinates are 23° 10' 0" North, 79° 57' 0" East. In case of Fig.1 (a), the latitude and longitude of the investigated area are 23.163°N, 80.102°E. In case of Fig.1 (c), the latitude and longitude of the investigated area are 22.947°N, 80.046°E.



Fig.1. (a) Satellite image of Jabalpur region, (b) Sequel image of Jabalpur region captured by Google Earth. (c) Satellite image of Jabalpur region, (d) Sequel image of Jabalpur region captured by Google Earth.

3. Overview of NDVI

The NDVI is a commonly used technique for measurement of crop health in agricultural applications. Because of the spatial variability in soil properties, different locations in a field may require different amounts of nitrogen to achieve high yield [26]. After obtaining the point information of NDVI, with the help of Geostatistics, the spatial continuity surface is produced and the crop characteristics are presented to develop the precision agriculture [27]. Remotely sensed images are characterized by their spatial and spectral resolutions. The terms spatial and spectral resolution represent pixels of an image displayed in a geometric relationship to one another; and variations within pixels as a function of wavelength respectively. NDVI of multispectral remote sensing image is based on spatial and spectral resolution. Variations in reflectivity of surface material across different spectral band provide a fundamental mechanism for understanding feature in remotely sensed image. Using remote sensing data, vegetation can be distinguished from most of the other materials by virtue of its notable absorption in the red and blue segments of the visible spectrum, its higher green reflectance and especially, it's very strong reflectance in the near-IR [26, 27]. There are several indices for highlighting vegetation area on a remote sensing image. NDVI is common and widely used for the same.

4. Methodology Based on NDVI

In this section, the NDVI technique is used for extracting the various features presented in the 3-band satellite image of Jabalpur region. Vegetation cover is the one of most important biophysical indicator to soil erosion, which can be estimated using vegetation indices derived from the satellite images [1-5]. Vegetation indices allow us to delineate the distribution of vegetation and soil based on the characteristic reflectance patterns of green vegetation. The NDVI is a simple numerical indicator that can be used to analyze the remote sensing measurements, from a remote platform and assess whether the target or object being observed contains live green vegetation or not [25-28]. The NDVI is calculated as

$$RNDVI = \frac{NIR - RED}{NIR + RED} \quad (\text{where } 0 < NDVI < 1) \quad (1)$$

$$GNDVI = \frac{NIR - GREEN}{NIR + GREEN} \quad (\text{where } 0 < NDVI < 1) \quad (2)$$

where RED is visible red reflectance, and NIR is near infrared reflectance. The wavelength range of NIR band is (750-1300 nm), Red band is (600-700 nm), and Green band is (550 nm).

The NDVI is motivated by the observation vegetation, which is the difference between the NIR and red band; it should be larger for greater chlorophyll density. It takes the (NIR - red) difference and normalizes it to balance out the effects of uneven illumination such as shadows of clouds or hills. In other words, on a pixel by pixel basis subtracts the value of red band from the value of NIR band and divides by their sum. Very low value of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow. Moderate values represent shrub and grassland (0.2 to 0.3), while high value indicates temperate and tropical rainforests (0.6 to 0.8). Bare soil is represented with NDVI values, which are closest to 0 and water bodies are represented with negative NDVI values [4-7].

Table 1. Thematic bands of NASA are as LANDSAT satellite.

| Band No. | Name | Wavelength (μm) | Characteristics and use |
|----------|------------------|------------------------------|--------------------------------|
| 1 | Visible blue | 0.45-0.52 | Maximum water penetration |
| 2 | Visible green | 0.52-0.60 | Good for measuring plant vigor |
| 3 | Visible red | 0.63-0.69 | Vegetation discrimination |
| 4 | Near infrared | 0.76-0.90 | Biomass and shoreline mapping |
| 5 | Middle infrared | 1.55-1.75 | Moisture content of soil |
| 6 | Thermal infrared | 10.4-12.5 | Soil moisture, thermal mapping |
| 7 | Middle infrared | 2.08-2.35 | Mineral mapping |

The bands are expressed in terms of wavelengths, in the order of 1 μm . Although, the other features can be extracted with the help of these four visible ranges (visible blue, middle infrared, thermal infrared and middle infrared), only three visible bands are used (near infrared, visible red and visible green) in this work for the feature extraction. In other words, the degree of greenness is equal to the chlorophyll concentration. NDVI values vary with the absorption of red light by plant chlorophyll and the reflection of infrared radiation by water-filled leaf cells.

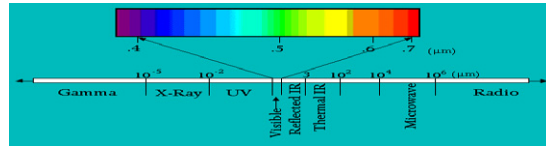


Fig.2. Visible ranges of the electromagnetic spectrum for feature extraction.

Fig.2. indicates the visible ranges of the visible blue, visible green, visible red, near infrared, middle infrared, thermal infrared and middle infrared. All visible ranges are captured by the satellite camera in form of bands through which features can be extracted after applying the NDVI method for different characteristics. Table.1. describe the wavelength range and the characteristics for different features.

A complete flowchart routine of the proposed methodology is illustrated in fig.3.

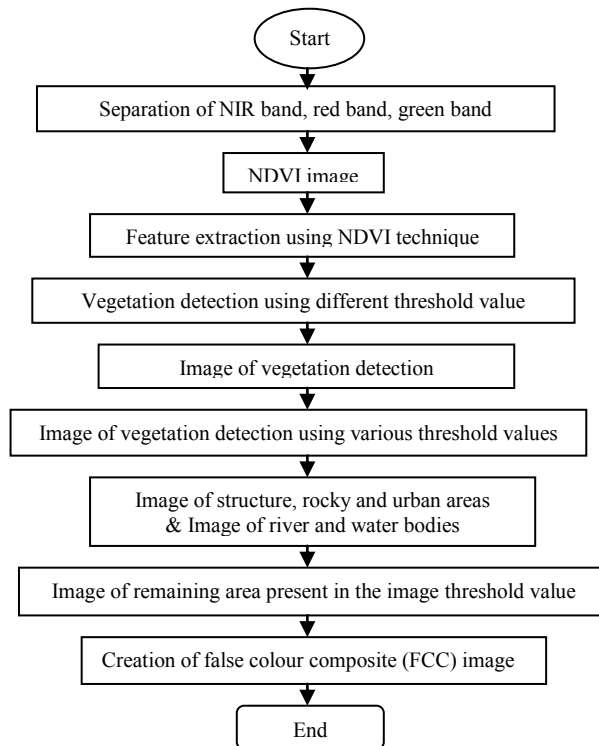


Fig. 3: Flowchart of the methodology.

4.1 Finding Vegetation in a Multispectral Satellite Image

For the detection of the vegetation index from a multispectral remote sensing image, the NDVI process needs to separate each and every band, which is present in the satellite image. After separation of different band, NDVI method is applied according to its characteristic like vegetation at different NDVI threshold value such as 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4 and 0.5. Various NDVI threshold value is used to extract best result from satellite image of Jabalpur region.

4.2 Creation of False Colour Composite (FCC) Images

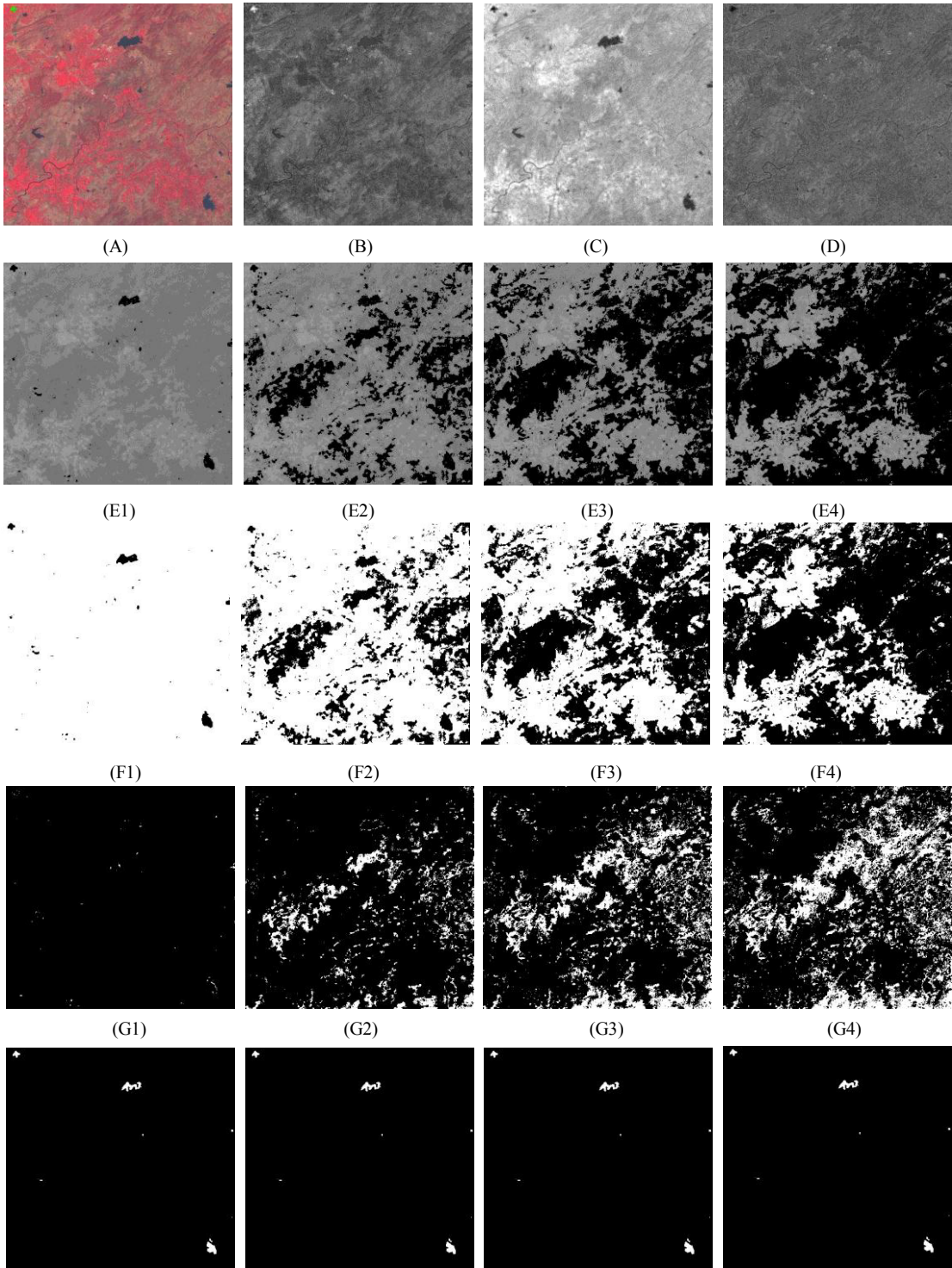
The alternation of the colour for an image, like red light for blue, green for red, blue for green, which is called false colour image or FCC. Basically, false colour composite is used to identify some specific feature by changing their colour.

5. Experimental Result and Discussion

The NDVI have been used widely to examine the relation between spectral variability and the vegetation vigor or growth rate. It is also useful to determine the production of green vegetation as well as detect vegetation changes. The-results, included in table 2, represent the various features, which have been extracted from the satellite image of Jabalpur region. The result is compared with the Google earth image, which shows the improvement significantly. After the analysis of first image [Fig.1 (a)], it has been found that the multispectral images are giving best result for all the features at NDVI value of 0.3, whereas second image [Fig.1 (c)], giving good result for all the features at NDVI value of 0.2 respectively. In this paper, the NDVI value is varied from (0.1 to 0.5) so that best features can be extracted from Jabalpur region. The lowest values are found on the less vegetated soils and presumably because reflection from the soil is high, and produce low values in NIR band and high values in red band; hence the NDVI values are low. Vegetation remains green (high NDVI values) due to availability of water in the soil. On the contrary, when soil water availability decreases, due to any environmental reason (stress by water deficit); the green vegetation tends to disappear, then the values of NDVI decreases.

Table.2. Different features of the first study area of Jabalpur region extracted from Fig.1. (a).

| Sr. No | Various NDVI Values | No. of Pixel for Vegetation/ Percentage | No. of Pixel for Water Bodies & River/ Percentage | No. of Pixel for Structures, Rocky & Urban Areas/ Percentage | No. of Pixel for Remaining Areas /Percentage | Total no. of Pixel 420×420 /Total Percentage |
|--------|---------------------|---|---|--|--|--|
| 1 | 0.1 | 175082/ 99.2528% | 396/ 0.2245% | 189/ 0.1071% | 396/ 0.2245% | 176400/ 100% |
| 2 | 0.15 | 170047/ 96.3985% | 747/ 0.4235% | 2582/ 1.4637% | 3024/ 1.7143% | 176400/ 100% |
| 3 | 0.20 | 139184/ 78.9025% | 866/ 0.4909% | 14659/ 8.3101% | 21691/ 12.2965% | 176400/ 100% |
| 4 | 0.25 | 94610/ 53.6338% | 3490/ 1.9785% | 31628/ 17.9297% | 46672/ 26.4580% | 176400/ 100% |
| 5 | 0.30 | 56678/ 32.1304% | 11602/ 6.5771% | 41445/ 23.4949% | 66675/ 37.7976% | 176400/ 100% |
| 6 | 0.35 | 32714/ 18.5454% | 13936/ 7.9002% | 42630/ 24.1667% | 87120/ 49.3878% | 176400/ 100% |
| 7 | 0.40 | 17602/ 9.9785% | 14395/ 8.1604% | 42653/ 24.1797% | 101750/ 57.6814% | 176400/ 100% |
| 8 | 0.50 | 3172/ 1.7982% | 14436/ 8.1837% | 42681/ 24.1956% | 116111/ 65.8226% | 176400/ 100% |



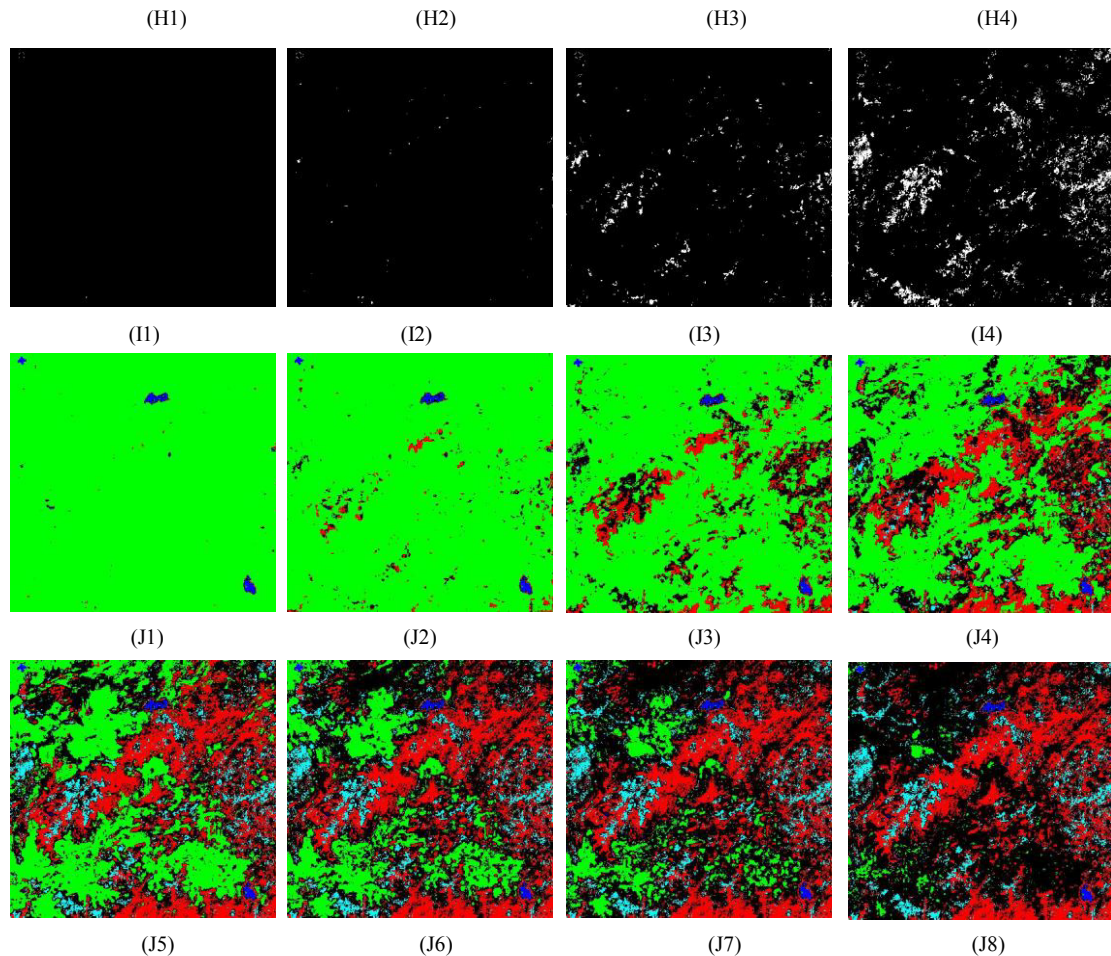


Fig4. (A) Satellite image of Jabalpur, (B) Red band, (C) NIR band, (D) Green band, (E) Different level of vegetation, (F) Various levels for vegetation index using threshold value, (G) Various levels for the structures, rocky and urban areas, (H) Various levels for river and water bodies, (I) Various levels for the remaining area, (J) Various levels of the false colour composite image.

In this paper, Fig.4 (A) represents the satellite image of first study area of Jabalpur region. Fig.4 (B), (C) and (D) represent the subsequently Red band, NIR band and Green band. Fig.4 (E1), (E2), (E3), and (E4) represent the vegetation index at NDVI value of 0.1, 0.2, 0.25 and 0.3. Fig.4 (F1), (F2), (F3), and (F4) represent the vegetation index using threshold value of 0.1, 0.2, 0.25 and 0.3. Fig.4 (G1), (G2), (G3), and (G4) represent the structures and rocky area as well as urban areas at various NDVI value. Fig.4 (H1), (H2), (H3), and (H4) represent the river and water bodies at various levels which are present in Jabalpur region. Fig.4 (I1), (I2), (I3), and (I4) represent the remaining area which are available in the Jabalpur region. Fig.4 (J1), (J2), (J3), (J4), (J5), (J6), (J7) and (J8) are the FCC image at the NDVI value of 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4 and 0.5. In the FCC image, each color represents some specific feature, which have been extracted such as green color denote vegetation, red color represents structures, rocky area and urban areas, dark blue color denote river and water bodies, sky blue color signifies remaining area presented in Jabalpur image.

Table.3. Different features of the second study area of Jabalpur region extracted from Fig.1. (c).

| Sr. No | Various NDVI Values | No. of Pixel for Vegetation/ Percentage | No. of Pixel for Water Bodies & River/ Percentage | No. of Pixel for Structures, Rocky & Urban Areas/ Percentage | No. of Pixel for Remaining Areas /Percentage | Total no. of Pixel 420×420 /Total Percentage |
|----------|---------------------|---|---|--|--|--|
| 1 | 0.1 | 157703/ 89.4008% | 14924/ 8.4603% | 1813/ 1.0278% | 1960/ 1.1111% | 176400/ 100% |
| 2 | 0.15 | 144488/ 81.9093% | 15030/ 8.5204% | 10494/ 5.9490% | 6388/ 3.6213% | 176400/ 100% |
| 3 | 0.20 | 81916/ 46.4376% | 15343/ 8.6978% | 54405/ 30.8418% | 24736/ 14.0227% | 176400/ 100% |
| 4 | 0.25 | 29023/ 16.4529% | 19991/ 11.3328% | 90061/ 51.0550% | 37325/ 21.1593% | 176400/ 100% |
| 5 | 0.30 | 10155/ 5.7568% | 25444/ 14.4240% | 98716/ 55.9615% | 42085/ 23.8577% | 176400/ 100% |
| 6 | 0.35 | 5015/ 2.8430% | 26304/ 14.9116% | 98991/ 56.1173% | 46090/ 26.1281% | 176400/ 100% |
| 7 | 0.40 | 2992/ 1.6961% | 26396/ 14.9637% | 98998/ 56.1213% | 48014/ 27.2188% | 176400/ 100% |
| 8 | 0.50 | 2249/ 1.2749% | 26406/ 14.9694% | 99000/ 56.1224% | 48745/ 27.6332% | 176400/ 100% |

6. Conclusions

In this paper, an improved method is presented for feature extraction from the multispectral remote sensing images. The normalized difference vegetation index technique with different threshold values has been employed for features extraction of Jabalpur region (India) as a case study. Simulation results included in this paper clearly shows that the percentage of vegetation is almost same for different threshold value. This implies that the result of vegetation and other features are accurate. In the first INSAT image, the percentage of vegetation, in the given study area of Jabalpur region is found to be 32.1304% at NDVI threshold of 0.3, water bodies & river are found to be 6.5771%, structures, rocky and urban area are found to be 23.4949% and remaining area is found to be 37.7976%. In the second INSAT image, the percentage of vegetation in the given study area of Jabalpur region is found to be 46.4376% at NDVI threshold of 0.2, water bodies & river are found to be 8.6978%, structures, rocky and urban area are found to be 30.8418% and the remaining area is found to be 14.0227%. The NDVI method gives superior results for vegetation varying in densities and also for scattered vegetation from a multispectral remote sensing image. By varying the value of threshold index, the varying densities of vegetation coverage can be detected. Apart from studies of agricultural needs and crop patterns, the vegetation analysis can be used in the events of unfortunate natural disasters to provide humanitarian aid and damage assessment and also to device new protection strategies.

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