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## Performance evaluation of vegetation indices using remotely sensed data

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### ABSTRACT

Vegetation is one of the most important components of the ecosystems. Knowledge about variations in vegetation species and community distribution patterns, alternations in vegetation phenological (growth) cycles, and modifications in plant physiology and morphology provide a valuable insight in to the climate, geologic and physiographic, characteristics of an area, so mapping vegetation cover is important to understand various ecological processes occurring in nature, their relationship and the various geomorphological changes occurring over the period of time. Remote sensing is the advanced tool for surveying. It provides the synoptic view of the area. Remote sensing satellites provide data with different spatial, spectral, radiometric and temporal resolutions. Based on requirement and level of study the different data products can be used for mapping. Mapping vegetation through remotely sensed images involves various considerations, processes and techniques. Increasing availability of remotely sensed images due to the rapid advancement of remote sensing technology expands the horizon of our choices for imagery sources. Various sources of imagery are known for their differences in spectral, spatial, radiometric and temporal characteristics and thus are suitable for different purposes of vegetation mapping. Various techniques have been developed to map the vegetation with varying accuracies and cost. The simplest one is to use vegetation indices, they are easy to understand and calculate. Various vegetation indices have been designed and have their specific utility for vegetation mapping. Some vegetation indices not only help to identify vegetation but also help to identify and map other land cover classes. The present paper will throw light on various vegetation indices developed, their applications and provide a detailed comparison study for their mapping efficiency based on spatial resolution of data used. This study reveals that NDVI gives the better result in terms of overall accuracy to assess the vegetation.

**Keywords:** Remote sensing, vegetation indices, NDVI, TDVI, SAVI.

### 1. Introduction

Vegetation is the land-cover in term of plant biomass. The vegetation may be of permanent type i.e. lasting or standing for months and years, such as reserve forests; others may be temporary grown for few months only, such as seasonal crops. The vegetation is the most important factor governing the ecology of the area. The vegetation in a particular area can provide inferences to derive various parameters such as soil information, water table information, delineating ground water potential zone, soil strata, geomorphology of the area, water shed identification, delineating faults and fractures, finding erosion potential zones, land use identification etc. and vice-versa i.e. vegetation can be mapped considering these parameters as auxiliary data for study.

The vegetation mapping is to identify and define the different vegetation cover on the earth surface and it evaluates particular vegetation type and its extent. Earlier, there was no such need to map the vegetation, as huge land portion was covered with forests and such advanced

techniques were not available to map the large area at once. Later, due to rapid industrialization and technological advancement demand for raw material increased many folds, so huge natural resources were exploited to fulfill the demand for raw materials and out of them forests suffered the most. India's Forest Cover accounts for 20.6% of the total geographical area of the country as of 2005. In addition, Tree Cover accounts for 2.8% of India's geographical area (Ministry of Environment and Forests, Government of India, 2009), which is significantly low compared to rising population.

With latest technology of Remote Sensing we can identify and define different phenomena and objects on earth surface and also their past, present and future by analyzing it from top of it. Satellite is just like our eye and is constantly watching various feature and phenomenon on earth surface from a far distance. Satellite images are very important, for instance for monitoring desertification (Tripathy & Ghosh, 1996), forest fragmentation, vegetation health and density as well as monitoring landform processes (Jacobberger & Hooper, 1991) and ecological zoning among others.

Vegetation indices (VIs) are being used to accurately inventory the global distribution of vegetation types as well as their biophysical (e.g. LAI, biomass, APAR) and structural (e.g. percent canopy closure) properties. Monitoring these characteristics through space and with time will provide valuable information for understanding the earth as a system (Townshend & Justice, 2002).

Various factors together govern the vegetation of the area. It is one of the main landscape components. Plant communities grow together in certain localization, because a particular environment supports the plants with similar requirements. Many factors have influence on the vegetation pattern. A particular type of vegetation has specific climatic, hydrological, edaphic, geomorphological, physiographic conditions and cultural practices are associated with it.

Most of the VIs formulated are related to the Simple Ratio. The VIs are designed considering the reflectance property of various objects and phenomenon that occurs on earth surface, because the reflectance obtained due to interaction of the EMR is affected by the physical and chemical properties of the object. The VIs are built on the observation that various pigments and chemical composition of the green leaves strongly response on satellite data. Green leaves absorb light in the red region of electromagnetic spectrum, with maximum absorption at about 690 nm, while the cell walls strongly scatter (reflect and transmit) light in the NIR region (about 850 nm) (Tucker C., 1979). This results in a strong absorption contrast across a narrow wavelength band of 650 - 850 nm, captured by the VIs.

Over the time, the demand for mapping available resources has increased, even as sensor technology and methods for deriving information from remote sensing images have continued to improve. Various methods based on vegetation indices have been designed to extract vegetation from the satellite data. These indices are calculated based on the spectral profile of the data available and have different capabilities to classify the pixels according to the response. Different vegetation indices classify the data based on specific reflection property of the object to particular band.

The present paper is focused to calculate and compare various vegetation indices for LISS IV data from IRS P6 and TM data from Landsat 5 satellite, examine vegetation indices performance to classify the data in to desired classes and discuss limitations and advantages of both the data for vegetation mapping applications. The paper discusses the introduction in

part 1. Part 2 describes the data resources used for study and the study area taken for analysis purpose. The methodology is described in part 3 followed by results, analysis in part 4, and conclusions and recommendations are given in part 5.

## **2. Data resources and study area**

**2.1 Data resources:** The satellite data and other data used for this research are summarized in table 1.

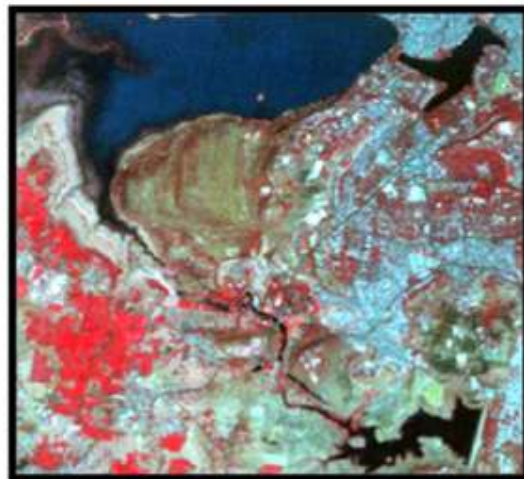
**Table 1:** Data resources

S.No.	Satellite/Sensor	Row	Path	Date of acquisition	Resolution
1	Landsat 5 TM	44	145	25-01-2011	30m
2	IRS P6 LISS IV	43	102	28-02-2005	5.8m

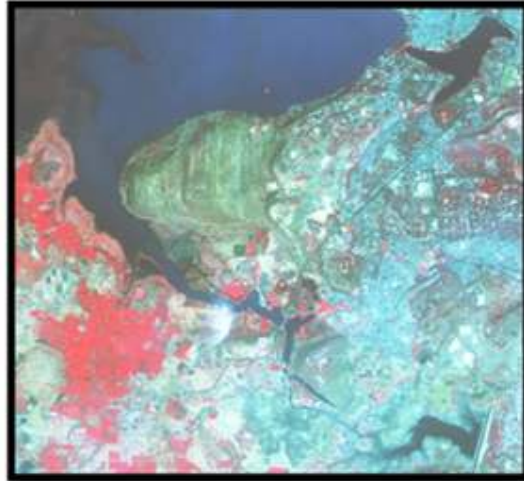
## **2.2 Study area**

For research purpose, part of Bhopal, which is the capital city of State of Madhya Pradesh, India is taken. The geographical location of the area lies in UTM zone 43N. Bhopal has an average elevation of 427 m with an annual rainfall of 1146mm and average temperature of 25 °C. Bhopal has slightly deep, well-drained, calcareous clayey soils on gently sloping plain with narrow valleys with moderate erosion (Fine, Montmorillonitic-calcareous, Hyperthermic, Vertic Ustochrepts) and has an irrigated agricultural practice. The main agricultural practice is to crop wheat with gram, pea (*Pisum sativum*), and other crops (Pandya M. R. et al., 2006). Well-distributed sample plots (14 in the Bhopal city) were selected as ground truth and validating the results.

The false color composite (FCC) of the study area as observed by the Landsat 5 TM sensor and LISS IV sensor are shown in figure 1 and figure 2, respectively.



**Figure 1:** FCC of study area observed by Landsat 5 TM sensor



**Figure 2:** FCC of study area observed by LISS IV sensor

### **3. Methodology**

The methodology for evaluating performance of various vegetation indices using remotely sensed data consists of identifying various land cover classes that can be extracted using different vegetation indices. Seven different land use classes namely: built-up, water body, sparse vegetation, dense vegetation, open land, rocky surface and unclassified were decided on the basis of site visit and vegetation indices capability to discriminate among them.

#### **3.1 Image processing in ERDAS software**

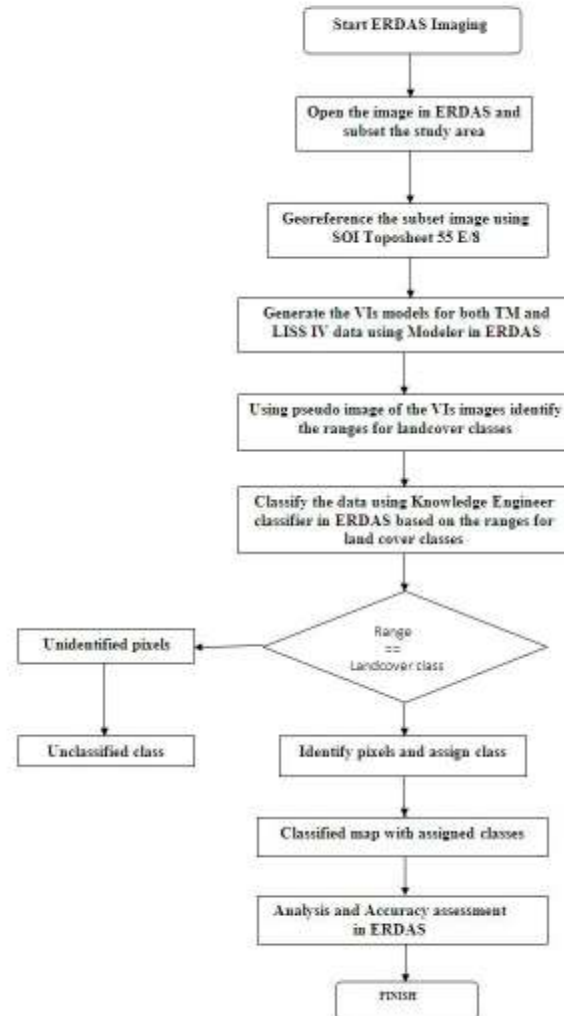
1. The study area subset was extracted from the Bhopal city Landsat 5 TM and IRS P6 LISS-IV image.
2. The subset image was georeferenced using DGPS data and references were taken from Survey of India Toposheet no. 55 E/8 that covers the study area.
3. Using ERDAS IMAGINE Image Interpreter or ERDAS IMAGINE Spatial Modeler module, we implemented algorithms for generating vegetation indices separately for both TM data and LISS IV data.
4. The density sliced images were generated from the output VI images that were used to collect ranges of VI corresponding to various land cover classes to map.
5. The Knowledge Engineer module of ERDAS was used to generate knowledge base for classifying the images.
6. The output classified images were further analysed in ERDAS software.

#### **3.2 Image analysis in ERDAS software**

- 1) The classified images were first compared visually to analyse the land cover classes at some of validation points to confirm accuracy.
- 2) Then accuracy assessment tool in ERDAS is used to calculate and compare the accuracy of both TM and LISS IV data separately.

3) The classified images were also analysed for identifying best among the vegetation indices for classifying the image in to desired land cover classes.

The entire methodology is summarized in the following flow chart shown in figure 3.



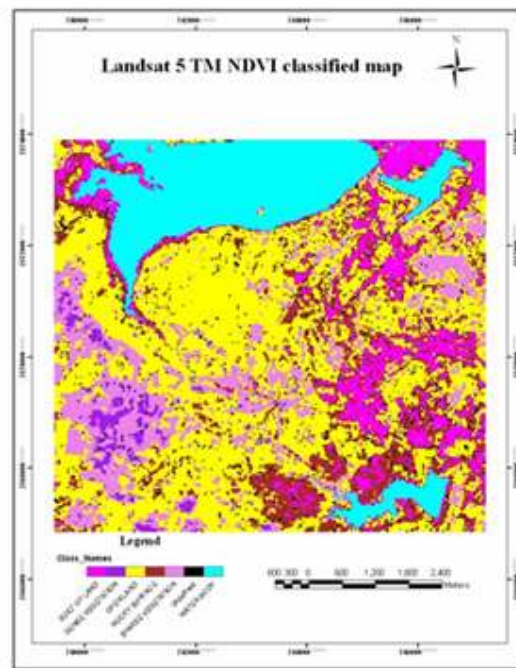
**Figure 3:** Flow chart of the methodology adopted

The methodology suggested is a simple technique based on the ERDAS 9.1 software. Based on the spectral properties of the data, we can evaluate different vegetation indices. The three vegetation indices Normalized difference vegetation index (NDVI), Transformed difference vegetation index (TDVI) and Soil adjusted vegetation index (SAVI) were calculated that provided good results for both TM and LISS IV data. These vegetation indices calculated for both LISS IV and TM data that differ in spatial as well as spectral resolution (refer table 1). Due to variation in spatial and spectral characteristics of the data, we can compare and evaluate performance of vegetation indices from both the data.

#### **4. Results and findings**

The outputs for vegetation indices are calculated using ERDAS IMAGINE 9.1 Interactive Modeller. The vegetation indices performance is evaluated based on overall accuracy obtained after classification of image using vegetation indices.

Each of Landsat 5 TM and IRS P6 LISS IV image is georeferenced in UTM WGS 84 projection system and the study area is subseted, then it is classified using knowledge classifier using index images. The index images are classified in to six classes: water body, built-up area, open land, rocky surface, sparse vegetation and dense vegetation for Landsat 5 TM and in to five classes (except rocky surface) for IRS P6 LISS IV image. One extra land cover class rocky surface is been extracted using lower resolution data compared to higher resolution data. The classified output for NDVI, TDVI and SAVI are calculated for the Landsat 5 TM and IRS P6 LISS IV data and are shown in figure 4a, 4 b, 5a, 5b, 6a, 6b, respectively. The five common land cover classes that can be mapped well using both the data sets are used for comparative analysis.



**Figure 4a:** NDVI from TM data

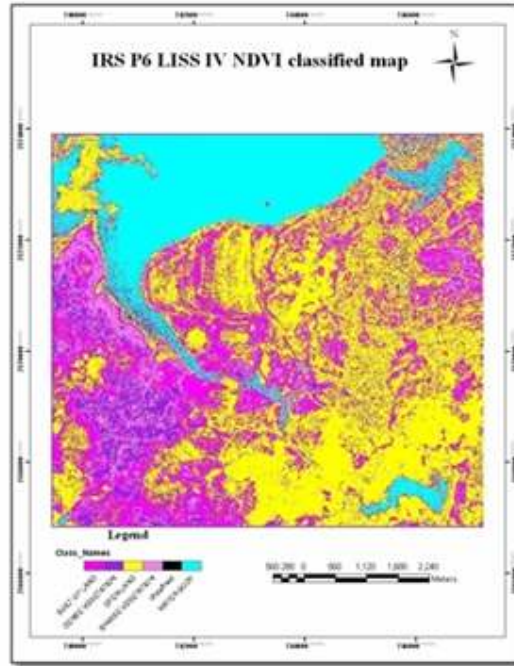


Figure 4b: NDVI from LISS IV data

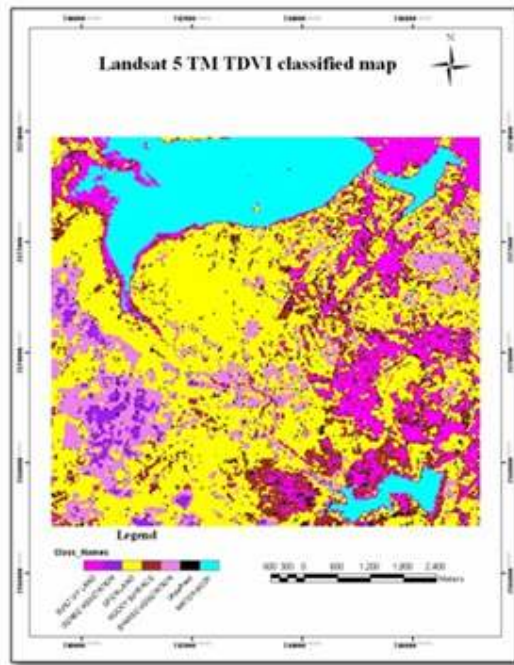
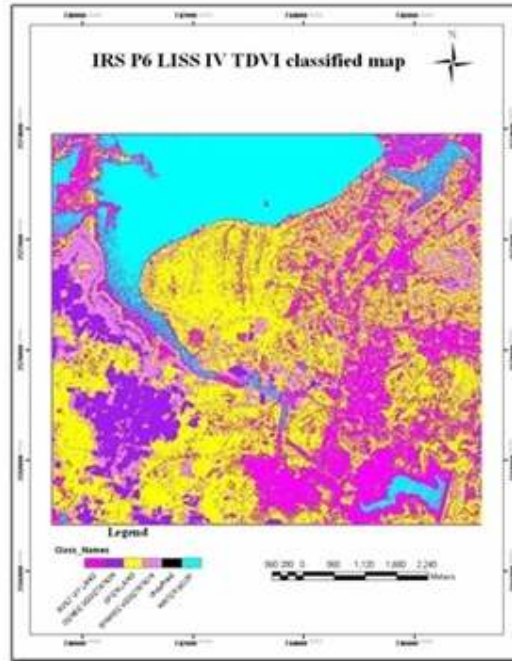
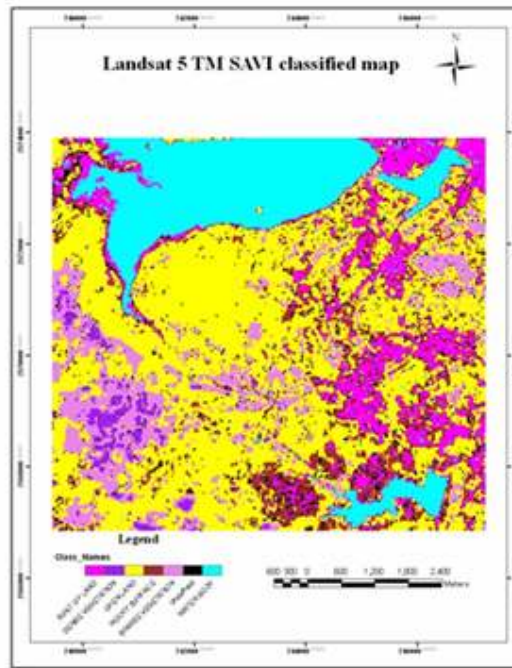


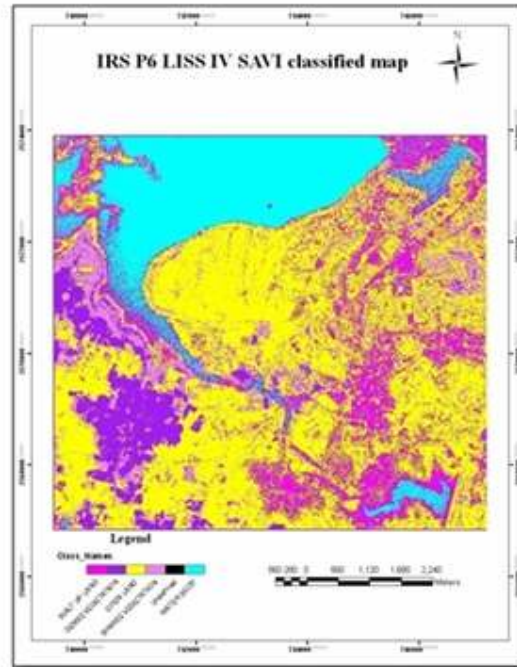
Figure 5a: TDVI from TM data



**Figure 5b:** TDVI from LISS IV data



**Figure 6a:** SAVI from TM data



**Figure 6b:** SAVI from LISS IV data

The classified index images are calculated for overall accuracy measurement known as  $k$  (Kappa)-coefficient. The coefficient expresses the proportionate reduction in error generated by a classification process compared with the error of a completely random classification. For example, a value of .82 implies that the classification process is avoiding 82 percent of the errors that a completely random classification generates (Congalton, 1991). The classified images are compared for the comparative accuracy using  $k$ -coefficient that is illustrated in table 2.

**Table 2:** Comparison among responses of TM and LISS IV data for different Vegetation Indices using k-value

Vegetation Index land cover class	Landsat 5 TM			IRS P6 LISS IV		
	NDVI	SAVI	TDVI	NDVI	SAVI	TDVI
Water body	1	1	1	1	1	1
Built-up land	0.7222	0.6753	0.4318	0.3506	0.4565	0.1667
Open land	0.4483	0.5098	0.6656	0.6753	0.7692	0.4599
Sparse vegetation	1	1	1	1	1	0.4792
Dense vegetation	1	0.8148	1	1	0.5833	0.734

The  $K$ -value of different vegetation indices corresponding to land cover classes helps us to identify the performance of vegetation indices. For both the data used for analysis it is confirmed that the NDVI has best overall accuracy. From the table 2, it is clear that water body and sparse vegetation are well classified by both the satellite data. Built up area is well classified using NDVI in coarser resolution data but it is not mapped well due to intermixing of pixels using higher resolution data. Open land is well mapped in SAVI using higher resolution data as the open fields, play ground, small plots between residential areas are well identified using higher resolution data.

Though high resolution data provides a high level details for mapping, but it causes some intermixing of pixels compared to if we use lower resolution data, that is due to the shadow of the trees, buildings or some higher constructions or features, which is identified in high resolution data and misclassified.

## **5. Conclusions and future recommendations**

The present paper aimed to observe performance of various vegetation indices for coarser and fine resolution satellite data and following are the conclusions.

Among various vegetation indices available the NDVI has shown best performance to classify vegetation among all discussed vegetation indices and it helped to map other land-cover classes also. Among the three NDVI, TDVI and SAVI, the  $k$ -value confirmed the efficiency of NDVI to map selected land-cover classes. Use of Landsat 5 TM and LISS IV data helps to validate the efficiency of NDVI. SAVI and TDVI produces result of comparable accuracy, so they can be improved by adding auxiliary data to map desired land cover classes. In case of LISS IV sensor image, it is observed that at places with mixed land use and high rise buildings, misclassification tendency is more and this may be due to poor accuracy in ground referencing or deviations in the image radiometry due to building shadows etc. and more investigations are required on this aspect.

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