

Comparative study of MODIS, LANDSAT-8, SENTINEL-2B, and LISS-4 images for Precision farming using NDVI approach

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Abstract: This study aims to understand the potential use and application of satellite images in analyzing the vegetation of a given area. It utilizes images from 4 sensors/satellites, namely *MODIS (Terra)*, *LANDSAT 8*, *SENTINEL 2B*, and *LISS 4 (Resourcesat-2)*. The area chosen for analysis is 'Bangalore North', a taluk in the Bangalore district of Karnataka, India, where about 23% of the total area is used for agriculture. The images obtained are analyzed for the extent of data that can be extracted, individual spatial variability, and their relative application in precision farming and vegetation analysis. The maps are generated using *NDVI* (Normalised difference in Vegetation Index) approach. They are then categorized into 14 classes, after which the maps are analyzed using a histogram and by extracting pixel count for each class and comparing the results among the sensors/satellites used. It was found that, of the four sensors/satellites, *LISS-4* is best suitable for precision farming and vegetation analysis as the map obtained has a higher and clear resolution, along with better spatial variability. In the absence of *LISS-4*, *Sentinel - 2B* was a better choice, and *MODIS* was unsuitable for this purpose.

1 Introduction

Today's world runs efficiently because of the numerous satellites and sensors constantly monitoring the planet, updating with information, and making it possible for anyone at any corner of the world to connect at any given time. While the use and applications of satellites are numerous and even uncountable, they are used relatively sparsely in understanding vegetation, specifically in agriculture. Therefore, this study focuses on understanding the extent and use of satellites for precision farming – a crop monitoring and management concept[1]. It was found to be extremely useful for analyzing an area for its state of vegetation at any time. The idea of precision farming comes from the Global Positioning System (GPS), which marks a location concerning its relative time and space[1]. Precision farming can hence help apply a precise and correct amount of inputs like fertilizers, water, and pesticides at the right time to increase and maximize productivity and yield. Since GPS uses satellite data and information, the study utilizes satellite images to obtain vegetation data for the

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chosen area, which is then further analyzed for various parameters. The study uses satellites/sensors found to be used for standard applications, namely MODIS, SENTINEL – 2B, LANDSAT -8, and a high-resolution sensor named LISS -4, which are studied and relatively compared to determine one best suited for the need.

2 Methodology

2.1 Study Area

Bengaluru/Bangalore is the capital city of Karnataka, located on the Deccan Plateau in the south-eastern part of Karnataka and spread across four Taluks; Bengaluru North, Bengaluru East, Bengaluru South, and Anekal. For this study Bengaluru North Taluk is chosen as the study area as shown in Fig. 1. It geographically lies between $77^{\circ} 18' 30''$ E and $77^{\circ} 46' 0''$ E longitude and $12^{\circ} 56' 30''$ N and $13^{\circ} 13' 0''$ N with an area of 795.49 sq. km[2]. It consists of a total of 210 villages and six towns/hoblies. Some of the significant parts of the Bangalore metropolitan city present in this taluk are Banaswadi, HBR Layout, Hebbal, Hennur, Jakkur, Jalahalli East & West, Peenya Industrial Area, Sanjeevani Nagar, and Yeshwantpur. The area has a broad agriculture profile with crops such as Paddy, Ragi, Maize, Banana, Grapes, Coconut, Rose, and many others cultivated in this region every season. Around 12,700 ha. of the available 55,000 ha. is utilized for agriculture (as of 2014 -2015). Thus for the present times, with an increased positive outlook in organic farming and organic products along with specialized farming techniques and interest in pursuing farming among urban dwellers of regions across the world, this study area can, thus, provide an approach for the urban dwellers as well as farmers by profession (both small scale and large scale) to monitor their land better and provide a medium to obtain maximized yield.

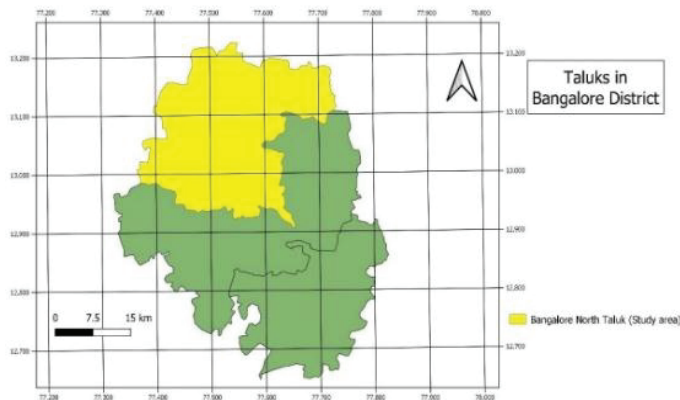


Fig. 1. Study area – Bangalore North (Highlighted in yellow)

2.2 Data Products

Normalized Difference in Vegetation Index is a widely used index to analyze vegetation of a given area from remote sensing data. It is a dimensionless quantity and uses the visible and near-infrared wavelength bands captured by the satellite/sensor to estimate the density of green (vegetation) in the given area. Thus, It is an essential guideline for vegetation cover in a particular region from remotely sensed data gained using space borne sensors. The value

of NDVI usually ranges from -1 to 1 and is calculated using a simple mathematical equation as shown [3]:

$$NDVI = \frac{NIR-Red}{NIR+Red} \text{ -----(1)}$$

Equation (1) represents the NDVI formula, where;

NIR = Near Infrared region

Red = Red/Visible region

Thus, the NDVI for a satellite/sensor is calculated using the respective bands corresponding to NIR and Red regions.

2.2.1 MODIS(Terra)

MODIS (Moderate Resolution Imaging spectroradiometer) is a key instrument aboard Terra. Terra's orbit around the Earth is timed, so it passes from north to south across the equator in the mornings[4]. Terra MODIS views the entire Earth's surface every 1 to 2 days[5], acquiring data in 36 spectral bands or groups of wavelengths.

Specifications:[6]

Orbit: 705km, 10:30 a.m. descending node (Terra) sun-synchronous, near-polar, circular

Spatial Resolution: 250 m (bands 1-2), 500 m (bands 3-7), 1000 m (bands 8-36)

Temporal Resolution: 1 to 2 days

With its low spatial resolution but high temporal resolution, MODIS data is helpful to track changes in the landscape over time. The design of MODIS was an inevitable compromise to satisfy the requirements of three different disciplines: atmosphere, ocean, and land, with spectral bands and spatial resolution selected to meet different observational needs and provide near-daily global coverage[7]. Examples of some applications are monitoring vegetation health using time-series analysis with the help of vegetation indices, long-term land cover changes (For example: to monitor deforestation rates), global snow cover trends, and many more.

NDVI for MODIS is calculated using bands 1 & 2, corresponding to Red and NIR reflectance (wavelengths) [6]. Equation (2) represents the formula.

$$NDVI_{MODIS} = \frac{B2-B1}{B2+B1} \text{ -----(2)}$$

2.2.2 Landsat 8

Landsat 8 orbits Earth in a sun-synchronous, near-polar orbit at an altitude of 705 km (438 mi), inclined at 98.2 degrees, and completes one Earth orbit every 99 minutes. The satellite has a 16-day repeat cycle with an equatorial crossing time: of 10:00 a.m. +/- 15 minutes. It is the most recently launched Landsat satellite and carries the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) instruments [8]. Landsat 8 acquires about 740 scenes a day in 9 spectral bands on the Worldwide Reference System-2 (WRS-2) path system [9], with a swath overlap (or side lap) varying from 7 percent at the equator to a maximum of approximately 85 percent at extreme latitudes. Providing moderate-resolution imagery, from 15 meters to 100 metres, of Earth's land surface and Polar Regions, Landsat 8 operates in the visible, near-infrared, short wave infrared, and thermal infrared spectrums (USGS).

NDVI for LANDSAT 8 is calculated using bands 4 & 5, corresponding to Red and NIR reflectance (wavelengths) respectively[9]. Equation (3), represents the formula.

$$NDVI_{LANDSAT8} = \frac{B5-B4}{B5+B4} \text{-----}(3)$$

2.2.3 Sentinel-2

The Copernicus Sentinel-2 mission comprises two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180° to each other. It aims at monitoring variability in land surface conditions, and its wide swath width (290 km) and high revisit time (10 days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions which results in 2-3 days at mid-latitudes) support monitoring of Earth's surface changes[10]. The satellite carries a wide swath high-resolution multispectral imager with 13 spectral bands. It can provide information for agriculture and forestry, among others allowing for the prediction of crop yields.

NDVI for SENTINEL 2B is calculated using bands 4 & 8 (Table 5), which correspond to Red and NIR reflectance (wavelengths) respectively[11]. Equation (4), represents the formula.

$$NDVI_{SENTINEL2B} = \frac{B8-B4}{B8+B4} \text{-----}(4)$$

2.2.4 LISS-4

The Indian remote sensing satellites use indigenously developed high-resolution cameras for generating data related to vegetation, landform/geomorphic, and geological boundaries. LISS – 4 on-board Resourcesat-2 is a high-resolution multi-spectral camera with 3 spectral bands and having a resolution of 5.8m[12] and a swath of 23km from 817km altitude. The panchromatic mode provides a swath of 70km and a 5-day revisit.

NDVI for LISS 4, is calculated using bands 3 & 4, which correspond to Red and NIR reflectance (wavelengths) respectively[13][11] . Equation (5), represents the formula.

$$NDVI_{LISS4} = \frac{B4-B3}{B4+B3} \text{-----}(5)$$

2.3 Methodology

The methodology followed for the study is as presented in the Fig. 2.

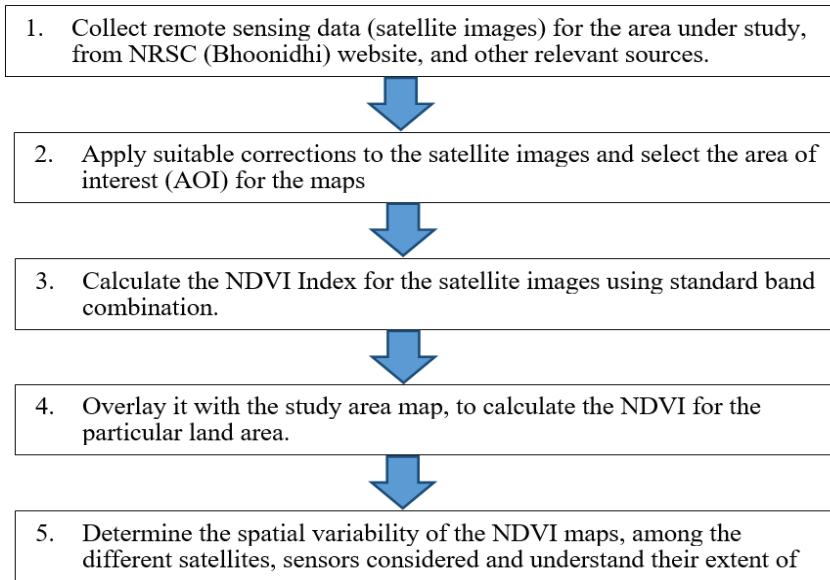


Fig. 2. Methodology flowchart

The first step is to obtain data, i.e satellite images in this study. Once the images are obtained, the next step is to use a Geographical Information System software (GIS) [QGIS- an open-source platform is used for the study], to apply suitable corrections and calculate NDVI to obtain the NDVI map. It is then overlaid with the study area boundary and the NDVI for the region is extracted and categorised into 14 different classes. The maps thus obtained are further analysed for the extent of vegetation and their potential application in precision farming.

3 Results

3.1 NDVI maps

With the NDVI approach and methodology, for the study area chosen, NDVI maps are generated and categorised into 14 classes (derived based on experimentation) for the month of 'February 2021' and are then analysed for their spatial variability, potential extent of application and relevant use.

3.1.1 MODIS (Terra)

The NDVI with MODIS's band combination ranges from 0.1215 – 0.6320, and is categorized into 14 different classes, representing various shades of colours indicating no/low vegetation to high vegetation regions respectively as shown in Fig.3. The red, with NDVI 0.1215 represents no vegetation region: can indicate built-up area. The green, with NDVI 0.6320 represents dense/high vegetation region: can indicate cropland. The range from 0.1215 to 0.3248 indicates different regions of low or no vegetation, with 0.1215 (red) as zero vegetation to 0.3248 (light orange) as very sparse vegetation. Similarly, the range from

0.3392 to 0.6320 indicates regions of live green vegetation, with 0.3392 as sparse vegetation to 0.620 as very high vegetation.

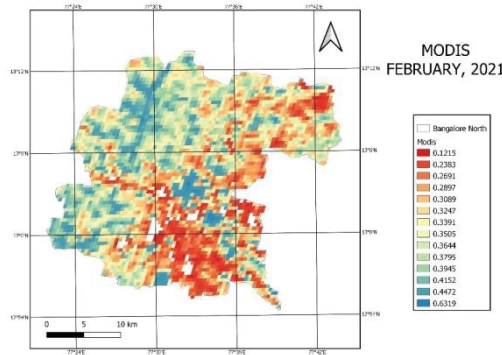


Fig. 3. NDVI map – MODIS – Bangalore North – February 2021

3.1.2 LANDSAT 8

The NDVI with LANDSAT 8's band combination ranges from -0.3176 – 0.5557, and is categorised into 14 different classes, representing various shades of colours indicating no/low vegetation to high vegetation regions respectively as shown in Fig. 4. The red, with NDVI -0.3176 represents no vegetation: can indicate built-up area. The green, with NDVI 0.5557 represents dense/ high vegetation: can indicate cropland. The range from -0.3176 to 0.1588 indicates different regions of low or no vegetation, with -0.3176 (red) as zero vegetation to 0.1588 (light orange) as very sparse vegetation. Similarly, the range from 0.1711 to 0.5557 indicates regions of live green vegetation, with 0.1711 as sparse vegetation to 0.5557 as very high vegetation.

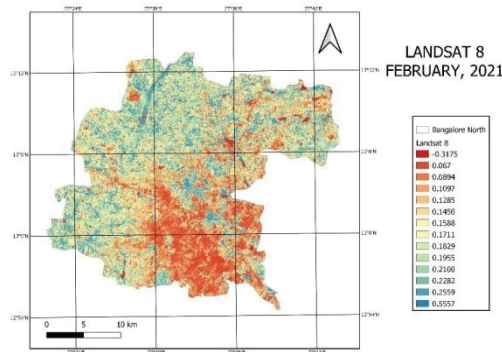


Fig. 4. NDVI map – LANDSAT 8 – Bangalore North – February 2021

3.1.3 SENTINEL 2B

The NDVI with SENTINEL 2B's band combination ranges from -0.4148 – 0.7600, and is categorised into 14 different classes, representing various shades of colours that indicate from no/low vegetation to high vegetation regions respectively as shown in Fig. 5. The red, with NDVI -0.4148 represents no vegetation: can indicate built up area. The green, with NDVI 0.7600 represents dense/ high vegetation: can indicate crop land. The range from -0.4148 to

0.2060 indicates different regions of low or no vegetation, with -0.4148 (red) as zero vegetation to 0.2060 (light orange) as very sparse vegetation. Similarly, the range from 0.2255 to 0.7600 indicates regions of live green vegetation, with 0.2255 as sparse vegetation to 0.7600 as very high vegetation.

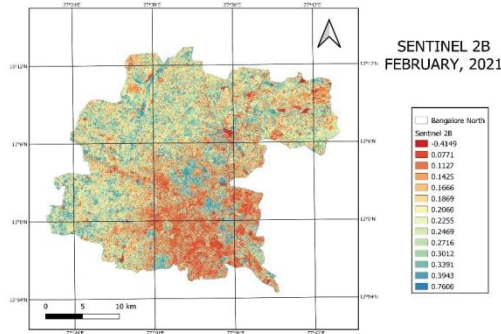


Fig. 5. NDVI map – SENTINEL 2B – Bangalore North – February 2021

3.1.4 LISS 4

The NDVI with LISS-4's band combination ranges from -0.3770 – 0.7861 and is categorized into 14 different classes, representing various shades of colours indicating no/low vegetation to high vegetation regions respectively as shown in Fig. 6. The red, with NDVI -0.3770 represents no vegetation: can indicate built-up area. The green, with NDVI 0.7861 represents dense/ high vegetation: can indicate cropland. The range from -0.3770 to 0.2394 indicates different regions of low or no vegetation, with -0.3770 (red) as zero vegetation to 0.2394 (light orange) as very sparse vegetation. Similarly, the range from 0.2638 to 0.7861 indicates regions of live green vegetation, with 0.2638 as sparse vegetation to 0.7861 as very high vegetation.

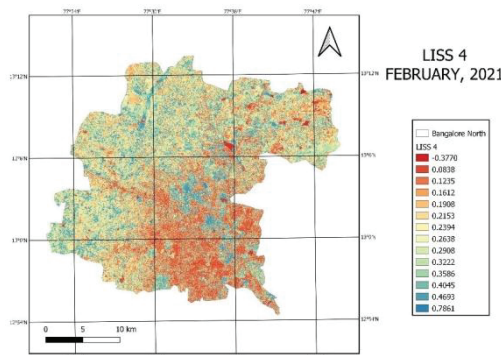


Fig. 6. NDVI map – LISS 4 – Bangalore North – February, 2021

3.2 Comparison of NDVI maps

The next step of the analysis is to compare the NDVI maps generated and determine the most suitable one for the purpose of precision farming.

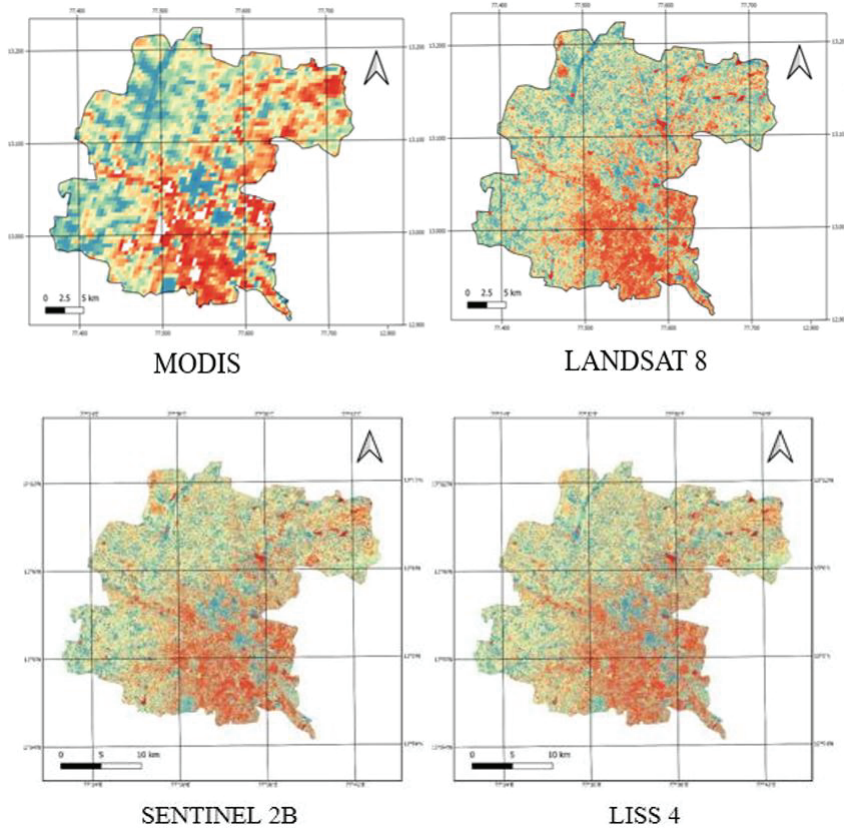


Fig. 7. NDVI maps – Bangalore North

In Fig. 7, all 4 maps are compared simultaneously. When observing LISS 4, SENTINEL 2B, LANDSAT 8 one after the other, there is visually no difference observed, especially when SENTINEL 2B and LANDSAT 8 are viewed together, which indicates that for overall study area analysis, any of the 3 are highly suitable. To verify the validity, consider, layer statistics of each map with various parameters as shown in Table 1.

Table 1. Raster layer statistics

Parameters	Modis	Landsat 8	Sentinel 2B	Liss - 4
Total no. of Pixels	5850	1543941	3475500	55630890
Minimum	0.1214	-0.3175	-0.4148	-0.4219
Maximum	0.6319	0.5557	0.76	0.8026
Range	0.5104	0.8732	1.1749	1.2246
Sum	1253.159	143606.4657	447808.7706	8371268
Mean Value	0.3438	0.1624	0.2251	0.2632
Standard deviation	0.0724	0.06915	0.1112	0.1334
Sum of Squares	19.1124	4226.3416	24609.2055	566257.5

In statistics, the standard deviation measures the amount of variation or dispersion of a set of values. A low standard deviation indicates that the values tend to be close to the mean of the set, while a high standard deviation indicates that the values are spread out over a wider range [14]. This would mean a lower standard deviation indicates lower variability, while a higher standard deviation has higher variability. From Table 1, LISS 4 has greater variability and is more suitable for the analysis. Considering the case of MODIS and LANDSAT 8, it indicates that MODIS has greater variability than LANDSAT, and hence is more suitable. To understand the phenomena, it can be seen that LANDSAT has more number of pixels, compared to MODIS, but this doesn't satisfy the standard deviation condition, where the standard deviation is inversely proportional to sample size and thus would still indicate MODIS is better than LANDSAT for overall analysis.

When MODIS and LANDSAT NDVI maps are viewed and compared together, LANDSAT proves to provide clearer distinction and variation than MODIS. While, MODIS generalizes the regions and more or less normalizes the NDVI, LANDSAT give more distinct variation, trying to match with real world scenario. Therefore, LANDSAT is the better choice of the two despite MODIS's standard deviation being higher.

This indicates, for selecting a map for the purpose of overall analysis, it is important to take in the various factors that make up the map predominantly,

1. Standard deviation (As the first step of conclusion).
2. The total number of pixels. (Along with Standard deviation)
3. Area of each pixel.
4. The actual image/ map generated.

Standard deviation hence is to be considered as the first criteria of conclusion, with relation with total number of pixels, where in the study it is very clear that LISS 4 is the best choice and when a situation arises where the standard deviation and number of pixels are varied questionably, or don't correlate with the comparison, then the 4 factors are compared and co and counter related, and the best map is to be chosen for performing required analysis. Therefore, considering the 4 factors, the order of preference for an overall area analysis would be

LISS 4 > SENTINEL 2B ≥ LANDSAT 8 > MODIS

Indicating LISS-4 is the most preferable and best option for precision farming analysis.

4 Conclusion

From the study, it can thus be concluded that a high-resolution satellite image such as LISS-4, is much preferable and suitable for precision farming and vegetation monitoring of an area, as it provides higher spatial variability, more data, and higher resolution and better area coverage, which can be correlated with actual ground features with potential quantifiable validity and would in turn help in efficient monitoring and management. It must also be noted that a higher resolution image would also indicate crop monitoring is possible for small, medium, large, and any scale farms, adding to its vast extent of application, which in the case for medium or low-resolution images, only to a minimum extent, was found to be applicable.

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