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Spatio-Temporal Dynamics of Vegetation Coverage and its relationship with Growth of Agriculture

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Abstract: In 2015, vegetation covered a substantial area, equivalent to the size of Proportional vegetation cover was highly variable, and declined in most areas between 2015 and 2023. Declines in proportional vegetated cover were particularly common in the whole study area. This article presents an enhanced Change Detection method for the analysis of Satellite images based on Normalized Difference Vegetation Index (NDVI). The Change Detection method used was NDVI differencing. NDVI method is applied according to its characteristics like vegetation at different NDVI threshold values such. From the empirical study, the forest or scrub land and Barren land cover types have decreased by about 6% and 23% from 2015 to 2023 respectively, while agricultural land, built-up and water areas have increased by about 19%, 4 % and 7% respectively.

Keywords: *NDVI, Remote Sensing, Sentinel images, Change Detection, Vegetation Index.*

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Introduction

Vegetation is the key component of the Earth's terrestrial ecosystems and plays a major role in soil, energy exchange, and biogeochemical cycles on Earth's surface. (Sidi Almouctar et al.)The spatiotemporal variability of vegetation coverage is of great importance in the future exploring the internal relationship between vegetation and climate change, exposing the process of evolution of regional environmental conditions and forecasting future trends in growth. As per World Population Statista World's population in 2024 is 8.02 billion. This increased population has a demand for resources like water, food and clothing. To fulfil the needs of human beings, there is continuous pressure on resources. The same is applied to the forest. In this study, we use the Food and Agriculture Organization (FAO) definition of forest that is "any land with a tree cover major than 10% and with an extension of minimum 0.5 ha in which trees have to reach at least 5 m of highness to maturity."(Spadoni et al.) The requirement of food is completed through agriculture. To increase the land there is continuous cutting of forests, scrubs and grasslands. Whole world occupies 38% of forest where Europe, South America and Africa are the major contributors. Vegetation cover varies in each region. Vegetation cover affects the condition and balance of the ecosystem. Vegetation cover density can be used as a parameter in measuring the ecosystem dynamics or in measuring the agriculture parameter.(Akbar et al.) As per Index Mundi, in Asia, there is only 14% forest, where India and China contribute 24.27 and 23.34 respectively of their region. South East Asia comprises 50% forest of their regions. Whereas India occupies 24.27 % of forest but only Himalayan and Sahyadri ranges having dense forests. In Maharashtra, there is only 20% forest area. In Nashik district the percentage of area under forest is also 20 percent.

Study Area

The present study was performed for Dindori tehsil of Nashik district, Maharashtra, India. It is located between 20° 05' 21" N to 20° 44' 52" and 73° 57' 31" E to 74° 01' 05" E covers a geographical area of 13202.50 Sq. Km. (Kale)The climatic zone of the investigation territory is 'semi-arid' with a mean yearly precipitation of 847 mm. (Bhasker et al.) It is higher in western part while decreasing towards eastern part (Bhasker et al.). The average temperature of Dindori tehsil is 25^0 c. Agriculture is a main occupation of this area. Grapes, vegetables and Sugarcane are the main crops grown in this region. Alost all area ranges height from 600m to Kem Dongar (900m) which is the origin of Kadwa River.

Forest- Teak and Sissoo trees are found in large numbers in this tehsil. Besides these, trees and shrubs like Anjan, Agave Bamboo etc. are also found here. (https://mahaforest.gov.in/)

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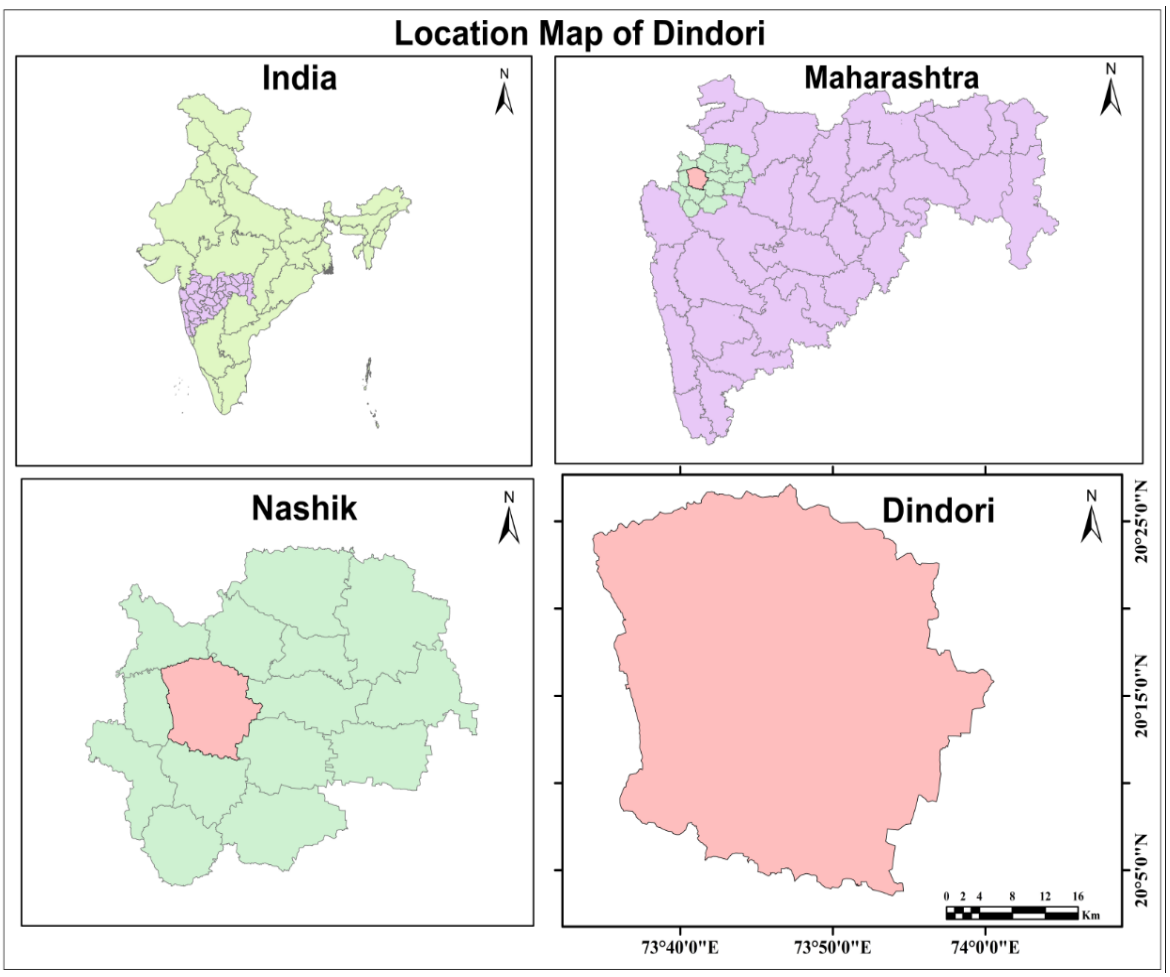

Materials and Methods

Data of the Study

Sentinel 2 data were acquired from Google Earth Engine. The Sentinel-2A satellite is operated by the European Space Agency (ESA). The Sentinel Multispectral Instrument (MSI) acquires 13 spectral bands ranging from Visible and Near-Infrared (VNIR) to Shortwave Infrared (SWIR) wavelengths along a 290-km orbital swath. The Sentinel 2A satellite is operated by the Google Earth Engine. It provides an accuracy of 10 m. Sentinel 2-A image captured on 07 December 2015 and 10 December 2023 over the study area were downloaded from Google Earth Engine and used for further study.

Sentinel 2 Bands

Band	Resolution	Central Wavelength	Description
B1	60m	443nm	Ultra-Blue (Coastal and Aerosol)
B2	10m	490nm	Blue
B3	10nm	566nm	Green
B4	10m	665nm	Red
B8a	20m	865nm	Visible and Near Infrared (VNIR)

Ref- https://gisgeography.com/sentinel-2-bands-combinations

Data Processing

The satellite data interpretation and classification were undertaken in QGIS 3.28.2 software. Dindori Tahsil study area was divided into Six classes i.e. Water, Built-up, barren land, scrub and grassland, sparse vegetation and dense forest. The same classification and processing were fallowed for both years i.e 2015 and 2023 and through NDVI index by using statistical calculators' area under each class were measured. Maps were prepared with proper colour compositions and legends for understanding, Statistical data was used for graphical representation and area comparison for both the years (Ghule et al.).

Methodology

In this Section, the NDVI technique is used for extracting the various features presented in the 3-band Satellite image of Dindori Tahsil. 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. Vegetation

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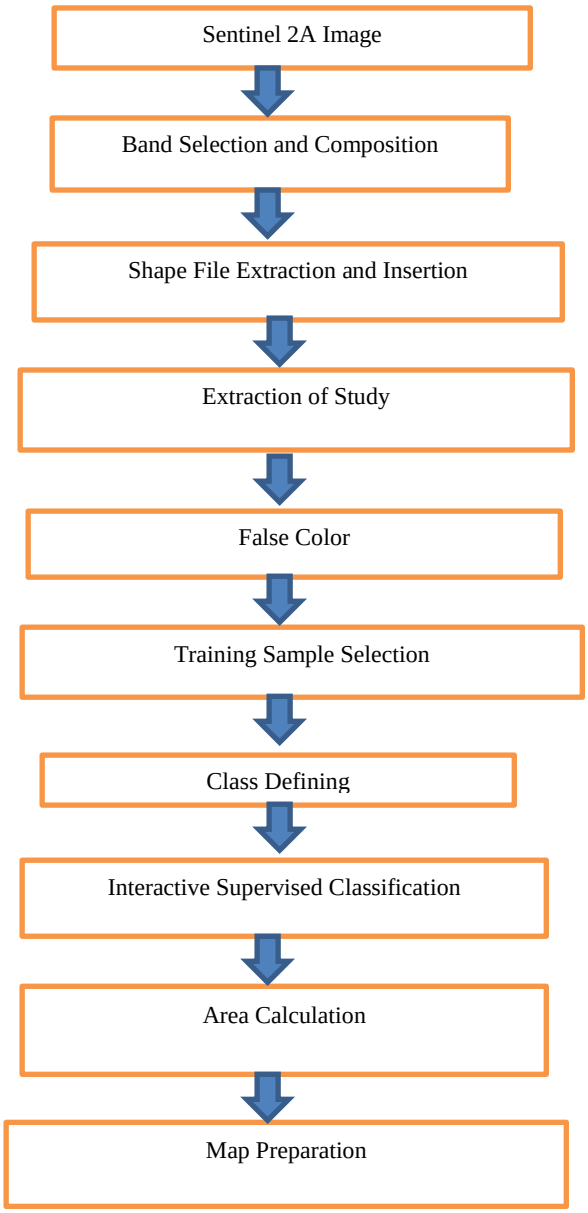
indices allow us to delineate the distribution of vegetation and soil based on the characteristic reflectance patterns of green vegetation. The NDVI is a simple numerical indicator that can be used to analyse the remote sensing measurements, from a remote platform and assess whether the target or object being observed contains live green vegetation or not. NDVI is a proxy for photosynthetic activity and primary production from vegetation biomass and is a common index for monitoring vegetation health (Ghule et al.).

Table 1: Satellite Images of 2023, 2014 and 2002 Characteristic. (GLCF: 2023, 2014 & 2002).

Sr. No.	Date	Source	Satellite Type	Sensor	Path/Row	Band	Resolution
1	7/12/2015	Google Earth Engine	Sentinel 2	Multispectral Instrument (MSI)	43 QCC	2,3,4,8	10M.
2	10/12/2023	Google Earth Engine	Sentinel 2	Multispectral Instrument (MSI)	43QCC	2,3,4,8	10M.

The all data processing and map preparation process are performed in QGIS 2.28.2 software. The various processes performed for this study are as follow.



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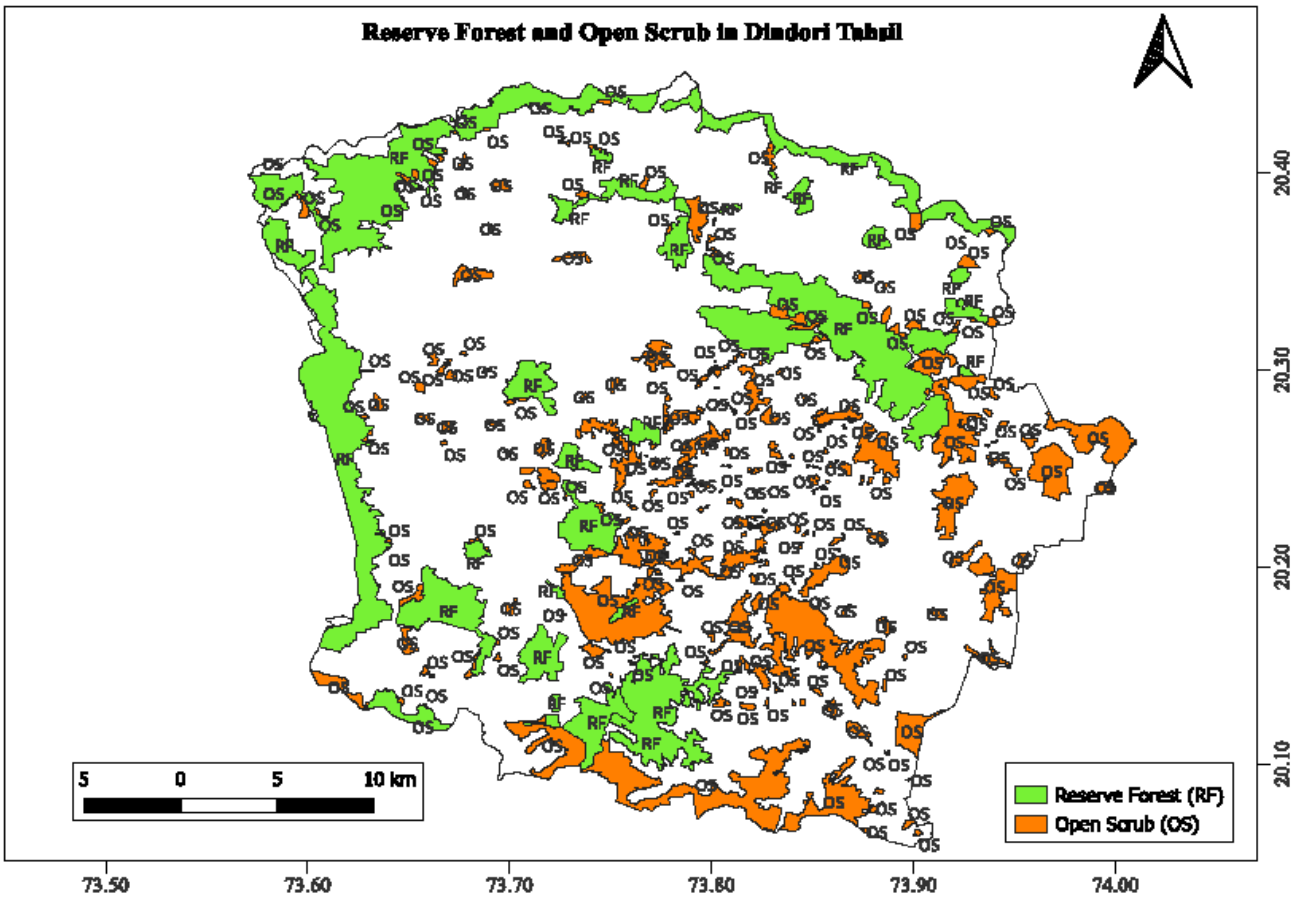

Following formula is used to calculate the NDVI.

NDVI= (NIR-RED) / (NIR+RED)

Where NIR is short-wavelength infrared reflectance and RED is visible red reflectance. NIR bands have wavelengths between 750 and 1300 nm, red bands between 600 and 700 nm, and green bands between 550 nm. The observation vegetation, or the difference between the red band and the NIR, serves as the basis for the NDVI; a higher NDVI corresponds to a higher density of chlorophyll. It normalizes the (NIR - red) differential in order to counteract the impacts of uneven illumination, such as clouds, hills or building shadows.

Various similarity indices have been used or proposed for comparing vegetation changes on reference sites to range monitoring sites (McR Holm et al.).The NDVI is worldwide accepted index. The normalized difference vegetation index values are constantly between -1 and +1. The NDVI value of non-vegetation areas is less than zero, whereas the NDVI value 0 to +1 shows a broad range of vegetation covers. Low vegetation density (0.1to 0.3) is represented by moderate values, whereas high vegetation density (0.6 to 0.8) is represented by high values.

Not only NDVI is useful but FVC is also one indices which can be calculate the fractional Vegetation cover to calculate the accurate forest cover.

FVC is derived from NDVI using the formula.

FVC= (NDVI-NDVIsoil) / (NDVIveg +NDVIsoil)

Where,

NDVIsoil= NDVI of bare soil (~ 0.2, site specific)

NDVIveg= NDVI of dense vegetation ((~ 0.8- 0.9, site specific)

Range of NDVI Values

Sr. No.	Range of NDVI value	Status of plants
1	-1 -0	Dead plants or inanimate object
2	0-0.33	Diseased plants
3	0.33-0.66	Moderately healthy plants
4	0.66-1	Very Healthy plants

Fractional Vegetation Cover (FVC) refers to the proportion of land area that is covered by vegetation, expressed as a fraction or percentage. It provides an estimate of how much of a given area is covered by vegetation (like trees, shrubs, grasses, etc.) compared to bare soil or other surfaces.

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Here's how you can interpret FVC:

1) Low FVC (close to 0%):

This indicates that the area has very little vegetation, often representing bare ground, desert environments, urban areas, or land that has been heavily disturbed (e.g., agriculture, deforestation).

It can also represent places with sparse vegetation, such as grasslands or tundra.

2) Moderate FVC (around 20%-50%):

This suggests areas with moderate vegetation cover, possibly including savannahs, wetlands, or regions with seasonal or sparse vegetation, such as parts of temperate forests or grasslands. Vegetation may be patchy, and areas might still have bare soil exposed.

3) High FVC (above 50%):

High FVC values typically indicate dense vegetation cover, such as forests, rainforests, and lush grasslands.

These areas are likely to be ecologically rich, offering better habitats for wildlife and contributing to climate regulation and carbon storage.

Result and Discussion-

Sentinel- 2 images of year 2015 and 2023 are used and prepared a map as follows. The range deretemined for the classification of various classes is as follow.

Class	NDVI Range
Water	-0.28-0.015
Built-up	0.015-0.14
Barren land	0.14-0.18
Shrub and grassland	0.18-0.27
Sparse Vegetation	0.27-0.36
Dense Vegetation	0.36-0.74

Considering above range, six classes are formed.

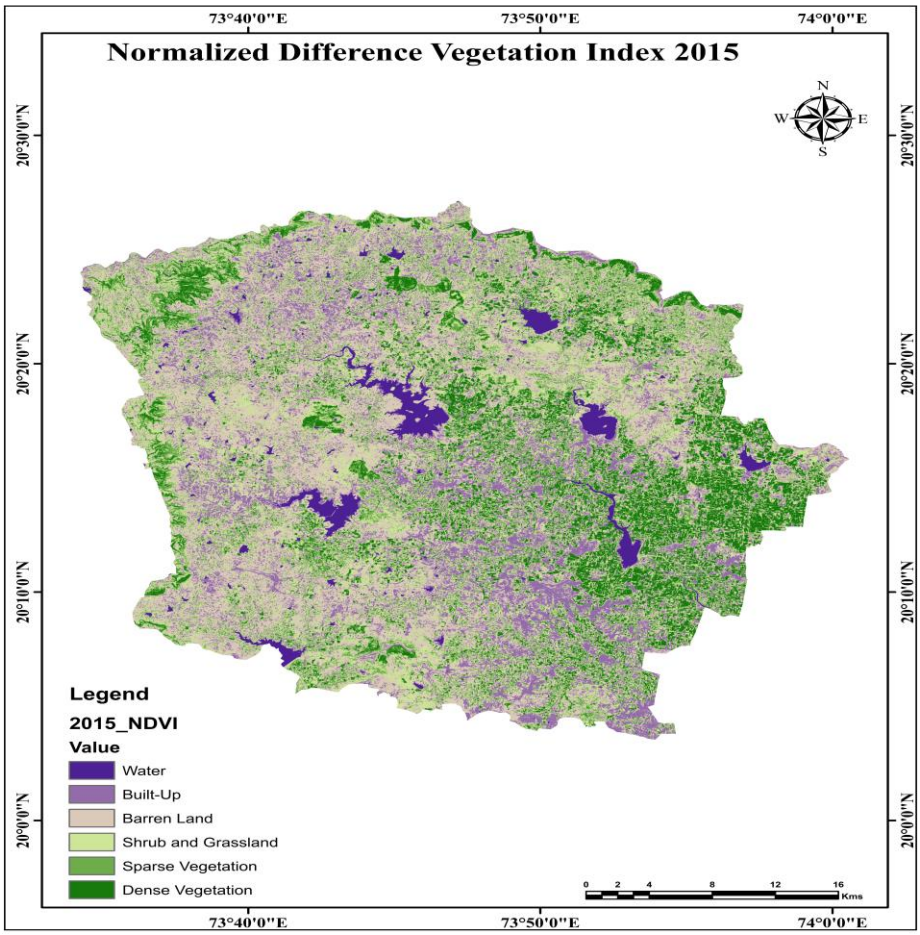

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Chart No. 1 NDVI Classification Percent in 2015 and 2023

Class	2015		2023	
	Pixel count	Percent	Pixel count	Percent
Water	378744	2.8702	549499	4.1642
Built-Up	2406102	18.2339	2853848	21.627
Barren Land	3984093	30.1922	4192131	31.7687
Scrub and Grassland	2772084	21.0073	2717616	20.5946
Sparse Vegetation	2035108	15.4224	1828366	13.8557
Dense Vegetation	1619647	12.274	1054318	7.9898
Total	**13195778**	**100**	**13195778**	**100**

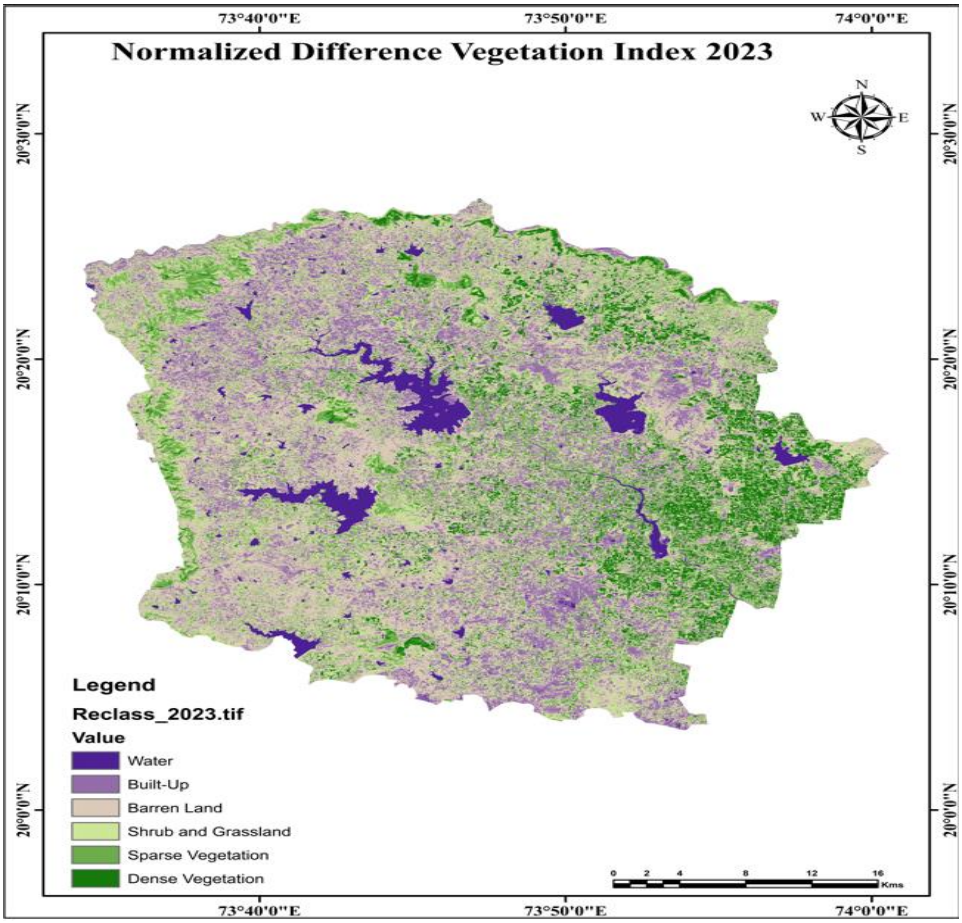

Chart No. 2 NDVI Classification Percent in 2023

Class	Pixel count	Percent
Water	549499	4.1642
Built-Up	2853848	21.627
Barren Land	4192131	31.7687
Shrub and Grassland	2717616	20.5946
Sparse Vegetation	1828366	13.8557
Dense Vegetation	1054318	7.9898
Total	**13195778**	**100**

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Table 1: Satellite Images of 2015and 2023 Characteristic. (Google Earth Engine).

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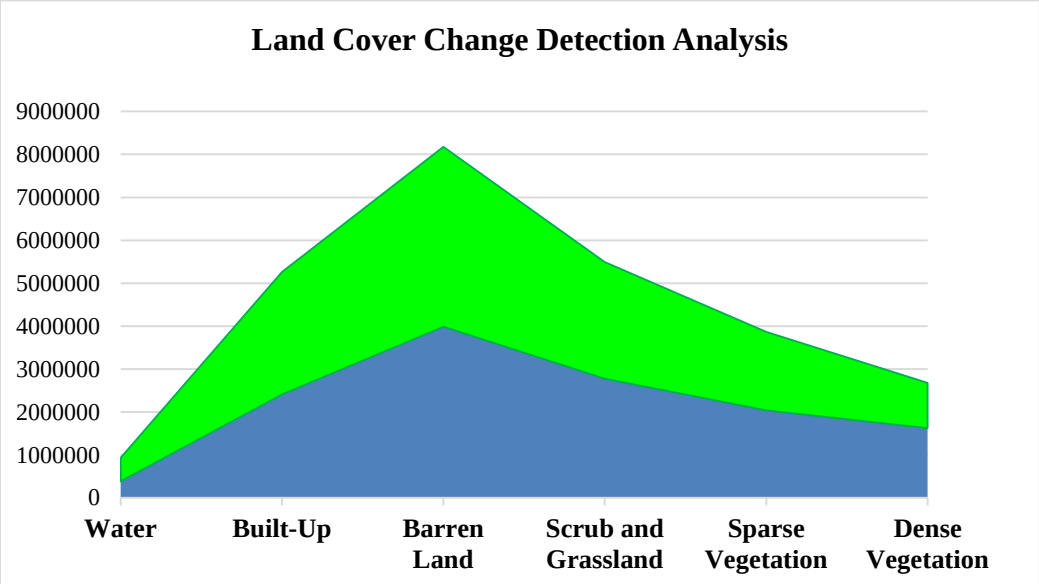

From the empirical study, the shrub and grassland, sparse vegetation and dense vegetation have decreased by 0.4, 1.5 and 4.2 % from 2015 to 2023 respectively. At the same time water, built-up area and barren land have increased by 1.2, 3.3 and 1.5% respectively.

Conclusion

GIS and remote sensing are now recognised widely as a valuable tool for managing, analysing, and displaying large volumes of diverse data pertinent to many local and regional planning In this study, Sentinel 2 satellite images that were taken in different years at the same period were used to determine the changes in the plant index values. The areas in the research area that had the highest NDVI values were the areas facing West, which had humid forest trees. In this area teak and condense sub forest vegetation are present. As the rains fall on the western side, this results in humid forest vegetation. Satellite images studies state that a high amount of grasslands and their sub-forest vegetation, holly plants were present, but that they were cut down due to demand. In the field studies, a small number of *Madhuca longifolia* (Moha) were seen in small amount but holly *Mangifera indica* (Mango) were seen frequently. On the west side of the research area, drought-resistant and heat-loving shrubbery can be observed. As this vegetation did not show a group property, a net classification could not be done. There is mixed deciduous forest and grassland in study area. The NDVI values show changes according to the years. The main reasons of these changes are the differences in vegetation type, the plant growth and the changes in flora. Agriculture is rapidly developed in study area. It is grown from % to %.

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Conflicts of Interest

The authors declare no conflict of interest.

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