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Assessing forest type variability in the Yellapur forest division of Uttara Kannada district, using a remote sensing approach

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Abstract

The study LULC classification of different forest types was conducted in the Yellapur forest division of Uttara Kannada district, geographically positioned between 74° 25' to 75° 6' East longitudes and 14° 44' to 15° 7' North latitudes. A Land Use and Land Cover map of these forest types was developed using Sentinel-2 satellite data processed through Google Earth Engine.

For dry deciduous forests, vegetation was the dominant land cover (67.18%) of the area, followed by agriculture (28.64%) and built-ups (3.98%). Moist deciduous forests had the largest vegetation cover (79.79%), with built-up areas (15.79%) and agriculture covering 3.57 percent. In semi-evergreen forests, vegetation dominated (91.71%) followed by built-up land (5.07%) and agriculture (1.99%). Semi-evergreen forests displayed the highest vegetation density compared to the other two forest types.

Normalized Difference Vegetation Index (NDVI) values indicated varying levels of vegetation health, with the highest values observed in semi-evergreen forests. The classification for dry deciduous forests achieved an overall accuracy of 97.29% and a kappa coefficient of 0.96, while moist deciduous forests had an accuracy of 98.36% and a kappa coefficient of 0.97. Semi-evergreen forests demonstrated similar accuracy with 98.11% and a kappa coefficient of 0.97.

Keywords: Land use land cover (LULC), kappa coefficient, normalized vegetation index

Introduction

Forests are widely acknowledged as one of Earth's invaluable natural resources. They play a crucial role in supporting life by offering various goods and services. Forests serve numerous ecological, economic and social functions, such as facilitating nutrient cycles, conserving soil, fostering species and genetic diversity and regulating greenhouse gases (Rao and Pant, 2001) ^[11]. Economically, forests provide timber, fuelwood, and non-timber forest products such as fruits, nuts, resins, and medicinal plants. Socially, forests are integral to cultural and spiritual practices. Many indigenous communities consider forests sacred and rely on them for traditional rituals and ceremonies. Forests provide recreational spaces and aesthetic beauty, enhancing society's overall well-being. Their diverse contributions make forests essential to livelihoods, supplying a wide range of resources (Zewdie, 2002) ^[15].

Land, a finite and vital resource for the economic advancement of nations, faces increasing strain due to population growth. The dynamic condition of land requires immediate attention. Understanding both land use and land cover is paramount for grasping the connection between human actions and the environment, crucial for preventing forest degradation (Dimiyati *et al.*, 1996) ^[4]. Land use reflects the interaction of societal values, governmental policies and the land's capacity to support human activities. Conversely, land cover describes the physical attributes of the land surface. Recognizing these disparities is crucial for effective planning and management to meet societal needs while alleviating human-induced pressures on land. Land use defines the function or purpose of land, guiding its management to fulfil human requirements (Skole, 1994) ^[16].

Land use/land cover change is recognized as the primary driver of ecosystem transformation and its associated services.

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The fundamental goal of studying such changes is to comprehend their underlying causes and take appropriate measures to minimize negative impacts while optimizing land utilization. Spatial and temporal analyses of land provide policymakers with valuable insights for crafting efficient management strategies. Land use and land cover changes are intricately linked, with impacts that influence each other reciprocally. Weather driven by natural processes or human activities, such changes disrupt environmental stability (Lu *et al.*, 2004) [17]. Change detection involves identifying differences in the state of an object or phenomenon over time and is essential for understanding the dynamic relationship between human societies and nature.

Materials and methodology

Study area

The present study was focused on various forest types within the Yellapur Forest Division in Uttara Kannada District. Located in the eastern part of the district, the Yellapur Forest Division covers a total area of 168,986.66 hectares, including Betta lands (protected forests), which represents 86.97% of the division's geographical area (1,902.28 km²). The division is bounded by longitudes 74°25' to 75°6' East and latitudes 14°44' to 15°7' North. The study area is depicted in Figure 1. The Yellapur Forest Division encompasses three distinct forest types viz dry deciduous, moist deciduous and semi-evergreen (Fig. 2).

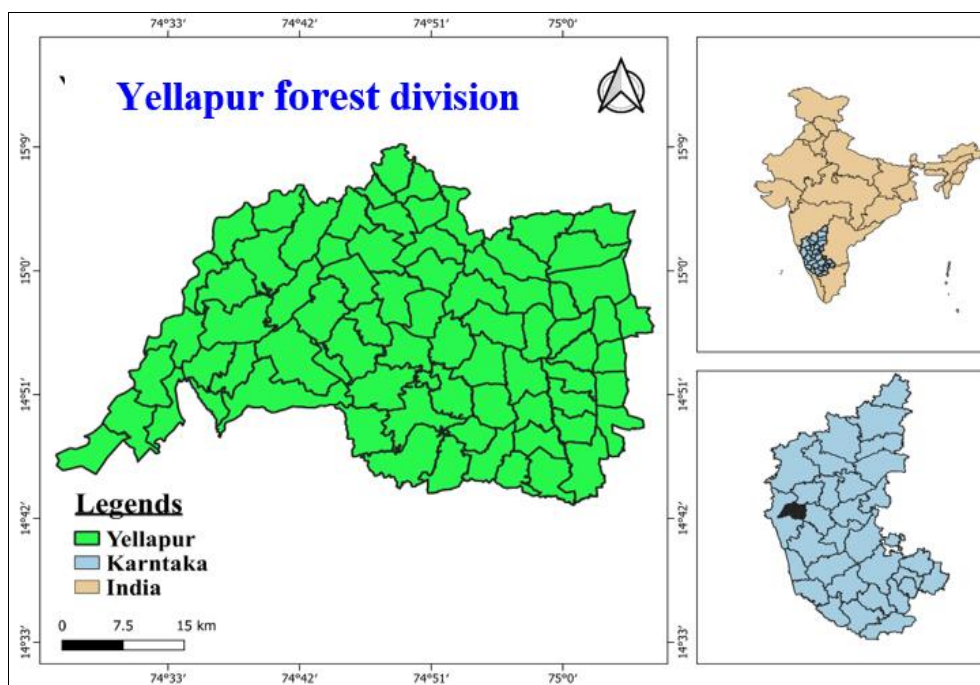


Fig 1: Study Area map



Fig 2: Location of different forest types in the Yellapur forest division

Experimental Details

For conducting the experiment, satellite images of the Yellapur area for different years were used. The ground truth data was collected based on the forest density classes. Forest inventory was done for biomass and carbon studies. The experiment are as follows:

Creating the shapefile of different forest types of Yellapur forest

A shapefile is a geospatial vector data format used in Geographic Information System (GIS) software. It contains information about the geometry (location and shape) and attributes (Data) of spatial features. This step involves defining and digitizing the boundaries of different forest types within the

Yellapur forest area.

Sattellite data

Sentinel-2 is an Earth observation mission from the Copernicus Programme that systematically acquires optical imagery at high spatial resolution (10 m) over the study area. Multi-spectral data with 13 bands in the visible, near-infrared and short-wave infrared part of the spectrum. The algorithm used was the maximum likelihood (Table 1).

Software

Google Earth Engine and QGIS is a platform for scientific analysis and visualization of geospatial datasets.

Table 1: Details of Sentinel 2 satellite data

Launch date	23 June 2015
Swath width	290 km
Repeat cycle	5-10 days
Scene size	110 x 110 km
Resolution (m)	Visible and NIR: 10 meters Red edge and SWIR: 20 meters Atmospheric bands: 60 meters

Pre-processing of satellite image

This involves correcting the raw satellite data for atmospheric

effects, sensor noise, geometric distortions and other imperfections. Pre-processing ensures that the satellite images are accurate and ready for analysis.

Radiometric correction

Radiometric correction for all the satellite images was done to remove the undesirable haze and noise. It was done to rectify variations in pixel digital numbers that are not caused due to image or scene being scanned. It was used for correcting the malfunctioning of the detectors, topographic and atmospheric effects and for adjusting the brightness value of the pixel in the image. Scan line error for sentinel-2 images was removed by focal analysis.

Calculation of vegetation index (NDVI):

Normalized Difference Vegetation Index (NDVI) is used to quantify vegetation health and cover. NDVI is calculated using the red and near-infrared bands of the spectrum of multispectral sensor of Sentinel-2. The Normalized Difference Vegetation Index (NDVI) is a widely used vegetation index that is calculated using the red and near-infrared (NIR) bands of satellite imagery. The formula for NDVI is:

$$NDVI = (NIR-RED)/(NIR + RED) = (B8 - B4) / (B8 + B4)$$

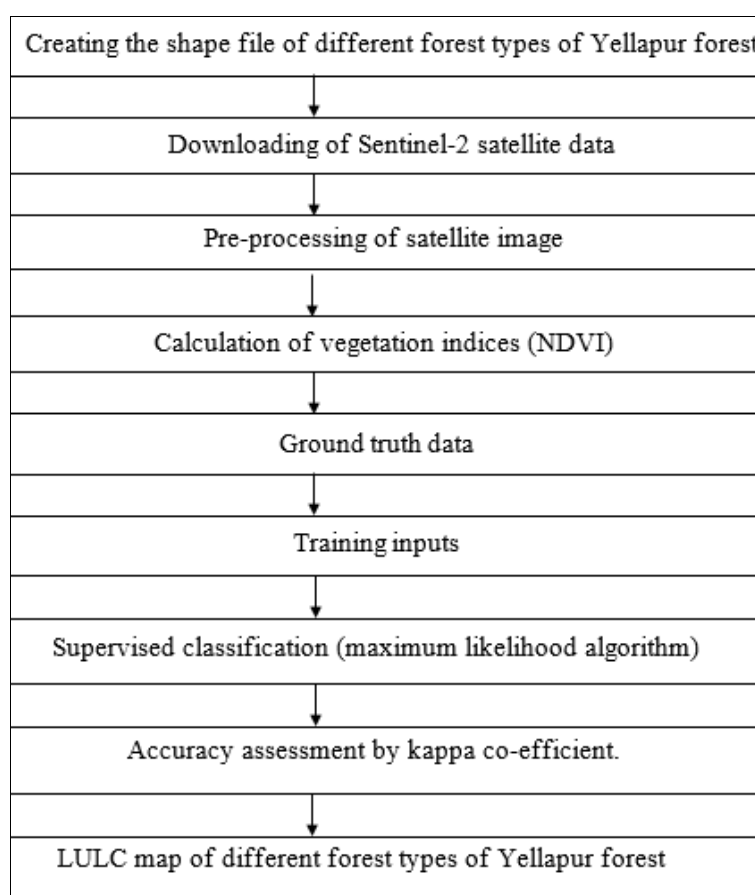


Fig 3: Methodology for LULC map of different forest types of Yellapur forest division

Ground truth data

Ground truthing involves collecting data on the ground to validate and calibrate the satellite image analysis. This can include direct observations, measurements, or photos taken at various locations within the study area.

Training inputs: Training inputs refer to the data used to train a

classification algorithm. This includes samples of known land cover types (e.g., different forest types) that are used to teach the algorithm how to recognize these classes in the satellite imagery.

Geometric correction

Geometric correction was done for the Sentinel 2 images. The satellite image was geo referenced and projected to UTM

projection.

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Supervised classification (Maximum likelihood algorithm)

Supervised classification is a process in which the algorithm assigns each pixel in the satellite image to a specific land cover class based on the training inputs. The maximum likelihood algorithm is a statistical method that calculates the probability of a pixel belonging to each class and assigns it to the class with the highest probability.

Accuracy assessment by Kappa coefficient

Accuracy assessment evaluates the performance of the classification algorithm. The kappa coefficient is a statistical measure that compares the observed accuracy with the expected accuracy (random chance) and provides a value between -1 and 1, where 1 indicates perfect agreement and values ≤ 0 indicates no agreement.

$$K = (ND - P) / (N^2 - P)$$

K= kappa coefficient

D= Sum of correctly classified class pixels

P= Sum of the product of row total and column total

N= Total number of pixels

Area calculation

Area calculation after reclassification of each image into four classes, the area calculation for each forest type such as dry deciduous, moist deciduous and semi-evergreen forest was done in Google Earth Engine. The area for different forest types is tabulated in excel and the area was calculated in percent.

LULC map of different forest types of Yellapur forest

The final output is a Land Use Land Cover (LULC) map that visually represents the spatial distribution of different forest types such as dry deciduous, moist deciduous and semi-evergreen forests within the Yellapur forest. This map is created based on classified satellite imagery and is useful for forest management, conservation and planning purposes.

Experimental results

LULC classification of different forest types of Yellapur forest division of Uttara Kannada district

The LULC classification of different forest types namely dry deciduous, moist deciduous and semi-evergreen of Yellapur taluk of Uttara Kannada district are classified. The results of the experiment are given below:

Normalized Difference Vegetation Index for different forest types

NDVI values were derived for various land use and land cover (LULC) classes for different forests using the RED and NIR bands from Sentinel-2 imagery. Sentinel-2 features having 13 bands of which band 4 (red) and band 8 (NIR) was chosen for NDVI calculation. The resulting NDVI values ranged from -0.08 to +0.59 for dry deciduous forests, -0.41 to +0.85 for moist deciduous forests and -0.06 to +0.91 for semi-evergreen forests reflecting varying vegetation health and density levels. Higher values correspond to healthier vegetation. These maps are used to differentiate the vegetation and non-vegetation of different forest types (Fig. 4).

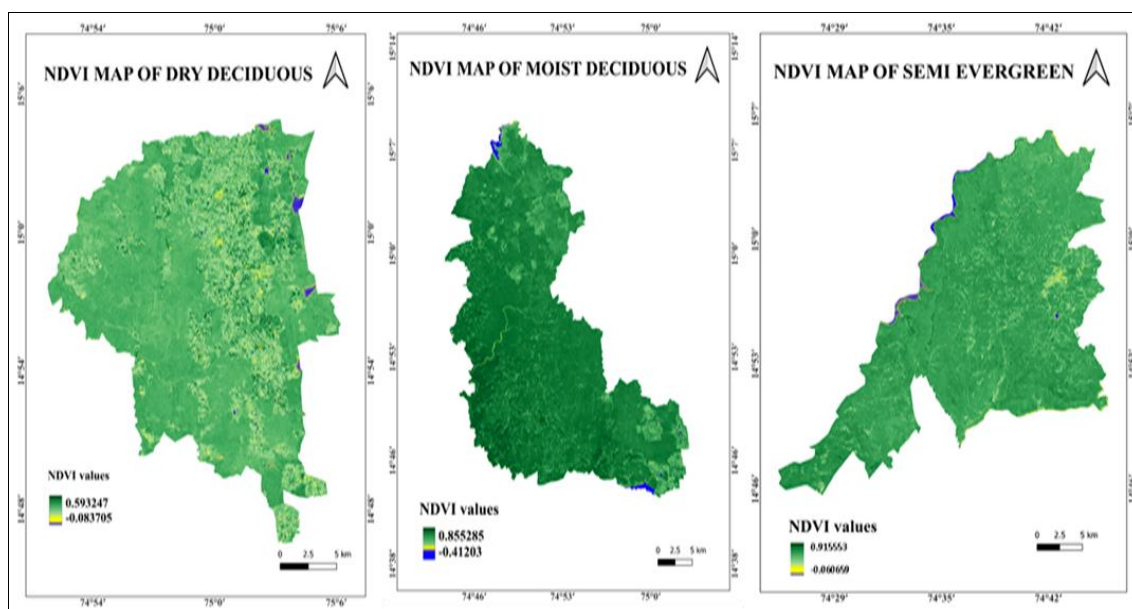


Fig 4: NDVI map of Different forest types Yellapur forest division

Area under different land use land cover Classes of dry deciduous forest: A detailed Land Use Land Cover (LULC) study using Sentinel-2 data for dry deciduous forests showed how different types of land cover are spread out and their size within the Yellapur forest division. The results showed that vegetation occupied the largest area, covering 27,947.31 hectares which constitutes around 67.18 percent of the total area. This was followed by agricultural land, which spans 11,914.63

hectares which is around 28.64 percent. Built-ups cover 1,658.57 hectares, accounting for 3.98 percent. Water bodies which include lakes, ponds and rivers occupy the smallest area at 76.748 (0.18%) (Table 2). The total area of the dry deciduous forest is 41,597.25 hectares. The LULC map for the dry deciduous forest of the Yellapur forest division is illustrated in (Fig 5).

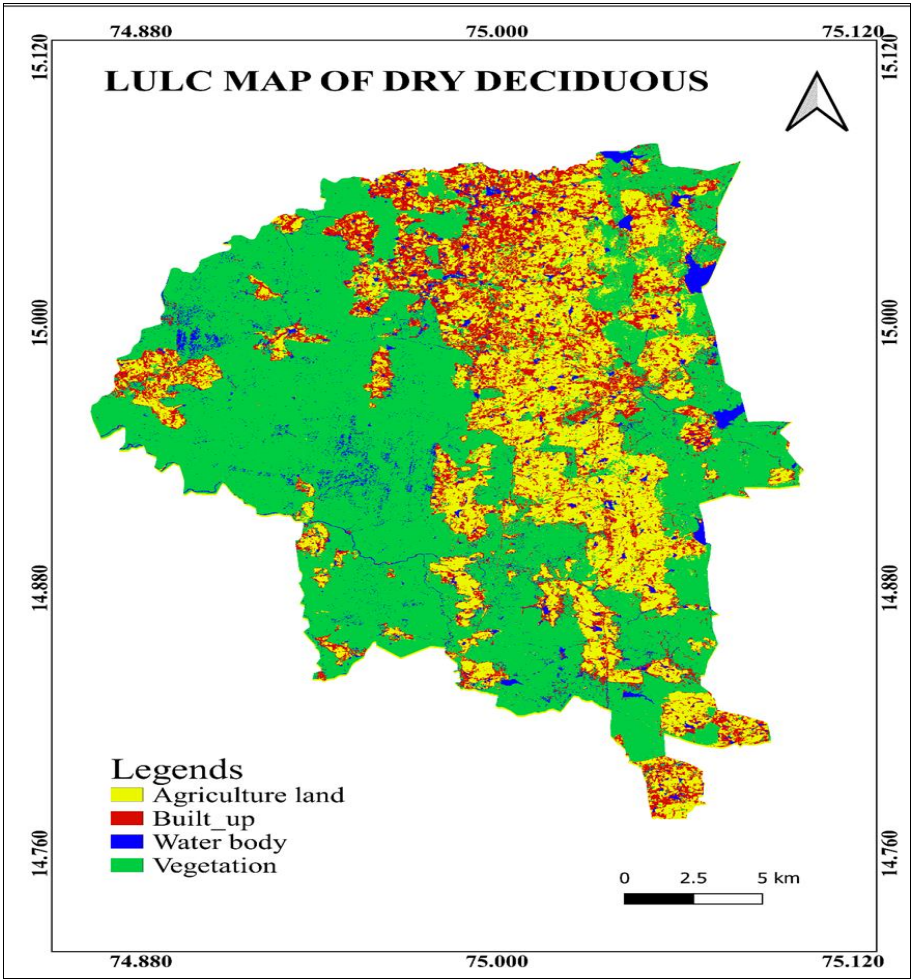


Fig 5: LULC map of dry deciduous forest in Yellapur forest division

Table 2: The area under different land use and land cover classes of dry deciduous forest of Yellapur forest division

Sl. No.	LULC Classes	Area (ha)	Area (%)
1	Agriculture land	11914.63	28.64
2	Built-ups	1658.57	3.98
3	Waterbody	76.74	0.18
4	Vegetation	27947.31	67.18
Total		41597.25	100

biodiversity. Built-up areas covering 13,472.4 hectares which represents 15.79 percent of the total area, highlight the regions of urbanization and infrastructure development. Agricultural land accounting for 3,046.46 hectares which equals 3.57 percent includes area under cultivation and open land. Water bodies like lakes, ponds and rivers occupy a minor portion of the land covering 718.78 hectares which accounts for 0.84 percent of the total area (Table 3).

Area under different land use land cover Classes of moist deciduous forest
A detailed study of Land Use and Land Cover (LULC) using Sentinel-2 satellite data for moist deciduous forests revealed important insights into how different types of land were distributed (Fig. 6). Vegetation emerged as the dominant land cover encompassing 68,077.31 hectares accounting for 79.79 percent of the total area including forests, plantations and other green spaces that are vital for ecological balance and

Table 3: The area under different land use and land cover classes of moist deciduous forest of Yellapur forest division

SL. No.	LULC Classes	Area (ha)	Area (%)
1	Agriculture land	3046.46	3.57
2	Built-ups	13472.4	15.79
3	Waterbody	718.78	0.84
4	Vegetation	68077.29	79.79
Total		85314.93	100

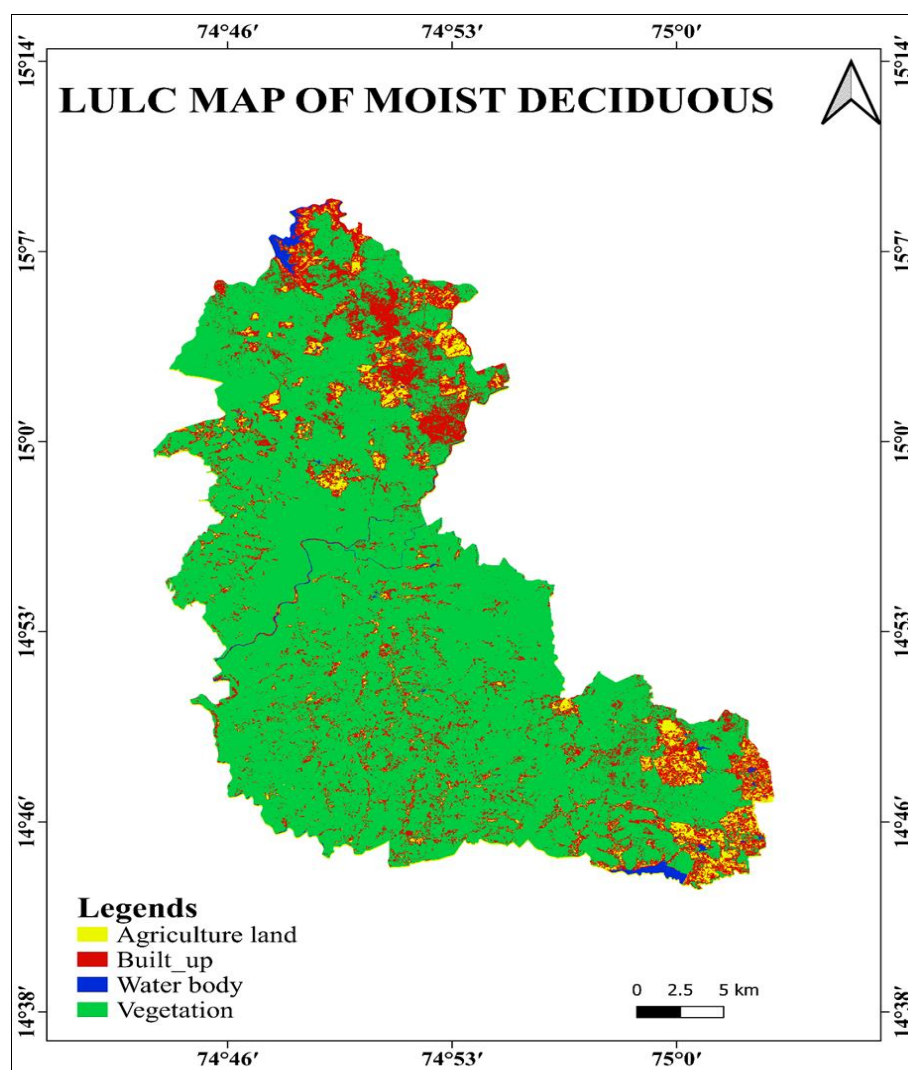


Fig 6: LULC map of moist deciduous forest in yellapur forest division

Area under different land use land cover Classes of semi-evergreen forest

A comprehensive analysis of Land Use Land Cover (LULC) using Sentinel-2 data in semi-evergreen forests provided valuable insights into the distribution and extent of various land cover classes within the Yellapur forest division. The findings revealed that vegetation, including forests and plantations, occupied the largest area covering 57,428.5 hectares constituting

approximately 91.71 percent of the total area followed by built-up land, spanning 3,173.48 hectares around 5.07 percent. Agricultural land covers 1,247.74 hectares, accounting for 1.99 percent. Water bodies including lakes, ponds and rivers occupy the smallest area at 768.91 hectares making up just 1.23 percent (Table 4). The total area of the semi-evergreen forest is 62,618.63 hectares. The LULC map for the semi-evergreen forest of the Yellapur forest division is illustrated in Fig.7.

Table 4: The area under different land use and land cover classes of semi-evergreen forest of Yellapur forest division

Sl. No.	LULC Classes	Area (ha)	Area (%)
1	Agriculture land	1247.74	1.99
2	Built-ups	3173.48	5.07
3	Waterbody	768.91	1.23
4	Vegetation	57428.5	91.71
Total		62618.63	100

The semi-evergreen forest has a higher percentage of vegetation compared to both the dry deciduous and moist deciduous forests. While the moist deciduous forest covers a larger area with 85,314.93 hectares, the percentage of this area covered by vegetation is lower at 79.79%. In contrast, the semi-evergreen

forest has a denser vegetation cover with 91.7% of its area covered. This demonstrates that even though the moist deciduous forest spans a greater geographical area, the semi-evergreen forest has a higher density of vegetation (Fig. 8).

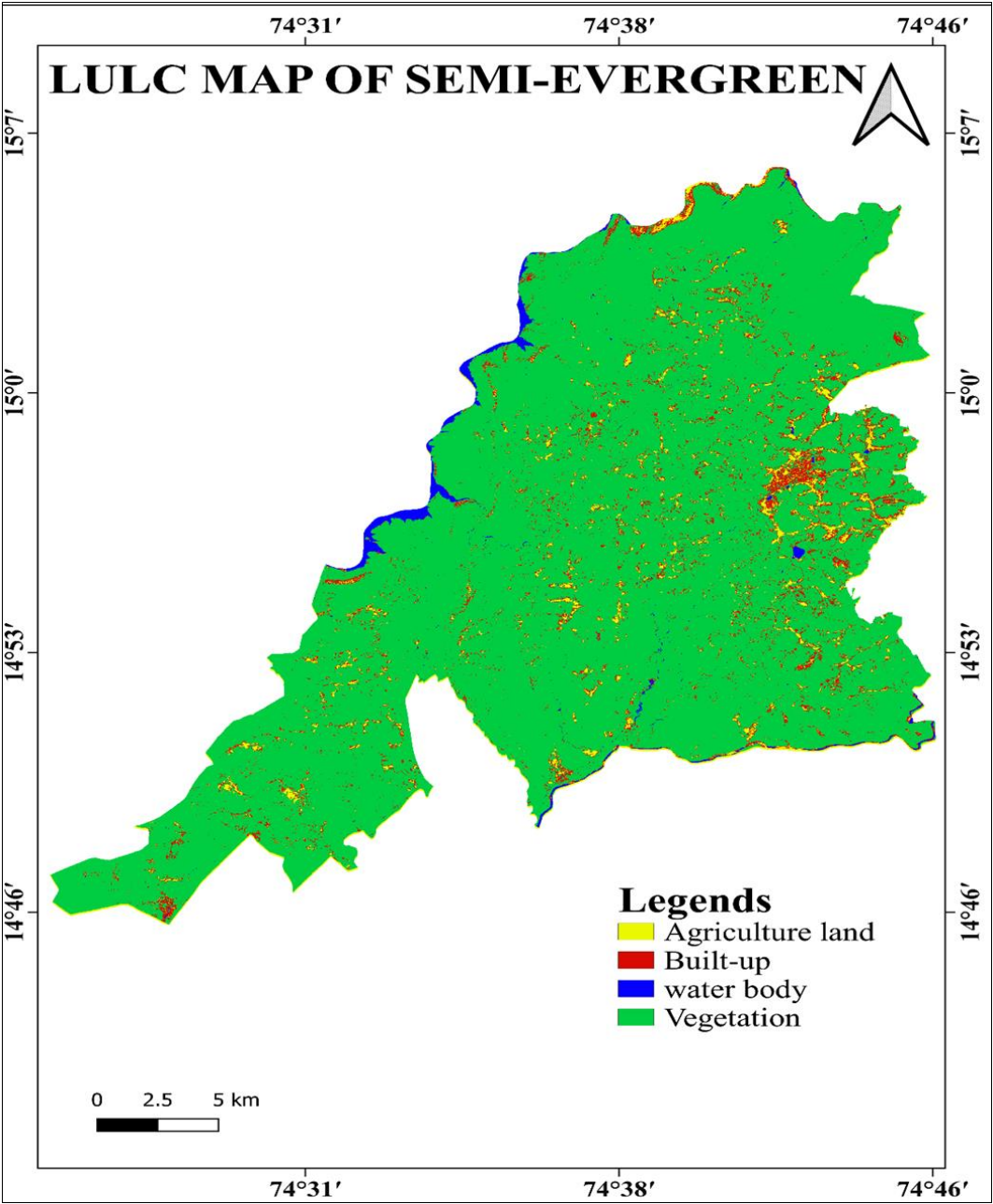


Fig 7: LULC map of semi-evergreen forest in Yellapur forest division

Accuracy assessment

An accuracy assessment was conducted in Google Earth Engine using the Confusion Matrix () function. The overall accuracy and kappa coefficient were computed using the accuracy () and kappa () functions, respectively. For the dry deciduous forest,

the overall accuracy was 97.29 percent, with a kappa coefficient of 0.96. For the moist deciduous forest, the overall accuracy was 98.36 percent, with a kappa coefficient of 0.97. Similarly, for the semi-evergreen forest, the overall accuracy was 98.11 percent, with a kappa coefficient of 0.97 (Table 5).

Table 5: The overall accuracy and Kappa coefficient of LULC mapping of the different forest types of the Yellapur forest division

Sl. No.	Different forest types	Overall accuracy (%)	Kappa coefficient
1	Dry deciduous	97.29	0.96
2	Moist deciduous	98.36	0.97
3	Semi-evergreen	98.11	0.97

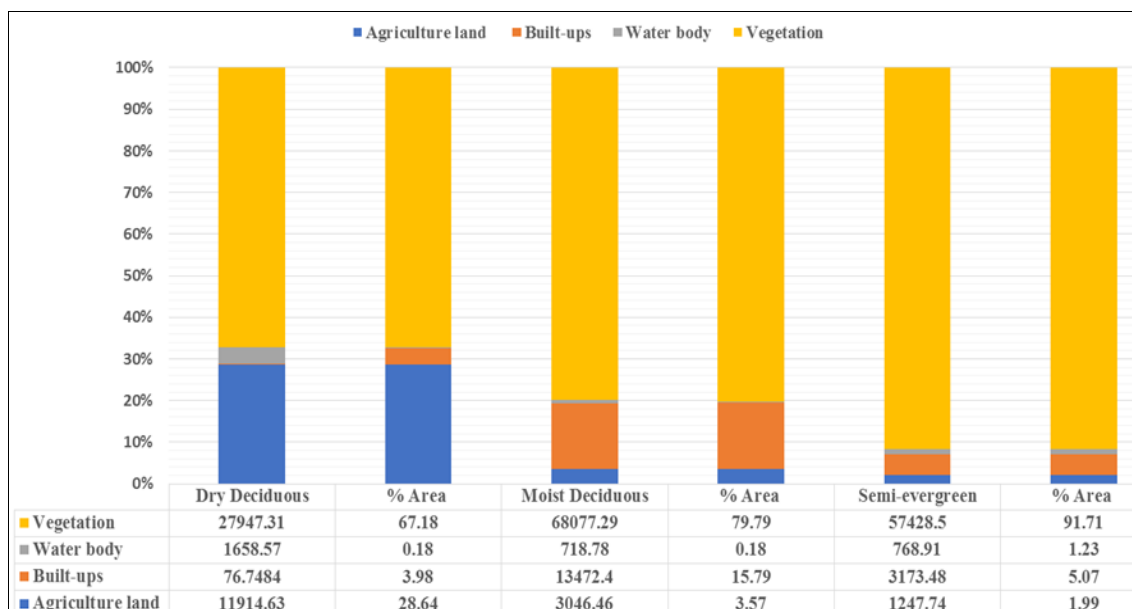


Fig 8: Area under different land use and land cover classes of different forest types of Yellapur forest division

Discussion

Among the dry deciduous, moist deciduous and semi-evergreen forests in the Yellapur Forest Division, the semi-evergreen forest stands out for its exceptionally dense vegetation cover. These forests thrive in areas with consistently high rainfall, creating optimal conditions for a diverse range of plant species. The moist deciduous forest has a lower but still substantial vegetation density. In contrast, the dry deciduous forest exhibits the least vegetation density, primarily due to seasonal leaf shedding, variable rainfall and increased human activity. The area under agriculture is more in the dry deciduous forest as compared to other forest types.

The extent of built-up land is also more significant in the dry deciduous forests of the Yellapur Forest Division due to the proximity to growing population centers and the higher demand for urban development, with the lower density of vegetation facilitating easier land conversion for housing, roads and infrastructure leading to a larger proportion of built-up areas compared to the moist deciduous and semi-evergreen forests. Water bodies are more common due to the need for reservoirs and tanks to support agriculture and human use during dry periods with the seasonal climate necessitating the storage of water during the wet months for use in drier times. Supervised classification is considered one of the most effective methods for land use and land cover studies. This technique has been successfully employed to identify changes in land use and land cover configurations, which in turn affect the landscape environment (Long *et al.*, 2008) [7].

Summary and Conclusion

Land use land cover of different forest types i.e. dry deciduous, moist deciduous forest and semi-evergreen is mapped using Google Earth Engine software. The study area was classified into four different LULC classes i.e. vegetation, Built-up, Agriculture land and water body. NDVI values, calculated using the red and NIR bands from Sentinel-2 imagery, ranged from -0.2 to +0.4 for dry deciduous forests, -0.4 to +0.8 for moist deciduous forests and -0.08 to +0.6 for semi-evergreen forests, indicating varying levels of vegetation health and density. Higher NDVI values reflect healthier vegetation. A detailed Land Use/Land Cover (LULC) analysis using Sentinel-2 data for dry deciduous forest revealed that vegetation is the predominant

land cover, occupying 27,947.31 hectares (67.18%), followed by agricultural land at 11,914.63 hectares (28.64%), Water bodies cover 76.748 hectares (0.18%) and built-up areas account 1,658.57 hectares (3.98%). The moist deciduous forest covered 85,314.93 hectares, with the vegetation being the largest land cover at 68,077.31 hectares (79.79%), Built-up areas occupied 13,472.4 hectares (15.79%), agricultural land covered 3,046.46 hectares (3.57%) and water bodies accounted for 718.78 hectares (0.84%).

The semi-evergreen forest covers 62,618.63 hectares with vegetation, including forests and plantations, making up 57,428.5 hectares (91.71%) of the area. Built-up land covers 3,173.48 hectares (5.07%), agricultural land spans 1,247.74 hectares (1.99%) and water bodies occupy 768.91 hectares (1.23%). The accuracy assessment in Google Earth Engine revealed that the dry deciduous forest had an overall accuracy of 97.29 percent and a kappa coefficient of 0.96, the moist deciduous forest had an accuracy of 98.36 percent with a kappa of 0.97 and the semi-evergreen forest achieved 98.11 percent accuracy and a kappa of 0.97.

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