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A multiscale analysis and classification of normalized difference vegetation index value method in Kannad Taluka, Aurangabad District, using remote sensing and GIS

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Abstract

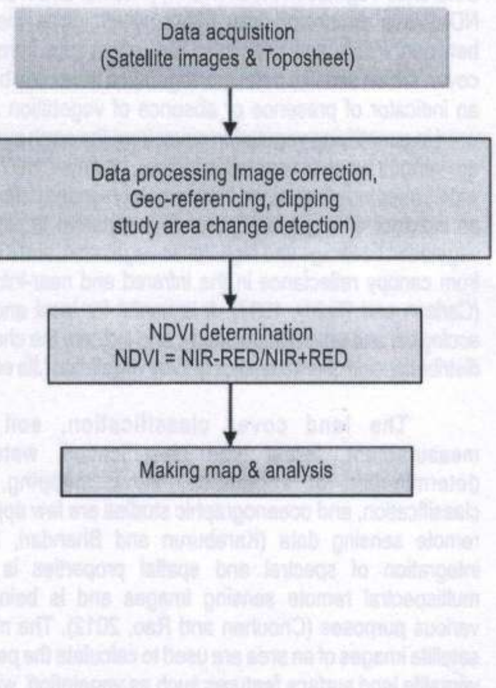
Aim: The main objective of the present study is to quantify and assess the changes in vegetation cover by using NDVI values from the Kannad Taluka of Aurangabad district, Maharashtra, India. The changes were studied during the period 2013 to 2020 to identify the probable causes of change in NDVI.

Methodology: The present study utilized Landsat images to evaluate and track the changes in vegetation cover by using the NDVI index values and classified in eight classes during seven years period.

Results: Two of the major NDVI classifications of this area were agriculture and urban area which showed a significant decrease in the year 2020 while in the water bodies, dense forest, sparse forest, grass land mixed with shrubs, grass land and barren land were increased. Area covered by agriculture and urban area was found 36.40% and 4.47 % in 2013 and which was noted to reduce by 21.64% and 2.53 % in 2020. The water bodies, dense forest, sparse forest, grass land and shrubs, grass land and barren land were found to be 1.79%, 6.18%, 9.71%, 12.71%, 12.92%, and 15.82 % in the year 2013 and were increased up to 2.17%, 14.28%, 13.52%, 13.49%, 14.54% and 17.83 % in 2020, respectively.

Interpretation: Area covered by agriculture has decreased by 14.76% in seven year period while the barren land increased by 2.01% in seven year period in Kannad Taluka. The loss of forest cover might be due to increased human population in the study area.

Key words: Agricultural land, GIS, Kannad Taluka, Remote Sensing, Vegetation cover



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Introduction

Vegetation represents an important part of the global ecological system performing important ecological functions. The earth surface systems are changing at rapid rate influencing the balanced environmental conditions. Mapping and modeling of vegetation cover can be used for detecting changes in the ecological systems and can guide in climate change mitigation options. The dynamics of the ecosystem represented by vegetation cover under the influence of human activities have become an important issue in the study of regional ecological environment (Guan *et al.,* 2021). The dynamics of regional ecological security and ecosystem services are greatly influenced by vegetation, which is frequently regarded as a comprehensive indicator of ecological environmental changes (Wen *et al.,* 2017; Fu *et al.,* 2017; Richardson *et al.,* 2013). As human activity has risen in recent decades, alterations in vegetation have profoundly captured the imprints of human activity, which have been made worse by climate change (Guan *et al.,* 2021). The ecosystem present in the selected study area, *i.e.,* in the Kannad Taluka of Aurangabad District is not an exception for such kinds of changes, therefore to identify the changes in vegetation cover and change in land use pattern is important to mitigate the adverse impact of abrupt changes in an area.

One of the most extensively used markers of photosynthetic activity of plants in ecology is the Normalized Difference Vegetation Index (NDVI) (Ritchter and Weiland, 2012). NDVI is a dimension less index, which gives the difference between visible and near infra red reflectance from vegetation cover. Within satellite data, the vegetation index can be utilized as an indicator of presence or absence of vegetation and can be used in quantifying vegetation cover from the earth surface. There are various types of vegetation indices, however, NDVI is the most widely used index, obtained from remotely sensed data and which is an indicator of vegetation cover. It is sensitive to place with low vegetation coverage and high dense vegetation, and it is calculated from canopy reflectance in the infrared and near-infrared bands (Carlson and Ripley, 1997). It is useful for local and worldwide ecological and environment study, and indicate the changes in the distribution and characteristics of local vegetation (Jia *et al.,* 2016).

The land cover classification, soil moisture measurement, forest type classification, water content determination in vegetation, snow mapping, ice type classification, and oceanographic studies are few applications of remote sensing data (Karaburun and Bhandari, 2010). The integration of spectral and spatial properties is carried in multispectral remote sensing images and is being used for various purposes (Chouhan and Rao, 2012). The multispectral satellite images of an area are used to calculate the percentage of versatile land surface features such as vegetation, water bodies, barren hilly areas, scrub area, open area, an agricultural area, thin forest, thick forest, and other features present in the images, and then make these extracted features available to the public for further analysis in order to avoid any natural disasters and for other uses. The appropriate satellite data and digital image processing tools are being used in evaluating images in terms of mathematical indices (Shikhar and Saklani, 2014). NDVI is a frequently used and well-known index value obtained mathematically from reflectance value used for studying the worldwide environmental and climatic change (Bhandari and Kumar, 2012). Recently, NDVI has been widely used for describing vegetation dynamic different (Sun *et al.,* 2015; Tao *et al.,* 2019; Wang *et al.,* 2020; Zhang *et al.,* 2013). Due to the development of satellite base remote sensing technologies with great precision for earth observation, the NDVI could be a powerful tool for long-term monitoring of dynamic vegetation cover for larger areas (Leroux *et al.,* 2017; Piao *et al.,* 2011; Zhou *et al.,* 2020). NDVI has been used by several researchers for vegetation monitoring (Yang *et al.,* 2011, Lan *et al.,* 2009), crop cover assessment (El-Shikha, 2007), drought monitoring (Kim *et al.,* 2008; Yamaguchi, 2010), and for agricultural drought evaluation at the national and global levels (Demirel *et al.,* 2009; Zhang *et al.,* 2009).

In remote sensing, the vegetation index (VI) is a simple and effective measuring parameter used to determine the earth surface vegetation covers and agricultural status with other land uses. In view of the above, this study was undertaken to investigate the kinds of changes that took place in Kannad Taluka from Aurangabad district as far as vegetation cover is concern, during the period 2013 to 2020. For this research, the multispectral satellite data from Landsat EMT+ was used and classified the vegetation and specific Land use (LU) and detected the changes, in terms of change in NDVI values.

Materials and Methods

Study area: Kannad a Taluka from Aurangabad district of Maharashtra state, India was selected as a study area for investigating the changes in land cover, specifically the change in vegetation cover of an area. It is the part of Marathwada region located 53 km away from the district headquarter, *i.e.,* Aurangabad city in north direction. Kannad taluka is bounded by Khultabad and Phulambri talukas towards the south, Chalisgaon taluka towards the north, Sillod taluka towards the east, and part of Gangapur taluka towards the west. Chalisgaon, Talode, Aurangabad and, Pachora cities are the nearby cities to Kannad. Kondbari is the smallest village whereas Shafepur is the largest village from taluka. It is 352 m above mean sea level having some part hilly terrain region.

The location map of the study area is shown in Fig. 1. Most part of Kannad taluka has hilly terrain; hence it is highly vulnerable to environmental degradation, specifically soil erosion due to high speed surface water runoff, which might affect the vegetation cover in sloppy region. Soil erosion might be affecting the productivity agricultural land in the study area. The presence of vegetation cover is a natural factor controlling soil erosion; hence, there is a need to study the vegetation cover of an area. The Kannad Taluka occupies 1523.23 km^2 area containing about 202 villages inhabiting approximately 3 lack human population. The Kannad

Taluka region was selected as a study area to determine the changes in vegetation cover and other land cover in-terms of NDVI index value determined from remotely sensed (RS) data. As NDVI value allows to delineate distribution of vegetation and indicate the different pattern of land cover in region. Hence, in the present study the NDVI determined from satellite images were used to determine the changes taken place in the selected study area.

NDVI technique: NDVI technique was applied in this section to extract different features from the 3-band Satellite image of the Kannad Taluka area. The most important biophysical indicator of a specific type of environmental condition in the region is the presence of plant cover or vegetation cover, which can be determined by using vegetation indices obtained from satellite images as explained by Ahmadi and Nusrath (2012); Karaburun and Bhandari (2010); Chouhan and Rao (2012). Based on the unique reflectance patterns of green vegetation, vegetation indices allow us to distinguish the spread of plants or the presence of bare land. NDVI is a simple numerical indicator that may be used to analyze remote sensing signals from a remote platform and determine whether or not the target or object being observed has live green vegetation.

NDVI was determined by the following equations:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

NIR stands for near infrared reflectance, whereas RED stands for visible red reflectance. The NIR band has a wavelength range of 750-1300 nm, while the Red band has a wavelength range of 600-700 nm. NDVI is determined by taking the ratio of the difference between the NIR and RED bands and NIR plus RED bands reflectance from the vegetation. It should be higher for greater chlorophyll density and indicate dense vegetation cover. It normalizes the (NIR-RED) difference to balance out the effects of uneven lighting, such as cloud or hill shadows. The study area's temporal images of LANDSAT 8 ETM + were procured along with toposheets and preprocessed using GIS software such as QGIS, ERDAS and ARC GIS 10.8, and later on NDVI maps were prepared according to the flow chart shown in Fig. 2. The NDVI values were grouped into different ranges for different type of vegetation cover and maps were prepared for the data obtained from 2013 to 2020 and data analysis was carried to determine the changes.

Data source: To study the vegetation cover of Kannad Taluka from Aurangabad district, the satellite LANDSAT 8 ETM+ images

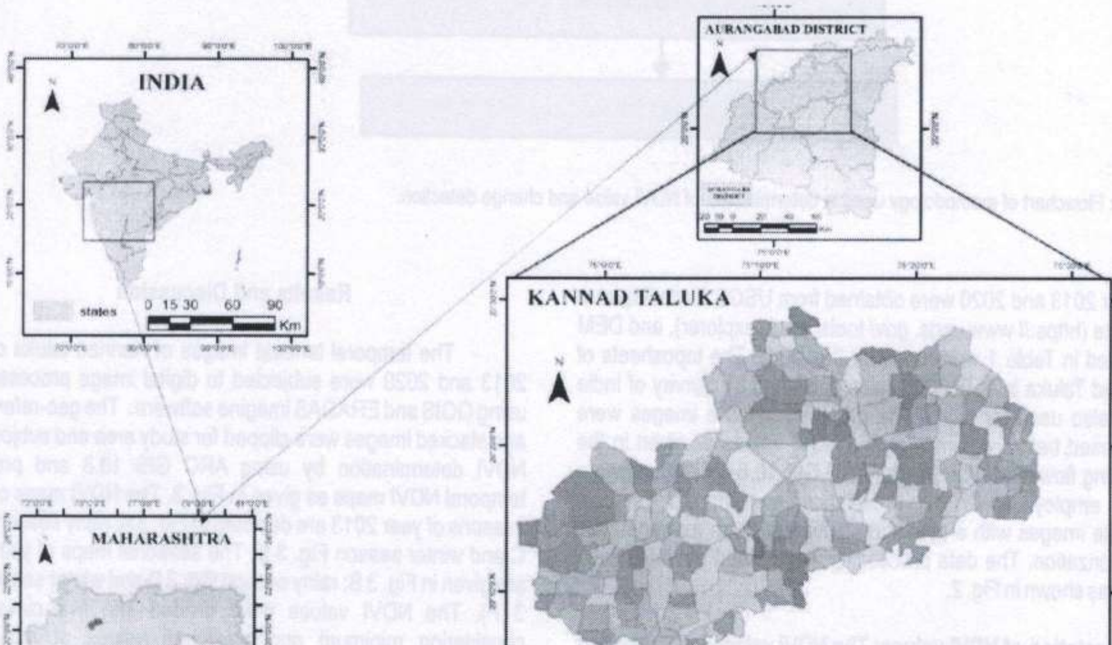

Fig. 1: Location map of the study area (Kannad Taluka from Aurangabad District, Maharashtra, India).

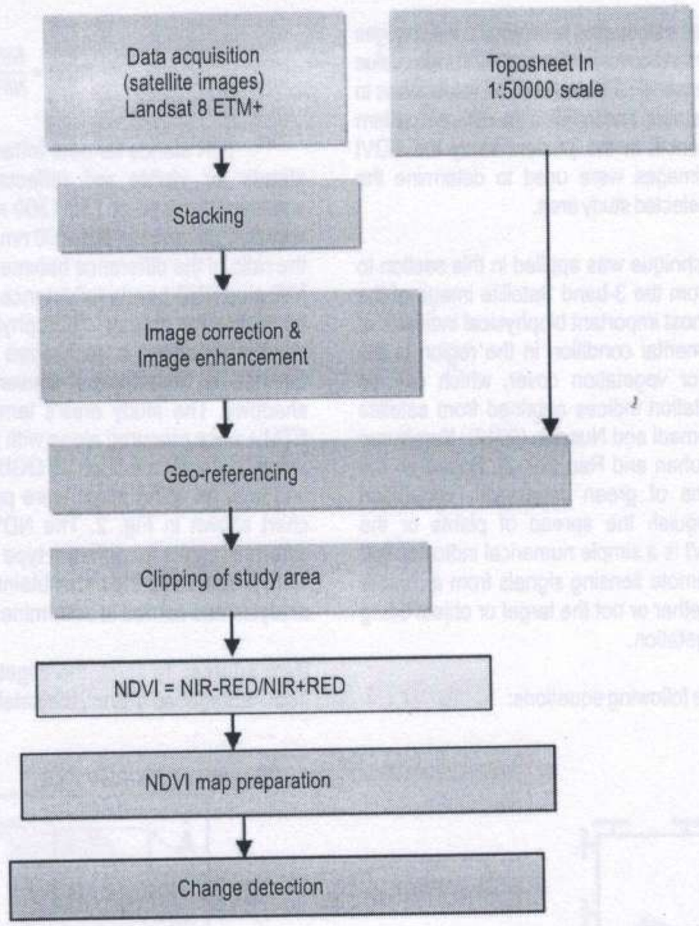

Fig. 2: Flowchart of methodology used in determination of NDVI value and change detection.

of year 2013 and 2020 were obtained from USGS Earth Explorer website (https:// www.usgs. gov/ tools/ earth explorer), and DEM as listed in Table 1 were used for the study. The toposheets of Kannad Taluka in 1: 50000 scales published by Survey of India were also used for study. The procured satellite images were processed before determining the NDVI values as given in the following flowchart (Fig. 2). The ARC GIS 10.8 & QGIS software were employed with high-resolution multispectral Landsat satellite images with a spatial resolution of 30 m for vegetation categorization. The data processing was carried out into seven steps as shown in Fig. 2.

Interpretation of NDVI values: The NDVI values ranged from -1 to +1 and represent different objects from the earth surface. The different authors such as Ramachandra and Kumar,2004; Karaburun, 2010; Chouhan and Rao, 2011 has categorized different types of land cover objects for specific range of NDVI values and in the present interpretation same will be referred for confirmation of vegetation type and for typical land cover type as given in Table 2.

Results and Discussion

The temporal landsat images of Kannad taluka of year 2013 and 2020 were subjected to digital image processing by using QGIS and ERADAS imagine software. The geo-referenced and stacked images were clipped for study area and subjected to NDVI determination by using ARC GIS 10.8 and prepared temporal NDVI maps as given in Fig. 3. The NDVI maps of three seasons of year 2013 are depicted in Fig. 3 A; rainy season Fig. 3 C and winter season Fig. 3 E. The seasonal maps of year 2020 are given in Fig. 3 B; rainy season Fig. 3 D and winter season Fig. 3 F). The NDVI values were divided into five classes by considering minimum and maximum values of NDVI and compared for vegetation cover. The present results showed numerous attributes, those were used to derive from a satellite image of Kannad taluka. Fig. 3 A, C and E shows the NDVI values variations in April, August, and November in 2013, the lowest values of NDVI were -0.073, -0.0058 and -0.17 on less vegetated land, and the high NDVI values were 0.45, 0.52 and 0.55, respectively. While in 2020, the lowest values of NDVI were-

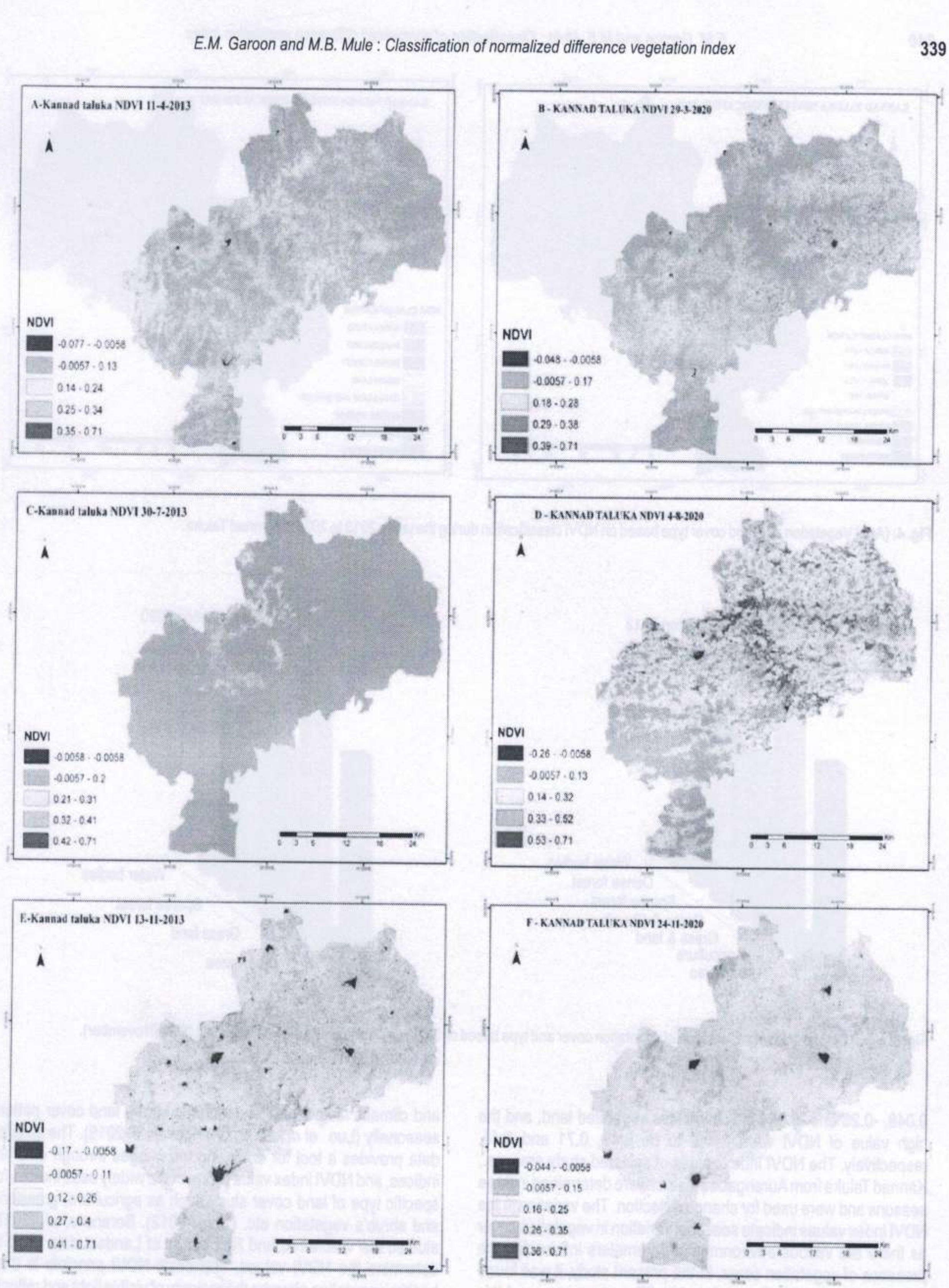

Fig. 3: (A, B, C, D, E and F) : NDVI in different categories during the years 2013 to 2020 in Kannad Taluka.

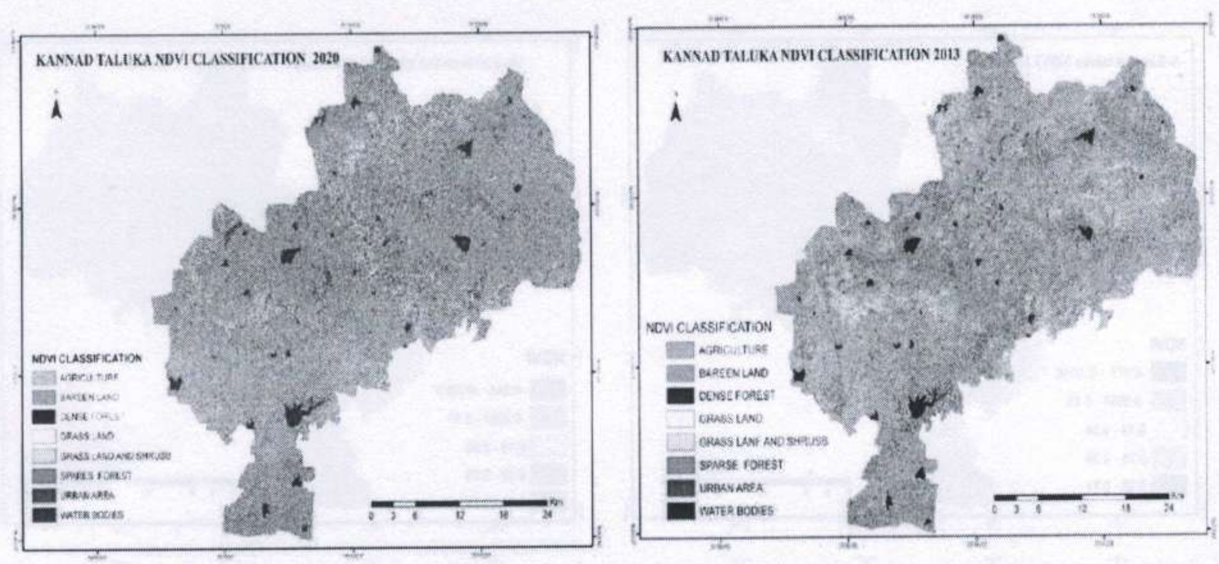

Fig. 4: (A, B) Vegetation and land cover type based on NDVI classification during the years 2013 to 2020 in Kannad Taluka.

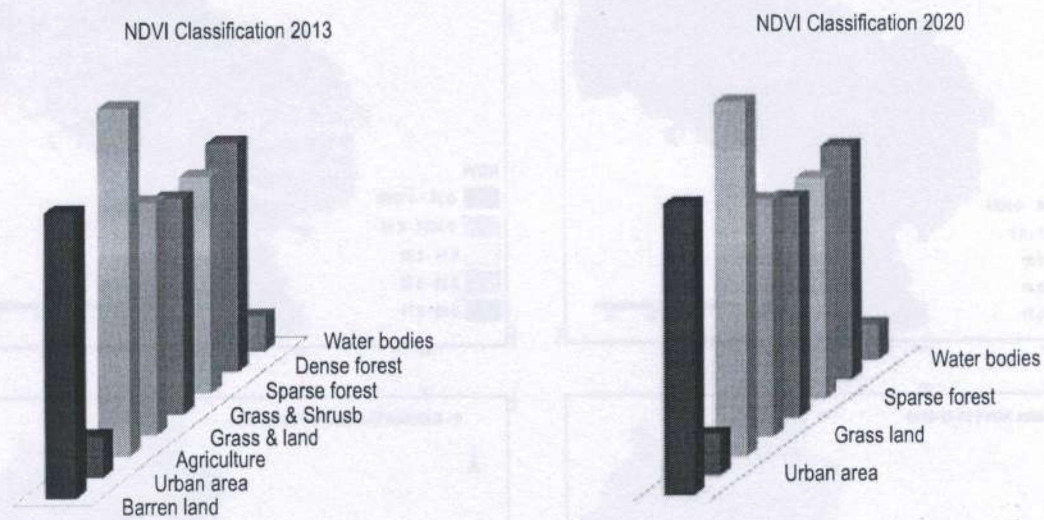

Fig. 5: (A, B) Diagrammatic presentation of vegetation cover and type based on NDVI values between the years 2013 to 2020 (November).

0.048, -0.26 and -0.044 indicating less vegetated land, and the high value of NDVI were found to be 0.49, 0.71 and 0.45, respectively. The NDVI index values of selected study area, *i.e.*, Kannad Taluka from Aurangabad district were determined in three seasons and were used for change detection. The variation in the NDVI index values indicate seasonal variation in vegetation cover as there are various environmental parameters influencing the presence of vegetation cover. In the present study, it was found that the NDVI values changed during different seasons and this might be due to different immediate environmental parameters and climatic factors and which changing the land cover pattern seasonally (Luo *et al.*, 2009; Changakakati, 2019). The satellite data provides a tool for analyzing the images through different indices, and NDVI index value is one of the widely used indices for specific type of land cover study such as agriculture, grassland and shrub's vegetation etc. (Sarp, 2012). Borana *et al.* (2017) studied the visible red and NIR bands of Landsat data used to determine the NDVI values. The basic NDVI principle is that, healthy vegetation absorbs the majority of visible light and reflects a considerable part of near-infrared light whereas sparse

Table 1: Data used for determination of NDVI values

Data type	Date category	Spatial resolution (m)	Date of Acquisition	Data source	Path/row
Landsat ETM+	Imagery	30	11/04/2013	USGS	146/46
Landsat ETM+	Imagery	30	30/07/2013	USGS	146/46
Landsat ETM+	Imagery	30	13/11/2013	USGS	146/46
Landsat ETM+	Imagery	30	29/03/2020	USGS	146/46
Landsat ETM+	Imagery	30	04/08/2020	USGS	146/46
Landsat ETM+	Imagery	30	24/11/2020	USGS	146/46

Table 2: NDVI value range for concerned objects present on earth surface

Range of NDVI Value	Name of the Objects
-1	Water Body
Value near to zero	Bare Soil and Barren land
0	Rocky surface, Sand and Cloud
0.2-0.3	Shrub , Grassland and Crop land
0.3-0.5	Sparse , Unhealthy Forest, Grassland mixed with deciduous vegetation and Agriculture land
>0.5	Dense and Healthy Forest or Evergreen vegetation

Table 3: The areas (km^2 & %) of different land cover and vegetation type determined from NDVI between the years 2013 to 2020 from Kannad taluka of Aurangabad district

NDVI Classification	2013 Area (km^2)	(%)	2020 Area (km^2)	(%)
Water bodies	27.26	1.79	33.08	2.17
Dense forest	94.18	6.18	217.54	14.28
Sparse forest	147.91	9.71	205.95	13.52
Grass land mixed with Shrusbs	193.57	12.71	205.45	13.49
Grass land	196.85	12.92	221.48	14.54
Agricultural land	554.54	36.40	329.60	21.64
Urban area	68.04	4.47	38.58	2.53
Barren land	240.98	15.82	271.64	17.83
Total	1523.32	100	1523.31	100

vegetation reflects more visible light and less near-infrared light. NDVI for a given pixel always results in a number that ranges from minus one to plus one (-1 to +1). As NDVI index value is an important ecological indicator, it was used prominently in ecological studies, specifically in vegetation cover study. Due to its spectral properties and relatively long history, NDVI has emerged as the most widely used method for evaluating vegetation cover and barren area worldwide (Adole *et al.*, 2016; Huang *et al.*, 2021; Soubry *et al.*, 2021).

The NDVI values were also used to calculate the density of vegetation and estimate biomass. It has been frequently utilized to investigate the relationship between spectral variability and variations in the pace of vegetation growth. It's also beneficial for determining green vegetation development and detecting changes in vegetation. The strengths of NDVI include its simplicity, low number of constituent spectral bands (only NIR and Red), easy access to long-term spectral databases needed for its calculation, overall reliability in the analysis of vegetation density and productivity, or its maturity as a result of its extensive use in vegetation and non-vegetation (Huang *et al.*, 2021). To determine the status of vegetation in Kannad Taluka, the normalized difference vegetation index (NDVI) was computed at a temporal scale, as NDVI is the most frequently acknowledged and used of all land cover mapping techniques. NDVI is a proxy for vegetation activity and productivity, and is a good measure for estimating vegetation response to climate change and a monitoring and reporting tool for climate change mitigation as found in the present observation.

NDVI classification from 2013 to 2020: In the present study, depending on the range of NDVI value for a different type of vegetation cover, the study area was classified for a different type of cover. The NDVI maps of month November of year 2013 and 2020 were selected for comparing changes taken place in vegetation cover and lands surface features. The maps were classified into eight classes such as water bodies, dense forest, and sparse forest, grass land mixed with shrubs, grass land, agricultural land, urban area and barren land. The NDVI values were categorized into eight classes such as water bodies, dense forest, sparse forest, grass land mixed with shrubs, grass land, agricultural land, urban area, and barren land; from the metadata of their maps and given in colour codes.

In the present study, two satellite images of Landsat 8 were selected from the month of November 2013 and 2020 from same season for vegetation and land cover change detection using NDVI value. The obtained values were classified by using ARC GIS 10.8 and obtained the NDVI values classification, which included water bodies, forests, agriculture, grassland and bare land. From both the images, the pixels range was determined for each class and determined the area of each class. The area of different classes were 27.26, 94.18, 147.91, 193.57, 196.85, 554.54, 68.04 and 240.9 km^2 to water bodies, dense forest, sparse forest, grass land mixed with shrubs, grass land, agricultural land, urban area, and barren land classes, respectively, in the month of November 2013. While in the month of November of year 2020, the areas were 33.08, 217.54, 205.95, 205.45, 221.48, 329.60, 38.58 and 271.64 km^2 to water bodies, dense forest, sparse forest, grass land mixed with shrubs, grass land, agricultural land, urban area, and barren land classes, respectively. The observations of the total area occupied by specific types of vegetation cover in different years were summarized in Table 2. The results indicate the change in vegetation cover the study area significantly over the seven-year period from 2013 to 2020. The percentage of vegetation cover and land type area were determined and listed in Table 2.

The % of cover (No. of pixels/Total Pixels) for each class type were obtained from satellite images obtained from year 2013 and 2020, and the maps were prepared and given in Fig. 4 A-B. From data of total area of each class the percentage values were determined. The determined percent areas for the year 2013, were as follows; 1.79, 6.18, 9.71, 12.71, 12.92, 36.40, 4.47 and 15.82 % for water bodies, dense forest, sparse forest, grass land mixed with shrubs, grass land, agricultural land, urban land, and bare land or barren land respectively, while in the year 2020 the percentages were found 2.17, 14.28, 13.52, 13.49, 14.54, 21.64, 2.53 and 17.83 % to water bodies, dense forest, sparse forest, grass land mixed with shrubs, grass land, agricultural land, urban land, and bare land or barren land respectively. Table 2 summarizes the observations from which we find the overall changes taken in various classes the year 2013 to 2020 specifically in urban land use, agricultural land and forest / grassland.The percentage of each class of vegetation type and land cover type is also given by using bar diagram and given in Fig. 5 A-B. Two of the major NDVI classification of this area of agriculture showed a significant decrease in the year 2020, while in the barren land it increased. Area covered by agriculture has decreased by 36.40% in 2013 to 21.64% in 2020, while the barren land it increased from 15.82 % in 2013 to 17.83 % in 2020 respectively. In Kannad Taluka, the loss of forest cover might be due to increased human population in an area. Milesia, *et al.* (2010) studied the correlation of NDVI and food production in India and concluded that the change in agriculture production and agricultural practices due to environmental parameters and climatic conditions were prominent and reflected the changes in NDVI values. Similar to our observation Revadekar *et al.* (2012) detected the vegetation cover change during the period 2011-2015 in Delhi area using NDVI value and reported changes in vegetation cover significantly. Gandhi *et al.* (2015) detected the changes in forest, scrubland and barren land along with the changes in agricultural land and built-up area from Vellore district, India and reported that human activities are responsible for such kinds of changes. Das (2021) has studied the 20 years MODIS-NDVI and reported that vegetation has increased significantly around Tehri Dam reservoir, Uttarakhand, India.

The present study reveals that there is significant change in vegetation cover in selected study area specifically in shrubs, grassland and forest cover along with built-up area and bare land. The seasonal environmental conditions and humans developmental activities might be responsible for change in vegetation cover along with climate change during the study period 2013 to 2020. Two of the major NDVI classification of this area is agriculture and urban area which show a significant change in the year 2020, while the barren land was increased. The Kannad Taluka human population increase might be responsible for the change in agriculture and vegetation cover.

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