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Research Article

Assessing land use pattern and species diversity of a tropical dry deciduous forest ecosystem using geospatial techniques

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Abstract

The present investigation was conducted at tropical dry deciduous forest ecosystem in Pench Tiger Reserve, located in the part of Madhya Pradesh and Maharashtra through RS and GIS techniques. Data were analyzed to work out the land cover, structure, and diversity, relationship between structural parameters and vegetation indices. Land cover was spatially analyzed by digitally classifying Land sat OLI data using supervised classification through MLA (maximum likelihood algorithm). Further, the distinction in structure composition and species diversity in various forest types of a dry deciduous forests were quantified by employed the quadratic random procedures, Tree and Shrubs layer in sampling units in each forest types were enumerated for their DBH.

Six land cover types viz. water bodies, scrubland, open forest, dense forest, very dense forest and agriculture land were delineated. The overall accuracy of classification varied from 91 - 93 percent for classes. More than 60 percent area of the park is covered by different forests. Structure and diversity analysis observed that density of dry deciduous forest ranged between 391 - 936 tree ha^{-1}, number of species ranges between 26 – 31 and basal area ranged from 36.69 - 64.32 m^{-2} ha^{-1}. Likewise, the Shannon index values varies from 1.98 to 2.80, Simpson index values from 0.063 to 0.130, species richness from 4.25 to 4.96 and beta diversity from 1.98 to 2.80. Very dense tropical dry deciduous forest recorded highest basal area and diversity. On the other hand, it was lowest in open tropical dry deciduous forests. The study also showed that NDVI was strongly correlated to Shannon Index and species richness thus it indicates that the diversity of forest type play a vital role in carbon accumulation. The study revealed that tropical dry deciduous forests of Pench National Park are moderately young and in immature state and have highly possible intended for carbon sequestration. The conclusion and suggestion emerged from the study are essential for the sustainable management of tropical dry deciduous forests of Pench National Park.

Keywords: LULC, National park, Species composition, SRS, Tropical forest; Vegetation, Vegetation indices

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INTRODUCTION

In the last decade of the 20th century, human activities such as deforestation, overharvesting, conversion of forest into non-forest, urbanization, fires, burning of fossil fuels and other land-use modifications had rapidly increased which caused the changes in atmosphere for instance increase a large amount of carbon dioxide (CO_2) and other greenhouse gases. The forest plays remarkable role in balancing global climate and sustaining global carbon cycle due to rapid increase in atmospheric CO_2, most scientists believe that it has implications on global warming.

The LULC pattern has vital role in global climatic condition. The increase in number of population and socio-economic requirements builds a force on transformation of land cover. That pressure creates unplanned and mismanagement changes on LULC. The LULC alteration leads to deforestation, global warming, biodiversity loss and extreme environmental crisis like landslides, drought, floods, etc. Hence, available data on LULC provides important contribution to execute the management of environment and planning for use in future. Moreover, geospatial technology has been used for monitoring and mapping of LULC in various tropical region of the world (Zhang *et al.* 2014; Wu *et al.* 2018 and Mishra *et al*. 2019). Vegetation analysis is an important tool to study species composition and phyto-sociological structure of the plant community. It helps to quantify various land, conservation management of endangered species, soil and water. Vegetation analysis plays a very important role in adaptation of plants to future climate change.

Geospatial technology provides reliable and unbiased information on LULC and species diversity analysis, their spatial distribution (Park and Lee 2016; Aslami and Ghorbani 2018). The estimation also helps to interpret the resources and modification in the ecosystem of forest, because forest can be influenced by several reasons like deforestation, pests & diseases, fires, grassland conversion which results in the changes of forest ecosystem. The present investigation helps in knowing the relationship between vegetation indices and structural attributes of forest and to estimate vegetation index that can correlate with the Shannon index. Vegetation indices (VIs) models are the most widely used models for estimation of the LULC in several studies (Geist and Lambin 2001; Foody *et al*. 2002; Yuan *et al.* 2005; Chetan et al. 2017). VIS are the arithmetical alteration of the innovative spectral reflectance which can be used to employ in knowing the vegetation types and cover (Rahman *et al.* 2003; He et al. 2006; Patel *et al*. 2007). The theory of this model helps in understanding the vegetation indices derived from vegetation, and vegetation has a high NIR wavelength due to the reason of spreading by leaf cells and a low red reflectance. The chlorophyll pigments absorption can be used in several satellite based vegetation index models for evaluating the vegetation parameters like biomass, leaf area and other activities (Baret & Guyot 1991; Verrelst et al. 2008). In order to understand the relationship between altitude, land cover and vegetation cover, remote sensing satellites and ground based techniques are used (Schlerf & Alzberger, 2005).

The conventional method derived from ground measurements is the most accurate but complicated to extend big areas and confirmed that it is very uneconomical as it requires lots of time and labour. In the recent years, RS and GIS techniques are most widely used for inventory, surveying, monitoring and mapping of the vegetation (Boyd *et al*. 1999; Lu *et al*. 2004; Ingram 2005; Maynard *et al*. 2007). RS and GIS are powerful tools to get precise information on the distribution of LULC transformation over large areas. A number of researchers employed the use of geospatial techniques for assessing LULC and vegetation in tropical country (Thakur *et al.* 2014; Soha & El-Raey 2019; Mishra et al. 2019).

MATERIALS AND METHODS

Study area

The vegetation of study sites is tropical dry deciduous forest ecosystem in Pench National Park (as Tiger Reserve) and surrounding environment. The total study area was 398653.25 ha, of which forests occupied more than 60 % area. The study area, Pench landscape lies between 20º35’ to 21º44’ N lat and 78º15’ to 79º40’ E long and shared both the boundaries of Madhya Pradesh and Maharashtra. It is also declared as Pench Tiger Reserves. The location of study area and the details of sample points are illustrated in (Figure 1).

The average annual rainfall is approximately 1400 mm with the south-west monsoon accounting for most of the rainfall in the region. The mean rainfall for the dry period was 59.5 mm. The temperature varies from 25ºC to 47ºC in the months of April to June. The temperature varies from 6ºC to 31ºC in winter. The temperature varies from the minimum of 0ºC in winter and maximum 47ºC in summer. Relative humidity normally lies between 20 to more than 80 percent. Relative humidity is lowest in the month of May and drops below 25 percent. During monsoon, the relative humidity reaches more than 80 percent. Geological survey of India has done mapping of the geological information (Griffiths et al., 2010). Lithologically, the area is divided into nine distinct geological zones namely Gneisses, Basalt, Chorbaoli formation, Lameta formation, Pench river, Lohangi formation, Laterite, Manganese and Amphibolites.

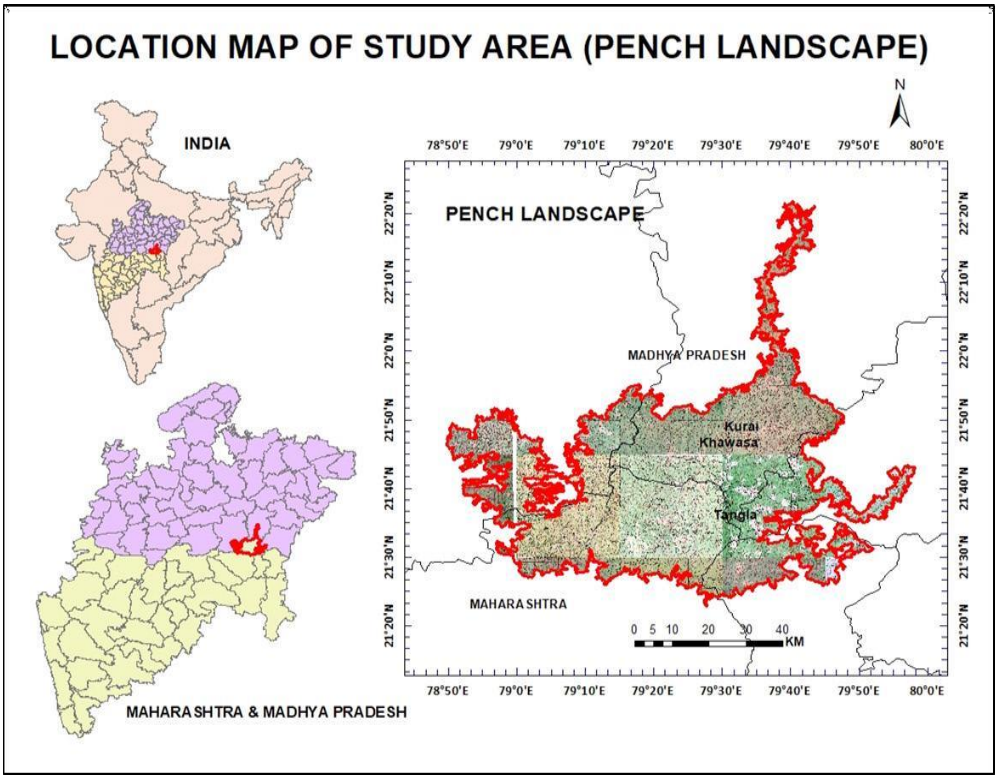

Figure 1: Location map of study area (Pench landscape).

Materials

LULC, structure and species diversity of a dry deciduous forest were analyzed using geospatial techniques along with ground measurements. The data is digitally analysed for determination of various LULC pattern and vegetation structure of different forests of Pench National Park to serve as primary stratification units (PSUs). The LULC and structural attributes investigation was first employed in these strata. Landsat 8 OLI of 144 path and 45 row, December 2017 and Sentinel 2A data of 2018 were used. Landsat 8 OLI Image (28 December 2017) was procured from open source earth explorer and Sentinel 2A data image of 16 October 2018 was procured using Python software. The data sets used in the study area (Pench National Park and surrounding) are given in (Table 1).

The digital analysis of data was performed on ERDAS Imagine (Version 9.1) and the subsidiary data together from SOI topomaps was determined in ARC-GIS (Version 10.3) in personnel computer. The geospatial analysis was carried out at Regional Remote Sensing Centre, Indian Space Research Organisation (ISRO), Nagpur, India.

Ancillary data

Location map of study area was prepared from survey of India toposheets 55/K 13,14,15, 55/N 11,12 and 55/O 1,2,3,5,6,7,10,11,14,15 (1:50,000) corresponding to the year 1967 and it would be used for rectification of satellite images. The location map was also used as reference map for precisely locating ground sample plots in the study area.

Stacking, Clipping and extraction of study area

Landsat 8 OLI of 144 path and 45 row, December 2017 and Sentinel 2A data of October 2018 were used. Landsat 8 OLI image (28 December 2017) was taken from open source earth explorer and Sentinel 2A data image of 16 October 2018 was procured using Python software. All the visible, near infrared and shortwave infrared bands was stacked in Landsat 8 OLI whereas all the visible and near infrared bands was stacked in Sentinel 2A. Later, the study area was exported in ARC-GIS after clipped and overlaid operations of the boundaries on two composition bands using ARC-GIS (Version 10.3).

Classification of satellite images and generation of vegetation indices

The supervised classification scheme was performed and the classification was made under ERDAS IMAGINE digital environment. Maximum Likelihood Algorithm Classifier was employed for classifying the LULC pattern and structural attributes of various dry deciduous forests. The generation of Vegetation indices such as EVI, SR, VDVI, NDVI and TNDVI map were performed using ERDAS Imagine (Version 9.3) software. Sentinel 2A data was used to generated

Table 1: Data sets used in the study area.

Data used	Path/row	Date of Pass	Wavelength width in µm/band	Spatial resolution	Swath (km)	Purpose
Landsat 8 OLI*	144 path/45 row	28/12/2017	Blue (0.45-0.51)	30m	185	Land use/ land cover
			Green (0.53-0.59)			
			Red (0.64-0.67)			
			NIR (0.85-0.88)			
			SWIR1 (1.57-1.65)			
			SWIR2 (2.11-2.29)			
Sentinel 2A**	-	16/10/2018	Blue (0.45-0.52)	10m	290	Vegetation analysis
			Green (0.54-0.57)			
			Red (0.65-0.68)			
			NIR (0.78-0.89)			

*- Operational Land Imager

**- First Sentinel-2

Vegetation indices map. The following vegetation indices are derived from different spectral bands presented in (Table 2).

Analysis of vegetation structure and Plants diversity analysis

The detailed methodology adopted for the characterization of vegetation in the study area is depicted in (Figure 2). The coordinates of the sample points in the field were taken with the help of Handheld GPS (Global position System). 15 sample plots were selected for ground survey and 5 sample plots in each forest types. The sample points used in the study area are given in (Table 3).

The phyto-sociological analysis in each forest types has been carried by stratified random sampling by laying plots of 30 x 30 m, 2 x 2 m and 0.5 x 0.5 m for trees, shrubs and herbaceous vegetation, respectively. In each sample plot, vegetation was enumerated for their girth at breast height (GBH). The GBH of individual tree was measured at 1.37 m, while shrubs were measured at 15 cm above ground level by using measuring tape. The vegetation data in each forest/strata was analyzed for the determination of various structural attributes and diversity parameters for trees, shrubs and herbs components were determined following (Thakur, 2018).

Relationship between vegetation indices and Shannon index

The relationship between vegetation indices (*viz*. EVI, SR, VDVI, NDVI and TNDVI) and structural attributes (basal area, density and species diversity) were developed (Hurcom & Harrison,1998). The best fitted module was employed on the basis of regression coefficient (r^2) and t- values. Best fitted module has been used for characterzing the structural attributes and Shannon index in a tropical dry deciduous forest of Pench National Park, India.

RESULTS AND DISCUSSIONS

Spatial distribution pattern of land cover classes

The land cover classification of study area was performed using maximum likelihood algorithm. Before classification, all the visible and infrared bands of Landsat OLI were stacked and thereafter the polygon boundary of pench landscape was overlaid and the study area was extracted in ARC-GIS. Standard False Colour Composite (SFCC) was generated with the band combinations of visible and near infrared bands. An overview of Standard False Colour Composite (SFCC) of study area is shown in (Figure 3).

Supervised classification scheme using maximum likely hood algorithm was employed for classification of land cover types in ERDAS digital image analysis software. Six land cover types *viz.,* water bodies, scrubland, open forest, dense forest, very dense forest and agriculture land were delineated. The results on spatial distribution pattern of LULC classes are presented in (Table 4) and also depicted through (Figure 4).

The Water bodies occupied an area of 7286.85 ha, scrubland 91314.3 ha, open forest 75704.8 ha, dense forest 123206 ha, very dense forest 41490.9 ha and agriculture land 59650.4 ha. The total study area comprises of 398653.25 ha. The forest occupies more than 60 percent of the total area and remaining 40 percent covered by water bodies, scrubland and agriculture. The classified image (Figure 5) shows the spatial distribution pattern of LULC class categories. Dense forest area occupied largest area, which accounted 30.9 per cent area of total geographical area, while water bodies occupied smallest area accounted only 1.83 percent of total area. The other classes *i.e.* scrubland, open forest, agriculture land and very dense forest, which covered 22.9%, 18.9%, 14.9% and 10.4% of total area, respectively. The overall classification accuracy varied from 91% to 93% for different land cover classes.

Table 2: Vegetation indices used in this study.

Sl. No.	Vegetation index	Equations	References
1	Normalized difference vegetation index (NDVI)	$\frac{NIR-Red}{NIR+Red}$	Rouse *et al.*(1973)
2	Enhanced vegetation index (EVI)	$G * \frac{NIR - Red}{NIR + C1 * Red - C2 * Blue + L}$ G (Gain factor)=2.5, C1=6, C2=7.5, L=1	Huete & Justice (1999)
3	Simple Ratio (SR)	$\frac{NIR}{Red}$	Jordan (1969)
4	Visible band difference vegetation index (VDVI)	$\frac{2 * Green - Red - Blue}{2 * Green + Red + Blue}$	Wang *et al.* (2005)
5	Transformed normalized difference vegetation index (TNDVI)	$\sqrt{NDVI + 0.5}$	Decring *et al.* (1975)

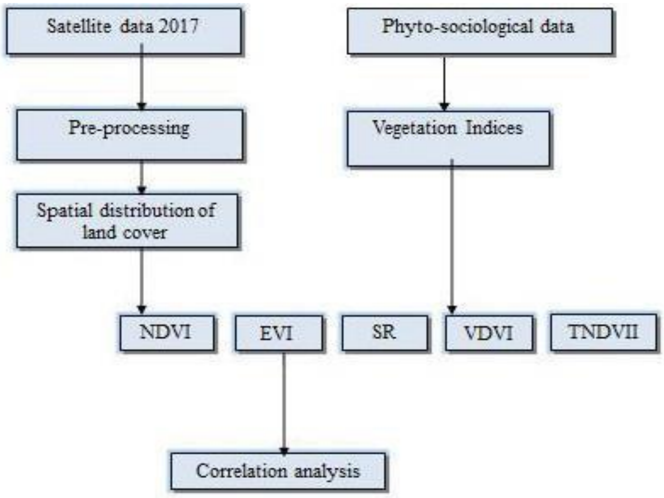

Figure 2: Flowchart of methodology for correlation between satellite based system and ground based techniques.

Table 3: Sample points used in the study area.

Forest type	Latitude	Longitude
Open Forest	21˚41'29" N	79˚26'39" E
Dense Forest	21˚26'57" N	79˚29'14" E
Dense Forest	21˚45'58" N	79˚27'52" E
Open Forest	21˚49'21" N	79˚30'30" E
Very Dense Forest	21˚38'34" N	79˚25'14" E
Open Forest	21˚30'36" N	79˚29'7" E
Very Dense Forest	21˚27'29" N	79˚30'39" E
Very Dense Forest	21˚38'16" N	79˚23'53" E
Dense Forest	21˚38'20" N	79˚26'43" E
Very Dense Forest	21˚39'14" N	79˚22'10" E
Open Forest	21˚27'49" N	79˚28'38" E
Dense Forest	21˚29'10" N	79˚27'54" E
Dense Forest	21˚49'20" N	79˚33'37" E
Very Dense Forest	21˚29'21" N	79˚29'31" E
Open Forest	21˚49'21" N	79˚31'38" E

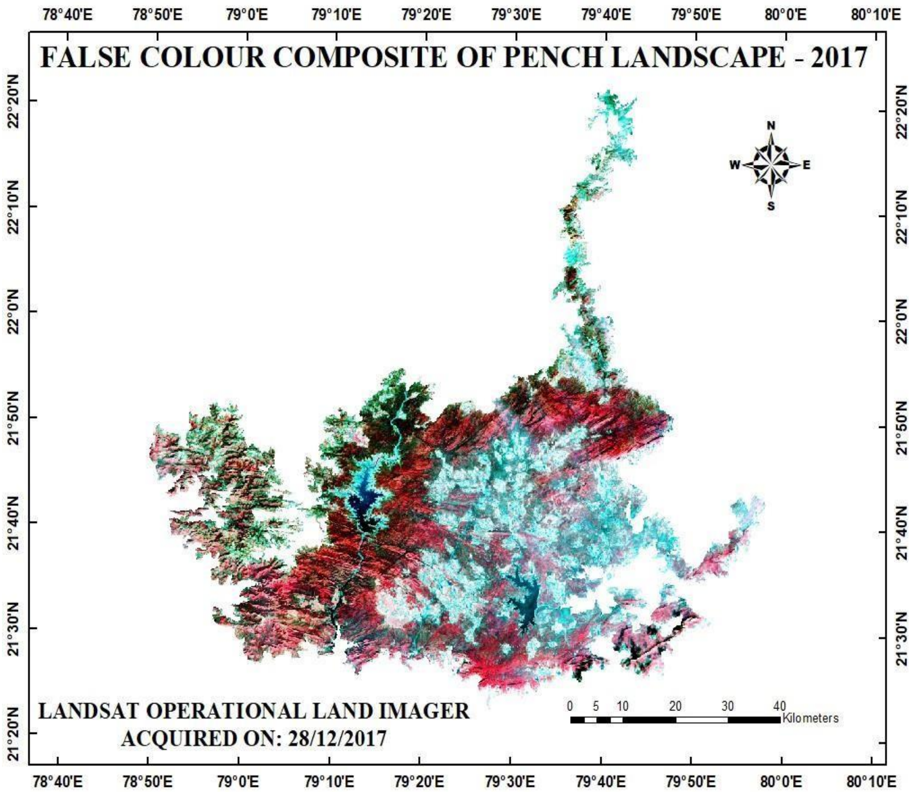

Figure 3: Standard False Color Composite of Pench Landscape, 2017.

Table 4: Spatial distribution pattern of land use/land cover classes.

Land use/cover	Area (ha)	Area (%)	Accuracy (%)
Waterbodies	7286.85	1.83	92
Shrub land	91314.3	22.91	93
Open Forest	75704.80	18.99	92.5
Dense Forest	123206.00	30.91	93
Very Dense Forest	41490.90	10.41	91
Agriculture land	59650.4	14.96	93
	398653.25	**100**	

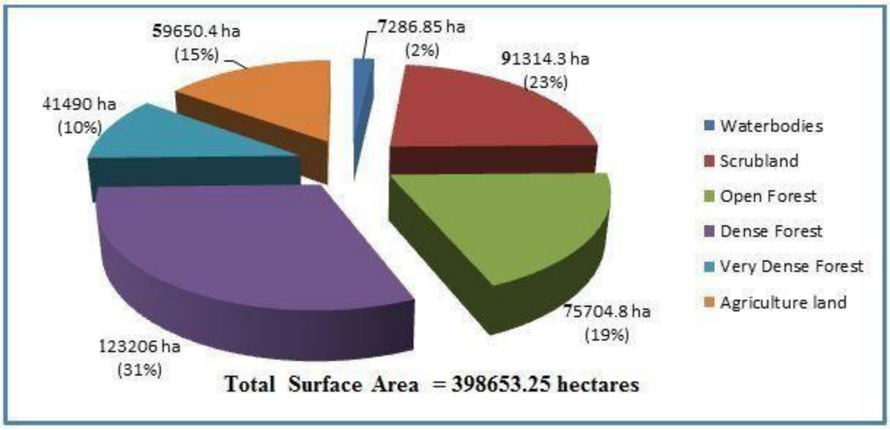

Figure 4: Distribution of land use/cover, 2017.

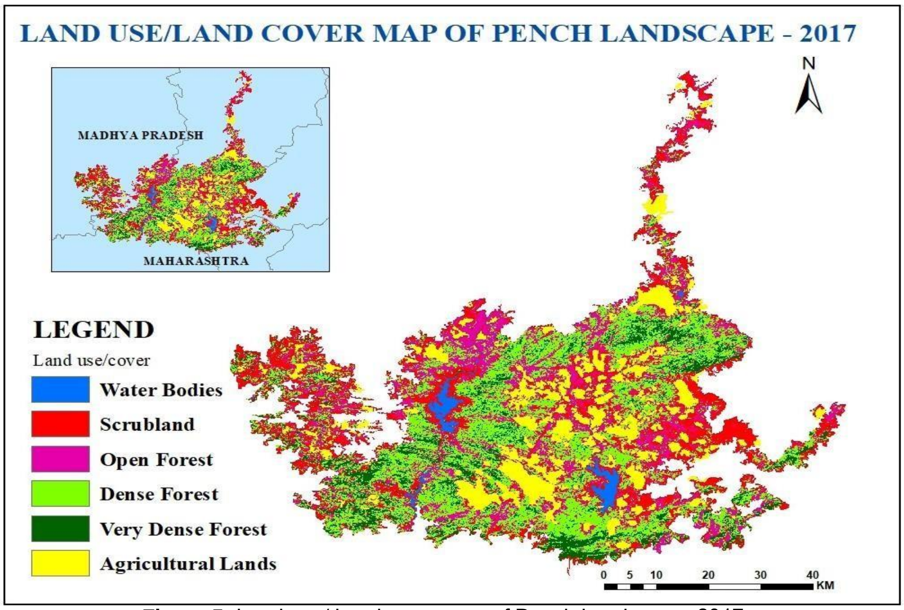

Figure 5: Land use/ Land cover map of Pench Landscape, 2017.

Remote sensing techniques were used by several workers for analyzing land use and vegetation in different surroundings through adopting various classification algorithms and was comparatively better classification technique appropriate for heterogeneous environments (Saxena *et al.* 1992; Sudhakar *et al.* 1994; Krishna *et al.,* 2001). Results of present study are compare with the (Sugumaran *et al.,*1994), (Sehgal and Dubey, 1997) and (Mahajan *et al.,*2001), Similar observations have been also reported by (Manugul et al., 2017) for 96% overall accuracy. The current study also performed maximum accuracies for scrubland, dense forest and agriculture land. This might be due to distinctive spectral behavior of respective forests, which could be simply distinguishable in near infrared bands and also achieving better accuracies compared to other classes. The present findings (single date satellite data) could be one of the possible reasons for the achieving classification accuracy below 93%. Higher spatial resolution with multi temporal data help in improving classification accuracies, however the present accuracies for different land cover types observed to be over 90%, which is quite satisfactory. The use of better spatial resolution observed maximum accuracy (100%) compared to single date satellite data (Kachhawaha 1993; Ravan et al. 1996). This result is in agreement with the finding of (Zhou, 2013 for 85% classification accuracy.

Overall vegetation composition of tropical dry deciduous forest

The tropical dry deciduous forests of the area are rich in species composition and variety of flora was found in three distinct canopy layers. Forty-one species were found in tree layer, seven species in shrub layer and nine species in herbaceous layers. In tree layer, the prominent species were *Tectona grandis, Terminalia tomentosa, Largerstroemia parviflora, Anogeissus latifolia, Dalbergia paniculata, Chloroxylon swietenia* and *Cleistanthus collinus*, whereas *Diospyros melanoxylon, Bauhinia racemosa, Acacia catechu* and *Mitragyna parvifolia* were common co-dominant species, while *Pterocarpus marsupium, Boswellia serrata, Adina cordifolia, Semecarpus anacardium* and *Cassine glauca as suppressed communities. Lantana camara, Woodfordia furticosa, Holorrhena antidysentrica, Grewia hirusta, Asparagus racemosus, Nycthanthes arbor-tristis* and *Carrissa carandus* were found in shrub layer and *Achyranthes aspera, Aristida funiculata, Tridax procumbens, Chrysopogon fulvus, Tephrosia hamiltonii, Mimosa pudica, Cyndon dactylon, Cyperus rotundus* and *Euphorbia hirta* were recorded in herbaceous layer (Table 5-7).

Structure analysis of dry deciduous forest

Results on density (trees ha^{-1}) and basal area (cross sectional area of stems ha^{-1}) extent maximum forest areas are illustrated in (Figure 6 and Figure 7). The density ranged from 391 to 936 stems ha^{-1}. Very dense forest reported the highest density followed by dense forest and lowest in open forest. Basal area ranged from 36.69 to 64.32 m^2 ha^{-1} in different forest types. Very dense forest observed maximum BA followed by dense forest. The minimum basalarea was recorded in open forest Figure 7.

Diversity analysis of dry deciduous forest

The different diversity indices were determined for different forest types to compare the difference in structural and diversity parameters among various forest types of Pench

Table 5: Tree Species of tropical dry deciduous forest.

Sl. No.	Species	Family
1	*Acacia catechu* (L.)	Mimosaseae
2	*Acacia leucocephala*	Mimosaseae
3	*Acacia nilotica* (L.)	Mimosaseae
4	*Adina cordiflora* (Roxb.) Hook. F	Rubiaceae
5	*Aegle marmelos* (L.) Correa	Rubiaceae
6	*Anogeissus latifolia* (R. Br.ex. DC)	Combretaceae
7	*Bauhinia racemosa* (Lamk.)	Caesalpiniaceae
8	*Bombax ceiba*	Bombaceae
9	*Boswellia serrata*	Burseraceae
10	*Bridelia retusa* (L.) spr.	Euphorbiaceae
11	*Buchanania lanzan* (Spreng.)	Anacardiaceae
12	*Butea frondusa* (Lam.) Taub	Fabaceae
13	*Careya arborea* (Roxb.)	Lecythidiaceae
14	*Casearia elliptica* (Wild)	Samydaceae
15	*Cassia fistula*	Caesalpiniaceae
16	*Cassine glauca* (Rottb.)	Celastraceae
17	*Chloroxylon swietenia* (Roxb.) DC	Rutaceae
18	*Cleistanthus collinus* (Roxb.) Bth. Ex. Hook. F.	Euphorbiaceae
19	*Dalbergia paniculata* (Roxb.)	Fabaceae
20	*Dendrocalamus strictus* (Roxb.)	Poaceae
21	*Diospyros melanoxylon* (Roxb.)	Ebenaceae
22	*Dolichandrone falcata* (Seem.)	Bignoniaceae
23	*Ehretia laevis*	Ehretiaceae
24	*Emblica officinalis* (L.)	Euphorbiaceae
25	*Ficus bengalensis*	Moraceae
26	*Gardenia cordiflora*	Rubiaceae
27	*Grewia tiliifolia* (Vahl.)	Tiliaceae
28	*Lannea coromandelica* (Hout.) Merr.	Anacardiaceae
29	*Lagerstroemia parviflora* (Roxb.)	Lythraceae
30	*Madhuca indica* (Gmel)	Sapotaceae
31	*Manilkara hexandra*	Sapotaceae
32	*Miliusa velutina* (Dunal)	Anonaceae
33	*Mitragyna parvifolia* (Roxb.)	Rubiaceae
34	*Pterocarpus marsupium* (Roxb.)	Fabaceae
35	*Schleichera oleosa* (Lour.) oken.	Sapindaceae
36	*Semecarpus anacardium* (L.F.)	Anacardiaceae
37	*Soymida febrifuga* (A.Juss)	Meliaceae
38	*Tectona grandis* (L.F.)	Verbenaceae
39	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae
40	*Terminalia tomentosa*	Combretaceae
41	*Ziziphus xyloflora,* (Sedgw) Sant	Rhamnaceae

Table 6: Shrub species of tropical dry deciduous forest**.**

Sl. No.	Species	Family
1	*Adhatoda vasica*	Acanthaceae
2	*Carissa carandus*	Apocynaceae
3	*Grewia hirtusa* (Vahl, symb.)	Tiliaceae
4	*Holorrhena antidysentrica*	Apocynaceae
5	*Lantana camara* (Linn.)	Verbenaceae
6	*Nyctanthes arbor-tristi,* Jacq.	Nyctanthaceae
7	*Woodfordia fruticosa* (Kurz)	Lythraceae

Table 7: Herbaceous species of tropical dry deciduous forest.

Sl. No.	Species	Family
1	*Achyranthes aspera*	Amaranthaceae
2	*Aristida funiculata* (Trin. et. Rupr)	Poaceae
3	*Tridax procumbens* (Linn)	Asteraceae
4	*Chrysopogon fulvus* (Spr)	Poaceae
5	*Tephrosia hamiltonii* (Drumm)	Fabaceae
6	*Mimosa pudica*	Mimosaseae
7	*Cynadon dactylon* (Prs)	Poaceae
8	*Cyperus rotundus* (L.)	Cyperaceae
9	*Euphorbia hirta*	Euphorbiaceae

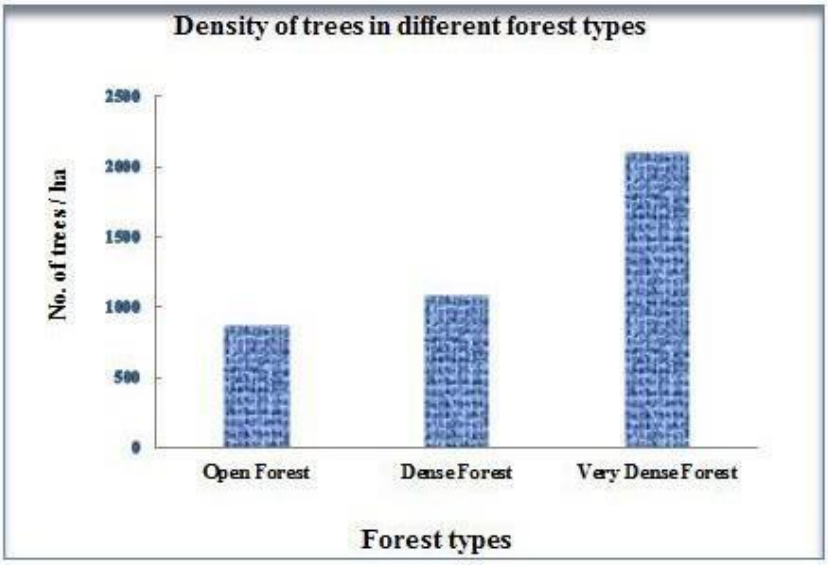

Figure 6: Density of trees in different forest types.

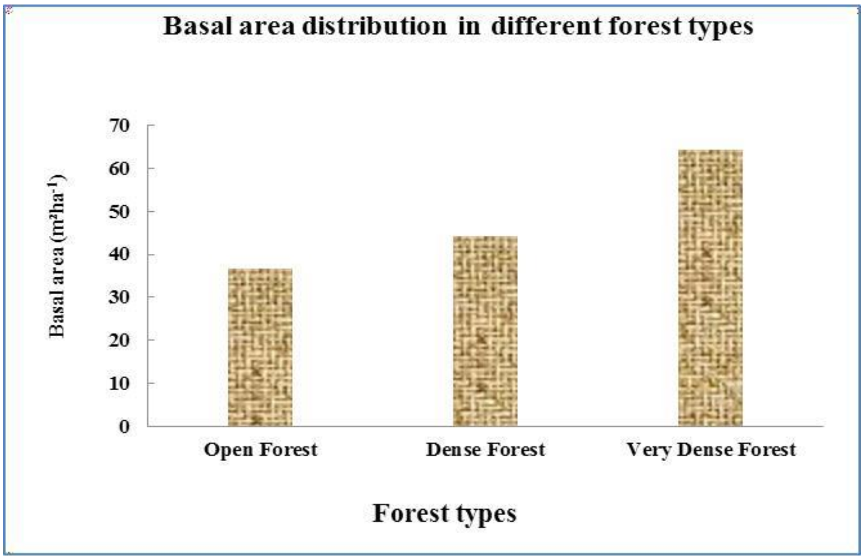

Figure 7: Basal area distribution in different forest types.

National Park. The results on species diversity of Pench National Park are given in (Table 8).

Shannon index among different forest types ranged from 2.53 to 2.97 in tree layer, 0.65 to 1.12 in shrub layer and 0.93 to 1.51 in herbaceous layer. Simpson index varied from 0.06 to 0.13 in tree layer, 0.37 to 0.54 in shrub layer and 0.26 to 0.51 in herbaceous layer. The Margalef's richness varied from 4.25 to 4.96 in tree layer, 0.77 to 4.77 in shrub layer and 4.81 to 6.82 in the herbaceous layer. Beta diversity in tree layer varied from 1.98 to 2.80, 1.40 to 2.33 in shrub layer and 1.28 to 1.80 in herbaceous layer. Interestingly, the present results on species diversity parameters are similar with others workers in the tropical environment (Singh and Singh 1991; Gupta & Shukla., 1991, Prasad and Pandey 1992; Singh *et al*. 2005; Thakur 2019). Prasad and Pandey reported the ranged from 0.32 to 3.76 andconcentration of dominance from 0.07 to 0.63 (Prasad and Pandey, 1992). The species diversity values of dry deciduous forests in present study were moderately worse than data reported by (Singh *et al.,*1984) and (Swamy, 1998).

Correlation between structural, diversity parameters and vegetation indices

Correlation analysis was performed to study the relationship between structural attributes, diversity and diversity indices of tropical dry deciduous forests and finding are illustrated in Table 9. Result indicates that Shannon index was significantly correlated with NDVI, SR, VDVI and TNDVI, while EVI exhibited negative correlation. Among the different parameters studied, NDVI, SR and TNDVI, EVI were strongly correlated with structural and diversity parameters, whereas VDVI showed non-significant correlation (Table 9). The NDVI, EVI, SR, VDVI and EVI map were depicted in (Figure 8). The best and maximum correlation coefficient (R^2) between species diversity and vegetation indices was found in NDVI with R^2 value with 0.869 followed by SR, TNDVI, EVI, VDVI and with R^2 value were 0.789, 0.698, -0.737 and 0.151, respectively. The present study indicated a positive and significant correlation between NDVI and Shannon index for different vegetation types of study area which matches with reports of earlier workers who found NDVI is key variable strongly correlated to vegetation analysis of (Thakur *et al.*, 2014). Presents finding confirms the result of previous worker (Zheng *et al.*, 2004).

Table 8: Diversity parameters for trees, shrubs and herbaceous layers of different forest types.

Forest Types	Shannon index	Simpson index	Margalef Index	Equitability	Beta diversity
Tree layer					
Open Forest	2.54	0.13	4.25	0.81	2.80
Dense Forest	2.71	0.08	4.95	0.82	2.27
Very Dense Forest	2.97	0.06	4.96	0.87	1.98
Shrub layer					
Open Forest	1.13	0.38	4.77	0.70	1.40
Dense Forest	0.71	0.49	3.69	0.51	1.75
Very Dense Forest	0.66	0.55	0.78	0.60	2.33
Herb layer					
Open Forest	1.52	0.27	6.82	0.78	1.28
Dense Forest	1.12	0.45	4.82	0.69	1.80
Very Dense Forest	0.94	0.59	4.82	0.58	1.80

Table 9: Correlations among important vegetation indices and structural parameters in dry deciduous forest of Madhya Pradesh.

	NDVI	EVI	SR	VDVI	TNDVI	Density	Basal area	Shannon Index
NDVI	1	0.69**	0.65**	0.52*	0.57*	0.61**	0.79**	0.86**
EVI		1	0.93**	0.26 NS	0.20 NS	0.22 NS	0.63**	-0.73 NS
SR			1	0.20 NS	0.23 NS	0.25 NS	0.62**	0.78**
VDVI				1	0.60**	0.11 NS	0.34 NS	0.15NS
TNDVI					1	0.39 NS	0.57**	0.69*
Density						1	0.71**	0.33 NS
Basal area							1	0.58*
Shannon index								1

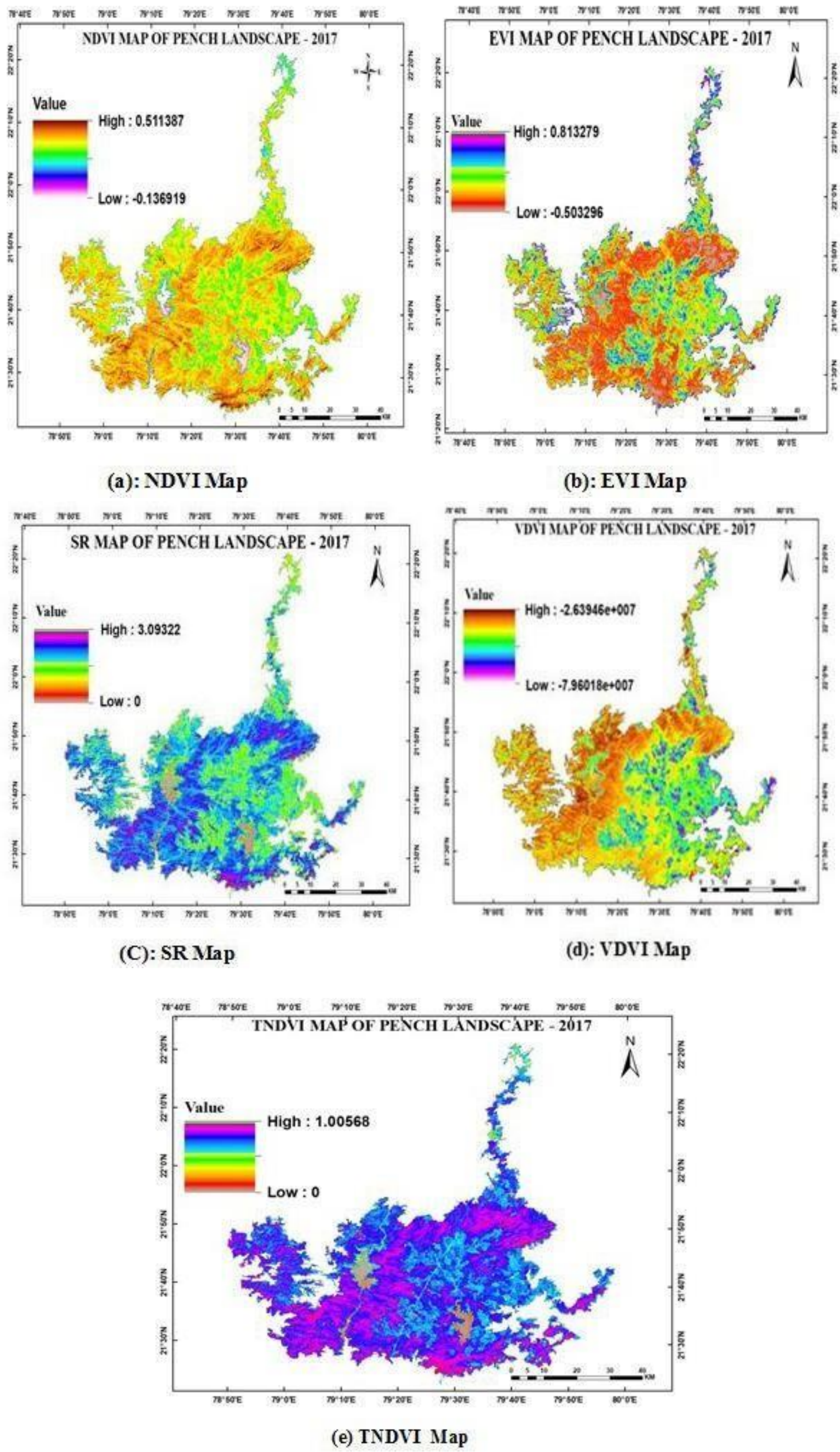

Figure 8: Vegetation indices maps of Pench landscape during 2017 (a): NDVI map (b): EVI map. (c): SR map (d): VDVI map and (e) TNDVI map.

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CONCLUSIONS

The study indicated that RS and GIS techniques were found quite useful techniques for the characterization of LULC pattern, species diversity analysis of a tropical dry deciduous forest of Pench National Park, located in the part between Madhya Pradesh and Maharashtra, India. The study also demonstrated that it is feasible to accomplish desirable classification accuracies (91- 93%) for various LULC classes in tropical dry deciduous forest using supervised classification through MLA. However, data should be free from clouds and preferably taken during October-December. Further, it is suggested to use multi date satellite data for enhancing the accuracy interval of classification and even more precisely delineating Very dense tropical dry deciduous forest. The utilization of multi temporal and high resolution satellite data will give an opportunity to understand the community level organization in different forests (Ravan, 1994).

The study reveals that tropical dry deciduous forests of Pench National Park are biologically as rich in terms of structure, diversity and biomass. But due to increased anthropogenic interferences these forests are degrading and affecting the density and also decreasing the number of trees in bigger diameter classes resulting poor above ground biomass in the forests. The study recommends adopting agri-silviculture practices and intensive conservative measures, silvipastural systems should be developed in natural open grasslands by planting MPTs and other palatable grasses to protect the forests from overgrazing and browsing. The study revealed that tropical dry deciduous forests of Pench National Park have highly possible intended for carbon sequestration and are moderately young and immature state, since most of the standing trees are in lower diameter class. The conclusion and suggestion emerged from the study are essential for the sustainable management of tropical dry deciduous forests of Pench National Park.

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