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Monitoring land use, species composition and diversity of moist tropical environ in Achanakmaar Amarkantak Biosphere reserve, India using satellite data

Abstract

The purpose of this study was to monitoring the land use, species composition and diversity in the Achanakmaar Amarkantak Biosphere Reserve of India with the conjunctive use of Resourcesat 2A satellite data via maximum likelihood algorithm. Later, the variations in structure and diversity in different forest types were quantified by adopting quadratic sampling procedures. Eight land cover types viz. Dense mixed forest, Sal mixed forest, Open mixed forest, Teak plantation, Bamboo Brakes, Agriculture, Habitation and Water bodies were delineated. The classification accuracy for different land use classes ranged from 76.69-99.07 per cent. The highest accuracy was observed in water bodies and grassland followed by Habitation & Agriculture, Teak plantation, Open mixed forest, Bamboo brake and Dense mixed forest. The accuracy was poor in Sal mixed forest. Results revealed that density of different forest types varied from 424 to 952 trees ha^{-1}, basal area from 8.33 to 29.93m^2ha^{-1} and number of species from 11 to 29. Similarly, the diversity ranged from 0.67 to 2.34, concentration of dominance from 0.09 to 0.75, species richness from 5.31 to 12.54 and beta diversity from 1.20 to 1.72. Sal mixed forest type recorded highest basal area and diversity was highest in Dense mixed forest, while Teak plantation recorded maximum density. It was poor in Open mixed 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 also developed reliable regression model for dry tropical forests by using NDVI and different vegetation indices, which can be derived from Resourcesat 2A satellite data.

Keywords: land cover, vegetation indices, GIS, GPS

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Introduction

The study is aimed to monitoring land use, species composition and biological resources in Achanakmaar Amarkantak Biosphere Reserve by using satellite remote sensing, GIS, GPS and ground based measurements. Application of remote sensing and GIS techniques is exploited for the development of spatial database that is quite necessary for conservation and sustainable development of natural resources. Further, the field surveys in selected plots of the AABR and surrounding areas help in gathering information on ground realities of socio-economic status and also traditional methods, and uses of ethno-biological resources. The wealth flora and fauna reflect natural heritage of biodiversity. Due to ecological and economic significance, Achanakmaar-Amarkantak Biosphere Reserve (AABR) was declared as 14th biosphere of the country by Government of India. UNSECO also recognized the Amarkantak Biosphere reserve as the one of the world's heritage sites. However, biodiversity is being increasingly threatened largely on account of various factors. Environmental degradation by unprecedented human activities like overexploitation of natural resources, deforestation, mining, infrastructure development, settlements are also placing severe pressure on biological resources, and leading to fragmentation and degradation of habitats, and resultant loss of biodiversity. These losses are irreversible and are a threat to well-being of local indigenous communities. It is important to protect the biodiversity of the upper catchment of Narmada as it is intricately linked to livelihoods and economy of indigenous of people of the region. Sustainable use of biodiversity therefore has both ecological and economic significance for holistic development.[1]

Remote sensing and GIS have proven to be very effective tools to analyse landscape level elements to characterize biodiversity of a region. Remote sensing provides data on landscape features, whereas GIS is used to analyse and record the relationships and patterns which occur within spatial data. Techniques such as spatial overlay are employed to allow a series of themes and criteria to be interpreted together, as well as in isolation, allowing you to compare the viability of different sites. Systematic mapping of species occurrence in a given area provides distributional pattern related to ecological parameters and their quantum of availability.[2–5] It also gives an insight into the region where conservation has to be initiated. The remote sensing, GIS and GPS tools have immense potential in determining and assessing the spatial variability of biological resources. This is assist in prioritization and evolving suitable strategies for conservation and sustainable development. Both qualitative and quantitative information is currently lacking on biological resources in Achanakmaar Amarkantak Biosphere Reserve.

At this time, geospatial techniques are emerged as efficient and powerful tools for monitoring land use, species composition and diversity in the tropical ecosystems.[3,5] A Geospatial technique provides trustworthy and impartial information on monitoring of various land use system, their spatial vegetation extent and also dynamic properties. The conservative methods of phyto-sociological analysis help in enhancement of vegetation composition at stand level. However remote sensing methods are quite useful for analyzing vegetation at large spatial scales.[2]

Materials and methods

Study area

A typical sub watershed representing a moist tropical ecosystem in Achanakmaar Amarkantak Biosphere Reserve (AABR) of India was selected for monitoring land use, species composition and diversity distribution in different vegetation types during 2017-2018. The watershed comprises an area of 626.76km², of which different forests cover more than 80 per cent area. After reconnaissance survey, a representative site (Forest range) with diverse vegetation types was selected. The AABR region is a unique natural heritage area and is the meeting point of the Vindhya and the Satpura Ranges, with the Maikal Hills being the fulcrum. This is where the Narmada River, the Sone River, Johila and several other small rivers emerge. The study area was located between 21⁰15' to 21⁰58' north latitudes and 82⁰25' to 82⁰5' east longitudes with an average elevation of 1048 metres (3438 ft). The mean annual temperature of the study area is about 16.1°C and the highest temperature goes beyond 31⁰C in May. The minimum temperature goes below 5⁰C in December. The mean relative humidity varies from 50 to 85% and the precipitation for the area is 1300-1900 mm per year. The location map and base map of the research site is depicted in Figure 1 & Figure 2.

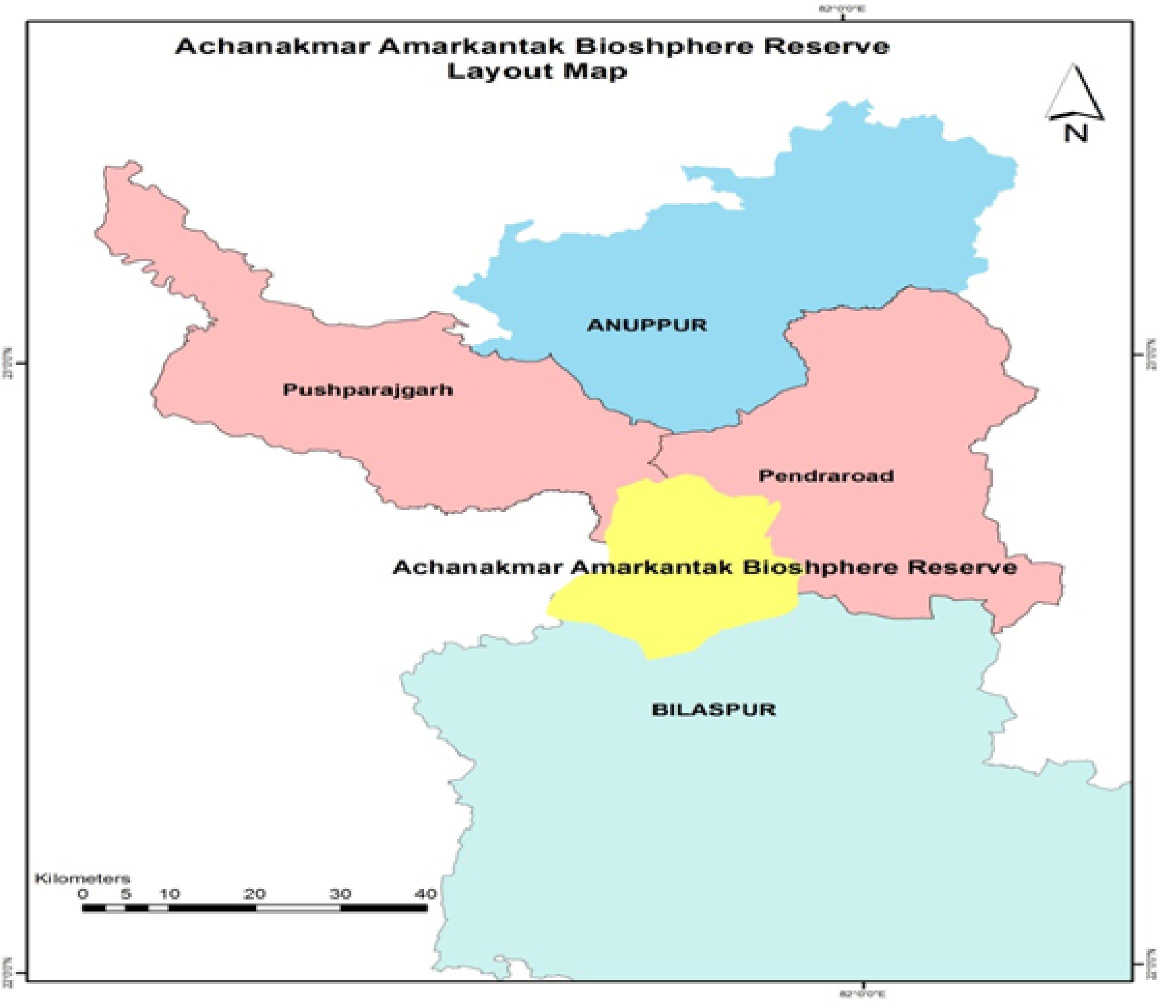

Figure 1 Layout map of the dry tropical forest of Achanakmaar Amarkantak biosphere reserve.

Selection of remote sensing data

Resourcesat 2A satellite data of path 144 and row 44, 43 December/ January 2017-2018 was procured from National Remote Sensing Agency, National Data Center (NDC), Hyderabad, India (Plate 1). The satellite image covers entire research site of Achanakmaar Amarkantak Biosphere Reserve and its surrounding environs. The image processes was performed on ERDAS Imagine software (Ver 2013) and the reference data collected from GPS and SOI topomaps were analyzed in iGIS software. Base map of study site was equipped from survey of India topomaps (64F/10, 64F/11, 64F/13, 64F/14& 64F/15) on 1:50,000 scale (Figure 2) and then used for geometric corrections of satellite image. The base map was also used as reference map for precisely locating ground sample plots in the study area. The contour and elevation information from SOI toposheets were also used for preparation of different physiographic maps.

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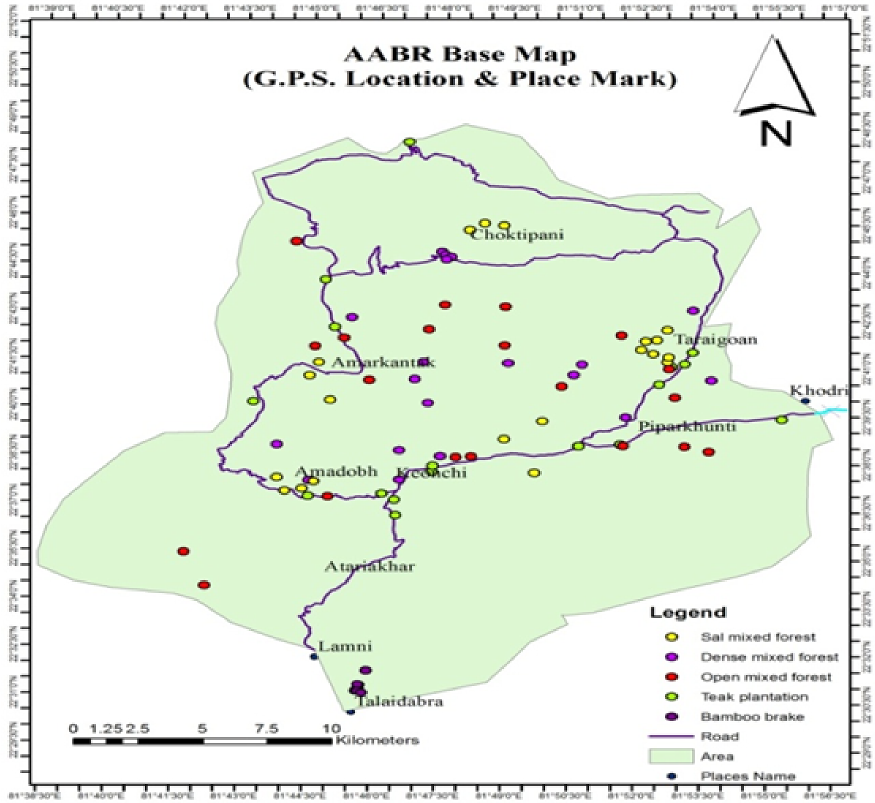

Figure 2 Base map of the study area.

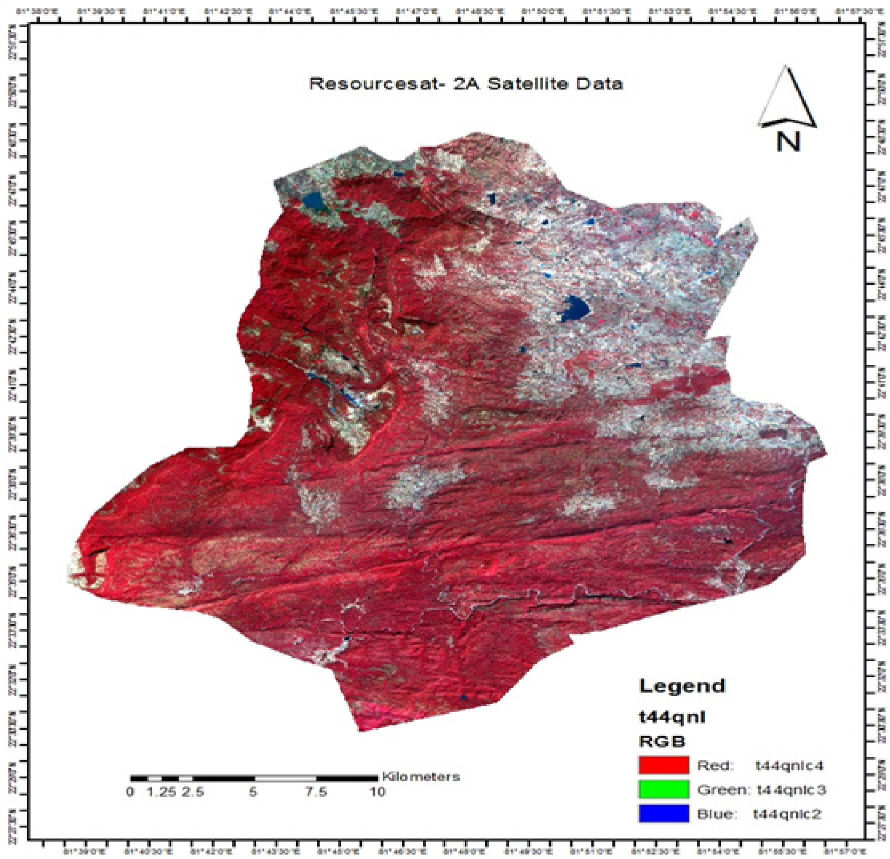

Plate 1 SFCC map of study area.

Pre processing and classification of Resourcesat 2A data

Due to geometric distortions present in raw satellite data it cannot be directly used for preparing thematic maps and deriving any site-specific biophysical information. The source of distortions occurs due to attitude, altitude and velocity of sensor platforms. The raw satellite data has to be corrected for these distortions. In the present study the SOI toposheets were electronically scanned on target Contex color scanner with a resolution compatible to Resourcesat 2A satellite data and a map scale of 1:50,000. The digital data generated from SOI toposheets (Map files) were used as Master (reference) for geometric corrections of the raw satellite data. Digital classification and monitoring of eight land use classes and species diversity was done using the maximum likelihood algorithm. Supervised classification was conceded by using ERDAS IMAGINE software and eight land use and vegetation classes were delineated.

Analysis of phytosociological and diversity analysis in different forests

The survey was conducted for the phyto-sociological analysis in each forest type has been carried by randomly laying twenty sample plots of 20 x 20 m and 5 x 5 m size for tree and shrub layers, respectively. In each sample plot, the trees and shrubs were enumerated for their girth at breast height (GBH)/ diameter at breast height (DBH) and heights. The GBH/DBH of individual tree has been measured at 1.37 m, while shrubs were measured for diameter at 15cm above ground level. The height of trees was measured using Ravi's multimeter, while shrubs by measuring pole marked in meters and centimeters. The data was analyzed for density, abundance, frequency and basal area following the methods were used by Thakur.[1] The importance value index value was derived for recognizing the predominant, co-dominant and suppressed plant communities in the AABR.

Plants diversity values for various components of trees and shrubs layer were analyzed by using diversity parameters and basal area values in each forest types and derived the diversity indices by using the formulas by Thakur.[1] Interestingly, the diversity indices were calculated for each forest types to perceive the difference in plant species diversity among each forest types. Species composition and diversity parameters were compared between the each five forest types for examine the deviation of plant diversity in tropical moist forests of Achanakmaar Amarkantak Biosphere Reserve of India.

Relationship between NDVI and species diversity

The relationship between Normalized Difference Vegetation Index and Shannon index was developed. The best fitted model was selected on the basis of regression coefficient (r^2) and t- values. This model was used for computation species diversity in each forest types of study area.

Results & discussions

Spatial extent of different land cover and vegetation types

In the study area, land use classification was performed by the using MLA. Before classification, Standard False Colour Composite (SFCC) is generated with the band combinations of 4, 3, and 2 to help in identifying few training areas for classification. An overview of SFCC of study area is depicted in Plate 1. The spatial vegetation extent analysis values of various land use with their classification accuracy is shown in Table 1. Interestingly, eight land use classes (i.e. Sal mixed forest, Dense mixed forest, Open mixed forest, Teak Plantation, Bamboo Brake, Agriculture and habitation and water bodies) were classified by Resourcesat 2A satellite data with using maximum likelihood algorithm. Among each land cover types, Dense mixed forest covered the maximum portion, while minimum was occupied by The classified image (Plate 2) shows the vegetation extent of various land use types.

Table 1 Spatial extended vegetation of AABR during 2018

Class name	Area (km^2)	Distribution (Percent)	Classification accuracy (%)
Dense Mixed Forest	246.3	39.2978	82.55
Sal Mixed Forest	186.49	29.754	76.69
Open Mixed Forest	90.8	14.4866	87.11
Teak Plantation	41.015	6.544	91.87
Bamboo Break	32.89	5.2471	88.36
Agriculture	21.95	3.5022	91.66
Water Bodies	5.29	0.8447	99.07
Habitation	2.03	0.3236	93.99
Total	626.76	100	

Dense mixed forest occupied 39.29 per cent of total studied area followed by Sal mixed forest in 29.75 per cent, Open mixed forest in 14.48 per cent, Teak plantation in 6.54 per cent, Bamboo brakes in 5.25 per cent, Agriculture in 3.50 percent, Waterbodies in 0.85 per cent of total area. Habitation was only found in 0.32 per cent area. Dense mixed forest was covered in 246.3 km^2, Sal mixed forests in 186.5km^2, Open mixed forest covered 90.8 km^2, Teak forest in 41.01 km^2, Bamboo brake in 32.89 km^2 and Agriculture in 21.95 km^2 area. The waterbodies occupied only 5.29 km^2, while habitation was confined to small patches covered in an area of 2.03 km^2. Similar study has been done by various scientists in different forest ecosystems in India through adopting various classification algorithms.[6,7]

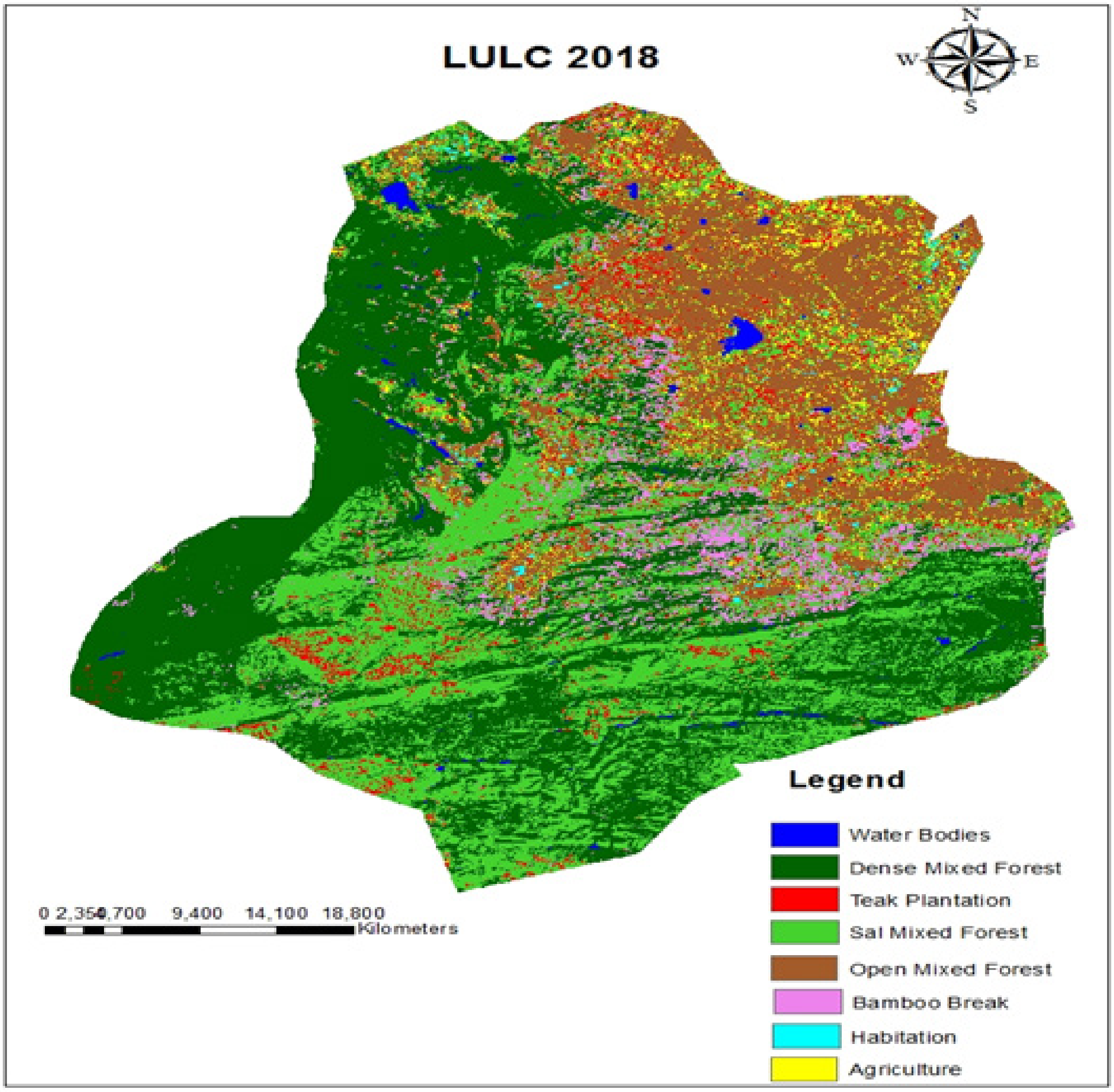

Plate 2 Classified image of the study area.

In each forest types, the classification accuracy was varied 76.69-99.07 per cent. The uppermost accuracy was recorded in water bodies, Agriculture followed by Habitation, Dense mixed forest, Open mixed forest, Teak forest and the Sal mixed forest was performed minimum accuracy. Land use and land cover analysis studied by Saha et al.,[8] and he reported overall 96 per cent accuracy of Aligarh district in Uttar Pradesh, India by using digitally classifying Landsat TM data. Interestingly, the uppermost classification accuracies were also perceived by other workers by using similar classification technique.[9–11]

Structure and diversity of AABR

Geospatial techniques are emerging as important tools for monitoring of land cover, species diversity and biological resources. The present study is also used to characterize land cover, vegetation structure and diversity by using Resourcesat 2A satellite data and ground methodologies. The moist tropical forests of AABR are luxuriant in species composition. A variety of flora is found in these forests. The species were distributed in three distinct canopy layers. Thirty four species were found in overstorey vegetation, sixteen species each were found in under storey vegetation (Table 2 & Table 3). In overstorey vegetation species like *Shorea robusta, Tectona grandis, Terminalia tomentosa, T. chebula, Dalbergia paniculata, Pterocarpus marsupium, Madhuca latifolia* were found as predominant species occupy top storey. On the other hand, *Lagerstroemia parviflora, Acacia catechu, Boswellia serrata, Lannea corremondillica, Cleistanthus collinus, Soynidia febrifuga, Schleichera oleosa, Cassia fistula, Buchanania lanzan, Butea monosperm, Emblica officinalis, Bamboos* etc were common co dominant species found in middle storey, while *Woodfordia frulicosa, Asparagus racemosus, Phoenix acculis, Andrographis paniculata, Curcuma sp., Dudonea viscosa* etc. were found in under storey vegetation (Table 4).

Table 2 Tree species composition of dry tropical forest ecosystem of AABR

SN	Common Name	Scientific Name	Family	IVI
1	Amaltas	*Cassia fistula L.*	*Caesalpiniaceae*	3.42
2	Aonla	*Emblica officinalis Gaertn.*	*Euphorbiaceae*	1.91
3	Bahera	*Terminalia bellirica (Gaertn.) Roxb.*	*Combretaceae*	1.46
4	Bahunia	*Bauhinia purpurea L.*	*Caesalpiniaceae*	1.56
5	Bargad	*Ficus benghalensis L.*	*Moraceae*	0.73
6	Beal	*Aegle marmelos (L.) Corrêa*	*Rutaceae*	0.47
7	Birari	*Chloroxylon swietenia DC.*	*Rutaceae*	2.03
8	Char	*Buchanania lanzan Spreng.*	*Anacardiaceae*	23.66
9	Dhamda	*Terminalia arjuna (Roxb. ex DC.)*	*Combretaceae*	18.73
10	Dhaora	*Anogeissus latifolia (Roxb. ex DC.)*	*Combretaceae*	1.02
11	Garari	*Cleistanthus collinus (Roxb.) Benth.*	*Phyllanthaceae*	0.59
12	Ghata	*Sterculia urens Roxb.*	*Malvaceae*	0.46
13	Gunja	*Lannea coromandelica (Houtt.) Merr.*	*Anacardiaceae*	10.24
14	Harra	*Terminalia chebula Retz.*	*Combretaceae*	4.7
15	Jamun	*Syzygium cumini (L.) Skeels*	*Myrtaceae*	3.81
16	Kalmi	*Adina dissimilis Craib*	*Rubiaceae*	12.79
17	Kari	*Saccopetalum tomentosum Hook.f. & Thomson*	*Annonaceae*	1.01
18	Kekar	*Garuga pinnata Roxb.*	*Burseraceae*	2.29
19	Kino	*Pterocarpus marsupium Roxb.*	*Leguminosae*	0.94
20	Kusum	*Schleichera oleosa (Lour.) Merr.*	*Sapindaceae*	2.99
21	Mahua	*Madhuca latifolia (Roxb.) J.F.Macbr.*	*Sapotaceae*	2.68
22	Saija	*Lagerstroemia parviflora Roxb.*	*Lythraceae*	12.63
23	Saja	*Terminalia tomentosa Wight & Arn.*	*Combretaceae*	20.77
24	Sal	*Shorea robusta Gaertn.*	*Dipterocarpaceae*	81.57
25	Salai	*Boswellia serrata Roxb. ex Colebr.*	*Burseraceae*	5.16
26	Teak	*Tectona grandis L.f.*	*Verbenaceae*	55.65
27	Tendu	*Diospyros melanoxylon Roxb.*	*Ebenaceae*	10.32
28	Tinsa	*Ougeinia dalbergioides Benth.*	*Papilionaceae*	8.89
29	Vilbha	*Semecarpus anacardium L.f.*	*Anacardiaceae*	6.59
30	Tanwar	*Wendlandia luzoniensis DC.*	*Rubiaceae*	1.27
31	Kumbhi	*Careya arborea Roxb.*	*Lecythidaceae*	0.88
32	Eucalyptus	*Eucalyptus tereticornis var. brevifolia Benth.*	*Myrtaceae*	0.53
33	Palas	*Butea monosperma (Lam.) Taub.*	*Leguminosae*	0.79
34	Semal	*Bombax malabaricum DC.*	*Malvaceae*	1.36
				303.95

Table 3 Composition of dry tropical forest ecosystem in shrub layer

S No	Species	Botanical name	Family
1.	Chind	*Phoenix acaulis*	*Arecaceae*
2.	Madar	*Calotropis procera*	*Asclepiadaceae*
3.	Gursukhri	*Grewia hirsuta*	*Tiliaceae*
4.	Dhawai	*Woodfordia fruticosa*	*Lythraceae*
5.	Jharber	*Ziziphus nummularia*	*Rhamnaceae*
6.	Mahul	*Bauhinia vahlii*	*Caesalpiniceae*
7.	Bans	*Bambusa bambos*	*Bambusaceae*
8.	Kachnar	*Bauhinia variegata*	*Cacsalpiniaceae*
9.	Sissal	*Agave americana*	-
10.	Sissal	*Agave sisalana*	-
11.	Henna	*Lawsonia innermis*	-
12.	Nasarbal	*Butea parviflora*	*Laguminosae (Papilionaceae)*
13.	Kantabans	*Dendrocalamus strictus*	*Graminae*
14.	Safed korea	*Wrightia tinctoria*	*Apocynaceae*
15.	Baichandi	*Dioscorea hispida*	*Dioscoreaceae*
16.	Makoi	*Ziziphus oenoplia*	*Rhamnaceae*

Table 4 GPS locations, habitat types and other attributes of sampling sites

Forest Type	Coordinates	Elevation (m)	Sub-climax species (arranging in ascending order according to dominance)
Sal mixed forest	Lat. 22°37'22.69" Long. 81°39'35.69"	1053	*Arthraxonhispidus, Ageratum conizoides, Commelinadiffusa, Colocasia esculenta*
Dense mixed forest	Lat. 22°38'52.46" Long. 81°41'45.68"	1032	*Arthraxonhispidus, Rungiapectinata, Phyllanthus nirui Curcuma angustifolia, Sidaacuta*
Teak plantation	Lat. 22°37'49.82" Long. 81°39'45.76"	1040	*Arthraxonhispidus, Evolvulusnummularius, Linderniadubia, Phyla nudiflora, Oxalis corniculata, Scopariadulcis*
Open mixed forest	Lat. 22°38'26.56" Long. 81°40'37.37"	1046	*Arthraxonhispidus, Macardonia procumbence, Phyllanthus nirui, Oxalis corniculata, Rungiapectinata, Sidaacuta*
Bamboo Brakes	Lat. 22°36'12.06" Long.81°41'48.23"	809	*Rungiapectinata, Evolvulusnummularius, Smithiaconferta, Oxalis corniculata, Phyllanthus nirui, Ocimumgratissimum*

Thirty four species belonging to 13 families in overstorey layer, 16 species representing 9 families in understorey vegetation were found in different forest type, similar trends were found in the Dry deciduous forest in Wildlife Sanctuary, Raipur Forest Division, Raipur, Chhattisgarh and was recorded lesser amount of diverse than the overstorey vegetation of present study.[12] Gómez-Díaz et al.,[13] 2017 recorded 264 plant species and 31 were endemic at Mexican forests under the species composition of herb communities among various elevations. Density of overstorey and understorey vegetation accounted for 553.68 trees ha^{-1} (ranged from 424 to 952 trees ha^{-1}) and 5870 shrubs ha^{-1}. Similarly kind of trends were found in Raipur Forest Division studied by Thakur[14] and he reported that the structural analysis of vegetation density ranged from 324 to 733 treesha^{-1} and 3149 to 6053 shrubs ha^{-1}. Similarly, frequency values were ranged from 11.7% to 100 % and basal area from 0.11to 14.07m^{2}ha^{-1}. *Shorea robusta, Cleistanthus collinus, Buchanania lanzan* and *Lagerstroemia parviflora* showed higher structural parameters values, and lowest was recorded by *Tectona grandis, Cassia fistula* and *Antidesma acidum*. Basal area values accounted from 8.33 to 29.93 m^{2}ha^{-1} in various forest types. Maximum values were account in Sal mixed forest followed by Dense mixed forest, Teak forest and minimum was found in Open mixed forest and comparable structural parameters to other tropical forests which has reported by several workers.[15–17] Tree density varied from 349 to 627, basal area from 9 to 14.79 m^{2}ha^{-1} and tree species varied from 9 to 14 in dry tropical forests by Singh et al.[15]

Shannon index values in different forest types ranged from 0.67 to 2.34, the diversity was highest in dense mixed forest, while it was lowest in Teak forest. In contrary, the Simpson index values were found to be highest in Teak forest followed by Sal mixed forest. It ranged from 0.09 to 0.75 in vegetation of different forest types. The concentration of dominance was found to be lowest in dense mixed forest; it was almost 79 per cent less than concentration of Teak forest. The species richness values ranged from 5.31 to 12.54 in all forest types in tree layers. Dense mixed forest recorded highest species richness followed by Sal mixed forest and Open mixed forest. Among the different forest types, the highest equitability was recorded in dense mixed forests and lowest in Teak forests in tree layer of different forests. Equitability values ranged from 0.25 to 0.67 and the Beta diversity values ranged from 1.20 to 1.72. It was highest in Open mixed forest and lowest in Sal mixed forest. Sal mixed forest type recorded highest basal area and diversity was highest in Dense mixed forest, while Teak plantation recorded maximum density. It was poor in Open mixed forests (Table 5). However many plant species are lost due to human pressure, and many species are replaced by exotic species which is affecting the ecology of this region e.g. Sal, Mahua were replaced by Pine and Eucalyptus which is damaging the diversity of this region.[2,15,16,18]

Table 5 Species diversity indices for vegetation of different forest type of tropical forest of India

Forest type	S	H'	□	D	E	B
Teak Forest	11	0.9	0.65	5.79	0.28	1.72
Sal Mixed Forest	14	0.67	0.75	5.31	0.25	1.58
Dense Mixed Forest	29	2.34	0.087	12.54	0.63	1.2
Open Mixed Forest	22	2.28	0.14	9.45	0.67	1.27

S= total number of species censused. H'= Shannon-Wiener index. □= Simpson's concentration index. D= Margalef's index of species richness. E= Pielou's evenness index. B= Beta diversity

Correlation and regression relationships between vegetation indices, structural and diversity parameters

The study was performed among various vegetation indices, structural and diversity parameters of AABR and results are shown in Table 6. Results indicate that the NDVI values were positively performed with species diversity. Species diversity was significant between NDVI, whereas it was insignificant with others indices *viz.* Advance Vegetation Index, Perpendicular Vegetation Index, Soil Adjust Vegetation Index, Ratio Vegetation Index and density. Normalized difference vegetation index was best fitted based on higher r^2 values for density, basal area and diversity values in moist tropical forest of AABR. Mean Normalized difference vegetation index and Shannon index (pooled data of OS + US) data shows a positive correlation among both at the level of 5 and 1 percent (Figure 3), (Plate 3 & Plate 4). Several earlier workers showed a correlation between vegetation indices and NDVI in various forest ecosystems.[19–21]

Table 6 Correlations among important vegetation indices and structural parameters in dry tropical forest of AABR

	NDVI	AVI	PVI	TVI	SAVI	RVI	LAI	Density	Basal area	Shannon index
NDVI	1	0.73**	0.67**	0.49*	0.50*	0.49*	0.86**	0.65**	0.82**	0.44*
AVI		1	0.93**	0.28NS	0.22NS	0.37NS	0.76**	0.24NS	0.57**	0.15NS
PVI			1	0.20NS	0.23NS	0.23NS	0.69**	0.25NS	0.58**	0.12NS
TVI				1	0.60**	0.72**	0.42*	0.11NS	0.34NS	0.24NS
SAVI					1	0.57**	0.35NS	0.39NS	0.53**	0.39NS
RVI						1	0.45*	0.24NS	0.48*	0.30NS
LAI							1	0.54**	0.72**	0.098NS
Density								1	0.82**	0.33NS
Basal area									1	0.49**
Shannon index										1

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

NS Non- significant

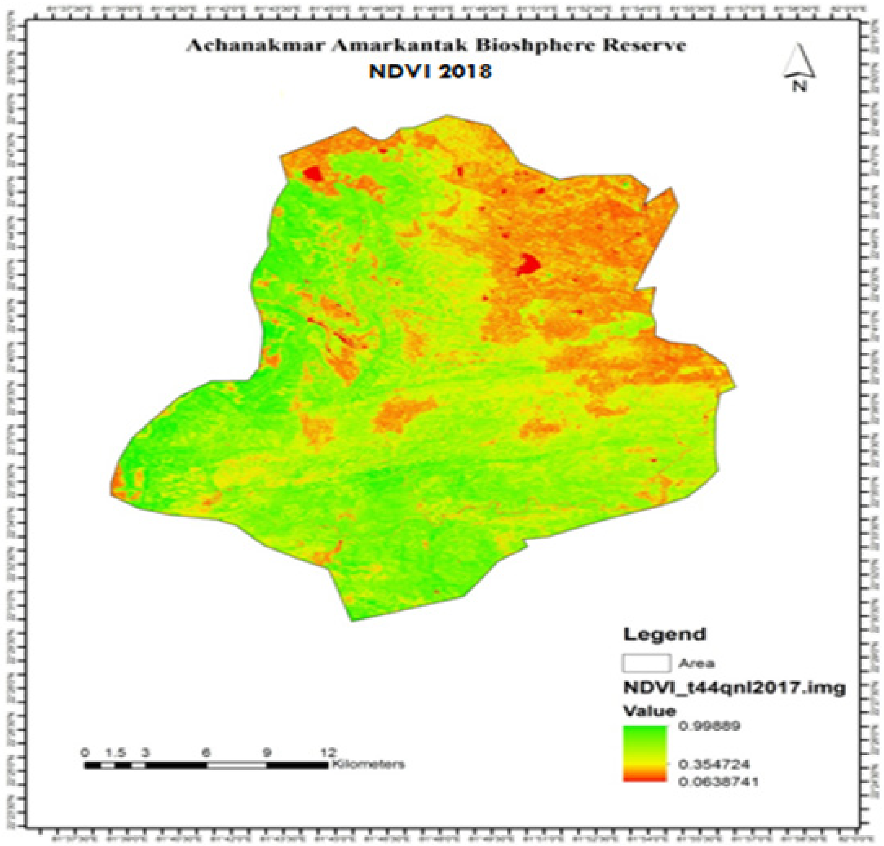

Plate 3 NDVI map of the study area.

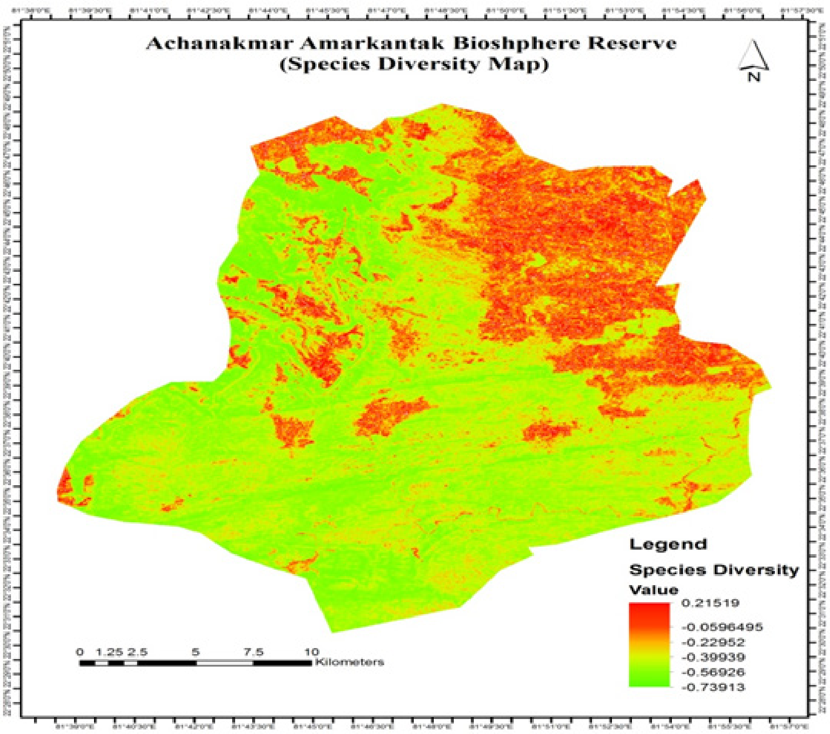

Plate 4 Species diversity map of dry tropical forests of AABR.

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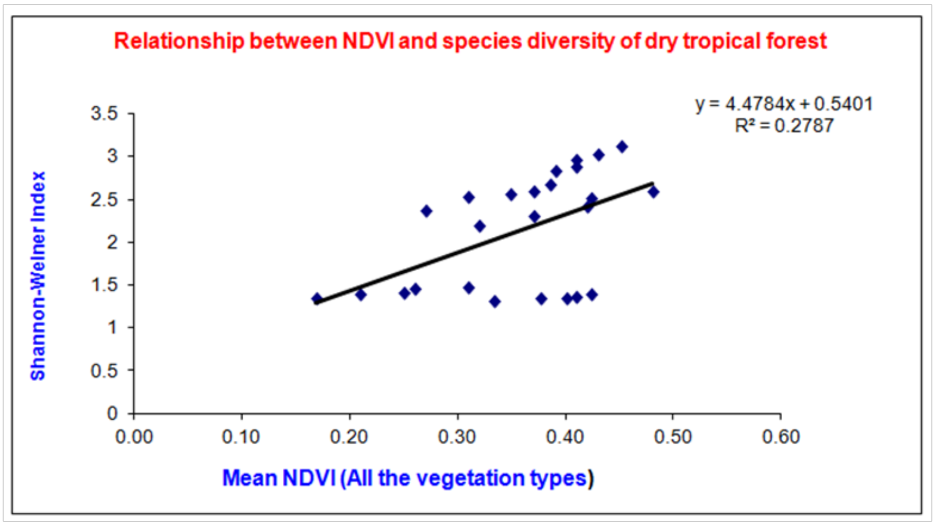

Figure 3 Relationship between NDVI and species diversity of dry tropical forest.

Conclusions

The present study on monitoring land use, species composition and diversity of Achanakmaar Amarkantak Biosphere Reserve of India by using Resourcesat 2A satellite data and the study indicated that moist tropical ecosystems of AABR is land of unique plant species, rich in biodiversity, however many plant species are lost due to human pressure, and many species are replaced by non-native species and Industrial activities like mining is practiced very close to Biosphere areas which is quite damaging and it should be regulated and other industries must be carried away from this region.

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Conflicts of interest

The author declares there is no conflicts of interest.

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