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Space remote sensing for spatial vegetation characterization

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Abstract. The study area, Madhav National Park (MP) represents northern tropical dry deciduous forest. The national park, due to its unique location (nearest to township), is under tremendous biotic pressure. In order to understand vegetation structure and dynamics, vegetation mapping at community level was considered important. Prolonged leafless period and background reflection due to open canopy poses challenge in interpretation of satellite data. The vegetation of Madhav National Park was mapped using Landsat TM data. The ground data collected from sample points were subjected to TWINSPAN analysis to cluster sample point data into six communities. The vegetation classification obtained by interpretation (visual and digital) of remote sensing data and TWINSPAN were compared to validate the vegetation classification at community level. The phytosociological data collected from sample points were analysed to characterize communities. The results indicate that structural variations in the communities modulate spectral signatures of vegetation and form basis to describe community structure subjectively and at spatial level.

Keywords. Remote sensing; community analysis; vegetation mapping.

1. Introduction

Vegetation maps at the community level are often useful in order to understand and explain vegetation occurrences and patterns. Many workers have discussed methods of analyses of vegetation gradients (Whittaker 1956, 1967; Austin 1985; Beals 1985). Methods of vegetation analyses can be discriminated as subjective and objective. Each method has certain advantages over other. Two Way Indicator Species Analysis (TWINSPAN) is one of the widely accepted objective methods, which is free from operator bias. But associations obtained by TWINSPAN have little meaning until communities are identified. and mapped with reference to geo-coordinates. Vegetation data in the spatial form is gaining importance due to its relevance in practical application. Remote sensing presents superior subjective approach where dominant species are identified based on spectral characteristics of the canopy. The approach produces higher accuracy. Treitz *et al* (1992) have demonstrated that quantitative analysis (TWINSPAN) of the field plots does not offer any advantage over subjective field plot information for classification of remote sensed data.

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Structural and phenological variations among plant communities modulate spectral signatures which are sensed by satellite sensors. Thus, remote sensing data describe qualitative characters of community structure (Thomas *et al* 1993). Vegetation mapping using interpretation of satellite remote sensing data provides qualitative characteristics of vegetation and can be adjusted to the requirements/objectives of the survey (Kuchler 1988). It provides homogeneous units to lay down sample plots for quantitative study of community structure (Roy *et al* 1993).

The study presented here considers remote sensing data as a basis to discriminate vegetation of Madhav National Park at the community level. TWINS PAN method was used to validate approach of community classification using satellite images. The valuable information thus obtained is coupled with field analysis in order to explain the structure of each community. This study presents an approach to cover the entire variation of communities in order to characterize vegetation of the study area.

2. Study area

Madhav National Park (165·32 km^2) is one of the oldest national park of Madhya Pradesh created in the year 1956. It is situated close to Shivpuri town, in the central highlands of India and forms the part of upper Vindhyan range. It is bounded by geo-coordinates 77°35′ to 77°45′ E and 25°20′ to 25°40′ N (figure 1). In general the upper Vindhyans are mostly sandstone Shales and limestones. Biogeographically Madhav National Park is located in zone 4, the semiarid zone as classified by Rodgers and Panwar (1988). Out of the two separate biotic provinces in this region, the national park is situated in province II i.e., Gujarat-Rajwara province (4B).

Physical and man-made features have divided the national park into three zones viz., north, central and south. Two highways passing through the park act as ecological barriers and prevent movement of wildlife and species interactions between three zones. The national park, being surrounded by human habitation, is under tremendous biotic pressure and the conservation of the ecosystem has become a challenging task.

The park represents northern tropical dry deciduous mixed forest type as well as thorn forests. Major vegetation types are *Anogeissus pendula, Boswellia serrata, Butea monosperma, Acacia catechu* and mixed dry deciduous forests.

3. Materials and methods

Landsat TM data (Path-row 146-02) in the form of false colour composite (FCC) (bands 4, 3 and 2, scale 1 : 50,000, February, 1989) and digital data (November, 1989 and January, 1990) were used for this study.

3.1 *Visual interpretation*

Landsat TM FCC was taken to the study area and reconnaissance survey of entire area was made to correlate image characteristics and ground features. Ground data were collected to identify different vegetation types represented in study area. The

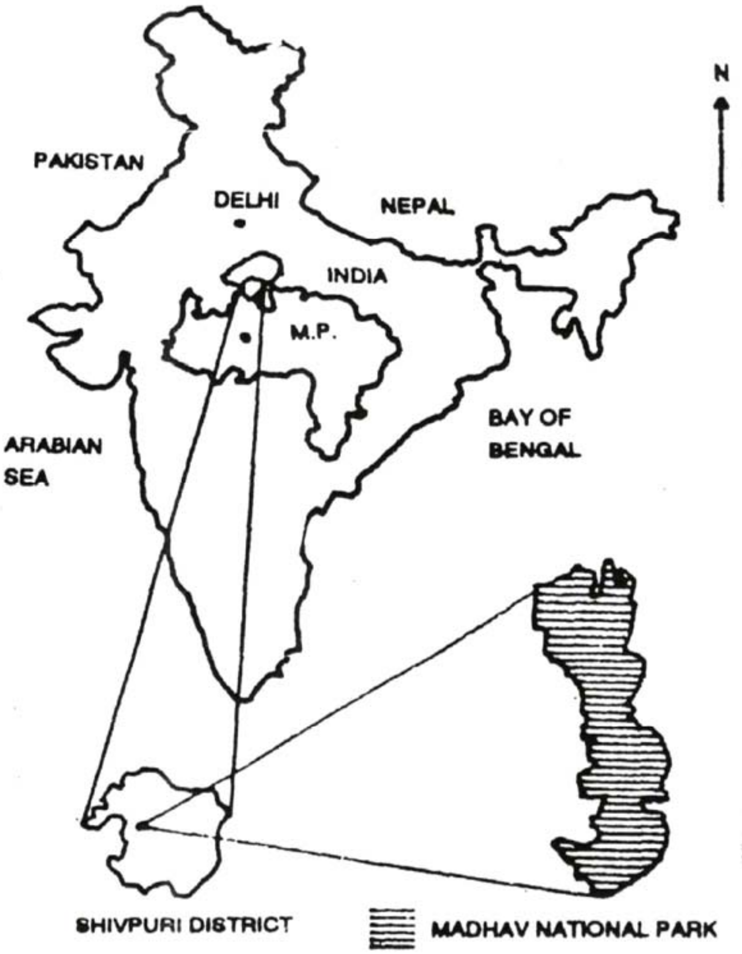

Figure 1. Location map of Madhav National Park.

spectral signatures (digital number—DN) of each vegetation type were extracted from digital data. These signatures in six Landsat TM bands were plotted to understand spectral response of vegetation types. The image interpretation key for vegetation type identification was derived (table 1). The vegetation map was prepared by visual interpretation of FCC based on size, shape, shadow, tone or colour, texture, site, association and physiography.

3.2 *Digital classification*

The digital analysis was performed on VAX 11/780 system with SEPIMAGE VIPS 32 Image Processing Software. The spectral separability of vegetation types in different bands was evaluated using bivariate distributions in multispectral feature space and transformed divergence matrix analysis (Jensen 1986). The bands showing high spectral separability were used for preparation of the vegetation maps by supervised maximum likelihood classification of digital data. Attempts were made

Table 1. Interpretation key for vegetation type identification using Landsat TM false colour composite.

Type	Tone	Texture	Physiography	Association	Phenology	Corresponding forest type described by Champion and Seth (1968)
Anogeissus pendula forest	Medium to dark brown	Smooth	On slopes of cooler aspects	Near to water source and nalas	Dried brown leaves	*Anogeissus pendula* forest (5/E1)
Boswellia serrata forest	Medium brown	Smooth	Table top of platen and slopes of warmer aspects	Sites with poor moisture	Leafless	*Boswellia* forest (5/E2)
Acacia catechu forest	Grayish with blue tinge	Smooth to medium	Plains, lower elevation	Open areas of the foot hills	Dried leafless with dried pods	Southern thorn forest (6A/C1)
Thorny scrub	Light gray	Uneven	Plain	Rough rock area	Dried leafless with dried pods	*Zizyphus* scrub (6B/DS1)
Butea monosperma mixed forest	Reddish brown	Medium	Plain	—	Few green leaves present	*Butea* forest (5/E5)
Dry mixed deciduous forest I	Dark red	Smooth to medium	Valleys, along the streams and rivers	Along the water source	Dense green crown cover	Southern dry tropical riparian forest (5/1S1)
Dry mixed deciduous forest II	Medium brown to light gray	Coarse to rough	Top of elevated areas	Away from water source	Mostly leafless except *Diospyros* species	Northern dry mixed deciduous forest (5B/C2)
Dry mixed deciduous forest III	Medium red	Smooth	Areas with low hilly configuration	Ground broken due to gully erosion	Leafy condition	Ravine thorn forest (6B/C2)
Riparian forest	Bright red	Smooth	Along drainage	Drainages with permanent water	Leafy condition	Tropical riparian fringing forest (4E/RS1)
Grasslands	Light gray	Smooth	Steep slopes and plains	Open forest areas	Dried tassels	Dry grasslands (5/DS4)

to improve digital classification using temporal dataset of November and January. The classification accuracy (in terms of omission) was evaluated using confusion matrix. A systematic field check was obtained to check the accuracy of classification at 109 points and classification accuracy with respect to ground truth was evaluated.

3.3 *Ground data analysis*

Eighteen sample plots (1000 m^2) in forest and two plots (100 m^2) in scrubland were laid randomly in different state observed on imagery insuring that these are true representatives of respective vegetation types. All trees were measured for girth (at l·33m height). Shrubs were measured for circumference at 10 cm above ground. The stands were clustered with TWINSPAN (Hill 1979) using relative abundance value area of tree species. The vegetation data were analysed for density, abundance, relative basal area (Curtis and McIntosh 1950; Phillips 1959). Any quantitative measure of abundance or a combination of several measures can be used as an importance value of the species (Whittaker 1975). In the present study, importance value was calculated as the sum of relative density and relative basal area (Blair and Brünett 1976). Species diversity was measured using importance values (Shannon and Weaver 1953). Equitability (*Ep*) was calculated as suggested by Pielou (1966). Dominance (*cd*) was measured by Simpson's index (Simpson 1949). Species richness is calculated as per Margalef (1958).

4. **Results and discussion**

4.1 *Vegetation and landuse*

Table 1 shows details of interpretation criteria to prepare vegetation map using Landsat TM FCC (figure 2). Figure 3 shows vegetation map prepared by visual interpretation of FCC. Accordingly, Madhav National Park comprises of the following vegetation types. *A. pendula* forest, *B. serrata* forest, *A. catechu* forest, *B. Monosperma* forest, mixed dry deciduous forest I, mixed dry deciduous forest II, mixed dry deciduous forest III, riparian forest, scrub and grasslands. Two reservoirs are situated in study area namely, Sakhya sagar and Madhav lake.

Digital data was classified using maximum likelihood classifier. Band 3 (red), 4 (infrared) and 5 (middle infrared) were selected for classification based on transformed divergence matrix analysis (Jensen 1986). Spectral signatures of various vegetation types have shown marked discrimination in red, near infrared and middle infrared bands (figure 4) . Classification accuracy (in terms of omission) was estimated based on confusion matrix which shows the number of pixels within training set that were categorized into each category (Jensen 1986). It ranged from 100% in case of scrub to 67% for mixed dry deciduous forest III. The overall accuracy in present study is 83·98%. Classification accuracy with respect to ground truth was also evaluated. The digital classification of single date data and temporal data set indicated that, for the phenological vegetation type, more than one season can enhance the accuracy of classification. Classification accuracy obtained using digital data of November and January was 64·5% and 58·21% respectively. Whereas, temporal data set has resulted higher accuracy (67·07%) (Ravan and Roy 1995). Figure 5 shows vegetation type maps obtained by digital classification.

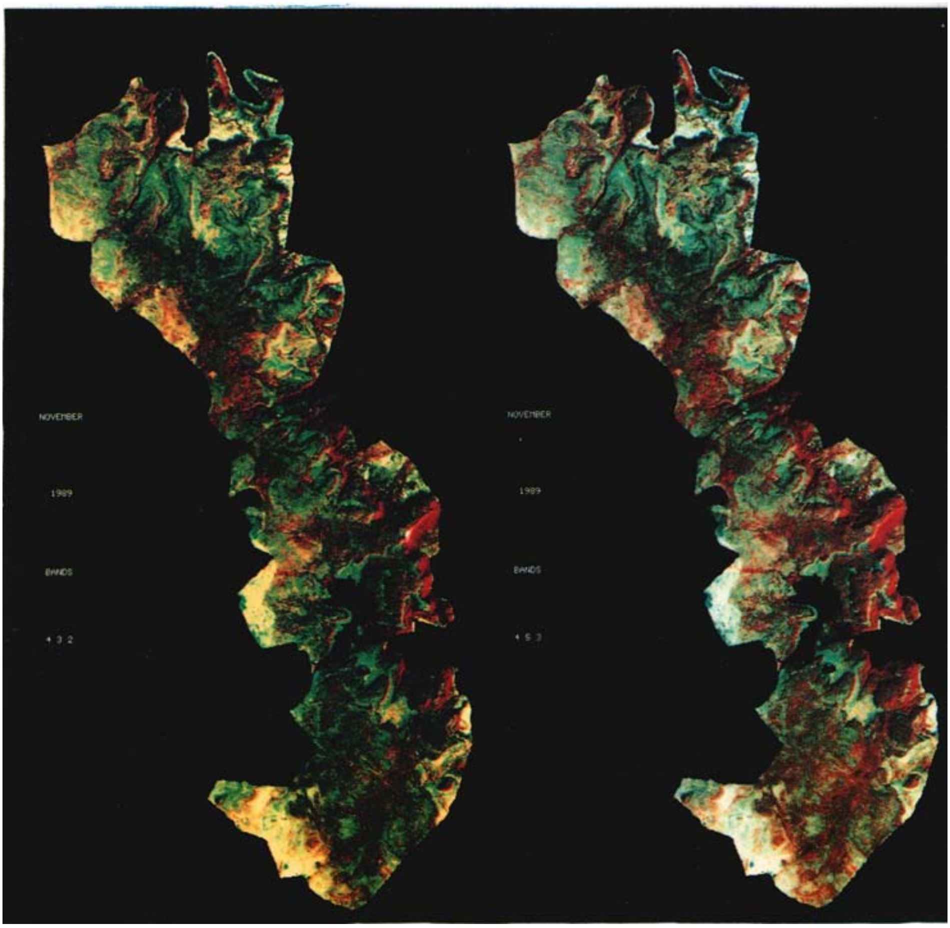

Figure 2. Landsat TM false colour composite (Nov. 1989).

4.2 *Community structure*

TWINSPAN (Hill 1979), a multivariate community classification technique, was used to determine natural tree species associations in forest. Two way table was interpreted to decide natural associations and their species composition. The clusters of sampling with similar species composition were formed in a hierarchical manner. The level of difference between one cluster and another was indicated by eigen values—an index of variance. Each cluster of stands indicates a different micro-topographical and edaphic condition, which thus support characteristics plant species or indicator species. The critical interpretation of indicator, preferential and non-preferential species, obtained through TWINSPAN analysis, was done to identify different species associations. In present study, 18 sample plots (0·1 ha each) were satisfactorily clustered into 6 node, further indicated as I-VI, and called communities. The idea was to cross check validity of subjective approach of community classification using remote sensing data. The results of TWINSPAN are presented

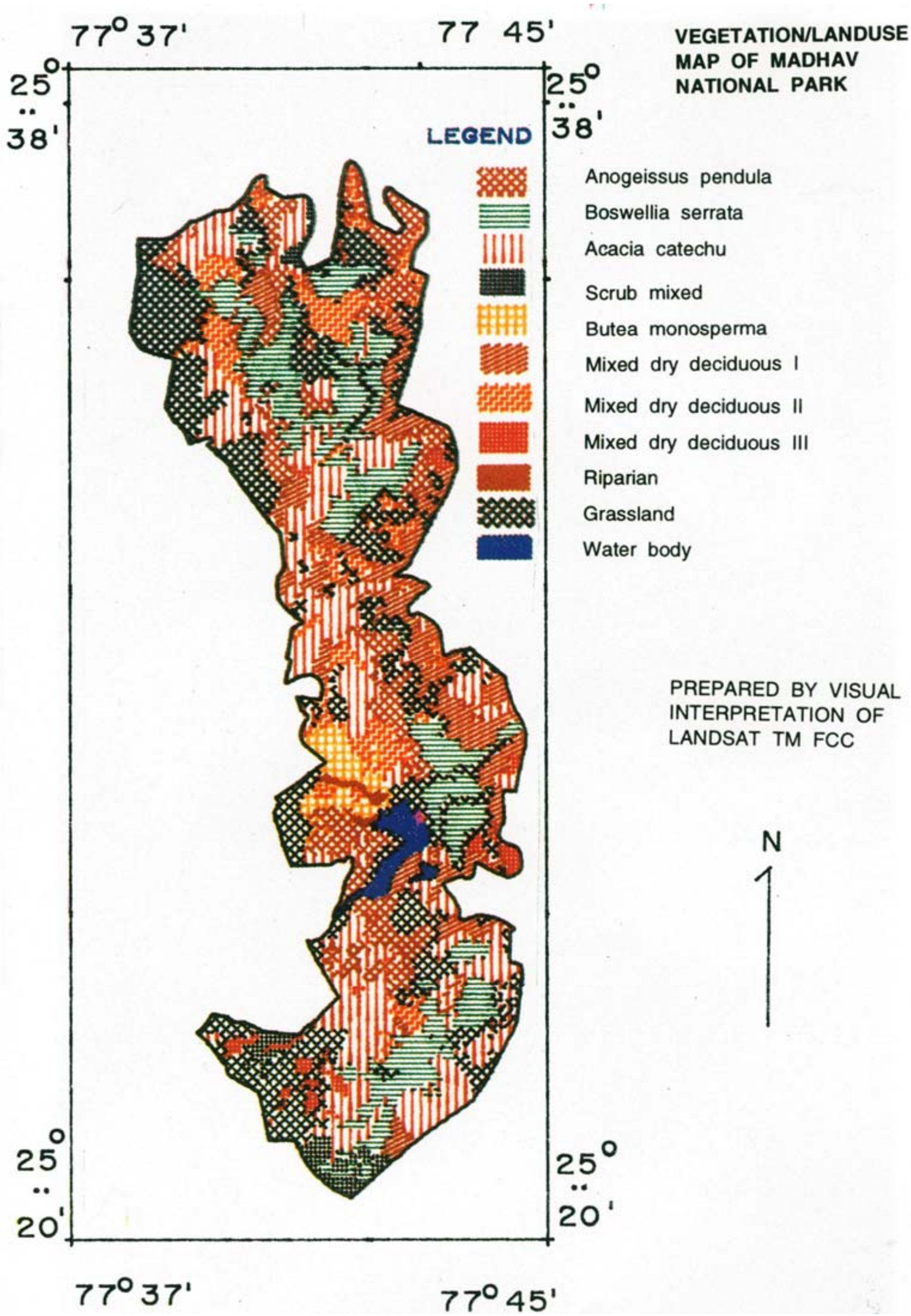

Figure 3. Vegetation map of Madhav National Park (prepared by visual interpretation of Landsat TM FCC).

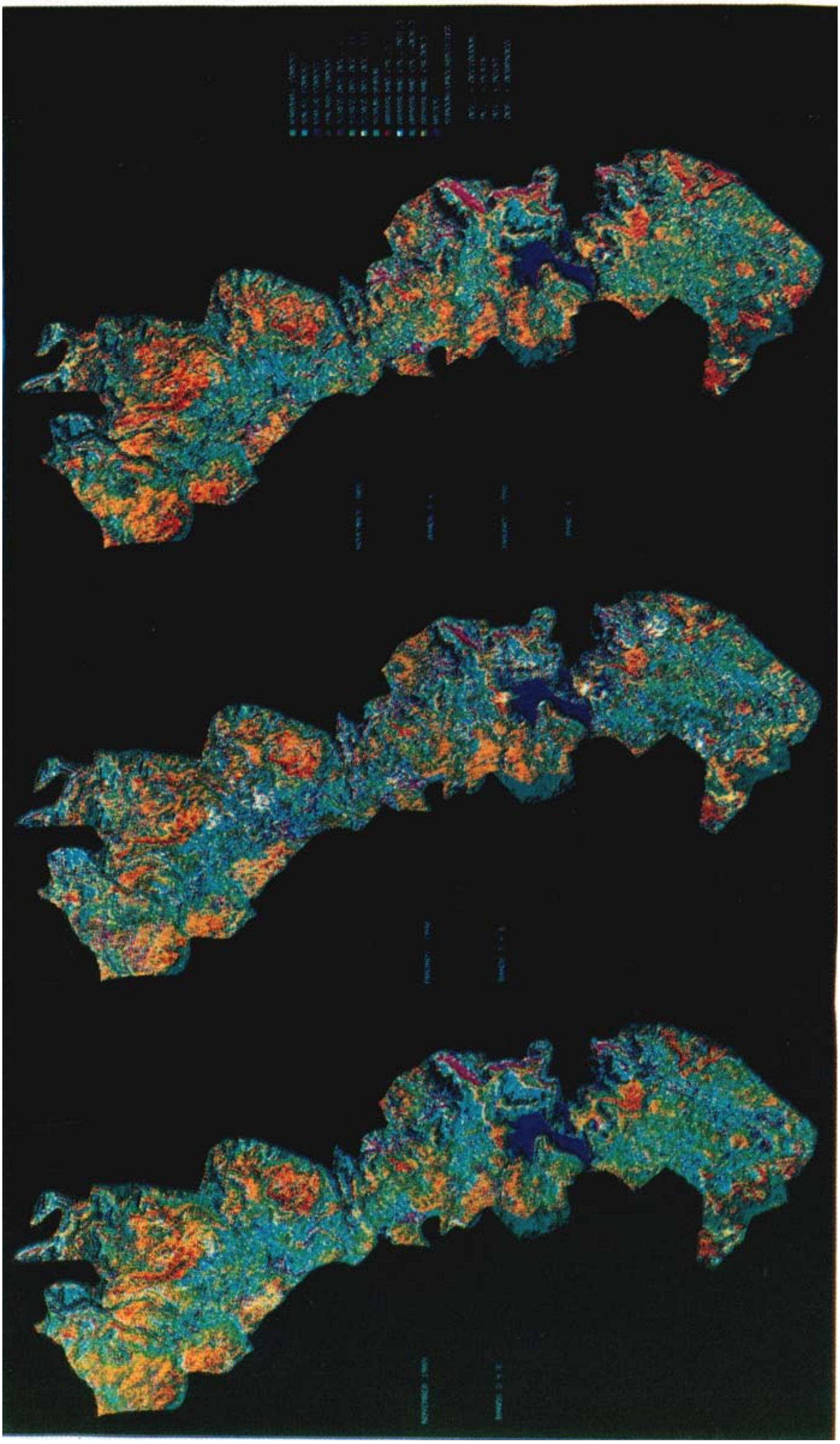

Figure 4. Supervised classification of Landsat TM digital data. I, November 1989; II, January 1990; **III**, Temporal data.

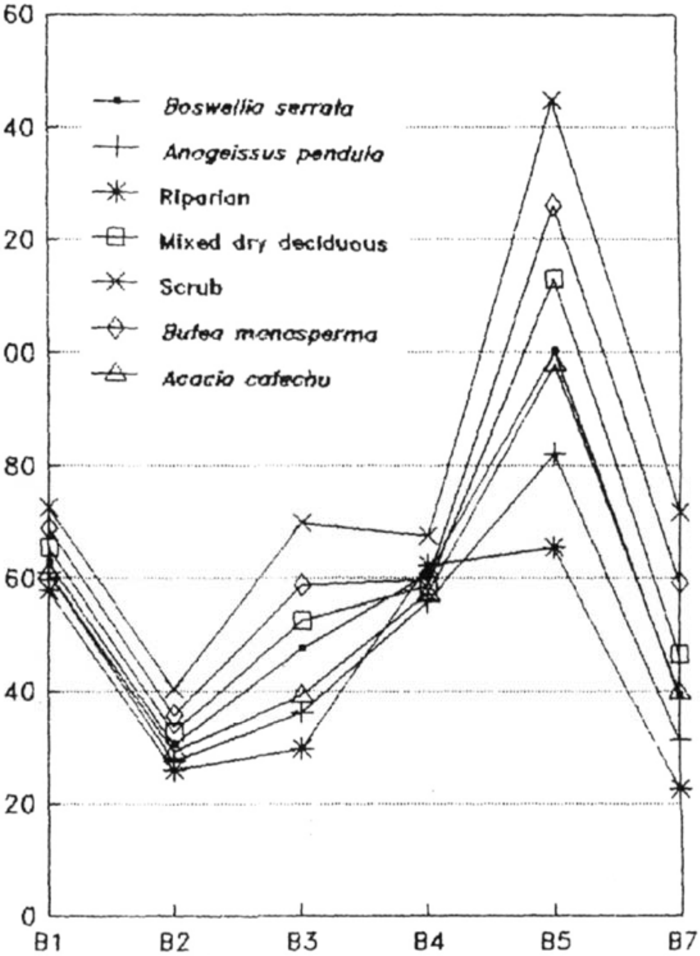

Figure 5. Spectral signature of vegetation communities in November, 1989.

in the hierarchical diagram (figure 6). The associations given by TWINSPAN in each nodum were compared with vegetation types discriminated on remote sensing data. The results showed complete agreement in case of *B. monosperma* and riparian forest. The comparison show fair match in case of A. *pendula* and *B. serrata* forest. Whereas *A. catechu* and mixed dry deciduous forests showed separation at low eigen value. Table 2 presents the composition of these communities in terms of the most important species. Table 3 presents diversity indices of these communities.

Analysis of table 3 based on Shannon index (*H'*), Equitability (*Ep*), and species richness (*d*) show that *A. pendula* forest is most homogeneous stand found to occur on slopes of cooler aspect. Dry mixed deciduous forest I is the most heterogeneous forest type. These forests are distributed at lower elevation and along 'nallah'. It was observed that the index values of A. *pendula* and dry mixed deciduous forest I differ significantly from that of other forest types. Vegetation types sorted in ascending order based on diversity indices are given as: A. *pendula* forest—

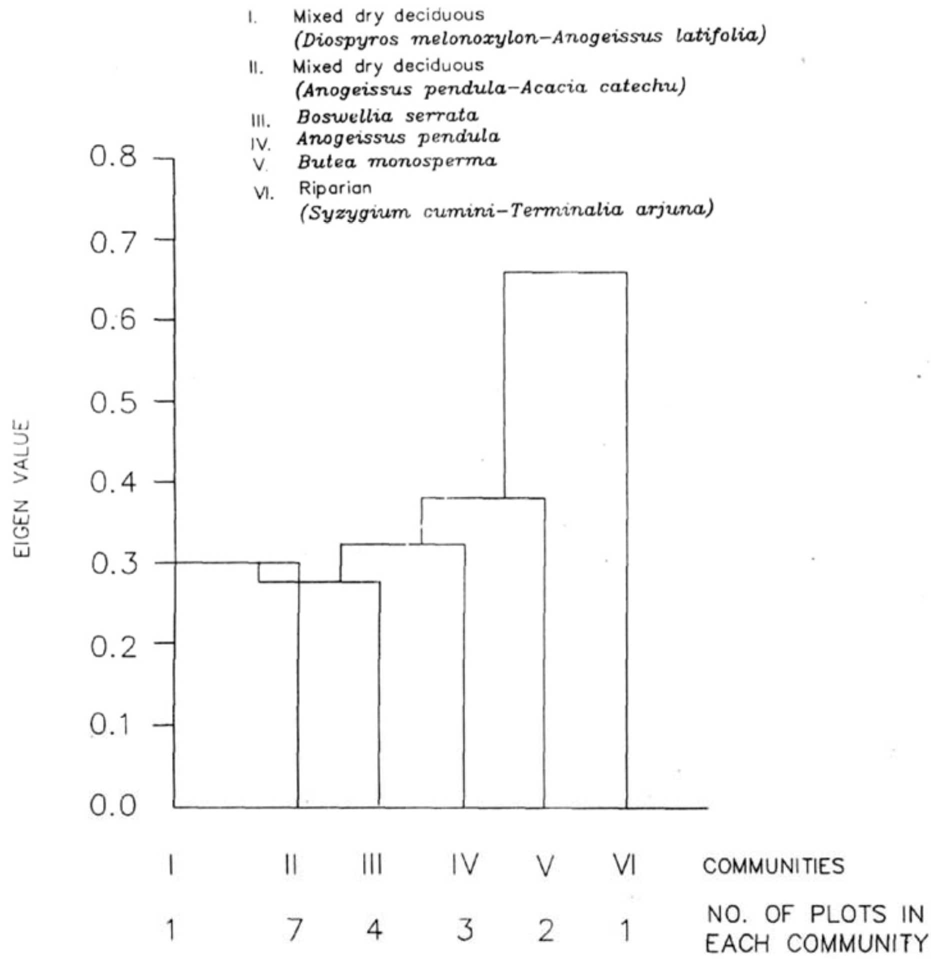

Figure 6. Community classification using TWINSPAN.

scrub—riparian forest—*B. monosperma.* forest—dry mixed deciduous forest II— *B. serrata* forest—*A. catechu* forest—dry deciduous mixed forest III and dry mixed deciduous forest I.

The results of visual and digital interpretation indicate clearly the possibility of delineation of vegetation communities. Such mapping provides most homogeneous mapping units based on species composition and other structural characteristics of vegetation. The vegetation map derived from visual interpretation of satellite remote sensing data provides basis for distribution of sample points and to understand vegetation dynamics at spatial level. The results obtained from digital interpretation of multispectral Landsat TM data provides vegetation classification with acceptable level of accuracy. The improvement in classification accuracy in case of temporal data can be correlated to phenological stages of dry deciduous forest. The bands taken across season cover phenological variations of forest and increase spectral

Table 2. Importance value index for the main plant species in 9 forest communities of Madhav National Park. Only species with an IVI 10 (max IVI = 200) in any one community are included.

Species	I	II	III	IV	V	VI	VII	VIII	IX
Anogeissus pendula	192	43	25	—	36	78	13	—	—
Boswellia serrata	—	69	—	—	—	—	—	—	—
Acacia catechu	—	16	65	—	21	46	48	—	27
Butea monosperma	0·5	—	—	78	2	—	—	—	85
Diospyros melanoxylon	5	17	4	30	35	25	23	—	—
Ziziphus xylopyra	—	41	18	2	26	24	8	—	—
Ziziphus oenoplia	—	0·6	0·6	47	13	1	9·77	—	—
Anogeissus latifolia	—	36	52	—	10	5	45	—	—
Syzygium cumini	—	—	—	—	—	—	—	99	—
Terminalia arjuna	—	—	—	—	—	—	—	43	—
Carissa opaca	2	—	—	1	—	—	—	14	—
Ziziphus mauratiana	—	—	0·3	—	1	—	—	—	40
Sida acuta	—	3	9	0·7	10	2	6	—	30
Lantana camara	—	—	—	—	—	—	—	—	17

I, *Anogeissus pendula*; II, *Boswellia serrata*; III, *Acacia catechu*; IV, *Butea monosperma*; V, Dry mixed deciduous I; VI, Dry mixed deciduous II; VII, Dry mixed deciduous III; VIII, Riparian; IX, Scrub.

Table 3. Diversity indices for vegetation types.

Vegetation type	*H′*	*Ep*	*d*	*Ds*
Anogeissus pendula	0·2029	0·2903	1·1652	0·9235
Boswellia serrata	1·8662	1·5498	5·8093	0·2086
Acacia catechu	1·9097	1·586	5·7966	0·2052
Butea monosperma	1·5079	1·5079	4·0934	0·2631
Dry mixed deciduous I	2·6883	1·6561	4·1549	0·1032
Dry mixed deciduous II	1·7398	1·5618	5·0892	0·2405
Dry mixed deciduous III	2·3256	1·7183	7·3266	0·1382
Riparian	1·4812	1·5522	3·6571	0·3153
Scrub	1·4542	2·0804	2·3544	0·2704

H′, Shannon-Wiener index; *Ep,* Pielou's Equatability; *d,* Species richness, *Ds,* Simpson's index of dominance.

separability between vegetation types. Very few studies have been done based on this approach. Roy *et al* (1993) have used remote sensing data for vegetation mapping, initial stratification, distribution of sample plots in Bakultala range of Middle Andaman Forest Division. The study highlights the community structure of each vegetation unit. The present study evaluates the applicability of the approach in dry deciduous forest. It is observed that vegetation type map and its community analysis results have complete agreement in the present study.

5. Conclusions

The qualitative characters of vegetation were mapped using Landsat TM data, which was prerequisite for the quantitative study of the community structure. The results describe the species composition and diversity levels in the strata (vegetation types) derived from Landsat TM data. It was observed that each vegetation type possesses peculiar community structure with respect to species composition and diversity. The communities discriminated using remote sensing data and TWINSPAN are comparable. However, phenological differentiation and site factors (physiography) allowed further classification of dry deciduous forest when remote sensing data was used. It is concluded that structural variations in plant communities modulates spectral signatures and forms basis to describe community structure subjectively. The community could be analysed quantitatively by laying down sample points at appropriate places. The approach helps in obtaining maximum information about community with the minimum effort and least time. The approach also allow to present all these aspects of community at spatial level.

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