SUSTAINABLE DEVELOPMANT OF FOREST RESOURSE THROUGH RS & GIS TECHNIQUES- A CASE STUDY IN R V NAGAR RANGE, VISAKHAPATNAM DISTRICT, ANDHRA PRADESH

Sudhakar S[a]*, Reddy Ch. S[a], Sudha K[a], Shilpa Babar[a], Swapna Potteti[b]

[a] Forestry and Ecology Division, National Remote Sensing Agency, Balanagar, Hyderabad- 500 037 India
[b] Department of Environmental Science, Osmania University, Hyderabad, India
*sudhakar_s@nrsa.gov.in

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ABSTRACT:

Forest ecosystem is a complex system having interactions with biotic and abiotic components. It includes not only plant and animal communities but also microorganisms, climate, sunlight, water and soil. Any slight difference in soil, slope, climate etc. makes for subtle difference in each habitat within an ecosystem. Therefore each parcel of landscape has characteristic soil, exposure, moisture and temperature/rainfall regimes, which meet the requirement of a given assemblage of plants. Some of such unique parcels of vegetation are being affected due to constant anthropogenic influences leading to severe fragmentation hence there is an urgent need to identify the priority areas for conservation and restoration of affected areas including rehabilitation of certain RET species associations in ecologically similar and environmentally suitable locations. Keeping in view of this, an attempt has been made to prioritize areas of conservation, locate areas to be restored, identify species composition to be rehabilitated in R.V.Nagar Range, Gudem-Saparla hilly tract covering an area of 312 sq.km in Visakhapatnam district, Andhra Pradesh (India), through satellite RS and GIS techniques. Satellite data of Landsat MSS 1973 and IRS-1D LISS III of 2003 were independently classified after geometric and radiometric normalization corrections and assessed the forest cover changes in 1 sq.km grid and generated as Sensitive Index (SI) map. Further the road and settlement buffer of 1000m was generated to represent Threat Index (TI) map. The phytosociological data collected at different elevation, slope and aspects in the study area were assessed based on species richness and Shannon & Weiner index for stand density, basal area per hectare and biodiversity index. The areas of higher values of these three parameters, considered to be the best suitable conditions for prioritizing the conservation area representing as Conservation Measure Index (CMI), were delineated with the aid of arc GIS tools. Besides, the distribution of RET species over the study areas aided in finding out the areas to be restored and type of species to be rehabilitated. By integrating SI, TI and RET Index with CMI, the study area was prioritized into Conservation Zones, also identified areas to be restored and finally the type of species to be rehabilitated in similar environmental and ecological areas. The study highlighted the usefulness of satellite remote sensing and GIS for decision making and implementation of conservation of high biodiversity areas embedded with RET species and also, restoration and rehabilitation programmes of such critical areas in forests of Andhra Pradesh, India thereby to achieve sustainable development of forest resources.

1. INTRODUCTION

India is endowed with a great variety of biological communities and is ranked sixth among twelve mega diversity countries in the world. As many as 45,000 species of wild plants, over 77,000 species of wild animals have so far been recorded, together comprising about 6.5% of the world's known wildlife (Singh *et. al.*, 2000). But India's green mantle along with its heritage of biodiversity is in grave trouble today due to population explosion, encroachment to forest land, shifting cultivation practices and degradation caused by overgrazing, illicit felling, lopping, for fuel and folder, removal of forest floor litter, forest fire, etc. In recent times, the planners and decision makers are facing several challenges associated with resources consumption by expanding population in the face of impending global changes. Some of the challenges are (1) Maintenance of sustained utilization and prevention of ecological degradation. (2) Altering landscapes to increase the production of desired or needed products. (3) Restoring degraded landscape to enhance their ecological or economic productivity and diversity.

Human encroachment into wilderness areas such as forests and wetlands in recent times has resulted in the degradation or destruction of these habitats. Loss of habitat and habitat fragmentation are areas of major concern in species conservation. Road construction, deforestation, draining of swamp lands etc. resulted in large areas of habitat being broken up into a series of smaller areas or fragmented. Fragmentation is mainly a part of human activities that alter size, shape, and spatial arrangement of habitat types on landscape and can result in changes to: 1. Decrease in the patch mean size of "natural" habitat 2. Smaller patch shape 3. Patch adjacency increment 4. Decrease in patch interior to edge ratio. However, the recent concern is on biodiversity conservation and identification of biological rich areas. (Roy *et. al* 1997, 2000)

Keeping these in view, there is an urgent need to create reliable database in terms of qualitative and quantitative inputs for restoration, rehabilitation and conservation strategies in the Ecologically Sensitive Areas (ESA) in the country. These ESA's are those specific areas having natural, cultural and geographical value or fragile/susceptible to factors of deterioration in the ecological balance. Most of the potential ESA's in the country are being degraded in recent times due to various impacts of developmental activities including biotic pressure. Due to its rich biological heritage, India has a special responsibility to conserve and use these resources in a sustainable manner. In the light of the above, about thirteen major parameters have been identified to recognize an area as Ecologically Sensitive Area. The thirteen *primary indicators* are grouped in 3 major categories such as (1) *species based* indicators (endemic, rarity, endangered, centres of evolution of domesticated species) related to the characteristics of species which are or may become threatened with extinction, (2) *Ecosystem based* (wildlife corridors, specialized ecosystems, special breeding sites, areas with intrinsically low resilience, sacred groves, frontier forest) are being essential to the survival of the first category, (3) *Geomorphologic features based* (uninhabited islands in the sea, steep slopes and origins of rivers) which are known to have substantial effect on ecosystems at large(Anonymous, 2000)

Identification of ESA all over the country is not an easy task though efforts are on to demarcate such areas in different biogeographical zones of India with certain prioritization criteria. However, a convenient starting point would be to consider such areas which are already known to be either ecologically important or under ecological stress such as the areas of Protected Area Network (PAN), corridors, National parks and wildlife sanctuaries, Tiger-Elephant Reserves, Protected and Reserve Forests, Biosphere Reserves, National Marine Parks, Coastal Regulation Zones, Mangrove ecosystem and Hill Stations.

According to latest estimates of Forest Survey of India (FSI), Dehra Dun, 2001 based on Oct. - Dec. 2000 data of IRS – 1C/1D LISS III satellite data, the area covered by forest cover in India is about 6,75,538 sq.km which is 20.55 percent of the geographical area of the country. It was also reported that the dense forest (>.4 canopy cover) is covered by 12.68%, (4,16,809 sq.km), open forest (.1-.4 canopy cover) occupy about 7.87% (2,58,729 sq.km). The per capita of forest cover in India is 0.08 ha which is quite less than the world average of 0.64 ha. However the *in situ* conservation involves protection of habitats of species through *Protected Area Network* in the country and it has grown steadily from 10 National Parks and 127 wildlife sanctuaries covering an area of 25,000 sq.km in 1970 to 89 National Parks and 489 Wildlife Sanctuaries in 2002, covering an area of 1,54,572 sq.km. The Wildlife Institute of India, Dehra Dun has also identified several gaps in the protected area network and recommended about 163 National Parks and 707 wildlife sanctuaries covering 5.74 percent of the total land in India (Rodgers *et. al.*, 2002).

It is noted that the natural virginity of most of the areas selected for protected areas in India has already been adversely attended by human activities even in the core area. On scrutiny, large patches of natural habitat within each protected area are found degraded for one reason or the other. Since the environmental process in totality are linked to each other very intricately and man being the biggest destroyer or alternator of the Earth's unique ecosystem, it becomes necessary to review our approach towards generating in puts for resource management plans of all the ecologically sensitive areas or Hot Spots in the country.

1.1 Objectives

It is now realized that all the concerned departments are keenly interested to work towards achieving sustainability through proper scientific planning in an obvious effort to control the consumption of natural resources to protect ecologically sensitive areas from exploitation and thereby to reduce the adverse impacts of social changes to the environment. The objectives of environmental considerations into spatial plans in the ecologically sensitive areas are:

1. To generate resource maps of the ecologically sensitive areas/hotspots in different ecosystems with a view to update database and provide to the concerned users as complimentary data and to monitor existing natural resources for assessing loss of natural resources over a period of time.

2. To idendified areas of Conservation Zones of natural forest resources

3. To prioritize conservation zones and to prepare Resource management plans to Restore & Rehabilitate rare, endangered/endemic & threatened species in such Ecologically Sensitive Areas/ HOTSPOTS

1.2 Study Areas

In view of the unique vegetation composition with several semi evergreen species in the tracts of Gudem valley of Visakhapatnam /Vizag district particularly of Lankapakala - Sapparlu area, it is proposed to study R.V Nagar Range (shown in Figure 1.), as one of the ESA/HOTSPOT. It is situated between 17^{o}48” to 18^{o} 00” N and 82^{o} 02” to 82^{o} 16” E and covers an area of 312 sq.km with high species diversity and wealth of medicinal plants.

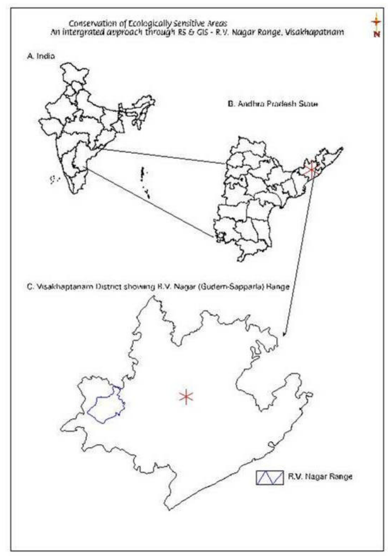


Figure 1. Location Map

2. MATERIALS AND METHODS

2.1 Data Used

The satellite data pertaining to IRS 1A LISS II of Dec 1988; IRS 1D LISS III of Dec 2002 and IRS 1D PAN of Dec 2002 were used for the study. Other working plan maps from State Forest Dept, Andhra Pradesh and collateral data including SOI toposheets are referred during the course of the study.

2.2 Methodology

Considering the importance of vegetation type map as prime input for landscape analysis for biodiversity characterization and its ecosystem status, the satellite remote sensing techniques were applied to segregate different vegetation types in the study area. In the present study more emphasis was given for tree species and their communities to understand the biodiversity characterization due to various topographical/environmental variables in the area under study.

Necessary data as mentioned in data source were procured from NRSA data center, NRSA and geometrically and radio metrically corrected with respective to SOI toposheets using second order polynomial transformation model. Average root mean square error of less than a pixel was maintained while preparing transformation model. In order to obtain radiometrically comparable apparent spectral radiance data suitable for further processing, the integer digital values of each band of all the images were converted into real numbers using spectral calibration data with the software modeler available with ERDAS. The data required are 'gain' and 'bias' of the sensor in use. However, the information of different sensors used could not be collected due to some technical problems, hence Dark Object Substraction (DOS) developed by Chavez *et al.* (1977) was used due to easy implementation. Another advantage point in using this technique is that it does not require any ground or above ground measurements of atmospheric constituents and is also susceptible to sensor noise (Green *et al.* 2000). After the normalization the data was subjected to various enhancements, classification techniques. After the scene was subjected to hybrid classification techniques unsupervised / supervised (MXL). Five levels of forest crown density classes at 20% interval through standard visual interpretation techniques, IRS 1D PAN satellite data was used to delineate.

The approach towards identifying Conservation Priority Zones (CPZ) depends on two input maps viz. (I) Conservation Measure Index(CMI) and Rare, Endangered/Endemic, Threatened Index (RET Index) (II) Sensitive Index (SI) and Threat Index (TI). However the following maps were generated for analysis.

Map-1 The CMI map is generated by integrating data thus prepared from the analysis of phytosociological data on stands, basal area per hectare and biodiversity index on elevation, aspect, slope (topographical) levels, canopy density (biophysical), drainage density (environmental) levels as these parameters are considered to be the drivers for the good conditions for the growth and development leading to form good ecological niches.

The weightages are as very high – 10-8, high; high – 6; medium – 4 and low – 2 for each of the parameter under categories as: elevation & aspect on I drainage density & canopy density on II and finally with slope on these parameters have considerable correlation in terms of good condition for better growth and development

Initially elevation and aspects are correlated as they are closely related and the common area weightages are extracted and similarly for drainage density and canopy density. And they are finally staged with slope to extract the common weighted areas as 8- very high, 6- high, 4 moderate, 2 low categories to represent CMI layer.

Map-2 RET Index map was created by generating 1 km buffer around the location of the endemic plant collected/recorded from the study area and weightages as 8- very high, 6- high, 4 moderate, 2 low were given from location point to away form it at interval of 200m.

Map-3 The Sensitive Index was basically derived from the forest cover type change and also fragmentation levels during the periods 1973 and 2002 as per their negative trends through analysis of 1 X 1 sq.km grids. The maps having these changes are indicative of sensitive to degradation hence they are considered as critical areas.

Map-4 The Threat Index map was generated from road and settlement buffer of 1km is with 200m interval with weightages from 8 near to 2 far off. with an assumption that the threat due to anthropogenic activity is high near to the road/settlement location and becomes less as we go away from the road/settlement locations.

IN PUT- I was prepared by staging Map-1 CMI and Map-2 RET index maps and scaled to 8- very high, 6- high, 4 moderate, 2 low categories.

IN PUT- II was generated by staging Map-3 Sensitivity Index Map and Map-4 Threat Index Map to depict both sensitive and threat areas in the study area and they further scaled to 8- very high, 6- high, 4 moderate, 2 low levels.

Finally the In Put- I and In Put – II maps were subjected to transitional matrix analysis and clubbed the areas having high In Put-I and low In Put- II as Priority –I (High) and followed by the Transitional areas as Priority –II (Medium) and finally the areas having low In Put-I and high In put-II as Priority – III (Low).

The three priority zones derived from the integration of input I & II maps derived from Remote Sensing satellite data coupled with field data was to derive **Conservation Priority Zone Map (CPZM)** for the entire study area. It is generally considered to identify and delineate large continuous patch within the CPZM for management. Keeping this in view very high-resolution satellite data from IRS-P6 LISS IV was used for **Selection of the Patches** having more than 10,000 hectare contiguous patches with less effect by fire, having in high rainfall zones represently different vegetation types. These areas are to be demarcated and identified as **Very Potential Sites for Conservation Areas (VPSCA)** and recommended for further intensive ecological studies and site level Habitat zonation.

In the present study, emphasis had also given to identify those RET species to be restored and rehabilitated. During the study critically threatened species were identified as RET categories and their locations were overlaid on Threat index map followed by Sensitive Index map to identify those species which were critically threatened to their existence. Initially the locations of these plots were overlaid on elevation, slope aspect, drainage density layers and derived its habitat conditions. Considering that they had ideal conditions for their survival and well being, GIS analysis was carried out species wise to segregate similar areas in the study area. These areas were considered suitable to rehabilitate those critically endangered species. Finally rainfall, contour, canopy density, and fire prone areas Further the areas that were degraded fragmented could be delineated for restoration by introducing similar species by afforestation methods were intersected to narrow down the potential sites for rehabilitation. The study also facilitated to explore further collection of these species in these areas. The model would work as **Species Exploration** as well as identification of suitable areas for restoration & rehabilitation of critically endangered species.

2.2.1 Field data collection and analysis: Phytosociological studies were conducted (during Sept-Nov, 2002) using quadrate method (size of the quadrate 20 x 20m for trees; 4 x 4m for shrubs and 1 x 1m for herbs) (Misra 1968). In each quadrant, girth at breast height at 1.37 m above ground level of each tree and number of individuals of each species measured and recorded. The saplings were recorded. Quantitative analysis of dominance and their relative values of frequency, density and basal area were calculated and summed to estimate Importance Value Index. The major communities were identified on the basis of their IVI values following . (Misra, 1968)

2.2.2 Vegetation analysis along gradient: Sample plots were collected along the gradient between 600m and 1200m (at 200m interval) above mean sea level in the study area to cover the entire variability of the existing vegetation. The altitude, slope and aspect maps were generated in digital format with the aid of Digital Elevation Model derived (following ERDAS software procedures) at 100m contour interval from SOI map sheets. The vegetation type map was prepared based on the phenological and spectral signatures coupled with intensive ground truth studies. The general vegetation structure and composition along the three topographical parameters namely altitude, slope and aspect were studied and a comparative assessment was made using biodiversity index parameters, stands per hectare and basal area per hectare and to understand the impact of topo/ environmental influence on growth and development of the species under study.

2.2.3 Vegetation type mapping: The vegetation type map was generated using standard digital classification techniques. The major vegetation types are Tropical semi evergreen, moist deciduous, dry deciduous, savannah and thorny scrub forest areas associated with non-forest categories of agricultural areas and plantations. Common tree species include *Terminalia chebula Buchanania lanzan, Diospyros melanoxylon, Semecarpus anacardium, Mitragyna parvifolia,* and *Wrightia tinctoria. They are associated with tall and short grasses of various species of Temeda, Imperata, Cymbopogon etc.*

A highly humid environment in Gudem - Sapparlu ranges with unique habitats having very interesting tropical semievergreen and moist deciduous species and maintaining remnants of the earlier ecological niches, need protection and conservation immediately. Interesting species like *Angiopteris erecta, Wendlandia gamblei, Smilax prolifera* and tree fern *Cyathea gigantia* grow with very restricted distribution. Due to the favorable humid surroundings, epiphytic orchids like *Aerides maculosum, Dendrobium macrostachyum, Pholidota pallida, Lusia teretifolia* species and several other orchids are found to be common. All these represent endangered species under wildlife protection act and deserve immediate attention and protection.

2.3. Analysis

2.3.1 Vegetation type and change assessment: Champion and Seth (1968) have described about 16 major vegetation types in India but with the changing climate and anthropogenic impact on environment particularly on forest, changed the species composition to a major extent.

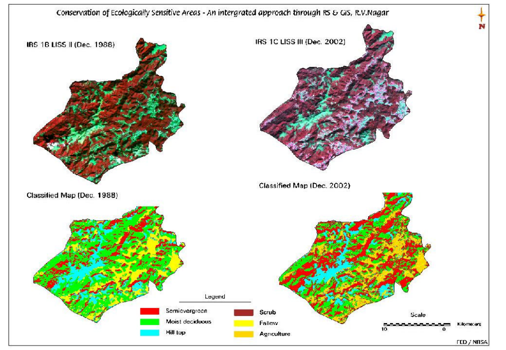


Figure 2. Forest type change detection between 1988 and 2002 periods

The satellite remote sensing technology, with the synoptic view of the earth features in temporal mode helped immensely to delineate forest types and Geographical Information System aided to carry out criteria based spatial modeling. The changes in vegetation cover typesduring 1988 and 2002 were given in Figure 2. and land cover statistics are shown in Table 1.

2.3.2 Phytosociological analysis: Phytosociological analysis is given in Table-2. & Table 8. The field data collected in these two sites was analyzed for (1) No of species, (2) No of individuals/ Stand density per hectare, (3) Basal area per hectare (4) Biodiversity index through Shannon and Weiner Index and (5) Simpson index in each of the vegetation type under study.

Sl. No.	Class	1988 (sq.km)	2002 (sq.km)
1	Semievergreen	55.19	69.68
2	Sec.Semievergreen	10.18	17.76
3	Moist deciduous	54.99	32.88
4	Sec.Moist decidous	86.82	72.93
5	Tree Savannah	48.39	31.29
6	Scrub lands	2.24	3.97
7	Agricultural fallow	53.83	82.41
8	Crop lands	0.37	1.08
	TOTAL	312.00	312.00

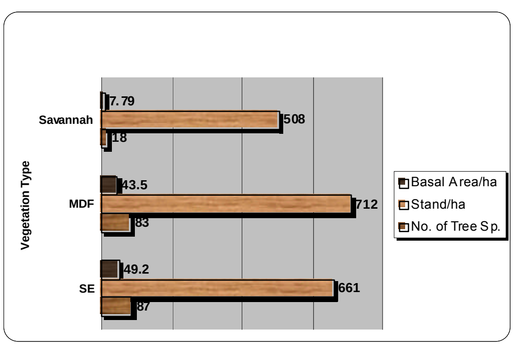
Table-1. Vegetation and Land Cover Statistics

Vegetation analysis clearly brought out the dominance of Semievergreen forest in the hill ranges between 900m and 1100m altitude. However the over all vegetation compositions haven shown a trend towards a transition from tropical semievergreen – moist – dry deciduous finally as thorny scurb at lower reaches mainly dominated by *Anogeissus latifolia, Tectona grandis, Terminalia alata, Dalbergia latifolia, Phyllanthus emblica.* The vegetation gradually changes from dry deciduous to moist deciduous in the altitudinal ranges from 600 m to 900 m and afterwards the vegetation becomes distinct semi everygreen forests and at higher altitudes it becomes bald hill tops with woodland savannha forests. The predominant species in this zone are *mainly Peterocarpus marsupium, Syzygium cumini, Xylia xylocarpa* under moist deciduous and in case of semi evergreen forests Schleichera oleosa, Mangifera indica, Michelia champaca, Pterocarpus marsupium are predominantly seen. The savannah forest generally at high hill plateau or bald hill tops are associated with species of dwarf tree species Terminalia chebula, T. alata, Holarrhena antidysenterica, Phyllanthus emblica associated with grasslands.

Parameters	**Semievergreen**	**Moist Deciduous**	**Savannah**
No. of tree species	87	83	18
Stand / Ha.	661	712	508
Basal area / Ha.	49.2	43.5	7.79
Shannon-weiner index	5.27	5.50	3.71
Simpson index	0.96	0.95	0.91
Dominant species			
1	Schleichera oleosa	Pterocarpus marsupium	Terminalia chebula
2	Mangifera indica	Grewia tilifolia	Terminalia alata
3	Michelia champaca	Syzygium cumini	Holarrhena antidysenterica
4	Pterocarpus marsupium	Xylia xylocarpa	Phyllanthus emblica
5	Bauhinia vahlii	Schleichera oleosa	Cassine glauca

Table-2. Phytosociological analysis

Altogether 45 (semievergreen-26, moist deciduous-16, savannah-3 plots of 20 X 20 m size) sample plots of 0.04 hectare size were laid in each of the vegetation types. Care was taken to cover different elevation, slope and aspects to study their influence on the stems/basal area per hectare and diversity. About 188 tree individuals have been collected from 45 randomly distributed plots. The stems was recovered per hectare 712 in case of moist deciduous forest but high



Graph 1. No. of Tree Sp., Stand/ha and Basal Area/ha in differenet vegetation types

basal area of 49.2 in semievergreen forests was recorded high (Fig. 2). The Biodiversity Index (BF) derived from Shannon and Weiner index which was recorded high in Tropical moist deciduous forests with 5.50 followed by semi evergreen with 5.27, savannah forests with 3.71. The high BI value of 5.5 in case of moist deciduous forest was due to the association of various species in and along the riverine forests shown in Graph 1. and Table 2.

Sl. No.	**Canopy density class**	**Area in sq. km**
1	<20 %	43.67
2	20-40 %	77.08
3	40-60 %	80.04
4	above 60%	58.3
5	Non forest	52.91
	Total	**312**

Table 3. Area statistics of canopy density

The canopy density was delineated into four classes as <20%, 20-.40%, 40-60%, >60% and nonforest categories using IRS-1D PAN data . The area statistics are given in Table-3

The analysis of forest canopy density with respective to stems, basal area per hectare and Biodiversity index shows a normal trend in having high Biodiversity Index in high density forests of more than 60% canopy cover followed by 40-60% range. In case of basal area, stands per hectare were recorded high in medium density class of 20-40% category shown in Table 4.

Parameters	Canopy Density			
	<20%	20-40%	40-60%	>60%
No. of tree species	18	36	45	96
Stand / Ha.	425	625	593	719
Basal area / Ha.	8.54	39	48.3	47.7
Shannon-Weiner index	3.81	4.74	4.9	5.5

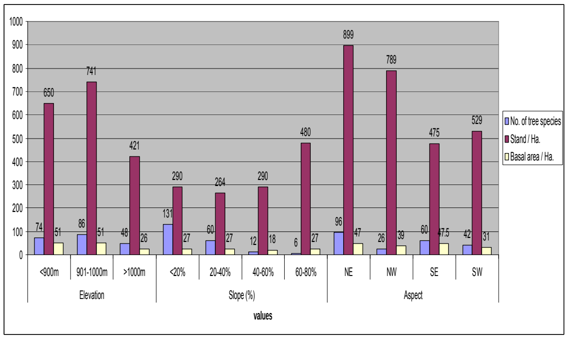
Table 4. Analysis of canopy density

2.3.3 Topographical and Environmental input analysis: The vegetation along the gradient in terms of its structure and composition was studied with respect to altitude, slope, aspect, rainfall regimes, drainage density to identify the zones of high biodiversity index and stems/basal area per hectare (Graph 2). The topographic, environmentally and ecologically sound factors are considered as well being of the forest growth and development as an overall indicator of high species richness and biodiversity. Such ecologically unique areas are considered as priority zones for conservation.

Parameters	Elevation			Slope (%)				Aspect			
	<900m	901-1000m	>1000m	<20%	20-40%	40-60%	60-80%	NE	NW	SE	SW
No. of tree species	74	86	48	131	60	12	6	96	26	60	42
Total no. of individuals	-	-	-	1945	475	87	96	-	-	-	-
Stand / Ha.	650	741	421	290	264	290	480	899	789	475	529
Basal area / Ha.	51	51	26	27	27	18	27	47	39	47.5	31
Shannon-weiner index	5.3	5.7	5	5.3	4.7	2.6	2.2	5.52	5.27	5.2	4.91
Simpson index	0.94	0.96	0.92	0.46	0.54	0.53	0.54	-	-	-	-

Table 5. Analysis of some Ecological parameters along elevation, slope and aspect gradients

2.3.3.1 Altitudinal based analysis: The analysis of some Ecological parameters stand and basal area/ha., BI along the gradient was in three zones as 800 – 900m, 900 – 1000m and 1000 – 1100m level. The stands and basal area per hectare was high in case of elevation between 900 – 1000 m and even the Shannon Weiner Index was also reported high, indicating favourable conditions for species richness shown in Table 5.



Graph 2. Variation in the no. of Tree Sp., Stand/ha and Basal area/ha along elevation, slope and aspect gradients

2.3.3.2 Slope based analysis: The biodiversity index was recorded high in the slope ranging from 40 – 60%, followed by the slope 20 – 40% with marginally less by 0.03% indicating this wide range of 20–60 would be the ideal zone of variability of species distribution. The other observation of having high basal area in the range of above 60 per cent slope areas but number of trees per hectare was reported high in case of 40 – 60% slope categories. (Figure 3)

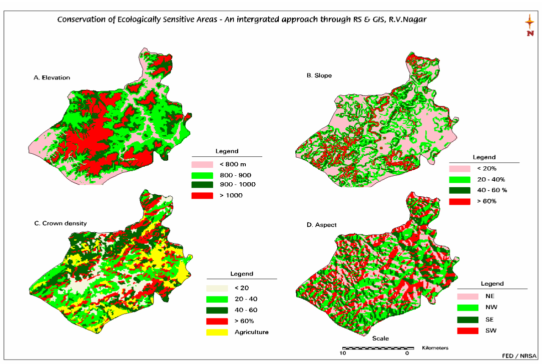


Figure 3. Topographic (Elevation, Slope and Aspect) and Crown Density input maps for analysis

2.3.3.3 Aspect based analysis: The study area was differentiated into four aspects as North East, North West, South East and South West. The parameters namely stand and basal area/ha., BI were analyzed and studied.

The general observation in the study site on Biodiversity Index showed high towards NE aspect but the basal area and stands per hectare were recorded high in case of NW. The variability of distribution of species an indicator given by biodiversity index was found high in NE aspect closely followed by NW. (Figure 3)

2.4 Results & Discussion

2.4.1 Conservation strategy and priority setting: The study area harbors considerable amount of good number of flowering plants reported and it is known to be an important phytogeographical reserve of the country. However the rich diversity is at stake due to various biotic influences. It is finally the manmade threats including destruction of natural habitats for agriculture, urbanization, grazing and over exploitation of gene pools which largely account for the rapid and often irrecoverable transformation of landscapes in the region.

The sustainable use of ecosystem and genetic diversity for the human welfare is necessary and one should strive for balance between conserving the diversity of nature and sustainable use. Generally the conservation priorities use multiple criteria such as species richness, biodiversity index, endemism, abundance, uniqueness and representativeness as well as the physical environment including topographic parameters (altitude, slope, aspect), ecological processes and disturbance regimes.

The spatial distribution of biological diversity is the foremost prerequisite for meaningful conservation planning of natural ecosystems. It serves several purposes such as locating the hotspots of diversity, assigning conservation values for different areas, in formation on the structure and dynamics of the vegetation and eventually formulating strategies for sustainable utilization of the resources. However, the conservation efforts lack clarity about the type of area to be preserved as Hotspot and the list of all that needs to be conserved and how best to conserve them. However, the biological elements such as the specific genes, species *per se* in an ecosystem, a set of taxonomically related species and the spatial and other habitat features such as unique micro and macro habitats, ephemeral zones, sensitive patches of the ecosystems, unique forest types and the whole ecosystem as such are the basic elements that demand conservation attention.

Further the non-timber forests products (NTFP) contribute immensely to the livelihood of forest dwelling communities in terms of household self-sufficiency, food security, income generation, accumulation of savings and most importantly risk minimization. But very little is known about the resource availability and quantity of extraction and its impact on conservation of biodiversity of the forest. The mapping of these resources would offer a perspective of economic value of forest resources. The economic richness map depicting the composition of medicinal plants (Triphala- *Phyllanthus emblica, Terminalis chebula and T.bellerica*) as distinct patches, such maps would help in formulating strategies for optimal and sustainable harvesting of the respective groups of species of high medicinal value. It is noted a positive correlation between the total species and medicinal plant species richness, suggesting that the over all plant diversity could serve as an indicator of medicinal resource value of the area.

2.4.2 Sensitive Index: Generally unprotected natural areas are subjected to land use changes over a period of time which ultimately shown as degradation, fragmentation and patchiness but in recent times such observations are also seen in protected areas due to anthropogenic activity along the fringe areas of the park. Hence the monitoring of land use/land cover of an area through temporal studies would be of immense help in demarcating such areas as sensitive zones. The (1) Forest fragmentation (2) Forest cover changes are two such approaches to identify Sensitive Areas in the study area. (Figure 5)

2.4.3 Fragmentation Model: The amount of forest and its occurrence as adjacent forest pixels within fixed-area "windows" surrounding each forest pixel were measured.

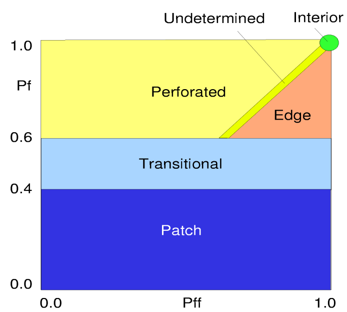


Figure 4. Forest Fragmentation Models

That information was used to classify the window by the type of fragmentation. The result was stored at the location of the center pixel. Thus, a pixel value in the derived map refers to "between-pixel" fragmentation around the corresponding forest location. Let Pf be the proportion of pixels in the window that are forested. Define Pff (strictly) as the proportion of all adjacent (cardinal directions only) pixel pairs that include at least one forest pixel, for which both pixels are forested. Pff (roughly) estimates the conditional probability that, given a pixel of forest, its neighbor is also forest. Fig. 6 Shows the classification model that identifies six fragmentation categories: (1) interior, for which Pf = 1.0; (2) patch, Pf < 0.4; (3) transitional, 0.4 < Pf < 0.6; (4) edge,

Item	1988		2002	
	SE	MDF	SE	MDF
Interior	103.5	1312.2	1754.45	927.8
Patch	380.9	1821.1	1043.3	1815.4
Transitional	1328.1	3361.9	1703.8	2735.8
Edge	875.9	2330.1	1091.9	2028.4
Perforated	2505.3	5308.2	3141.8	3050.3
Undetermined	8.8	33.1	8.1	25.6

Table 6. Fragmentation Analysis from 1988 to 2002

Pf > 0.6 and Pf - Pff > 0; (5) perforated, Pf > 0.6 and Pf – Pff < 0, and (6) undetermined, Pf > 0.6 and Pf = Pff. It is noted when Pff is larger than Pf, the implication is that the forest is clumped; the probability that an immediate neighbor is also forest is greater than the average probability of forest within the window. Conversely, when Pff is smaller than Pf, the implication is that whatever is non-forest is clumped. The difference (Pf – Pff) characterizes a gradient from forest clumping ("edge") to nonforest clumping ("perforated"). When Pff = Pf, the model cannot distinguish forest or nonforest clumping. The case of Pf = 1.0 ("interior") represents a completely forested window for which Pff must be 1.0. (Kurt Riiters model, 2000) (Figure 4 and Table 6)
As per the model, five classes were segregated and analyzed. It was observed that the intact/interior areas were decreased from 1973 to 2002 indicating a disturbance and further fragmentation of contiguous forest areas. At the same time other categories, especially Patches have also been increased from 1973 to 2002 depicting over all degradation of forest cover which needs proper conservation measures to safe guard the existing forest cover. Staging both fragmentation and forest cover change grids of (1X1 sq. km size) generated the Sensitive Index. Accordingly rating was given based on the percentage of changes. (8 high – 2 Low, 6 high – 4 moderate) (Table 9)

2.4.4. Threat Index: The conservation and management of protected areas is generally contingent upon our understanding of the pressures on them from within and outside. These pressures are temporally dynamic and spatially heterogeneous. Especially in the tropical areas, where the daily needs of millions of human dwelling in and around the forest ecosystems are derived from the areas, these threats are very severe. Based on several physical parameters and socio economic data layers and by using GIS tools, the threat induced maps can be developed that indeed represent the actual disturbance levels to different areas of these forest areas. There are two common threats to any forest areas. They are: 1. The settlement associated pressures from human population, cattle and sheep; 2. Developmental activity associated threats due to major and minor roads; All the two components can be combined and derive a composite threat induced spatially distributed values in the form of a map. Such maps would be of immense help for mitigation measures to safe guard the reserve forest area. (Figure 5)

2.4.5 RET Index: The reserve forest Rare (R), Endangered-Endemic (E) and Threatened species were recorded in the study area with their location as point source information and better of 1000m with 200m interval around its location was created and analysed in association with other input maps. (Figure 5)

Sl. No.	Species	Plot-id
1	*Antidesma menasu* Miq. ex Tul.	16
2	*Barleria longiflora* L.f.	1,2
3	*Curcuma pseudomontana* Graham	14
4	*Dendrobium herbaceum* Lindl.	18
5	*Glochidion tomentosum* Dalz.	7
6	*Habenaria hollandiana* Sant.	17
7	*Habenaria lawii* (Wight) Hook.f. (*Peristylus lawii* Wight)	14, 22
8	*Habenaria longicorniculata* Graham	9
9	*Habenaria roxburghii* Nicols. & Saldanha	11,14
10	*Hemigraphis latebrosa* Nees var. *incana* Gamble	14
11	*Hoya pendula* Wight & Arn.	11
12	*Knema attenuata* (Hook.f. ex Thoms.) Warb.	11,20
13	*Memecylon jadhavii* Reddy, Reddy & Raju	3
14	*Nothopegia heyneana* (Hook.f.) Gamble	19
15	*Radermachera xylocarpa* (Roxb.) Schum.	17
16	*Wendlandia gamblei* Cowan	22
17	*Zingiber roseum* Roscoe	11

Table 7. Endemic plants of Peninsular India occurring in RV Nagar Range with plot number.

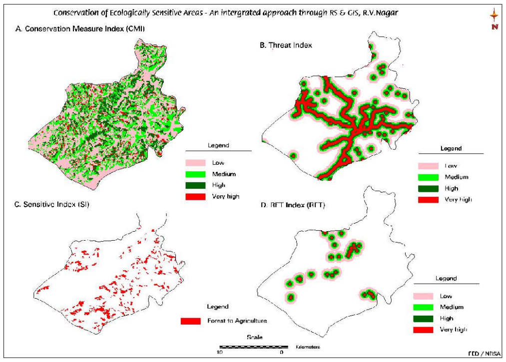


Figure 5. Different indices for critical analysis to identify areas for conservation, restoration and rehabilitation

2.4.6 Conservation Measure Index (CMI): The vegetation types occurring in the study area are basically of Tropical Semi evergreen, Moist deciduous, Dry deciduous, Thorny-scrub forest areas and Savannah forests.

The standard phytosociological data was collected in each of the forest type. In addition, care was taken to distribute the plots randomly keeping in view of the topographical and environmental factors. (Figure 5)

2.4.7 Integration of data and Analysis: The deforestation, forest degradation and habitat fragmentation have grave consequences on forest biodiversity but the gravity of the situation in terms of its rate, causes, magnitude, pattern and trends of landscape changes are yet to be studied and well documented. Earlier a few studies documented the deforested over a period of time to bring out the magnitude of their effects on biodiversity at locale level. Realizing the deforestation determines the status of biota; the fate of biodiversity depends upon the existence and integrity of the reserve forest. Thus the conservation planning information about landscape changes must be integrated with data on spatial distribution of biodiversity. By superimposition of layers of data on vegetation types, topographical data coupled with ground truth information/phytosociological data through GIS analysis provide a powerful tool for identification of specific areas for conservation.

In the present study, emphasis was given to topographical, environmental and species based analysis to identify and demarcate the areas for conservation. Keeping these in view three major parameters namely stems and basal area per

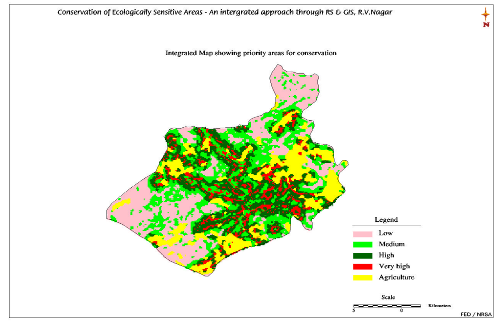


Figure 6. Integrated map showing priority areas for restoration

hectare, Shannon and Wiener biodiversity index were analyzed for elevation, slope, aspect and also analyzed species richness and canopy density. These parameters are considered to be the ideal condition for the growth and development of various plant species and diversity in the area understudy. Such demarcated areas were considered ideal in having high biological rich areas thus needs conservation as gene pools.

The priority areas are considered as a function of high weightages of stands, basal area per hectare and biodiversity index, on crown density, with respect to elevation contours, slope and aspect. (Figure 6 & Table 10 (a,b,c,d))

2.4.8 R V Nagar Analysis: The phytosociological analysis on three topographic parameters namely elevation, slope and aspect were attempted to understand their impact on three ecological factors namely stands, basal area per hectare and biodiversity index. The over all analysis showed that the medium elevation and slope with SE aspect would be the ideal condition for the growth and development with high biological richness.

Items	classess	Stems/ha	Basal area/ha	Shannon index
Elevation	<800	650	51	53
	901-1000	741	51.5	5.7
	>1000	421	26	5
Slope	<20%	515	31.7	5
	21-40%	461	40.4	5.37
	41-60%	962	51.5	5.4
	>60%	675	56	4
Aspect	NE	899	47	5.52
	NW	789	39	5.27
	SE	475	47.5	5.2
	SW	529	31	4.91
Drainage Density	V.High	-	-	-
	High	-	-	-
	Medium	-	-	-
	Low	-	-	-
Canopy Density	<20%	425	8.54	3.81
	21-40%	625	39	4.74
	41-60%	593	48.3	4.9
	>60%	719	47.7	5.5

Table 8. Phytosociological analysis based on Elevation, Slope, Aspect, Drainage density and Canopy density

Items	Elevation			Slope				Aspect				Canopy Density			
	<800	901-1000	>1000	<20%	21-40%	41-60%	>60%	NE	NW	SE	SW	<20%	21-40%	41-60%	>60%
Stems/ha	6	8	4	4	2	8	6	8	6	2	4	2	6	4	8
Basal area/ha	6	8	4	2	4	6	8	6	4	8	2	2	4	8	6
Shannon index	6	8	4	4	8	6	2	8	6	4	2	2	4	6	8

Table 9. Weightages assigned to Elevation, Slope, Aspect and Canopy density

The following tables depict the various analysis and priority setting for delineating conservation areas (Table 10 (a, b, c, d)).

Items	Elevation	Slope (%)	Aspect	Drainage Density	Canopy Density (%)	Priority
Stems/ha	901-1000	40-60	NE	-	>60	**1**
Basal area/ha	901-1000	>60	SE	-	40-60	**1**
Shannon index	901-1000	20-40	NE	-	>60	**1**
Species Richness	-	-	-	-	40-60	**1**

Table 10-a Prioritization of conservation zones

Items	Elevation	Slope (%)	Aspect	Drainage Density	Canopy Density (%)	Priority
Stems/ha	801-900	>60	NW		20-40	**2**
Basal area/ha	801-900	40-60	NE		>60	**2**
Shannon index	801-900	40-60	NW		40-60	**2**
Species Richness					>60	**2**

Table 10-b Prioritization of conservation zones

Items	Elevation	Slope (%)	Aspect	Drainage Density	Canopy Density (%)	Priority
Stems/ha	>1000	20	SW	-	40-60	**3**
Basal area/ha	>1000	20-40	NW	-	20-40	**3**
Shannon index	>1000	<20	SE	-	20-40	**3**
Species Richness	-	-	-	-	20-40	**3**

Table 10-c Prioritization of conservation zones

Items	Elevation	Slope (%)	Aspect	Drainage Density	Canopy Density (%)	Priority
Stems/ha	-	20-40	SE	-	<20	**4**
Basal area/ha	-	<20	SW	-	<20	**4**
Shannon index	-	>60	SW	-	<20	**4**
Species Richness	-	-	-	-	<20	**4**

Table 10-d Prioritization of conservation zones

After successful integration and analysis of the above database, four priority levels weredelineated. However, it was further prioritized in the priority I category by selecting the patches having more than 10,000 hectares of contiguous patches. There are about three patches could be segregated meeting the criteria. These patches represented in different vegetation types covering Semi evergreen, Moist and Dry deciduous forest types. Further those patches falling in fire prone areas with less rainfall zones were discarded and finally a patch having in high rainfall zone was selected for further analysis at Habitat Niche level using IRS- LISS III/ IV data. The high-resolution data with 5.8 meter spatial resolution would be the ideal in understanding the Habitat Niche condition and these areas are recommended for conservation at highest priority.

2.4.9 Restoration of RET Species: The physical conditions of a particular site determine what community of plants will survive for the long term without special care. When confronted with a previously farmed or other wise disturbed area, it may be difficult to determine the vegetation history of the site. The topographical and other environmental factors on a site is one of the best clues to restore RET species existing in those sensitive pockets.

In study site, it was found about 6 sample plots (plots 2, 7, 11, 18, 19, 20) having RET species were in critical out of 15 plots as they were collected proximity to road/settlement locations as depicted from the Threat index map were further overlaid on to the Sensitive index map to find out which of those sample plots are likely to be in danger. These sample plot locations of the plots are falling into any negatively vegetation cover changed grid. The species are likely to be no danger of extinction It was noted that 19th sample plot having *Nothopegia heyneana* is in high alert category as they fall (1) rail/road and settlements, (2) negatively changed vegetation cover grid. Considering that this species is likely to be in danger of loosing its entity, the areas suitable to rehabilitate has been attempted.

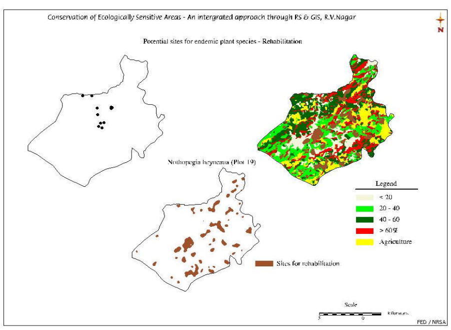


Figure 7. Prioritizing areas for species exploration and rehabilitation

The sensitive index coupled with threat index map would help to identify the areas to be restored with proper scientific management practices. The forest management should understand the reasons for the degradation of the critical areas. The reasons may be due to anthropogenic activities, podu cultivation, fire or fire wood extraction including intensive grazing. After understanding the reasons for the deterioration of such critical and sensitive areas, necessary management plans has to be drawn to mitigate any adverse impacts. The management resource plans should also address the implementation of plantation of natural trees in the gap areas to fill the canopy cover and also create necessary fire lines to avoid fires spread to other potential areas.

2.4.10 Rehabilitation of RET Species: The present work address the ability of the vegetation to grow luxuriantly in conditions favourable to them in terms of its topography (elevation, slope, aspect) and drainage density. The RET species which are falling into sensitive/threat index map are to be protected and rehabilitated so that these species would expected to strive better in ecologically similar conditions. The RET species that are critical and likely to be locally extinct could be taken up for rehabilitation through conditioning of topography and environmental aspects such as drainage/canopy density/rainfall etc. cover areas. Though a critical parameter on soil condition is missing, it probably taken care by itself since we have incorporated topographic and environmental conditions in to the model. (Figure7)

2.5. Conclusions

The tropical rain forests are the most species rich terrestrial environments with two or three layers of tree species and shrub, herb layers. In recent times the forest are being destroyed through active logging or to make away for agriculture leading to the fragmentation of forest of virgin areas. Such forest fragmentation not only leaves the organisms that remain within them a smaller habitat but also exposes them to stressful environment conditions, particularly at the forest edge, that differ from those deeper within the forest. Edge effect includes 1. abiotic effects (changes in environmental conditions) 2. direct biological effects (changes in the abundance and distribution of species). 3. indirect biological effects (changes in species interactions such as predation, broad parasitism, competition, herbivory, pollination and seed dispersal).

The Gudem-Sapparlu ranges cover R.V.Nagar range, Visakhapatnam District, Andhra Pradesh is one of the unique site having reminiscence of species of endemic RET and medicinal species distributed in variety of vegetation types. Besides the site is experiencing very high anthropogenic activities such as podu cultivation thereby high fragmentation and disturbances were observed. Hence such areas need to be understood to prioritise potential areas for conservation and prepare management plans for restoration and rehabilitation of RET species. In this site about 188 tree individuals were collected from 45 randomly distributed plots. Some of the highlighting points observed in the analysis were the point of biodiversity index derived from Shannon and Weiner index which was recorded high in Tropical moist deciduous forests with 5.50, semi evergreen with 5.27 followed by savannah forests with 3.71. The high value of 5.5 in case of moist deciduous forest was mainly due the association of various species in and along the moist stream network. The other interesting observation was of having high stems per hectare 712 in case of moist deciduous forest but had high basal area of 49.2 in case of semi-evergreen forests in the region. Indicates good rainfall resource allocation in well distributed high altitude zones with good conditions.

The Forest Resource Management Plan requires identifying the areas for conservation, restoration and rehabilitation of the RET species. The potential sites for conservation are identified and demarcated during the study are to be taken up for necessary action to safe guard from anthropogenic activities and preserve as gene pool. Further the degraded areas are to be restored through intensive afforestation programmes by introducing locally growing plant species thereby protecting biodiversity and also restore the ecological stability to the area under study.

The Conservation Measurement Index (CMI) in the present context is based on purely with biological data coupled with topographical and environmental inputs to derive conservation zones. However, it is equally important to incorporate the data on animal species including the distribution of wild relatives of plant and animal species to develop an appropriate index. It is generally assume that the interior protected forest areas are less threatened than peripheral areas, since the later are biologically less diverse but require more protection than areas of high conservation value. It is also realized that the socio economic factors such as economic, cultural and religious importance of various habitats are equally important to address the impact of anthropogenic activities in the fringe areas of protected areas. The CMI is to prioritise the zones for easy management practices but entire area needs equal degree of protection. The present study indicates that the interior areas are more biologically rich and diverse but less threatened and biodiversity of such areas is subject to natural phenomena than to anthropogenic pressure whereas the peripheral areas are more threatened by human impact and unless the integrity of the peripheral habitats is maintained, the whole protected area network would be endangered. Hence the interior and peripheral zones thus require different types of management interventions for the maintenance of biodiversity.

The analysis of sensitive index, threat index maps are indicative maps of degradation area in and peripheral zones of the protected areas where intensive management practices are needed. The maps generated through Conservative Measure Index (CMI) provide necessary zones of high priority zones for conservation. The integrated study using sensitive index, threat index, RET index maps coupled with CMI maps have been proved to be of immense help in prioritizing the zones for bioprospecting and biodiversity conservation strategy. Such prioritized zones are further recommended for conservation management plans as genetic pool areas. The present study on restoration and rehabilitation of RET species through a new light of understanding and implementation of recommendation to propagate any species existing in the study area and improve its population and genetic resources on a long term basis.

The present study is a preliminary attempt to understand conservation , restoration and rehabilitation strategies in protected and natural reserve forest areas based on limited variables such as phytosociological indicators (stems, basal area per hectare and biodiversity index), topographical variables (elevation, slope, aspect) and drainage density, rainfall zones through suitably average weighted approach using RS & GIS techniques. But there is a wide scope to improve the model by incorporation other meteorological/climatic factors and other phytosociological data collected from field through intensive sampling techniques covering all vegetation types at community level. It is further recommended to avail high resolution satellite data from IRS-Resourcesat LISS IV MSS integrated with CARTOSAT PAN data for identification and delineation of different major communities for the entire study area and suitably sampled through random and transect methods to improve stratification. Further the model can be improved by integrating various other variables from field data at community level, topography, climatic coupled with census data base at micro watershed level to address issues concerned with vegetation, soil, water conservation, restoration and rehabilitation of RET species in protected reserve forest areas in the country.

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