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Assessment of Forest Fragmentation and Species Diversity in North Andaman Islands (India): A Geospatial Approach

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ABSTRACT

The present study was carried out in the context of conservation biology research, focusing on the species diversity in the fragmented landscapes of island ecosystem. The study analyzed the levels of forest fragmentation and its effect on species diversity in the North Andaman Islands using satellite remote sensing data and a GIS-based fragmentation model in conjunction with phyto-sociological analysis. Results depict that the model performed well when the forest is considered as a single unit, compared to the scenario wherein the individual forest types are accounted. Additionally, the phyto-sociological data analysis results are correlated with the fragmentation model, which indicates that majority of the area is under intact category, contemplating that the process of fragmentation in these islands is in its initial phase. Taking a note of such observations, conservation measures are recommended to facilitate the sustainable management of the pristine vegetation glory of these islands.

KEY WORDS: Forest / GIS / Remote sensing / Visual interpretation / Random sampling

ABBREVIATIONS: GIS- Geographical Information System, LISS-Linear Imaging Self Scanner; SOI-Survey of India, EG – Evergreen, SEG – Semi evergreen, MD – Moist deciduous

Mathematics Subject Classification: 00A06, 92D40

Journal of Economic Literature (JEL) Classification Number C02, Q 23, Q 57,

INTRODUCTION

Habitat fragmentation is considered to be the major threat to biological diversity, and is one of the primary reasons of the present extinction crisis (Lovejoy et al., 1986, Laurence et al., 1998, Harrison and Emilio 1999, Baker 2000, Bierregaard, 2001). Fragmentation of forest into small patches causes threat to biodiversity as well as to the survival of important species by suspending the availability of resources (Lovejoy *et al.*, 1986,). Analysis of habitat fragmentation and its effects related to species, is one of the emerging foci of ecological and conservation biological research (Noss & Csuti, 1997). Characterization of habitats, their configuration and degree of fragmentation, provides reliable information on the biodiversity distribution pattern. Forest fragmentation alters the ecological niches of sensitive species by restricting their population growth and survivability and also modifies the physiognomy of communities by changing species composition and continuity. The theory of island biogeography aptly explains the effects of fragmentation on the changes in the species composition of tropical rainforests. Globally, fragmentation studies reveal the consequence of extinction of species (Wilcox & Murphy, 1985), shifting the species composition, favoring the abundance of certain species (Meffe & Carroll, 1994) while affecting the area-sensitive species.

The potential of Geographical Information Systems (GIS) and remote sensing have long been recognized in assessing the ecological impact of natural disturbances in forested ecosystems (eg: Prasad *et al.* 2008b). The maps derived from satellite imagery offer a better understanding of forest fragmentation and its impact on species diversity and various methods and data have been used for identifying the pattern of fragmentation by different researchers (Shailay menon *et al.* 1997, Armando *et al.* 2000, Robert *et al.* 2000, Ritter *et al.* 2002, Porwal *et al.*, 2003, Laxmi *et al.* 2005)

STUDY AREA AND OBJECTIVE

North Andaman Islands, (12^{0} 95 ^{II} N and 92^{0} 86 ^{II} E), the present study site, form one of the major districts of the Andaman Islands, consisting of about 70 small and large islands with an area of 145,800 ha. Due to the fragile insular ecosystem and rich biological diversity these islands were declared as Biosphere Reserve by Indian National Man and Biosphere Reserve committee in 1974 (Prasad *et al.* 2008a; www.indian-ocean.org). The development and colonization programs carried out by post independent Indian government led to the immigration of people from mainland, India. The population of the district consists of migrants mostly from West Bengal, Tamil Nadu and Andhra Pradesh states of India. An increase in the immigrant population affected the natural resources of these islands by increased logging rates and encroached forests for agricultural use. Over time, the consequences of expanding population profoundly disturbed much of the ecological equilibrium of the islands' natural vegetation with increasing habitat areas. While, the greatest loss of endemic and rare species have been reported from the Saddle Peak national park in North Andaman. Increasingly, people have moved to inhabit and occupy inaccessible parts of these remote islands by clearing forestland for shelter, agriculture and other domestic purposes. Because of all these interventions, the forest which was once described by Champion and Seth (1968) as "Forest in its pristine glory, if it is found anywhere in Southeast Asia, it is in Andaman Islands", has declined, resulting in significant species loss. In this context, the present study was carried out to analyze the forest fragmentation scenario of North Andaman Islands using GIS-supported fragmentation model, and investigates how species diversity and species composition varies with different levels of fragmentation in the landscape.

MATERIALS AND METHODS

Satellite data processing and classification

IRS-P6 LISS III satellite data of 11^{th} Feb 2004 (23.5 m resolution) was used for mapping forest types and non-forest themes (*Fig.*1). Geometric rectification of the satellite data was carried out using georeferenced IRS -1D LISS III image of March 1999. Image stretch corrections were applied to improve the quality of the satellite image for proper delineation of different classes. The thematic layer generated from 1999 satellite data (Prasad *et al.* 2007a) showing various land use and land cover classes of the study area, was used as a base layer to interpret 2004 data by on screen visual interpretation technique (adopted from Prasad *et al.* 2007a) using Arcview 3.3 software. Polygons were then drawn around areas of change on the image and the corresponding areas were reclassified on the classified map (Prasad *et al.* 2008b) finally delineating various themes such as EG, SEG, MD, coastal forest, and other non-forest classes. Since in the present study main focus was on interior forest fragmentation we have interpreted mangroves and littoral forest together as class - coastal forest while mudflats, agriculture, settlement, barren under non-forest as single class. The study provides a pre tsunami scenario of the islands vegetation. Keeping in view of the field data collected which was used for validation, the model was applied only for the interior/hinterland forest types (predominantly EG, SEG, MD) and not for the coastal type. Hence from the final classified map coastal forest was masked out, retaining interior and other non-forest classes.

Fragmentation model

A GIS-fragmentation model developed by the Image Analysis & Image Processing Division of the National Remote Sensing Agency, based on the concepts of Ritters *et al.* (2000), was used to categorize the forest into various fragmentation classes. The model uses a sliding algorithm with overlapping windows and identifies the amount of forest and its occurrence as neighbouring forest pixel within the fixed area of "windows" surrounding each forest pixel. The value thus obtained when a window slides over an image grid was used to classify the windows by type of fragmentation. The result was stored at the location of centre pixel and, if the centre pixel was not forest, then a null value was assigned to that location. Thus, a pixel value in the derived map refers to between-pixel fragmentation around the corresponding forest location (adopted from Ritters *et al.* 2000).

Running the model

The classified map, picturing predominant forest types and non-forest categories, was converted into grid format to run the model (*Fig.*1). The rationale of the model was, the fragmentation is a contextual measurement for which differences in forest types are not over emphasized (Ritters *et al.* 2000). Keeping this in view, first, the model was applied to the entire data at different window sizes by recoding the thematic classes of classified map into two main classes as forest and non-forest, in order to identify the actual area of forest under each fragmented category. Then, an attempt was also made to analyze the functionality of the model, by running for the three predominant forest types (EG, SEG and MD) separately. Since window size plays an important role in categorizing the forest into various fragmented classes, a 5 x 5 window size was chosen as appropriate for the study after running at various window sizes (Table 1). The scale of mapping proposed in North Andaman is on 1:50,000 scale, and the satellite data of IRS P6 LISS III provided a spatial resolution of 23.5 m. Considering the minimum mapping unit, 5 x 5 pixels has been realized as optimum for deriving the reliable analysis using 5 x 5 window size. The model finally classified, the forest area into six categories as interior, patch, transitional, edge, perforated and undetemined.

Field Inventory and Data analysis

The Phyto-sociological data collected by stratified random sampling method using GPS during October 2001- January 2002, as a part of project "Biodiversity characterization at landscape level (in Andaman islands) using remote sensing and GIS" (Anonymous 2003, Prasad 2006, Prasad *et al.* 2007b)), was used to validate the results of the model. The field inventory plots (100 plots of 0.1 ha size) were overlaid on the fragmentation map derived from the model and were categorized under different fragmented classes in each forest type *viz.*, EG, SEG and MD. Within each plot, data was collected for type of species, their DBH (at 1.37 m), bole height along with seedling and sapling records.

Phytosociological data analysis

The data was analyzed using two scenarios as described below

1. Entire forest as single unit

In this analysis, field plots (100 of 0.1 ha) were clustered into five classes (undetermined, the sixth fragmented class was ignored as it constitutes negligible area) irrespective of forest types to find out the variation in species diversity in five fragmented classes viz., interior, patch, transitional, edge and perforated. In this case, a general preliminary diversity analysis was done to validate the fragmentation categories.

2. Individual forest types

Since comparative plots are not available in each fragmented class for each forest type (due to inaccessibility either in terrain/location of islands) and based on the results of fragmentation model, where higher proportion of area was recorded for interior and perforated classes the plots were grouped into two classes in each forest type as *intact* formed from grouping of interior and patch classes and *fragmented* from transitional, edge and perforated classes .The data was analyzed in detail for different diversity and dominance parameters *viz.,* Shannon-Wiener index of diversity (Shannon and Weiner 1963), Simpson's index of dominance (Simpson 1949) Important value Index (Cottam and Curtis 1956), Family Importance Value Index (Mori *et al.* 1983) and Sorenson index for similarity (Sorenson1948).

RESULTS AND DISCUSSIONS

Satellite data

The thematic map (*Fig* 1) derived from the satellite data reflects forest (interior) fragmentation scenario of the area under study. The fragmentation of the interior forest is mostly as a result of anthropogenic disturbances. The change detection (post tsunami) analysis using LISS III (1999) and SPOT (2005) data carried out for the same study area by Prasad *et al.* (2008b), concluded that the change in interior forest observed could be attributed to the human logging and other activities, since the chance of tsunami waves penetrating the deep forests is minimal. Thus the satellite data (2004) used in the study represented similar forest structure (interior types) for both pre and post tsunami conditions and can be considered for extracting current fragmentation scenario.

Fragmentation model

Running the model at various window sizes (Table 1) shows that the percentage of interior forest decreases with increasing window size and, at a larger scale, the interior forest remained as a minor component where patch, edge and perforated zones dominated. The application of the fragmentation model for the entire forest data (5 x 5 window), irrespective of forest type reflect 82% of forest in intact condition and rest under other fragmented classes. The results correlate with the study carried out (Anonymous, 2003) using GIS-based, BIOCAP, software for investigating forest fragmentation in the North Andaman Islands with a 100 x 100 window size. The software module classified the forest into four categories as intact/non-fragmented, low, moderate and high fragmented classes, recording 78% of the area under intact and 12% as highly fragmented (Porwal *et al.* 2003). This indicates that the forest of these islands is largely of continuous nature and fragmentation process is in its initial stages (*Fig.*2). On the other side, the results of the model when run for each individual forest type showed a lesser amount of area as continuous forest and major under other fragmented categories (*Fig.*2). EG showed

51% of forest as intact followed by MD (44%) and SEG (41%) and for fragmented class it is reverse: with 59 % in SEG, 56% in MD and 49% in EG (*Fig.*3).

Forest fragmentation assessment fairly depends on both spatial and attributes scale of analysis (Ritter *et al.* 2000). When model was applied by classifying grid with two classes as forest and non-forest, forest fragmentation categories changed with the changing window size. And when the model run for individual forest types almost an equal percentage of area was observed in interior and perforated groups for both SEG and MD with exception to EG where high percentage of interior area was recorded. The model was able to differentiate various fragmented classes when run for individual forest types, whilst, when applied for entire forest, it categorized most of the area under interior class. The reason for such kind of variation can be explained as; when the model runs for individual forest type, it was able to classify the patches within each forest type and wherever other forest type occurred there it indicated the discontinuity of forest as fragmentation. While in the case of entire forest, the model considered all the forest patches irrespective of types as a continuous large tract area resulting in high interior class. Since, in natural conditions there is possibility of intermixing of patches of different forest types among each other, resulting in large interior forest area, the prediction of model is apt, considering entire forest as single type instead of individual forest types. (*Fig.*2)

Phytosociological data analysis

Entire forest as single unit (Table 2)

Species richness and diversity was found to be more in interior and edge classes, and number of stems/ha more in perforated class. Presence of Large continuous forest in interior class supported high species richness. In case of edge class, the edge effect, that probably enhanced the proliferation of secondary vegetation along forest margins, invasions of weedy or generalist species, alteration of ecological niches that support wide range species (Paromita Ghosh, 2004) contributed for higher species richness. In general, it was found that the species richness of plants is high at edge situations where xeric species coexist with some interior species (Levenson, 1981). The low basal area (42.34 m^2) in accordance with high stem density observed in perforated class is an indicative of forest disturbances, which favored rapid growth of young stems of light demanding species with smaller girth. The high basal area observed in interior and edge class can be attributed to the existence of stems with larger girths. The analysis shows that there is loss of species diversity and richness from intact forest to fragmented classes. Though the stems ha^{-1} is higher in perforated class, it is mainly due to the accumulation of invasive species, which overthrows native species pool. Overall, this analysis gives a scenario of high species diversity in interior class with certain degree of variations in other fragmented classes, depicting a sign of low/initial forest fragmentation conditions in these islands

Individual forest types:

Species Diversity

Results of analysis with individual forest types (Table 3) show high species richness in intact class of both EG and SEG but in case of MD no variations observed. Shannon diversity for three types in intact forest ranged between 5.6 – 5.9, with least in MD and maximum in EG, in case of fragmented it ranged between 5.5 for MD to 5.9 in SEG. Simpsons diversity index ranged from 0.96 to 0.98 for both the intact and fragmented classes in all forest types. Simpson's value indicates almost equal dominance of various species, maintaining high evenness and low dominance. However, the Similarity index highlights the species sharing between the intact and fragmented classes of three forest types and it was observed that more than 60% of species were shared among three forest types. Fragmented class of EG and SEG show a great deal of similarity in species composition with 76% of species being common for both the forest types. This could be explained as a result of the sharing of similar resources and environmental gradients by different forest types within the biome.

Stem density and Basal area

The number of stems recorded per hectare is high for fragmented class in each forest type, whereas high basal area was recorded in intact forest of both EG (60.5 m^2) and SEG (51.3 m^2) and in case of MD it is high in fragmented class (54.5 m^2). In general an inverse relationship exists between basal area and stem density. Increase in number of stems in fragmented classes of all the three forest types may be due to the external anthropogenic disturbances and interventions that have paved a good pathway for rapid regeneration of species by increasing the number of stems with low basal area. Whereas, in an intact forest, large girth trees with heavy buttresses contributed for increase in basal area. In the fragmented class of MD increase in basal area is mainly due to the high density and dominance of *Pterocarpus dalbergoides* [an endemic species found only in Andaman Islands, even not in Nicobar Islands of same archipelago].

Least difference was observed between the species diversity parameters in intact and fragmented classes for each forest type (Table 3). This could be due to the spatial intermixing of different forest types among themselves that maintain the intactness of forest, thus having least variation on species diversity. Both the types of analysis either entire/individual forest showed similar pattern of species diversity and other parameters values (with few exceptions) for intact forest and other fragmentation classes. The values varied only marginally, indicating low forest fragmentation levels, which have made the model to differentiate the forest into various fragmentation categories, retaining high percent of area under interior class. Now in this context it is clear that there exist certain forest disturbance factors affecting the intactness of the forest and these attributes have principally governed the delineation of fragmented classes such as transitional, edge, and perforated. Furthermore, the investigation will now examine the extent of variation in dominance, species behavioral pattern, endemism and regeneration status within intact and fragmented groups in relation to fragmentation processes.

Dominance

Results based on Important Value Index values show *Dipterocarpus gracilis* and *Myristica glaucescens* in EG, *Pterocarpus dalbergoides* and *Celtis wightii* in SEG, and *Pterocarpus dalbergoides* in MD, as important dominant species in both interior and fragmented classes of individual forest types respectively (Table 4). In EG and SEG the type of dominant species varied, acting as representatives of intact and fragmented classes, while in MD both the classes dominated by same species. Data analysis confirm that, in the entire North Andaman, *Pterocarpus dalbergoides* and *Dipterocarpus gracilis* occupy major proportion of the forest owing to their large girth and buttresses.

Family Importance Value Index show Dipterocarpaceae in EG (49.59 intact, 41.04 fragmented), Anacardiaceae and Sterculiaceae in SEG (29.92, 29.40), Ebenaceae and Fabaceae in MD (29.97, 45.48) as the most important and dominant families. The data analysis at family levels suggests a scenario where the EG Dipterocarpaceae family dominates both the classes, whilst, in SEG and MD each class showed their own dominant family. Based on this analysis it can be assumed that Sterculiaceae and Fabaceae families in SEG and MD, are the signs of forest disturbances as they dominated the fragmented class.

Species Behavioral Patterns

Phyto-sociological data analysis (Table 3) revealed about 91 species in EG, 75 in SEG and 83 in MD as common occurring in both intact and fragmented classes of each type, behaving like *companion* species that survive in any type of community without depicting special affinities for any association. With in each forest type certain unique species have been identified that restricted themselves either to intact or to fragmented class and sometimes in other forest types behaving like *preferential* species showing association only with a particular community. Similarly it was also observed that some species strictly restricted themselves to particular forest and to particular fragmentation class. These species may act either as selective species being uncommon in other associations or as *exclusive* species completely/almost confining themselves to a particular association and behave as *stranger* species.

Rare and Endemic

About 59 species in (32 intact, 27 fragmented) EG, 60 (37, 23) in SEG and 67 in (31, 36) MD are represented as singletons which can be considered as *rare* and play important role in enhancing species richness and diversity. Special attention should be focused on these rare species since they may undergo extinction if their habitats are destroyed. Simultaneously, 45 species belonging to endemic and IUCN red data category were also recorded in both interior and fragmented classes.

Regeneration status

The data analysis on seedling and saplings of various species reveals a very poor regeneration status. Overall, for 21-35% of species sapling data and 18-25% species seedling data was recorded, in both the categories, for each forest type. Comparatively high sapling and seedling percentage was observed in fragmented class of EG and SEG and intact class of MD. The reason for this type of trend in EG and SEG could be the forest gaps (open condition) created by disturbance factors and in MD, the existence of open canopy condition both in intact as well as fragmented class, favored the vigorous growth of dispersed seeds by providing the optimal growth factors; whereas in intact class the closed canopy conditions restricts the dispersal as well as survivability of seeds. But the poor regeneration status observed for species that show 35% sapling & 25% seedling data, is due to the dominance of certain species, inter and intra specific competition for the similar resources, grazing by animals, or other physiological factors. Two species *viz., Fragraea morindaefolia* and *Elaeagnus latifolia* - are represented only as seedlings and saplings. These species might have migrated from other community and started stabilizing themselves in the new community by the process of Ecesis. Adult trees of these two species were not encountered during the sampling, might be due to their low population and ecological amplitude.

Consequences

The process of fragmentation reduces the survival capacity of interior species that require an undisturbed habitat away from the habitat edge or ecotones. A majority of species are interior species and threat to damage this intact forest can cause a great loss of species as well as change species composition. The forest patch loses productivity and rich diversity that it once had as part of the larger forest (Robbins *et al.*1989). Fragmentation process exposes the intact interiors of remaining habitat to edge effect, which favors the growth and survival of some species, while harming other and leads to the extinction of those species that survive in the matrix of different habitats, such as companion species. The ultimate result is the loss of biological diversity, decline in the number and abundance of species as well as loss of endemic, rare and endangered species. There is a great impact on the area sensitive species like stranger species. With the increased habitat fragmentation these species are lost first. So extensive habitat loss declines diversity, changes species composition, reduce population densities and species richness in the landscape (Turner, 1996).

CONCLUSION

The technology of remote sensing and GIS has proved beneficial to forest fragmentation studies. The fragmentation model is useful for categorizing the forest as a single unit, rather than for individual types. Results obtained from the phyto-sociological studies reveal least variations between three-forest types indicating the forest intactness and confirming the results of the fragmentation model [with forest and non-forest categories and 5 x 5 window size]. However the model is limited by the size of kemel or window chosen for study. With increasing window size the interior forest decreased rapidly, patch areas disappeared and perforated forest changed into transitional forest. The correlation of field data results with the fragmentation classes proves the suitability of window size 5 x 5 for the present study.

Based on the model and ground truth, it was observed that the process of forest fragmentation is at its initial stage. On ground conditions, it may not possible to differentiate the forest into various categories as given by model, but the model indicates the severity of fragmentation that may occur in real scenario. The initialization of fragmentation process will have effects on the species, resulting in the specialization of species based on their distribution as companion, preferential, exclusive, and so on. In the first instance importance is given to endemic, rare and threatened species by identifying their habitat zones using remote sensing and GIS extrapolating techniques and then suggesting conservation steps. In the second instance concentration is diverted to stop the loss of species, by preventing illegal logging, settling and deforestation activities to conserve one of the world's richest tropical pristine forests of North Andaman Islands.

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Tables

Table.1: Percentage of Forest in Different Fragmentation categories

Fragmentation Category	Window size	3x3	5x5	7x7	9x9	11x11	13x13
		Percentage of area under fragmentation category					
	Interior	90.9	82.6	75.7	69.8	64.9	60.8
	Patch	0	0.2	0.5	0.6	0.8	0.9
	Transitional	1.3	1.8	2.8	3.1	3.5	3.9
	Edge	6.4	6.1	7	7.6	7.7	20.9
	Perforated	1.3	9.2	14	18.8	23.1	13.6

Table.2: Species diversity in different fragmented classes (Entire forest)

Parameters	Fragmentation categories				
	Interior	Patch	Transitional	Edge	Perforated
No. of Sample Plots	27	10	7	36	7
Species Richness (Jackknife Estimate)	191	96	103	187	106
Shannon-wiener diversity index	6.26 ±0.43	5.62 ±0.68	5.29 ±0.56	6.06 ±0.52	5.46 ±1.06
Simpson diversity index	0.98 ±0.04	0.97 ±0.07	0.96 ±0.05	0.98 ±0.06	0.96 ±0.15
Stems / ha	740 ±179.4	691 ±154.2	734 ±111.2	739 ±160.9	821 ±137.7
Basal area / ha	54.05 ±34.2	44.05 ±17.1	41.65 ±11.9	53.18 ±26.6	42.34 ±13.2

Table: 3. Species diversity in different forest types (Individual forest types)

Forest Types	Evergreen		Semi-evergreen		MD	
Parameters	**Intact**	**Fragmented**	**Intact**	**Fragmented**	**Intact**	**Fragmented**
Species richness	124 ±6.51	118 ±6.87	116 ±6.44	105 ±5.81	111 ±5.89	111 ±6.4
Shannon Diversity	5.8 ±0.52	5.5 ±0.62	5.9 ±0.57	5.9 ±0.86	5.6 ± 0.47	5.5 ±0.51
Simpson Diversity	0.97 ±0.04	0.96 ±0.07	0.97 ±0.06	0.98 ±0.03	0.97 ±0.04	0.96 ±0.05
Stems / ha	798 ±169.05	800 ±159.03	681 ±159.24	714 ±123.07	712 ±152.81	745 ±181.62
Basal area / ha	60.56 ±34.15	50.73 ±15.42	51.3 ±22.80	48.4 ±27.75	40.97 ±17.60	54.5 ±22.86
Endemic species	26	25	21	24	20	18
Preferential species	31	26	37	29	27	16
Companion species	91		75		83	
Exclusive species	15	9	12	8	7	10

Table-4: Predominant Species in each forest fragment class and their IVI

	Fragmentation category			
Forest Type	**Interior**	**IVI**	**Fragmented**	**IVI**
EG	*Dipterocarpus gracilis*	26.87	*Myristica glaucescens*	36.30
	Myristica glaucescens	22.57	*Dipterocarpus gracilis*	17.85
	Artocarpus chaplasha	12.74	*Dipterocarpus grandiflorus*	13.45
	Dipterocarpus grandiflorus	11.06	*Celtis wightii*	10.50
	Dipterocarpus costatus	10.27	*Drypetes assamica*	7.61
SEG	*Celtis wightii*	16.66	*Pterocarpus dalbergoides*	21.11
	Buchanania splendens	13.52	*Dipterocarpus gracilis*	19.37
	Artocarpus chaplasha	13.40	*Celtis wightii*	13.20
	Pterocymbium tinctorium	11.78	*Pterocymbium tinctorium*	11.89
	Planchonia andamanica	10.93	*Artocarpus chaplasha*	10.47
MD	*Pterocarpus dalbergoides*	30.91	*Pterocarpus dalbergoides*	48.21
	Diospyros oocarpa	17.21	*Diospyros oocarpa*	16.66
	Celtis wightii	13.17	*Diospyros pilosula*	14.25
	Diospyros pilosula	10.99	*Aglaia oligophylla*	10.97
	Terminalia bialata	9.87	*Celtis wightii*	10.03

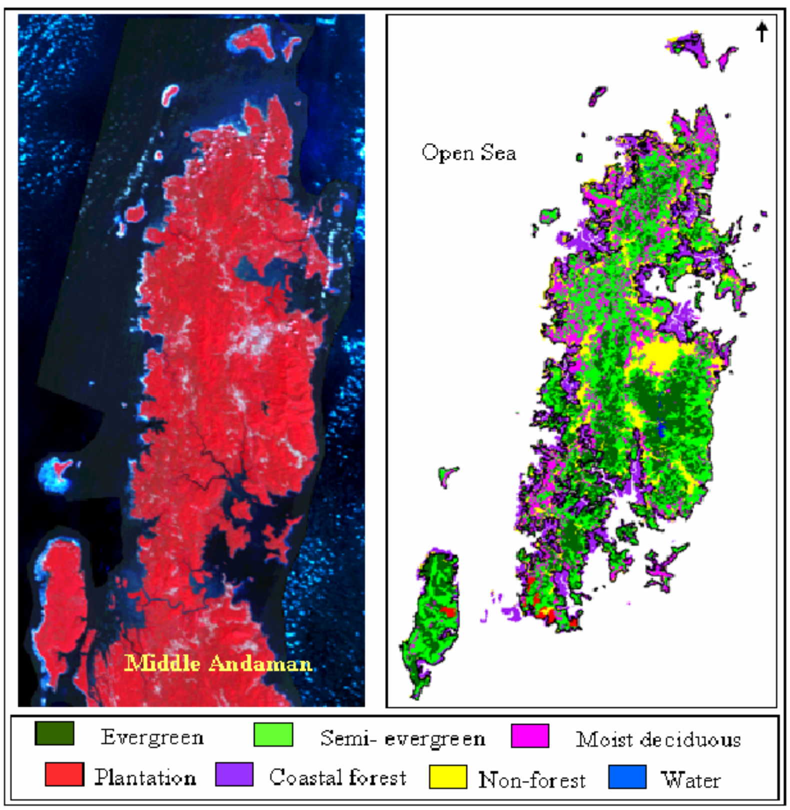

Figure.1. False Colour Composite and Classified map of study area

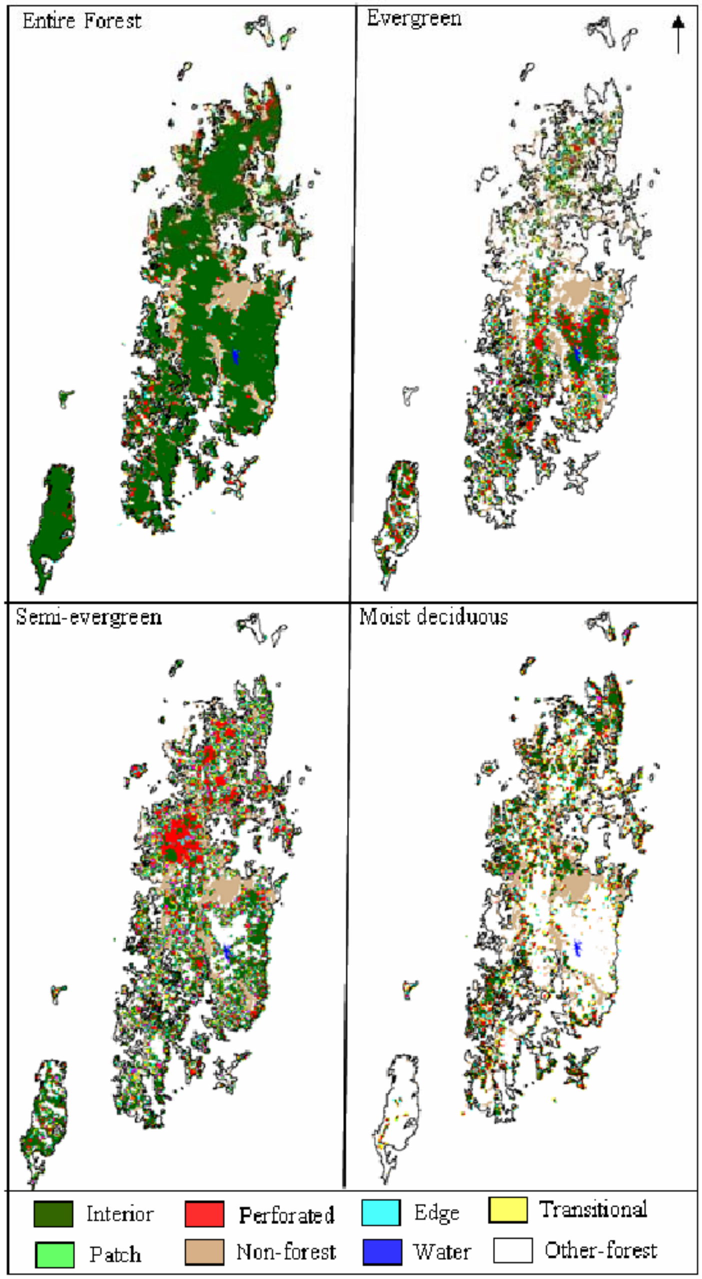

Figure.2. Forest Fragmentation in North Andaman Islands
as derived from the model

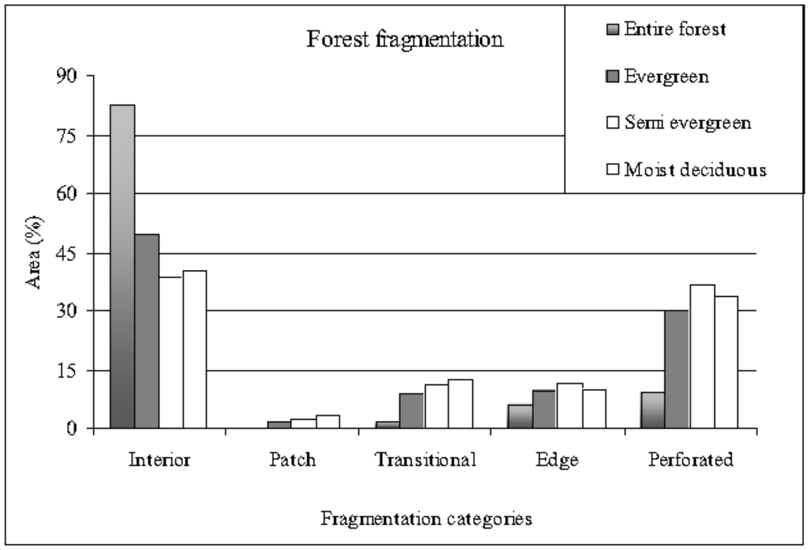

Figure.3. Percentage of Forest in Different Fragmentation categories