Conservation planning for the Western Ghats of Kerala: II. Assessment of habitat loss and degradation

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Habitat change analyses for conservation planning in India were hampered by lack of efforts to utilize the existing spatial data. While, traditionally, most change analyses involving remote sensing data were of short term in nature (≤ 10 years), the ecological history studies of long term (> 10 years) were essentially non-spatial in nature, and have contributed little to site-specific explanation on dynamics of habitat loss and consequent impact on biodiversity. In this study, GIS tools are applied to analyse habitat loss, and transformation over a period of 30 years beginning late 1950s for Western Ghats of Kerala. It is shown that over a thirty-year period the evergreen/semi-evergreen habitat has declined by 47% while the deciduous habitat has marginally increased by 7%. Landscape variables such as perimeter/area ratio were shown to be better indicators of habitat degradation rather than simple estimates of habitat loss. Attention is drawn to building a comprehensive data base for conservation planning.

THE Western Ghats of peninsular India is one of the 18 global hot spots of biodiversity[1]. The diversity of climatic, edaphic and biotic regimes have shaped the evolution of some 3500 taxa of angiosperms, 117 amphibians, 150 reptiles, 508 birds, 79 mammals, and as yet unknown number of taxa from the less studied groups of organisms. That this unmatched diversity is under threat is well known and is also relatively better documented than for any other region in India.

The loss of forest cover is also reasonably well documented for large areas[2]. However, other forms of habitat change, more specifically, change in physiognomy of the vegetation over long time scales (> 10 years), corresponding to foresters' concept of 'rotation forestry' for large areas are unknown. Estimates of habitat changes are crucial for understanding dynamics of vegetation, assessment of impact of the changes on patterns and process of the ecosystem and for evolving rational and sustainable forestry policies. Besides, information on the habitat changes is a vital input to the assessment of Protected Area Networks for large tracts. These estimates of changes linked to a spatial information system could serve as an additional and crucial component in suggesting and locating the local 'hot spots' of biodiversity and thus help in prioritizing habitats for long-term conservation. Again, such a spatial data base comprising habitat changes, extant habitats, serve as a 'bench mark' state of environment against which impacts of proposed developmental projects could be assessed. In this paper, an attempt has been made to arrive at the habitat changes of the Western Ghats of Kerala using published maps of the French Institute[3] and the maps of landuse by the National Remote Sensing Agency (NRSA)[4] and the Kerala Landuse Board[5]. The first objective of this paper is to document habitat changes over a 30-year period in all of 14 districts of Kerala (except Kannur and Kasaragod) using GIS tools. A second objective is to assess the habitat degradation using landscape ecological variables. As a sequel to the analysis, a conservation strategy for the Western Ghats of Kerala is proposed[6].

Study area

The state of Kerala comprising 14 districts (Figure 1) is located between 8°18′–12°48′N lat. and 74°52′–77°52′E long. The altitude varies from below sea level to around 2500 m in the high ranges. The vegetation is predominantly tropical evergreen forest biome with an average annual rainfall of above 2000 mm. Details of forest vegetation types, geology and climate as also conservation potential are found in Nair[7]. The total area of the state is 38,863 km². A total of 29,494 pixels, each of 1.3 km², covered the 14 districts.

Methods

Vegetation/landuse maps

The source for the first set of data is 1 : 1 million map of vegetation of sheet Cape Camorin by the French Institute and is based on data obtained in late 1950s. The present day districts of Kasargod and Kannur were covered by the adjoining sheet of Dharwar and were not used in this analysis. Hence these two districts were excluded in the change analysis. A country wide mapping of landuse/landcover was undertaken by NRSA, Hyderabad in collaboration with a number of agencies[9]. The aim was to map five different classes of landuse at level I and 25 categories in level II on a 1 : 250,000 scale. A visual interpretation of IRS LISS-I imagery was carried out on two time coverages. Thus, the temporal sampling in September–October 1988 and January–February 1989 enabled a better discrimination of vegetation physiognomy and consequently a higher order of accuracy of classification of vegetation types. Landuse/landcover maps covering all of the 14 districts of Kerala were obtained from the Kerala Landuse Board, Thiruvananthapuram. These 14 maps formed the second set of data.

Digitization

Landuse/landcover maps of 1 : 250,000 scale covering all the districts of Kerala depicting forest habitats were digitized. The French Institute map of 1 : 1 million scale of vegetation of 1961 was also digitized using the same geographical coordinates as those of 1 : 250,000 scale maps. Forest division boundaries as they existed in early 1990s were obtained and digitized. All digitization was done on Ao Calcomp digitizer using TOSCA 2.12 (ref. 10) and the resulting vectors rasterized in IDRISI 4.1 (ref. 10). The RMS errors for digitization were checked and found to be within the specified and acceptable limits for the scales of maps used. A plane coordinate system was used for digitization. No geographical projection of the digitized maps was done due to logistical reasons. It was observed that the north-south orientation of the districts in Kerala is less pronounced compared to the east-west direction. This would mean that errors due to longitudinal change are minimal. This was found to be true at least with respect to area calculations. The margin of error was found to be $\pm 0.5\%$ compared to 3.5% in NRSA-derived estimates. In any case, as these 'products' are aimed at focusing at a planning level, the relative errors will be constant and would not alter the conclusions of the study. It is, however, possible to project these digitized maps and integrate with other themes.

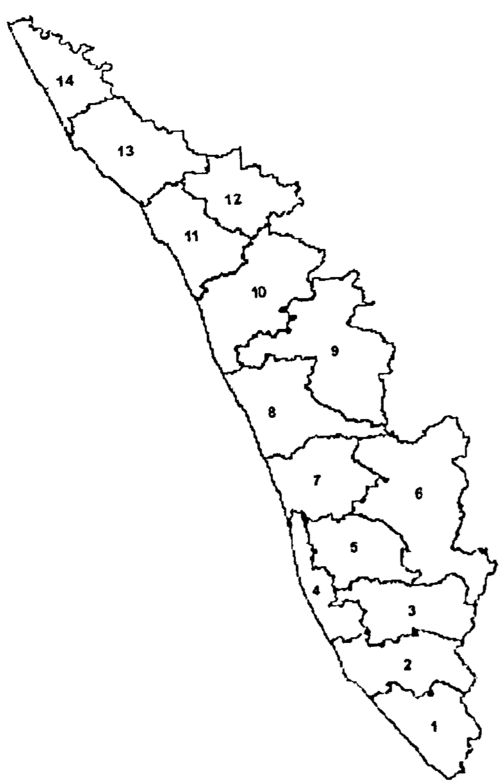

Figure 1. Revenue districts of Kerala 1. Thiruvananthapuram; 2. Kollam; 3. Pathanamthitta; 4. Alappuzha; 5. Kottayam; 6. Idukki; 7. Ernakulam; 8. Thrissur; 9. Palakkad; 10. Mallappuram; 11. Kozhikode; 12. Wynad; 13. Kannur; 14. Kasargod.

Map accuracy

There are essentially three basic categories of accuracy issues that are relevant to our purpose. The first one deals with locational or positional accuracy and it refers to the margin of error in the representation of geodetic coordinates (lat., long.) of ground features with respect to a standard reference map. In this paper, the 1 : 250,000 scale map of the Kerala Landuse Board is taken as a reference map while the 1 : 1 million scale map of the French Institute as the map for which geodetic coordinates are compared. For a 1 : 250,000 and 1 : 1 million scale map, positional accuracy, thus would be 62.5 m and 250 m respectively.

The second issue refers to the interpretation or classification accuracy. This is a measure of agreement between classification and verification of these classes and is used as a measure of total map accuracy. The landuse/landcover map accuracy was intended to be 85% (ref. 11). However, no estimation of the accuracy, as such, of these maps is available. A more recent study by NRSA[11] estimates the accuracy achieved using IRS multispectral data to be between 79 and 88%. The third category of accuracy deals with preparing a map or printing and is often referred to as the Minimum Mappable Unit (MMU). Different agencies depending upon the requirement, adopt a range of MMUs. The World Conservation Monitoring Centre (WCMC) has adopted for its protected area data base an MMU of 5000 ha for a scale of 1 : 2 million while in USA, for the same

Table 1. Monserud and Leemans (1992) categories of overall map classification agreement for districts of Kerala

Category	District
Good (0.58 0.70)	Idukki
Very Good (0.71 0.85)	Palakkad, Wynaad, Kollam, Pathanamthitta
Perfect/excellent (> 0.85)	Alappuzha, Kottayam, Ernakulam, Kozhikode, Thiruvananthapuram, Malappuram, Thrissur

scale, the unit was 100 ha (ref. 12). In this report, we adopt 1 km^2 as the operational unit for the 1 : 1 million scale and 0.56 km^2 for the 1 : 250,000 scale. By convention, NRSA has used 0.56 km^2 as the MMU. For the comparison of two data sets, however, the scale adopted was 1 : 1 million. Hence, the accuracy involved also is reduced to one km^2.

Accuracy of areal extent of administrative units. In order to cross check the accuracy of areal extent of the 1961 and 1988 maps, areal extent of the 14 districts was compared with that of Govt of India and NRSA estimates. Two major points seem to emerge from such a comparison. Firstly, as the minimum mappable unit is 100 ha (refs 13–15), thematic features and changes in habitat of this dimension would not be represented in analyses. For example, diffuse plantations of sizes less than 100 ha will be underestimated. Similarly, changes in physiognomy of isolated land parcels of size 100 ha will not be represented. Secondly, as there is a limitation due to the scale used, these results would be useful in only macro level planning and in policy formulations rather than in microlevel, site-specific, action-oriented tasks. Thus, at regional scales involving forest division of size varying from a few hundred to several hundred square kilometres, the results of this study would be appropriate and applicable. In fact, a state-wide conservation strategy using the division as a unit is attempted in Prasad *et al.*[6].

Analyses. Initially cross tabulation was done in ERDAS using all values of the maps including '0' values of the background. The vegetation types in 1961 French Institute map and those in 1988 landuse maps were synchronized such that a comparison is possible. Thus the evergreen and semi-evergreen categories in the French Institute maps were merged as also of shrub savanna, woodlands/shrubs into one category of degraded/scrub. All other classifications were merged into non-forest category. The accuracy of areal extent of various non-forest categories was also checked from the NRSA-derived estimates[16]. The estimates are within 5–10% error margin of those of Bureau of Economics[16].

These modified map layers formed the basis for computations of areas, extent of habitats and all other analyses. These include a cross classification or cross tabulation to analyse changes in forest habitats over a 30-year period. The cross tabulation was done in IDRISI

Table 2. Monserud and Leemans (1992) categories of map classification agreement between different habitat categories of various districts of Kerala

District	Deciduous	Degraded/scrub	Evergreen/ semi-evergreen	Plantations	Non-forest
Alappuzha	–	–	–	–	Perfect/excellent
Ernakulam	Very poor	–	Poor	–	Perfect/excellent
Idukki	Fair	Very poor	Very poor	–	Very good
Kollam	Very poor	Fair	Fair	Perfect/excellent	Perfect/excellent
Kottayam	Very poor	Verypoor	–	–	Perfect/excellent
Kozhikode	Very poor	–	Poor	–	Perfect/excellent
Malappuram	None	–	Poor	–	Perfect/excellent
Palakkad	Good	Very poor	Poor	Very good	Perfect/excellent
Pathanamthitta	Poor	Very poor	Fair	Fair	Perfect/excellent
Thrissur	Poor	–	Poor	Poor	Perfect/excellent
Thiruvananthapuram	Poor	–	Fair	–	Perfect/excellent
Wynaad	Good	–	Very poor	Very poor	Perfect/excellent

Table 3. Area (km^2) of forest cover in 1961

District	Deciduous	Degraded/ scrub	Evergreen/ semi-evergreen	Plantation	Non-forest	Total
Alappuzha	0.00	0.00	0.00	0.00	1440.09	1440.09
Ernakulam	178.91	0.00	137.55	0.00	2108.08	2424.54
Idukki	644.08	1281.31	1348.24	0.00	1803.98	5077.61
Kannur	5.31	25.23	159.32	0.00	2778.72	2968.58
Kasargod	6.62	0.00	0.00	0.00	1952.63	1959.25
Kollam	707.53	0.00	223.86	18.75	1582.67	2532.81
Kottayam	84.31	36.11	0.00	0.00	2122.64	2243.06
Kozhikode	174.10	0.00	257.87	0.00	1939.89	2371.86
Malappuram	41.28	0.00	722.35	0.00	2866.39	3630.02
Palakkad	106.63	31.98	883.53	25.35	3383.76	4431.25
Pathanamthitta	641.33	196.81	668.16	41.52	1037.65	2585.47
Thrissur	545.70	0.00	302.95	113.36	2118.39	3080.40
Thiruvananthapuram	295.05	0.00	225.32	0.00	1695.63	2216.00
Wynaad	340.09	0.00	260.38	88.95	1424.14	2113.56
Total	3770.94	1571.44	5189.53	287.93	28254.66	39074.50

4.1. Typically, a cross tabulation is a matrix consisting of a number of cells which correspond to the intersection of different values of two attributes. The two attributes in this case refer to the categories in French Institute map and those of Kerala Landuse Board maps. Each cell contains information relating to how frequently a particular combination of values occur for a given set of observations. The cross tabulation is used in deriving an index of agreement, called Kappa coefficient κ, between different categories or two classifiers[17,18]. Kappa is a scalar measure of agreement between two classifiers. The details of computation, its application in comparing maps and threshold values for categorizing different degrees of agreement are given in Monserud and Leemans[18]. These threshold values of Kappa are adopted in this paper to classify districts as well as individual categories within the district.

Results and discussion

Map classification agreement (Kappa coefficient)

The results of cross tabulation of French Institute map and the landuse maps lead to three-tier classification of all districts. In the scheme of Monserud and Leemans[18] map classification agreement, as many as seven districts

Table 4. Area (km^2) of forest cover in 1988

District	Deciduous	Degraded/ scrub	Evergreen/ semi-evergreen	Plantation	Non-forest	Total
Alappuzha	0.00	0.00	0.00	0.00	1441.44	1441.44
Ernakulam	38.97	28.25	81.35	99.37	2185.17	2433.11
Idukki	1117.43	590.89	837.04	121.83	2439.72	5106.91
Kannur	6.32	0.00	166.86	1.06	2820.00	2994.24
Kasargod	0.00	128.88	66.39	8.79	1802.12	2006.18
Kollam	195.26	59.19	138.41	344.21	1811.19	2548.26
Kottayam	20.03	19.92	0.00	37.01	2160.68	2237.64
Kozhikode	27.54	8.67	117.88	5.64	2212.93	2372.66
Malappuram	462.90	43.91	222.19	119.64	2802.15	3650.79
Palakkad	614.72	335.81	163.58	234.71	3100.25	4449.07
Pathanamthitta	408.50	59.57	587.48	212.10	1323.06	2590.71
Thrissur	348.97	10.39	138.83	384.99	2199.96	3083.14
Thiruvananthapuram	140.61	84.30	135.29	108.15	1759.96	2228.31
Wynaad	673.23	21.34	77.63	48.00	1325.10	2145.30
Total	4054.48	1391.12	2732.93	1725.50	29383.73	39287.76

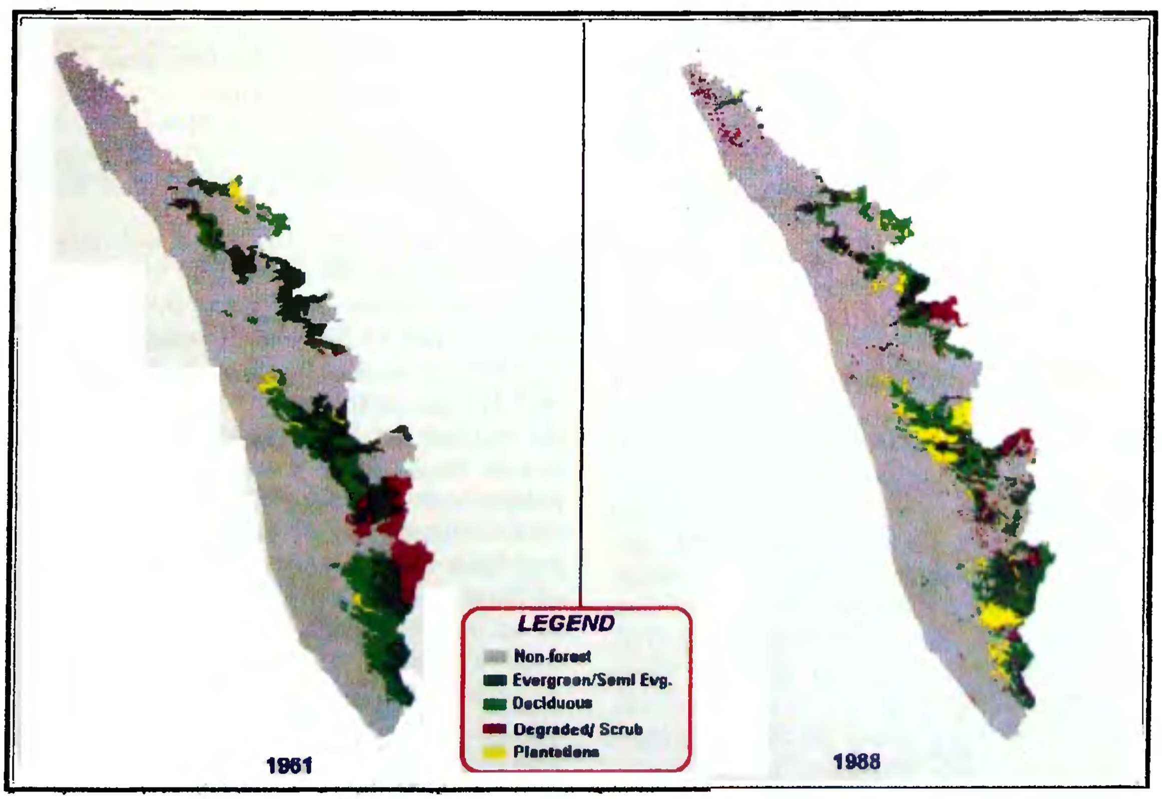

Figure 2. Forest cover of Kerala, 1961 and 1988.

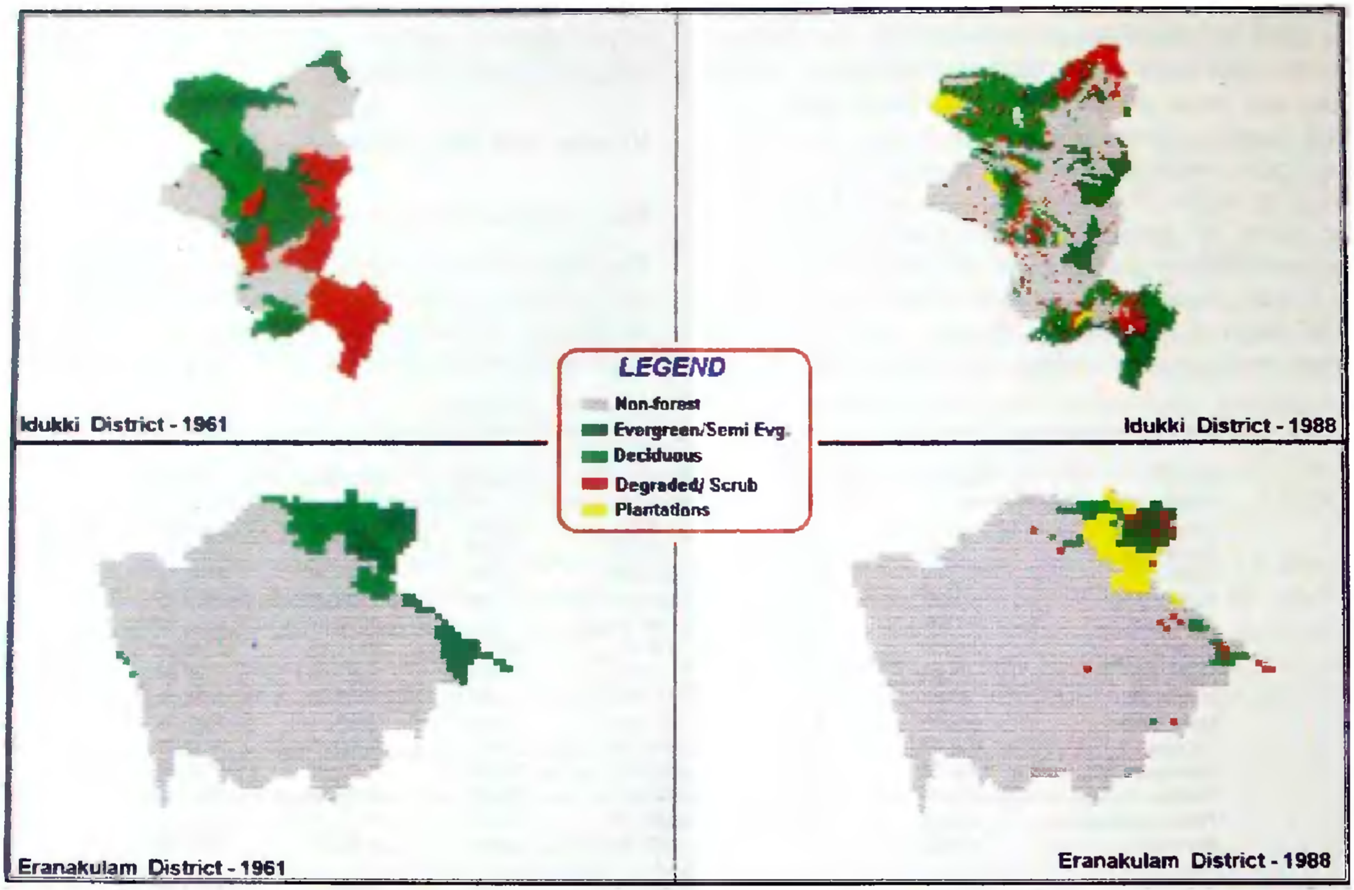

Figure 3. Forest cover Kerala – Idukky and Ernakulam district.

have perfect/excellent agreement (> 0.85) (Table 1). Four districts are classified under very good (0.71–0.85) category. Only Idukki is an exception (0.58–0.70). The result indicates two things. Firstly, the non-forest and forest categories in both maps are well matched and are comparable with a high precision despite the scale differences, interpretation and cartographic methods. Secondly, the habitat changes reported are less due to map errors and more because of actual or plausible transformations of habitat categories. This is in contrast to the results of Menon and Bawa[19] where the overall Kappa was found to range from 0.4 to 0.2 bordering the category poor to fair. This is perhaps more to do with the quality of map data, its compilation and analysis. In a situation where tree crops such as rubber and coconut dominate and often are intermingled, it is very difficult to identify forests and tree crops separately. This identification is made more difficult in small scale mapping. In order to be useful in a variety of environmental applications, it is suggested that the Kappa statistic be at least in the range of 0.58–0.70 (ref. 18). It is seen from Table 2 that among the categories, there is often poor to very poor agreement. It thus appears that there has been a substantial transformation of habitats. However, in the case of Palakkad, Pathanamthitta and Thiruvananthapuram districts, there is fair to good agreement in some categories.

State wide loss of forest cover and habitat changes

Loss of forest cover. The aggregated forest area in all 14 districts over the entire state in 1961 and in 1988 was found to be 10,820 and 9,904 km^2 respectively (Tables 3 and 4). Thus the average annual rate of loss of forest cover was 0.28% over the thirty-year period or 8.4% loss in the entire period. The NRSA study of deforestation for Kerala between 1972–75 and 1982–85 was to be 0.3% per year. A study conducted on 1 : 1 million scale for entire Kerala[20] covering 80 years from 1900s estimated the loss to be highest. A recent study by Menon and Bawa[19] for 19 districts of Western Ghats of Kerala, Karnataka and Maharashtra estimates the loss to be 0.33% per year. The estimates for India and for tropical countries are 9 and 11% respectively[21,22].

Habitat changes. For the entire state, there was a substantial decline of 47% of the evergreen/semi-evergreen habitat and 11% decline in degraded/scrub category. The extent of deciduous forest cover has gone up by 7.5%. The tree plantations (hardwood, softwood, mixed species,

Table 5. Perimeter/area ratios and shape index of habitat categories for different districts of Kerala

District	Evergreen/semi-evergreen 1961	Evergreen/semi-evergreen 1988	Deciduous 1961	Deciduous 1988	Degraded/scrub 1961	Degraded/scrub 1988	Plantation 1961	Plantation 1988
Ernakulam								
Perimeter/area	0.94	1.47	0.88	1.93	0.00	2.84	0.00	0.98
Shape index	3.11	3.53	3.31	3.20	0.00	4.63	0.00	2.81
Idukki								
Perimeter/area	0.49	1.16	0.60	1.17	0.40	1.78	0.00	1.28
Shape index	5.11	9.59	4.29	11.02	4.08	12.26	0.00	4.00
Kollam								
Perimeter/area	0.49	1.49	0.43	1.58	0.00	1.45	1.72	0.88
Shape index	2.05	4.92	3.26	6.05	0.00	3.15	2.11	4.58
Kottayam								
Perimeter/area	0.00	0.00	0.69	2.10	1.54	3.19	0.00	1.85
Shape index	0.00	0.00	1.78	2.56	2.61	3.76	0.00	3.20
Kozhikode								
Perimeter/area	0.98	1.26	0.80	1.58	0.00	3.47	0.00	1.73
Shape index	4.46	3.79	2.96	2.41	0.00	1.96	0.00	1.13
Malappuram								
Perimeter/area	0.47	0.70	1.51	0.89	0.00	2.84	0.00	1.13
Shape index	3.56	2.94	2.74	5.46	0.00	5.55	0.00	3.47
Palakkad								
Perimeter/area	0.61	1.41	1.25	0.94	1.37	0.79	1.55	0.76
Shape index	5.12	4.95	3.65	6.64	2.18	4.04	2.20	3.31
Pathanamthitta								
Perimeter/area	0.35	1.29	0.58	1.74	0.55	2.64	0.95	1.18
Shape index	2.53	8.79	4.17	10.03	2.19	5.44	1.73	4.79
Thrissur								
Perimeter/area	0.65	1.31	0.74	1.01	0.00	2.97	0.94	0.93
Shape index	3.18	4.44	4.85	5.39	0.00	2.56	2.81	5.13
Thiruvananthapuram								
Perimeter/area	0.72	1.87	0.68	1.54	0.00	2.41	0.00	1.44
Shape index	3.05	5.94	3.31	5.27	0.00	6.51	0.00	4.15
Wynaad								
Perimeter/area	1.07	1.11	0.85	0.85	0.00	2.41	0.78	1.68
Shape index	4.88	2.74	4.40	6.21	0.00	3.33	2.07	3.24

bamboo and others) have increased nearly six times the 1961 estimate (Figure 2). This estimate is perhaps minimal due to the scale factor of maps used in the analysis.

Regionwide loss of forest cover and habitat changes

Loss of forest cover. For the northern region comprising of Kozhikode and Malappuram districts, there is a loss of 174 km^2. The central region of Thrissur and Palakkad registered a net increase of 154 km^2. The southern zone of Thiruvananthapuram, Pathanamthitta, Kollam and Kottayam districts has by far lost the largest area of 589 km^2 to non-forest use. Similarly, the 'high altitude zone' comprising of Idukki and Wynaad districts accounted for the loss of 475 km^2 of forest area. It is quite remarkable to note that although the population density has doubled from 354 to over 750 km^2 in the span of 30 years, this has not correspondingly caused the decline of forest cover by a factor of two. However, as will be demonstrated under section, habitat degradation, indicators of habitat degradation point to more than two-fold decline in habitat quality. It is, of course, too simplistic to ascribe the loss of habitat quality with increase of human population alone. The perspective plan for Kerala does not appear to take the loss of forest cover and habitat changes into its overall framework of planning of land resource development. In order to be environmentally compatible, it is time now to incorporate these concerns into a development planning framework.

Habitat changes. While the southern zone has recorded 23% decline in evergreen/semi-evergreen habitat, the highest was found to be in central region (71%). The northern region witnessed 65% decline and the high altitude 43% of this habitat. The deciduous habitat, on the contrary, has witnessed an increase in all regions excepting for south, where it declined by 55%. The north zone witnessed a two-fold increase, the central zone and high altitude zone also increased by 20% and 82% respectively. To a large extent, this increase appears to be at the expense of evergreen/semi-evergreen and to an extent degraded/scrub habitat. The GIS output in Figure 2 indicates the statewide spatial changes. In many of the districts, the changes in evergreen/semi-evergreen habitat are due to substantial increase of plantations.

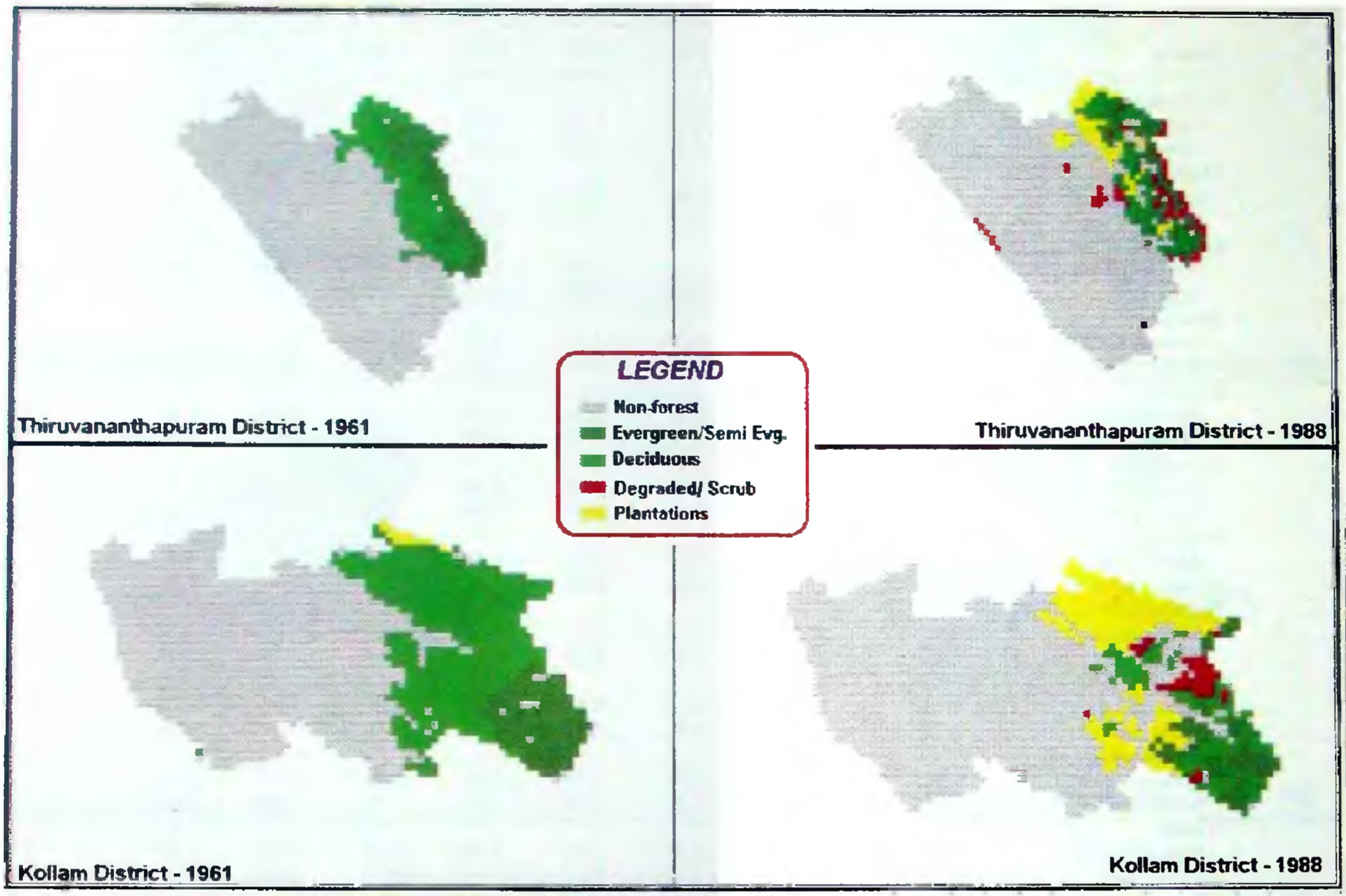

Figure 4. Forest cover of Kerala – Thiruvananthapuram and Kollam districts.

Districtwise loss of forest cover and habitat changes

Loss of forest cover. The three districts with substantial decrease in forest cover are Kozhikode, Kottayam and Kollam. The districts of Palakkad, Wynaad and Malappuram have gained substantially. It is quite possible that subsequent to the construction of hydel projects, most surrounding localities with a history of local deforestation have shown a net gain in forest cover. This was shown to be the case with some of the hydel projects in Idukki.

Habitat changes. While the districts of Wynaad, Palakkad, Malappuram and Idukki (Figure 3) have witnessed substantial gain of deciduous habitat, there is also an equally strong tendency to lose evergreen/semi-evergreen habitat. This indicates the overall anthropogenic pressures appear to affect the evergreen habitat more in northern parts than in southern districts. This is an expected result as the length of dry season increases from 1–2 months in south to 3–4 months in the northern districts[3]. It would be interesting to observe if this effect is aggravated further by size of fragment and history of landuse of the fragment. The enhanced plantation activity is reflected in a substantial increase in area in all the districts. This is particularly so in Kollam (Figure 4), Palakkad, and Wynaad districts. We would, therefore, expect a relatively high degree of habitat degradation in these districts compared to others.

Habitat degradation

The two indices of landscape ecology, viz. perimeter/area and shape index[23] $P/2\sqrt{\pi A}$ of habitat patches are given for each of the 12 districts of Kerala in Table 5. It is apparent that in most districts and in all categories of habitat, excepting for plantations, the two indices show marked increase in the values. This denotes increase of edge effect, an ecologically undesirable influence on most species populations and communities.

Conclusions

The study on habitat transformations in Western Ghats has demonstrated and brought into focus the utility[24] of published spatial data such as the International Vegetation Map and landuse/landcover maps. Besides these maps, historical time series optional remote sensing data such as Landsat, IRS, SPOT and others can be profitably made use of in the assessment of dynamics of landuse/landcover in general[25] and forest vegetation in particular. As there are already a number of studies on forest versus non-forest cover changes, the need of the hour is to focus on various forest habitat categories. Comparing these maps by using Kappa statistic has a number of advantages. First, this is an objective method making pixel by pixel comparison. A useful feature of Kappa statistic is the provision of quantifiable measures of transition between various categories within a map and across maps. These quantities are useful in a variety of studies, ranging from summarizing differences, and complex ecological spatial modelling[26] to global climate research[18], to providing basic data on extant habitats[24].

The habitat transformation may be used in terms of assessment of biodiversity values for a number of taxa for which quantifiable data can be obtained. In addition, impact of humans on each of the component transformation can be assessed and the resulting process can be explicitly incorporated into prioritization of sites and species conservation. The spatial data base for the districts and divisions can be easily made use of by any user. The GIS files were so far ported to a number of other GIS and image processing systems including PC ARC/INFO, ERDAS, Imagine, EASI/PACE and Map and Image Processing System (MIPS).

The assessment of habitat degradation through the use of landscape indices has been shown to be very promising and may, infact, be the required approach in the national forest monitoring programmes. As has been shown conclusively that loss of habitat *per se* may not have direct relationship with growth of human popultion alone, it is all the more essential to try and monitor forest habitat changes using the simple, yet effective, landscape pattern indices.

In addition, a wide variety of spatial data existing on soils, wastelands, wetlands, water resources, along with voluminous tabular data on population, socio-economic data have to be built into an operational meta data base to facilitate a truly integrated and objective assessment of conservation planning.

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