6.1. Introduction

Land cover change is one of the most critical dynamic elements of ecosystems. Tropical forests, which play vital roles as repositories of biological diversity and regulators of global biogeochemical and hydrological cycles (Houghton, 1999; Cairns et al., 2000 and Myers et al., 2000) have undergone rapid land cover changes especially in the last few decades (Bockstael et al., 1995 and Pijanowski et al., 2000). Global estimates show that deforestation in the tropics during 1990-
2000 was 14.2 million hectares per year while reforestation was only 1.9 million hectares, which resulted in a net loss of 12.3 million hectares of forest per year (FAO, 2001). South Asia experienced a negative rate (0.13 percent per annum) of forest cover change, which was approximately half the negative rate of change in the world (0.22 percent per annum) and double the negative rate of change for the whole Asian region (0.07 percent per annum). These trends point out the prevalence of complex and multidirectional changes in forest cover dynamics which could be attributed to local level management measures.

Remote sensing offers an important means of detecting and analyzing temporal changes and since the early 1970s satellite data have been commonly used for change detection studies (Jensen et al., 1993). The use of remotely sensed data for monitoring tropical deforestation and assessing the drivers of deforestation has been operationalised by a range of programmes. Noteworthy programmes include NASA’s (National Aeronautics and Space Administration) Landsat Pathfinder Project on Deforestation in the Humid Tropics (Townshend et al., 1995 and Kalluri et al., 2001) and the TREES (Tropical Ecosystem Environment Observations by Satellite) project (Stibig and Achard, 2003). Such work has demonstrated that satellite remote sensing can provide satisfactory results for regional forest cover mapping and for obtaining up-to-date and uniform estimates of the total forest area in a region. Furthermore, a range of change detection techniques have been developed for monitoring land cover dynamics from remotely sensed imagery (Coppin et al., 2004 and Lu et al., 2004). Such techniques have been used to explore the relationships between shifts in vegetation patterns and factors such as human
activities, natural disturbances and topography (Turner et al., 1996 and Cohen et al., 2002). Moreover, remote monitoring of deforestation as well as successional regrowth has yielded valuable insights into processes such as the dynamism of ecotones, rates of succession, and invasion of weeds, which in turn has provided substantial evidence concerning the drivers of land cover change (Nelson and Holben, 1986; Sader et al., 1990 and Mausel et al., 1993).

The present study was conducted with the aim of critically evaluating the effectiveness of conservation measures since Anamalai Wildlife Sanctuary was declared as protected area in 1976. The key question was whether the declaration of a protected area was sufficient to conserve biodiversity at local scales. Specific objectives were to characterize the land cover in and around the sanctuary, to locate vulnerable areas of land cover change and to identify probable proximate and underlying causes of land cover change in the area in order to refine and prioritise future conservation actions.

6.2. Materials and methods

6.2.1. Imagery

Two suitable cloud-free images were available for this study, spanning the period from before the designation of protected area status to the present. A Landsat Multi Spectral Scanner (MSS) image dated 9th February, 1973 was downloaded from the Global Land Cover Facility (http://glcf.umiacs.umd.edu/) and an IRS P6 LISS III image dated 8th March, 2006 was acquired from National Remote Sensing
Centre (NRSC) Data Center, Hyderabad, India. The Landsat MSS data had a spatial resolution of 80m and four wavebands (0.5 – 0.6, 0.6 – 0.7, 0.7 – 0.8 and 0.8 – 1.1\(\mu\)m) while the LISS-III image had a spatial resolution of 24m and four bands (0.52 – 0.59, 0.62 – 0.68, 0.77 – 0.86 and 1.55 – 1.70\(\mu\)m). The digital number (DN) values of the Landsat MSS and IRS P6 LISS III data were converted into radiance values using the corresponding satellite sensor parameters.

6.2.2. Change analysis

The first stage of the change analysis was to perform a radiometric intercalibration of the first three bands of the Landsat MSS and IRS P6 LISS III images. This was done by identifying spatially homogenous calibration sites in both the images where no landcover changes had taken place. For the calibration sites, radiance values were collected from the two images and a least square regression was performed. The radiance values of the entire MSS image were transformed based on the regression model. The LISS III data, having a spatial resolution of 24m, was resampled to 80 m, the original spatial resolution of MSS data, for further analysis. Since the objective was to study the vegetation condition changes over a period of time, Normalized Differential Vegetation Index (NDVI) images were generated from the Landsat MSS and IRS P6 LISS III data. The NDVI images were examined, mean and standard deviation values were calculated and a thresholding technique (Tunf Fung and Ellesworth, 1988) was applied to separate vegetation from other land cover. Threshold values of ‘k’ standard deviations from the mean was iteratively selected. The ‘k’ value was 0.1 in the first iteration, which was increased in increments of 0.1
in subsequent iterations, until an acceptable ‘k’ value of 0.7 was reached and this was applied to both images. Binary images having values of 0 and 1 representing non-vegetation and vegetation respectively were generated for the two different years. A boolean operation ‘AND’ was applied between the two binary images to identify the unchanged areas. Change due to conversion of vegetation to non-vegetation was defined as a negative change while non-vegetated area converted into vegetated area was defined as positive change. The positive change area was determined by subtracting the unchanged areas from the 2006 dataset and subtracting the same area from the 1973 data produces negative change. The detailed methodology is explained in Fig. 2. The derived positive and negative change images were filtered using neighborhood majority function through a 3x3 kernel in order to reduce errors from geometric correction. The filtered images were overlaid on the original images in order to visually confirm the changes in land cover from one category to other. A vector layer depicting land cover change was generated and area statistics calculated.
Fig. 6.1. Flow diagram depicting the details of change detection technique followed in the study.

1. Geocorrected MSS Data
2. Geocorrected LISS III Data
3. MSS DN to Radiance Conversion
4. LISS III DN to Radiance Conversion
5. Image Regression
6. MSS comparable radiance with respect to LISS III radiance
7. NDVI MSS
8. NDVI LISS III
9. Delineation of Forest/Non forest area by Thresholding Techniques.
10. Mask (Binary Map) for Time T1
11. T₂ > T₁
12. Mask (Binary Map) for Time T2
13. Boolean AND
14. No Change Areas
15. (Mask (T1) – No change Area) > 0
16. Negative Change (Vegetation → other landcover)
17. Change Map
18. (Mask (T2) – No change Area) > 0
19. Positive Change (other landcover → Vegetation)
6.3. Results

The land cover change map and area matrix are given in Fig. 6.2 and Table 6.1 respectively. An area of 1046 ha undisturbed (intact) forest formations was converted into disturbed forest formations from 1973 to 2006. Other important transitions were from undisturbed forest to non forest categories, with 19 ha being converted into plantations, 28 ha to agriculture/fallow/barren lands and 91 ha to water bodies. A significant positive change was also observed from 1973 to 2006, as an area of 1183 ha disturbed forest formations was converted to intact/undisturbed forest formations. The term intact/undisturbed forest formation is relative here. Actually it is a successional stage recovering from a previous disturbances or secondary forest. Grasslands have undergone several transitions, with 1558 ha being converted into plantations and another 29 ha converted into agriculture and fallow lands. Some of the plantations (197 ha) were converted to fallow lands while the inverse (104 ha) has happened in some other areas.
Table 6.1. Land use/Land cover changes (area in hectare) in Indira Gandhi Wildlife Sanctuary from 1973 to 2006.

<table>
<thead>
<tr>
<th></th>
<th>UIFF</th>
<th>DSFF</th>
<th>GL</th>
<th>PLN</th>
<th>AFB</th>
<th>WB</th>
</tr>
</thead>
<tbody>
<tr>
<td>UIFF</td>
<td>-</td>
<td>1046</td>
<td>0</td>
<td>19</td>
<td>28</td>
<td>91</td>
</tr>
<tr>
<td>DSFF</td>
<td>1183</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>GL</td>
<td>0</td>
<td>155</td>
<td>-</td>
<td>1558</td>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>PLN</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>197</td>
<td>29</td>
</tr>
<tr>
<td>AFB</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>104</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>WB</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

UIFF - Undisturbed/Intact Forest Formation, DSFF - Disturbed/Secondary Forest Formations, GL – Grasslands, PLN – Plantations, AFB - Agriculture/Fallow/Barren Lands, WB - Water bodies

6.4. Discussion

The primary aim of the study was to assess the effectiveness of conservation measures in protecting the biodiversity at local scale. The result indicated that the natural forest cover in the area during the study period was degrading at a rate of 0.07% annually while regenerating at a rate of 0.03% per year. This resulted a negative rate of change of 0.04% per year. This was far lower than previous estimates available for the region. For example, Menon and Bawa (1997) estimated an annual rate of decline of 0.57% in the whole Western Ghats during 1920 – 1990 and Jha et al., (2000) estimated a decline of 1.16% per year during the period of 1973–1995 in southern Western Ghats. Prasad et al., (1998) estimated an amount of 0.9% (during 1961–1988) in the Kerala part of Western Ghats. These studies, conducted on a regional basis, incorporated largely unprotected areas. Hence, the present results demonstrate that designation of protected area status has been
effective in reducing rates of degradation and deforestation, though current conservation strategies within the Indira Gandhi Wildlife Sanctuary may be in need of some refinement.

Fig. 6.2. Map showing change areas from 1973 to 2006 in Indira Gandhi Wildlife Sanctuary, India.

The next step was to understand the proximate and underlying causes of land cover change. Broadly speaking, two major and divergent trends, degradational and successional, were observed in the study. The degradational trend indicators are the transformation of undisturbed forest to disturbed forest and other non-forest land covers. The spatial location of land cover change indicated that most of these transformations have occurred on the fringes of the sanctuary or near to
settlements inside the sanctuary. These changes could generally be attributed to four clusters of causes: livelihood dependence of local people, infrastructure development, agricultural expansion and forestry operations, at the proximate level.

A number of villages on the fringes of the sanctuary mainly depend on the sanctuary for their livelihood. The population in these villages is over one hundred thousand and the main occupation is agriculture. In addition, there are about 36 tribal settlements, two privately owned tea plantations and one area of revenue land inside the sanctuary. It has been observed that there is a high population growth rate in these settlements and their economic condition is far below satisfactory (Sajeev et al., 2002). The major demands of the population on the forest of the sanctuary are timber for building construction, small timber for agricultural implements, huts and fencing purposes, firewood for domestic consumption, grasses for rearing goats and cattle and for roofing of houses. In addition, infrastructure developments like construction and maintenance of roads and buildings for the support of people who are residing inside the sanctuary and associated movement of machinery are contributing to the degradation of a system which was already under pressure. Another major threat is grazing. The tribes settled in the dry forests on the eastern side maintain large stocks of cattle, buffalo, sheep, goats, horses and ass. There has been an alarming increase in the number of livestock that graze in the forests (Kumar et al., 2002) and this is probably playing an important role in the degradation of undisturbed or intact forest.
Agriculture is the most common occupation of the villagers. Towards higher elevation in the Valparai region, people are more occupied with the plantation crops of tea, coffee and cardamom, whereas the north-eastern portion in the lower reaches is dominated by rice, ground nut, sorghum, ragi, tapioca and banana cultivation. Before the declaration of protected area status, villagers used to cultivate millet and tubers using a shifting cultivation method. The restriction on shifting cultivation has caused an expansion of cultivation near to settlements, observed in the present study as an area increment of 0.6 km$^2$ in agriculture/fallow/barren lands since 1973 at the expense of forest and grasslands. Geist and Lambin (2002) made a similar observation that agricultural expansion is, by far, the most important land use change associated with deforestation globally. Underlying driving forces often underpin the more obvious or proximate causes of tropical deforestation (Geist and Lambin 2001). In this respect, the land cover change in Anamalai Hills can be seen as resulting from a complex set of social, political, economic and cultural variables. The high population growth rate and the associated pressure on the sanctuary is one of the major reasons for land cover change in the area. It has been widely recognized that population growth or pressure is a significant driver and often the primary underlying cause of deforestation (Wibowo and Byron, 1999; Sandler, 1993 and Vanclay, 1993). However, within the sanctuary a whole series of other factors have been influential in modifying patterns of land use, such as the drastic changes that have been taken place in tribal social customs (Sajeev et al., 2002). Importantly, there have been uncoordinated development policies of the various government agencies which
have conflicted with conservation efforts. Notable examples are the provision of grants for goat grazing and lemon grass collection while these activities are prohibited within the sanctuary.

Positive land cover changes or successional trends in vegetation at the study site were indicated by the conversion of disturbed forests and plantations to the undisturbed forest category which was observed particularly in the western part of the sanctuary. This is likely to have resulted from the prevention of shifting cultivation in the protected area since 1976, with previously disturbed sites undergoing the re-establishment of forest vegetation. The abandonment of teak and coffee plantations and the efforts of the forest department to plant indigenous species as well as natural regeneration, a high level of protection and favourable climatic conditions have also contributed to the positive land cover changes. This provides some indication of the natural resilience of the system even after the prolonged human disturbances.

6.5. Conservation Implications

There is a need to support successional indicators while controlling degradational indicators. Increasing the level of protection especially in vulnerable areas should be a priority for conservation. Increasing the pace of planting of indigenous species in abandoned plantations could considerably enhance the positive land cover changes. At the same time, it is essential to reduce the livelihood over-dependence of people from outside and inside the sanctuary on forest. Small scale encroachments and agriculture expansion should be prevented. Sustainable
infrastructure development by different government agencies should be coordinated and monitored by a single nodal agency.

6.6. Chapter summary

Land cover change assessment for a period of 33 years helped to identify the rates and characteristics of land cover transformations. Two major and divergent trends, degradational and successional, were observed in the study. The degradational trend was indicated by the transformation of undisturbed forest to disturbed forest and other non-forest categories. These changes can be attributed to a number of causes, principally livelihood dependence, agricultural expansion and infrastructure development resulting from population growth in and around the area and uncoordinated policies of the different government agencies. The positive successional changes resulting from protection of the area showed the resilience of the system even after prolonged disturbances on vegetation cover. The observed degradational transitions exceed the rates of successional changes. Hence, the sanctuary appears susceptible to continuing disturbances under the current management regime, however, the impacts of such processes are substantially lower than in surrounding unprotected areas.

6.7. Reference


