2.1. Introduction

Ecological systems do not exist as discrete units but represent a continuum on an environmental gradient consisting of different land cover types in the form of landscapes. Landscapes represent a mosaic of interacting ecosystems in relatively large to very large areas consisting of patches of land use and land covers (Forman and Godron, 1986). High quality information on the extent and distribution of land cover types is an essential prerequisite for management of landscape. It is one of
the easily measured indices to assess the effects of changing environmental conditions.

An underlying assumption of many forest ecology and forestry practices is that vegetation communities are largely influenced by the dominant species in an association, and that understanding the distributions of the largest, most abundant woody species will lead to an understanding of vegetation communities and their functional role as a whole (Eyre, 1980). These functional groups are defined as groups of species either exhibiting similar responses to an environment or having similar effects on major ecosystem processes (Kelly and Bowler, 2002 and Lavorel and Garnier, 2002). Such groups are considered to be a powerful link bridging the gap between plant physiology and ecosystem processes (Diaz and Cabido, 1997), and provide a promising framework for predicting ecosystem response to human-induced global changes (Craine et al., 2001 and Lavorel and Garnier, 2002).

Scaling down of vegetation communities or functional groups to species level is another concern for ecologists and ecosystem analysts as these are the scales on which species interact with each other and with their changing environment. Global patterns of species diversity are well documented and reasonably understood for vascular plants and vertebrates (Gaston, 2000). For smaller scales, such as 1 m² or 1000 m², it is impossible to answer seemingly trivial questions such as “What is the mean species density?” or “Which are the most frequent taxa?” (Dengler, 2009). Therefore, the present study aims to identify the major land cover types in the Anamalai hills and to characterize the compositional
attributes such as species richness, dominant species, stand density and species diversity in the area.

2.2. Materials and Methods

2.2.1. Land cover mapping

An IRS P6 LISS III image dated 28th March, 2006 was acquired from National Remote Sensing Centre (NRSC) Data Center, Hyderabad, India. IRS P6 LISS III image have a spatial resolution of 24 m and four bands (0.52 – 0.59, 0.62 – 0.68, 0.77 – 0.86 and 1.55 – 1.70µm). The image was geometrically corrected with respect to Enhanced Thematic Mapper (ETM+) satellite data based on 1st order polynomial regression between ground control points (RMSE<0.5 pixel) to compute the coefficients for two co-ordinate transformation equations, and registered to the UTM projection. Based on the knowledge of the data and ground truth information, nine different land cover classes were identified in the study area. Parametric signatures were used to train a statistically based (e.g. mean and covariance matrix) classifier to define the classes. Training sites were digitized within ERDAS Imagine (ERDAS, 2006), using the AOI tools. The inquire cursor was used to identify a single pixel (seed pixel) that represents the training sample then neighbours to the seed pixel were added to the training sites. After several iterations with different criteria, the maximum size of area (geographic constraints) and spectral Euclidian distance were limited to 500 pixels and 10 respectively. After the signatures were defined, the image was classified using the maximum likelihood parametric rule. Accuracy of the classification was tested using overall accuracy, producer’s accuracy, user’s accuracy and Kappa statistics (Congalton, 1991). Comparison of classified image
with reference data was done using an accuracy assessment cell array. The GPS points collected during the field survey have been used as reference data. The reference points were imported to cell array after making the projection parameters identical. These reference values were compared to the class values of the classified image. Accuracy report was generated with overall accuracy, producer’s accuracy, user’s accuracy and Kappa statistics.

2.2.2. Phytodiversity assessment

A stratified transect survey was conducted in the Anamalai hills during the period of 2005-2006. The strata were delineated by taking into consideration of the long term climatic observations and altitudinal variation of the study area. Though there were a few weather stations scattered over the area, the datasets available from these stations were a maximum of five years. Therefore, the present study used a global database, called WORLDCLIM, which is a 50 year average datasets (see the other characteristics of the database in Hijmans et al., 2005). The topographic informations were derived from SRTM (Shuttle Radar Topographic Mission) data. The sample spacing of SRTM was 3 arc seconds (90 m) while the vertical accuracy was ± 16 m. The SRTM digital elevation model was placed over climatic data to study the changes in climatic parameters with respect to elevation. Four strata were delineated and transects sampling was conducted in these strata. The transect length was 2 km in most cases. Circular plots of 10 m radius (plot size – 314 m²) were laid on every 200 m interval along transects. In each plot, all woody plants with ≥ 30 cm GBH (Girth at Breast Height i.e., 1.3 m from the ground) were identified at species level, counted individuals and measured GBH using a tape. A
total of 19 transects (thirteen 2 km transects + six 1 km transects) with 179 sampling plots were surveyed. In addition, 27 sampling plots have been collected randomly especially in shola forest and evergreen patches since one or two kilometer continuous stretch was not available for these habitats.

The data were quantitatively analysed for density, frequency and abundance following Curtis and McIntosh (1950). The relative values of density, frequency and abundance were determined as per Philips (1959). These values were summed up to get Importance Value Index (IVI). For calculating diversity of the area, two indices were used in addition to simple species richness (number of species). The first one was Shannon-weiner diversity index and the second was Simpson diversity index. The later was calculated from Simpson dominance index.

**Frequency**

Frequency denotes the homogeneity of distribution of various species in the ecosystem. It was calculated as follows and expressed in percentage.

\[
\text{Frequency} = \frac{\text{No. of quadrats in which a species occurred}}{\text{Total number of quadrats studied}} \times 100
\]

The species which is well distributed and have a chance of being recorded in any part of the ecosystem, will have frequency 100 %. While a species which is restricted to certain areas will be encountered in low frequency value.

**Abundance**

Abundance of a species is determined as the number of individuals per quadrat.

\[
\text{Abundance} = \frac{\text{Total number of individuals of the species}}{\text{No. of quadrates in which the species occurred}}
\]
Density

Density is defined as the number of individuals of a species in a unit area and is an expression of the numerical strength of a species in a community. From the sampling data the density was calculated as follows:

\[
\text{Density} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats studied}}
\]

Relative density

Relative density (RD) is the study of numerical strength of a species in relation to total number of all species and is calculated as

\[
\text{Relative Density} = \frac{\text{Number of individuals of species}}{\text{Number of individuals of all species}}
\]

Basal area and Relative Basal Area

The average basal area and the relative basal area was calculated out of the average diameter of the stem at breast height using the following formulae:

\[
\text{Basal area} = \frac{(\text{GBH})^2}{4\pi}
\]

\[
\text{Relative Basal Area} = \frac{\text{Total basal area of individuals}}{\text{Total basal area of all species}} \times 100
\]

Importance Value Index (IVI)

Importance Value Index provides an overall importance of a species in a community. It is the sum of Relative Density, Relative Basal area and Relative Frequency for each species involved. It is assessed by the following formula:

Importance Value Index = Relative Density (RD) + Relative Frequency (RF) + Relative Dominance
Species richness

Species richness is the oldest and simplest concept of species diversity. It is the number of species in the community. McIntosh (1967) coined the name *species richness* to describe this concept.

Shannon-Weiner Index

The species diversity of the study area was calculated by Shannon-Weiner Index (Shannon and Weiner, 1949) as given below:

\[ H' = -\sum p_i \ln p_i \]

where \( H' \) is the measure of diversity, \( p_i \) is the proportion of the total sample belonging to the \( i^{th} \) species.

Simpson indices (Dominance and diversity)

The concentration of dominance was determined by Simpson’s index (1949) as given below:

\[ D = \sum p_i^2 \]

where \( D \) is the Simpson index of dominance and \( p_i \) is the proportional individuals of species \( i \) in the community.

To convert this probability to a measure of diversity, the following formula is used.

\[ 1 - D = 1 - \sum p_i^2 \]

where \( 1 - D \) is Simpson’s index of diversity.
2.3. Results

2.3.1. Land cover mapping

The analysis showed that the area is dominated by deciduous forest (487.6 km\(^2\)) and evergreen forest (230.2 km\(^2\)) (Fig. 2.1). The nine land cover classes, their area statistics and estimated classification accuracy are given in Table 2.1. The pristine grasslands, a particular feature of the hills, covered an area of 86 km\(^2\). In addition to natural vegetation types, the other land cover types in the area are plantations, agriculture areas and reservoirs, which altogether contributed an area of 108.9 km\(^2\) (11.2%). Overall classification accuracy was 83% and the Kappa statistic was 0.79. The lowest producer’s accuracy is observed for tropical thorny scrub forest (58.8%) followed by montane wet temperate forest (66.7%). In case of user’s accuracy, the lowest is reported for teak plantations (69.2%) followed by tropical deciduous forest (75.9%).
2.3.2. Phytodiversity assessment

About 169 tree species were found in the sampling. The distribution of sample points with other compositional attributes in different vegetation types is given in Table 2.2. Evergreen forest showed maximum number of species. The stand density was higher at shola forest while average basal area was higher in semi-evergreen forest. Both the diversity indices (Shannon and Simpson) showed that evergreen forest was highly diverse in comparison with other forest types, whereas the dominance in the evergreen forest was lower. The highest dominance was observed in dry deciduous forest followed by moist deciduous forest. *Vateria indica*
was the dominant species in the study area, followed by *Maesa indica, Anogeissus latifolia, Nephelium longana* and *Croton oblongifolius*. The top ten dominant species in the sanctuary is given in Table 2.3. In addition, the sanctuary is a hub of many endemic species. The major ones include *Aglaia tamilnadensis, Dysoxylum malabaricum, Myristica malabarica, Syzigium malabaricum* and *Vernonia travancorica*. Population density of tree species across girth class interval showed that around 34.3% of individuals belonged to 30-60 cm gbh (Table 2.4). The highest number of species was also observed in the same category. The study area represents typical mature stands with good regeneration.

**2.4. Discussion**

**2.4.1. Land cover mapping**

The distribution of vegetation was according to the prevailing environmental conditions in the area. The western part of the study area, where high amount of rainfall available, is characterized by luxurious rainforest whereas the drier parts in east is characterized by deciduous forest. In addition to this common trend, the local distribution of vegetation communities was a function of topography of the area. The lower rainfall (<800 mm) and lower elevation (<400 m) areas in the Amaravathi and Udumalpet ranges contain scrub forests; the medium altitude ranges around Upper Aliyar, Kadamparai and Topslip are characterized by deciduous forests; the upper altitude ranges (> 800m) and high rainfall areas like Varagaliar, Panathiar and Anakunthi are characterized by wet evergreen forests. The slopes in the mountainous areas (>1500m) support typical wet temperate
forest (shola forest), whereas tops of the mountains are characterized by extensive stretches of grasslands.

Table 2.1. Area statistics of major land cover types and their classification accuracy in Indira Gandhi Wildlife Sanctuary, India (Area statistics is derived from the IRS P6 LISS III data dated 28th March, 2006).

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Land cover Type</th>
<th>Area (Sq. km)</th>
<th>Area (%)</th>
<th>Producer Accuracy</th>
<th>User Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tropical Evergreen Forest</td>
<td>230.2</td>
<td>23.8</td>
<td>87.5%</td>
<td>89.4</td>
</tr>
<tr>
<td>2</td>
<td>Montane wet temperate forest</td>
<td>21.8</td>
<td>2.2</td>
<td>66.7</td>
<td>83.3</td>
</tr>
<tr>
<td>3</td>
<td>Tropical Deciduous Forest</td>
<td>487.6</td>
<td>50.3</td>
<td>90.0</td>
<td>75.9</td>
</tr>
<tr>
<td>4</td>
<td>Thorn Scrub Forest</td>
<td>34.3</td>
<td>3.5</td>
<td>58.8</td>
<td>76.9</td>
</tr>
<tr>
<td>5</td>
<td>Grasslands</td>
<td>85.8</td>
<td>8.9</td>
<td>70.0</td>
<td>95.5</td>
</tr>
<tr>
<td>6</td>
<td>Teak Plantations</td>
<td>31.3</td>
<td>3.2</td>
<td>75.0</td>
<td>69.2</td>
</tr>
<tr>
<td>7</td>
<td>Tea Plantations</td>
<td>30.2</td>
<td>3.1</td>
<td>100.0</td>
<td>84.6</td>
</tr>
<tr>
<td>8</td>
<td>Agriculture and Fallow lands</td>
<td>36.5</td>
<td>3.8</td>
<td>84.6</td>
<td>91.7</td>
</tr>
<tr>
<td>9</td>
<td>Water bodies</td>
<td>10.9</td>
<td>1.1</td>
<td>100.0</td>
<td>90.0</td>
</tr>
<tr>
<td></td>
<td>Total Area</td>
<td>968.6</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall Classification accuracy - 82.67
Overall Kappa statistics - 0.79
Table 2.2. The different compositional attributes such as species richness, diversity indices, dominance index, stand density (per hectare) and average basal area (per hectare) with respect to vegetation types in Anamalai wildlife sanctuary, India

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Evergreen</th>
<th>Shola</th>
<th>Semi evergreen</th>
<th>MDF</th>
<th>DDF</th>
<th>Thorny Scrub</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of plots</td>
<td>30</td>
<td>11</td>
<td>53</td>
<td>38</td>
<td>34</td>
<td>40</td>
</tr>
<tr>
<td>No. of tree species</td>
<td>81</td>
<td>17</td>
<td>55</td>
<td>32</td>
<td>18</td>
<td>27</td>
</tr>
<tr>
<td>Shannon diversity index</td>
<td>4.175</td>
<td>3.000</td>
<td>3.450</td>
<td>3.214</td>
<td>2.982</td>
<td>3.121</td>
</tr>
<tr>
<td>Simpson index of dominance</td>
<td>0.021</td>
<td>0.071</td>
<td>0.054</td>
<td>0.075</td>
<td>0.093</td>
<td>0.059</td>
</tr>
<tr>
<td>Simpson index of diversity</td>
<td>0.979</td>
<td>0.929</td>
<td>0.946</td>
<td>0.925</td>
<td>0.907</td>
<td>0.941</td>
</tr>
<tr>
<td>Stand density/ha.</td>
<td>347</td>
<td>446</td>
<td>276</td>
<td>192</td>
<td>212</td>
<td>69</td>
</tr>
<tr>
<td>Avg. Basal area/ha.</td>
<td>31.4</td>
<td>41.4</td>
<td>62.3</td>
<td>27.2</td>
<td>13.2</td>
<td>2.13</td>
</tr>
</tbody>
</table>

The occurrence of plantations in the area dates back to the end of 18\textsuperscript{th} century. About 150 years ago, these hills contained undisturbed and contiguous tracts of forest, but they were opened for plantations during the last century (Congreve, 1938 and Sundararaju, 1987). The medium elevation and medium rainfall areas in the Top slip plateau were used for teak plantations and higher elevation and rainfall areas in the Valparai Plateau were used for tea plantations. This history is reflected in the extensive distributions of plantations now observed in the vegetation type map. In addition, there are about 36 tribal settlements inside the sanctuary and agriculture is the most common occupation for these villagers.
The lower producer’s accuracy of thorny scrub forest and shola forest could be attributed to their similarity in species composition with deciduous and evergreen forests respectively. Since teak is deciduous tree, the misclassification and thereby lower user’s accuracy was obvious for teak plantations and deciduous forest. Most of the water body pixels were classified accurately.

Table 2.3. Top ten dominant species in Anamalai wildlife sanctuary, Western Ghats, India (based on Importance Value Index)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Species</th>
<th>Relative Density</th>
<th>Relative Frequency</th>
<th>Relative Dominance</th>
<th>IVI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Vateria indica</em></td>
<td>1.66</td>
<td>1.30</td>
<td>7.69</td>
<td>10.66</td>
</tr>
<tr>
<td>2</td>
<td><em>Maesa indica</em></td>
<td>4.90</td>
<td>3.08</td>
<td>2.29</td>
<td>10.28</td>
</tr>
<tr>
<td>3</td>
<td><em>Anogeissus latifolia</em></td>
<td>3.91</td>
<td>2.49</td>
<td>3.26</td>
<td>9.66</td>
</tr>
<tr>
<td>4</td>
<td><em>Nephelum longana</em></td>
<td>2.58</td>
<td>2.14</td>
<td>3.17</td>
<td>7.89</td>
</tr>
<tr>
<td>5</td>
<td><em>Croton oblongifolius</em></td>
<td>3.31</td>
<td>2.37</td>
<td>2.02</td>
<td>7.70</td>
</tr>
<tr>
<td>6</td>
<td><em>Syzygium cumini</em></td>
<td>1.59</td>
<td>1.78</td>
<td>2.72</td>
<td>6.09</td>
</tr>
<tr>
<td>7</td>
<td><em>Persea macrantha</em></td>
<td>1.79</td>
<td>2.49</td>
<td>1.75</td>
<td>6.03</td>
</tr>
<tr>
<td>8</td>
<td><em>Vitex leucoxylon</em></td>
<td>3.31</td>
<td>1.66</td>
<td>0.92</td>
<td>5.90</td>
</tr>
<tr>
<td>9</td>
<td><em>Vitex altissima</em></td>
<td>1.66</td>
<td>2.25</td>
<td>1.98</td>
<td>5.89</td>
</tr>
<tr>
<td>10</td>
<td><em>Syzygium caryophyllatum</em></td>
<td>2.12</td>
<td>1.78</td>
<td>1.94</td>
<td>5.84</td>
</tr>
</tbody>
</table>
Table 2.4. Population structure of tree species along girth class frequencies

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>GBH class (cm)</th>
<th>No. of Species</th>
<th>No. of Individuals</th>
<th>% of individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30-60</td>
<td>125</td>
<td>518</td>
<td>34.3</td>
</tr>
<tr>
<td>2</td>
<td>60-90</td>
<td>99</td>
<td>363</td>
<td>24.1</td>
</tr>
<tr>
<td>3</td>
<td>90-120</td>
<td>74</td>
<td>170</td>
<td>11.3</td>
</tr>
<tr>
<td>4</td>
<td>120-150</td>
<td>61</td>
<td>111</td>
<td>7.4</td>
</tr>
<tr>
<td>5</td>
<td>150-180</td>
<td>48</td>
<td>85</td>
<td>5.6</td>
</tr>
<tr>
<td>6</td>
<td>180-210</td>
<td>30</td>
<td>42</td>
<td>2.8</td>
</tr>
<tr>
<td>7</td>
<td>210-240</td>
<td>22</td>
<td>28</td>
<td>1.9</td>
</tr>
<tr>
<td>8</td>
<td>240-270</td>
<td>11</td>
<td>14</td>
<td>0.9</td>
</tr>
<tr>
<td>9</td>
<td>&gt;270</td>
<td>24</td>
<td>43</td>
<td>2.8</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>169</td>
<td>1509</td>
<td>100</td>
</tr>
</tbody>
</table>

2.4.2. Phytodiversity assessment

The purpose of the sampling methodology adopted in the present study was to address the heterogeneity of the area and to avoid problems from the edge effect. Therefore, a combination of line transect with circular plot is taken for the study. Areas are never uniform, and organisms are usually distributed somewhat patchily even in the same climatic and topographic stratum. This distribution could be depending upon a number of other factors such as soil profile, type of parent material, water holding capacity and organic content. The transect sampling was adopted for representing these gradients of diversity and heterogeneity. The
circular plots enabled the smallest possible edge for a given area i.e., edge to area ratio is minimal in circular plots (Krebs, 1989).

Thirteen transects were of 2 km length, and six were of 1 km length. 1 km transects were selected in those areas where there are steep slopes (difficult to climb) or elephant movements. 206 sample plots with an area of 0.065 km$^2$ (which is approximately 0.001 of the total area) were surveyed. A sampling effort of 0.01% could be considered as ideal sampling. But by considering the terrain, extent of area, effort and cost, the sampling was limited to 0.001% as reported by Roy et al. (2002 and 2007).

Shannon-weiner and Simpson diversity indices indicated high diversity in the area in similar to many other places (Ayyappan and Parthasarathy, 1999, Srinivas and Parthasarathy, 2000). Tree density (stand density) in evergreen forest was 347 trees/ha which was slightly lower than the mean tree density (419 trees/ha) observed for Western Ghats closed-canopy evergreen forest (Ghate et al., 1998).

The lowest basal area observed for thorny scrub forest was in correspondence with the similar trend in Mudumalai wildlife sanctuary (Joseph et al., 2008). The size class distributions of the stems were found to exhibit negative exponential or inverse J curve, indicating a good regenerating population (Richards, 1996), a case commonly reported from Western Ghats biodiversity hotspot. For example, Ganesh et al. (1996) in Kakachi, Parthasarathy (2001) in Sengaltheri, and Pascal and Pelissier (1996) in Uppangala noted similar trends in their respective study areas.
2.5. Chapter summary

Land use/land cover assessment indicated that the area is dominated by deciduous forest followed by evergreen forest. Overall classification accuracy observed was 83%. The distribution of vegetation was according to the prevailing climatic and topographic gradients existing in the area. The presence of plantations and tribal settlements reflected the history of the landscape. Characterization of compositional attributes such as species richness, stand density, species diversity, dominance and basal area yielded valuable information about the organization of this tropical forest.

2.6. Reference


ERDAS. 2006. *ERDAS iamgine tour guides*. Leica Geosystems Geospatial Imaging, LLC.


