CHAPTER – VI
LANDUSE AND LAND COVER ANALYSIS

6.1 Introduction

The landuse and land cover pattern of an area is regulated by natural and socio-economic factors that are often controlled by humans including the alterations made in the surface of earth (Lambin et al., 2001). Over the period, land is becoming a limited resource due to vast pressure in agricultural and demographic development. Hence, understanding the processes behind LULCC is vital for both scientific and policy actions (David et al., 2001). For systematic assessment, the LULC data is required to analyze the landscape dynamics and associated problems for maintaining the ecosystem in a sustainable way. This information will support in observing the dynamics of LULC under immense population pressure. Moreover, the quantum of change in utilizing the land resources is essential for proper planning and management.

Traditionally, the method of monitoring landuse and land cover changes is based on field study (surveying) combined with large scale aerial photography, which is often time consuming, exhaustive and expensive. Recently, remote sensing technology has gained its application in regional as well as in global scales. Constant upgradation in methodology, software development and data processing made this tool an efficient system for providing reliable information on various natural resources. Furthermore, an integrated remote sensing (RS) and GIS approach can efficiently deal with the spatio-temporal information related to LULC change. It is well recognized in the scientific realm and is considered as an effective tool in quantifying LULCC (Yeh & Li, 1999).

The landuse system is extremely dynamic and substantial transformation occurs due to changing socio-economic and natural environment that may lead to unfavorable effects on the fragile environment. The change in landuse and land cover of an area can
adversely affect the water and energy balance, which directly influence the climatic condition in all scales. Besides, its implications on environmental sustainability, LULC change can also affect the food security of the region. For example, conversion of agriculture land to settlement may become a threat to future food security (Brown, 1995). Therefore, understanding the trends in land use change in relation to the driving factors will provide essential information on land use planning and sustainable management of resources (Turner et al., 1995).

In India, the pace of urban population is increasing day by day with 22.5 million in 1991 to 35 million in 2005 (Chauhan & Nayak, 2005). Such rate of urban growth leads to the transformation of fertile lands to settlements and other recreational land for human use. Moreover, the same phenomenon is applicable at a basin scale where life is supported through various biogeochemical cycles. The population pressure and climatic variability affects the LULC pattern in the Tamiraparani sub-basin. The twin cities of Tirunelveli and Palayamkottai have been expanding considerably without even sparing the agricultural lands. The climatic variability and failure of monsoon also affects the productivity of the study area that can induce significant soil erosion and water quality problems in different land use conditions. The present study is designed to examine the LULCC in the Tamiraparani sub-basin and it describes the result of LULCC classification in the study area derived from multi-temporal Landsat ETM+ imageries of 30 meter resolution (1992, 2002, and 2012). The data and methods used for LULC classification and processing have been discussed in the methodology section.

6.2 Results

6.2.1 Landuse and Land cover distribution

The landuse and land cover distribution of six landscape types for the year 1992, 2002, and 2012 are shown in figure 6.1. The geospatial extent in square kilometer and
area coverage in percent for the study area is shown in Table 6.1 and its graphical representation is also shown in the figure 6.2 and 6.3. The classified landuse types in the study area are agricultural land, barren land, fallow land, forest, settlement, and water bodies. The details of these landuse types are discussed below.

6.2.1.1 Forest Land

Forest refers to the land that covers more than 10 percent of the area or more than 0.5 hectares with tree canopy and able to reach a minimum height of 5 m. They can be determined by the presence of trees and the absence of other landuses. In the study area, the forest landuse is the most dominant landscape with an average terrestrial coverage of 36% (Table 6.1). They are semi-evergreen in nature and being a reserved forest with strict forest management practice, the forest land has been noticed with a marginal increase in its coverage area. In 1992 the coverage of forest land is 729.36 Km$^2$ and it increased to 754.83 Km$^2$ with a raise of 25.47 Km$^2$ in 2002. Later in 2012, a marginal increase of 9.49 Km$^2$ of forest land has been noticed in the study area which account for a total aerial extent of 764.32 Km$^2$. A close examination of forest land and agricultural land (probably plantations) especially in the foot hills of the study area reveals a dynamic relationship with each other, i.e., the forest land is increased in the last 20 years by sparing the agricultural land in the foot hills of the Western Ghats (Figure 6.1). Particularly, the afforestation program organized by the state government has also improved the forest land cover in the study area.

6.2.1.2 Agricultural Land

Agricultural lands are primarily used for crop cultivation to sustain human life. The main cultivated crops in the study area are paddy, sugarcane, groundnut, pulses and plantains. The spatial extent of agricultural land shows a significant decreasing trend in the study area (Figure 6.1). Between 1992 and 2002, there is a reduction of 5% in
agricultural land and from 2002 to 2012 it is further reduced to 4%. In 1992, the spatial coverage of agricultural land is 596.65 Km$^2$ which contributes to 28.7% of the study area. However, such spatial extent of agricultural land is reduced in 2002 with a total coverage of 493.3 Km$^2$ that accounts for 23.7% of the study area. Whereas, the agricultural land is further reduced to 410.47 Km$^2$ in 2012 which accounts for 19.7% of the study area (Table 6.1). The decrease in agricultural land for the last 20 years is mainly due to frequent monsoon failure and land degradation, which results in conversion of agricultural land into barren land. It is also observed that the agricultural lands associated with the alluvial plains of Tamiraparani river is being converted to settlements near Tirunelveli - Palayamkottai stretch. Such anthropogenic pressure is a major factor for agricultural land reduction.

6.2.1.3 Barren Land

Barren land is the second most dominant land cover in the study area. They are associated with exposed soil and thorny bushes. The spatial coverage of barren land in 1992 is 428.28 Km$^2$ which corresponds to 20.6% of the study area. In the year 2002, the barren land cover is further raised to 585.38 Km$^2$ covering 28.1% of the study area and a marginal raise is observed with a spatial extent of 629.87 Km$^2$ covering 30.2% in 2012 (Table 6.1). The difference between 1992 and 2002 barren land cover is 7.5% which is quite high. This is happened due to poor rainfall, lack of man power to retain agricultural activities and poor socio-economic conditions that has forced the young farming generation in search of alternative livelihood. However, this trend has been decelerated between 2002 and 2012 with a marginal increase of 2.1%. This can be attributed to the existence of stabilized land conditions in different landscapes, but still there is a fluctuation of nearly 2% in the study area except agricultural land, which showed a difference of 4% (Figure 6.1).
6.2.1.4 Fallow Land

Fallow lands are associated with agricultural lands and used for cultivation but, they are temporarily un-cropped for one or more season, but not less than one year (Ruthenberg, 1980). The fallow land cover in 1992 is 217.09 Km\(^2\) comprising of 10.4% of the study area. This is due to the effect of varied agricultural practices such as crop rotation, dry land farming and rain fed agriculture (Figure 6.1). It is also noted that these lands are engaged in cultivation only on favorable seasons. The time of image acquisition is also responsible for such a high rate where most of the standing crops have been harvested at that time and left as fallow. However, in 2002, the spatial extent of fallow land is reduced to 128.22 Km\(^2\) comprising of 6.2% of the study area. However, in 2012, a slight increase (0.9%) in fallow land is noticed as compared to 2002, which accounts for 7.1% of the study area (Table 6.1). This is due to the unavailability of water to cultivate these lands and left idle for years, which slowly transforms to barren land. This is observed in the northern part of the study area by comparing the 1992 image with 2012 image. In 1992, the agricultural land and its associated fallow lands in the northern part of the study area are linked with stream channels. Later in 2002, these lands are transformed to fallow and barren land, the barren land has increased by occupying the fallow lands in 2012. This trend is noticed in the whole study area where the water availability is scarce.

6.2.1.5 Water bodies

Water bodies are comprised of surface water in the form of river, streams, canals, ponds, lakes, tanks and reservoirs. The water bodies in the study area show a negligible variation from 1992 to 2012 (Figure 6.1). In 1992, the aerial extent of water bodies is 68.75 Km\(^2\) covering 3.3% of the study area. In 2002, it is slightly reduced to 65.6 Km\(^2\), which accounts for 3.2% of the study area. Later in 2012, a marginal increase is noticed with an aerial extent of 66.06 Km\(^2\), which is negligible (3.2%) when compared with 2002.
data (Table 6.1). The availability of water in the water bodies is controlled by rainfall, evaporation, and water usage through irrigation and domestic supply. Consequent failure of northeast monsoon is one of the main reason for unavailability of water in the study area, which induces transformation of agricultural land into fallow land, and long-term fallowness leads to barren lands. It is also noticed that the major water bodies (ponds and tanks) are found parallel to the main channels of Tamiraparani and its tributaries. This reveals that the water draining from minor streams are collected in the ponds and tanks before it joins the main channel of Tamiraparani river. Such water bodies are essential for irrigation as well as for groundwater recharge.

6.2.1.6 Settlements

Settlements are areas of human habitation covered by built up areas such as buildings, road networks, and other utilities in association with water, vegetation, and vacant lands. The settlement areas are directly proportional to the population of that area and it increases steadily due to better access of daily human needs. The aerial extent of settlements in 1992 was 42.37 Km$^2$ covering 2% of the study area. Due to urban expansion, the settlement has increased to 55.17 Km$^2$ corresponding to 2.6% of the area and the settlement areas have increased to 64.9 Km$^2$ that account for 3.1% of the area in 2012 (Table 6.1). This highlights that around 0.5% of settlement area is increasing every 10 years. The fertile agricultural land, fallow land and few parcels of barren lands have contributed to the expansion of settlement areas. The down streams of Tamiraparani river (eastern part of the study area) is observed with an increasing urban development in the twin cities of Tirunelveli – Palayamkottai stretch followed by Melapalayam, and Pettai (Figure 6.1). These areas show significant urban growth and thereby reducing the fertile agricultural land and urban sewage is dumped into the Tamiraparani river. Such intense pressure is degrading the environmental condition of the river system and adjacent lands.
Table 6.1 Landuse and land cover distribution for the year 1992, 2002, and 2012

<table>
<thead>
<tr>
<th>Landuse Class</th>
<th>1992</th>
<th>2002</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area in Sq.km</td>
<td>Area in%</td>
<td>Area in Sq.km</td>
<td>Area in%</td>
</tr>
<tr>
<td>Forest</td>
<td>729.36</td>
<td>35.0</td>
<td>754.83</td>
</tr>
<tr>
<td>Water bodies</td>
<td>68.75</td>
<td>3.3</td>
<td>65.6</td>
</tr>
<tr>
<td>Agriculture</td>
<td>596.65</td>
<td>28.7</td>
<td>493.3</td>
</tr>
<tr>
<td>Fallow Land</td>
<td>217.09</td>
<td>10.4</td>
<td>128.22</td>
</tr>
<tr>
<td>Settlement</td>
<td>42.37</td>
<td>2.0</td>
<td>55.17</td>
</tr>
<tr>
<td>Barren Land</td>
<td>428.28</td>
<td>20.6</td>
<td>585.38</td>
</tr>
</tbody>
</table>

6.2.2 Landuse transformation

Between 1992 and 2012, significant amount of land transformation has occurred in which 259.08 Km² of land has involved in land transformation process. The changes detected in different landuses such as forest, water bodies, agriculture, fallow land, settlements, and barren land are shown in the Table 6.2. The forest land in the study area has gained 25.47 Km² between 1992 and 2002 and 9.49 Km² between 2002 and 2012 with a total gain of 34.96 Km² within 20 years (1992-2012). Meanwhile, the agricultural land has lost (-) 103.35 Km² in 1992-2002 and (-) 82.83 Km² in 2002-2012 with a total loss of (-) 186.18 Km² (1992-2012). The vanished agricultural lands from 1992 to 2012 was transformed to forest (28.8 Km²), barren land (138.99 Km²) and settlement (18.39 Km²) (Table 6.3).

The agricultural lands in the form of plantations near to the foothill areas have been converted to forest land through afforestation and strict forest protection measurements by the Tamil Nadu state government. The barren land in the study area has gained 157.1 Km² between 1992 and 2002 and 44.49 Km² in 2002 and 2012 with a total gain of 201.59 Km² (1992-2012) (Table 6.2). Such increase is due to the transformation of agricultural land (138.99 Km²), fallow land (59.91 Km²) and water bodies (2.69 Km²) to barren land (Table 6.3).
Figure 6.1 Landuse and land cover map for the year 1992, 2002, and 2012
Figure 6.2 Distribution of landuse and land cover in area

Figure 6.3 Distribution of landuse and land cover in area %
This increase in noticed throughout the plains especially in the north and northeastern part of the study area. Climate induced change such as failure of monsoon and raising surface temperature followed by socio economic condition has provoked the raise of barren lands in the study area. The fallow land and water bodies showed a mixed response. In which, the fallow land has lost (-) 88.87 Km$^2$ during 1992-2002 and gained 18.66 Km$^2$ in 2002-2012 with a total loss of (-) 70.21 Km$^2$ (1992-2012) (Table 6.2). The lost fallow land has been transformed to forest (6.16 Km$^2$), barren land (59.91), and settlement (4.14 Km$^2$) (Table 6.3). Fallow land to forest transformation has been noticed in the foothills of Western Ghats and is associated with the agricultural lands (plantations). The transformation of fallow land to barren is noticed mostly in the northern part of the area where water availability is scarce. Fallow lands associated with agriculture in the eastern part of the study area have been changed to settlements. This is due to the urban expansion in the twin cities of Tirunelveli and Palayamkottai. In the case of water bodies, the area lost is (-) 3.15 Km$^2$ during 1992-2002 and area gained in 2002-2012 is 0.46 Km$^2$ with a total area loss of (-) 2.69 Km$^2$ (1992-2012) (Table 6.2). The lost water bodies have been transformed into barren lands (Table 6.3). They are shallow in nature and most of them are seasonal. The settlement has gained 12.8 Km$^2$ and 9.73 Km$^2$ during 1992-2002 and 2002-2012 respectively with a total gain of 22.53 Km$^2$ for the last 20 years (1992-2012) (Table 6.2). The graphical representation of landuse change and land transformation is shown in figure 6.4 to 6.6.

6.2.3 Driving force identification

According to IGBP and IHDP, the three main driving forces of landuse and land cover are natural environments, landuse management, and socio-economic factors (Nunes & Auge, 1996; Turner et al., 1995; Vellinge, 1998). In which, the natural environments include climatic variables and regional morphology such as temperature, precipitation and
land topography. But, landuse management refers to developmental policies, such as land allotment, zoning, urban area development, transportation and water networks for irrigation and drinking water supply. The socio-economic factors include demographic information, literacy level, societial factors, economy and technology development. The driving forces behind natural environments are controlled over a global scale (for example climate change) and the regional disturbances in topography are controlled either by long-term natural process or by anthropogenic activities.


<table>
<thead>
<tr>
<th>Landuse Class</th>
<th>Change detection (Area in Sq.km)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>25.47</td>
<td>9.49</td>
<td>34.96</td>
</tr>
<tr>
<td>Water bodies</td>
<td>-3.15</td>
<td>0.46</td>
<td>-2.69</td>
</tr>
<tr>
<td>Agriculture</td>
<td>-103.35</td>
<td>-82.83</td>
<td>-186.18</td>
</tr>
<tr>
<td>Fallow Land</td>
<td>-88.87</td>
<td>18.66</td>
<td>-70.21</td>
</tr>
<tr>
<td>Settlement</td>
<td>12.8</td>
<td>9.73</td>
<td>22.53</td>
</tr>
<tr>
<td>Barren Land</td>
<td>157.1</td>
<td>44.49</td>
<td>201.59</td>
</tr>
</tbody>
</table>

**Table 6.3** Land transformation from 1992 to 2012

<table>
<thead>
<tr>
<th>Land transformation</th>
<th>Area Sq.km</th>
<th>Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture to Forest</td>
<td>28.80</td>
<td>11.1</td>
</tr>
<tr>
<td>Agriculture to Barren</td>
<td>138.99</td>
<td>53.6</td>
</tr>
<tr>
<td>Agriculture to Settlement</td>
<td>18.39</td>
<td>7.1</td>
</tr>
<tr>
<td>Fallow to Forest</td>
<td>6.16</td>
<td>2.4</td>
</tr>
<tr>
<td>Fallow to Barren</td>
<td>59.91</td>
<td>23.1</td>
</tr>
<tr>
<td>Fallow to Settlement</td>
<td>4.14</td>
<td>1.6</td>
</tr>
<tr>
<td>Water bodies to Barren</td>
<td>2.69</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>259.08</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>
**Figure 6.4** Graphical representation of land use change during 1992-2002, 2002-2012, and 1992-2012

**Figure 6.5** Graphical representation of land transformation in Km² for the period of 20 years (1992-2002)

**Figure 6.6** Graphical representation of land transformation in % for the period of 20 years (1992-2002)
They have the capability to convert a particular landuse such as water bodies and forest over a period of time. Whereas, the driving force behind landuse management is controlled by the suitability of different land conditions. For instance, the reduction in agricultural land in the study area for the last 20 years is due to the combination of natural environment and socio-economic factors such as low rainfall in the plains, increase in surface temperature, reduced soil moisture condition, high rate of evapo-transpiration, reduced water storage level in the reservoirs and ponds, and reduction in vegetation cover. These factors are linked with climate change and it alters the socio-economic condition of the area, for example food security, economic status, and population growth. This will enhance the possibility of further land degradation through human activities like mining, forest logging, and transforming the natural resources into value added products for human use.

The main driving factors of agriculture landuse change for the past 20 years include the farming practices adopted in the study area such as cultivation of water demanding crops like paddy, sugarcane, plantains etc. The water demand for cultivating such crops is high and the water availability in the basin is scarce including the storage capacity of major reservoirs. However, construction of check dams in the Tamiraparani river has somehow supported the standing crops along the alluvial plains but, in unfavorable conditions the water supply for irrigation ceases. This scenario triggers the transformation of agricultural land into fallow land, where dry land cultivation practice is adopted such as cultivation of pulses and other cash crops. The groundwater is the only source for such cultivation and the water yield gradually decreases due to poor recharge potential. If such condition persists for a period of time then the fallow land gradually becomes barren. The soil type also plays an important role in landuse shift because specific soils support only a few crops and the water holding capacity of the soil determines its cultivation pattern.
The flood plains of the study area are generally composed of alluvial soil and most of the crop productivity is noticed in this type of soil followed by red loamy soil and black cotton soil. But, the black cotton soil often generates cracks in the dry seasons due to high plasticity and clay content and makes it unfit for cultivation. This reveals that the scarcity of water is the major driving force for soil based landuse shift in the study area.

The urban development in the study area is driven by infrastructure, transportation access, demographic trends, and economic development. The migration of rural population to the cities for better employment opportunity is the main cause for urban expansion. This results in increased urban land utilization and exploitation of various natural resources without even sparing the fertile lands.

However, such conditions can be restored, not entirely but in a small scale by adopting sustainable landuse management policies through technology development. For the socio-economic factor, the driving force includes the GDP in agricultural, industrial, and service sectors and most importantly the education levels in the society. Because, most of the damage happening in the landscapes is due to either lack of knowledge and skills or unscientific method of exploitation, precisely the long term effect on the environment. For minimizing the effect of such land degradation, a well-planned landuse policy is required to address the long-term impact and the capability to withstand the effect of future climate change.

6.2.4 Accuracy assessment

Accuracy assessment highlights the possible sources of errors in a classified image, thus enhancing the map quality. The standard method to represent the accuracy of classification result is confusion matrix or simply called as error matrix (Foody, 2002). This method expresses the number of samples assigned to a particular class relative to number of samples assigned to remaining classes. They can be measured using three
different scales in percent namely producer’s accuracy, user’s accuracy and overall accuracy. Producer’s accuracy is defined as total number of correct classified units of class xy divided by total number of class xy units identified in reference data. Whereas, user’s accuracy is defined as the correct class xy divided by total number of units classified as class xy and overall accuracy is the sum of all correctly classified units divided by total number of units (Congalton & Green, 2009). The Kappa coefficient is another measure for accuracy classification which is based on the difference between the actual agreement in the error matrix and the chance agreement and is indicated by the total row and columns.

For the present study 300 validation pixels covering six LULC types have been identified from field survey and the ground truth points were marked with a global positioning system (GPS). The producer’s accuracy, user’s accuracy, overall accuracy and Kappa coefficients are computed and shown in Table 6.4. The overall accuracy for the classification performed in 1992, 2002, and 2012 datasets is 85.55, 82.81 and 83.59% respectively. The overall Kappa coefficient of 1992, 2002 and 2012 landuse maps are near to 0.8 which indicates acceptable accuracy for landuse classification.

Table 6.4 Accuracy assessment of classified LULC for 1992, 2002 and 2012 time series

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Producers accuracy %</th>
<th>Users accuracy %</th>
<th>Kappa coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>98.61</td>
<td>85.29</td>
<td>80.39</td>
</tr>
<tr>
<td>Water</td>
<td>66.67</td>
<td>84.85</td>
<td>87.5</td>
</tr>
<tr>
<td>Agriculture</td>
<td>97.73</td>
<td>95.64</td>
<td>90.77</td>
</tr>
<tr>
<td>Fallow</td>
<td>94.87</td>
<td>92.57</td>
<td>95.12</td>
</tr>
<tr>
<td>Settlement</td>
<td>50.00</td>
<td>76.19</td>
<td>89.54</td>
</tr>
<tr>
<td>Barren</td>
<td>95.00</td>
<td>90.21</td>
<td>94.56</td>
</tr>
</tbody>
</table>

| Overall accuracy | 85.55% | 82.81% | 83.59% |
| Overall Kappa coefficient | 0.8186 | 0.7930 | 0.7995 |
6.3 Discussion

The haphazard urban growth, declined water resources and rapid destruction of agriculture lands and its conversion to fallow and then to barren land needs special attention to study the landuse and land cover pattern and changes in the Tamiraparani sub-basin. The present study highlights the long term (1992-2012 – 20 years) change in landuse/land cover of Tamiraparani sub-basin. The analysis of multi-temporal landuse maps indicates that the spatial extent of forest, settlement and barren land have increased drastically. Whereas, water bodies, agricultural land and fallow land have greatly declined during the last 20 years. The geographical area of barren land has increased to 10% during these 20 years, and the extent of agricultural land is decreased to 9%. Such variation indicates deprived environmental condition with loss of biodiversity. The increase in forest land cover up to 1.7% indicates the rejuvenation of Kalakad - Mundanthurai Tiger Reserve (KMTR) through strict forest conservation measures and increase in settlement area up to 1% indicates the urban growth in the study area, which is more confined to the twin cities of Tirunelveli - Palayamkottai. This expansion represents the conflict between the population and agricultural land, and may cause serious agricultural crisis. The decrease in water bodies (0.1%) and fallow land (3.3%) and subsequent conversion to barren land signifies the non-availability of water (monsoon failure) and rising temperature in the study area can be related to the effect of regional climate change.

The increasing trend in barren land results severe soil erosion in an extreme rainfall condition. Moreover, the runoff from barren land contains high level of dissolved ions and increases the concentration of total suspended sediments in the surface water. The urban expansion near to the Tamiraparani river has induced serious river water contamination leading to degradation of water quality. Similarly, the alluvial plains of
Tamirparani river and its tributaries are actively engaged with agricultural activities induces abnormal nutrient loadings in the river water. Therefore, there is a need to establish buffer zones along the riparian areas of main streams and tributaries to reduce anthropogenic effects on river water quality. Finally, an optimal landuse management strategy must be adopted in the study area.