Geo-Environmental Analysis Using Multitemporal Satellite Data and GIS Techniques - A Case Study for Bhavani River Basin, Tamil Nadu, India

S. Muthusamy¹, R.R. Krishnamurthy¹, M. Jayaprakash¹ and P. Mohana Perumal²

¹Department of Applied Geology, University of Madras, Chennai, Tamil Nadu, India
²Centre for Remote Sensing, Sathayabama University, Chennai, Tamil Nadu, India

Correspondence should be addressed to S. Muthusamy, muthusamy.geo@gmail.com

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Abstract The northern and north-eastern (Eastern Ghats), the southern and south-eastern sides of the basin are dominated by rugged discontinuous hills, with altitudes ranging from 300 to 1,000 meters. Based on the quantitative analysis on LULC, it was observed that a rapid growth in built-up land between 1973 and 2003 while the periods between 1993 and 2003 witnessed a reduction in this class. It is expected that the expansion of built-up area will follow the same trend from the year 2003 onwards. Considerable changes in agricultural pattern in this study area though there is not much changes in water resources may be an indication that the influence of climate change induced effects are expected to be vital factor in Bhavani River Basin. Considerable changes in agricultural pattern in this study area though there is not much changes in water resources may be an indication that the influence of climate change induced effects are expected to be vital factor in Bhavani River Basin. However this should be further validated by the analysis of socio-economic, hydro-meteorological and other field data pertaining to the study area.

Keywords Landuse Landcover, Change Detection, Remote Sensing, Environmental Changes, Bhavavni Basin

1. Introduction

Landcover information is needed to monitor the impact and effectiveness of management actions associated with sustainable development policies (Sedano et al. 2005). Countries within the tropics are developing rapidly, producing land cover changes of ecological and climatic significance, such as colonization of marginal lands, deforestation, dry lands degradation, landscape fragmentation and rapid urbanization (Lambin 1999). Inevitably these processes place great pressure on natural resources, perhaps most noticeably on forests (Foody 2003).
In recent years, satellite remote sensing techniques have produced multi-sensor satellite data at very high spatial, spectral and temporal resolutions (Liang 2004). This data coupled with improved computer processing and storage capabilities (Bossler 2002) have proved to be of immense value for preparing up to date and accurate land use/cover maps in less time, lower cost and with better accuracy (Foody 2003; Cingolani et al. 2004; Jansen and Di Gregorio 2004; Tottrup 2004). In cases of inaccessible regions this technique is perhaps the only method of obtaining the required data in a cost and time-effective manner (Sedano et al. 2005). Geographic Information Systems (GIS) which excel in storage, manipulation and analysis of spatial and socioeconomic data (Burrough and McDonnell 1998), provide a wider application when combined with remote sensing techniques which have been effective in land use/cover mapping of tropical environments (Baban and Wan-Yusof 2001; Colombo et al. 2004).

1.1. Land Use and Land Cover Classification Systems

Each classification is made to suit the needs of the user. In order to address the issues associated with classification like class definitions, multiple land uses on a single land parcel, minimum representable area and to standardize the LULC information that could be generated using remote sensing data. Anderson (1976) and NRSA (2009) developed some criteria for classification systems.

- The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data should be at least 85 percent.
- The accuracy of interpretation for the several categories should be about equal.
- Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.
- The classification system should be applicable over extensive areas.
- The categorization should permit vegetation and other types of land cover to be used as surrogates for activity.
- The classification system should be suitable for use with remote sensor data obtained at different times of the year.
- Effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensor data should be possible.
- Comparison with future land use data should be possible.
- Multiple uses of land should be recognized when possible.
- Image analysts determine the measurement of spectral reparability by determining quantitatively the relation between class signatures. Signatures are refined by improved ground truth and accuracy assessment analysis. By utilizing the developed signatures in multi-spectral classification and thematic mapping, the analyst generates new data for analysis (ERDAS, 1999).
- Contemporary global change consists of two broad types: systemic and cumulative. Systemic change operates directly on the biochemical flows that sustain the biosphere and, depending on its magnitude, can lead to global change, just as fossil fuel consumption increases the concentration of atmospheric carbon dioxide. Systemic change is largely associated with, but not limited to, the Industrial Age and thus has grown especially important over the more recent past. Cumulative change has been the most common type of human-induced environmental change since antiquity. Cumulative changes are geographically limited, but if repeated sufficiently, become global in magnitude. Changes in landscape, cropland, grasslands, wetlands, or human settlements are examples of cumulative change. Some cumulative changes reached continental and even global proportions long before the 20th century, including deforestation and modification of grasslands (Turner and Butzer, 1992).
2. Study Area

The study area falls in the Latitude 11°30ʹ00ʺN, Longitude 76°30ʹ00ʺE (Figure 1). Survey of India Toposheets (58A11, 58A12, 58A14, 58E15, 58A16, 58E2, 58E6, 58E7, 58E10, 58E11) and the satellite imagery of Landsat MSS: 1973 Landsat ETM+: 1993, Landsat ETM+: 2003, SRTM-DEM-90M are used. The choice of data sources is considered comprehensively the spatial resolution, spectral resolution, time resolution, price and other factors. In this study, LANDSAT TM / ETM+ data and DEM data in 90m of resolution are used. TM / ETM data has 30 m in spatial resolution, 7-band of the spectral resolution, Spectral Range 0.450 - 2.35 µm and 16 days for time resolution. ERDAS IMAGINE 8.7 and ArcGIS 9.2 are used to process analyse the above mentioned remote sensing data.

Bhavani Basin is the fourth largest (6,500 km²) sub-basin in the Cauvery Basin (81,000 km²). The western part (Western Ghats) is hilly terrain with an altitude ranging from 300 to 2,400 meters. The northern and north-eastern (Eastern Ghats), the southern and south-eastern sides of the basin are dominated by rugged discontinuous hills, with altitudes ranging from 300 to 1,000 meters.

Bhavani Valley, a flat terrain covering around 20% of the basin area, starts from the foothills of Western Ghats and stretches eastward all the way to the confluence of the Bhavani River with the Cauvery river (NWDA 1993). The northern part of the upper Bhavani Basin is drained by the Moyar River and the southern part by the Bhavani River. Below the Lower Bhavani Project (LBP) reservoir the Bhavani River continues eastward traversing the Bhavani Valley. In the upper Bhavani Basin the major part of the yearly precipitation falls from June to September, during the south-west monsoon.

In the lower Bhavani Basin most of the rain falls during the less reliable north-east monsoon, from October to December. Yearly average precipitation in the upper Bhavani is estimated at 1,600 mm per year and the value of 700 mm per year is an approximation for the lower Bhavani. The total average yearly areal precipitation is about 6,500 Mm³ above the LBP reservoir (4,100 km²) and approximately 1,700 Mm³ below (2,400 km²). Potential yearly evapotranspiration (ET) in the central upper Bhavani Basin is about 800 mm and around 1,600 mm in the lower Bhavani Basin (based on soil map information from the Indian Department of Agriculture).

The population in the basin has increased about 200% during the last 50 years to about 2.5 million. More than 50% of the workforces in the Nilgiris district are occupied with livestock, forestry, fishing, hunting, plantations or orchards, and 14% are working in the agriculture sector as cultivators or agricultural labourers. In the Erode district, almost 55% work in agriculture and about 45% in the non-agriculture sector (Census of India 1991a, b). In the parts of the Bhavani Basin that fall within the Erode and Coimbatore districts there are irrigated lands with canals and groundwater, and rain-fed crop lands, often with supplemental groundwater irrigation. Cultivated crops are Sugarcane, paddy, groundnut, pulses, fodder sorghum, sugar cane, coconut, sesame, turmeric and banana.
3. Methodology

**MULTITEMPORAL SATELLITE DATA**
- Lineament Map
- Geomorphology Map
- Land use and Landcover Map

**DEM-DATA**
- Terrain parameters

**Survey of India Toposheet**
- Drainage Map
- Geology Map
- Soil Map

**Change Detection Analysis Using Multi Temporal Satellite Data**

**LANDUSE / LANDCOVER CHANGES**

*Figure 2: Shows the Methodology Flow Chart*
The interactions of geomorphology, geology, hydrology, topography, soil, drainage and even anthropogenic disturbances can result in a complex of Geo-environmental types where deciduousness and moisture are highly variable and dynamic. Hence, in this study the combination of remote sensing and GIS techniques have been used to prepare relevant thematic maps and more particularly to study the land use and land cover changes in the study area. Following the Anderson (1976) classification, present area of imagery from the individual years, a post classification, approach of subtracting the classification maps, 1973, 1993 and 2003, was applied. This is perhaps the most common approach to change detection and has been successfully used by (Yang and Lo et al. 2002) to detect land changes in the Atlanta, Georgia area. Since this study involves the preparation to thematic maps, creation of digital elevation model and organization and integration of spatial information using a GIS the above methodology (Figure 2) has been adopted for this study.

4. Results and Discussion

4.1. Thematic Maps of the Study Area

A) Geology of the Study Area

The vast expanse of granulite -gneiss terrain of central and northwest Tamil Nadu encloses discrete, isolated sequences of high grade schists and basic rocks which occupy a supracrustal status in the lithostratigraphic column. These are referred to as ‘Sathyamangalam’ in Tamil Nadu. The rocks of Sathyamangalam Group generally occur as dismembered bands and lenses within the Peninsular Gneissic Complex (Bhavani Group) in an east- west trending linear belt in central Tamil Nadu occupying parts of Coimbatore, Erode, Salem, Namakkal and Tiruchirapalli Districts (GSI, 2006). Bhavani Group is a mixture of gneisses of different composition and texture such as highly fissile mica gneiss, quartzo-feldspathic gneiss, augen gneiss, hornblende gneiss, hornblende-biotite gneiss, biotite gneiss, granitoid gneiss and pink migmatite. Part of this gneiss is considered to be para as well as ortho-gneiss and part their migmatitic equivalents shows in the study area (Figure 3).

B) Geomorphology and Soil Types

The Bhavani Basin forms part of the uplands of the state. Physiographically the basin can be divided into hilly area, the upland area and plains area. The prominent geomorphic units identified in the district through interpretation of Satellite imagery are 1) Structural hills, 2) Inselberg, 3) Ridges, 4) Valley fill, 5) Pediments, 6) Shallow Pediments, (GGWB, 2006). The hilly area is represented by the Western Ghats in the northwestern part, the Biligiri Rangan hills in the north, Bodamalai Betta hills in the northwestern parts and Konbattarayan hills in the north central part. The Kongunadu uplands lie south of Bhavani River and the Lower Bhavani canal passes through these uplands. Scattered hillocks and knolls of moderate elevations occur within these uplands. The plains area is characterized by an undulating topography with a general gradient due east and southeast. The plains are limited to the east and southwestern border of the study area (Figure 3).

The soils of study area can be broadly classified into 6 major soils types viz., Red calcareous soil, Red non calcareous soil, Black soil, Alluvial and Colluvial soils, Brown soil and Forest soil. Major part of the study area covered by red calcareous soils. They are mostly sandy to loamy and characterised by the hard and compact layer of lime of the study area (Figure 3).

C) Drainage

A Drainage map of the area was prepared from survey of india toposheet and SRTM data. Digital elevation map of Drainage produced and presented in the (Figure 3). This Digital Elevation Model
(DEM) clearly presents the elevator hillocks and mountains in the study area and its shows the drainage pattern of water bodies.

Figure 3: Map Showing The Thematic Maps
(Geology, Geomorphology, Soil, Drainage) of the Study Area

4.2. Ground Truth Validation

The LULC maps prepared using Multidate remote sensing data of this study are validated in the field by choosing random sampling method showing in the (Figure 4). All the important categories are verified and the total accuracy of this classification is estimated as 98 percent.
Figure 4: Showing the Ground Truth Validation of the Study Area

Figure 5: Chart Showing the LULC Changes in the Years of 1973, 1993 and 2003
From the above Table 1 & Figure 5 Chart derived, it can be seen that there has been a major decrease in the crop land and forest area. The percentage of scrub forest has drastically declined to around 44%. Next to scrub forest is Crop land (Kharif + Rabi), which has gone down by 30.09%. Equally the cropland (Kharif + Rabi), the percentage of crop land (Kharif) has decreased by 30.09 %. Around 16% of decrease in Evergreen forest, while wasteland has been decreased by 6%. Also there is very little decrease noted in the water bodies and Decidious forest area. While most of the wasteland area has been lost, there is notable increase in Crop land (Rabi) and Land without Scrub. Also, around 1% increase is noted in settlements and less than 1% was noted in Plantations. The percentage of both Plantations and Coffee plantation has increased to same extent at around 0.3 %. All above, Tea plantation has increased drastically by around 16%. In the present Study, Survey of India (SOI) toposheet of 1973 and the satellite imagery of Landsat MSS: 1973 Landsat ETM+: 1993, Landsat ETM+: 2003 of different years from 1973, 1993, 2003 were compared qualitatively and quantitatively. This study has given the land use changes during these years. Different Environmental land use categories were identified viz. Settlements, Evergreen Forest, Forest Plantations, Decidious Forest, Forest Blanks, Plantations, Crop Land (Rabi), Crop Land (Kharif + Rabi), Crop Land (Kharif) Wastelands, Land with scrub, Fallow Land, Scrub Forest, Land without scrub, Tanks, Water bodies. The results of landuse/landcover assessment based on visual interpretation for different years of satellite data (From 1973, 1993, 2003) and its area are showing in Table 1. The variations in the land use pattern (Figures 5.1 & 5.2) are clearly shown and the changes in area can be seen. More pixels of Crop Land (Kharif), Evergreen Forest, Scrub Forest, Crop Land (Kharif + Rabi) are seen in 1973 LULC map than 2003 map (Figures 5.1 & 5.2). But the sudden decrease in the subsequent years in 1973 to 2003. Constant increase in Plantations- Tea, Land without scrub, Crop Land (Rabi). Agricultural and fallow lands are changing based different agricultural practices and monsoonal effect.

The overall Landuse/Landcover according to the 1973 data has been calculated as 7737Km$^2$ and sparsely irrigated as 50%. Out of total area, around 26% of the area is covered with forest; in the

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Land Use/ Landcover</th>
<th>1973</th>
<th>1993</th>
<th>2003</th>
<th>Percentage of Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Settlements</td>
<td>45.20</td>
<td>53.20</td>
<td>63.05</td>
<td>0.81</td>
</tr>
<tr>
<td>2</td>
<td>Crop Land (Kharif)</td>
<td>886.72</td>
<td>626.45</td>
<td>620.53</td>
<td>-30.09</td>
</tr>
<tr>
<td>3</td>
<td>Crop Land (Rabi)</td>
<td>507.53</td>
<td>503.53</td>
<td>526.45</td>
<td>5.15</td>
</tr>
<tr>
<td>4</td>
<td>Crop Land (Kharif + Rabi)</td>
<td>1186.72</td>
<td>858.27</td>
<td>985.60</td>
<td>-30.13</td>
</tr>
<tr>
<td>5</td>
<td>Plantations</td>
<td>708.04</td>
<td>714.04</td>
<td>713.80</td>
<td>0.26</td>
</tr>
<tr>
<td>6</td>
<td>Plantations - Coffee</td>
<td>4.30</td>
<td>5.30</td>
<td>11.30</td>
<td>0.27</td>
</tr>
<tr>
<td>7</td>
<td>Evergreen Forest</td>
<td>1010.30</td>
<td>993.30</td>
<td>949.91</td>
<td>-16.42</td>
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<tr>
<td>8</td>
<td>Scrub Forest</td>
<td>1038.62</td>
<td>1024.62</td>
<td>971.36</td>
<td>-43.97</td>
</tr>
<tr>
<td>9</td>
<td>Forest Blanks</td>
<td>5.38</td>
<td>8.38</td>
<td>10.38</td>
<td>0.23</td>
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<tr>
<td>10</td>
<td>Forest Plantations</td>
<td>340.74</td>
<td>410.74</td>
<td>545.69</td>
<td>1.77</td>
</tr>
<tr>
<td>11</td>
<td>Wastelands</td>
<td>170.58</td>
<td>249.58</td>
<td>35.83</td>
<td>-6.14</td>
</tr>
<tr>
<td>12</td>
<td>Land with scrub</td>
<td>155.55</td>
<td>452.55</td>
<td>158.12</td>
<td>0.12</td>
</tr>
<tr>
<td>13</td>
<td>Land without scrub</td>
<td>90.23</td>
<td>99.23</td>
<td>81.46</td>
<td>3.09</td>
</tr>
<tr>
<td>14</td>
<td>Tank</td>
<td>24.05</td>
<td>34.05</td>
<td>18.28</td>
<td>-0.26</td>
</tr>
<tr>
<td>15</td>
<td>Deciduous Forest</td>
<td>975.34</td>
<td>963.34</td>
<td>962.87</td>
<td>-0.57</td>
</tr>
<tr>
<td>16</td>
<td>Water bodies</td>
<td>160.27</td>
<td>155.27</td>
<td>156.08</td>
<td>-0.19</td>
</tr>
<tr>
<td>17</td>
<td>Plantations - Tea</td>
<td>40.31</td>
<td>46.31</td>
<td>389.70</td>
<td>15.92</td>
</tr>
<tr>
<td>18</td>
<td>Fallow Land</td>
<td>83.54</td>
<td>95.54</td>
<td>86.55</td>
<td>0.14</td>
</tr>
<tr>
<td>19</td>
<td>Total area</td>
<td>7433.42</td>
<td>7433.42</td>
<td>7433.42</td>
<td></td>
</tr>
</tbody>
</table>

All the values are in KM$^2$
remaining, 24% of the area is covered by other geomorphologic features. Similarly, for the year 1993, land cover changes reveal that forest land covered 26% of the area; sparsely irrigated surface covered 20% in the (Figure 5.1). For the year 2003, the irrigated and forest land are reduced approximately 5% and its shows settlements are gradually increased from 1973 to 2003 in the (Figure 5.2).

Figure 5.1: Showing the Landuse/Landcover Map of the Study Area for the Year of 1973 & 1993
5. Conclusion

Considerable all the important land use and land cover categories both the scrub forest and cropland areas are undergone major changes during 1973-2003. LULC changes describes results confirm that both the scrub forest and cropland area might have converted mainly for forest plantations especially in tea plantation. Several important land use and land cover categories such as settlements, agriculture, plantations, forest blanks and fallow lands have not undergone many changes during the last three years. Considerable part of waste land areas are reduced during the last three years. This may be an indication that the study area has the impact of proper land use planning adopted by the local government through various rural development authorities. The reduction in cropland equally kharif shows that there is a considerable shift in cropping practices in the study area. This might have attributed by the availability and changes in socio economic conditions.

Recommendations

Since the study area comprised of Hilly area, Flood plain area, undulating terrain with scrub forest cover there should an integrated management approach is required for effective management of this River Basin as detailed below:

a) The proper integrated hill area management plan (IHAM) should be adopted to enhance the density of the forest.

b) Due to rapid conversion of agriculture area, the study area needs to adopt proper land management practices.
c) The water storage potential of Bhavani Sagar reservoir should be regularly monitored through proper watershed management practices.

d) There are uncontrolled mining activities, observed during field visits especially near the Bhavani Sagar reservoir dam and this should be regulated by the authorities.

References


