INTERNATIONAL JOURNAL OF GEOMATICS AND GEOSCIENCES
Volume 2, No 3, 2012

Research article ISSN 0976 – 4380

Landuse / Land cover dynamics study in Nilgiris district part of Western Ghats, Tamilnadu

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ABSTRACT

Rapid Landuse and Land cover dynamics were investigated in the Nilgiris district of Tamilnadu State during the periods 1973-2009 by the combined use of Remote Sensing and Geographic Information Systems (GIS) techniques. Landsat-MSS, Landsat-TM and IRS-P6-LISS III satellite imageries were used to assess the Landuse and Land cover changes through visual interpretation techniques. The detailed analysis has revealed that the area under forest and settlement increased 9.35 km^2 and 1.02 km^2 every year for the past 36 years respectively. Whereas the forest plantation, tea plantation, barren rocky land and agro-horticulture shows a considerable declining for the period of 36 years. Encouragement of tourism and industrial development has altered the natural system of Nilgiris environment. The Nilgiris today is the most industrialized and commercialized hill area in the state. The rabid commercialization without corresponding improvements in infrastructures and amenities has long begun to strain the carrying capacity of the hills.

Key words: Landuse and Land cover, Nilgiris, Remote Sensing and GIS, Western Ghats.

1. Introduction

The landuse/land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on landuse / land cover and possibilities for their optimal use is essential for the selection, planning and implementation of landuse schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of landuse resulting out of changing demands of increasing population. There has been a worldwide increasing awareness and studies on landuse and land cover changes in the last few decades. And Landuse and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes (Okude, 2006). So this makes landuse mapping and change detection will provide relevant inputs in the direction of decision making for implementation of appropriate policy responses (Fasona and Omojola et al., 2005). So this paper examined the significance of landuse and land cover changes for different periods in Nilgiris district and their contributions to the emerging patterns in global landuse and land cover studies.

Landsat Enhanced Thematic Mapper (ETM) and IRS-P6-LISS III datas were used for the landuse mapping coupled with detailed ground truth verification. In addition, the study examines the need for proper geomanagement of land and its importance of the availability of detailed, accurate and up-to-date geoinformation in the proper management in the Nilgiris hilly environment.

1.1 Landuse/Land cover change – Problem Context

Land cover change has been described as the most significant regional anthropogenic disturbance to the environment (Roberts et al, 1998). In essence both landuse and land cover changes are products of prevailing interacting natural and anthropogenic processes by human activities. Studying landuse dynamics is essential in order to examine various ecological and developmental consequences of landuse change over a period of hiatus. Following are the key points that lead to dedicated study on landuse/land cover change. Landuse and land cover change with land degradation are as a result of motivated by the same set of proximate and underlying factor elements to environmental processes, change and management through their influence on biodiversity, heat and moisture budgets, trace gas emissions, carbon cycling, livelihoods, a wide range of socio-economic and ecological processes (Desanker et al., 1997; Verburg et al., 2002; Verbug et al., 2000; Fasona and Omojola, 2005).

Landuse change detection allows for the identification of major processes of changes and, by inference, the characterization of landuse dynamics. The reason for such consequence is a result of over dependence on primary resources with direct effect on biodiversity; landuse and land cover dynamics, terrestrial ecosystem and climate (atmospheric composition, vegetation and temperature changes). With rapid urbanization and a restricted land area, the available land per individual shrinks drastically. The result is an urgent need for proper geo-management of land that is dependent upon the availability of a detailed, accurate and up-to-date data. One major consequence of the globally recognized rapid land cover change is the loss of biodiversity and ecosystem functioning. The rate of biodiversity loss has been accelerating rapidly throughout the industrial era. Major changes in human activities, particularly through large scale construction have been identified as the major cause of the dramatic changes in landuse and land cover patterns globally.

1.2 Landuse/ Landcover – Potential Impacts

These dramatic landuse and land cover changes that would have once required centuries now obtain a few decades to evident. The increasing concern for the management of natural resources in recent times has been necessitated by the increasing demographic pressures and its associated man-made activities which have leads to serious environmental stress and ecological instability. In the last 300 years, the impacts of landuse changes have assumed significant to threatening proportions (Briassoullis, 1999). Expectedly outside a few exceptions, it is human and not nature's agency which brings about these changes and which is responsible for their magnitude and severity. Of course these changes have been found to be more profound in developing countries, due to the high inclination of the population growth rate and over-exploitation of the subsequent natural resources without considering the environmental prospect. Although, it is now widely accepted that multiple factors in synergetic interactions with dominate landuse change processes and that these contributory clusters vary across regions and time, agricultural expansion or reduction is one of the proximate causes of landuse and land cover change (Geist et al., 2005). Today, roughly a third of the world landscapes are being used for growing building, agriculture practices and grazing domestic animals (Ramankutty et al., 2005). The impacts of these environmental problems are serious in both short and long term. In the short term food security, human vulnerability, health and safety are at risk and in the long term feasibility of the earth is being threatened (Briassoullis, 1999).

Nilgiris has the fastest rate of deforestation and population growth in the hilly environment. Competing landuses (settlements mainly) are contributing to the decline of forest plantation and woodland areas and rising demand for fuel wood and charcoal is also a major cause of degradation of forest and plantation. Over harvesting, agricultural encroachment and unregulated burning are believed to be contributing to the decline of many species in the wild. Depletion and degradation of the natural resource base intensifies competition to less stressed areas.

2. Study Area

The study area is the Nilgiris district, which is located in Tamilnadu state. It is elongated in the east - west direction and bounded by 11°30' and 11°15' North latitude and 76°45' and 77° 00' East longitudes (Figure 1). The Nilgiris is an ancient land mass thrust upwards at the junction of the two major mountain ranges near the southern end of India some 70 million years ago. 57% of the surface of the Nilgiri hills rises over 1000 m above the Mean Sea Level (MSL) and 47% of that towers over 1800 m with the pinnacle formed by the big mountain at 2670 m. The total areal extent of the district is around 2551 km^2 and is one of the smallest districts in the state.

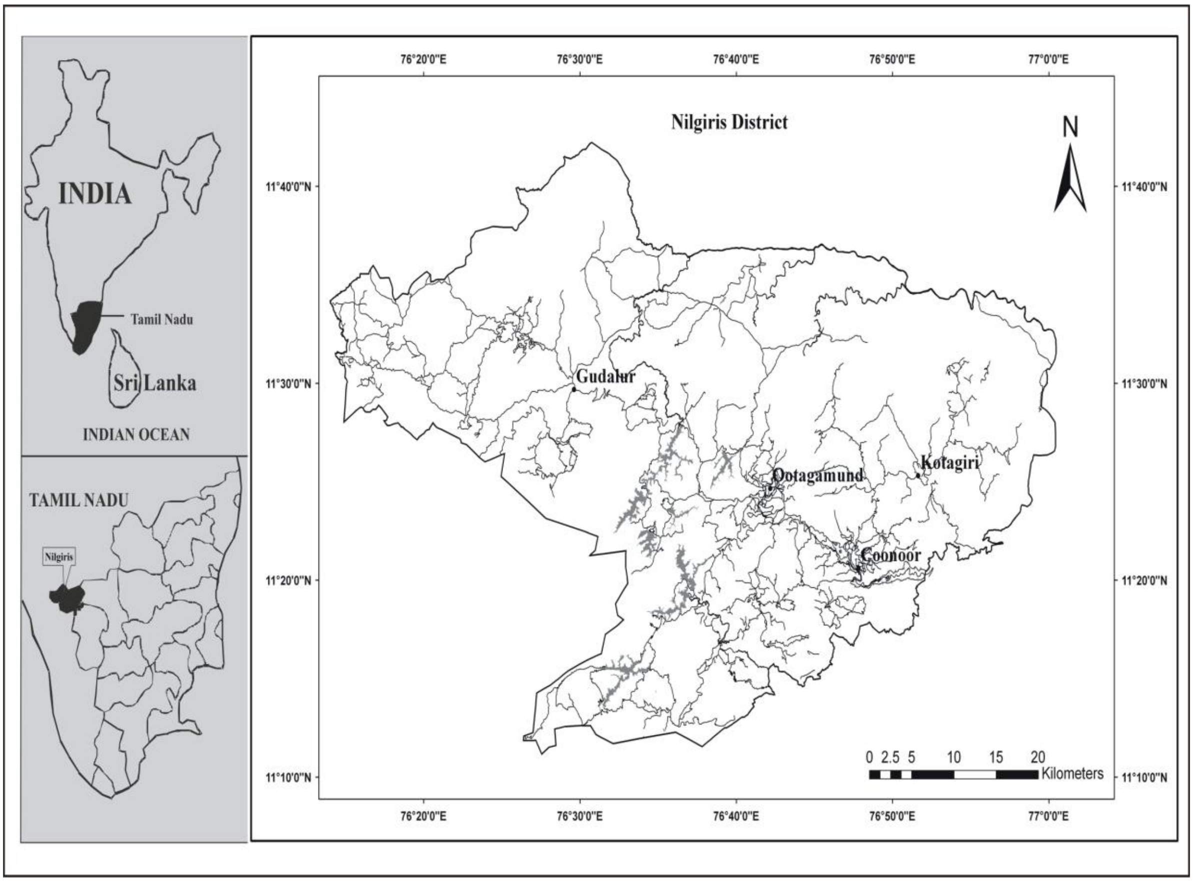

Figure 1: Study area location map

The district is bounded by the states on the west by Kerala, on the north by Karnataka and on the southeast and south by Coimbatore district of Tamilnadu. The Nilgiris district comprises four taluks viz., Udhagamandalam (1199 km^2), Gudalur (726 km^2), Coonoor (229 km^2) and Kotagiri (397 km^2). These are 55 revenue villages and 640 hamlets in the district. Nilgiris is mostly hilly district located on the fragile environment of Western Ghats with an elevation ranging from 300 m in the Moyar Gorge to 2634 m above MSL at Doddabetta peak. Major part of the district is under forest cover (56%), about 20% of the district is under plantation crops such as tea, coffee, vegetables, areca nut, coconut, etc., out of which tea plantation dominates and is found at all slopes. Average annual rainfall of the district is 1920.8 mm. Since this district is situated at an elevation of 900 to 2636 m above MSL during summer the climate remains to the maximum of 21°C to 25 °C and the minimum of 10°C to 12°C. During the winter the temperature available to the maximum 16°C to 21°C and minimum of 2°C. As the following table 1 depicts, Nilgiris has experienced a much sharper growth in population both before and after independence. According to the latest census, the population of Nilgiris district is 7, 64,826. With the livelihood opportunities being limited in hill areas, the growth in population/immigration only aggravated the poverty situation and marginalized the indigenous people (SNC Newsletter, 1986). Note the continuous surge in population for five decades from 1921 to 1971 (Table 1).

Table 1: Comparison of population growth rate (%) in different Decades

Year	Tamilnadu	Nilgiris
1901-1911	8.6	5.1
1911-1921	3.5	6.7
1921-1931	8.5	33.8
1931-1941	11.9	23.9
1941-1951	14.7	48.7
1951-1961	11.9	31.3
1961-1971	22.3	20.7
1971-1981	17.5	27.6
1981-1991	15.4	12.7
1991-2001	11.2	7.7
Source : Census of India-2001		

2.1 Geomorphology

Nilgiris district is a mountainous district of Tamilnadu with many hill ranges and broad valleys with slopping towards plain. The prominent geomorphic units were identified in the district through interpretation of satellite imagery are Crust line, debris slope, alluvial fills, colluvial fills, gullied valley, vegetation filled valley, fractured filled valley, intermountain valley, bazada zone, escarpments, pediments, deep pediments, shallow pediments, undissected plateau, dissected plateau, erosional plateau, flood plain, pediplain, moderate pediplain, residual hill (fig 2). The Nilgiris hills rise abruptly from the plains (300 m above MSL) to an average elevation of 1370 m above MSL. Some of the prominent peaks are the Doddabetta (2634 m), the highest peak in Tamilnadu, Kolari (2625 m), Mukurthi (2554 m), Kudikadu (2590 m), Devabetta (2552 m), the conical grass covered Bear hill (2531 m) and Nilgiris peak.

2.2 Geology and Soil

In the study area, the lithology is the charnockite group of bedrocks, covered by the ubiquitous red laterite or lateritic soil. This is taken as a common factor for the whole district. Because of its uniform nature, it is not taken into account for our study (Figure 3). The soil of Nilgiris district can be broadly classified into five major soil types viz., lateritic soil, red sandy soil, red loam, black soil, alluvial and colluvial soil. Major part of the district was covered by lateritic soil, red sandy soil and red loams are occurring as small patches. Block soil is developed in the valleys; where the water logging is also common during the monsoon period. Based on the erodable nature of soil was classified highly eroded clay, very deep eroded clay, moderately eroded clay, gravelly clay, moderately eroded gravelly clay, gravelly loam with escarpment, calcareous loam and calcareous cracking clay (Figure 4). The alluvial and colluvial soils are seen along the valleys and major river courses respectively. The Doddabetta landform has many high peaks having steep slope and escarpments with or without soil cover around which a radial drainage pattern occurs (Parthasarathy and Vaidyanathan, 1974). The Ootacamund landform has gentle mounds with a thick soil cover. The Nilgiris falls in the tropical zone of weathering. Most part of the Nilgiris is deeply weathered and at some places thick soil cover of up to 40 m was found. The exposed area reveals a humus zone of 0.50 to 1.0 m followed by red or brown or yellow silt and clay. The weathered zone between the clay and the fresh rock is normally about a meter thick. The soils are derived from rocks, having an admixture of organic matter and capable of supporting vegetation. Intense rainstorm followed by dry period have helped formation of considerable depth of weathering, and at some places extended up to 45 m. Rocks seen along gentle slopes in few road cuttings are only boulders derived from bluffs (Seshagiri et al., 1982).

3. Materials and Methods

The Geographical Information System (GIS) and Remote Sensing (RS) techniques were adopted for preparation of various thematic layers for evaluating landuse changes in the present study area. Survey of India (SOI) toposheets 58A/2, 6, 7, 8, 10, 11, 12, 13 and 15 at 1:50,000 scale were used as a predominant source for base map preparation. The geometrically corrected IRS-P6- LISS III satellite image was used for preparation of geomorphology map. Soil map was prepared using as a source of National Bureau of soil survey and landuse planning, Nagpur with Department of Agriculture, Tamilnadu and based on Geological Survey of India (1995), geology map was prepared for entire study area. Cloud free Landsat-MSS, Landsat-TM and IRS-P6- LISS III satellite imageries were used to assess the Landuse / Land cover changes for the years 1973, 1991, 2000 and 2009. The Global Land Cover Facility (GLCF) is the primary source of orthorectified Landsat scenes for the years 1973and1991. IRS-P6- LISS III imagery was obtained from National Remote Sensing Centre (NRSC) for the year 2009. The standard methods of visual interpretation techniques have been employed for the interpretation, classification and delineation of landuse categories and geomorphological features, based on tone, texture, shape, size, pattern and differential erosion characteristics of the satellite imagery. In addition to this, ground truth verification was applied and incorporated with landuse/land cover and geomorphology maps. Finally areal changes were calculated for each landuse class in different time scale. The detection of changes from initial status of 1973 to final situation of 2009 was also reported to get an exact idea about how much alteration has taken place in different landuse categories over the last 36 years. The comparison of the landuse/ land cover statistics supported in identifying the percentage of change, Annual rate of change between 1973-1991, 1991-2009 and 1973-2009. In achieving this, the first task was to develop a table showing the area in km^2 and the percentage change for each year (1973, 1991 and 2009) measured against each landuse/land cover type. Percentage of change was determined based on the following formula:

$$\text{Percentage change } (\%) = \frac{\text{Observed change}}{\text{Sum of change}} \times 100$$

In obtaining annual rate of change, the observed change (km^2) is divided by the number of study year 18 years (1973-1991), 18 years (1991-2009) and 36 years (1973-2009)

$$\text{Annual rate}\,(\text{km}^2) = \frac{\text{Observed change}}{\text{Number of study year}}$$

4. Result and Discussion

4.1 Landuse / Land cover change detection

Landuse refers to the way in which land has been used, usually with accent on the functional role of land for economic activities. Land cover refers to the physical characteristics of the earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created entirely by human activities, for example, settlements. The landuse pattern of Nilgiris is very important because this area is identified as one of the biodiversity hot spot in the world. Besides, this area is prone to the landslides, a phenomenon of land flow associated with heavy rainfalls during the monsoon. Hence, the identification and delineation of landuse pattern of this area is more essential for monitoring the environmental alteration and stimulation of the existing condition. Here, the standard method of visual interpretation techniques were adopted to demarcate the different periods of various zones of natural and man made patterns.

4.1.1 Landuse changes in 1973-1991

In the present study, an attempt has been made to carry out landuse change detection analysis for entire Nilgiris district. Change detection involves the use of multi-temporal datasets to derive landuse and land cover changes for different period of satellite image.

Table 2: Landuse / land cover distribution between 1973 - 2009 in Nilgiris district

S.No	Landuse class	Area (km^2)			Percentage (%)		
		1973	1991	2009	1973	1991	2009
1	Dense forest	656.91	826.59	993.34	25.75	32.4	38.93
2	Open forest	67.33	8.27	116.03	2.64	0.32	4.55
3	Forest plantation	469.20	290.36	305.41	18.39	11.38	11.97
4	Settlement	7.49	29.11	44.29	0.29	1.14	1.74
5	Waterbody/Lake/Reservoir	32.87	39.51	29.26	1.29	1.55	1.15
6	Tea plantation	483.45	471.23	437.55	18.95	18.47	17.15
7	Forest blank	82.59	9.84	24.43	3.24	0.39	0.96
8	Mixed forest	248.31	328.75	239.65	9.73	12.88	9.39
9	Land with scrub	40.19	23.83	47.65	1.58	0.93	1.87
10	Barren rock/Stony waste	34.31	29.02	3.52	1.34	1.14	0.14
11	Industrial/Mining area	2.92	6.71	1.48	0.11	0.26	0.06
12	Agro-Horticulture plantation	400.69	477.51	288.63	15.7	18.71	11.31
13	Land without scrub	25.32	10.84	20.36	0.99	0.42	0.8

Types of change vary from short term to long term but influence of environmental factors should be considered in change detection assessment. Spatial and spectral resolution of recent satellite sensors gives high quality of satellite datasets to delineate the landuse and land cover information. As seen from the table 2, 656.91 km^2 of dense forest was significantly increased over a period of 18 years. The annual rate of 9.43 km^2 was increased in thick dense forest (Table 3). Open forest was drastically reduced from 67.33 to 8.27 km^2 with the annual rate of

3.28 km^2 and forest plantation was found significant reduction (469.2 to 290.36 km2) at the annual rate of 9.94 km^2 for the period of 1973-1991. The main trees covered in forest area are sandalwood, bamboo, teak, eucalyptus, blue gum and wattle. From the environmental point of view, eucalyptus erupted into a major argument during the 1980s when experiments conducted by the Central Soil and Water Conservation Research and Training Institute proved that the eucalyptus absorbed enormous quantities of subsoil moisture, which was suspected to be a contributory factor to the water scarcity on the Nilgiris hill. In response to a sustained operation (SNC Newsletter 1995) against the random use of the species, the government finally agreed to stop planting eucalyptus under its forestry development programs. Meanwhile, the only industrial unit which was using the tree as a raw material turned sick, thereby severely reducing the demand for the tree (Venugopal, 2004). On the other hand, tea plantation was slightly decreased from 483.45 to 471.23 km^2 while the mixed forest was increased from 248.31 to 328.75 km^2 at the annual rate of 4.47 km^2. Land with scrub, land without scrub and rocky area were found significant reduction and considerable increase was noted in industrial area. The conversion of land with scrub or grass lands to agro-horticulture like vegetable plots also alters the sub-surface water conditions in addition to promoting landslides. This may be evidenced for decreasing land with scrub while increasing agro-horticulture plantation. Settlement was increased significantly from 7.49 to 29.11 km^2. It was significantly increased 1.2 km^2 every year from 1973 to 1991. This unexpected growth for settlement in the late 1980s and the earlier 1990s, witnessed particularly, tourism grew to be a major industry spawning a host of tourism related activities like hotels, lodges, travel and other entertainment related services (Venugopal, 2004).

4.1.2 Landuse changes in 1991-2009

Dense forest was extensively increased from 826.59 to 993.34 km^2 with the annual rate of 9.26 km^2 (table 2 and 3). Significant growth of open forest was found at the annual rate of 5.99 km^2 and forest plantation was found negligible increase from 290.36 to 305.41 km^2 at the annual rate of 0.84 km^2. Tea plantation was slightly decreased from 471.23 to 437.55 km^2 at the same time the reduction of mixed forest was found at the annual rate of 4.95 km^2. Land with scrub and land without scrub were found significant increase and extensive reduction was noted in industrial and rocky area. Considerable increase was noted in settlement from 29.11 to 44.29 km^2 at the annual rate of 0.84 km^2 and rocky area was reduced with the annual rate of 1.42 km^2 (Fig 5 and 6). The constant increase of urban growth by means of improvement of tourism associated with favorable climatic condition. While about 50,000 - 100,000 person visit the Nilgiris hill for every month during the “non-season” in the months of June to February and the visitors number doubles to 100,000 - 200,000 during the “season” in the month of March to May, peaking in the month of May when over 300,000 person visit in the district (Venugopal, 2004). Significant reduction was noted in agro-horticulture plantation from 477.51 to 288.63 km^2 with the annual rate of 10.49 km^2.

4.1.3 Landuse changes in 1973-2009

In order to obtain the information of landuse and land cover changes from the satellite data over the period of past 36 years (1973-2009), the areal changes were calculated and estimated the annual rate of changes in each land use class. Nilgiris district was commercial and main tourist center of the Tamilnadu state, of which forest was main land type which was increased 336.43 km^2 with the annual rate of 9.35 km^2 during this decade (Table 2 and 3). At the same time, forest plantation and tea plantation were decreased rapidly, decreased area were 163.79

and 45.9 km^2 respectively. Urban of Nilgiris hill increased from 7.49 to 44.29 km^2 and the annual rate reached 1.02 km^2 (Figure 7 and 8). This unexpected growth of settlement witnessed the increased population with commercialization in the late1980s to1990s. Nilgiris was a woody environment, and the dominant type of land was forest. Although the area of urban was much smaller than other districts, the change rate of urban was quite fast between the periods of 1973 to 1991than the 1991-2009. At the same time, dramatic decrease was obtained in agro-horticulture and crop land in past 36 years. This decline was evidenced due to the lack of field labors, low income from agriculture and climate change.

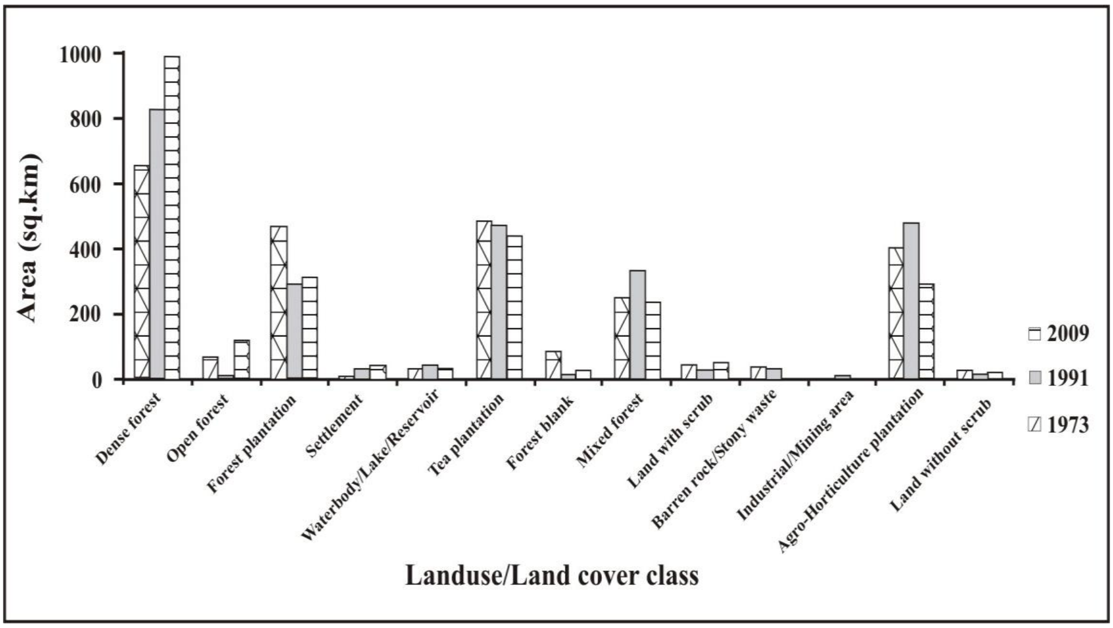

Figure 5: Area of landuse and land cover distribution

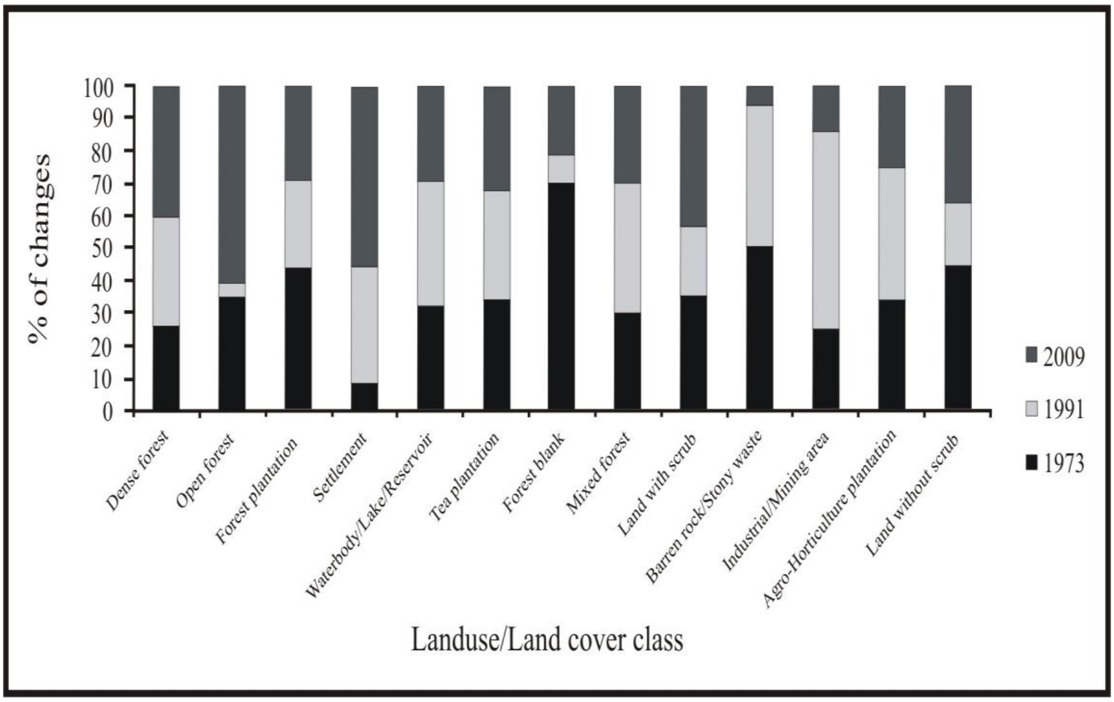

Figure 6: Percentage of landuse and land cover distribution

Table 3: Summary of decadal landuse/land cover change detection between 1973 - 2009 in Nilgiris district

S.No	Landuse class	Landuse/Land cover changes (km^2)					
		1973-1991	Annual rate	1991-2009	Annual rate	1973-2009	Annual rate
1	Dense forest	169.69	9.43	166.74	9.26	336.43	9.35
2	Open forest	-59.06	-3.28	107.75	5.99	48.69	1.35
3	Forest plantation	-178.83	-9.94	15.04	0.84	-163.79	-4.55
4	Settlement	21.62	1.20	15.18	0.84	36.79	1.02
5	Waterbody/Lake/Reservoir	6.65	0.37	-10.26	-0.57	-3.61	-0.10
6	Tea plantation	-12.23	-0.68	-33.67	-1.87	-45.90	-1.27
7	Forest blank	-72.75	-4.04	14.59	0.81	-58.16	-1.62
8	Mixed forest	80.44	4.47	-89.10	-4.95	-8.66	-0.24
9	Land with scrub	-16.36	-0.91	23.81	1.32	7.45	0.21
10	Barren rock/Stony waste	-5.28	-0.29	-25.50	-1.42	-30.78	-0.86
11	Industrial/Mining area	3.78	0.21	-5.23	-0.29	-1.44	-0.04
12	Agro-Horticulture plantation	76.82	4.27	-188.88	-10.49	-112.06	-3.11
13	Land without scrub	-14.49	-0.80	9.52	0.53	-4.96	-0.14

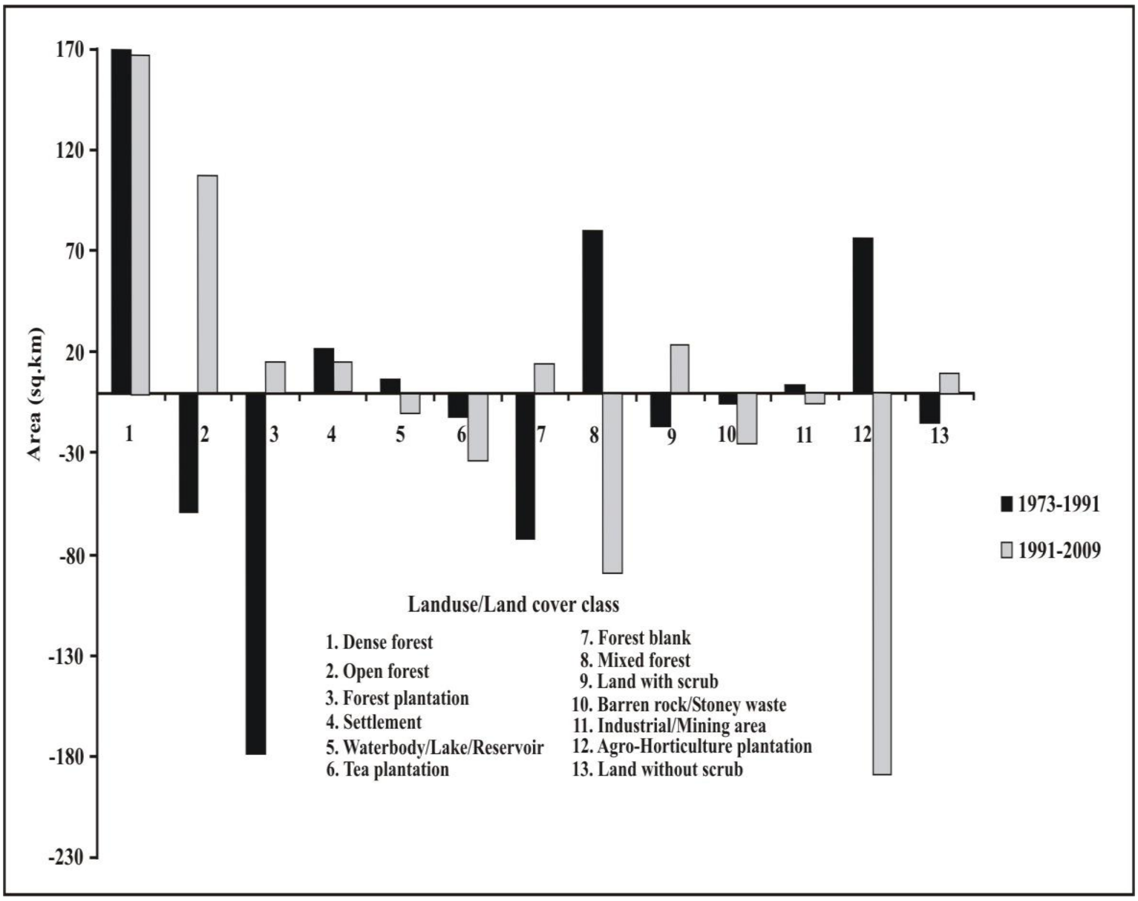

Figure 7: Landuse and land cover changes

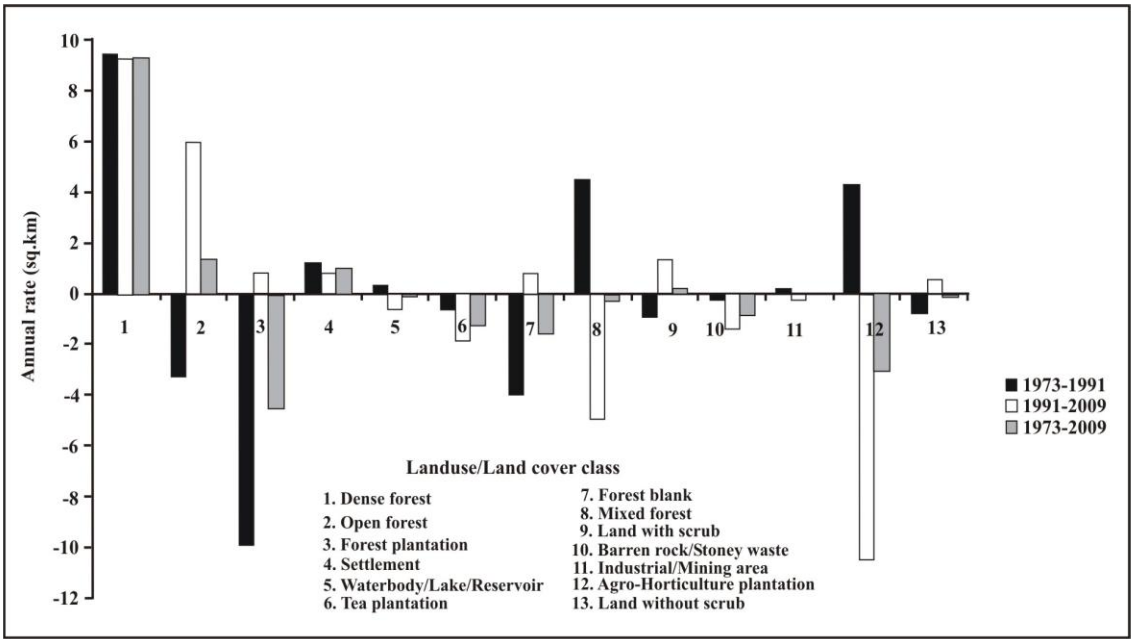

Figure 8: Annual rate of landuse and land cover distribution

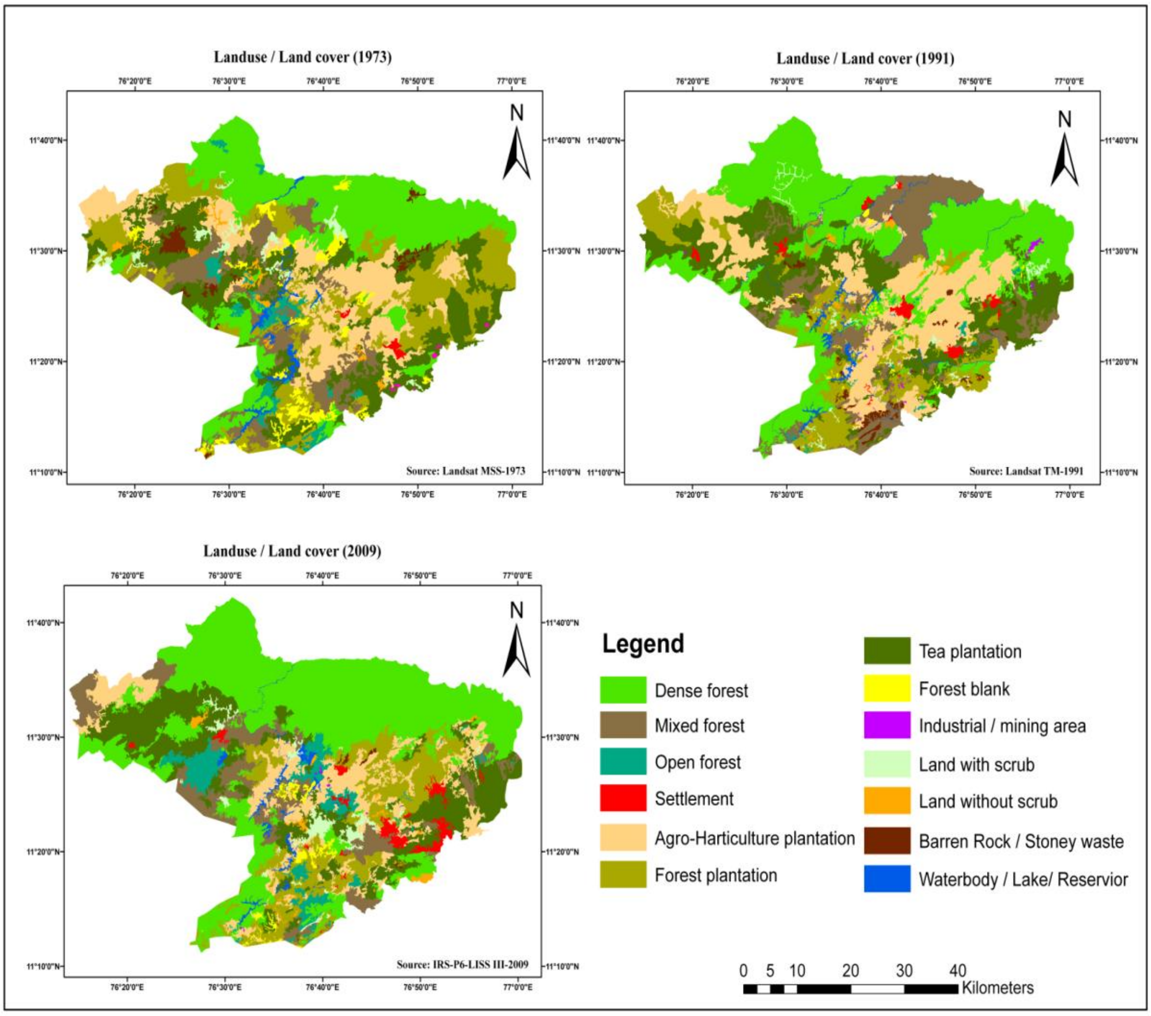

Figure 9: Landuse and land cover map of Nilgiris district in 1973, 1991 and 2009

5. Conclusion

The landuse system is highly dynamic which undergoes significant changes according to the changing socio-economic and natural environment. The changes in any form of landuse are largely related either with the external forces and the pressure within the system. Transformation of marginal lands from forests and barren areas into agriculture is basically to fulfill ever-increasing demand of food, fuel wood, fodder and timber. The process of rapid land transformation has not only brought about an ecological crisis in the region but has also threatened the agricultural economy of the watershed through accelerated soil erosion, deforestation and reduction in ground water recharge. The present study of landuse and land cover changes using multi-temporal Remote Sensing clearly shows the extent of changes in different landuse features. The land under agriculture and settlement has increased significantly at the sum of reduction of forest plantation and partially of barren land. Major changes have also been detected in forests especially open forest to dense forest and mixed forest. One possible implication to the problem facing the Nilgiris is a gradual crop diversification. The local government has initiated measures to encourage floriculture and revival of fruits cultivation such as strawberries as a substitute for the monoculture tea. The successes of these measures depend on whether viable markets can be created for these products, especially those produced by small farmers. However, the future environmental stability of the Nilgiris hill will largely turn on making tea an economically sustainable crop. Tea can be supplemented by non-farm activities like tourism and other services. A master plan is being implemented since the 1990s to normalize landuse in the hills and ensure urbanization and commercialization. The land used for tea estates without considering proper drainage and slope ultimately results in loss of natural ecosystem and ends in massive frequent landslips.

Acknowledgement

The author wish to thank University Grants Commission (UGC), Government of India, New Delhi for the project funding (No. 34-54/2008(SR)) and authorities of Bharathidasan University for the support and facility.

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