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Remote Sensing And GIS For Change Detection And Eco Degradation Studies In The Nilgiris – South India

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Abstract: For many years, growing concern has been expressed over the environmental degradation in mountain ecosystems. Modern technologies such as Geographic Information Systems (GIS) and Remote Sensing can facilitate effort to monitor and analyse the changing resources bases of such ecosystems. This study is an attempt to quantify the rate and type of environmental degradation occurring in the Nilgiris, south India using such techniques. Eco-degradation activity in the Nilgiris is related to following causative factors viz., slope, landuse, geology, geomorphology, drainage, lineaments and rainfall. A change detection map and a transition matrix was prepared from satellite data of three different decades, which indicates the amount of change that has taken place. A zonation map was arrived by GIS analysis which divides the study area in to four zones of degradation. This map is useful for selecting suitable locations for implementation of the hill area development programme.
Key words: Remote Sensing, GIS, Eco degradation.

1.0 Introduction

In the recent years the focus of conservation has shifted from conservation of ecosystem and species to conservation of habitats. Mountain slopes, hills, ponds, lakes, coastal dunes, marshes and lagoons are few landscape that support many life forms. The management of ecosystems requires inventory and monitoring of large areas of natural landscapes in desired scales. Ecological security in the hilly terrain area is to be monitored carefully and it is done by proper landuse planning and management. Other than the anthropological activities, geology, geomorphology, drainage network, slope and climate play an important role in the ecological degradation of in the hilly regions. This study involves the understanding the role of these factors in the eco-degradation occurring in the Nilgiris over the past few decades. Remote sensing and GIS are the two modern technologies used comprehensively to facilitate efforts in the direction of eco-restoration and mountain development. Many workers have done exhaustive research on these lines. A few of these include Shrestha[1], Bitter[2] , Stones and Estes[3] . As of now most applications have been operationalised due to the integrated approach. A few of the applications are the ones demonstrated by Price et al.[4] and Lee et al[5]. Much work has been attempted to integrate GIS and remote sensing in various fields, a few of them being vegetation change[5], environmental management[6], marine pollution[7], and coastal resources management[5]. The objective of this study is to address the ecostatus using Remote Sensing and conventional data to arrive at site specific plans for

tackling problems such as improper landuse practices, forest degradation and soil erosion in the Nilgiris Hill ranges.

2.0 Study Area

The Nilgiri Hills (Blue Mountains) of south India, is one of the magnificent and oldest mountain ranges in the world, lying at the junction of Eastern and Western Ghats of Indian peninsula. The Nilgiri District (Figure 1), has a geographical area of 2549 km^2 and is basically, a hilly district forming part of environmentally fragile western ghats with an elevation ranging from 300 m in Moyar gorge to 2634 m above msl at Doddabetta peak. The district forms a part of Nilgiris Biosphere. Bhavani and Moyar are the two important rivers.

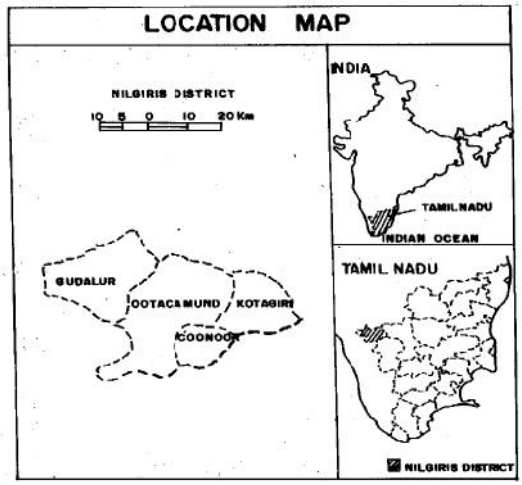

Figure 1 Study Area

Geologically, the main Nilgiris massif is composed of Charnockites (pyroxene granulites/gneisses). Three sets of steep dipping joints trending (1) NNE-SSW (2) NNW-SSE (3) East-West are prominent. All the prominent escarpments on the hills area developed along one or more of these three joint directions. Being a hilly area with steep slopes, rate of soil creep and erosion is quite rapid and hence soil thickness does not exceed more than a meter. Light yellows to reddish brown clayey soils are of common occurrence. Humus soils of about 0.5m thick are confined to the areas covered by thick vegetation. Major part of Nilgiris district is under forest cover (56%) about 20% of the district under tea, coffee, arecanut, coconut etc., plantation. Tea plantation is found at all slopes. Grasslands, shola, eucalyptus, pine and other forest plantations are also seen in the district varying attitudes, high rainfall, varying temperature regimes have endowed Nilgiris with a diverse natural heritage. With such a diversified ecosystem, improper landuse practices and planning is leading to the degradation of fragile ecosystem.

2.1. Problems of the District

Though the Nilgiris district has 56% of the area under forest cover and has bountiful of vegetation/greenery, with an annual average rainfall of 1800-2000mm, the fragile ecosystem is under threat due to biotic pressure/human activities and improper landuse practices. The major issues/problems of the district are: landuse practices in conflict with the terrain, degradation of shola forest and grassland, forest fire/encroachment, landslides and, biotic pressure. These types of landuse practices have resulted in heavy soil erosion, land degradation and siltation of streams/rivers/reservoirs. Annual cropped areas remain fallow for about 6 months in a year and these areas on high slopes are the most vulnerable to soil erosion especially during rainy season (the area receives heavy rainfall). Landslides (basically soil/debris slides) are common in Nilgiris and are frequent and an annually recurring phenomenon during the rainy season.

3.0 Methodology And Data Used

The study has been carried out in a phased manner. The different phases are as follows:

1) Collection of data (Satellite, Conventional) 2) Preparation of various thematic maps/layers 3) Ground truth-using GPS survey, 4) Post Ground Truth mapping, 5) Final preparation of various thematic maps / layers, 6) Digital Database Creation, 7) Integration and overlay analysis and 8) Zonation of eco-degradable and restorable areas. The first phase involved collection of various data and information such as IRS-1B, Landsat-MSS and TM satellite data and conventional data such as topographical maps from survey of India, Geological survey of India, publication and reports from different departments. The various satellite data included:

Indian Remote sensing satellite, IRS IB LISS II (1993, Feb), Geocoded, FCC, LANDSAT MSS Data – 1973, LANDSAT TM Data – 1989. After carrying out preliminary interpretation of satellite data, extensive field transverse in the district were been carried out. Detailed data/ information were collected on various features during the visit.

3.1. Thematic Maps

3.1.1 Slope Map

The slope and aspect of a region are vital parameters in deciding landuse of and area. A slope map on 1:250,000 scale was derived from SOI topographic maps by `WENTWORTH' method. The slope map and classes (regrouped) are described in Table 1.0

3.1.2 Landuse/ Land Cover Map

The Landuse/ Land Cover Map is prepared by using satellite data of three different years as described in the methodology section (Figure 2). It is notices that the Nilgiri district is characterised by the presence of vast forest, tea plantations, vegetable crops and barren steep slopes. The northern part of the district is of deciduous forest area (Mudumalai), the western part is predominantly grassland and shola (Mukurthi). Tea plantations are seen mainly in the central, Eastern part of the district. Annual cropped areas are seen in and around Ooty and Coonor and Central part of the district. Ever green forest, sholas are seen mukurthi and southeastern, northeastern part of the district. It was observed that in most of the areas, present day landuse practices adopted are not in tune with terrain condition (slope).

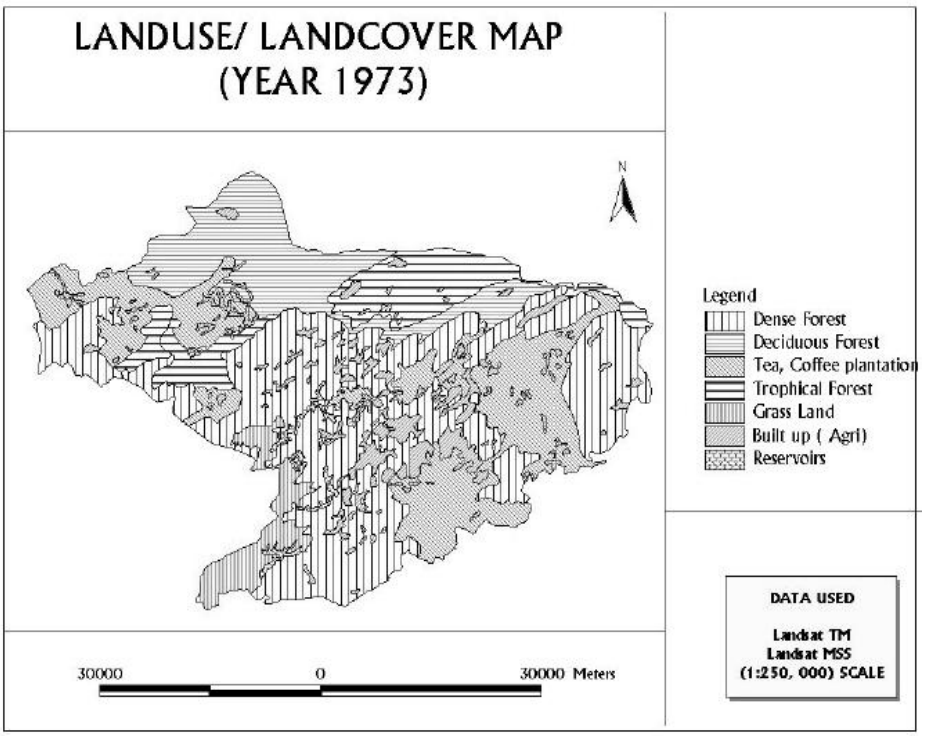

Figure 2 Map showing the Landuse / Landcover units of the study area during 1973.

Table 1.0 Description of slope and regrouped slope classes for the Nilgiris.

Slope class	Description	Regrouped classes	Description	Landuse Practice
1	Nearly level	1 and 2	Nearly level to mode sloping	Potatoes cabbage
2	Very gentle sloping	3 and 4	Moderate to steep sloping	Agriculture plantation
3	Gently sloping	> 4	Very steep sloping	Forestation
4	Moderately sloping			
5	Moderate to steep			
6 and above	Very steep sloping			

3.1.3 Geology and Hydro-Geomorphology Map

These maps were prepared from satellite images and existing mineral map of the Geological Survey of India on 1:500,000. Geologically, the Nilgiris massif is composed of pyroxene gneisses interbanded with pyroxene granulites and garnetiferous quartzofelspathic gneisses. On the Nilgiris plateau there are a number of laterite cappings, which are aluminous. The regional foliation trend of rocks varies from ENE-WSW to East-West with steep dips varying from 60 degrees to vertical, indicating synforms and antiforms. Three sets of steep dipping joints trending (1) NNE-SSW (2) NNW-SSE (3) East-West are prominent. The prominent escarpments on the hills area developed along some of these three joint directions. Geomophologically, the entire district is comprised of plateau landforms. The plateaus are (i) Ooty plateau (ii) Mukurthi plateau (iii) Gudalur plateau (iv) Moyar plateau. Good to very good groundwater prospect zone of Nilgiris district lies in the north western part of Gudalur taluk.

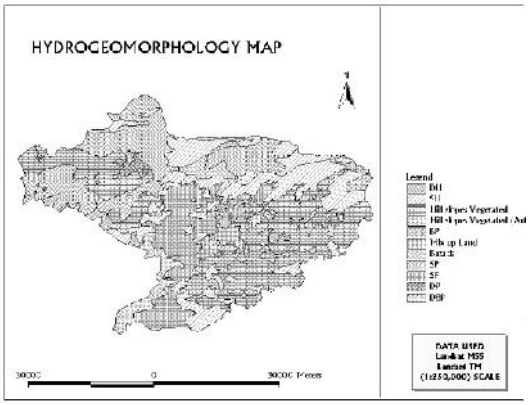

Figure 3 Satellite image derived hydro- geomorphology map of the Niligiris district.

The drainage morphometry throws light on lithologic and structural controls of the watershed, relative run off, recharge, erosional aspects etc. In the study area the drainage pattern is parallel to sub parallel, dendritic to sub dendritic and trellis.

3.1.4 Landuse Change Detection

Significant effort has gone into the development of change detection methods using remotely sensed data to understand the changes in ecosystem of hill ranges. Using the multi-date images and GIS and change detection map was prepared for the Nilgiris. Table 3 lists the type of changes that have occurred between 1973to 1989 and 1973 to 1993.

Table 2 Major landuse changes between 1973 to 1989 and 1973 to 1993 in the Nilgiris

Category	1973-1989	1973-1993
Forest to Tea Plantation	23 Sq.km	34 Sq.km
Deciduous forest to Built up	14 Sq.km	17 Sq.km
Scrubland to Dense Forest	8.5 Sq.km	6.0 Sq.km
Deciduous forest to Dense forest	Not observed	4.3 Sq.km

4.0 Data Base And Gis Analysis

A digital database for entire Nilgiris district was generated on 1:250,000. All the thematic maps were digitized in a Geographical Information System (GIS) environment. The spatial data for entire district was integrated using the decision rules arrived at by incorporating the inputs from various layers/ maps. GIS was used to monitor the eco-status of the Nilgiris. The major inputs are the various themes and their attribute table was generated. The eco-status is obtained by associating the relevant weight and rank of the respective themes. The analysis is done on a polygon basis by using the basic overlay operations.

5.0 Concept Of The Model

The aim of study is to assess the eco-status of the Nilgiris. The study is carried out with considerations of relevant parameters such as are landuse/landcover, hydro-geomorphology, slope, geology, drainage density and lineament density. Weights and ranks are assigned to each theme separately for this study the required value, which is the sum product of weightage and rank of the scheme is given by,

$SI = W \times R$ (1)

SI = Suitability Index
W = Weight of each theme
R = Rank of each class

The eco-status sites are classified as Highly degraded, Moderately degraded, Slightly degraded, and not degraded. The above-mentioned zonation are derived by grouping the suitability index.

5.1 Assigning Rank And Weightage

It is the primary input for the multi criterion analysis. The weight and ranks for the themes are assigned based on their range of suitability for the site selection. The criteria, which are considered for the study are landuse/landcover, hydrogeomorphologly, geology, slope, lineament density, and drainage density.

5.2 Weightage for Themes

This is assigned based on their close contribution to the site for zonation of the eco-status. The weightages for different themes are given in percentage as follows:

5.2.1 Landuse/Landcover

It is the indicator of present status of the land utilization, for the eco-status and mountain developmental studies. The suitability ranks are assigned by considering the fact that the dense forest category is less prone for degradation. The next landuse category is deciduous forest, which has a low rate of degradation. The next group is the tea and coffee plantation that is moderately prone to degradation. The grasslands are degraded easily and hence are assigned higher rank. The last landuse category is built up land where more erosion and hence higher rank is assigned.

5.2.2 Slope

The slope and aspect of a region are vital parameters in deciding suitable landuse for the area. In general, the terrain of the Nilgiris district is highly undulating and hilly. The slope varies from gentle in valley region to very steep in dissected slopes.

5.2.3 Geology

The study area is entirely comprised of charnockite which is prone for erosion due to joint and fracture pattern present in that rock type, and also it is easily weathered by natural agencies. Hence, it is assigned higher rank in that theme.

Table 3. List of themes and the corresponding weightage

Themes	Weights
	Eco degradation
Landuse/Landcover	25
Slope	25
Geology	20
Hydrogeomorphology	10
Drainage density	15
Lineament density	5
Total	100

Table 4. Landuse categories and the corresponding ranks

Category	Rank
Dense forest	1
Deciduous forest	2
Tea coffee plantation	3
Scrubland	1
Grass land	4
Build up land	4

Table 5. Slope classes and geomorphic units with their ranks

Slope Class	Rank ED	Geomorphic Classes	Rank ED
1	I	SH	1
2	I	DH	1
3	II	HVA	3
4	II	HVN	4
5	III	BP	3
6	III	MIXUP	4
		BAZADA	2
		SP	2
		DBP	1
		DP	2
		Pediment	1

SH-Structural Hills; DH-Denudational Hills; HVA-Hill slopes vegetated artificially; HVN-Hill slopes vegetated naturally; BP-Buried pediment; SP-Shallow pediment; DBP-Deep buried pediment

Table 6. Slope category (as contour interval) and the corresponding ranks

Contour Interval	Category	Rank
0 – 0.8	Poor	1
0.8 – 1.7	Low	2
1.7 – 2.6	Moderate	3
2.6 – 3.5	High	4
3.5 – 4	Very high	5

6.0 Zonation

The analysis clearly brought out the most degraded, moderately degraded, less degraded and not degraded areas in the Nilgiris.

Zone I	Most Degraded
Zone II	Moderately Degraded
Zone III	Less degraded
Zone IV	Not degraded

From the zonation we can clearly observe that the intensity of eco-degradation was less during 1973 but during the next 20 years the considerable human impact has caused the Ecodegradation. It is also evidenced from the Ecodegradation status map of 1993 that around the settlement areas (Eg. Coonoor, Gudalur and Udagamandalam) significant degradation process has been operational.

7.0 Discussions And Conclusions

In this study multi temporal remote sensing data (Satellite images of 1:250,000 scale) have been used to prepare geomorphology, slope, landuse and landuse change maps of the Nilgiris district. Slope map was prepared using 1:250,000 topographical maps. Integration of all the thematic maps in a GIS and subsequent analysis shows that ecodegradation in the Nilgiris district has been considerable over the past 2 decades due to various factors. Analysis of landuse/landcover reveals that human interference has been the major cause for the said degradation. From the landuse/landcover map of 1973 it is observed that 23 sq.km forests have been converted into 34 sq.km as tea plantation and 14 sq.km has been converted into 17 sq.km as built up land. Some scrubland category has changed into dense forest. The restoration of dense forest from shola category is about 31 sq.km, and the increase in Tea Plantation from the source of Built up areas is about 34 sq.km. From the statistics prevailing during 1973, landuse/landcover change map indicates that the urbanization and human impacts are the major cause for the degradation. A similar change/trend is observed during 1993. From the landuse/landcover map of 1993. It is clearly evident that conversion of forestland to tea plantation is about 35 sq.km, which is a 15 sq.km increase compared to the areal extent during 1973. Forest category has been restored to an extent of 60 sq.km during 1993 which is relatively less while compared to landuse/landcover map during 1973 (85 sq.km). It indicates the degradation status distributed among other categories such as built up land in to Tea as 66 sq.km. Next noticed factor, is the geomorphology in the area the hill slopes are mainly covered by weathered material (B.P) which is favorable for the landuse/landcover categories such as tea plantation and forest category. The moderate slope category is mainly comprising of intensive tea plantation (HVA landscapes). The next geomorphological feature is the plaints having slope range less. And it is encounted by annual crops such as carrot, gappages, and potatoes which is also leads to degradation of Ecosystem mainly due to human impacts. Though this study attempted to explore the role of geology and geomorphology in the ecodegradation in the Nilgiris, it is observed that human factor has more weightage in this regard. Given similar geomorphic geologic setting, different amounts of human impacts lead to differing eco-degradation. This fact has been explored using GIS Analysis. The study clearly brought the impending threat to the fragile environment of the Nilgiris District. Due to indiscriminate / improper landuse practices the Nilgiris district under going rapid and destructive

changes. Regarding the forest sector, it was observed that, degradation / encroachment of sholas and grass land and the biotic pressure area the major issues. The study has highlighted the degradation of shola /grass land as well the problem of grazing by cattle in and around Mudumalai.

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