CHAPTER 2

REVIEW OF LITERATURE

2.1 INTRODUCTION

This chapter lists and reviews the various research works carried out in the field of Watershed Management, Remote Sensing and GIS application and about the Nilgiris. Remote sensing and GIS are the two modern technologies used comprehensively to facilitate the efforts in eco-restoration and mountain development. The present study attempts to study the land degradation status and to suggest developmental activities in the mountains. Many workers have done exhaustive research on the subject related to the land degradation/soil erosion and mountain development using remote sensing and GIS. A few of these include Stones and Estes (1993); Bitter (1997); Shrestha (1998).

2.2 STUDIES ON THEMATIC MAPS GENERATED FROM DIFFERENT SOURCES

Maps representing information on geomorphology, landuse, slope, geology, landuse change etc. form the basic for sustainable development and management of hilly regions. Javed Akram (2000) has delineated the Geomorphology of Bulandshahr district, Uttar Pradesh, India using Landsat TM & IRS I A, LISS II digital data. By visual interpretation techniques the author has demarcated four broad geomorphic zones. Also band ratioed images were used to identify certain geomorphic units. The author concludes that satellite data is useful in identifying various geomorphic landforms in understanding the river morphology and its behavior.

Sushil Pradhan (2002) used remote sensing to carryout **r**egional land cover mapping of the Hindukush-Himalayan (HKH) region using satellite image: The study acquired 12 scenes of the WiFs satellite data covering the whole HKH region. Each of these scenes were rectified and geometrically corrected using ground control points (GCPs) from defense mapping agency aerospace center (DMAAC), Missouri, USA. All the GCPs were verified in the Operational Navigation Chart (ONC) of scale 1:1000, 000, and the same locations were identified on the images and registered. Overall root mean square error (RMS) was limited within a pixel. Then it was re-sampled to pixel size 180m x 180m. which maintains the original DN of pixels. Landsat TM data was used for the identification of different agricultural landuse types and forest types. There is no doubt that it would produce more accurate result, but the question is about the cost, which is about 20 times expensive than using the IRS-WiFs satellite data. Therefore, author opine that WiFs data is good enough to be incorporated with the proposed methodology for a regional or national level study. In the analysis, broadleaf forest and coniferous forest has been found as the dominant land cover classes, which are 43.3 and 26.6 percent, respectively. The methodology will work well and is recommended to use at a watershed level using medium or higher resolution satellite data.

NRSA (1989) has published a ‘Manual of Nationwide Land Use/Land Cover Mapping using Satellite Imagery’. This manual gives a comprehensive list of land cover types of India and a well suited methodology for preparation of land use maps. The Landuse map for the Nilgiris was prepared based on the guidelines given in this manual.

Krishna Pahari et al (1996) conducted a study to assess the utility of satellite remote sensing and GIS for monitoring the land use conditions and the rate of soil erosion in a mountain watershed. This formed a basis for suggesting alternative, sustainable measures of landuse based on limits of soil erosion. This involved interpretation from aerial photographs as well as digital image processing of high resolution satellite data, namely SPOT, HRV and Landsat TM data. The results showed that high resolution satellite data can be successfully used to monitor the landuse changes in a mountain watershed. Similarly, GIS can be successfully used for making spatial analysis of soil erosion. However, it still needs further verification and development for estimating the precise rate of soil erosion. Overall, it was found that remote sensing and GIS can be successfully used for monitoring land use dynamics and soil erosion in a mountain watershed and then for making sustainable landuse modeling. This result of this study is used as guidelines for this thesis.

Kandasamy (1986) has prepared landuse / landcover map, drainage, geomorphology maps for Nilgiris district using satellite imagery 1973 and 1983. The author studied the landuse / land cover change over one decade and found that, there is a reduction in forest cover and increase in Tea plantation annual crops. The author also conducted morphometric analysis for Sillahalla watershed and found that Horton's law of stream order is valid for the Nilgiris. Runoff estimation was also worked out for the watershed and it is found the computed value tally with the discharge measure at the site.

Jayakumar et al (2003) have delineated the Landuse/landcover map by digital image processing of IRS 1C LISS III data. The author have expressed that out of 247 villages, only 36 could be clearly identified in the study area since most of the villages were comprised of very few houses interspersed with trees and agricultural field.

Chen Xiuwan (2002) attempted to analyze the relationship between land cover change and regional social and economic development by using land cover change information from remotely sensed data. A post classification method is used to detect land cover change from multi-temporal satellite data, and particular attention is given to the selection of an appropriate method for land cover classification. Ancillary data, such as elevation, slope, aspect, geology, soils, hydrology, transportation network, vegetation, etc should be incorporated in to the classification process to improve the accuracy and quality of remote- sensing-derived land cover classification and change detection. Use of a GIS allows further spatial analysis of the data derived from remotely sensed images and analysis of the impact of land cover change on regional sustainable development. The land cover change has occurred in the past decade as a result of both natural forces and human activities.

Graciela Metternicht (2001) developed a methodology for computing the amount of land cover changes that have occurred within an area by using remote sensing technologies and fuzzy modelling and it concentrates on the formulation of a standard procedure that uses the concept of fuzzy set and fuzzy logic, can define the likelihood of changes detected from remote sensing data. The method accounts only for spatial changes of an object or surface feature but changes to the attributes are not likely to be detected, unless significant spatial changes occur. The accuracy of the method is dependent on the spatial resolution of the remotely sensed data used and it is helpful to identify the areal extent and location of the areas undergoing a large number of changes.

Lo and Robert L. S (1990) tried a GIS approach to assess the impact of new town development on the environment through integrating past and current aerial photographic data of land use with topographic and geologic data. Image overlaying and binary masking techniques were useful in revealing quantitatively the change dynamics in each category of land use and also applied to assess the impact of such terrain attributes as slope, surface hydrology, and geology on these land use changes.

Westmoreland et al (1992) proposed a framework for analyzing ancillary data and developing procedures for incorporation of ancillary data to aid interactive identification of land use categories in land use updates using an integrated image processing / GIS that permits simultaneous display of digital image data with the vector landuse data to be updated. About 75% of the area that experienced a change in landuse was correctly labeled using the combination of automated and visual interpretation procedures.

Siddiqui et al (2004) carried out land use studies focusing on mapping the past and present conditions and the extent of forests and rangelands using remote sensing and GIS technologies. These technologies provided a possible means of monitoring and mapping the changes occurring in natural resources and the environment on a continuous basis and have been used to evaluate the geographic extent and distribution of the forest and to monitor temporal changes in the forest cover between specified years.

Landuse classification in mountainous area was carried out by Dhruba and Alfred (2001) by using image processing and GIS techniques and refined by using ancillary data and expert knowledge. Intensity normalization of the individual spectral bands is implemented for removing the variations in the solar illumination angle. Landsat TM data of the year 1988 was used and geo-referenced and nearest neighbor interpolation was followed during resampling. Maximum likelihood method was used for classification from the training samples. NDVI was generated to identify the forest types into dense and degraded and DEM was developed from SPOT PAN data to improve the classification. The maximum accuracy of the final classification is 97% and over all classification accuracy increased to 94% and expert knowledge of the area considerably improves classification accuracy.

2.3 MORPHOMETRIC ANALYSIS

In hilly terrains that have a well developed drainage network, morphometric analysis provides important information on soil erosion, ground water etc. Strahler (1957) gives an elaborate account of the various morphometric parameters and their significance.

Sameena et al (2005) have carried out quantitative morphometrical analysis for 30 sub-basins of Bhadra river basin, Karnataka south India. They have studied the applicability of Horton’s laws. They have listed the relationship between morphometric parameters and observation on IRS-ID LISS-III data.

Srinivas Vitalla et al (2004) have delineated the drainage lines from topographic maps and updated with satellite imagery and carried out quantitative morphometrical analysis for sub watersheds independently using GIS techniques. They conclude that the conventional methods of morpohometric analysis are time consuming, tiresome and error prone, while the use of GIS techniques allows for more reliable and accurate estimation of parameters of a watershed. The morphometric analyses of different subwatersheds show their relative characteristics with respect to hydrologic response of the watershed. Such studies indicate that morphologic parameters coupled with integrated thematic maps can help in decision making process for water resources management.

Carlos Hendrique Grohmann (2004) conducted morphometric analysis using Geographical Information System (Grass and R Software) for the area Quadrilatero Ferrifero region, South San-Francisco Craton. The integration between GIS and Statistics in morphometric analysis allows agility and precision for determination of necessary parameters.

Carlos Hendrique Grohmann (2005) conducted Trend-Surface analysis of morphometric parameters in south-eastern part of Brazil.

Suresh et al (2004) have computed the drainage morphometry of subwatersheds of Terai watershed at the foothills of Himalaya, India and estimated the sediment production rate of different sub-watersheds of the study area using Jose and Das (1992) model given by:-

$$\text{Log (SPR)} = 4919.8+48.64 \log (100+Rf)-1337.77 \log (100+Rc)-1165 \log (100+Cc). \quad - \quad (2.1)$$

where, Rf - form factor

Rc - circularity ratio and

Cc - compactness coefficient.

Sediment production rate is the volume of sediment produced per unit drainage area per unit time. This model suggests the possibility of use in the context of the Nilgiri Hills also.

Mishra et al (1984) have studied the effect of different topographical elements such as area, drainage density, form factor, etc. on sediment production rate of the subwatersheds in the Damodar Valley in eastern India, and concluded that the increase of the form factor reduces the sediment production rate. This observation by Misra etal has relevance to the watersheds of Nilgiris as different form factors are witnessed here in the Nilgiris.

Singh et al (1997) conducted morphometric studies using remote sensing and GIS techniques for Kanhar River Basin of Vidarbha region central India. The author computed the morphometric parameters and used the parameters for the watershed development of the basin.

Guruswamy (1974), prepared a report on the morphometric and water budget studies of Baldi Nadi sub basin of Song river, Dehradun along with the hydrogeological studies. The author worked out the morphometric parameters of Baldi Nadi drainage network and computed the water budget details of the basin, thus implying the relationship between the two.

Sarangi (2003) studied the development of user interface in ArcGIS for Estimation of Watershed Geomorphology. A Geographic Information System tool was used to develop an interface (built-in macro) within ArcGIS for the estimation of watershed morphological parameters. This was developed using Visual Basic for Applications (VBA) language based on Arc Objects technology developed by the Environmental Systems Research Institute (ESRI). The author demonstrates one interface for Geomorphological estimation. The drainage density is one of the Geomorphological parameters, which provides the information about the behavior of the watersheds to rainfall events. If drainage density is high, it implies a well-developed natural surface drainage pattern. A high drainage density map occurs due to several watershed features as well as the rainfall pattern. The drainage densities of delineated watersheds of Cowansville region are 9.3 km/sqkm 9.46 km/sqkm and 10.14 km/sqkm. It was observed that, drainage density is higher for smaller watersheds. Moreover, higher drainage density also reflects high rainfall in the watersheds and also reflects quick transformation of overland sheet flow into rill, channel, rivulet and stream flows, which in turn, implies low infiltration characteristics of the watershed surface soils. Besides, drainage density will be usually low in well-vegetated or well-forested watersheds as the direct Impact of rainfall is reduced due to abstraction through interception of the incoming rainwater. It was also observed from the metadata of the region that the low drainage density is obtained from the watershed having more forest and land covers. Interfaces for different purposes can be developed to estimate watershed based parameters and also link the geo-referenced watershed parameters with the hydrological models to estimate surface runoff, sediment loss, ground water potential etc.

2.4 LAND DEGRADATION

Degradation of land in hilly terrain is a perennial problem due to human interference. This is especially true for the Nilgiris where Tea plantation is a major activity. A project entitled “Assessment of Eco-Degradation in Nilgiris district of Western Ghats was carried out at Institute of Remote Sensing, Anna University in the year 1986 under Western Ghats Development Programme. Various thematic layers were prepared using satellite data. Vegetation degradation, soil erosional degradation and human impact analysis on the watershed were carried out. Combining these three factors, the district was classified in to four categories i.e. highly degraded, moderately degraded, slightly degraded and areas where there is no degradation. The study was useful for Agricultural Engineering Department of the Government of Tamilnadu.

Bhuvanesh Prasad et al (1997) used remote sensing and GIS Technology for the subwatershed prioritization of Trijuga watershed of Nepal. From the topographic map two sub watersheds were delineated. The author calculated soil loss using RKLSCP equation. Soil loss status and land sensitivity were taken as the basis for their prioritization. The ‘C’ factor in the equation was calculated from the satellite data and landuse change was mapped from two time data. They calculated few parameters such as degradation speed index (DSI) and sensitivity index (SI). The present rate of soil erosion is considered as present condition (PC). The DSI, SI, and PC were taken as condition and used for prioritization analysis. Though this study is relevant to our work, since I have not estimated soil erosion values this method is not adopted in my thesis.

Gosain (2004) used remote Sensing and GIS-based technology for watershed management, for the Doddahalla watershed, wherein micro-watershed prioritization has been carried out using criteria cutting across hydrological, demographic and socio-economic parameters.

Biswas et al (2002) used remote sensing and GIS in watershed prioritization for a subwatershed constituting a major portion of a watershed enveloping Nayagram Block, Midnapore District, West Bengal, and a small portion of Mayurbhanj District, Orissa. The micro watersheds under this subwatershed were prioritized based on three conventional methods viz., morphometric analysis method, standard Sediment Yield Index (SYI) method, and Soil Conservation Service (SCS) runoff curve number method and by a newly proposed method which is a combination of morphometric method and SYI named as Silt Morphometry Index (SMI) method. The SMI method appears to be a better alternative for prioritization out of all the methods in view of non-availability of all the information regarding soil, landuse, hydro geomorphology and the storm characteristics and can be used instead of conventional methods for prioritization of watershed components.

Saha (1996) used remote sensing and GIS to study soil erosion hazards. Assessment and inventory on soil erosion hazard are essential for formulation of effective soil conservation plans of a watershed for sustainable development. The objective of this study was to assess and map soil erosion hazard of Doon valley, Dehradun district, Uttar Pradesh, India, following GIS based scalogram modeling approach using remote sensing (IRS-1B, LISS-I) derived physiography, soil and land cover and DEM derived terrain slope map and ancillary data of soil characteristics and rainfall as inputs. Integrated Scalogram modeling approach resulted in seven classes of soil erosion hazard in the study area with numerical values of Erosion Hazard Index (EHI) ranging between 1 (Very low hazard) to 3.5 (very high hazard). The results indicate that satellite remote sensing and GIS techniques are indeed valuable tools for soil erosion hazard assessment by integration of soil erosion controlling soils, terrain and climatic parameters.

The ISRO (2001) has carried out integrated mission for sustainable development for Nilgiris district in collaboration with IRS and State Government departments and voluntary agencies. They have prepared various thematic layers for Nilgiri districts. Watershed wise integration of thematic layers was carried out and wherever the landuse was in conflict with terrain, suitable action plans were suggested.

Tomar et al (2002) used integrated approach of Remote Sensing and Geographic Information System in characterization and evaluation of natural resources for watershed management in upper Shipra watershed, Meghalaya. Site specific action plan of Upper Shipra Watershed (USW) in Ri-Bhoi district of Meghalaya India has been prepared by integrating natural resources information generated from satellite data in conjunction with other conventional and socio economic data. This work provides a package of landuse practice and action plan for land and water resource development recommended to maintain the ecosystem of the area and to meet the demands on sustainable basis with people’s participation.

Bhagera (1986) discussed the problems created by an unattended watershed and their effects on watershed degradation. The most serious problem of unattended watershed is excessive soil erosion. The problems caused by excessive soil erosion are infertility of soil, creation of gullied/ravenous land, mass movements (especially landslides), damage of surface cover, drought (due to reduction of soil moisture), flood (due to excess run off), excess sediment yield and loss of forest.

Sharma et al (2002) carried out a study to prepare micro-watershed development plans using Remote Sensing and GIS for a part of Shetrunji river basin, Bhavnagar district, Gujarat, India. They used multidate satellite data and prepared thematic maps such as landuse, hydro geomorphology, soil, slope, groundwater level and quality etc. They used these maps in GIS environment and suggested action plans for the watershed development.

Kandasamy and Venugopal (2002) generated cadastral level resources information system and action plans for Mynalli watershed in the Nilgiri district using remote sensing, GPS & GIS. They have prepared thematic maps such as landuse, slope, and watershed boundary. These maps were digitized, edited and labeled in the GIS environment. They concluded that the slope based landuse practice is a must for preserving the ecology of Nilgiris. They suggested the annual crops in 0-10% slope,agricultural plantations/horticulture/forestr plantation in 10-33% slope andpermanent tree cover/forest/silvipasture in >33% slope. Based on this, the authors prepared action plans for the watersheds. A similar approach has been adopted in this thesis also to suggest the action plan.

2.4.1 Soil Erosion

Land degradation is caused by many factors such as soil erosion, deforestation, land slides, water logging, salinity and pollution and industrial causes. Out of these, soil erosion is the most widely and most common form of land degradation. A number of research works have been done in the area of soil erosion.

Many researches have used the universal soil loss equation (USLE) model, which is an empirical procedure developed by Wischmeir and Smith (1965) from statistical analysis of erosion data from a large number plot studies under different conditions. This model enables the planners to locate the potential erosion zones in a watershed and to try alternative combinations of cropping and management practices for effective erosion control within specific limits. In this model the average annual loss in tons per hectare is calculated using the relation A = RKLSCP where,

A is the average annual soil loss in tons per hectare,
R is a rainfall factor,
K is a soil erodability factor,
LS is a slope length and steepness factor,
C is a cropping factor, and
P is a conservation practice factor.

All the factors of the USLE are geographic in nature. Therefore computation of these factors can be done easily and efficiently using GIS. USLE does not calculate the deposition of the eroded soils within the watershed surface.

Mongkolsawat et al (1994), studied ten watersheds, covers an area of approximately 41 thousand hectares and located in Khon Kean and Udon

Thani provinces, Northeast Thailand. Landscape of the study area is gently undulating with sparse dipterocarp tress and isolated patches of forest remnants. A set of factors as identified in the USLE were studied and reviewed. These include rainfall erosive factor (R-factor), soil erodibility factor (K-factor), slope and slope length factor (LS-factor), and vegetative cover factor (C-factor) and conservation practice factor (P-factor). Each factor which consists of a set of logically related geographic features and attributes is used as data input for analysis. The factor layers were collected from existing information and extracted from Landsat MT imagery. Spatial K-factor was formulated from detailed reconnaissance soil map of the Land Development Department (LDD) of Thailand. Digital elevation model (DEM), interpolated from elevation contours, and was employed to generate the slope and LS-factor. Spatial vegetative cover, extracted from Landsat TM imagery, was used to determine the spatial C-factor and consequently P-factor, values of which are based on experimental results.

Mutua and Klik (2004) studied the soil erosion management using the RUSLE-GIS for Masinga catchment, Kenya. To evaluate viable management options, soil erosion modelling at the catchment scale needs to be undertaken. This paper presents a comprehensive methodology that integrates an erosion model, the Revised Universal Soil Loss Equation (RUSLE) with a Geographic Information System (GIS) for estimating soil erosion at Masinga catchment, which is a typical rural catchment in Kenya. The objective of the study was to map the spatial mean annual soil erosion for the Masinga catchment and identify the risk erosion areas. Current land use/cover and management practices and selected, feasible, future management practices were evaluated to determine their effects on average annual soil loss. The results can be used to advice the catchments stakeholders in prioritizing the areas of immediate erosion mitigation.

Pickup and Nelson (1984) made use of Landsat images to distinguish soil erosion, stability and deposition in arid central Australia. It has been shown that a radiance measure based on the 4/6-5/6 MSS data space may be used to categorize eroding, stable and depositional surfaces in the arid lands of central Australia. This concept of soil stability has been used in the present thesis for the Nilgiris district.

2.5 CONCLUSION

The conventional approach for land degradation and watershed management are time consuming and uneconomical. From the review of literature, it is seen that remote sensing and GIS are the useful, reliable and economical tools for the integrated study of watershed.