Sustainable Land Resource Management Using Remote Sensing Techniques: A Case Study

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Over exploitation of available natural resources to meet the growing demand of the ever increasing population has resulted in the degradation of land by various processes, namely soil erosion by water and wind, waterlogging, soil salinization and/or alkalization, shifting cultivation, compaction, etc., apart from dwindling per capita arable land. The study area though is endowed with rich natural resources, suffers from a variety of problems, ranging from demographic pressure to accelerated land degradation.

Realizing the potential of spaceborne multispectral measurements in providing spatial information on natural resources the author reports here the results of a study which was taken up in the southern part of Sonbhadhra district of Uttar Pradesh, to generate the information on natural resources from Indian Remote Sensing Satellite (IRS-IA) Linear Imaging Self-scanning Sensor (LISS-II) images through a systematic visual interpretation & its subsequent integration with the collateral information to develop various thematic maps on Land Use/Land Cover, Geomorphology, Soils, etc. These thematic maps have been integrated and the kind & level of land degradation, its intensity and areal coverage in the study area has been mapped & characterized. Specific management plans of various land units for the entire study area have been suggested.

Introduction

Land provides an environment for agricultural production, but it also is an essential condition for improved environmental management. The objective of sustainable land management (SLM) is to harmonise the complimentary goals of providing environmental, economic, and social *opportunities* for the benefit of present and future generations, while maintaining and enhancing the *quality* of the land (soil, water and air) resource (Smyth and Dumanski, 1993). Sustainable land management is the use of land to meet changing human needs (agriculture, forestry, conservation), while ensuring long-term socioeconomic and ecological functions of the land (Dumanski, 1994; World Bank, 1997).

Sustainable land management combines technologies, policies, and activities aimed at integrating socioeconomic principles with environmental concerns, so as to simultaneously maintain and enhance production , reduce the level of production risk, and enhance soil capacity to buffer against degradation processes, protect the potential of natural resources and prevent degradation of soil and water, be economically viable ,be socially acceptable, and assure access to the benefits from improved land management (World Bank, 1997; Pieri, et al., 1995).

So, to regenerate the potential of these areas, to ease the intense demographic pressure on our limited land resources and to sustain the impressive improvement in crop production since the “green revolution” with the indigenous scientific knowledge, it is seriously warranted to map the degraded lands critically and most efficiently so as to acquire reliable data about them (Hir, 1990; Venkataramani, 1991; Yadav, 1996). Therefore, it is essential to characterise and map degraded areas, so that site-specific development plans could be made (Shegal and Sharma, 1988). Sustainable Land Management requires an accurate assessment of various degradation processes, of how widespread it is, how severe the damage is and whether or not it is practically controllable or reversible (Barrow, 1991). It is in this context that the present study was undertaken for ascertaining the nature, extent and spatial distribution of degraded lands in the study area with the ultimate objective of providing location specific data base for district level planning to rehabilitate such lands.

Remote Sensing data, both from aerial and space platforms have been found very useful for providing information on various aspects of degraded lands. Several studies on mapping eroded lands (Rao et al., 1980; Singh and Dwivedi, 1983; Karale et al. 1989) ravinous lands (Singh and Dwivedi, 1986; Karale et al. 1988), were reported using MSS data and with promising results. Landsat MSS data in conjunction with Landsat Thematic Mapper (TM) data with middle and thermal-IR bands helped deriving better information on eroded lands (Singh et al. 1987; Dwivedi and Deka, 1990), and shifting cultivation areas (Kushwaha and Unni, 1987; Kushwaha, 1990); Quantative assessment of soil erosion has been done by IRS LISS-I & II data (Singh and Dwivedi, 1983; Dwivedi and Kushwaha, 1990; Ahmed et al. 1996).

Study Area

The area of study which is a part of Sonbhadra district in Uttar Pradesh lies south of the river Son and extends between Lat. $23^0$52'55" to $24^0$37' N and Long. $82^0$40' to $83^0$27'20" E. It is covered in 14 topographical sheets of Survey of India on 1:50,000 scale 63 P/2, P/3, P/4, P/7, P/8, 63 L/10, L/11, L/12, L/14, L/15, L/16; 64 M/1, M/5 and 64 I/13. It covers about 4205 sq. kms. of area.

In Sonbhadra, especially south of river Son, there are several factors responsible for an accelerated rate of conversion of vegetation types into poorer crown cover types. The farming output is not sufficient to meet the food energy requirements of the villagers. Operation of the agro-ecosystems in this area, requires a considerable amount of subsidy from the surrounding forest ecosystems in the terms of fodder and fuel wood. All requirements of the local people for fuel wood, timber, fodder and other forest products are met from the forest. The excessive fuel needs of the villagers and nearby townships results in felling and lopping of trees for firewood. About 81 to 100% of the fuel needs, and 80-87% of the fodder needs are met with from the natural forest ecosystems and thus for each unit of energy obtained in agronomic yield (including milk), 3.1 units of energy are expended from the surrounding natural ecosystems in the form of fodder and fuel wood (Singh et al., 1991). These authors have estimated that fuel wood needed is 2,255.9 KJ x 10^5 per year per ha of cultivated land. Further, the labour population involved in quarrying activity alone harvests 5004 tonnes of firewood annually. Grazing is quite serious and has affected the regeneration of forest trees to a remarkable extent (Pandey, 1990). Moreover, quarrying for limestone, establishment of cement factory and thermal power projects and construction of G.B. Pant Sagar reservoir, have resulted in a rapid build up of human population, and displacement and resettlement of original population giving further impetus to the degradational processes.

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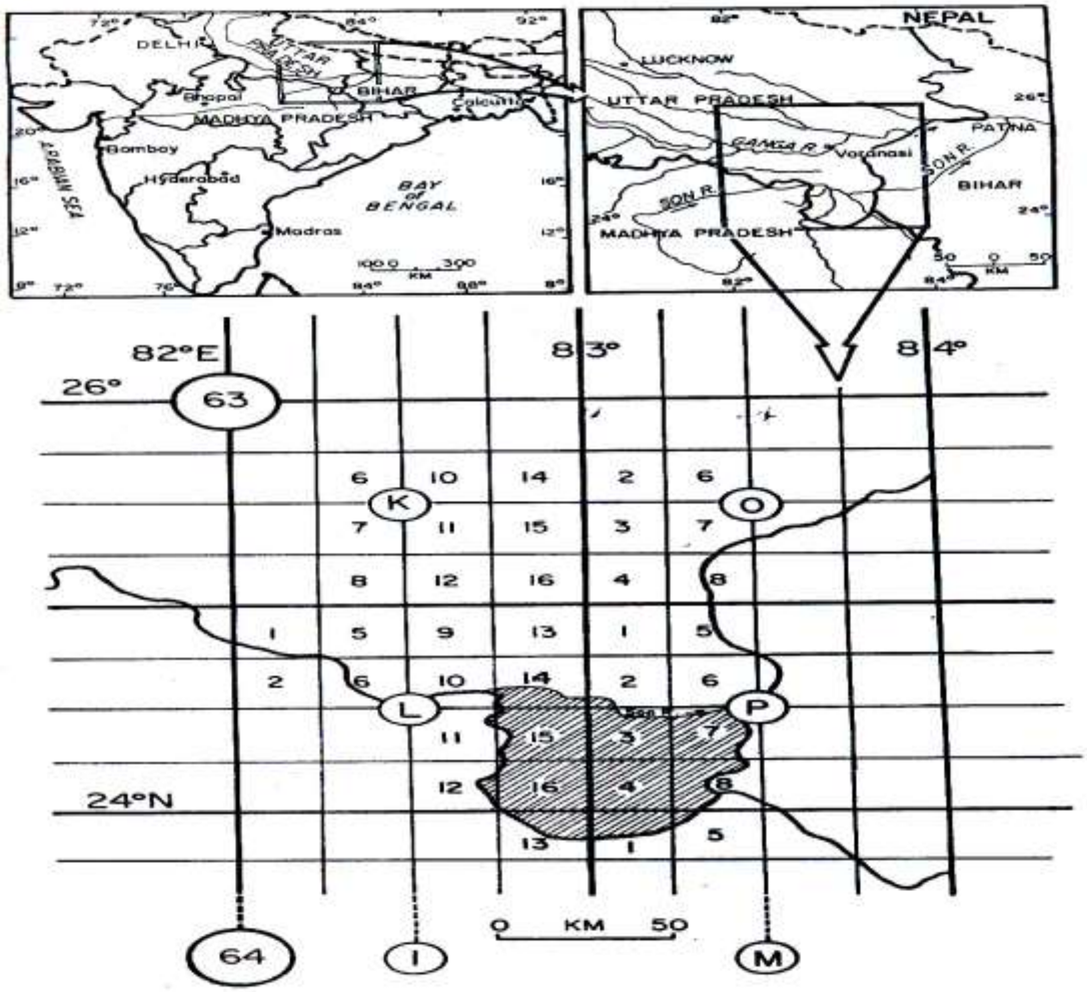


Fig.1 The Study Area

Materials & Methods

Data Sets

In the present study, data of February, 1991 in the form of Geocoded False Colour Composites (FCC's) of IRS-1A (Indian Remote Sensing Satellite) of LISS-II with standard colour combination of blue, green and red for green (Band 2), red (Band 3) and infra-red (Band-4) spectral bands with a spatial resolution of 36.25 meters is used. Along with data of Feb. 1991, multi-temporal data of April 1990, September 1991 and November 1991, for a part of the study area (63 P/7), for the purpose of standardising the interpretation key has also been used. Secondary data in the form of Survey of India (SOI) topographical maps on 1:50,000 scale (of as many no.'s as FCC's on similar scale) covering the entire study area were used to prepare base maps.

Methodology

Visual interpretation, of 1RS-1A (LISS-II) standard False Colour Composites (FCCs) for the period of Feb. 1991 on 1:50,000 scale for the entire study area (consisting of 14 scenes) have been undertaken for the land resource analysis of the area. Secondary data in the form of Survey of India (SOI) topographical maps on 1:50,000 scale (of as many no.'s as FCC's on similar scale) covering the entire study area were used to prepare base maps.

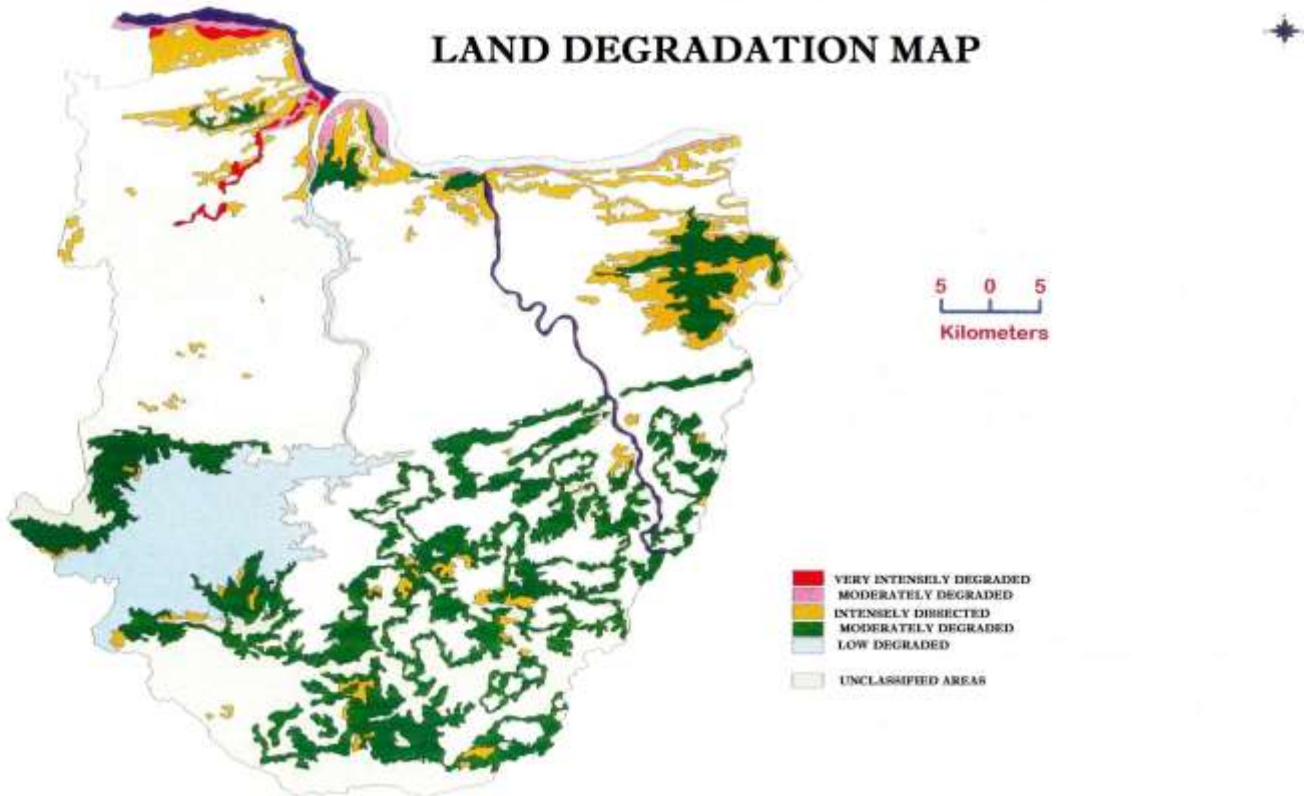
Using remotely sensed imagery of IRS IA data of LISS II on 1: 50, 000 scale and base map of the same scale, various thematic maps such as Land Use & Land Cover, Geomorphological map of the study area have been constructed through visual interpretation and digitized using Arc Info (8.1) software. The identification and delineation of various units have been based on the variation in tone, texture, shape, association, pattern and differential erosional characteristics along with sufficient ground truth and local knowledge to finalize these maps. Adequate field checks have been conducted to derive information on landforms and to establish the relationship between the image elements and landform characteristics. Using the landform map as a base, information on soil depth and qualitative erosion status of each geomorphic unit has been collected following the standard soil survey procedures *(AISLUS, 1970)*, resulting into the identification of major Land degradation processes prevalent in the study area. By Integrating the Geomorphological, Land Use & Land Cover, and ground truth data, the Land Degradation Map of the study area has been arrived at.

Results & Discussion

The major categories delineated (Fig. 2) with the help of satellite data are described below & the areal extent of each of the units is given in Table 1.

i) **Very Intensely Degraded** : The area is dissected by lower order streams/rivulets and is comprised of dissected terrace plain. It exhibits gully formation due to wearing action of concentrated runoff generated on sloping land with alluvium of low cohesion. The dissection is so intense that it has resulted in the intricate network of gullies joining a nearby stream. Area occupied by this category is 20 sq.kms i.e. 0.47% of the total study area.

ii) **Intensely Degraded :** Intense degradation in the form of severe sheet erosion is mainly found to be associated with piedmont areas and some upland areas in the southern part of the study area. It is composed of unassorted colluvium with significant slope of 5^0-10^0 thus facilitating sheet erosion. This area is characterised by the incidence of heavy overgrazing resulting in depletion of vegetation i.e., have poor vegetative cover resulting in bare lands prone to sheet erosion during monsoons. The total area under this unit has been estimated as 301 sq.kms comprising 7.16% of the total study area.



iii) **Moderately Degraded** : This is found on either side of river Son and constitutes terrace plain composed of loose and friable alluvium, pediplains and fewer piedmont areas of granitic terrain. The lands exhibit undulating nearly flat surface with 2^0 to 3^0 slope having moderate to slight degradation in the form of sheet wash, resulting in loss of 0-5 cm of top soil in about 50% of the mapping units. Such type of degradation is common in the vicinity of villages, on pastures and rainfed cultivated/fallow lands. This category occupies an area of 769 sq.kms which accounts for 18.29% of the total geographical area.

iv) **Low Degraded** : This unit comprises of a part of G.B. Pant Sagar reservoir (falling in U.P.), segment of river Rihand below the G.B. Pant Sagar and eastern segment of river Son beyond Rihand confluence. It is mainly because of combined effect of mining activity resulting in sedimentation of the reservoir and the fly ash generated from the thermal power plants disposed through pipelines into ash ponds situated along the periphery of the reservoir (Majumdar and Sarkar, 1994; Gautam, 1995; Singh et al., 1997). The ash finds its way into the reservoir and then into Son River system. This category is estimated to cover an area of 362 sq.kms which amounts to 8.61% of the total geographical area.

v) **Unclassified** : Areas falling outside the purview of this aspect are put under unclassified. The total area falling under this category is 2706 sq.kms accounting for nearly 64.25% of the study area.

The characteristics of different degraded lands and their management are summarised in Table I.

Conclusion

Land degradation map of the study area has been arrived at by integrating the Land Use & Land Cover, Geomorphological Map along with the ground truth data.

This integrated map information depicting broad pattern of the land degradation prevalent in the study area shall be helpful to develop strategies for the resource assessment through scientific and detailed analysis and mapping of the multiple dimensions of the natural resources.

The study reveals that remote sensing data is helpful in mapping, inventorying & monitoring the land resources of the region thereby facilitating the formulation of integrated action plans for the sustainable development of natural resources.

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Table I : Degraded Land Categories Of The Study Area & Their Management

S.No.	Type of Degradation	Geomorphic Unit	Description of Mapping Unit and Surficial Characteristics	Remedial Measures
1.	Very Intensely degraded	Dissected Terrace Plain	Very heavy surface runoff has lead to formation of network of wide gullies, sub soil with Kankar pan exposed at more than 15% of the area.	Social forestry or orchards should be planted in rotation with pasture carpeting consisting of soil bunding species.
2.	Intensely degraded	Piedmont and Upland areas	Poor vegetative cover, moderately steep slope of 50-100 thus facilitating erosion. Most of the areas exhibit large percentage of cobbles and pebbles while finer materials i.e., sand and grit washed down to lower reaches. Sub soil is exposed in 30-35% of the area.	Intensive erosion control measures in the form of vegetative barriers in undulating sloping areas and 'broad bed and furrow' method of cultivation with conservation ditches should be undertaken in plain areas, restricted cultivation with short duration varieties in rotation with pastures and agro-horticulture crops resistant to salinity and alkalinity should be preferred.
3.	Moderately degraded	Terrace plain, pediplains and fewer piedmont plains	Undulating flat surface with 20 to 30 of slope, intensively cultivated, Moderate surface runoff, Sub soil is exposed in 10-15% of the area with top soil already being lost from 50% of the area.	Ground water potential should be tapped to enhance production, improvement of physical condition of soil through application of bulky organic manures, deep ploughing and farming for pulses, millets and development of orchards are suggested.
4.	Low Degraded	Part of G.B. Pant Sagar Reservoir	Because of mining activity fly ash from ash ponds concentrated in and around the reservoir find its way into the river systems.	Afforestation & construction of embankments along ash ponds to avoid spill over into the fresh water ecosystem.
5.	Unclassified	-	Study was confined to arable/culturable lands only.	