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Geo-spatial technologies for identification, mapping and assessment of land degradation in Dhule district of Maharashtra

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Abstract : Land degradation due to soil erosion is a major environmental issue posing threat to sustainable livelihood. Geo-spatial technology such as Remote Sensing and Geographical Information System could greatly enhance the inventory of soils and land degradation over large areas by providing multi-temporal data when used along with ground truth information of high positional accuracy. Multi-date IRS-P6 LISS-III sensor data of the year 2005-06, combined with ancillary data such as land use / land cover, slope, and soil erosion were used for assessment and mapping of land degradation in Dhule district, Maharashtra. Criteria and framework devised by NRSC for identification and delineation of land degradation categories have been adopted. Land degradation induced by various processes such as water, anthropogenic activities and others causes, their types, *i.e.*, sheet erosion, gully erosion, mine and mine dumps, stony waste areas, expressed in varying degrees of severities, are delineated following on-screen visual interpretation. To understand the relationship between degradation process and its environmental setup, a matrix is generated in accordance with standard image interpretation keys like tone, texture, size, pattern, association etc. The results indicate that area of 3,103.80 km^2 (43.25% of TGA) in Dhule district, Maharashtra are affected by land degradation.

Additional key words : Remote sensing, Geographical Information System, land degradation

Introduction

The information on land degradation is needed for a variety of purposes like planning, reclamation programmes, rational land use planning, bringing additional areas into cultivation and also to improve productivity levels in degraded lands. The land degradation is increasing at alarming rate due to various factors like, over exploitation and mismanagement of natural resources and basic socio-economic factors like land shortage, inappropriate land use, severe economic pressures on farmers, poverty and population growth.

According to National Commission on Agriculture, about 175 million hectares of land in India constituting 53.3 per cent of the total geographical area is subject to various kinds of degradation. According to the reports of Department of Agriculture and Co-operation (DAC 1994), 107 million hectares of area was found under various types of degraded lands. According to one of the recent studies, degraded lands increased from 130 million hectares in 1987 to 188 million in 1993 (Annonymous 2002). Remote Sensing and GIS techniques, encompassing larger domain of geo-spatial technologies, are often considered as cost effective for the collection of data over large areas that would otherwise require a very large input of human and material resources (Saxena *et al.* 2000). Synoptic coverage in discrete spectral bands provided by space borne sensors at regular interval enabled inventorying degraded lands and monitoring their temporal behaviour at operational level. The largest category of land is affected by water erosion, which accounts for 80 per cent of degraded land that results in loss of topsoil. Among the remaining categories, salinization, water-logging, and loss of top soil from wind erosion, are the most pervasive problems. Salt affected land, has grown from 7.18 million ha in 1987 to over 10 million ha in 1993 (Annonymous 2002). The present investigation was undertaken to highlight the land degradation scenario in Dhule district, Maharashtra using remote sensing and GIS.

Material and Methods

Study area

Dhule district is located in the north western part of the Maharashtra state and lies between 20°37'25" and 21°37'59" N latitude and 73°51'01" & 75°11'54" E longitudes, covering an area of about 7,177.21 km^2 (Fig. 1). The climate of the district, in general, is dry, receiving an average annual rainfall of about 713 mm. However, the western hilly areas receive more rainfall. Geological formations from basaltic lava flows belonging to Deccan Trap of upper cretaceous to Eocene age and Tapi alluvium lying over the Deccan

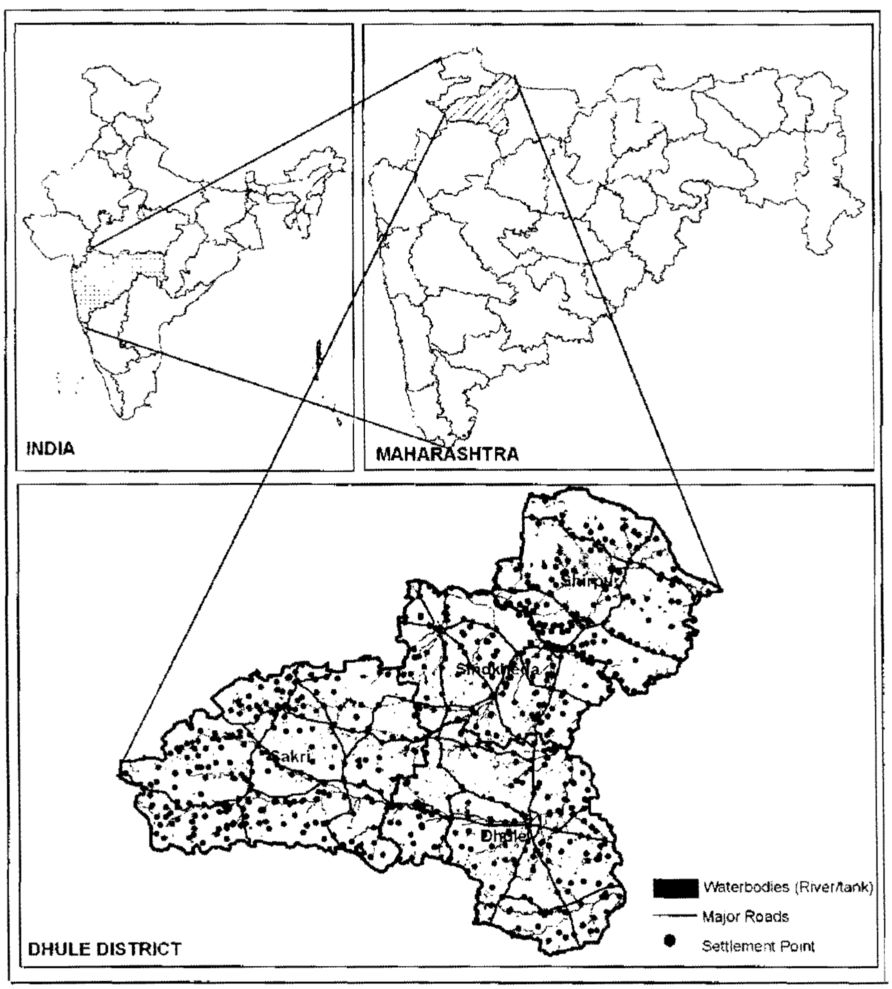

Fig. 1. Location map of study area

Table 1. Satellite data used in the study

Sr No	Sensor	Path	Row	Date of Pass		
				Kharif	Rabi	Zaid
1	LISS-III	95	57	10-Oct-05	14-Jan-06	20-Apr-06
2	LISS-III	95	58	10-Oct-05	14-Jan-06	20-Apr-06
3	LISS-III	96	57	8-Nov-05	19-Jan-06	1-Apr-06
4	LISS-III	96	58	8-Nov-05	19-Jan-06	1-Apr-06

Traps are seen. The Dhule district supports about 2134 km^2 (29.11 per cent) of forest land. Rainfed agriculture is the mainstay of the people.

Data Used

Multi-temporal, geo-rectified, IRS-P6, LISS-III data of 23.5 m spatial resolution acquired during *kharif, rabi* and *zaid* seasons of 2005-2006 (Table 1) are used for delineation of land degradation categories. Ancillary data in the form of 19 Survey of India topographic maps on 1:50,000 scale (46G/16, 46H/13, 46K/4, 7, 8, 11, 12, 14, 15, 16, 46O/2, 3, 4, 46L/1, 5, 9, 10, 13, 14), existing land use land cover (2005-06), wasteland (2005-06), soil erosion, slope maps were used as reference, to enrich the interpretation.

To understand the relationship between land degradation process and its environmental setup, the land degradation process matrix generated by NRSC (2007), has been referred (Table 2). Deductive logic approach was followed to delineate various land degradation categories in which, the areas where there

Table 2. Land degradation (LDD) process matrix

LDD Process	LDD Type	Field indicators	Physiography	Land Cover	Soil Type	Climate	Remote sensing data	Remarks
Water erosion	Sheet erosion	Muddy runoff during rainy season, Soil colour is lighter than surrounding soils. Concretions / coarse fragments on surface	Plains / valleys / pediments with > 1-3% slope	Cropland without bunnding, fallows, land with or without scrub, degraded forest	Predominantly in soils with fine texture, low organic matter and weak structure	Humid and semi-arid climates. Erosion rate is more with high intensity rainfalls	Conspicuous in black soils than red and alluvial soils	Information need to be deduced from available soil maps. RUSLE can be used to quantify soil loss
	Gullies	Well defined and permanent incised land neither cultivable nor traversable	occurs on >5% slope lands, starts at the lower element of slope and gradually creeps to upper slopes	Mostly land with or without scrub	Predominant in loams and associated textures	Humid and semi-arid climates. Erosion rate is more with high intensity rainfalls	Conspicuously manifested	Depth is the deciding factor between ravines and gullies
Anthropo-genic	Mining and dump area / stone quarry	Associated with open cast mining & its surrounding	-	Wastelands, land with / without scrub	-	-	Discernible through deductive logic	-
Other	Barren rocky / stony waste	Contiguous rock exposure on surface or covered with stones	Hill / pediment region	Wastelands	No remarkable soil cover	Semi-arid and arid regions	Conspicuously manifested	Clues can be taken from SOI topomaps

Table 3. Visual interpretation keys for land degradation

Land degradation processes	Land degradation type/class	Colour / Tone on standard FCC	Texture (on LISS-III) data	Pattern	Size	Shape	Association
Water erosion	Sheet erosion	Slightly brighter than surrounding land	Smooth to medium	Contiguous patches	Small to large	Irregular	Slopping cultivated / land with poor vegetation in rainy season
	Gullies	Brighter than surrounding land/grey in colour depending on soil colour	Medium to slightly coarse	Discrete to contiguous patches	Small to medium	Irregular	First order streams
Anthro-pogenic	Mining and dump area / stone quarry	Shades of white, red, black & yellow	Smooth to medium	Discrete	Small to medium	Irregular / regular	Hilly / Plain areas
Other	Barren rocky / stony waste	Light to medium grey/yellowish white	Smooth	Discrete / contiguous	Small to medium	Irregular	Hilly / plain / pediment region

is no scope for land degradation was delineated first. Subsequently, the land degradation units that are quite evident are delineated followed by areas which required more logical analysis. On-screen visual interpretation using three seasons satellite data, following standard image interpretation keys (Table 3) like tone, texture, size, pattern, association *etc.* was employed, for delineation and mapping of various land

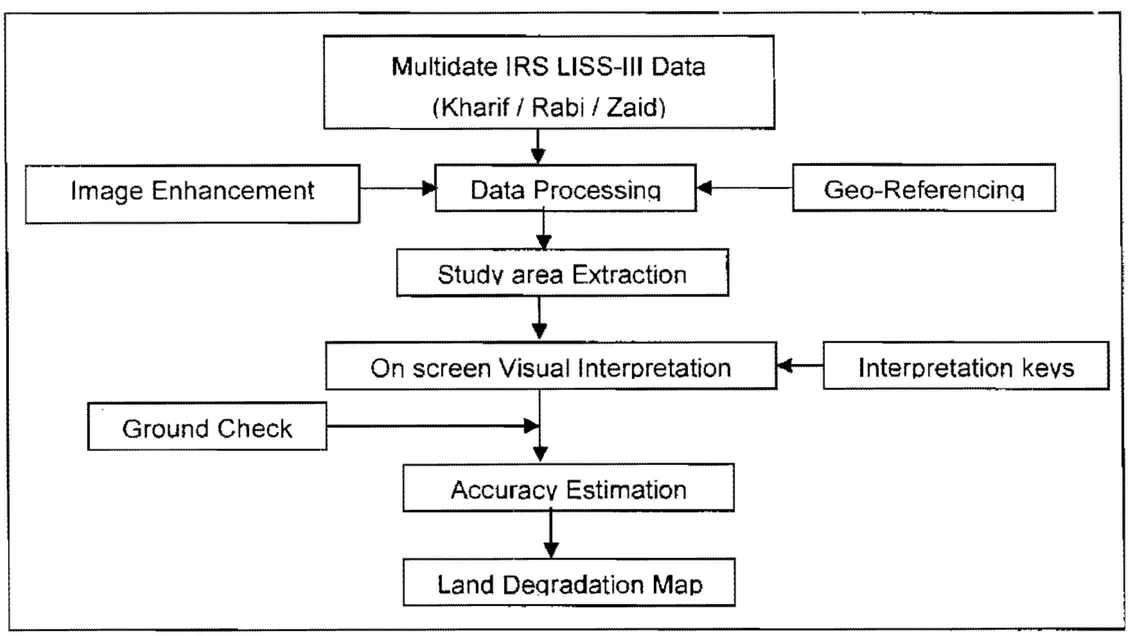

Fig. 2. Flowchart of methodology adopted in the study

degradation classes on 1:50,000 scale. Land degradation types such as sheet erosion, gullied land, mining and mine dump areas, barren rocky / sheet rock areas etc., are delineated in the study area. General flowchart of methodology adopted in the study is given in fig. 2.

Results and Discussion

Water erosion, anthropogenic activities and other causes such as barren rocky / stony waste areas are the major land degradation processes identified in the study area. Various anthropogenic activities, such as mining, industries have also contributed to decreased biological productivity, diversity and resilience of the land. Area mapped under different land degradation categories are presented in table 4 and their spatial distribution is depicted in fig. 3.

Degradation due to water erosion (W): The degradation due to water erosion is the most common and well spread form of land degradation in the study area. The displacement of soil material by water results in either loss of top-soil or terrain deformation or both. This category includes degradation types such as splash erosion, sheet erosion, rill, gully and ravines.

Sheet erosion (Wsh1): Water erosion resulting from loss of top soils occurring mainly in the areas having less or no vegetation and the areas where land use is dominated by single cropping, scrub land, open forest and grazing land on the slopes ranging 5 to 10 per cent. The loss of top soil is often preceded by compaction and/or crusting, resulting in decrease of infiltration capacity of soils. On the remote sensing images, these area look slightly brighter than surrounding background with smooth texture. With multi-date temporal information, it is observed that areas where thick vegetation and intensive cropping exist, this problem is less obvious. An area of 2954.38 sq km (41.20 per cent) of the district was delineated in this category of sheet erosion.

Gullied land (Wgu3): All along the Tapi river and its tributaries in central part of the district, gullies are demarcated, which are formed as a result of localized surface run-off affecting the unconsolidated material resulting in the formation of perceptible channels causing undulating terrain. When rills goes unrestricted / neglected and erosion continues for a long time, it develops into gullies. They are commonly found in sloping lands, developed as a result of concentrated run-off over fairly long time. They have medium to slightly coarse image texture with greyish white tones. These are the first stage of excessive land dissection followed by their networking which leads to the development of ravinous / bad lands. They are mostly associated with stream courses, sloping grounds, alluvial plains and foothill regions. The gullied land of 1.0 per cent (71.96 sq km) was mapped in the area.

Degradation due to anthropogenic activities (Hmd): Human economic activities have also contributed sizably to decreased biological productivity, diversity and resilience of the land. These are the areas subjected to removal of earth material (both surface and sub-surface) by manual and mechanized

Table 4. Land degradation categories and their area statistics

Code	Symbol	Land Degradation Process	Land Degradation Type	Severity of Problem	Land Use	Area (km^2)	% Area
55	Wsh1	Water Erosion	Sheet erosion	slight	Agriculture	1362.48	18.98
37	Wsh1		Sheet erosion	slight	Scrub	529.23	7.37
20	Wsh1		Sheet erosion	slight	Forest	1065.67	14.85
35	Wgu3		Gullies	Severe	Scrub	71.96	1.00
40	Tbs	Others	Barren Rocky / stony waste	Severe	Scrub	73.67	1.03
152	Hmd	Anthropogenic	Industrial affected area	Severe	Scrub	0.79	0.01
			Total			3103.80	43.25

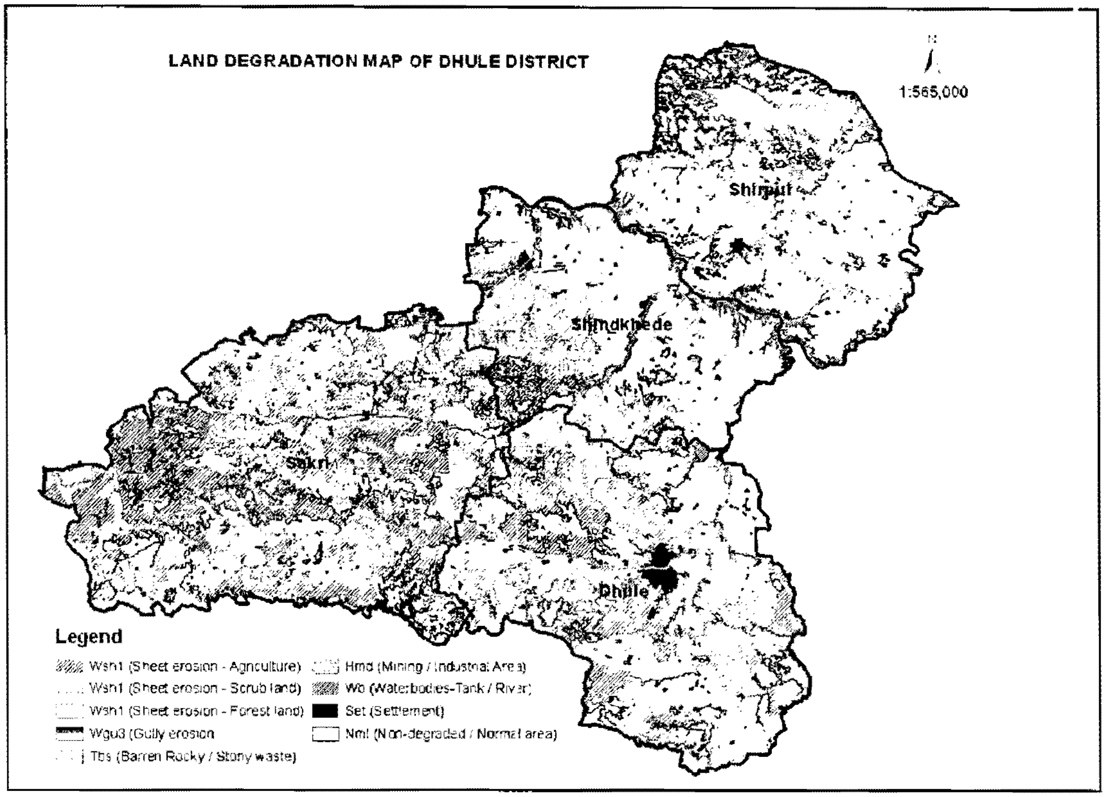

Fig. 3. Spatial distribution of land degradation categories in Dhule district

operations. Large scale quarrying and mechanizations results in mining and mine dumps. It includes surface rocks and stone quarries, sand and gravel pits, brick kilns, etc. In the study area, mine dumps and stone quarries were mapped, based on their bluish shades when filled with water. Feature association and ground checks are done to confirm these areas. Mine dumps are those areas where waste debris is accumulated after extraction of required minerals. Generally these lands are confined to the surroundings of the mining areas, occupying meager portion of 0.01 per cent (0.79 sq km) of the district.

Degradation due to barren rocky / stony areas (Tbs): Barren rocky / stony areas are the rock exposures of varying lithology, often devoid of soil and vegetal cover. They occur in hill forests as openings or as isolated exposures on plateaus and plains. These can be easily delineated from other type of degraded land because of their severe nature of degradation and typical spectral signature. On satellite data they appear as irregular discrete/contiguous medium to large patches of light to medium grey/yellowish white colour in all three seasons and are associated with hills and pediments on northern part of the Satpura ranges. Barren rock / stony areas occupy about 1.03 per cent (73.67 km^2) of the district.

Normal areas / non-degraded areas (Nml): This class includes the areas like dense forest, dense scrub, dense tree clad, intensively cropped area on very gentle slope with none to very slight erosion. About 53.18 per cent (3817.11 km2) of the area is classified as normal or non-degraded areas. These areas need to be carefully safeguarded and put to optimal usage.

Conclusion

The study demonstrates the effectiveness of the remote sensing and Geographical information system, which are the key components of geo-spatial technology in identification, mapping and assessment of land degradation processes. Out of the total degraded land in the district sheet and gully erosion contribute about 97.6 per cent, whereas anthropogenic activities and barren rocky / stony waste area accounts 0.03 and 2.37 per cent, respectively. This signifies that water erosion is the major cause of concern in the study area. It calls for immediate action to improve vegetation cover by adopting soil and water conservation practices, along with efforts to increase the water table and water storage at watershed level, which will help farmers to cultivate crops round the year. Also there is a need to grow social forestry and forest trees on fallow and open scrub land.

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