



IRS-1C Applications in Land Use/Land Cover Studies: Indian Experience

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Abstract

The Indian experience, in use of remotely sensed data for land use/land cover analysis, gained over past many years through the implementation of various projects. The satellite IRS-1C which was launched on December 28th, 1995 provided a new dimension to the mapping capability of land use/land cover analysis on various scales. Based on different studies, it is concluded that WiFS data can be used for level-I classification for national and regional level applications, whereas LISS-III alone can be use up to level-III for subregional scale and a combination of LISS-III and PAN data can be used for village-level information. IRS-1C data have been extremely useful in the generation of district-wise land used and cover maps, depicting the information up to level-II on 1:250,000 scale for land use planning and National Wasteland Inventory Project. A systematic study was carried out to identify and map 13 different types of wastelands on 1:50,000 scale up to village and micro-watershed level for some districts using IRS 1C data. A digital data with standard codification system in four different spatial layers were generated for the entire country, and about 63.85 million ha have been estimated as wastelands through this study. Various watershed programs are being implemented in the country consulting this database. A successor to this project “Monitoring of Wastelands,” which aim at reporting the changes in wastelands statistics in India, considering various developmental programs launched by Govt. of India since early 1990 has been implemented using IRS 1C data.

Keywords Land use/land cover · Wastelands · Degraded lands · Remote sensing · Indian remote sensing satellites

Introduction

Information on land use/land cover in the form of maps and statistical data is very vital for spatial planning, management and to implement various applications in the field of agriculture, forestry, pasture, urban, industrial, environmental studies, economic production, etc. Today, with tremendous growth in the population, reduced man land ratio and increased land degradation, the need for optimum land utilization assumes much greater relevance.

The draft outline on the National Land Use Policy and strategy on Optimum Land Use Planning and the creation of National Land Use Conservation Board (NLUCB) in 1985 clearly indicate the serious concern of the Government in this regard. Further, with the present thrust that the agricultural planning in the country should be based on Agro-Climatic Zones, the prima-facie need is to have a comprehensive information on the spatial distribution pattern of land use/land cover, particularly on the availability of agricultural land during Kharif and Rabi crop seasons, cropped area during both seasons and area under fallow,

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apart from the other land use/land cover classes. Besides, it is also required to know their area for the whole country covering all the Agro-Climatic Zones in all the districts (NRSA 1995). This needs land use inventory surveys periodically, to mark information available on the type, spatial distribution, location, areal extent, rate and pattern of change for each category of land use/land cover on the land. By using IRS 1C remote sensing data, an up to date, accurate and reliable information related to land use/land cover pertaining to a large area is made available on the basis of operational, timely and cost-effective criteria.

In recent times, the information on land use/land cover in the form of thematic maps, records and statistical figures is inadequately available and lack of up to date information on the changing land use patterns and processes is observed (Nagaraja 2002). Over the years, the efforts made by the various Central/State Government Departments, Institution/Organizations etc., is sporadic and often efforts are duplicated. In most of the cases, as the time gap between reporting, collection and availability of data is more, the data often become outdated.

However, the organizational efforts in publishing maps, reports and statistical data by the Survey of India (SOI), National Atlas and Thematic Mapping Organization (NATMO), National Bureau of Soil Survey and Land Use Planning (NBSS and LUP), All India Soil and Land Use Survey (AIS and LUS), Central Arid Zone Research Institute (CAZRI), Ministry of Agriculture, Settlement Survey and Land Records, Revenue Department, National Sample Survey, State Land Use Boards, Town and Country Planning Organization (TCPO) and other local agencies are noteworthy. The analysis of land use/land cover maps from the satellite data is well understood by the knowledge acquired from various studies conducted at National Remote Sensing Centre (NRSC) or erstwhile National Remote Sensing Agency (NRSA) in collaboration with different agencies (NRSA 1992).

Ever since the launch of the first remote sensing satellite (Landsat-1) in 1972, land use/land cover studies were carried out on different scales for different users. Wasteland mapping of India was carried out on 1:1 million scale by NRSC using 1980-82 Landsat Multi-Spectral Scanner data. About 53.3 Mha (16.2%) of wastelands were estimated based on this study. (Nagaraja and Gautam 1996) Subsequently mapping on 1:50,000 scale was carried out by NRSC for all districts in the country using Landsat Thematic Mapper data as well as IRS LISS-II data using 13-fold wasteland classification (Roy and Giriraj 2008).

At the instance of Planning Commission, the Department of Space in collaboration with various work centers at different states carried out land use/land cover mapping of all 442 districts using IRS LISS-I data based on visual and digital interpretation techniques. This task provided first

national-level spatial maps including statistical details on land use/land cover in 22 different categories (NRSA 1989). Since the mapping was carried on 1:250,000 scale using a coarse resolution satellite data, small settlements, linear features like transportation network could not be delineated (Gautam et al. 2000). To derive accurate statistics on agricultural land use, thumb rules were worked out based on extent of small settlements, length of transportation lines like roads and railways from the existing topographical maps for applying necessary corrections. Due to the small scale and low resolution of the data used, the maps/statistics generated are moderately accurate and the statistics on land use categories could not be generated at village level.

The launch of IRS-1C satellite with WiFS, LISS-III and PAN sensors has provided an opportunity for the first time to derive the land use/land cover information at regional and local levels, on appropriate scales with an assured frequency for updating. The capability of IRS 1C, WiFS, LISS-III, composite (merged) data of LISS-III and PAN sensors is discussed in the current paper, and their versatility to derive information regarding the categories or classes of land use/land cover is mentioned.

Land Use/Land Cover Analysis using IRS-1C Data

The details of payload and the capability of each of the sensor are already described. The specific advantages are: the WiFS data have the potential to monitor the dynamic phenomena every 5 days at level-I; LISS-III has the potential to generate the level-III information up to 1:50,000 scale. The composite data of LISS-III and PAN have the potential to generate information on 1:10,000 scale at local/village level (Rao et al. 1996). The possible scales on which land use/land cover can be generated, level of classification and the minimum mapping units that can be achieved using different sensors are shown in Table 1

Land Use/Land Cover Classification System

With the changing times and increasing demand on the availability of information on land use/land cover, it becomes necessary to have a standard classification system, precise definition of land use/land cover and its categories, uniform procedures of data collection and mapping on different scales for all the States and Union Territories.

Realizing the need for an up to date Nationwide land use/land cover maps by several departments in the country, as a prelude, a land use/land cover classification system was developed by NRSC, DOS, taking into consideration the existing land use classification adopted by NATMO, CAZRI, Ministry of Agriculture, Revenue Department, AIS and LUS, etc., and the details obtainable from satellite

Table 1 Possible scale and minimum mappable units using IRS-1 C for land use/land cover Analysis

Sensor	Scale	Minimum mappable unit (MMU)	Area (ha)	Level of classification
WiFS	1: 250,000	3 × 3	56.25	Level-I
LISS-III	1: 50,000	3 × 3	2.25	Level-II/III
PAN	1: 10,000	3 × 3	0.009	Level-III/IV

imagery (FAO 2000). The classification system provided the conceptual framework for discussions with nearly 40 user departments/institutions in the country and finalize acceptable 22-fold classification system which was adopted for Nationwide land use/land cover analysis (Gautam et al. 2000) shown below Fig. 1

Four levels of classification are suggested in this scheme, each level being useful at various information/decision-making levels. Level-I information can be used at inter-state and state-level planning; level-II, at state-level to regional level planning, level-III, at regional to local level of planning, whereas level-IV information can be used at local or micro-level planning (Gautam et al. 2000).

Methodology

Although initial efforts were made since mid-seventies for applications of different interpretation techniques in land use mapping, the major thrust for operational methodologies (visual, digital) came from the project on national land use/land cover mapping (NRSA 1989). Figure 2 shows the flow chart of detailed analysis explained in the study. The methodology essentially involves the following steps.

- Data loading, merging and geo-referencing.
- Ground truth collection, training sets.
- Signature generation for classification.

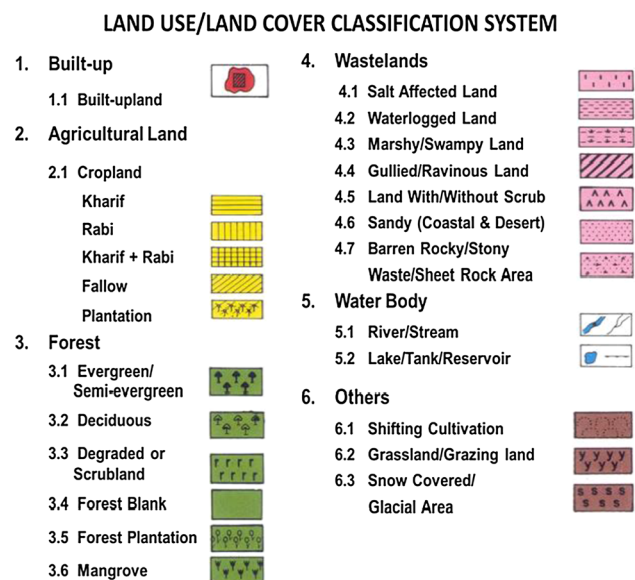


Fig. 1 Land use/land cover classification system

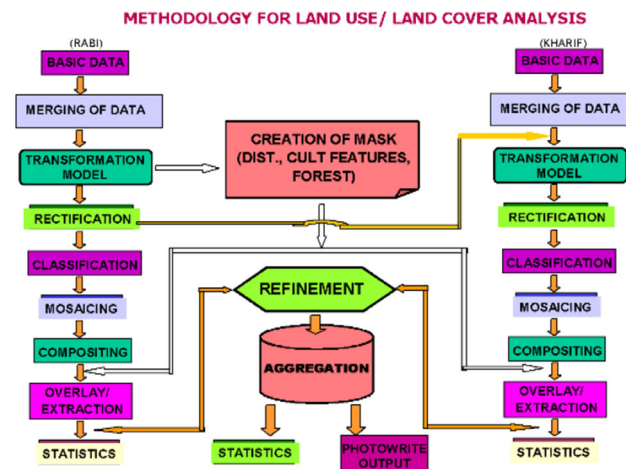


Fig. 2 Methodology for land use and land cover

- Demarcation of boundaries and transfer of administrative and cultural features.
- Extraction of statistics and final report.

Precise demarcation of the boundaries, transportation network, cultural features and important locations is carried out by the process of digitization from topographical maps. Geo-referencing has been done by extracting GCPS from topographical map using map image transformation model. Multi-spectral classification was carried out using maximum likelihood algorithm. The classification proceeds through selection of the training areas, calculation of the statistics for the identified training areas and the decision boundary of maximum probability based on mean vector, variance, covariance and correlation matrix of the pixels. (Gautam et al. 2000).

Adequate training sets are selected for the same land use class for the purpose spread all over the scene. After evaluating the statistical parameters of training sets, reliability test of training sets was calculated by measuring the statistical separation between classes by computing divergence matrix. Another approach for evaluating spectral separability is the use of confusion matrix (Rao et al. 1996). Ensuring all non-diagonal elements of the confusion table as zero, misclassification can be minimized. The overall accuracy of the classification is finally assessed with reference to ground truth data.

Results

Land Use/Land Cover Analysis Using WiFS Data

Using digitally mosaiced WiFS data, about ten classes pertaining to level-I and level-II classifications could be achieved in the study area, Andhra Pradesh. The study area is covered in parts of three WiFS scenes. The digital analysis of land use/land cover has been carried out using three bands, namely red, near infrared (NIR) and texture of NIR. The classified data of erstwhile Andhra Pradesh are shown in Fig. 3

WiFS data have been found to be adequate to bring out all the level-I classes. The land use classes like crop land, water bodies, barren lands, dense forest and waterlogged areas, could be identified and classified more accurately using WiFS data. The interpretation accuracy has been found to be as high as 80–85% (Rao et al. 1996). Here, the interpretation accuracy has been calculated using the kappa accuracy, which is determined from the error matrix, considering the number of correctly classified units and also errors of commission and errors of omission.

Land Use/Land Cover Analysis Using LISS-III Data

Digitally classified output of land use/land cover of Kaziranga National Park and the corresponding raw data are shown in Figs. 4 and 5 respectively. The classification has been carried out using NDVI for areas within national park and using maximum likelihood classification for the rest of the area (RRSC 1990). The level-III classes such as type of plantation, namely teak, sal, homestead plantations and different levels of grass in the Kaziranga National

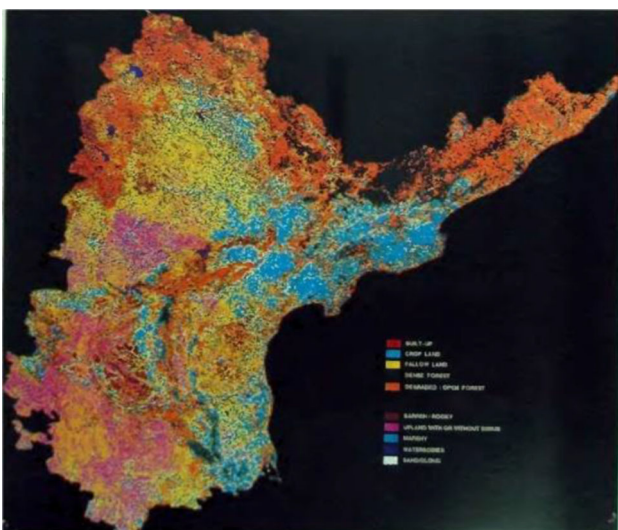


Fig. 3 Digitally classified land use/land cover map of Andhra Pradesh using IRS IC (WiFS) data of 11 Feb. 1996



Fig. 4 IRS LISS-III data of Kaziranga and environs



Fig. 5 Land use/land cover map prepared using digital classification technique

Park (high, medium and low) could be identified and classified.

Major linear features such as roads, rail network and small settlements are clearly separable using LISS-III data. The waterlogged areas within the national park are clear and areas of water bodies as small as 0.25 acres also could be classified accurately (Gautam et al. 2000).

Land Use/Land Cover Analysis Using Composite Data (LISS-III and PAN)

The composite (merged) data of LISS-III and PAN for the part of Ranga Reddy district, South of Hyderabad, is shown in Fig. 6. The land use/land cover details are very sharp in this data compared to LISS-III alone. Also, all the linear features are clear and details like cart tracks could be identified. The grape gardens along Nagarjunasagar road (regular, bright red patches), which are less than 1/2 acre extent, are clearly seen. Individual farm houses and cluster of few houses are easily separable which is very crucial to



Fig. 6 Merged data of LISS-III and PAN of part of Ranga Reddy district

derive accurate statistics of different land use categories. It is thus possible to prepare spatial land use maps up to 1:10,000 scale and to derive the village-level statistics (Gautam et al. 2000).

Land Use/Land Cover Studies by Other Institutions

An analysis on vegetation extraction based on spectral deviations carried out by Visvesvaraya Technological University in association with Karnataka State Remote Sensing Centre in the year 2016 used IRS 1-C LISS-III data as primary source to generate land cover vegetation extraction and the classified data is utilized for agricultural, vegetation analysis, desertification and forest monitoring (Parveen et al. 2016). Another study carried out by same organization proved that a simple method is adapted for the extraction and mapping of vegetation areas using multi-temporal LISS-III images and automatic computation is performed based on pixel based classification which is validated by comparing change map values with image ratioing techniques. (Parveen et al. 2017).

In a study performed by Department of Forestry, Faculty of Agriculture, University of Ilam, Iran, represented nine main classes of land use such as settlements, gardens, agriculture, bare land, forest (very sparse, sparse, dense and semi-dense) and the quantification of LULC changes are acquired using temporal data of LISS-III in the west of Iran and to understand the status of Zagros forest ecosystem (Mahdavi Ali 2010).

In the creation of database for ecological modeling of Himalayan Region by Remote Sensing Centre, Science Technology and Environment, Shimla, high-resolution IRS PAN and LISS-III data are merged at 1:12,500 scale to

generate level-IV classification in terms of hierarchy such as built-up to parks level, forests to open land level and flora to species level (Rajendar et al. 2010).

Multi-source classification using maximum likelihood classifier conducted by Department of Earth Sciences, Indian Institute of Technology, Roorkee, in the year 2005, obtained the classification accuracy from IRS-1C LISS-III image in a case study of Himalayan region implemented accounted 86.94% which increased to 92% on the combination of NDVI and DEM (Saha et al. 2005).

Research at Centre for Spatial Informatics, IIIT Hyderabad, in 2010 proposed a conceptual framework focusing on the patterns of land use/land cover changes reflecting the impact of phyto-diversity in the region of North Andaman Islands by using three Global Earth Observation class satellite data sets such as Landsat, LISS-III and SPOT in which LISS-III data are analyzed to detect change in forest scenario (Rama Chandra Prasad et al. 2010).

Land Use/Land Cover Classification Accuracy

Accuracy implies comparison between map and the reference information and this requires certain rules to carry out consistently. The accuracy assessment was carried out using 750 random points generated using stratified random sampling approach. Stratified random points generated and these were distributed equally over all the classes and with a good spread across the study area. Under this approach, it was ensured that a minimum of 25 random points covers each LULC class. After generating the sample points, reference data are prepared against each sample points and confusion matrix for all the LULC classes is prepared. From this table for each LULC class, user as well producer's accuracy were calculated (Table 2). Overall accuracy in terms of kappa coefficient was also arrived. (NRSA 1995).

National Wasteland Inventory Project (NWIP)

Wasteland mapping of India was carried out on 1:1 million scale by NRSA using 1980–82 Landsat Multi-Spectral Scanner data. About 53.3 Mha (16.2%) of wastelands were estimated based on this study (NRSA 1985). Subsequently mapping on 1:50,000 scale was carried out by NRSC for all districts in the country using Landsat Thematic Mapper data as well as IRS LISS-II data using 13-fold wasteland classification.

The 1:1 million wasteland maps prepared by NRSA showed that 146 districts had wastelands covering more than 15 percent of their area. These districts were considered as critical (except for border districts) and selected for

Table 2 Overall classification accuracy of land use/land cover categories

Class Name	Reference Points	Classified Points	Number Correct	Producers Accuracy (%)	Users Accuracy (%)	Kappa Coefficient
Built-up	33	36	31	93.94	86.11	0.85
Kharif	61	62	58	95.08	93.55	0.93
Rabi	37	41	36	97.30	87.80	0.87
Zaid	26	30	26	100.00	86.67	0.86
Fallow land	46	47	42	91.30	89.36	0.89
Ag. plantation	34	36	33	97.06	91.67	0.91
Evergreen forest	45	41	40	88.89	97.56	0.97
Deciduous forest	58	60	55	94.83	91.67	0.91
Degraded forest	37	37	35	94.59	94.59	0.94
Forest blank	22	31	22	100.00	70.97	0.7
Forest plantation	83	76	73	87.95	96.05	0.96
Swamps/mangroves	30	30	30	100.00	100.00	1
Grass lands	28	32	28	100.00	87.50	0.87
Shifting cultivation	29	30	29	100.00	96.67	0.97
Wastelands	65	57	56	86.15	98.25	0.98
River/stream	43	35	34	79.07	97.14	0.97
Lake/tank	36	33	30	83.33	90.91	0.9
Snow	37	36	36	97.30	100.00	1
Totals	750	750	694			

Overall classification accuracy = 92.53%

Overall kappa coefficient = 0.9204

detailed mapping in Phases I and II (1986–89) using Landsat TM data. In Phase III (1990–92), districts having 5–15% coverage of wasteland were mapped using IRS 1A and 1B data, and in Phase IV and V (1995–97) the remaining seven districts of Madhya Pradesh and the rest of the country, respectively, were completed using IRS 1C data at the instance of National Wastelands Development Board (NWDB), Ministry of Rural Development, Govt. of India (NRSA 2000).

Wasteland Classification

Confronted by varying estimates of the extent of wastelands, including the NRSC figure based on remote sensing, it became evident that the NWDB had to provide precise definitions of the various categories of wasteland. The technical task force constituted by the NWDB proposed a classification system consisting of thirteen categories of wasteland, as follows:

1. Gullied and/or ravinous land
2. Land with or without scrub
3. Waterlogged and marshy land
4. Land affected by salinity/alkalinity coastal/inland
5. Shifting cultivation area
6. Under utilized/degraded notified forest land
7. Degraded pastures/grazing land.

8. Degraded land under plantation crops
9. Sands—Desertic/coastal
10. Mining/industrial wastelands
11. Barren rocky/stony waste/sheet rock area
12. Steep sloping area
13. Snow covered and/or glacial area

Since the workload in the project was enormous, all the State Remote Sensing Centres and some central organizations were involved in the mapping task. In order to maintain a consistent standard and a uniform system, a manual of wasteland mapping procedures was prepared giving details of mapping and final drawing. Training workshops were organized at NRSC to instruct all the scientists involved in the project (NRSA 2000).

Wastelands Distribution in India

Methodology developed based on pilot studies was used for the identification and delineation of different types of wasteland using enhanced satellite data. Both Landsat Thematic Mapper (TM) and Indian satellite (LISS-II and LISS-III) data were used for mapping purposes. Hybrid methodology, i.e., both visual and digital techniques, was used to extract the wastelands thematic details.

Village boundaries, forest boundaries and watershed (up to micro-watershed having 500 ha area) boundaries were

incorporated into the wasteland maps. The final product is a wasteland map with village, forest compartment and micro-watershed boundaries at 1:50,000 scale. All this information is available in the digital form covering 8000 + map sheets on 1:50,000 scale. It is possible to associate wasteland units with particular villages/micro-watersheds using these maps. In addition, possible ownership can be determined by comparison with cadastral maps available at scales of 1:4000 and 1:8000. The vector-based digital database generated under this project using standard codification was organized in four different layers, namely base layer, administrative layer, watershed layer and wasteland layer (NRSA 2000) (Figs. 7, 8, 9, 10).

Under first wastelands mapping exercise, about 63.85 million ha (20.17%) of land has been estimated as wastelands. About 8000 wasteland maps covering the country were prepared under this project. After completion, the maps are sent to various state users for wasteland reclamation measures. The Wastelands Atlas of India generated out of this project is released for public by Prime Minister of India on May 22nd, 2000 in New Delhi (Fig. 11).

All these 63.85 million ha are highly degraded lands in the country. Apart from this, the process of degradation exists in the agricultural lands such as single cropped areas and fallow lands. Based on statistics generated under land use/land cover project and the wasteland inventory project, it is estimated, about 145 million ha are under degraded land, i.e., 63.85 M ha under severe extreme degraded lands, 13.76 M ha under moderately degraded lands and 67.49 Mha under slight to moderate degraded lands (Nagaraja and Gautam 1996).

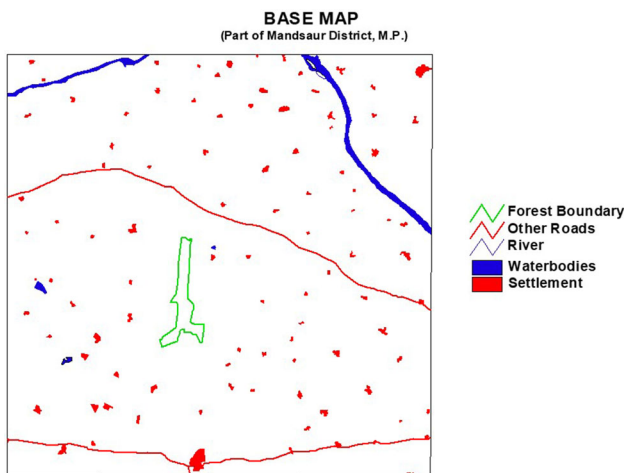


Fig. 7 Base map

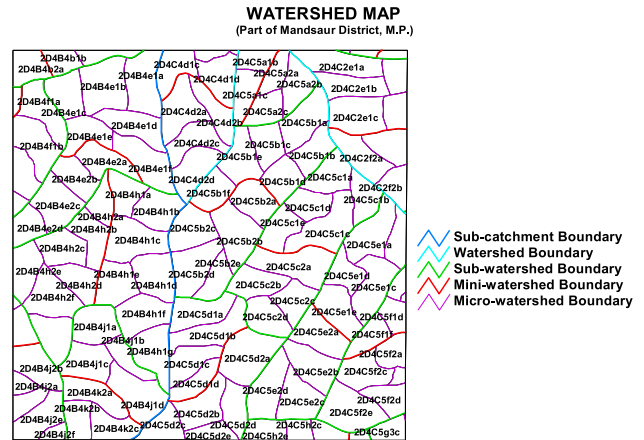


Fig. 8 Watershed map

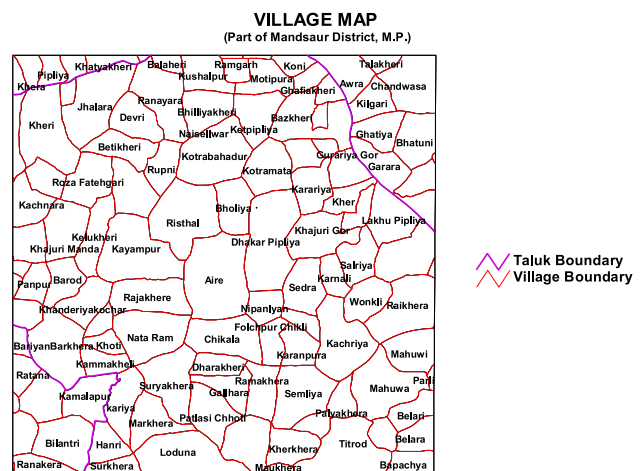


Fig. 9 Village map

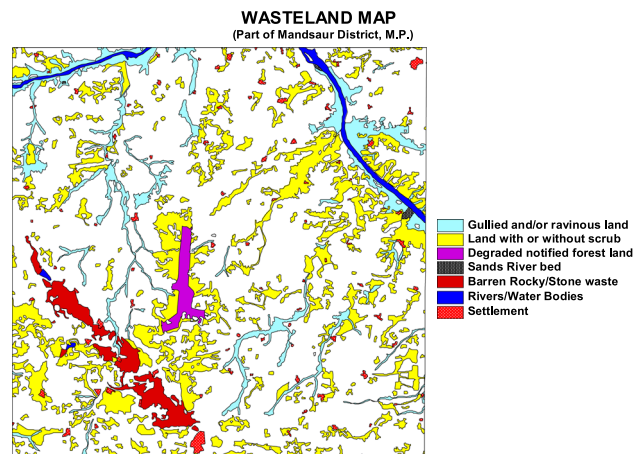


Fig. 10 Wasteland map



Fig. 11 Wasteland atlas release by Prime Minister India

National Wastelands Updation Mission

The mapping of wasteland was done under 1st cycle using satellite data which were spread over long period of time (1986–1997) in different phases. Under second exercise, entire country was mapped using IRS-1C data acquired in year 2003. Further it was felt to improve the 13-fold classification system to 28-fold classification system where subclasses are included to map the severity of degradation. New wasteland classification will help in wastelands reclamation programs considering the severity of wastelands. The maps will help to retrieve the information at village/watershed (500 ha.) level, for implementation of wastelands/watershed programs. Similar to earlier data, wasteland data sets are being organized into different geospatial layers, namely base, village, wasteland and watershed. In the present study, the methodology followed (heads up interpretation) and the spatial resolution of the satellite data used (23 m) are different from the earlier study; hence, the database is expected to be more accurate compared to earlier exercise. The present wasteland map will provided necessary impetus for wastelands reclamation by the user communities like district level administrators, planners, decision makers, rural development agency officials, line department officials, NGO, etc. (NRSA 2005).

Sub-Categorization of Wastelands

Since there are financial and time constraints, it is obviously not possible to develop all the wastelands/degraded lands in a short period. Therefore, it is essential that the department may concentrate on certain wastelands which require aggressive intervention through Government funds for development.

Accordingly, there is a need to create a Vision for, say, 20 years down the road. Keeping this destination in view, a

road map needs to be designed with properly marked off milestones and sign posts in the field of watershed management.

For suggesting a proper and focused management of wastelands, a task force for classification of wastelands/degraded lands into ABC category was formed to look into the aspects of prioritization/classification. The task force recommended that the Wastelands in India can be broadly divided into following categories.

A—Those lands which do not require any attention as nothing is to be done about them at the moment. These lands are like cold snow-clad deserts, hot desert, etc.

B—Those lands which require direct Government Action—predominantly in the form of subsidy, grant etc., and aim at environmental improvement on community basis. In this category, backward forward linkages, etc., are required.

This “B” category can be further sub-divided into 1, 2 and 3.

B1 category is one where governmental intervention becomes a must on account of the factors such as poor response, low absorption capacity, etc. These factors need special attention as the role of the other players is limited and they do not have a meaningful role in this field.

B2 category is for those lands where some infrastructure is needed for development. There is a potential for response and where some sort of linkages, awareness etc., are already in existence, and therefore, these lands can be developed by inducing catalytic action arranging availability of inputs by involving other players and putting in place appropriate backward and forward linkages with asset creation and individual livelihood systems being brought to center stage.

B3 categories are those where proper managerial strategies are required.

In all these B1, B2 and B3 categories, a further classification of V, E, D, i.e., vital, essential and desirable categorization is to be done.

C—Those lands which are on the threshold of a new economic order at a local level where resolution of second generation issues and addressing sustainability concerns are required.

The committee felt that the existing database on wastelands is not adequate for further categorization into B1, B2, B3 etc., which is required for taking up developmental activities. (While initiating the NWI Project in the year 1986–87, the requirement of sub-categorization was not envisaged and 13-fold classification recommended by the task force, which was constituted by Planning Commission, was adopted for the project). Considering the availability of high-resolution data presently and the users’ requirements, a detailed 28-fold classification was developed based on pilot studies carried out by NRSC and

Table 3 Wastelands classification system

WASTELAND CLASSIFICATION SYSTEM		
1. Gullied and/or Ravinous land	1.1	Shallow
	1.2	Medium
	1.3	Deep/Very Deep
2. Land with or without Scrub	2.1	Land with Scrub
	2.2	Land without Scrub
3. Waterlogged and Marshy land	3.1	Permanent
	3.2	Seasonal
4. Land affected by Salinity/Alkalinity	4.1	Strong
	4.2	Moderate
	4.3	Slight
5. Shifting Cultivation	5.1	Current Jhum
	5.2	Abandoned Jhum
6. Under Utilized/Degraded Notified Forest Land	6.1	Scrub dominated
	6.2	Agricultural land inside notified forest land
7. Degraded Pastures/ Grazing Land	7.1	Degraded Pastures/ Grazing Land
8. Degraded Land Under Plantation Crop	8.1	Degraded Land Under Plantation Crop
9. Sands (Riverine/Coastal/Desert)	9.1	Flood Plain
	9.2	Levees
	9.3	Coastal Sand
	9.4	Semi-Stabilized to Stabiliz(>40 m)
	9.5	Semi-Stabilized to Stabilized Moderatel High (15-40 M) Dune
	9.6	Semi-Stabilized to Stabilized Low (< 15 M)
	9.7	Closely Spaced Inter-Dunal area
10. Mining/Industrial Wasteland	10.1.	Mining Dumps
	10.2.	Industrial Wasteland
11. Barren Rocky Area	11.	Barren Rocky Area
12. Steep Sloping Area	12.	Steep Sloping Area
13. Snow Covered and/or Glacial Area	13.	Snow Covered and/or Glacial

CAZRI. The classification was reviewed by the task force and recommended for updating study. The comparative classification system used for the project is presented in Table 3 (NRSA 2005).

Distribution of Wastelands in India

About 55.27 million ha forming 17.45% of the wastelands to the total geographical area of the districts covered were estimated through the second exercise. A comparative table of state-wise and category-wise wastelands for the years 1986–2000 and 2003 are also shown in Tables 4 and

5 respectively. An area of 18,620 Sq. km. covering Rann of Gujarat, basically a marshy tract mostly under high tide zone, is not included under total wastelands area.

The very high percentage of area under wasteland in Jammu and Kashmir (69.24%), Himachal Pradesh (50.90%), are due to snow cover and degraded forest; Nagaland (22.37%), Manipur (59.01%) and Mizoram (21.20%) are due to shifting cultivation, Sikkim (53.67%) is due to degraded forest and in Rajasthan (29.64%) due to Sandy area. Among all the states, Punjab has a minimum 2.33% and Jammu & Kashmir has a maximum 69.24% of area under wastelands. Among the 583 districts, 19 districts

Table 4 State-wise comparison of wastelands of India (area in sq. km.)

S.No	State	No. of dist	Total geog. area	1986–2000		2003		Change
				W. L. area	% to TGA	W. L. area	% to TGA	
1	Andhra Pradesh	23	275,068.00	51,750.19	18.81	45,267.15	16.46	– 2.35
2	Arunachal Pradesh	16	83,743.00	18,326.25	21.88	18,175.95	21.70	– 0.18
3	Assam	23	78,438.00	20,019.17	25.52	14,034.08	17.89	– 7.63
4	Bihar	37	94,171.00	5880.00	6.20	5443.68	5.78	– 1.75
5	Chhattisgarh	16	135,194.00	10,185.98	7.53	7584.15	5.26	– 227
6	Goa	2	3702.00	613.27	16.57	531.29	14.35	– 2.21
7	Gujarat	25	196,024.00	43,021.28	21.95	20,377.74	10.40	– 11.55
8	Haryana	19	44,212.00	3733.98	8.45	3266.45	7.39	– 1.06
9	Himachal Pradesh	12	55,673.00	31,659.00	56.87	28,336.8	50.90	– 5.97
10	Jammu & Kashmir	14	101,387.00	65,444.24	64.55	70,201.99	69.24	4.69
11	Jharkhand	19	79,706.00	15,884.00	19.93	11,165.26	14.01	– 5.92
12	Karnataka	27	191,791.00	20,839.28	10.87	13,536.58	7.06	– 3.81
13	Kerala	14	38,863.00	1448.18	3.73	1788.80	4.60	0.88
14	Madhya Pradesh	49	308,252.00	6,073,253	19.70	57,134.03	18.53	– 1.17
15	Maharashtra	33	307,690.00	53,489.08	17.38	49,275.41	16.01	– 1.37
16	Manipur	9	22,327.00	12,948.62	58.00	13,174.74	59.01	1.01
17	Meghalaya	7	22,429.00	9904.38	44.16	3411.41	15.21	– 28.95
18	Mizoram	8	21,081.00	4071.68	19.31	4469.88	21.20	1.89
19	Nagaland	7	16,579.00	8404.10	50.69	3709.4	22.37	– 28.32
20	Orissa	30	155,707.00	21,341.71	13.71	18,952.74	12.17	– 1.53
21	Punjab	17	50,362.00	2228.40	4.42	1172.84	2.33	– 2.10
22	Rajasthan	32	342,239.00	105,639.11	30.87	101,453.86	29.64	– 122
23	Sikkim	4	7096.00	3569.58	50.30	3808.21	53.67	3.36
24	Tripura	4	10,486.00	1276.03	12.17	1322.97	12.62	0.45
25	Tamil Nadu	29	130,056.00	23,013.90	17.70	17,303.29	13.30	– 4.39
26	Uttar Pradesh	70	240,926.00	22,971.60	13.17	16,984.16	7.05	– 6.12
27	Uttaranchal	13	53,483.00	16,079.72	30.07	16,097.46	30.10	0.03
28	West Bengal	18	88,752.00	5718.48	6.44	4397.56	4.95	– 1.49
29	Union Territory	20	10,973.00	574.30	5.23	314.38	2.87	– 2237
	TOTAL:	597	3,166,412.00	638,518.31	20.17	552,692.26	17.45	– 2.71

mainly distributed in NE states, Jammu & Kashmir and Rajasthan have got more than 50% of geographical area under wastelands. A total of 103 districts have 41–50%, 76 districts have 31–40%, 98 districts have 21–30%, 126 districts have 11–20%, and 161 districts have less than 10%. The distribution of different districts is shown in Fig. 12.

Ten districts are having more than 5,00,000 ha mainly distributed in J&K, Rajasthan and Gujarat, 49 districts between 2,00,000 and 5,00,000 ha, 89 districts between 1,00,000 ha, 114 districts between 50,000 and 1,00,000 ha. The distribution of different districts (area-wise) is shown in Fig. 13.

The category-wise distribution of wastelands shows that highest percentage (4.76%) belongs to the category “land

with scrub” followed by “underutilized forestland” (3.42%). The former is mainly distributed in the southern states of India, whereas the later is distributed throughout the country. The total geographical area of the country is covered in 597 districts, out of which fourteen (14) districts are newly formed and the statistics are not generated separately as these are covered as combined district. The wasteland statistics for these fourteen districts can be extracted after obtaining authentic boundaries. In view of this, analysis is carried out for 583 districts for which wasteland statistics are generated. (NRSA 2005).

Table 5 Category-wise comparison of wastelands (area in sq. km.)

S.No	Category	Wastelands		Percentage		Change	
		1986–2000	2003	1986–2000	2003	Area	%
1	Gullied and/or Ravinous land	20,553.35	19,039.34	0.65	0.60	– 1514.01	– 0.05
2	Land with or without scrub	194,014.29	187,949.49	6.13	5.94	– 6064.80	– 0.19
3	Waterlogged and marshy land	16,568.45	9744.97	0.52	0.31	– 6823.48	– 0.22
4	Land affected by salinity/alkalinity coastal/inland	20,477.38	12,024.05	0.65	0.38	– 8453.33	– 0.27
5	Shifting Cultivation area	35,142.20	18,765.86	1.11	0.59	– 16,376.34	– 0.27
6	Under utilized/degraded notified forest land	140,652.31	126,551.81	4.44	4.00	– 14,100.50	– 0.52
7	Degraded pastures/grazing land	25,978.91	19,344.30	0.82	0.61	– 6634.61	– 0.45
8	Degraded land under plantation	5828.09	2138.24	0.18	0.07	– 3689.84	– 0.21
9	Sends-inland/coastal	50,021.65	33,984.20	1.58	1.07	– 16,037.45	– 0.12
10	Mining/industrial wastelands	1252.13	1977.35	0.04	0.06	72,521	– 0.51
11	Barren rocky/stony waste/sheet rock area	64,584.77	57,747.11	2.04	1.82	– 6837.65	0.02
12	Sleep sloping area	7656.29	9097.38	0.24	0.29	1441.10	– 0.22
13	Snow covered and/or glacial area	55,788.49	54,328.16	1.76	1.72	– 1460.33	0.05
	Total wasteland area	638,518.31	552,692.26	20.17	17.45	– 85,826.05	– 2.71

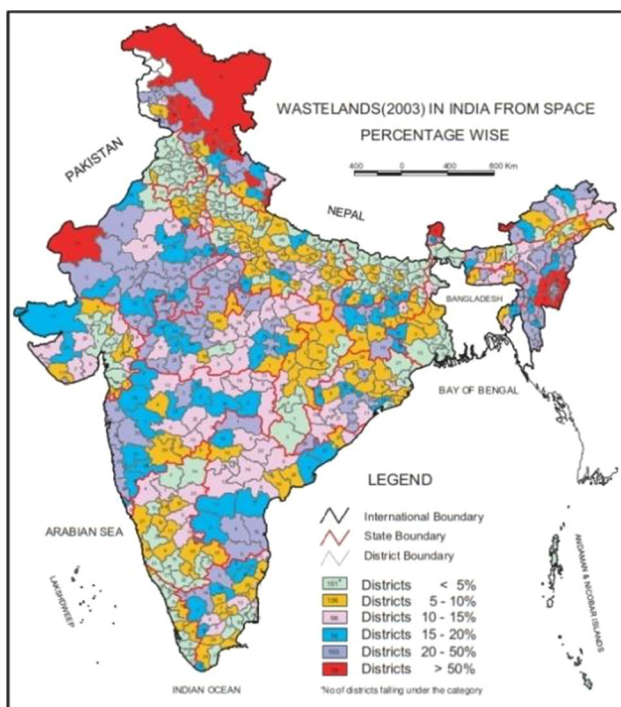


Fig. 12 Percentage-wise distribution of wasteland atlas

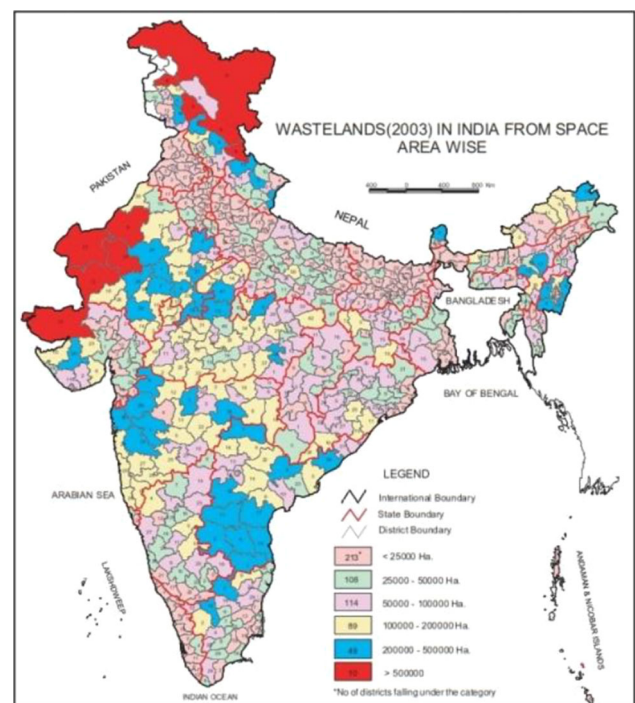


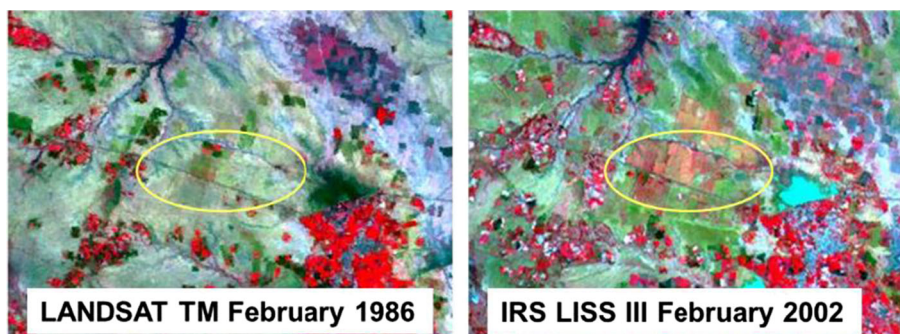
Fig. 13 Area-wise distribution of wasteland atlas

Wasteland Dynamics

Wasteland mapping was carried out for two time periods, i.e., 1986–2000 and 2003. The first cycle was carried out in five phases using three period data sets, i.e., 1986–88, 1991–92 and 1997–98. The second cycle was completed using one year, i.e., 2003 data. The comparative analysis of

statistics shows that there is reduction of 8.58 million hectares area between those time periods, equivalent to 2.71% to total geographical area of the country. In three states, namely Meghalaya, Nagaland and Gujarat, the reduction in wasteland area is more than 10%, can be due to shift from shifting cultivation to permanent cultivation in the North Eastern part of states and due to reduction/

Fig. 14 Greening of scrubland in parts of Nellore district, Andhra Pradesh



elimination of Rann of Kutch in Gujarat. In another 19 states, the reduction in wastelands varies between 0.42% and 7.63%, due to various watershed programs implemented. Part of the changes could be due to the methods and classification adapted of the analysis, data sets used etc. There is an increase in wastelands in some states mainly due to change in snow cover in states like Jammu & Kashmir, Sikkim and Uttaranchal. There is an increase in wastelands in Kerala by 0.88% mainly due to inclusion of new category, namely seasonal waterlogged area which is not mapped in first cycle (NRSA 2005). Category-wise change analysis indicates that there is a reduction in wasteland areas in all the categories except for mining/industrial waste and steep sloping area. As an example, changes in the wastelands in Nellore district Andhra Pradesh are shown in Fig. 14.

Conclusions

The Indian experience, in use of remotely sensed data for land use/land cover analysis, gained over past more than 20 years of implementation of various projects especially “Nationwide Land Use/Land Cover Mapping for Agro-Climatic Zone Planning” and “National Wasteland Inventory Project.” The former project was sponsored by Planning Commission of India and later by Ministry of Rural Development (MRD) of Govt. of India. Many Ministries and Departments in the Government of India and different state governments are institutionalizing remotely sensed derived information for day to day planning and monitoring.

Based on different studies, it is concluded that WiFS data can be used for level-I classification for national and regional level application, whereas LISS-III alone can be used till level-III classification for subregional scale and a combination of LISS-III and PAN data can be used for village-level information.

Realizing the importance of spatial land use/land cover information and the corresponding change patterns for planning and developmental activities, land use census

mission, under Natural Resource (NR) Census, aims to generate land use/cover information at multiple national scales with synergistic use of all information sources that are being implemented under National Natural Resource Information System (NNRMS) program.

The Monitoring of Wastelands Project, which aim at reporting the changes in wastelands statistics in India, considering various developmental programs launched by Govt. of India is being analyzed using the latest satellite data biannually.

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