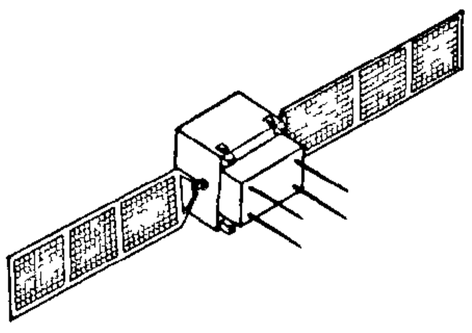


Special Issue on:
Remote Sensing for National Development

IRS-1A Application for Land Use/ Land Cover Mapping in India

D. P. RAO, N. C. GAUTAM, R. L. KARALE AND BALDEV SAHAI

ABSTRACT: *Land use/land cover inventories are needed for the optimal utilisation and management of land resources of the country. Remote sensing application with IRS-1A LISS-I data helped generation of districtwise land use/land cover maps for the whole country on 1:250,000 scale to serve the requirement of agroclimatic zonal planning, initiated under the Planning Commission of the Government of India. Both the visual interpretation and the digital classification techniques were employed in mapping land use/land cover categories. Outlining categoric abstraction scheme and the system of classification, the methodologies for mapping and aggregating agricultural land uses of the Kharif and Rabi seasons into a holistic format are briefly presented in the paper. Completion of land use/land cover maps of 442 districts in record time of one effective year established the operational utility of IRS-1A data in land use/land cover mapping in an efficient and cost-effective manner.*

INTRODUCTION

Land is the most important natural resource which embodies soil, water and associated flora and fauna involving the total ecosystem. Of late, the growing population and human activities are increasing the pressure on the limited land and soil resources for food, energy and several other needs. An assessment of the land available for productive uses reveals an alarmingly decreasing trend in the per capita availability of arable land from 0.48 ha in 1951 to 0.20 ha in 1981, and by 2000 AD it is estimated to decline further to 0.15 ha.

Comprehensive information on the spatial distribution of land use/land cover categories and the pattern of their change is a prerequisite for planning, utilisation and management of the land resources of the country. Land use/land cover inventories are assuming increasing importance in various resources sectors like agricultural planning, settlement and cadastral surveys, environmental studies and operational planning based on agroclimatic zones. Information on land use/land cover permits a better understanding of the land utilisation aspects on cropping patterns, fallow lands, forests, grazing lands, wastelands and surface water bodies, which is vital for developmental planning.

ILRI (1977)[1] has emphasised the land use planning in the following words: "The land use planning may be concerned with putting environmental resources to new kinds of productive use. The need for land use planning is frequently brought about, however, by changing needs and pressures; involving competing uses for the same land. The function of land use planning is to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man, whilst at the same time conserving those resources for the future".

The information requirements for land use planning comprise reliable, up-to-date and comprehensive data on physical, ecological and socio-economic resources. It is well established that remote sensing has the potential to make the most significant contributions in the area of land use data collection and more so in the agricultural land use[2]. The latter is apparently the most important area of interest to practically all countries of the world, and especially

to the developing countries like India where agriculture forms the backbone of the national economy.

INTERPRETATION OF REMOTELY SENSED DATA FOR LAND USE LAND COVER

A remote sensor records response which is based on many characteristics of the land surface, including natural and artificial cover. An interpreter uses tone, texture, pattern, shape, size, shadow, site, association to derive information about land use activities from what is basically information about land cover[3]. The title 'land use mapping' is quite often applied to remote sensing image classification procedure as a whole, which tends to amalgamate the distinct concepts of mapping land use and land cover[4].

The generation of remotely sensed data/images by various types of sensors flown aboard different platforms at varying heights above the terrain, and at different times of the day and the year, does not lead to a simple classification system. In fact, many researchers believe that no single classification could be used with all types of imagery and all scales[2]. To date, the most successful attempt in developing a general purpose classification schme compatible with remote sensing data has been attempted by Anderson *et al.*[5,6]. Many of the other classification schemes used with remotely sensed data are basically modifications of Andersons classification scheme. This classification system is commonly referred to as USGS or Anderson classification system. Four levels of classification are suggested. Level-I information can be used at inter-state and statewide levels of planning. Level-II, at statewide to regional scale of planning. Level-III, at regional to local scales of planning, whereas Level-IV information can be used at local or micro level planning.

CRITERIA FOR LAND USE/LAND COVER CLASSIFICATION

In order to develop a land use/land cover classification system for the land use conditions prevalent in India, it is essential to consider certain criteria and limitations of satellite data and that of the study areas. This is particularly relevant, because a classification system using satellite data should provide a framework to satisfy the needs of a majority of users. For this, certain guidelines and criteria for evaluation have been established. They are:

1. The land use/land cover classification system involved should be applicable over large areas.
2. The classification system should be suitable for using satellite data obtained at different periods of the year.
3. Assemblage of land use/land cover categories must be possible.
4. The minimum interpretation accuracy and reliability in the identification of land use/land cover categories from satellite data should be at least 85 to 95 per cent.
5. Due to the small scale of satellite imagery certain land use/land cover categories may be generalised. For example, different agricultural crops can be put together under the main category of agriculture.
6. Choice of data should be planned on the basis of the dominant use the map is intended to serve and the levels of details needed. For most purposes, imagery obtained in Kharif and Rabi seasons would be ideal for land use mapping.
7. To decide on an appropriate classification, or the categoric level within a classification, an arbitrary decision must be made. One must decide on imagery scale or on the scale of representation of data. Data based on scales of 1:1 million, 1:250,000 and 1:50,000 should serve the three levels, namely Level-I, Level-II and Level-III classification, respectively.

LEVELS OF CLASSIFICATION USING SATELLITE DATA

The National Land Use/Land Cover Classification system was designed as a reconnaissance scheme applicable in Indian environment with varying needs and perspectives. The land use/land cover categories can be expanded or reduced to any degree and be made more responsive to the information the region needs. At this stage, the classification scheme is not intended to be final, but is so designed that it contains all possible categories which might be encountered in the interpretation process. The following is a brief discussion on each of the categoric levels.

Level-I: The level-I classes are readily available from IRS imagery. The ground area of the minimum mapping unit would vary depending upon the method of interpretation and scale of mapping. Using visual interpretation, the minimum mapping unit (3 mm x 3 mm) on 1:1 million scale is equivalent to 900 ha (9 sq. km) on the ground (Table 1). The level-I classification has been successfully applied using both the digital and the visual methods of data interpretation.

Level-II: The level-II classification is readily achieved on IRS LISS-I FCC imagery of 1:250,000 scale. The minimum mapping unit, on this scale, represents 56.25 ha on the ground. Satellite imagery of different cropping seasons of the year are required to obtain level-II information. It should be

Table 1. The minimum mappable units at various scales

Categoric level	Scale	Smallest mappable unit on the map (mm)	Area covered on the ground (ha)
I	1:1 M	3 x 3	900
II	1:250,000	3 x 3	56.25
III	1:50,000	3 x 3	02.25

noted that the reference level, knowledge of the area and skill of the remote sensing scientist/interpreter have a determining effect on the level of details and accuracy of mapping. At this stage, the classification scheme is not intended to be final and likely to undergo further changes. However, it contains all possible categories which might be encountered in the interpretation process.

COMPREHENSIVE CLASSIFICATION SYSTEM DEVELOPED BY NRSA

The array of information available on land use/land cover need to be grouped under a suitable classification system. The classification system should not only be flexible in its scope, definition, and nomenclature of its categories, but also be capable of incorporating information obtained from different sensor data and other sources. Such a land use classification system, based on the understanding that the remote sensing techniques can be used effectively to complement traditional surveys for an accurate inventory of the land use and land cover in the country, was proposed by Gautam and Narayan to suit the Indian conditions[7]. Subsequently, National Land Use/Land Cover Classification System for India has been developed under the National Remote Sensing Agency, Department of Space in consideration of the views of the several user departments including the Planning Commission of India[8]. The system is fairly compatible with those followed by most of the other government departments in the country (Table 2).

Table 2. Land use/land cover classification system

Level-I	Level-II
1. Built-up land	1.1 Built-up land
2. Agricultural land	2.1 Crop Land
	i) Kharif
	ii) Rabi
	iii) Kharif +Rabi[a]
	2.2 Fallows[b]
	2.3 Plantations[c]
3. Forest[d]	3.1 Evergreen/semi-evergreen forest
	3.2 Deciduous forest
	3.3 Degraded or scrub land
	3.4 Forest blank
	3.5 Forest plantation[e]
	3.6 Mangrove
4. Wastelands	4.1 Salt affected land
	4.2 Waterlogged land
	4.3 Marshy/swampy land
	4.4 Gullied/ravinous land
	4.5 Land with or without scrub
	4.6 Sandy area (coastal and desertic)
	4.7 Barren rocky/stony waste/sheet rock area
5. Water bodies	5.1 River/stream
	5.2 Lake/reservoir/tank/canal[f]
6. Others	6.1 Shifting cultivation
	6.2 Grassland/grazing land
	6.3 Snow covered/Glacial area

[a] It includes land under agricultural crops during Kharif, Rabi (both irrigated + unirrigated) and the area under double crop, during both the seasons.

[b] It is that land which remains vacant without crop during both the Kharif and the Rabi seasons.

[c] It includes all agricultural plantations like tea, coffee, rubber, coconut, arecanut, citrus and other orchards.

[d] It includes those areas which occur within the notified forest boundary as shown on the Survey of India topographic maps on 1:250,000 scale. Those occurring outside the notified areas are also included under forest class, but the area estimates of the two will be shown separately.

[e] It includes plantations within the notified forest boundary eg., cahew, casuarina, eucalyptus, etc. Those occurring outside the notified areas will be classified under category 2.3. The area estimates of the two will be shown separately.

[f] It includes inland fresh water lakes, salt lakes, coastal lakes and lagoons.

NOTE : 1. Mining and industrial wastes, salt-pans, reclaimed lands, classes relevant to a particular district will be mapped separately, wherever feasible. These will be classified under Others.

2. Tidal/mud flats which are visible during low tides along the coastal areas will also be mapped separately if these are identified on satellite imagery. These will be classified under Others.

INDIAN REMOTE SENSING SATELLITE DATA FOR MAPPING LAND USE/LAND COVER

A major impetus for IRS data utilisation in land

use/land cover mapping was provided by the Agroclimatic zonal planning initiated under the Planning Commission, Government of India, to fulfill the need to study district–wise land use information for the whole country. A project on nationwide land use/land cover mapping was formulated for mapping at 1:250,000 scale using IRS LISS-I data of two seasons. IRS-1A satellite data operating in the four discrete spectral bands in the visible and infrared region of 0.45–0.86 microns with a ground resolution of 72.5m in case of LISS-I and 36.25m, in case of LISS-II offer adequate information on land use/land cover. The principal applications of IRS spectral bands are given in table 3.

Table 3. Indian Remote Sensing Satellite (IRS-1A) – spectral bands and their principal application

Band	Wavelength (microns)	Application
1.	0.45 – 0.52	Coastal environmental studies (coastal morphology and sedimentation studies) Soil/Vegetation differentiation coniferous/deciduous flora discrimination.
2.	0.52 – 0.59	Vegetation vigour assessment; rock/ soil boundary differentiation; turbidity and bathymetry in shallow water.
3.	0.62 – 0.68	Strong chlorophyll absorption leading to discrimination of vegetation types and sub-types, mapping of cultural features.
4.	0.77 – 0.86	Delineation of surface water features, landform/geological studies, mapping of settlement and transport network.

Some of the special merits of IRS data, in the context of land use/land cover mapping are summarised as follows:

1. Identification and delineation of land use/land cover categories over large areas is speedily possible because of synoptic view of 25,752 sq. km (148 x 174 km) on a single IRS LISS-I scene.
2. It provides land resources data in four different bands of the electromagnetic spectrum matching the mapping needs under Indian conditions as borne out by earlier investigations.
3. Spatial resolution of LISS-II data allows mapping on 1:50,000 scale with level-III categoric extraction. Land use classes with areas as small as 0.13 ha could thus be delineated.
4. Spatial resolution of LISS-I allows quick and economical land use inventories for gross estimates as compared to any other method of surveying.
5. In view of the uninterrupted and assured IRS data availability, reliable, near realtime baseline information for any year (since its launch) or any period in a month (provided it is not cloudy) is possible for every part of the country.
6. It provides repetitive coverage of the same area once in 22 days and thereby facilitates monitoring land use/land cover changes.

Development of methodologies

Although initial efforts were made in 1986 for application of visual interpretation techniques in land use mapping as a part of Remote Sensing Applications Missions Project, the major thrust for operational methodologies (visual, digital) came from the project on nationwide land use/land cover mapping. As stipulated by the Planning Commission, district-wise information on agricultural land use during both the cropping seasons, namely Kharif and Rabi and also other land use categories and their area estimates was necessary for evolving suitable plans to increase agricultural production based on agroclimatic zones.

Visual interpretation

The methodology developed by National Remote Sensing Agency for visual interpretation of multidate satellite data comprises the following six major steps (Figure 1):

1. *Selection and acquisition of data*: Standard FCC imagery of IRS LISS-I of Kharif and Rabi seasons.
2. *Preliminary visual interpretation*: IRS LISS-I FCC imagery of Kharif and Rabi seasons are interpreted individually making use of the interpretation keys. The boundaries of land use/land cover classes are plotted onto transparent overlay, such as artian or polyester tracing sheets.
3. *Ground data collection and verification*: Following the previously drawn scheme, and traverse plan, ground truth information is collected as per specific proforma to cover at least 10 per cent of the district area. Areas of doubtful preliminary interpretation are particularly verified.
4. *Final interpretation and modification*: Based on the ground truth data, modifications are effected and classes as well as their boundaries refined.

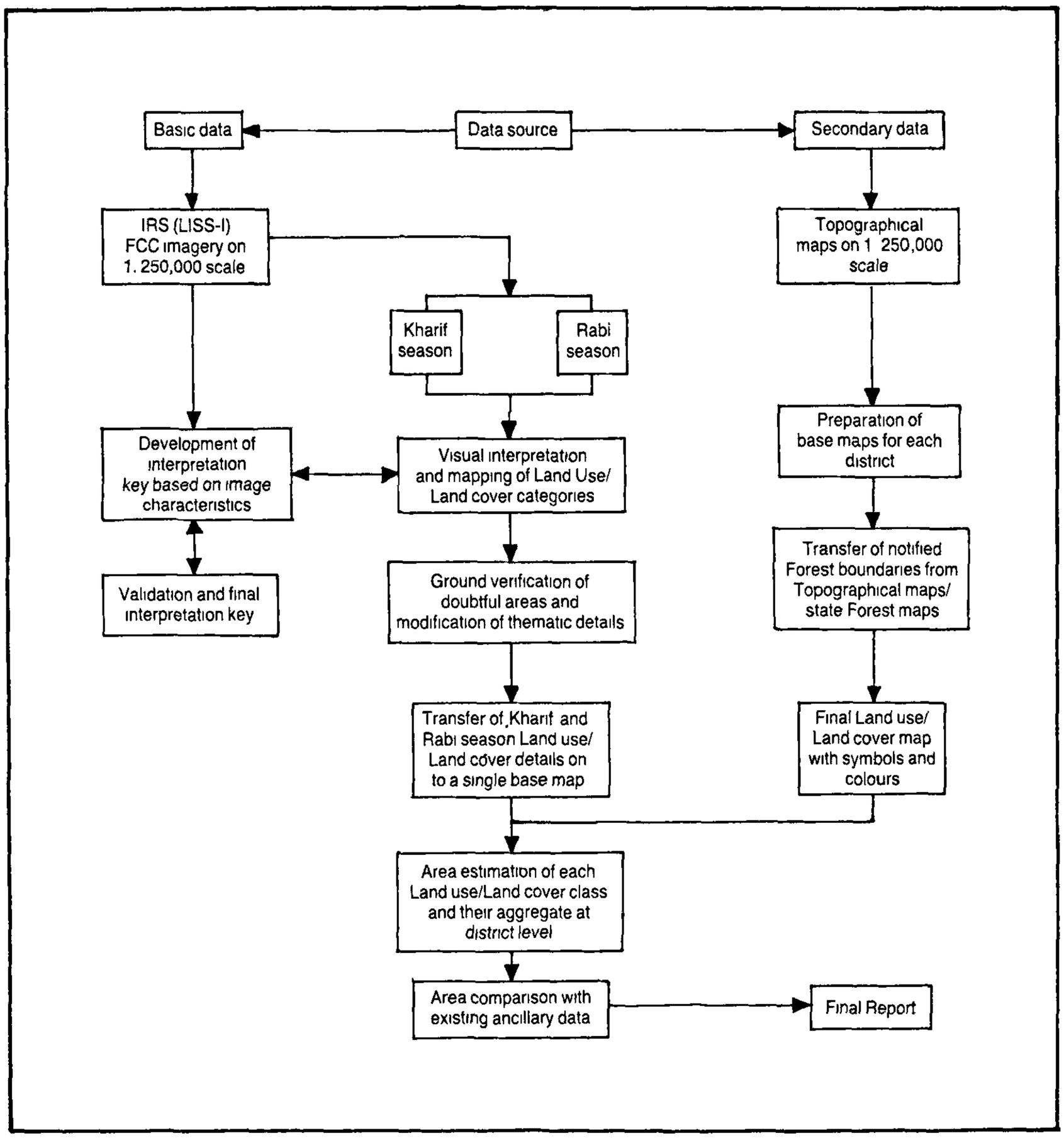


Figure 1. Methodology of land use/land cover mapping for visual interpretation of IRS-1A LISS-I imagery.

5. *Area estimation*: Areas under different classes are estimated by planimetric measurements to complete district land use statistics.
6. *Final cartographic map preparation and reproduction*: Fair drawing originals are made as per predesigned specifications and cartographic symbols.

Land use/land cover maps of 273 districts in the country have been completed following the visual interpretation approach. A sample map is illustrated in figure 2.

DIGITAL CLASSIFICATION

Operational methodology of land use mapping was not available in digital domain, particularly for large area coverage involving two seasons data. Pilot studies were therefore carried out at the Regional Remote Sensing Service Centre, Nagpur and a viable methodology using IRS LISS-I data has been developed. The methodology comprises the following seven steps (Figure 3):

1. Data acquisition, loading, merging and georeferencing.
2. Ground truth collection.
3. Demarcation of district boundary and transfer of administrative and cultural features.
4. Stratified classification of the two seasons data.
5. Refinement.
6. Aggregation of Rabi and Kharif classification.
7. Statistics and final output.

Supervised classification is carried out in stratified manner for both Rabi and Kharif seasons with maximum likelihood classifier. Stratification is effected by digitisation of forest boundary from Survey of

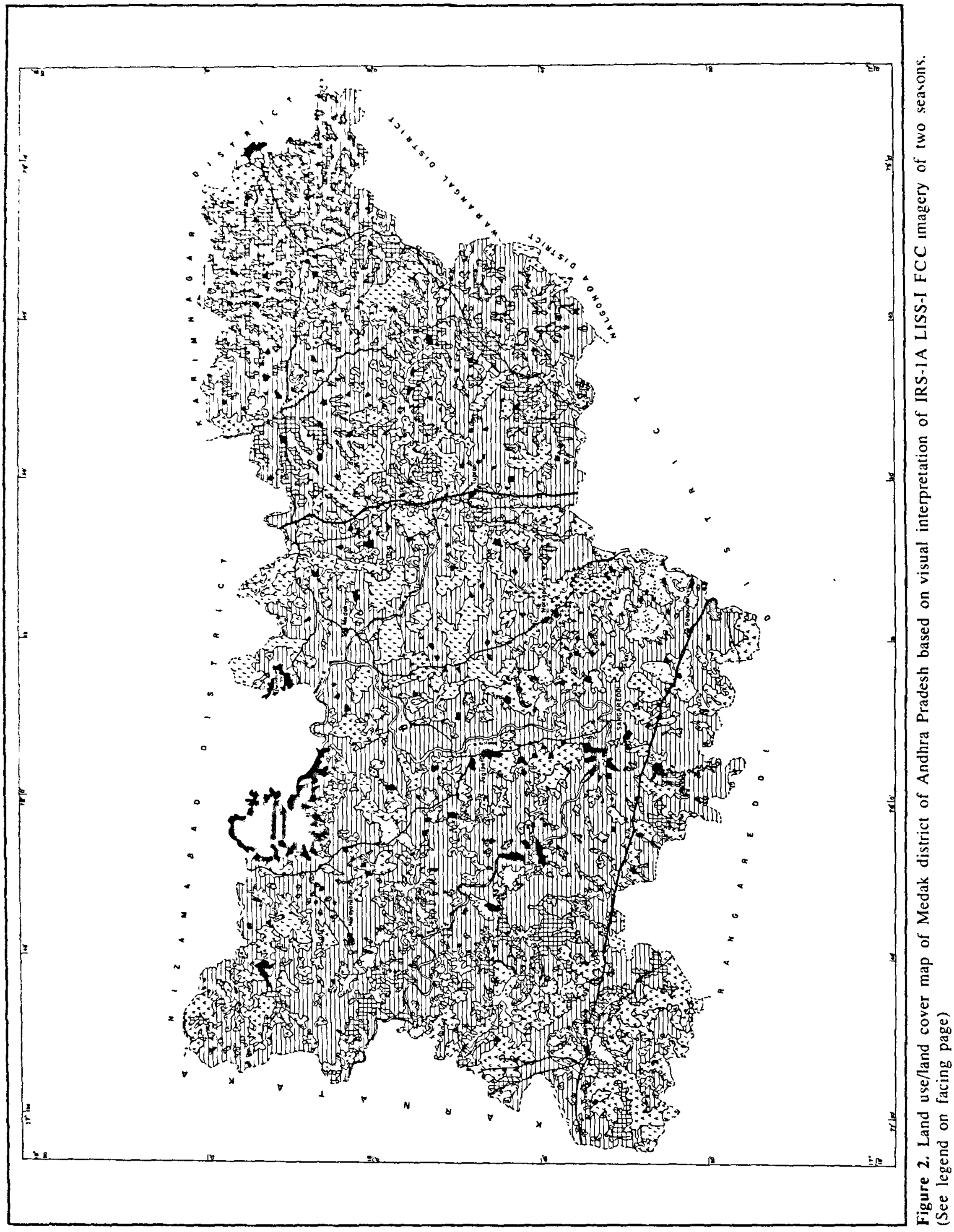
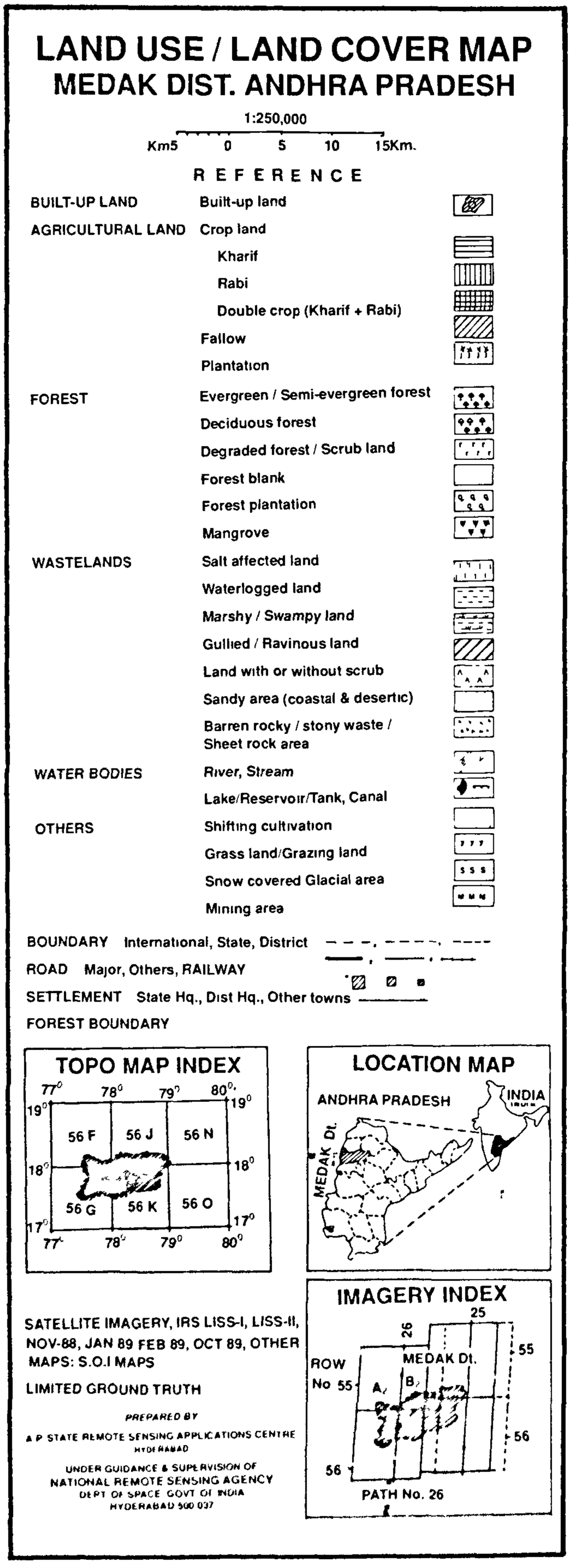


Figure 2. Land use/land cover map of Medak district of Andhra Pradesh based on visual interpretation of IRS-1A LISS-I FCC imagery of two seasons. (See legend on facing page)



India (SOI) topographical maps (also other sources) and creation of mask files. The classification proceeds through selection of the training sets, calculation of the statistics of the training sets and the decision boundary of maximum probability based on mean vector, variance, covariance and correlation matrix of the pixels.

Normalised Difference Vegetation Index (NDVI) is adopted for classification of forest areas. Gaussian post-normalisation is used in bringing the NDVI in the range of 0–255. Look-up table (LUT) is prepared for output grey values for each project area based on limited ground truth.

The methodology allows human logic and intuition through a specifically developed program REFINE, for correcting and modifying discrepant classification arising out of spectral similarity of two or more classes in a non-forest stratum. In referential refinement, classification of a pixel in one cropping season is evaluated and, if necessary, corrected with reference to its classification in the other season.

Rabi and Kharif seasons classified scenes are reformatted to a single output through the process of pixel to pixel aggregation. Finally the land use statistics and the photo-write compatible tape of the aggregated classified output are generated for the project area.

This methodology has been successfully followed in generating districtwise land use/land cover maps of 168 districts. A sample map generated by digital techniques is shown in figure 4.

CONCLUSIONS

Land use/land cover mapping using IRS-1A LISS-I data has been a unique exercise for three major reasons. First, it has served to highlight the special merits of IRS data for land use mapping under Indian conditions. Secondly, it has been synergistic in developing operational methodologies, both for visual interpretation and digital analysis. And finally, completion of mapping in 442 districts in record time of one year (effectively operational) has enthused a particular sense of accomplishment and rendered a high degree of confidence to tackle similar projects of national importance. Overall, it can be concluded that IRS-1A data has come of age in India in providing a viable, authentic and cost effective means of obtaining land use resource inventory, operationally.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance given by Dr.V. Raghavaswamy, Scientist in Land use Division

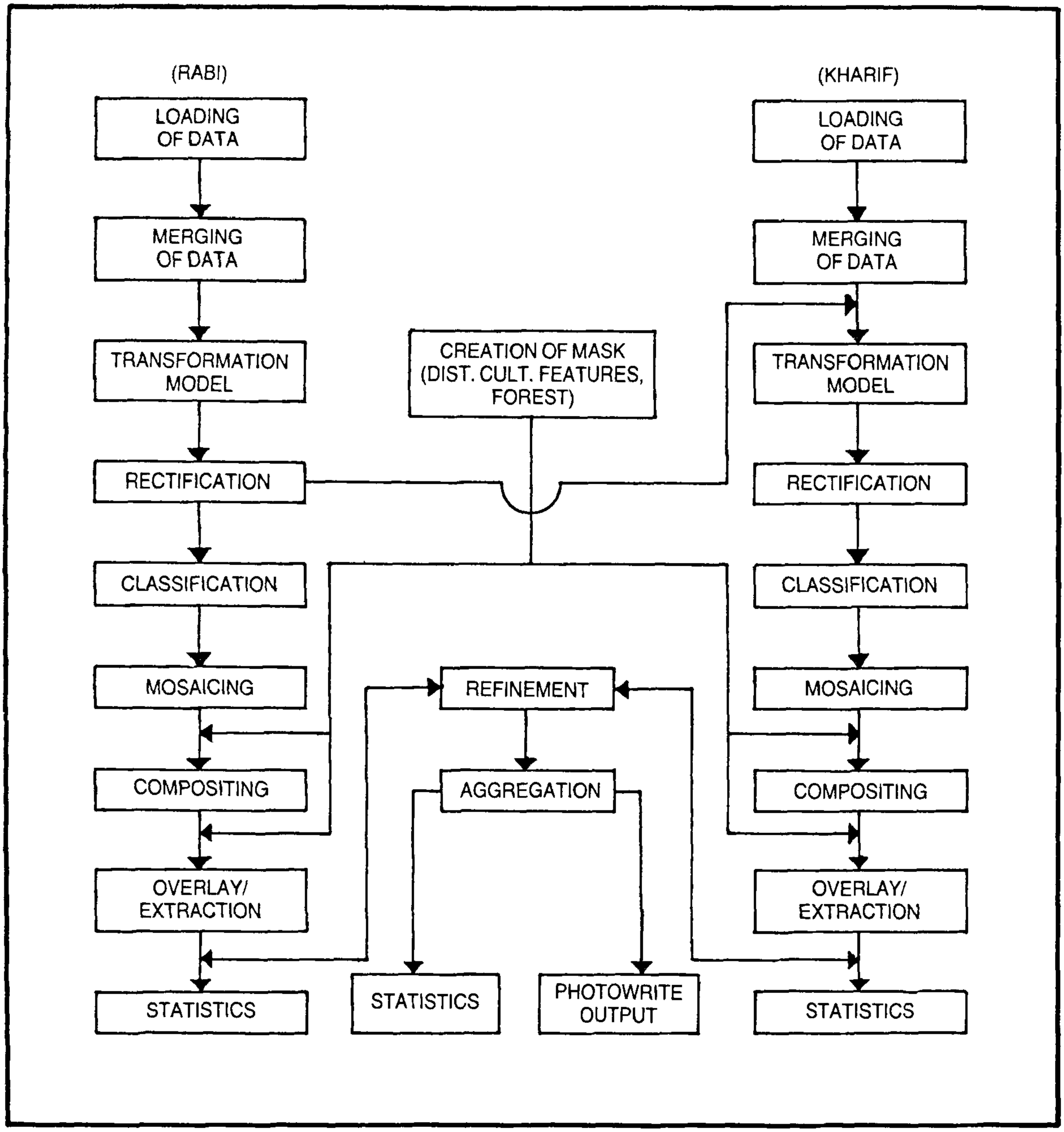


Figure 3. Methodology of land use/land cover mapping using digital techniques:

of the National Remote Sensing Agency in reading through the manuscript and providing suggestions.

REFERENCES

1. Anonymous, A framework for land evaluation, international institute for land reclamation and improvement, Netherlands, Publn. **22**, 1977.
2. Nunnally, N. R., Interpreting land use from remote sensor imagery, in remote sensing techniques for environmental analysis (ed. J. E. Estes and L. W. Senger) Hamilton, Santa Barbara, Calif., 1974.
3. Anderson, J. R., *Photogram. Engg.* **37**, 1971, 379.
4. Sung *et al.* Land use/land cover mapping of Taiwan by automated multispectral interpretation of Landsat imagery, *GSFC report* 923-77-210, Maryland, 1977.

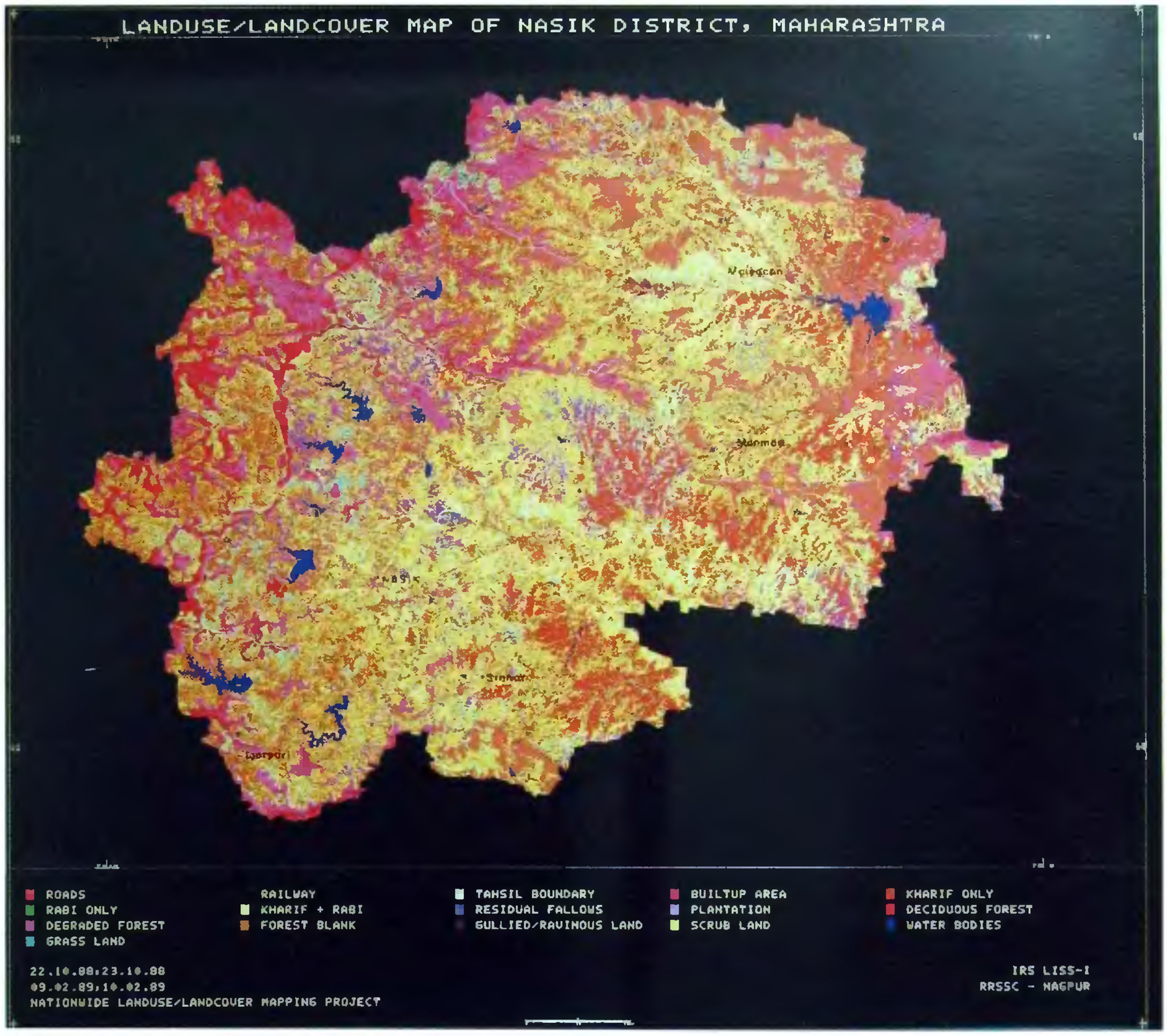


Figure 4. Land use/land cover map of Nasik district of Maharashtra generated by digital analysis of IRS-1A LISS-I data of two seasons.

5. Anderson, J. R., Hardy, E. E. and Roach J. T. A Land use classification system for use with remote sensor data, *Circular 671*, USGS, Washington, 1972.
6. Anderson, J. R. *et al.* A land use/land cover classification system for use with remote sensing data. *Professional paper 964*, USGS Publications, 1976
7. Gautam, N. C. and Narayan, L. R. A., Suggested land use/land cover classification for India using remote sensing techniques, Pink Publications, Mathura, 1982.
8. Anonymous, Description and classification of land use/land cover, *Tech. Rep.*, 01/90, NRSA, July 1990, pp. 1–81.
9. Anonymous, Manual of nationwide land use/land cover mapping using satellite imagery, part-I, NRSA, 1989, pp. 1–58.
10. Anonymous, Manual of nationwide land use/land cover mapping using digital techniques, Part-II, RRSSC, Nagpur, February, 1990, pp 1–78.