IRS-1C applications in land use mapping and planning

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Land use/land cover information is a prerequisite for optimal land use planning. Considerable experience was gained using remote sensing data from Landsat I through Landsat V in preparing land use land/cover maps on scales ranging from 1 : 1 million to 1 : 50,000. IRS-1C data have been extremely useful in the generation of districtwise land use/land cover maps, depicting the information up to level-II for the whole country on 1 : 250,000 scale for land use planning of 15 agroclimatic zones in the country. The launch of IRS-1C on 28 December 1995 provided a new dimension to the mapping capability on land use/land cover details on various scales and levels and for different users. The details of sensors have been described elsewhere in this issue and hence not repeated. Wide Field Imaging Sensor (WiFS) data for the entire Andhra Pradesh, LISS-III data of Kaziranga National Park and its environs and composite (merged) data of LISS-III and PAN of urban fringe of Hyderabad were analysed to evaluate the capabilities of sensors for land use applications. Based on this study, 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 up to level-III and a combination of LISS-III and PAN data can be used for cadastral level information.

THE growing pressure of population coupled with increasing variety of demands made on land resources, have brought extra pressure on the available land resources all over the country. Hence, in order to use land optimally, it is not only necessary to have the information on existing land use/land cover but also the capability to monitor the dynamics of land use resulting out of changing demands of increasing population.

Conventional ground methods of land use mapping are labour intensive, time consuming and are done relatively infrequently. These maps soon become outdated with passage of time, particularly in a rapidly changing environment. In recent years, satellite remote sensing techniques have been developed, which have proved to be of immense value for preparing accurate land use/land cover maps and monitoring changes at regular intervals of time.

In case of inaccessible region, this technique is perhaps the only method of obtaining the required data on a cost and time-effective basis. An article on IRS-1A applications for land use/land cover mapping in India has appeared (*Curr. Sci.*, 1991, **61**, 153–161).

Current status

The organizational efforts in publishing maps, reports and statistical data by Survey of India (SOI), National Atlas and Thematic Mapping Organization (NATMO), National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), All India Soil and Land Use Survey (AIS&LUS), National Remote Sensing Agency (NRSA), Space Applications Centre (SAC), Central Arid Zone Research Institute (CAZRI), Ministry of Agriculture, Settlement Survey and Land Records, Revenue Departments, National Sample Surveys, State Land Use Boards, Town and Country Planning Organization (TCPO) and other local agencies are noteworthy.

Ever since the launch of the first remote sensing satellite (Landsat-1) in 1992, 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 NRSA using 1980–82 Landsat Multi Spectral Scanner data. About 53.3 Mha (16.2%) of wastelands were estimated based on this study. Subsequently mapping on 1:50,000 scale was carried out by NRSA for 241 districts critically affected by land degradation in the country using Landsat Thematic Mapper data as well as IRS-LISS-II data using 13 fold wasteland classification.

At the instance of Planning Commission, the Department of Space carried out land use/land cover mapping of all 442 districts using IRS LISS-I data based on visual and digital interpretation techniques in collaboration with various work centres in different states. This task provided first national level spatial maps on land use/land cover along with statistics in 22 different categories. Since the mapping was carried out on 1 : 250,000 scale using a coarse resolution satellite data, small settlements, linear features like transportation network could not be delineated. 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 data has provided an opportunity for the first

time to derive the land use/land cover information at regional, local and cadastral levels, on appropriate scales with an assured frequency for updation. The paper presents the early results of analysis of WiFS, LISS-III and IRS-1C composite (merged) data of LISS-III and PAN for evaluation of the capability of sensors to derive the information on land use/land cover categories.

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 has the potential to monitor the dynamic phenomena every 5 days at level-I; LISS-III has the potential to generate the level-III up to 1 : 25,000 scale. The composite data of LISS-III and PAN has the potential to be enlarged on a 1 : 10,000 scale without loss of data to look out for cadastral level information. The possible scales on which land use/land cover can be generated, level of classification and the minimum mappable units that can be achieved using different sensors are shown in Table 1.

Realizing the excellent and useful information that can be extracted from IRS-1C data, the Department of Agriculture, Government of Andhra Pradesh has requested NRSA to carry out mapping of five taluks to derive the statistics at village level which will most likely be extended to the entire state using LISS-III data.

Objectives

The following are the objectives of this study:

- To analyse the land use/land cover using WiFS data for the state of Andhra Pradesh.
- To study the capabilities of LISS-III data and PAN and LISS-III merged data for large scale mapping at micro level.

Study area

Area covered by Andhra Pradesh state was selected to analyse the WiFS data. Kaziranga National Park and environs in Assam were selected to analyse and derive the land use/land cover data using LISS-III. A part of Ranga Reddy district, Andhra Pradesh was selected for analysis of composite (merged) data of LISS-III and PAN data.

Table 1. Possible scale and minimum mappable units using IRS-1C 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 : 25,000	3 × 3	0.56	Level-II
PAN	1 : 10,000	3 × 3	0.009	Level-III/IV

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 the elements of tone, texture, pattern, shape, size, shadow, site and association to derive information about land use activities, which is also the basic information about land cover. 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.

The generation of remotely sensed data/images by various types of sensors flown aboard different platforms at varying heights about 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. To date, the most successful attempt in developing a general purpose classification scheme compatible with remote sensing data has been

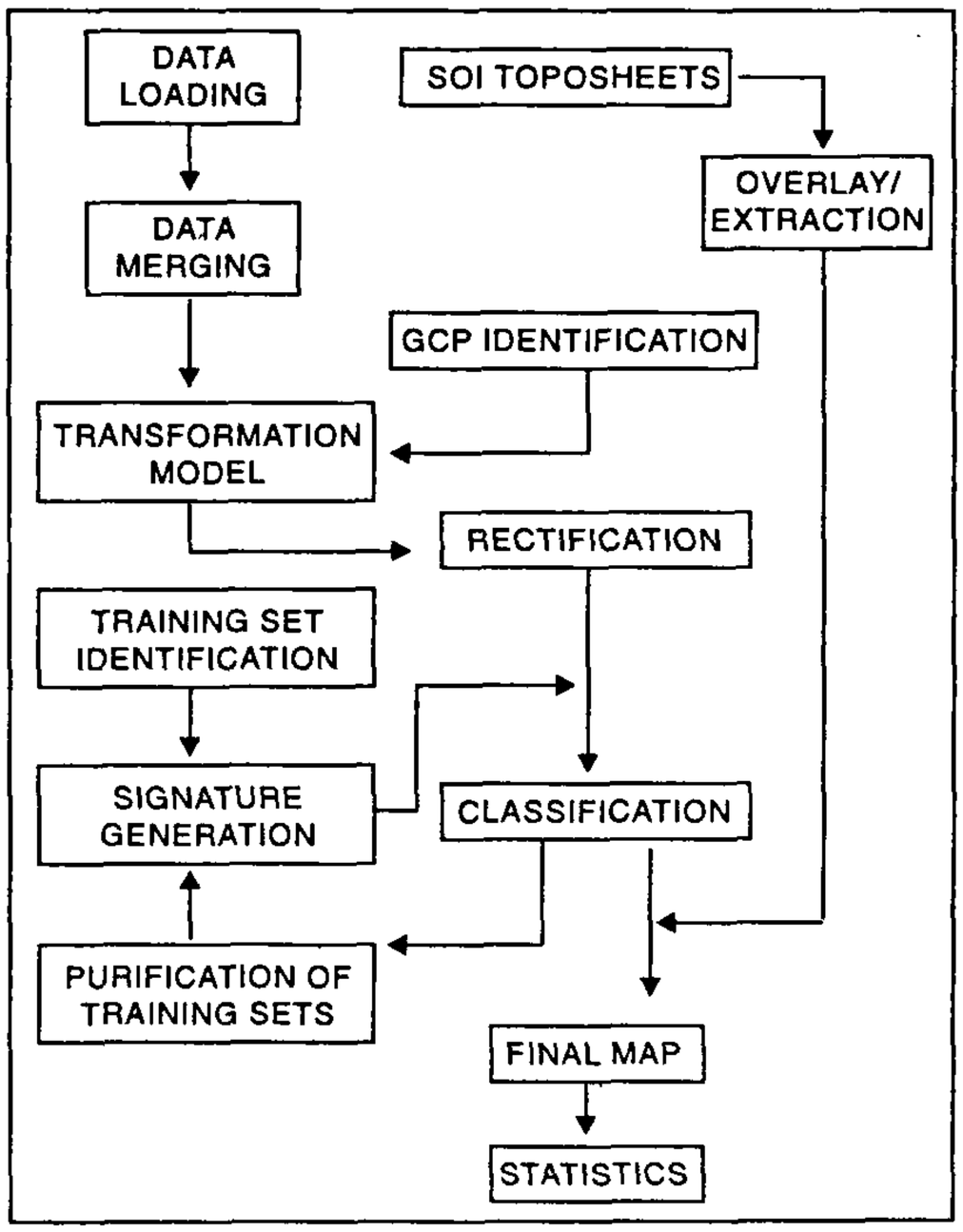

Figure 1. Methodology for landuse/land cover analysis.

attempted by Anderson *et al.*[2] which is also referred to as USGS classification scheme. Other classification schemes available for use with remotely sensed data are basically modifications of the above classification scheme.

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. In the present study, the classification system developed by NRSA in consultation with different users has been adopted.

Methodology

Although initial efforts were made since mid seventies for application 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. Figure 1 shows the flow chart of detailed analysis procured in the study. The methodology essentially involves the following steps.

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

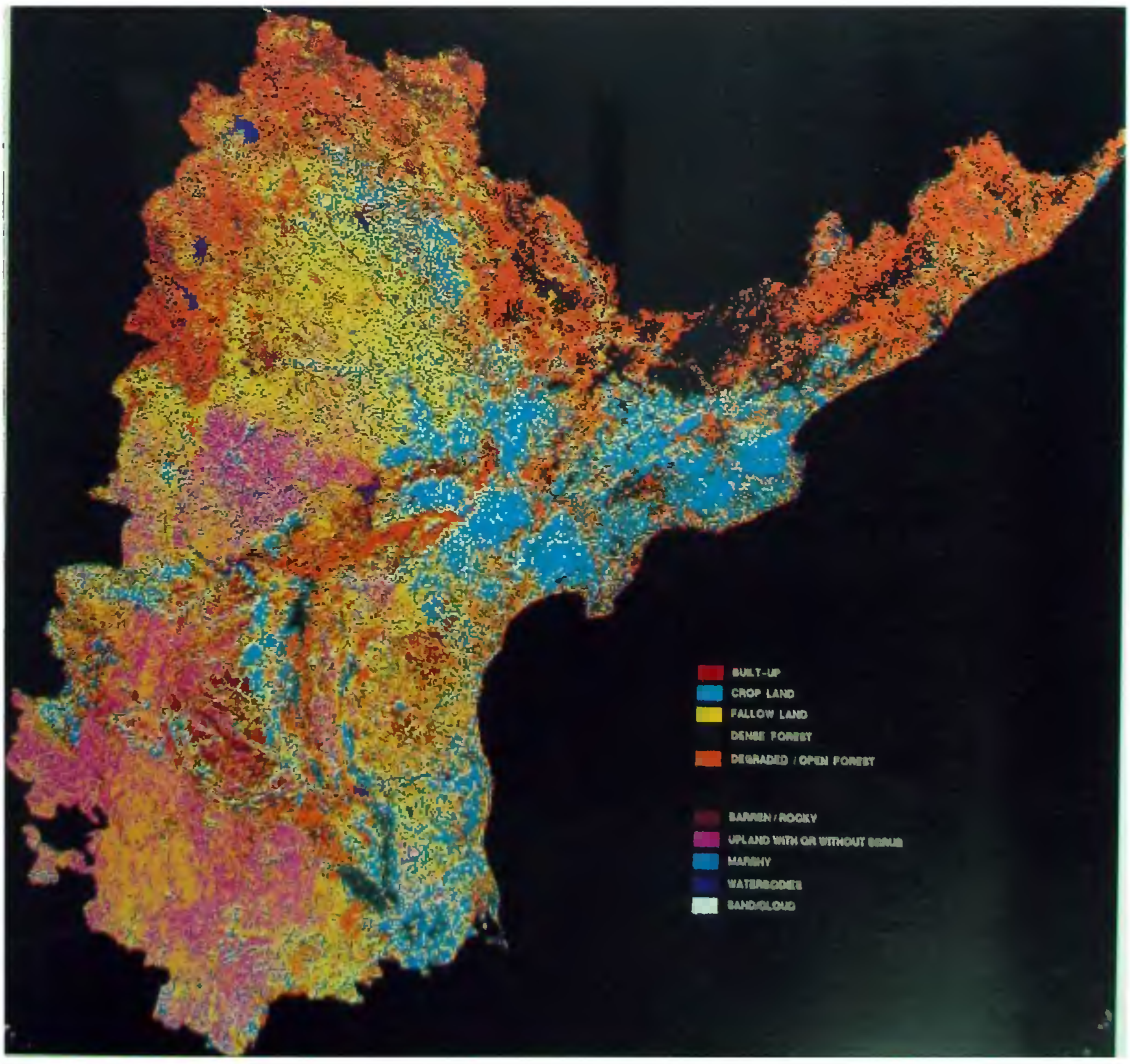

Figure 2. Digitally classified land use/land cover map of Andhra Pradesh using IRS 1C (WiFS) data of 11 February 1996

- 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, important locations is effected by digitizing these features from topographical maps. Georeferencing has been done by extracting GCPS from topographical map using maps image transformation model. Multispectral 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. 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. 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

About ten classes of level-I and level-II could be achieved using the digitally mosaiced WiFS data of Andhra Pradesh. Andhra Pradesh is covered in parts of three WiFS scenes (path/row 103-61; 103-66; 98-61). The digital analysis of land use/land cover has been carried out using three bands, viz. red, near infrared (NIR), and texture of NIR. The texture of NIR has been derived using textural analysis in EASI PASE software. The classified data of Andhra Pradesh are shown in Figure 2.

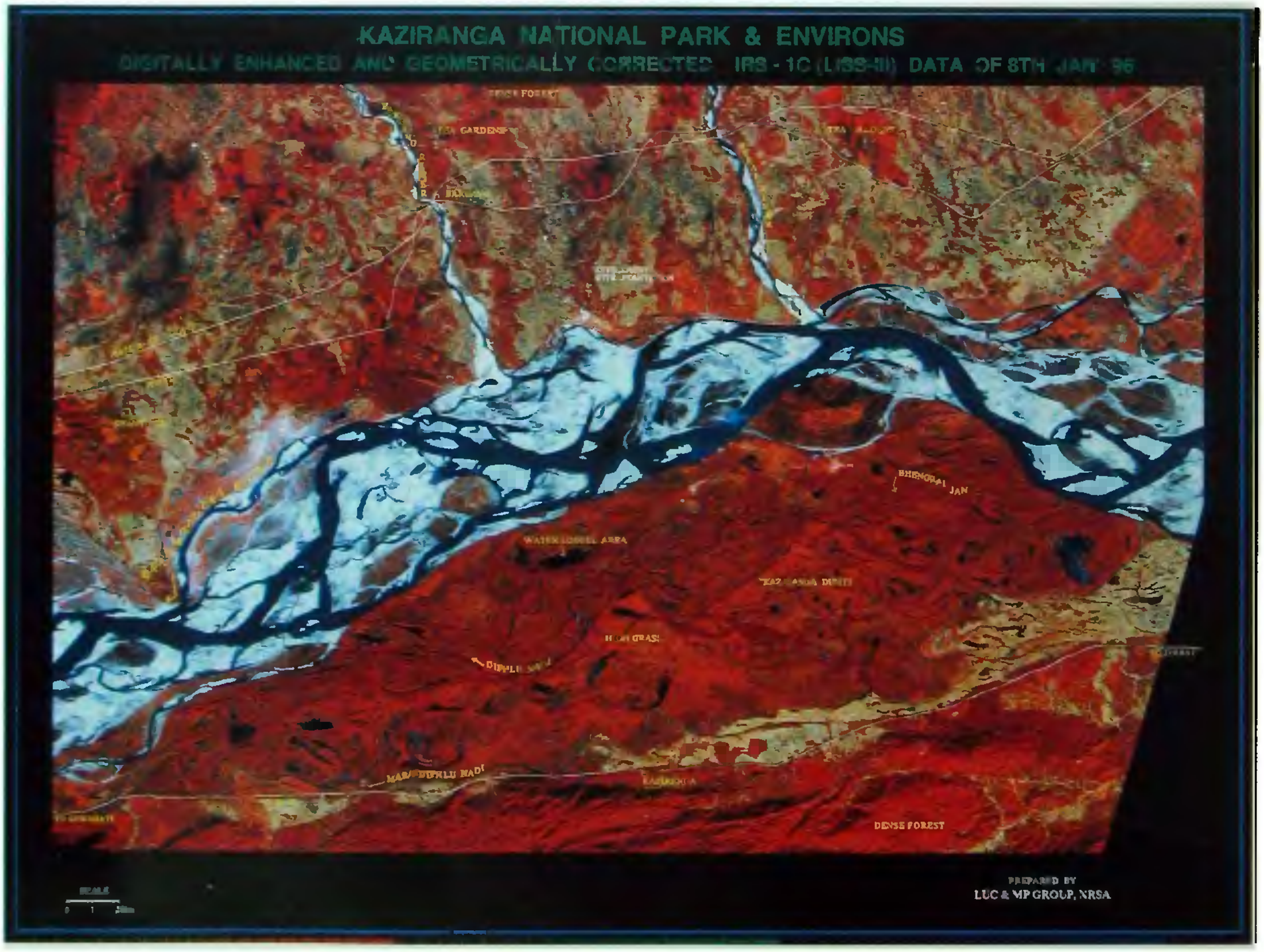

Figure 3.

WiFS data have been found to be adequate to bring out all the level-I classes derived from IRS-1A level LISS-1 data on 1 : 250,000 scale under land use/land cover mapping of agroclimatic zone planning. In the present study winter season (rabi) data were used for analysis. Due to the limitation of data (single season) some of the classes like open/degraded forest and uplands could not be separated, in some areas, with the result that some of the uplands in parts of Nizamabad, Medak and Ranga Reddy districts were mixed with degraded forest. Also some of the fallow lands in south-western part of the state have been misclassified as upland due to similar spectral signature in both the cases. Using multi season data, this problem can be solved by analysing the accurate land use/land cover information. The land use classes like crop land, water bodies, barren lands, dense forest water logged areas could be identified and classified more accurately using WiFS data. The interpretation accuracy has been found to be as high as 80–85%. 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 Figures 3 and 4 respectively. The classification has been made using NDVI for areas inside the park and using maximum likelihood classification

Figure 4.

for the rest of the area. The level-III classes such as type of plantation, viz. teak, sal, homestead plantations, different levels of grass in the Kaziranga National Park (High, Medium, Low) could be identified and classified. At the time of data collection, there were no crops in the study area and most of the agricultural area is under fallow. Major linear features such as roads, rail network and small settlements are clearly separable using LISS-III data. The water-logged areas within the national park are clear and areas of water bodies as small as 0.25 acres also could be classified accurately.

Land use/land cover analysis using composite data (LISS-III and PAN)

The composite (merged) data of LISS-III using PAN of part of Ranga Reddy district, South of Hyderabad,

Figure 5.

is shown in Figure 5. The land use/land cover details are very sharp in this data compared to LISS-III. Also, all the linear features are clear and details like car 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 derive accurate statistics of different land use categories.

It is thus possible to derive the land use/land cover statistics at cadastral level, which takes the process of mapping beyond what has been achieved so far, viz. to prepare spatial land use maps up to 1 : 10,000 scale and to derive the village level statistics.

Conclusions

The study demonstrates that the data from Indian Remote Sensing Satellite (IRS-1C) can be used to map and monitor land use/land cover details rapidly at different levels. This provides more consistent and accurate base line information than any of the conventional data sources or the sources from any of the satellites launched so far. The availability of spatial information at village/cadastral level is a major step for planning at micro level. Further, this data will help in estimating the area under different crops more accurately which forms base line information for crop production estimation on an operational basis.

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