IRS-1C applications for urban planning and development

V. Raghavswamy, S. K. Pathan*, P. Ram Mohan, R. J. Bhanderi* and Padma Priya

National Remote Sensing Agency, Balanagar, Hyderabad 500 037, India
*Space Applications Centre, Ahmedabad 380 053, India

Over the years, satellite-based remote sensing data have been successfully utilized for mapping, monitoring, planning and development of urban sprawl, urban land use and urban environment. With the successful launch of IRS-1C satellite and the availability of high spatial resolution data in 5.8 m in single panchromatic band (0.50–0.75 μm) and 23 m (LISS-III) resolution data in four multi-spectral bands along with the stereo and revisit capability of 5 days, it would now be possible to explore its potential either singularly or in combination in the different areas of urban land use survey and planning, such as urban housing, urban utilities and infrastructure, urban transportation and traffic planning, urban water supply and sanitation, urban cadastral and real estates, urban tourism and recreation, urban ecology and hazards, urban census, urban fringe area land use dynamics, urban landscape design besides other areas like urban land use change detection and updation, urban base map preparation, urban green belt or open space mapping, urban encroachment of slums onto vacant lands and urban land use zoning.

The present study demonstrates the potential of IRS-1C data applications attempted using multispectral LISS-III and PAN data both singularly and as combination of merged data sets over Hyderabad, Lucknow and Ahmedabad cities.

URBANIZATION and industrialization are universal processes. These processes occur both due to in-growth and due to continuous rural population migration to urban centres/settlements (in search of better economic opportunities) resulting in overcrowding and haphazard development. This is primarily because the level of economic development is linked to growth of particularly the big metropolitan and mega urban centres. The ongoing programme of the Ministry of Urban Affairs and Employment, Government of India on the 'Integrated Development of Small and Medium Towns (IDSMT)' is one such effort to discourage the already over-congested big cities from developing into an unmanageable size. Further, the economic liberalization and the new industrial policy is another such effort to help in the decongestion of large urban centres. This warrants a shift in the single window 'Intensive urbanization' approach to 'Decentralized approach' in urban growth and development. The focus of such an approach is on the sustainable development of cities. One such effort is the recently proclaimed 73rd and 74th amendment of the Constitution which aims at implementation of town/metropolitan plans and for the integrated development of urban and rural areas.

Rapid urban growth and development had resulted in increase in the share of India's urban population from 159 million (23%) in 1981 to 217 million (26%) in 1991. This is expected to increase to 326 million (32%) by 2001. Correspondingly, the total number of urban settlements had increased from 4029 in 1981 to 4689 in 1991. Out of these, the 'million plus' cities increased from 12 in 1981 to 23 in 1991 (with 70.5 million population), which by the turn of the century will increase to 40 cities. While the all-India average growth rate during the decade 1981–91 has been 36.19%, the corresponding growth rate of the class-I towns (with more than 1 lakh population) has been 46.87%. For example, Hyderabad registered a decadal growth rate of 57.48% (ref. 1). Out of the 20 cities around the world with more than 10 million population (mega cities), New Delhi, Calcutta and Mumbai figure very prominently in the list. It is estimated that at least 5 cities out of 20 will contain over 16 million people each by 2001 and by 2015 over 70% of the population in Latin America, Africa and Asia will live in cities[2].

All this rapid and haphazard growth of urban sprawl and increasing population pressure is resulting in deterioration of infrastructure facilities, loss of productive agricultural lands and green open spaces, loss of surface water bodies and depletion of groundwater aquifers zones, besides causing air pollution, contamination of water, health hazards and micro-climatic changes. To address these issues effectively, it requires up-to-date and accurate data at regular intervals of time on the changing urban sprawl, urban land use, urban resources and urban environment. It is here that satellite remote sensing with its ability to provide reliable and accurate data offers excellent possibilities to map, monitor and measure the various facets of urban development. The information thus generated helps to formulate suitable plans and strategies for effective urban planning and development. Considering the high dwelling density and low floor space area (FSA) here due to compact parcel size and lack of physical spacing and homogeneity in the surface built-up features in Indian cities, remotely sensed data of high spatial resolution along with multispectral resolution data are required for detailed urban surveys. It is in this context that the availability of space-borne data from IRS-1C becomes more relevant and important for urban planning and development.

Satellite remote sensing data for urban planning and development

Satellite data complements and supplements data available from both aerial photographs and conventional ground sources for urban planning. Though data from large scale aerial photography are desirable for urban surveys, it is slow, becomes outdated fast, is costly and difficult to obtain at regular intervals of time. Although small format aerial photography (SFAP) provides details of urban areas and is 5 to 10 times cheaper than normal photography, it is precluded due to operational and other data limitations. The biggest strength of satellite-borne-sensor data is its periodicity, fastness and economic efficiency. Also, the data being available in analogue and digital form, it is amenable to both visual and digital analysis for extraction of information.

The current satellites allow data to be generated up to 1 : 50,000 scale using IRS (LISS-II) and up to 1 : 25,000 scale using SPOT data. Today, with the availability of IRS-1C data[3], it is not only possible to generate data on 1 : 50,000/1 : 25,000 scales using LISS-III, but it has been seen with the PAN data that it is possible to generate up to the desired scales of 1 : 20,000, 1 : 15,000 and 1 : 12,500, useful for urban planning. The various urban hierarchical and information levels and the desired mapping scales are given in Table 1.

Using satellite data, different urban features can be identified and mapped using a false colour composite (FCC) of three bands or single band data wherever applicable. Also, the digital data can be enhanced or merged with high resolution data for better feature identification and mapping. Earlier studies have proven the usefulness of visible and near infrared multispectral bands for urban feature identification and mapping[4–6]. Also, the use of thermal band data (10.4–12.5 μm) available from Landsat (TM) data has also been demonstrated in mapping 'urban heat islands'[7].

Major potential areas of urban applications using IRS-1C data

There are a variety of potential areas of urban applications

Table 1. Urban hierarchical and information levels and activities

Hierarchical order	Urban: Urban hierarchy of management levels	Mapping scale	Information level	Regional/administrative: Regional hierarchy	Regional/administrative: Administrative hierarchy	Activities/actions
1	National capital region/spatial priority urbanization regions (SPURS)*	1 million	I	Country	Nation	Broad land use/land cover for national and regional perspective policies
2	Metropolitan city region state capital region*	250,000/ 100,000	I and II	Macro-region/ sub-region (agro-climatic region)	Group of states	Spatial development strategies
3	Metropolitan/urban development area (UDA) or medium town$	50,000	II and III	Meso-region	State/group of districts	Spatial strategies and broad structure plans
4	Municipality/city-district or small town$	25,000/ 10,000	III	Micro-region	District	Land use plans/sectoral plans
5	New township/census ward†	8,000 4,000	IV and V	Tract	Taluk/group of villages	Detailed land use plans
6	Urban node/project site†	1,000	VI	Site	Village	Ground plans and urban design

*Strategic decision level; $Tactical decision level; †Technical decision level.

Table 2. Data base: IRS-1C sensor data and other map data

IRS-1C sensor	Path-row	Date of pass	Type of data	Map data	Study area
PAN	100-60	20.01.96	CCT	SOI guide map on 1 : 20,000 scale	Hyderabad
PAN	100-52	20.01.96	CCT	SOI guide map on 1 : 20,000 scale	Lucknow
PAN	93-56	10.01.96 and 02.02.96	CCT	Cadastral map of Jodhpur village panchayat	Ahmedabad
LISS-III	100-60	20.01.96	CCT	SOI toposheet on 1 : 50,000 scale	Hyderabad
LISS-III	93-56	10.01.96 and 02.02.96	CCT	SOI Toposheet on 1 : 50,000 scale	Ahmedabad

which can be possible using IRS-1C data. The few important such applications are urban housing, urban utilities/amenities and infrastructure, urban transportation and traffic planning, urban water supply and sanitation, urban cadastral and real estate, urban tourism and recreation, urban ecology and hazards, urban census, urban fringe area land use dynamics, urban landscape design, urban base map preparation and updation of city guide maps, urban encroachments of slums and urban land use zoning.

Examples of IRS-1C data utilization

Urban land use and infrastructure identification and delineation

Urban land use reflects the morphology, economic and socio-cultural framework of a city or a town. Here, IRS-1C LISS-III and PAN data (Table 2) have been digitally merged and the enhanced standard FCC was generated through Laplacian filtering technique and edge enhancement operations using the EASI-PACE image processing software available on IBM RS 6000 computer system (available at NRSA, Hyderabad and SAC, Ahmedabad). Further, the merged (LISS-III and PAN) data sets were generated by taking intensity from PAN data hue and saturation from LISS-III data, after converting blue, green and red channels of LISS-III into IHS channels. Subsequently, using these data sets various details of urban land use classes of level-III were identified (up to level-II details are possible using IRS-1A/1B LISS-II data on 36 m spatial resolution) such as low/medium and

Figure 1. IRS-1C (LISS-III and PAN) digitally merged and enhanced image of Hyderabad city.

high rise structures associated in the residential use, slum areas, industrial complexes, major and minor roads and bridges, education institutions, open spaces such as parks, garden, playground, stadia and race course, utilities such as sewage-treatment plant, agricultural research farm, bus .depot, vacant lands and newly developing layouts, etc. as seen in Hyderabad (Figure 1).

Further, plot-wise urban development was attempted by registering (using GCP from SOI map sheet) the cadastral parcel boundary map of Jodhpur gram panchayat (now a part of Ahmedabad city and located in the south western direction) onto the IRS-1C (PAN) data. It has been observed that both voids (filled with structures) and non-voids (vacant lands) can be delineated on a plot by plot basis (Figure 2).

Urban transport network identification and mapping

Transport network forms an important infrastructure element of the whole urban area. It allows connectivity and movement of people, traffic and goods from both intra (within) city and inter (outside) city hinterlands. Here, the IRS-1C (LISS-III and PAN) merged image data set was converted to TIFF and GRID format and made compatible to ARC-INFO GIS environment. This GRID has been geometrically corrected by selecting GCP on the image and SOI map sheets. The geometrically corrected grid data were imported in ARC/INFO GIS and on screen digitization was attempted for drawing the existing and newly identified major and minor roads and intersections, crossings and bridges and railway lines. An example of the transport network map plotted on 1 : 15,000 scale for a part of Ahmedabad city is shown in Figure 3.

Urban city guide map change detection and updation

SOI city guide maps form the largest land use and topographic maps available on 1 : 20,000 scales for a few selected cities in the country today. Although these

Figure 2. Field boundaries of urban area on IRS-1C merged data of Jodhpur village, Ahmedabad.

maps provide the detailed possible information on urban land use, majority of these maps are outdated (surveyed up to 1970s) and are restricted in areal coverage to a limited city area and often do not show the extended coverage and the recent developments within and near fringe areas of the cities.

As an example, here, part of the southeastern corridor of Hyderabad city guide map has been digitally merged with the IRS-1C (PAN) data, which clearly brings the different land use information such as roads, bridges, residential colonies, industries, institutions, new layouts, development onto the vacant lands/tanks and historical monument sites, etc. as surveyed in the city guide map of 1973–74 period and recent developments noticed in the IRS-1C (PAN) data of 1996, over a period of more than 20 years (Table 2 and Figure 4). A similar view of the PAN data over Lucknow city brings out the finer details of the newly developed land uses as seen in the different geographical setting and siting (Figure 5).

Discussions

IRS-1C (LISS-III and PAN) data have been found very useful and have provided an insight into the variety of some of the possible applications and also PAN data have been found useful to generate large scale photographic and maps outputs onto 1 : 20,000, 1 : 15,000 and 1 : 12,500 scales. The LISS-III visible and near-infrared bands are comparable with that of SPOT (MLA) data and also the spatial resolution of 23 m of IRS-1C (LISS-III) and that of SPOT of 20 m. It has been seen that the IRS-1C (PAN) data recorded in 0.50–0.75 μm of the EMS show different urban features, both in gray tonal variations and also their physical geometry, size, shape and pattern in true perspective. On being merged and enhanced with the multispectral LISS-III data, a greater contextual clarity, separation and discrimination between urban features have been noticed due to high spatial resolution of 5.8 m, which allowed to classify detailed urban land use classes up to level-III on a

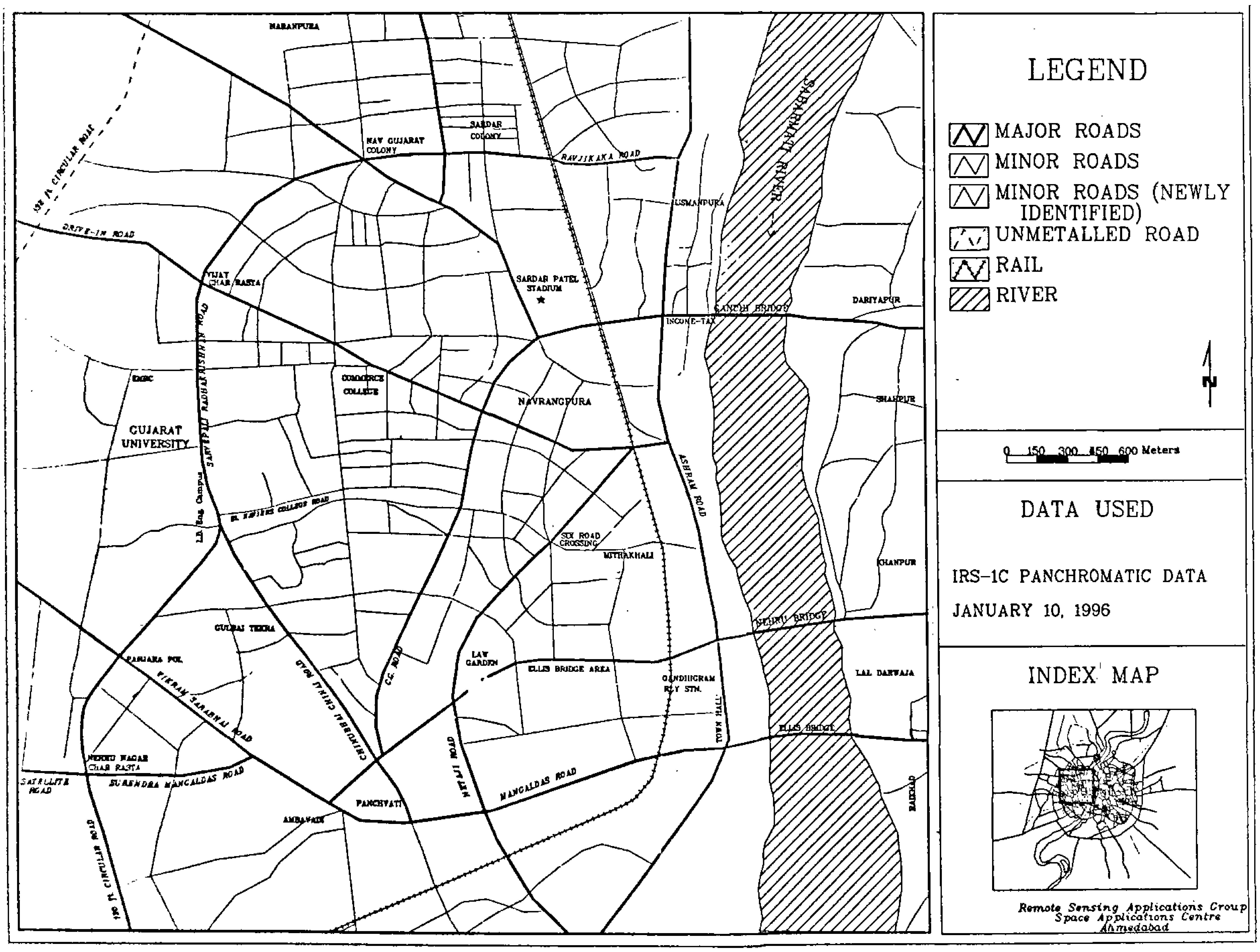

Figure 3. Transportation network map of a part of Ahmedabad city.

large scale up to 1 : 15,000 with a minimum mapping area (3 × 3 mm) of about 0.20 ha on the ground. On a scale of 1 : 12,500, the minimum mapping area reduces to 0.14 ha on the ground. This will facilitate urban planners to a greater extent in generating detailed land use information.

The PAN data alone have been geometrically accurate enough to register both the 1 : 20,000 topomap and the cadastral map with an RMS error of about 12 m in the case of latter[8]. The PAN data also allowed to identify new roads and bridges clearly and accurately. The merging of cadastral land parcel details onto the PAN data will help in monitoring the land use alternatives, deviations/encroachments from the original land use plan, besides the real estate progress of development.

Another area where the use of IRS-1C data is seen, is in undertaking the updation of city guide maps and preparation, wherever these maps are not available. Out of 4689 urban towns, only 55 towns have guide maps on 1 : 20,000 scale (census, 1991). Further, the PAN

Figure 4. IRS-1C (PAN) image digitally merged with guide map of Hyderabad city.

Figure 5. IRS-1C (PAN) digitally enhanced image of Lucknow city and its environs.

stereo data would help urban planners in deriving height/elevation information which is important in urban 'site suitability' and 'landscape designing' and 'environmental sensitivity analysis' using GIS computer techniques.

Conclusions

The emergence of IRS-1C data enhances the operational use of satellite data in the area of urban surveys and urban planning. It would now be possible to monitor the changing urban land use dynamics more frequently and at less cost. Finally, with the 73rd and 74th amendments of the Constitution and the thrust for mini master plans for implementing the 'Integrated development schemes for the urban and rural villages' in the country, IRS-1C class of satellites will immensely benefit urban planners and decision makers a long way in the years to follow.

1. Mapping and monitoring urban sprawl using remotely sensed satellite data, Hyderabad City Project Report (published), NRSA, 1994, pp. 1–84.
2. Kamlesh Lulla, *Space Shuttle Observations Database for Global Urban Applications. Cities of the World as seen from Space*, Geocarto Publications, Hongkong, 1993, pp. 15–20.
3. *IRS-1C Data Users Handbook*, NRSA publication, 1995, pp 1–169.
4. Raghavswamy, V. *et al.*, *Curr. Sci.*, 1991, **61**, 243–247.
5. Raghavswamy, V., *Remote Sensing for Urban Planning and Management, Book on Space Technology and Geography*, NRSA publication, 1994, pp. 295–323.
6. Subudhi, A. P. and Debajit Mishra, *Photonirvachak*, 1989, **3**, 17.
7. *A TDP report on Urban Ecological Studies*, NRSA publication, 1995.
8. Pathan, S. K. and Bhanderi, R. J., Usefulness of IRS-1C data for Urban Land Use Planning and Development, RSAG, SAC, 1996, pp. 1–7.

ACKNOWLEDGEMENTS. We thank Mr K. Balaji and Mr S. C. Jayanthi and A. V. Balasubramanian, Scientists, NRSA for their help in the preparation of this paper.