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Remote Sensing Applications
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Chapter #	Title/Authors	Page No.
1	Agriculture *Sesha Sai MVR, Ramana KV & Hebbar R*	1
2	Land use and Land cover Analysis *Sudhakar S & Kameshwara Rao SVC*	21
3	Forest and Vegetation *Murthy MSR & Jha CS*	49
4	Soils and Land Degradation *Ravishankar T & Sreenivas K*	81
5	Urban and Regional Planning *Venugopala Rao K, Ramesh B, Bhavani SVL & Kamini J*	109
6	Water Resources Management *Rao VV & Raju PV*	133
7	Geosciences *Vinod Kumar K & Arindam Guha*	165
8	Groundwater *Subramanian SK & Seshadri K*	203
9	Oceans *Ali MM, Rao KH , Rao MV & Sridhar PN*	217
10	Atmosphere *Badrinath KVS*	251
11	Cyclones *Ali MM*	273
12	Flood Disaster Management *Bhanumurthy V , Manjusree P & Srinivasa Rao G*	283
13	Agricultural Drought Monitoring and Assessment *Murthy CS & Sesha Sai MVR*	303
14	Landslides *Vinod Kumar K & Tapas RM*	331
15	Earthquake and Active Faults *Vinod Kumar K*	339
16	Forest Fire Monitoring *Biswadip Gharai, Badrinath KVS & Murthy MSR*	351

Urban and Regional Planning

5.1. Introduction

Expansion of urban area due to increase in population and migration from rural areas and the impact is bound to have on Urban areas in terms of infrastructure, environment, water supply and other vital resources. For organized way of planning and monitoring the implementation of physical urban and regional plans high-resolution satellite imagery is the potential solution. Remote Sensing data is being widely used for urban and regional planning, infrastructure planning mainly telecommunication and transport network planning, highway development, accessibility to market area development in terms of catchment and population built-up area density, etc. With remote sensing it is possible to identify urban growth, which falls out side the formal planning control and remedial measures can be taken timely to provide necessary basic infrastructure to improve health and hygiene.

Remote Sensing and GIS technique combined together facilitate the planners, in making decisions, for general public and investors to have relevant data for their use in minimum time. The advantages and utilities of both the techniques are given below. Even though the initial investment is slightly higher to organize digital data base for using GIS, its utility is immense in coming years. The data can be updated at regular intervals and the data will be transparent and it will be useful for public participation in planning process. However, remote sensing data, limited use was made for resource inventory with course resolution data. Slowly with Thematic Mapper (TM) the resolution was increased to 30 mts and more details were seen on the image. This data was also used in urban and regional planning in limited way like urban sprawl mapping and land use inventory etc. IRS 1A/1B which is near equivalent to TM data was widely used in our country for resource mapping and land use mapping and same data was used in preparation of Regional plans of BMRDA and as well mapping of land use of National Capital Territory (NCT), Delhi for 1993. With SPOT satellite the resolution further improved to 10 mts and this data was used in urban planning as well in regional planning to update the land use and base details. IRS-1C/1D satellite provided 5.8 m high-resolution data, which was used in preparation/revision of development plan. This data was used in revision of development plans of Hyderabad Urban Development Authority (HUDA) planning area, for Ahmedabad Urban Development Authority (AUDA) planning area, Jammu Urban Development Authority (JUDA), Pimpri Cinchwad Municipal Corporation and other towns. Now Cartosat-1 of 2.5 meter resolution, Cartosat-2 of 1 meter resolution and Resourcesat LISS-IV of 5.8 meter resolution data being used for base & land use thematic mapping of Hyderabad Metropolitan Area and Dadra Nagar Haveli (UT) on 1:10000 and 1:5000 scales. The IRS high resolution Cartosat-1 Satellite data is being used up to class-1 towns for generating thematic information under National Urban Information System (NUIS) approved by the Ministry of Urban Development (MoUD).

5.2. Urbanization Scenario and Issues: Global and National

The world's population is quickly becoming urbanized as people migrate to the cities. Figure 5.1 shows the urban population growth between 1950 and the year 2000. In 1950, less than 30% of the world's population lived in cities which grew to 47% in the year 2000 (2.8 billion people).

According to UN reports, half of the world's 6.7 billion people are expected to live in urban areas by the end of 2008. The world population is expected to increase to 9.2 billion, by 2050. By that time, urban population is expected to rise from nearly 3.4 billion in 2008 to 6.4 billion in 2050. Also, these are global figures. When the data are disaggregated by world region, they show marked differences in the level and pace of urbanization. In the Americas, Europe, and Oceania, the proportion of people living in urban areas is already over 70%. Although the figures for Africa and Asia are currently much lower, 39% and 37%, respectively, many cities in those regions will double their populations in the next fifteen years (UN 2006).

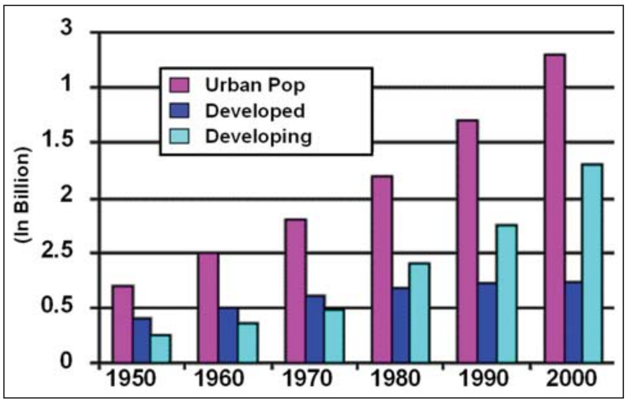

Figure 5. 1: World Urban Population Growth in Past 5 decades (Source: www.earthtrends.wri.org)

Developed nations have a higher percentage of urban residents than less developed countries. However, urbanization is occurring rapidly in many less developed countries, and it is expected that most urban growth will occur in less developed countries during the next decades.

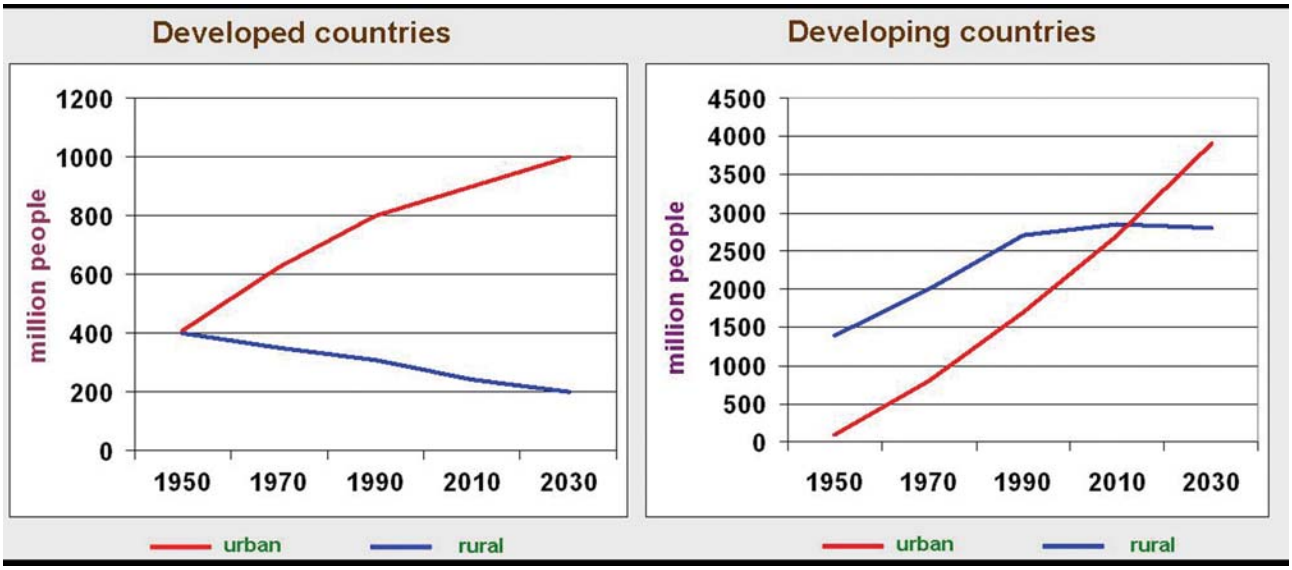

Figure 5.2: Projected Urban Rural Population in Developed and Developing Countries (Source: www.globalchange.umich.edu)

Figure 5.2 shows the projected growth of the urban and rural populations in developed and less developed countries. The urban population of India according to the population census 2001 was 285 million spread over 5161 urban agglomerations/towns. The urban population has been growing at a much higher rate than the total and the rural population as a result; its proportion in the total population has increased from around 11 % in 1901 to about 28 % in 2001. Cities with over 5 million inhabitants are known as megacities. There were 41 in the year 2000. This number is expected to grow as the population increases in the next few decades. It is predicted that by the year 2015, 50 megacities will exist, and 23 of these are expected to have over 10 million people.

In India, the Class I urban agglomerations/cities accounted for 62 percent of the urban population of the country in 2001. A further breakup of the population of cities indicates that the majority (42%) of the population of Class 1 urban agglomerations/ cities lives in 27 metropolitan urban agglomerations/cities with a population of more than a million each. Class I cities account for roughly 61% of country's urban population. Almost one-fourth of the total urban population is living in more then one million population cities (Table-5.1).

Table 5.1: Population in each size Class during 1991-2001 – INDIA

Size	Class	No of UA/Towns	Population distribution %	
	1991	2001	1991	2001
All Classes	4689	5161	100	100
I (> 1,00,000)	300	423	64.91	61.48
II (50,000-1,00,000)	345	498	10.95	12.30
III (20,000- 50,000)	944	1386	13.30	15.00
IV (10,000-20,000)	1170	1560	7.91	8.08
V (5000-10,000)	740	1057	2.62	2.85
VI (<5000)	198	227	0.31	0.29
Others	992*	10#	-	-
Total Urban Population	217,551,812	285,345,954	26	28

* Statutory towns and Census towns population breakup data is not available.

Gujarat towns (Anjar, Bhachu, Bhuj, Gandhidham, Kandla, Morvi, Mundra, Rapar, Wananer) population data is not available.

Source: Census of India (1991 & 2001)

The rapid growth of urban areas is the result of two factors: natural increase in population (excess of births over deaths), and migration to urban areas. Migration is defined as the long-term relocation of an individual, household or group to a new location outside the community of origin. Today, the movement of people from rural to urban areas (internal migration) is most significant. Although smaller than the movement of people within borders, international migration is also increasing. Both internal and international migration contribute to urbanization.

Urbanization refers to the process by which rural areas take on urban characteristics. It also refers to more concentration of people in human settlements. The urbanization process is much more than simple population growth; it involves changes in the economic, social and political structures of a region. While the current pace of urbanization is not unique in human history, the sheer magnitude is unprecedented, with vast implications for human well-being and the environment. Rapid urban growth is responsible for many environmental and social changes in the urban environment and its effects are strongly related to global change issues. The rapid growth of cities strains their capacity to provide services such as energy, education, health care, transportation, sanitation and physical security. Cities have become areas of massive sprawl, serious environmental problems, and widespread poverty. The intense concentration of population, industry and energy use has lead to severe local pollution and environmental degradation. Furthermore, a city's ecological footprint extends far beyond its urban boundaries to the forests, croplands, coal mines and watersheds that sustain its inhabitants.

City dwellers in developed countries, characterized by some of the highest per capita levels of consumption in the world, are largely responsible for these trends. While an American city with a population of 650,000 requires approximately 30,000 square kilometers of land to service its needs, a similar sized but less affluent city in India requires only 2,800 square kilometers (UNEP, 2005). Similarly, urban residents in the developed world generate up to six times more waste than those in developing countries.

However, developing countries are becoming wealthier and more urban, bringing their consumption levels closer to those of the developed world. As a result, they are fast becoming significant contributors to the global problems of resource depletion and climate change. In the cities of the developing world, where population growth has outpaced the ability to provide vital infrastructure and services, the worst environmental problems are experienced with severe economic and social impacts for urban residents like inadequate household water supplies, waste accumulation, unsanitary conditions etc. Developing country cities also experiencing the worst urban air pollution as a result of rapid industrialization and increased motorized transport.

Nevertheless, cities possess unparalleled potential to increase the energy efficiency and sustainability of society as a whole. They have an unrivaled capacity to absorb large population sustainably and efficiently. With proper planning and long-term vision, dense settlement patterns offer economies of scale that can actually reduce pressures on natural resources from population growth and increase energy efficiency. Because people live close together and need less space in cities, each person requires less critical infrastructure like sewers, electricity, and roads than in suburbs or other decentralized human settlements. Innovations in building construction, energy efficiency, waste management, and transportation are just a few of the ways that we can make cities mores sustainable.

Given increasing responsibilities and limited funds, city governments must make strategic choices about which environmental and social problems to tackle first. This will require balancing immediately pressing environmental problems such as water and sanitation with long-term concerns such as energy use and climate change, while also reconciling the often competing demands of economic growth and environmental protection. The choices made in cities today will help determine the extent to which urbanization will be a positive force for human development and the future of the global environment.

So, as we understand, although one of the key geographical developments over the last two centuries has been that of urbanization, it has also raised various issues and problems. It is essential for governments, planners and researchers to understand and study the urbanization process and its associated problems. Latest technologies like Remote Sensing and Geographical Information Systems (GIS) can help resolve some of the urban issues and also acquire best approaches for urban planning, governance and management.

5.3. Planning Approach

Planning is continuous process and for the planning condition of the land on which the settlement is built, its effects on the surrounding lands and the change occurred in land use determines the importance of land resource and its use by mankind. Thus, a sustainable habitat planning demands a comprehensive understanding of the different uses of land. In order to prepare urban development plan, the planners need detailed information on the distribution of land and its use in city and its surroundings. For example, the city planners and engineers are required to plan optimum routes for transportation, construction of better utilities, pipe lines for water, gas sewerage with minimum construction cost as per different terrains. For planning these utilities in better way the availability of total information in a spatial and tabular form assumes importance. It also becomes essential to integrate both spatial and non-spatial information for perspective planning and management. With the advent of remote sensing and GIS, the city planners have begun to evaluate the resources though a multi disciplinary approach for timely results and with less preparation cost and man power support. The process of planning is political in nature in the sense that it must deal with the value of many groups of people within the area where planning is conducted. Planning is also predictive in the sense that it must identify alternative future and evaluate these in terms of goals which are based on values. The general concerns of planning are physical, man made or built environment and natural environment, economic, political, social and fiscal. Out of the stated planning activities, remote sensing is most useful for depicting information on physical component, especially the natural component of the physical environment. Under Jawaharlal Nehru National Urban Renewal Mission (JNNURM) it is mandatory to reform urban local bodies wherein one of application is e-governance using IT applications, such as GIS and MIS for various services. To carry out such application one of basic requirement is satellite/aerial data. The urban and regional development plans are of four types based on the requirement of plan implementation (Table 5.2).

Table 5.2: Mapping Scales for Various Plans

S.No.	Type of Map / Planning Exercise	Size of Planning Area		Data source
		Metropolitan Level	Small and Medium	Satellite Data
01.	Map of Regional Setting	1:250,000 1:1,000,000	1:100,000 – 1:250,000	
02.	Perspective Plan	1:100,000 1:250,000	1: 50,000 1: 100,000	Satellite Data, Census Data & Collateral Maps
03.	Development Plan	1: 25,000 1: 50,000	1: 10,000 1: 25,000	Satellite Data, Census Data, Collateral Maps & Ground truth
04.	Plan of Project / Scheme	1: 1,000 1: 5,000	1: 500 1: 2,500	Satellite Data, Aerial Data, Census Data, Collateral Maps, Ground truth & GPD Data

Source: Urban Development Plans Formulation & Implementation (UDPFI) Guide lines prepared MUD, GOI 1996.

The Perspective Plan is a long term (20-25 years) written document supported by necessary maps and diagrams providing the state government with the goals, policies, strategies and general programmes of the urban local authority regarding spatio-economic development of the settlement under its governance.

The Development Plan conceived within the framework of the approved perspective plan, is a medium term (generally five years) plan providing the people comprehensive proposals for socio-economic and spatial development of the urban centre indicating the manner in which the use of land and development therein shall be carried out by the local authority and other agencies.

Annual Plan, conceived within the framework of a development plan, is a plan containing the details of new and ongoing projects that the local authority intends to implement during the respective financial year and for which necessary fiscal resources shall be mobilized through plan funds and other sources.

Projects/schemes Conceived within the frame work of approved development plan, projects/schemes are detailed working layouts with all supporting infrastructure, and documents including cost of development, source of finance and recovery instruments for their execution by a public or private agency.

5.4. Remote Sensing & GIS Technology use in Urban and Regional Planning Information

Remote sensors may be categorized as passive sensors – which observe reflected solar radiation – or active sensors – which provide their own illumination of the sensed object. Both types of sensors may provide images or simply collect the total amount of energy in the field of view. Sensors can be located on satellites, piloted aircraft, unpiloted aerospace vehicles or in ground stations; thus, the data acquired by space-based remote sensing instruments feed into a wide array of mapping and other application services.

Remote sensing instruments provide unique views of Earth and its processes. Space – based sensors gather data from Earth's atmosphere, land and oceans that can be applied to a wide variety of resource management tasks. One of the best known of these applications is the collection of satellite images (NOAA, visible and near-infrared radiometers, for example) of the weather and storms that appear on the television and newspapers. Such images, along with sounding and other data, allow forecasters both to predict the paths of severe storms as they develop and to predict weather in advance. Government agencies with the responsibility of managing large tracts of land, or of providing information regarding land conditions, make use of data from the land remote sensing satellites. Commercial data users with interests in agriculture and forestry, land use and land cover, geological information, and mineral exploration, and many other industrial sectors also use data acquired from the land remote sensing satellite systems. In Urban and Regional planning field, IRS products are widely used for urban sprawl and land use/land cover mapping, Utility planning and management, Infrastructure planning and location of major industrial, recreational, institutional facility in context to the Region.

While most local environmental surveys still depend on manual interpretation of aerial photography, the use of digital imagery for regional and urban analysis is now commonplace and will undoubtedly increase in the future. As a source of geographical information, digital remote sensing represents more than a simple extension of conventional aerial photography, requiring fundamentally different approaches to the analysis of Earth surfaces. In GIS context, especially the important features of remotely sensed data are their sampling characteristics in the space and time domains.

Maps for centuries have been an important means for storing, analyzing and communicating information about geographic phenomena. The GIS is systematic procedures for automatically doing what maps have been doing for centuries. However, the base of the GIS is a data file from which maps can be made, whereas the map file itself is the traditional database. The data base manipulation techniques, which include various analytical functions and data processing function, which can be performed on spatial, automated data. Since Remote Sensing Satellites provides continuous images once the database is created in GIS environment, which allows updating and results can be obtained in less time and used for decision making.

The advantage of Remote Sensing data:

- It provides reliable data at regular intervals
- It provides base data that is built-up area information and location
- It provides land use land cover information
- It provides base for plan monitoring and implementation

The advantages of GIS:

The GIS is widely used in Urban/Regional Planning is wide because of following advantages over traditional system of keeping maps.

- Data is maintained in a physical compact data files
- Large amount of data can be maintained and extracted at will with great speed
- Various computerized software modules/tools allow for variety/type of manipulation, including map measurement, map overlay, transformation and geographic design and data manipulation
- Graphic and non-graphic information can be merged and manipulated simultaneously in a related manner

The limitations

- Both the techniques required trained manpower
- Investment in Hardware and Software
- Time consuming and problems in initial stages of GIS data base design and creation

- Changing data formats and software, which will create problem in merging old data with new data
- Storage environment

5.5. Retrospective

Before making any development exercise the first task, both from planning point of view and statutory requirement, is to prepare or obtain a reliable accurate and upto-date base map of respective city and its region for which plan is being prepared. Data is collected from conventional source and data was analyzed in conventional forms for preparation of Development Plan/ Regional Plan. Area estimation was done through planimeter and grid method. The conventional secondary data sources are mentioned below.

- Census of India Publications
- Tabular data from various planning agencies
- Old Municipal property maps
- Land use details from land revenue records
- Municipality/village parcel maps from Land Records office
- Old published Gazettes and other publications
- Maps prepared from other planning agencies like Public Works Department , Public health, power, etc.
- National Atlas and Thematic Mapping Organisation Maps
- City guide and tourist maps
- Specified field survey
- Topographical maps of Survey of India

The shortcoming of above data source is not upto date and survey year is different for each data source which creates complication in data compilation. Data inaccuracy is incorporated due to mechanical mode of adjustments of maps. In absence of latest survey sheets, employing the field survey to record land use or any other details for planning purpose is difficult. Thus, the task of plan preparation takes longer time. By the time plan is approved lot of development takes place, which creates problem in implementation. To speed up the process of data collection, satellite images were used from 1972. In early days the resolution was coarse and thematic details were not up to the level of users in urban planning.

The base map was prepared from available map source and land use inventory was carried by field survey method or from revenue records. The colour maps and single column area table were made for analysis. Plan document contained more of tables and less of spatial details.

For few cities one time digital data was prepared and used for preparation of Regional / Development Plan. The analysis was limited to generation of area estimates and preparation of thematic map plots.

5.5.1. Prospective

So far conventional source data have been the major input for generation of base maps for preparation of development plans. Of late the emerging techniques of aerial photography and remote sensing are being used increasingly for generation of base maps and updating of existing base maps in conjunction with conventional collateral data and limited field survey. The innovative techniques of survey are

- Conventional aerial photography and Photogrammetry
- Digital Photogrammetry
- High-resolution satellite image survey
- Use of Global Positioning Systems and Geographic Information Systems (GIS)

Now, IRS Cartosat-2 satellite provides 1-meter resolution of the panchromatic data enables planners to distinguish ground features as small as 1-meter. The accuracy and interoperability of the imagery makes ideal for mapping analysis.

With increase in spatial resolution, GIS database expected to increase many folds due to amount of information available in the image. Each Urban Development Authority/Town and Country Planning Organisation (TCPO) or Regional Planning Board expected to have advanced data processing systems. The information pertaining to development plan (DP) is expected to be on web site where citizen can interact with Development Authority for their need. This will increase citizen's participation. As per the 74th amendment, each Panchayat /Municipality will have power for preparation of Development Plan and execution. Since the town areas are small, with high-resolution data land use variation can be mapped, GIS will help in updating information and data retrieval for citizens.

To increase the public participation web based packages are expected. The web is best available mechanism for providing the general public with route for direct involvement in the planning process and access to relevant data including,

- Access to relevant spatial and non-spatial information in a multi-media format (text, graphics, maps, photographs, video, animation and sound);
- Access to relevant planning tools (including GIS) via intuitive and user-friendly interfaces such that little or no prior training is required;
- Access to problem-specific data for use with the above; and
- Formal and informal mechanisms for communication with other users for the exchange of ideas, feedback and comparison of decisions made without the social and psychological barriers normally associated with more formal channels such as open planning meetings and written/telephone correspondence

The other area will be Multimedia planning Technologies in Planning where it is possible to manipulate and display the following types of data:

- Text of infinitely variable size and structure;
- Still images, like bitmaps and raster, either generated or captured and digitized;
- Still and animated computer-generated graphics;
- Audio, whether synthesized or captured and replayed sound; and
- Video or moving frames

Multimedia software applications are computer tools based on the simultaneous display and processing of several types of multimedia data. These tools allow for interactive exploration of the data. Base information and Plan details should be translated to soft copy form. The working procedures are to be developed to adopt the new approach in planning. Although automated GIS are just beginning to have practical benefits, they have been adapted to many application areas.

5.5.2. Role of Remote Sensing

Remote sensing (RS) data depicts spatial location of various activities and analyzing the linkages between activates, regional plan, development plan and environmental plans are prepared. RS data is immensely used in creating database on following aspects and with GIS data analysis tools, information can be processed as per the planning requirements.

Perspectives Plan/ Development Plan preparation

- Present land use (statutory requirement)
- Infrastructure network (Roads, Railways, and Settlements)
- Hydrological features (River/Stream, lakes)
- Regional level landscape
- Updation of base maps
- Urban sprawl, land use change and population growth, and
- Master plan/ Regional plan proposals

Infrastructure Planning

- Road alignment
- Utility planning (Sewage treatment plant , garbage dump site selection, water works)
- Road network and connectivity planning
- Growth centre locations

Environmental Planning

Remote sensing data enables mapping of environmental parameters like green cover, surface water bodies and drainage network with other collateral data following are possible to study and to analyse the urban environment.

- Urban land use indicators and Impact assessment
- Development of Urban Information System (UIS)
- Decision Support System (DSS)
- Development of Urban Indicator Observatory (UIO)
- Municipal Information System (MIS)

5.6. Review of literature

Urbanization is an index of transformation from traditional rural economy to modern industrial one. It is progressive concentration (Daveis, 1967) of population in urban unit. In the 21st century the majority of the world's population are living in urban areas for the first time in the history (Miller, 2003). In 1892, the famous city planner Patrick Geddes had leased an observatory in Edinburgh to set up the "Civic Observatory and Laboratory" with a goal "Outlook Tower" as it came to be known – to give visitors insight into the plan, function and inner working of the city Edinburgh (Geddes, 1915). More than a century later urban historians can still learn from Geddes' idea of taking a view from above city/town for effective Urban planning (Jensen and Keys, 2003).

There has been a strong interest in using earth observation data in urban areas for several decades (Tuyahov *et al.*, 1973; Jensen, 1983; Haack *et al.*, 1997). In an early attempt to relate remotely sensed reflectance to socio-economic parameters, Forster (1983) devised a classification scheme for Landsat imagery that could be applied to urban areas to produce a residential quality index. Remote sensing data have also been used in attempts to estimate population (Lo, 1986 and 2001) and quantify urban growth and land use (Mesev *et al.*, 1995; Stehanov *et al.*, 2001). Welch (1982) conducted a resolution analysis of satellite sensors and demonstrated that 0.5 to 10 m spatial resolution is necessary to adequately characterize urban infrastructure in most of the cities/towns. Jensen and Cowen (1999) have identified a hierarchy of urban/suburban attributes that can be measured using remote sensing data. The current/near future high resolution satellite data from Cartosat-1/2, Cartosat-3, RISAT, ASTER, LANDSAT ETM in optical, microwave, infrared, thermal will begin to meet urban needs.

Remote sensing data provides reliable information on urban growth and current land use changes. Aerial photos, IKONOS and QuickBird images over a decade were used to monitor and analyze urban growth in Al-Seeb Wilayat, Oman by Al-Awadhi and Azaz (2004). For urban development in metropolitan area of Athens, multi-spectral satellites images were used to locate and identify the irregular settlements zones (Weber *et al.*, 2005) wherein indicators such as indices, Brightness Index and Normalized Difference Vegetation Index; and supervised classification methods were applied to the images. In order to locate and identify these regions, common biophysical characteristics related to the urban and sub-urban landscape structures were identified. Results were integrated within a Geographical Information System (GIS), allowing the user to check the legal situation of the classified areas. Such techniques are very fruitful to identify specific irregular settlements in organic growth. A study on urban growth in Istanbul has also been done using Landsat 5 TM and Landsat-7 ETM+ satellite data (Kaya, 2007). After the classification of the images separately, eight main land use/cover classes were obtained and the classified outputs were compared to get the extent of urban growth and land use change. In another study carried out for Shiraz city in Iran, different satellite images since 1976 to 2005, and population census of Shiraz city in this time period were used wherein the land use coverage for different dates were classified and measured (Ibrahim and Sarvestani, 2009).This was further used to calculate the built-up and vegetation per capita with respect to population which helped in estimating the reduction in natural resources due to urbanization and population increase.

Urban planners also require information related to the rate of growth, pattern and extent of sprawl to provide basic amenities such as water, sanitation, electricity, etc. In the absence of such information, most of the sprawl areas lack basic infrastructure facilities. GIS and remote sensing data along with collateral data helps in analysing the growth, pattern and extent of urban sprawl. A study on measuring urban sprawl through 'Entropy Approach' for patterns of urban growth over different time scales done by Lata *et al.,* (2000), has discussed the use of remote sensing data and GIS for quantifying the urban sprawl trends at various land use sites, viz., commercial, industrial, residential sensitive and mixed zones. IRS-1C Pan sharpened merged data was used and entropy was used to indicate the degree of urban sprawl by examining whether land development in a city is dispersed or compact. A larger value indicated occurrence of urban sprawl. With the spatial and temporal analyses along with modeling it has been possible to identify the pattern of sprawl and subsequently predict the nature of future sprawl. The work done by Sudhira *et al.*, (2004) has brought out the extent of sprawl taking place over a period of nearly three decades in Mangalore city, India, using LISS-III satellite data and GIS techniques. The study has also attempted to describe some of the landscape metrics required for quantifying sprawl. Remote sensing and GIS provides vital tools which can be applied in the analysis of land use / land cover and change in rural fringe as well at city level. The study done by Nigam (2000) evaluated the effectiveness of High-Resolution satellite data and computer aided GIS techniques in assessing the land use change dynamics within the city as well in fringe. The methodology adopted involved the visual interpretation of land use on accurate overlays with the land use classification. The land use maps were crossed with each other to identify and quantify the land use changes types. Finally, hot links and user interface were developed so that the information could be provided to the user.

Satellite data in association with GIS provides cost effective methods for infrastructure planning and urban environment assessment studies. Landsat satellite data have been used to provide information for integrated land resources, agriculture and rural access road planning in Atacora Province, Benin (Beaumont,1992). Sriram *et al.,* (2001) in their study have used IRS LISS II data to determine the least cost alignment of highway in Panchmahal and Dahod districts, Gujarat,India. Site selection for waste disposal has been identified using IRS-1C-PAN (5.8m spatial resolution) and LISS-III (23.5m spatial resolution) satellite data for Ranchi Municipal area (Upasana and Nathawat, 2001). Rajaram *et al.*, (2001) have used Indian Remote Sensing data along with ground information on water and air quality to carry out Environmental Impact Assessment study for Konkan railway alignment in India. In another study done by Cristina *et al.,* (2003) human settlements and photosynthetic activity derived from satellite data have been used to monitor the impact of human activity on the environment in Mediterranean basin.

Quantification of green space patterns is a pre requisite to understand green space changes in urban areas and is essential for monitoring and assessing green space functions. This study (Kong *et al.*, 2005) presented a new method for quantifying and capturing changes in green space patterns supported by GIS and remote sensing, the method comprised of quantification of local area green spaces by the “moving window” technique (using FRAGSTATS), and a gradient analysis involving sampling from the urban center to the fringe. In another study by Faryadi and Taheri (2008), the direct effects of urban green space dispersal and density on quality of the environment of the regions of Tehran city have been investigated and evaluated. The measurements have been done by means of land use layers in GIS, satellite images of vegetation cover dispersal and density and calculating the normalized difference vegetation index (NDVI). Comparison of these indices, and analysis of the correlation level between them helped in identifying the regions which have the least green space area per capita. Reza *et al.*, (2009) have carried out a study for Mashad city, Iran to detect changes in extent and pattern of green areas and to analyze the results in terms of landscape ecology principles and functioning of the green spaces. Landsat TM and IRS LISS-III image were used and a post-classification comparison done to determine the changes in green space areas. Then, landscape ecology calculations were done to derive metrics that quantified pattern of the changes in the green areas.

Satellite data has lot of applications in the field of landscape archaeology also. The utility of satellite remote sensing techniques towards locating and identifying ancient ports of Gujarat in India were studied in detail by Thakker (NNRMS, 2000). High resolution satellite data has also been used to study the ruins of Hampi, Karnataka, India by UdayRaj *et al.*, (NNRMS, 2000).Interrelationship between palaeo drainage courses and sites in Saraswati Basin, India have been studied using remote sensing data by Gupta *et al.,* (NNRMS, 2000). Nalanda and other archaeological sites like Kausambi, Ahichhatra, Lumbini, Sravasti were surveyed for their ruins using satellite remote sensing techniques by Thakker (2001). A long term archaeological research project using remote sensing data has been done in Burgandy region, France wherein a 2000 year period has been analyzed to find Celtic and Roman sites (Manual of Remote Sensing, 2006). Radar data has also been used to penetrate sand in Sudanese desert and reveal watercourses. Landsat-5 TM image as well as JERS-1 SAR image has been used to determine the distribution and position of the ruins of Khmer Civilization in Cambodia, Northern Thailand (Manual of Remote Sensing, 2006). Thus Remote Sensing data has provided not only a synoptic view of the sites but also helped in identifying existing sites and also potential sites. Airborne and satellite imagery has been used to investigate ancient Maya settlement, subsistence and landscape modification in the dense forest region of Guatemala (Manual of Remote Sensing, 2006). The remote-sensing technology has been used to investigate large seasonal swamps (*bajos*) that make up 40% of the landscape. Through the use of remote sensing, ancient Maya features such as sites, roadways, canals, and water reservoirs have been detected and verified through ground reconnaissance. Micro environmental variation within the wetlands was elucidated and the different vegetation associations were identified in the satellite imagery. More than 70 new archaeological sites within and at the edges of the *bajo* were mapped and tested. The use of Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM), 1-m IKONOS satellite imagery, as well as high-resolution airborne STAR-3*i* radar imagery at 2.5 m backscatter/10 m Digital Elevation Model (DEM)—have opened new possibilities for understanding how a civilization was able to survive for centuries on a karst topographic landscape.

A lot of semi-automated and automated methods for classification and information extraction from satellite imagery in urban areas have been developed the world over. Morphological and Neural approaches have been investigated for feature extraction from high resolution satellite data (Pesaresi and Benediktson, 2000). These attempts were made on high resolution Indian Remote Sensing (IRS 1C) and IKONOS remote sensing data. A fuzzy classification approach for high-resolution multispectral data over urban areas have been investigated in detail using IKONOS Panchromatic and multispectral imagery by Shackelford and Davis (2002). Gamba and Houshmand (2001) had carried out a research work on C-band total power AIRSAR data and optical images of Santa Monica, Los Angeles, wherein a suitable neural classification algorithm, based on the use of Adaptive Resonance Theory (ART) networks has been applied to the fusion and classification of optical and SAR urban images. The interaction between the two methods lead to encouraging results in less CPU time than classification with fuzzy clustering alone or other classical approaches (ISODATA). In another research attempt done by Mena and Malpica (2004) a new technique, named Texture Progressive Analysis (TPA) has been used in order to obtain the segmented binary image from high resolution satellite image which has been further vectorised using morphological methods to derive the road network. Mayunga *et al.,* (2005) have developed a semi-automatic method to extract buildings in structured and unstructured urban settlements areas from high-spatial resolution panchromatic imagery using radial casting algorithm to initialize snakes contours and the fine measurements of building outlines were carried out using snakes model. The advent of Light Detection and Ranging (LiDAR) technique has provided a promising resource for three-dimensional building detection. A study by Meng *et al.,* (2009) presented a morphological building detecting method to identify buildings by gradually removing non-building pixels.

The government of India has taken an important initiative to strengthen municipal governance, like enactment of the 74th Constitution Amendment Act (CAA), 1992. Through this initiative, Ministry of Urban Development, Govt. of India launched a National Urban Information System (NUIS) with an objective generation of multi scale (10 K, 2 K & 1 K) hierarchical Urban Geospatial database including thematic data for various levels of Urban Planning, Infrastructure development and e-governance using satellite, Aerial and Ground Penetrating Radar (GPR) techniques for all the 5621 Urban Local Bodies (ULB's). In NUIS phase-I, 152 towns covering at least 3 to 4 cities/ towns in all states have been taken up and will be completed by July 2010 (NUIS, 2006). Because many ULBs in India or other part of world were now using IT as an administrative tool, the capacity for integrating remote sensing images and other GIS data for day-today urban e-governance applications were relatively wide spread and is beginning to be the focus of research.

5.7. Major Application Projects

5.7.1. Regional Planning

Regional plans are prepared for metro regions, city/town conurbation and special economic zones. The main objective of the plan is to provide guideline for development direction, polices of land use regulation, and land use zoning for future development considering the national / local polices. One of the vital input towards preparation of these plans is existing land use / land cover spatial information.

Regional Plan 2021 of National Capital Region (National Capital Region Planning Board (NCR-PB))

The project aim was to generate inputs on urban sprawl, existing land use, and image atlas using high resolution data. The National Capital Region (NCR) covers an area of 33578 sq km consists of National Capital Territory (NCT) of Delhi (1,483 sq km), sub-region, Haryana (13,413 sq km), sub-region, UP (10,853 sq km) and Rajasthan (7629 sq km) surrounding Delhi. Its population is expected to increase from 370 lakhs (2001) to 641 lakhs by 2021 including 138 lakhs (2001) to 235 lakhs for NCT Delhi during the same period. The project was taken up with following objectives:

- To map Urban sprawl and land use/land cover of 1999 using IRS-1C (LISS III + PAN) data on 1:50,000 scale, to create GIS layers and preparation of NCR land use mosaic
- To study land use changes between 1993 and 1999 for monitoring the urban growth and land use patterns
- To generate Image Atlas for regional and towns planning
- Creation GIS database for Regional Plan Proposals

IRS 1C (PAN & LISS-III) merged data of March/April, 1999 and land use data of 1993 & 2004 comprised the database. Based on the visual interpretation techniques feature identification, land use classification was designed and 67 sheet-wise land use/land cover maps were prepared, supported by limited ground verification. The GIS database comprises of layers of

- Administrative boundaries (State, District, Taluk & Forest)
- Land use of 1993
- Land use of 1999
- Road
- Rail
- Canal
- Drainage
- Watershed
- Ground water prospects
- Derived map of conservation areas (ground water rechargeable areas, forest & hills, streams/drainage/ Waterbodies)
- Derived map of urbanizable areas
- Proposed transportation corridor alignment based on existing land use

Sheet-wise land use colour plots were generated on 1:50,000 scale for about 75 map sheets. The satellite based analysis of NCR has revealed about 47% of area is already converted into built-up area, which include available open spaces and greenery. A GIS database is also generated for Regional Plan 2021 (RP 2021) for entire area of NCR based upon draft RP 2021 criteria for following themes.

- Proposed Land use of 2021
- Policy zones for development
- Settlement Plan of 2001 and 2021
- Transport Plan (Road and Rail) of 2001 and 2021
- Ground water rechargeable area
- Environmental sensitive and Ground water rechargeable areas

After reviewing objections and suggestions received, RP 2021 map plots were generated on 1:50,000 scale. Study maps were created using GIS database which were included in final report of RP 2021. As per the area tables generated for Controlled / Urbanizable area, total controlled area in NCR is about 25% out of which 10% is earmarked as urbanizabe area and further 3.5% is concentrated in NCT, Delhi.

Apart from the above work, land use/land cover maps were prepared on 1:50,000 scale and digital database was also created for five counter magnet town namely Bareilly in Uttar Pradesh, Gwalior in Madhya Pradesh, Kota in Rajasthan, Hissar in Haryana and Patiala in Punjab.

5.7.2. Master / Development plan

The scale of plan is large compared to regional plan. These plans are prepared as per the sate town planning act. The objective of the plan is to show future urbanizable zones, proposed land use structure, public utility network including transportation system and conservation aspects. Since the scale of plan is large, IRS high resolution images are suitable for extracting physical inputs towards preparation of plans.

A Plan for Sustainable Development, Hyderabad 2020 Draft Master Plan for Hyderabad Metropolitan area. Hyderabad Urban Development Authority (HUDA):

The Hyderabad Urban Development Authority (HUDA) planning area covers an extent of 1905.04 sq.kms inclusive of about 172.6 sq.kms. of Municipal Corporation Hyderabad (MCH) area. Outside the MCH area, it consists of 12 – Municipalities, Osmania University, 13 outgrowths and 4 other census towns of census urban agglomeration (HUA). As per census 2001, Hyderabad Urban agglomeration population was about 57.52 lakhs and projected population for Master Plan is about 136.43 lakhs The project was taken up with following objectives:

- Mapping existing land use on 1:12,500 scale
- Updating of base maps of HUDA
- Creation of land use register (proposed and existing), and
- Creation of Digital database for entire HUDA area

IRS-1C (PAN + LISS-III) merged data of Feb, 1997 and April 1998 on 1:12500 scale along with SOI map sheets on 1:25000 scale and HUDA base maps on 1:1000 scale were used as the data base in the study. Also limited ground truth was carried out for verification of updation of land use up to 2000.

The GIS database comprises of layers of

- Administrative boundaries (HUDA, Zone, Cantonment, Municipality, Village & Parcel)
- Land use 2000
- Road
- Rail
- Canal
- Drainage
- Land use proposals

Since the 1984 base maps had become out dated, in 1999 – 2000 HUDA, launched a joint project with the National Remote Sensing Agency (NRSA), Hyderabad to update not only base maps but also the land use maps for the non MCH area with the help of IRS Satellite (LISS III and PAN) as well as ground verification in 2000. The NRSA – HUDA study produced colour coded thematic land use maps (47 plates) for the non-MCH area in 1:10000 scale (approx). It was thus possible to have updated physical features and land use within a short period of time a fairly high degree of accuracy suitable for land use planning at metropolitan sale. A major benefit of this Land Use data is that is available in GIS base. The map can be further modified and additional non-geographical information incorporated as and when needed. Land Use statistics are generated.

As per the area estimate, residential area is about 12.7 % where as agriculture and vacant category is 66 % of the total study area. Residential land requirement estimated for 2020 is about 421 sq.km taking 550 persons per hectare (PPH) in MCH & 250 PPH in non MCH) and additional requirement estimated to around 132 sq.kms.

Creation of Urban Landuse database for Dadra & Nagar Haveli (UT) for Development Plan using Remote sensing & GIS techniques:

The preparation of a Development Plan of a town and its urbanisable area is based on understanding the geo-graphical location, spatial distribution pattern and composition of present landuse and socio-economic data. Preparation of development plan of a town is the statutory requirement according to the State Town Planning Act. Towards this, high resolution Cartosat-1 (PAN) ortho corrected data of 2007 was interpreted and using GIS techniques and a spatial database was prepared at 1:10000 scale. Further the database details were updated using Cartosat-2 data on 1:5000 scale. The Cartosat-2 of 2007 data was othocorrected using Cartosat-1 stereo data and by using GCPs. The study area covers an area of 490 sq.kms. and is surrounded by Valsad District of Gujarat and Thana District of Maharastra. The Census (2001) aggregated the total population of the UT at 2.2 lakhs distributed over 72 villages and two census towns Silvassa and Amli. Various thematic details such as road network, settlement nodes, built-up area footprints, water bodies, surface drainage and canals and other landuse details up to Level-III

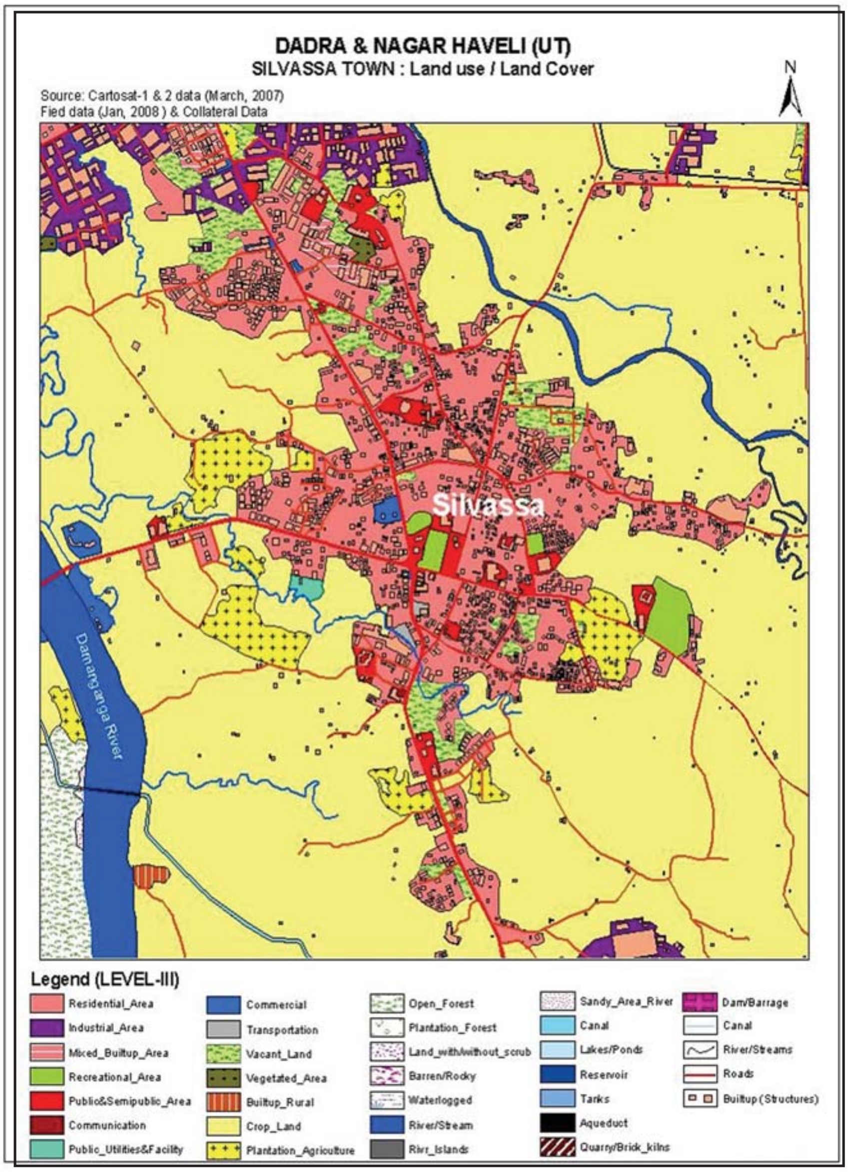

Figure 5.3: Urban Landuse Map of Silvassa

was captured and ground checked in 2008. Figure 5.3 shows urban landuse for Silvassa town. The Cartosat-2 data enabled to map the built-up area foot prints clearly due to its high resolution. The spatial land use distribution suggests distribution of settlement nodes all over UT and industries in and around Silvassa and Amli towns. The major area under landuse is covered under the agricultural use followed by forest/plantation. The GIS data base helps to prepare the Development Plan by analyzing the database for transportation, environmental sensitivity, settlement zoning, and for policy regulations on the proposed land uses by the Department of Town Planning, Govt. of UT.

5.7.3. Infrastructure Facility Mapping

These plans are prepared within the frame work of national / local development polices. Basically the aim of this plan is to develop efficient way of optimizing the infrastructure and facility network. These plans are also useful for management purpose. Data capture of existing infrastructure and location of facilities is possible with high resolution satellite imagery and aerial photos. Route alignment of infrastructure and facility location analysis is possible with GIS.

Route Alignment Study of 400kv D/C Teesta – V – HEP to New Siliguri Transmission line using IRS-Satellite Imagery and GIS techniques:

Remotely sensed satellite data offers a very useful scientific base for carrying out the route alignment corridor surveys, because it provides information on terrain features such as topography and slope, current land use, forest/vegetation cover, water bodies / drainage, built-up areas, road, rail, sanctuaries/parks and others which are the guiding factors to support the decisions during the Pre-feasibility and Feasibility studies. Further, GIS helps in carrying out the integration (spatial and non-spatial data) and the spatial analysis to support the decision process.

Under the project, the route alignment corridor survey between Teesta-V-HEP in Sikkim and New Siliguri town in West Bengal was undertaken for Powergrid Corporation of India Limited, Gurgaon, Haryana. The study was conducted using the topomap data in conjunction with other collateral maps, ground traverses to identify three alternate routes based on, 'maximum avoidance criteria' indicators. The selection of the optimal route (from the three alternate routes) was based on IRS PAN+LISS-III merged satellite data and DEM analysis using a 'semi-automated' method in a GIS environment (figure 5.4).

Thus, final route selected, covers a ground distance of 105.05 km between Teesta and New Siliguri town. Different sets of map like the base map, land cover map, flood sub-mergence maps, terrain profile map are prepared on 1:50,000 scale supported by area estimates, number of crossings and angular bends of turnings of the final route line alignment.

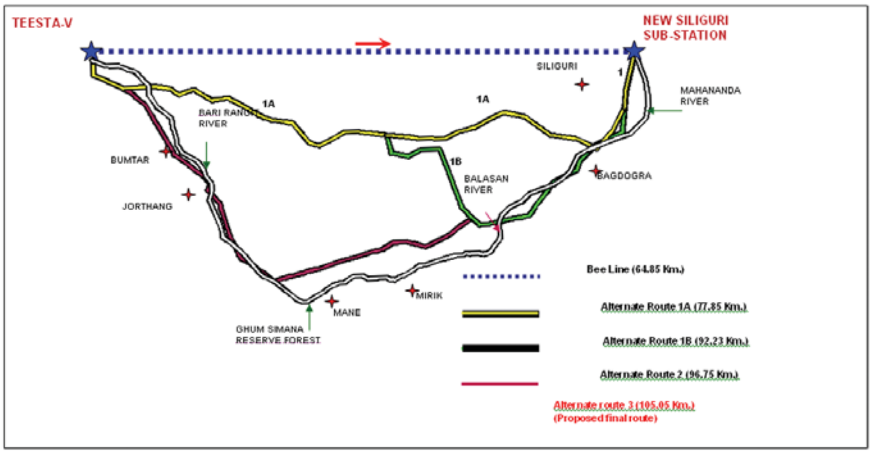

Figure 5.4: Alignment of three alternate routes for powerline between Teesta and New Siliguri

East Cost Gas Pipeline Alignment using CARTO-1 Stereo data and GIS Techniques:

M/s Reliance Gas Transportation Infrastructure Limited (RGTIL), Mumbai planned to connect Chennai and Cuttack with Kakinada through a Gas pipeline (~1200 Km) for supplying LPG. Towards this, for optimization of Route alignment and fixation of corridor, a feasibility study has been initiated using geospatial techniques.

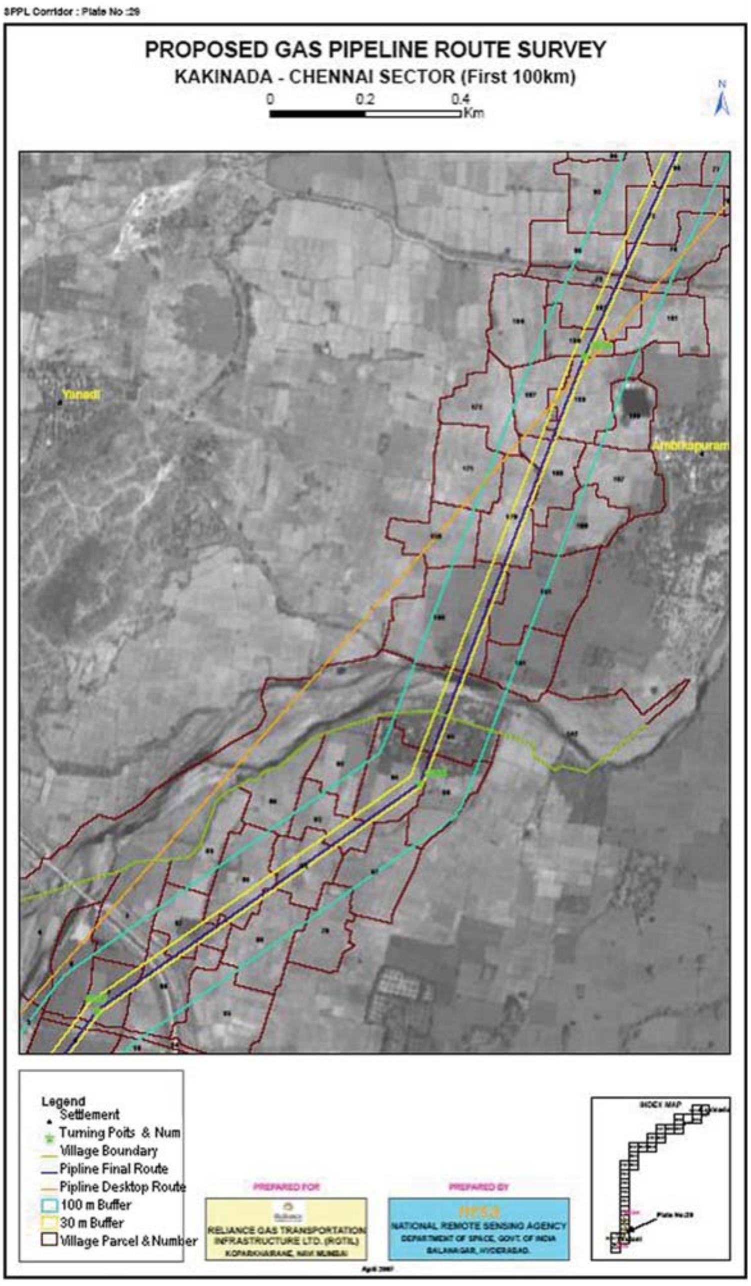

Figure 5.5: Proposed Gas Pipeline Route overlaid with parcels for Kakinada-Chennai Sector

Cartosat-1 PAN (2.5 m) stereo data (2007), orthorectified with the help of DGPS derived GCPs is used for generating the primary avoidance layers like, extent and spatial distribution of habitations, waterbodies (rivers/ streams and tanks/lakes), wetlands, wastelands, vegetation, geology, soil and disaster prone areas. Legacy data like administrative boundaries, forest boundaries, national parks / sanctuaries is collected and geospatial database is created as per the methodology developed on rule base using GIS techniques.

Desktop route is examined through overlay method to generate alternate routes between starting and end points through Maximum Avoidance Criteria, and the final alignment is optimized considering the field data. Using GIS tools, buffers of 30 m & 200 m are generated for the final route. The statistics of Turning Points (TPs), segmented distances between TP's and extent of passage of final route through the villages are generated using referenced (village) parcel vectors warped to the orthorectified Cartosat-1 PAN data. The study is initially completed for ~500 km stretch between Chennai to Kakinada covering ~220 villages and the outputs have been generated onto a spatial scale of 1:10,000. A sample of the CARTOSAT-1 imagery overlaid with the final route, village/parcel boundaries and buffers is shown in Figure 5.5.

The results of the study will enable RGTIL to decide on the cost implications and environmental considerations, based on the current pattern of land utilization and infrastructure development.

Land Use / Land Cover study of Assessment GAIL's proposed LNG pipe line Kochi-Mangalaore-Bangalore using Remote Sensing and GIS Techniques:

Liquefied Natural Gas (LNG) is assuming greater importance in the energy segment as it is used to operate Power Plants and Industrial (fertilizer) Plants. Supply of LNG from source to various destinations (located in different states) through near sub-surface pipelines is techno-economically feasible and has a definite edge over other modes of transport for bulk quantity supply covering large distances. M/s. Gas Authority of India Limited (GAIL) propose to setup a sub-surface pipeline network covering parts of Kerala, Karnataka and Tamil Nadu for transportation and distribution of LNG supplied by Petronet LNG Ltd. (PLL) through a pipeline to be commissioned between Kochi - Mangalore - Bangalore over a distance of 912 Km .

Here, using IRS-1D (LISS-III) satellite data of 2002 with ground truth data of April 2003 Land Use /Land cover mapping and assessment for the corridor of 1 km has been carried. Also, mapping covering 5 km circles at Receipt and Dispatch stations also been carried. The pipeline segments (5 km interval) passing through each land use/land cover category has been estimated along with the geographical extent of the each of the land use/land cover classes.

The study indicated 693 km length of pipeline passes through agriculture land, 119 km of wasteland, 71 km of built-up area, 23 km of water bodies, 6.4 km of forest and 0.5 km of other land use classes. The total number of crossings (road, rail, canal, river/streams) along the pipeline route is around 891 with maximum number of crossings of the pipeline along road and river/streams. Geographically, agriculture is predominantly covering an area of 663 sq km (74%) land followed by 113 sq.km (13%) wasteland, 81 sq.km (9%) built-up area, 29 sq.km (3%) water bodies, 7.33 sq.km (0.8%) forest and 3.1 sq.km (0.3%) other land uses classes along the corridor. Figure 5.6 shows one out of 38 maps prepared for the pipeline corridor study. Inputs were used in Environmental Management Plan (EMP).

5.7.4. Urban Information Systems

Urban information system includes both spatial and non spatial data for planning and management of urban settlements. To facilitate planning and management of urban settlements by Urban Local Bodies (ULBs), National Urban Information System (NUIS) project is approved by Govt. of India.

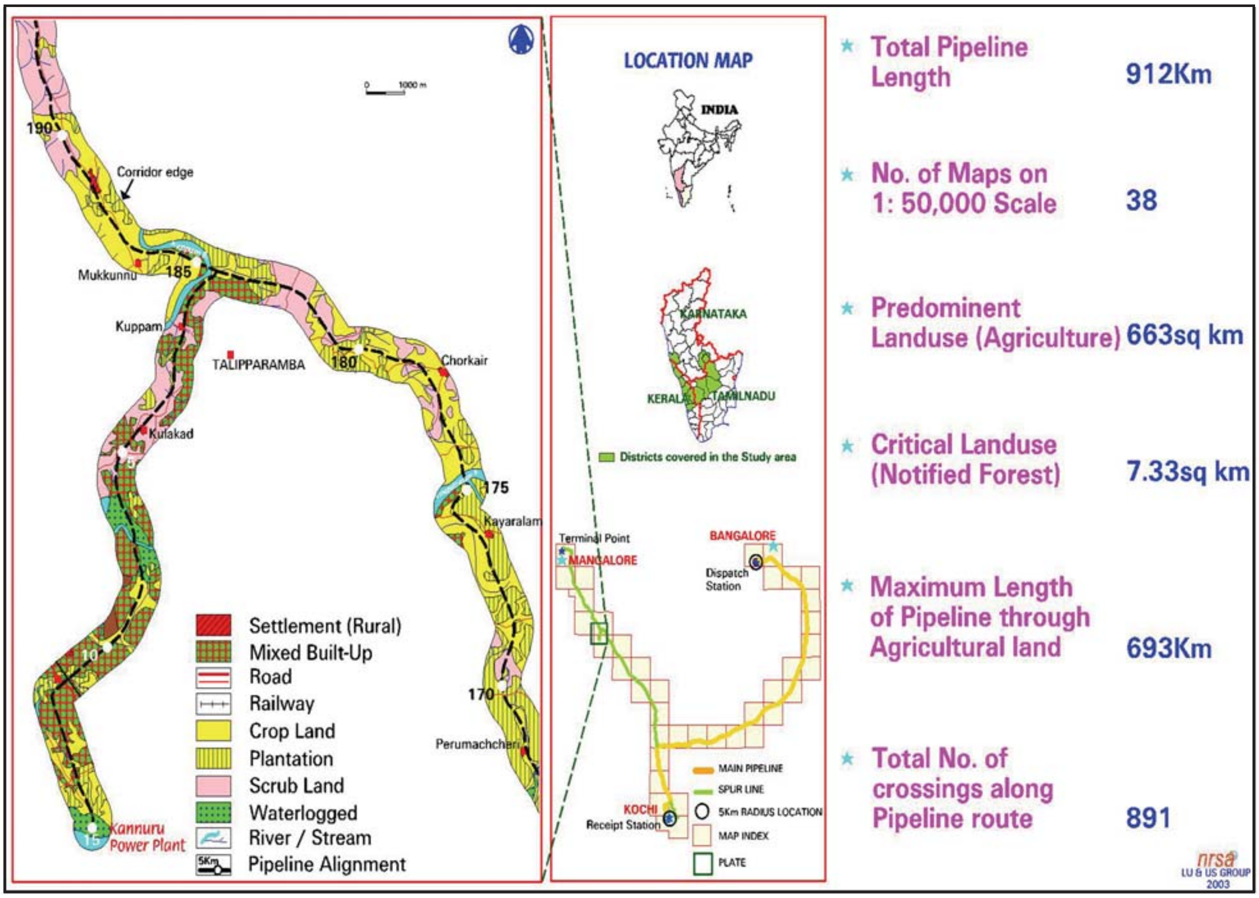

Figure 5.6: Landuse/Landcover along the proposed Gas Pipeline route for Kochi-Bangalore-Mangalore Corridor

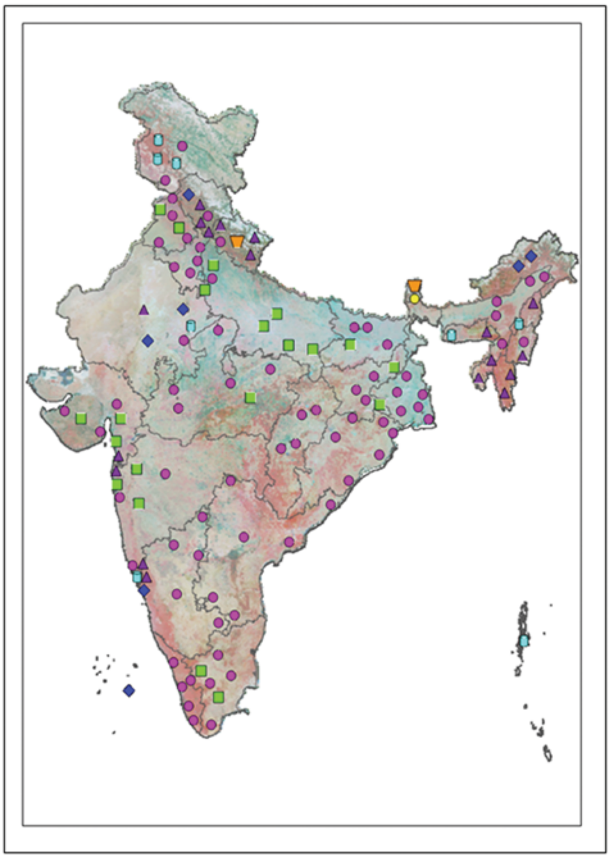

Figure 5.7: Distribution of NUIS Phase-I towns

National Urban Information System (NUIS) Scheme:

The National Urban Information System (NUIS) project was taken up on national mission mode to enable establishing town level geospatial database under a single National (Central) Scheme. Broadly it comprises two major components a) Urban Spatial Information System (USIS) to meet the spatial (base and thematic maps/image) data requirements of urban planning and management functions, and b) National Urban Data Bank and Indicators (NUDBI&I) to develop town level urban database to support development of Indices through a network of Local Urban Observatories (LUOs) under the National Urban Observatory (NUO) programme. The NUIS project envisages developing USIS and NUDBI covering all the 5161 Cities/Towns/UA's in the country in three phases. The Phase-I covers 158 towns with a geographical area approximately 55,755 sq.km. The geographical distribution of towns is given in Figure 5.7 and conceptual scheme of NUIS and is shown in Figure 5.8.

The major objective of NUIS is to generate multi-scale hierarchical Urban Geospatial and non-spatial (attribute) databases for various levels of planning and decision support to meet requirements of Urban planning, Management and Governance. Development of Urban Spatial Information System to support and strengthen the outreach of geospatial database to SNA and ULB through the use of GIS tools and techniques to assist in better urban decision making and governance.

The thematic database was prepared at 1:10000 scale using Cartosat-1 PAN and LISS-IV multi spectral Satellite data, 1:2,000 scale database prepared from aerial photographs, and for selected towns on 1:1,000 scale underground assets survey (Water supply and sewerage network) using Ground Penetrating Radar (GPR). NUIS Thematic mapping comprises of 12 primary layers and 4 incorporated layers.

Primary Layers

- Urban land use
- Physiography (outside core area)
- Geomorphology (outside core area)
- Geological Structures (outside core area)
- Lithology (outside core area)
- Soils (outside core area)
- Drainage
- Surface waterbodies
- Road
- Rail
- Canal
- Transportation Nodes

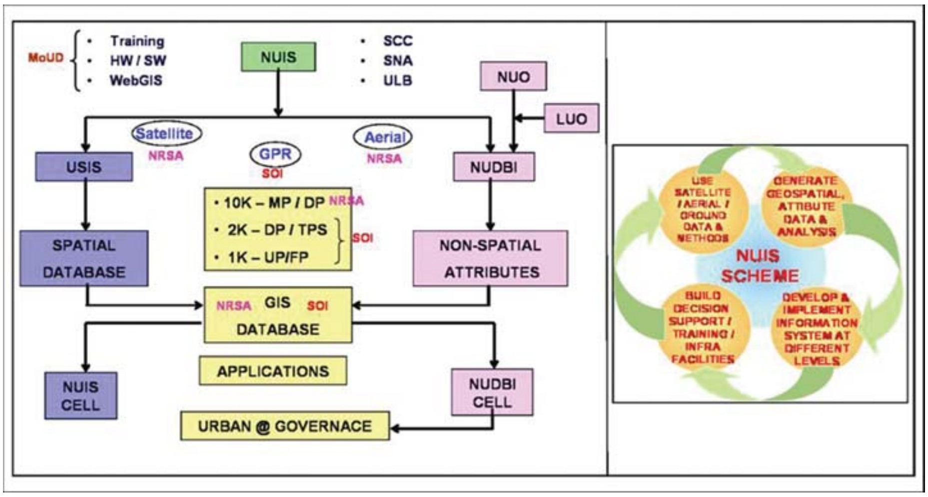

Figure 5.8: NUIS Scheme

Incorporated Layers

- Administrative Boundaries
- Forest Boundary
- Settlement & Village Locations / Names
- City / Town Boundaries

In phase-I, among 158 towns, as a priority, database for Korba town covering 276 sq.k was prepared as shown in figure 5.9. The geospatial databases of towns would enable the preparation of urban plans to meet the requirements of different levels of urban planning. Applications/ automated integration techniques developed in GIS would provide inputs to Master/ Development/Zonal Planning and Utilities management and help to build capacity among town planning professionals at State and Local Body level on the use of remote sensing and GIS techniques.

5.7.5. Archaeological Studies

Remote Sensing being a non-destructive technique has gained lot of importance in the field of archaeological applications. It has helped in recognising and studying potential archaeological sites on the basis of signature variations on the satellite data. This relevance of this study has been mainly to use high resolution Indian satellite data, and advanced geospatial technologies towards newer applications in archaeology.

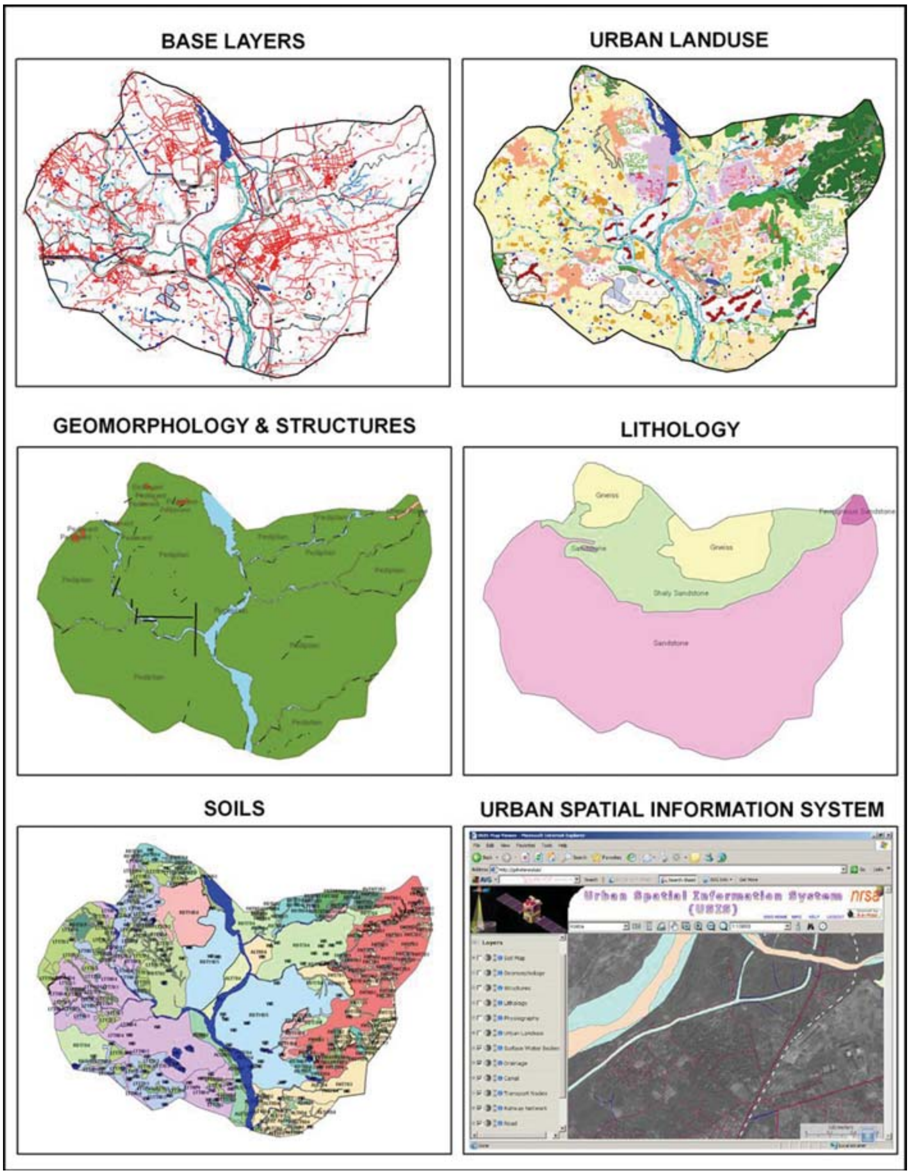

Figure 5.9: Snapshot of NUIS Database of Korba town, Chattisgarh

Satellite based Archaeological Study of Ancient Nalanda Site and Environs, Bihar:

The Objectives of the study were mainly:

- To establish the feasibility of high resolution satellite remote sensing data in archaeological reconnaissance surveys for identification, delineation and monitoring of archaeological sites
- To examine potential sites for further archaeological research and excavations

Nalanda is located at 90 km south-east of Patna, Bihar and 11 Km north of Rajgir. The study area covers 16 sq km in and around Nalanda including the 1.5 sq.km present excavated site. It is located between 25° 6' to 25° 10' and 85° 24' to 85° 30' E as shown in figure 5.10.

Nalanda, is an ancient Buddhist ruin, located close to the village Bargaon in Bihar. Nalanda has a very ancient history of being established as a Buddhist Centre of learning, going back to the days of Mahavira and Buddha in 6th & 5th century B.C. Based on the findings of Nalanda by Buchanan in 1838, General Alexander Cunningham identified the site for the first time in the year 1861-62 which was followed by A.M.Broadley, who carried out some excavations. Later, for about twenty years, beginning with 1915-16 upto 1937, the Archaeological Survey of India (ASI) excavated the site, besides its preservation and collection of antiquities. Excavations conducted in 1974-1982 and recently in 2004-2005, have revealed the existence of ruins of temple close to the Nalanda. Further, it is stated that the 2500 year old Nalanda University was spread over 16 sq.kms. However, till now only 1.5 sq.kms of the ruins has been reported to be excavated by ASI.

The following datasets were used for the study:

- Satellite data: CARTOSAT-1 PAN Aft and IRS LISS-IV images

Figure 5.10: Location and regional setting of Nalanda site (source: www.mapsofindia.com)

- Field data: Ground Penetrating Radar (GPR) based ground survey for short-listed prospective sub-surface sites for detailed investigation
- Secondary Data: SOI Map / ASI Maps / Monument Plans and Literature

High resolution CARTOSAT-1 PAN data was used to locate the present site and determine its extent and precincts. Various structures present on the site were identified. IRS LISS IV multi spectral data was used in stand alone mode and also merged with CARTOSAT to observe features in vegetated areas. Since vegetation is highlighted in the multi-spectral data, it would help in the better differentiation of features especially in contrast with vegetation since historic sites are hidden under vegetation. Topomaps were used as a base for the study. The detailed land use / cover like settlements, agricultural fields, waterbodies, exposed ground, roads and canal/streams were also extracted from the imagery following heads up interpretation approach.

The already excavated site was correlated with the neighboring land use to identify its extension. The position and alignment of the structures in the site was studied with reference to existing literature. Some conspicuous features, outside the existing site were identified on the imagery and further verified during the ground truth. Ground Penetrating Radar (GPR) survey was carried out for one of the identified mound, in consultation with ASI, to know and study the sub surface structures and to assess its relation with existing site of Nalanda.

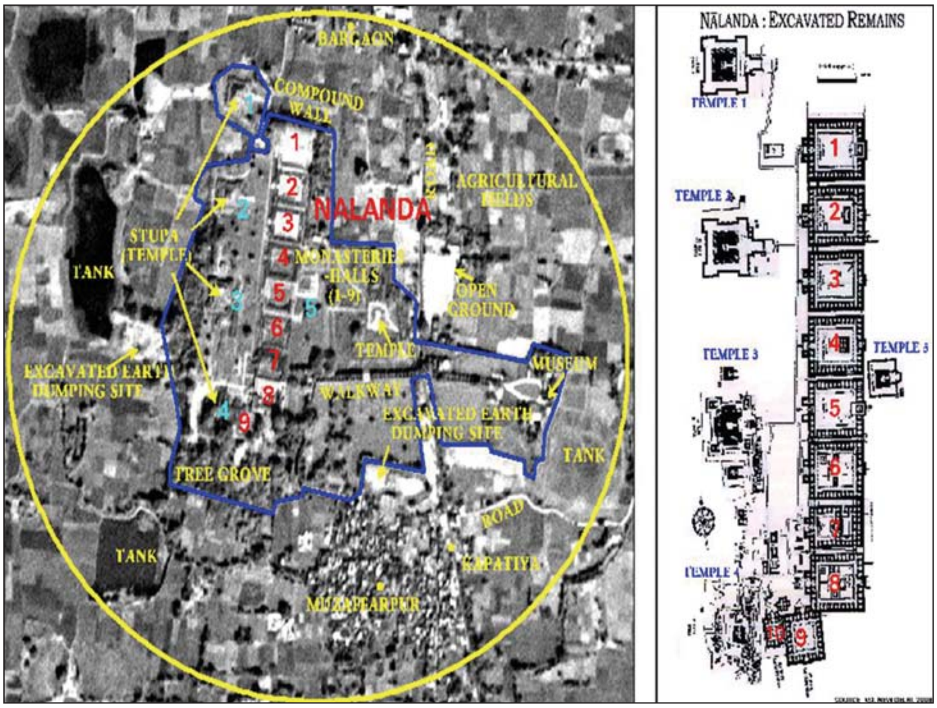

Figure 5.11: CARTOSAT-1 PAN image (03 Feb, 2006) and ASI map(2006) showing the Nalanda site

The imagery clearly showed the location, extent, pattern and layout of Nalanda. A comparison of the features in CARTOST-1 PAN image and ASI map (Figure 5.11), reveals that nine of Ten Monasteries and four out of the five temples/stupas, with their geometric shape and pattern, were distinctly visible on the image. The left out monastery (No.10) and the temple (No.4) were noticed in ruins during the ground truth visit. The monasteries 1,2 and 3 show the presence of a paved surface over the others (unpaved surface). Other details identified on the image include the compound wall, pathways, entrance to the monasteries, vegetation/trees, tanks, lakes, settlements, approach roads besides the cultivated lands with field bunds. Traces of the compound wall were also seen on the CARTOSAT-1 image. The Newly developed settlement, Muzaffarpur, was seen 200 meters to south of the site. The older settlement, Bargaon, is located at 350 m to the north of the site.

Three conspicuous features identified on the image were confirmed with ground truth as mounds of 4-5 m height. One of them was near Begumpur settlement about 1 km north of existing site and two others were near Jagdishpur settlement about 2-2.5 km south-east, as shown in Figure 5.12. The mound at Begampur was the closest to the existing site and its plan on the image resembled the plan of stupa in the already excavated site. On discussion with ASI, GPR survey was carried out for this mound, which yielded results giving the features beneath the mound upto a depth of 5 m. The results showed an almost square shaped structure with extended corners and internal cubicles made of brick.

Detailed ground investigations is required to confirm whether the mound is really a part of ancient Nalanda or just another structure, which could have existed at the same time as Nalanda and having its own archaeological importance.

The study using Indian Remote Sensing satellite data has offered a valuable insight into Nalanda site towards establishing baseline information to serve as a repository for further monitoring and archaeological investigations. This has also demonstrated the capability of Indian remote sensing data, in conjunction with ground surveys, to carry out archaeological exploration studies.

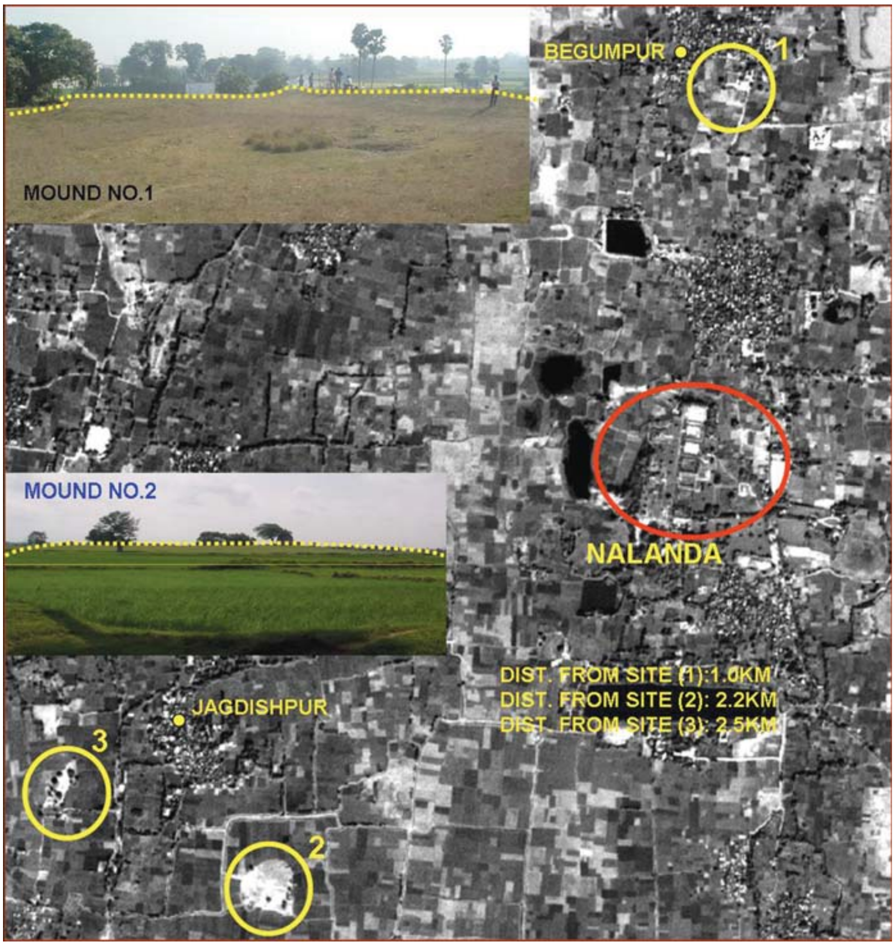

Figure 5.12: Three mounds as seen on Cartosat-1 and its ground photos

5.8. Scientific Methods

The present chapter has tried to look into the utility of remote sensing data and scientific methods in solving some of the urban problems. Applying remote sensing technology to urban areas is relatively new and with the advent of high resolution satellite data and advances in digital technology, it has gained momentum.

Some of the requirements of urban planners which remote sensing is able to provide are:

- the location and extent of urban areas
- the nature and spatial distribution of different land-use categories
- primary transportation networks and related infrastructure
- 3-D structure of urban areas
- Ability to monitor changes in these features over a time

5.8.1. Feature Extraction and Classification

One of the very basic tasks is mapping of urban/rural settlements. Landcover and land use is an obvious product of remote sensing which is the basic element for any kind of urban planning. The land use map generated by thematic classification of a satellite sensor image can be viewed as end product as it constitutes a document showing the existing situation before any planning action. However, it is also a starting point for further analyses. Direct identification techniques like visual interpretation, feature extraction, classification etc., are widely used for image interpretation. Visual or Manual interpretation has so far been recognized as effective tool in urban mapping. But in recent times, there has been a shift to digital techniques which has been improved with the advances in spatial resolution. Traditional techniques used for image classification include unsupervised, supervised, hybrid and fuzzy classification. Various image classification techniques developed include both semi-automatic and automatic techniques and some of the latest information extraction techniques include linear feature extraction, spectral mixture modeling etc. Traditionally, image classification procedures were mainly in the spectral domain, while the latest image segmentation procedures involve spatial descriptors and make use of panchromatic data.

Another important aspect of remote sensing in urban areas is the delineation of urban areas based on the morphological variability of settlements. Urban/rural settlements can be detected through differences in spectral signatures between the built environment and vegetation and crops. Although the fundamental elements of size, color, shape, pattern, texture etc., are used for any feature identification, its shape, texture, pattern, association, contextual information are more effective in classification of urban features and characteristics.

In metropolitan and urban areas, problems relating to rapid transformations in terms of land cover and land use are very pronounced. As a result, availability of timely information on urban areas is of considerable importance. A very basic issue in urban planning has been non- availability of information/database for Master Plan Development Plan preparation for urban areas. Visual and digital techniques are used to map land use/land cover, infrastructure, utilities, topography etc which constitutes urban database at required scale. Multi-scale geospatial database can be generated in association with GIS techniques, which are useful for planning, management and governance of urban areas at various levels. GIS is a major tool in analyzing the urban spatial database and decision making process.

5.8.2. Change Detection

Change monitoring, which requires comparison of two images of different times is an important analysis technique for urban studies. The simplest way to detect change in settlements is to visually compare images at two or more different times. Spatiotemporal analysis helps in studying urban sprawl and growth process. The physical changes in distribution of urban activities can be provided. This helps in measuring and monitoring the location and extent of urbanization. Many dimensions of change can be monitored directly through optical and also microwave data. The size of a settlement is related to the areal extent of built up area which in turn is related to the size of the population. Allometric growth model and Central Place theory has been extensively used to estimate population on the basis of the built-up area extent.

Haphazard development in urban fringes can be monitored using temporal data. In this era of rapid urbanization, it is vital to have a means of monitoring on a global or regional scale. Change detection algorithms include Visual interpretive methods, Post classification comparison, knowledge based visions etc., which are mainly applied on multispectral data. Change detection is also carried out through spatial, textural and numerical analysis. eCognition is one of the very latest techniques used to delineate urban settlements which tries to imitate human visual perception and image understanding, the software generates image objects using multi resolution segmentation.

5.8.3. Fusion and Photogrammetry

Image fusion helps in producing imagery that includes best of both, especially high spatial resolution and spectral resolution which is useful for urban studies. It combines the inherent advantages of each dataset into one. This increases image clarity, allows efficient mapping and maximizing information on urban areas. Some of the existing techniques include Principal Component Analysis, IHS transform, Brovey transform and Wavelet transform being the latest. Merging can not only been attempted on multi resolution sensors but also with GIS data or DEM or ancillary data.

Photogrammetry, is one of the first techniques to have used remote sensing data for measurements. It is a 3-dimensional coordinate measuring technique that uses photographs or images as the fundamental medium for measurement. Images corrected for terrain slope are essential for urban areas so that there is a true representation of each feature and the real change is evident. Towards this process, known as orthorectification, DEM plays a very important role. DEM can also be used for rendering 3D visualizations, urban flood or drainage modeling, terrain analyses etc.

5.8.4. Environment and Transportation Analysis

The environmental impact on urbanization is an important aspect to be included in planning, design and sustainable development of urban areas, for example, slums can be easily and directly identified on satellite imagery. Remotely sensed data and observations are providing new tools for addressing environment related human health problems relevant to human settlements. It is also significant for identifying, measuring, mapping and monitoring characteristics of natural and man-made hazards or disasters. Vulnerability mapping helps in identifying the locations which are at risk from hazards. Post disaster analysis, for example, the extent of flooding and related damage can also be assessed. As the cities/ towns expand, the encroachment and impact on environment is ever increasing. Degradation of water habitats, higher storm water runoff leading to urban flooding etc are some of the environmental issue very much related to urban development. An indicator used in this regard is the impervious surface area which can be derived from satellite data. Thermal infrared data have been applied in analysis of a wide variety of ecological processes that relate directly or indirectly to urban areas. The urban heat island resulting from replacement of natural cover to urban land use can be observed and studied using thermal infrared data. This helps in understanding how urbanization and urban sprawl affect biophysical and land-atmosphere interactions

The most dynamic element of urban area is the various modes of transportation. Road patterns, its width and alignment can be directly identified and digitized from remote sensing data. A detailed feature/asset inventory of items like dividers, sidewalks, culverts, gutters etc can be prepared from high resolution imagery. Alignment of new roads/rail can be determined in conjunction with parcel and environmental data. Capacity of road intersections, turn lanes can be studied by taking images of same location over a period of time.

5.8.5. Historical sites study

Remote Sensing data can be used in detection of historical settlements or archaeological sites with respect to its position in the ancient and modern landscapes. Soil marks and crop marks clearly seen on satellite image are used to identify sites without any ground surveys. Vegetation signatures in multi spectral imagery are very good indicators of archaeological sites. The different state of vegetation on an archaeological site and the natural background gives a different spectral response which helps in easy identification of the sites. Combining DEM with satellite imagery shows a high degree of correlation between signature and elevation which strengthens historical site detection. The boundary walls of archaeological sites can be easily identified which are otherwise difficult to be seen on the ground. By incorporating ancillary layers like soil, hydrology and elevation in GIS along with remote sensing data, the historical features can be related to present existing site.

5.8.6. Urban Modeling

The thematic database/maps generated needs to be further analysed for various applications. Urban models can be used to support planning, policy and management decisions. Urban simulation is the process through which the plans, policies are tested or their efficiency and impact. Automata models and visualization in urban simulation represent the state-of-the art in modeling of human settlements. Two classes of automata which are significant are Cellular automata (CA) and Multi-agent systems (MAS). CA are generally employed for interaction between static units like buildings, parcels, infrastructure objects whereas MAS is used for more fluid like movements. Simple computer animated design models of buildings have been improved upon by virtual reality models which are capable of supporting applications such as urban design, facilities management, environmental analysis, disaster management etc.

Remote sensing analysis in conjunction with urban modeling has potential to provide information needed for planning and management decisions. Planning Support Systems (PSS) incorporate and integrate different data components such as spatial data sets, GIS, urban models etc. Possible future land development scenarios can also be prepared. The use of scenarios is one of the essential concepts in bridging urban modeling and urban planning and management. A link to planners and the public is provided and communicated via scenarios that are defined or explored within a PSS.

5.9. Economic Benefits of Remote Sensing & GIS in Urban Applications

The use of remote sensing & GIS technology in urban applications are being operationalised due its advantages in time, cost benefits, reliability over the traditional ground methods. For any urban applications such as urban planning including infrastructure as well as for municipal applications (tax, water supply etc.,) up-to-date maps/ geospatial data are required. The traditional method of preparing maps through ground survey has been time consuming and expensive. These maps require timely updation in phase as rapid development takes place in cities like Delhi, Bombay, Hyderabad, Bangalore. Preparation of maps/geospatial databases are essential for preparing Master plans / zonal plans as ground surveys are impractical for such large areas. However, necessary attribute data such as collecting house hold data, utility data are to be carried out by ground based methods. The following table provides broad guide lines of economic benefits of using remote sensing and GIS technology from NRSC experience.

Table 5.3: Cost and time requirements for preparation of Urban thematic maps in various scales

Sl. No.	Description Project Activity	RS& GIS Methods		Traditional Ground Methods (~ estimated values)	
		~Cost per Sq.km (RS)	~Time required	~Cost per Sq.km (RS)	~Time required
1	Thematic quality Urban Landuse /Land cover mapping and GIS database creation for Delhi NRC region (34,000 sq.km) on 1:50,000 Scale. This database is being used for regional plans	1000	1 year	10,000	More than 2 years
2	Cartographic quality Large Scale Mapping on 1:10 K using High Resolution satellite data. 5000 sq.km covering 40 towns	10,000	2 years	25,000	More than 3 years
3	Thematic quality Urban Landuse / Land cover mapping and GIS database creation for Hyderabad, HUDA region on 5,000 Scale using High resolution Satellite data. These databases are being used for master/zonal plans and infrastructure plans.	5000/-	For 2000 sq.km 6 months	20,000/-	More than 2 years

The values shown in table 5.3. are only approximately estimated. The cost and time elements may vary depending upon intended use of map/geospatial database, level of information content, accuracy and time. RS& GIS technologies are effective and suitable for large areas rather than small areas. For example, to prepare a map of town covering 10 sq.km, ground based methods are recommended and for town/city covering more than 100 sq.km, RS &GIS methods are only practical solution. The economic & time benefit ranges from 30% to 60% based scale of mapping, required accuracy and information content by using RS&GIS technologies over the traditional ground methods. Presently, metropolitan urban local bodies are implementing the RS& GIS technologies for preparation of base maps/thematic maps and geospatial databases for Urban Planning.

5.10. Conclusions

Spatial maps prepared on a 1:10,000/1:5000 scales using High Resolution Satellites (CARTOSAT) data offer an important “Urban Asset” for urban planning and development. Resources information content derived from remotely sensed data has been “proved useful” for the preparation of Regional Perspective Plans, Master Plans/Development Plans and Infrastructure plan. In archeology, remote sensing data found useful in identifying archeology sites for excavation. Various visual methods and digital techniques are operationally tested for ‘data capture’ at a higher degree of accuracy and in this respect many “benchmark studies” have been carried out in the country. Urban GIS offers, application driven solutions as a “value addition” for strengthening urban planning and development scenarios. Integration and fusion of satellite derived information with available conventional/ground based data in a GIS environment offers a “valuable outreach” for the success of urban studies.

References

Batty M, 1992, Urban modeling in computer graphic and geographic information systems environment, Environment and Planning Board.

Beaumonta TE, 1992, *Advances in Space Research*, **2 (8)**: 91-96

Bracken Ian, 1981, *Urban Planning Methods, Research and Policy Analysis*, Mathew & Co., USA.

Cristina Milesi, Christopher D Elvidge, Ramakrishna R Nemani and Steven W Running, 2003, *Management of Environmental Quality*, **14(1)**: 99 - 107

Dana Tomlin C, 1990, *Geographic information system and cartographic modeling*, Published by Prentice-Hall. Inc., NewJersey.

Davies D Wayne, 1967, Centrality and the Central Place Hierarchy, *Urban Studies*,**4(1**) : 61-79.

DDA,1990, Master plan for Delhi Perspective 2001, prepared by Delhi Development Authority, Delhi.

Executive Office of Environmental Affairs Office of Geographic and Environmental Information (MassGIS), October 2002, Getting Started With GIS A Guide for Municipalities.

Forster B, 1983, Some urban measurements from Landsat data, *Photogrammetry Engineering and Remote Sensing*, **49**: 1707- 1716.

Govt. of India, 1988, *Report of National Commission on Urbanization* ,Volume- VI, Published by Govt. of India.

Govt. of India, September 2008, Ministry of Home Affairs, National Disaster Management Division, "Proposed Amendment in Town and Country Planning Legislation.

Haack B, Guptill S, Holz R, Jampoler S, Jensen J and Welch R, 1997, Urban analysis and planning, *Manual of Photographic Interpretation*, ASPRS, Bethesda.

Jensen Jens Toftgaard and Garry Keys, 2003, Mapping Urban History, International association for History and Computing's XVth Conference, Tromso, Dennmark.

Jensen JR, 1983, Urban/suburban land use analysis, *Manual of Remote Sensing*, second ed. ASP, Falls Church,1571–1666.

Jensen JR and Cowen DC, 1999, Remote sensing of urban suburban infrastructure and socio-economic attributes, *Photogrammetry Engineering and Remote Sensing,* **65(5)**: 611–622.

Kaya Sinasi, 2007, Multi-temporal Analysis of Rapid Urban growth in Istambul using Remotely Sensed data*. Environmental Engineering Science*, **24(2)**: 228-233.

Kong Fan-hua , Nobukazu Nakagoshi, Yin Hai-wei and Akira Kikuchi, 2005, *Chinese Geographical Science*, **15(3)**: 254-261.

Konstantino G, 2008,Comparison of Nine Fusion techniques for very High Resolution Data, *Photogrammetry Engineering and Remote Sensing* , **74(5)**: 647-659

Lata Madhavi K, KrishnaPrasdV, Badrinath KVS and RaghavaswamyV, 2000, www.gisdevelopment.net/application/urban/sprawl/urbans0004

Lo CP, 1986, Accuracy of population estimation from medium-scale aerial-photography, *Photogrammetry Engineering and Remote Sensensing*, **52(12)**: 1859–1869.

Lo CP, 2001, Modeling the population of China using DMSP operational linescan system nighttime data, *Photogrammetry Engineering and Remote Sensing*, **67(9)** : 1037–1047.

Maithani M and Sokhi BS, 2002, "Modeling Land Transformation using Remote Sensing and GIS –Case study, Hardware and surrounding Areas", *ITPI Journal*, **2(2)**: 181.

Manual of Remote Sensing,2006, Volume 5: "Remote Sensing of Human Settlements".

Meng Xuelian, Le Wang and Currit Nate, April 2009, *Photogrammetric Engineering and Remote Sensing*, **75(4)** : 437-442.

Mesev TV and Longley PA,1995, Morphology from imagery— detecting and measuring the density of urban land-use, *Environmental Planning,* **27(5)** : 759–780.

Miller RB, 2003, Cities for space: potential applications of remote sensing in urban environmental research policy, *Environmnetal science & Policy*, **6** : 129-137.

MUA&E, 1996m ,UDPFI guidelines, **I** :1-253.

NCRPB, 1988,Regional Plan, 2001, New Delhi.

NCRPB, 1999, “Delhi 1999 A fact sheet,New Delhi.

NCRPB, 1999, “National Capital Region Directory,New Delhi.

Nigam RK, 2000, www.gisdevelopment.net/application/urban/fringe/urbanf0001.htm

NNRMS, Training course on Remote Sensing for Archaeology, NRSA, Dept. of Space, Hyderabad, 2000.

NRSA,1994, Mapping and Monitoring urban sprawl Hyderabad city. Project report, 1-84.

Patrick Geddes, Cities in Evolution, Lodon, 1915, Chapter XIV “The Study of Cities”

Pesaresi M and Benediktsson JA, 2000, Geoscience and Remote Sensing Symposium Proceedings, **7**:3066 - 3068.

Raghavswamy V, Pathan SK, Ram Mohan P, Bhandari. RJ and Priya P,1996, IRS-1C Applications for Urban planning and development, *Current Science*, **70(7)**: 582-588.

Rajaram B, Nagarajan R and Khire MV, 2001, *International Journal of Remote Sensing*, **22 (16)**: 318 -3201.

Ramesh B, 1988,Monitoring Urban Land uses using Aerial photographs and SPOT Image data, ACRS, Bangkok.

Rateliffe John, 1981, *An introduction to Town and Country planning* , Book Published by Hutchinson company Ltd., 62-65 Chandos place, London WC 2N 4NW.

AC, Ahmedabad, 1997, Revised development plan of Ahmedabad Development Authority area –2011, Volume 1: Remote Sensing and GIS approach. Technical Report SAC/RSAG/TR/12/Aug/19997.

Srirama.B, Bhatt MR and Pathan SK, 2001, www.gisdevelopment.net/application/utility/transport/ma0557.htm

Stefanov WL, Ramsey MS and Christensen PR, 2001, Monitoring urban land cover change: an expert system approach to land cover classification of semiarid to arid urban centers, *Remote Sensing of Environment*, **77 (2)**: 173–185.

Surendra S and Aggarwal R.C, 1998, “Application of Remote Sensing & GIS Techniques for National Capital Region”, Proceedings of First Workshop of Southern Region State Town Planners on “ Remote Sensing and GIS in Urban Development Planning, Management and Emerging Information Needs”.

Thakker PS, 2001, Remote Sensing of Cosmic cities in Ancient India. NNRMS Special issue on Archaeological Applications of Remote Sensing, Dept. of Space, Govt.of India, Bangalore, **26**: 43-54.

Tuyahov AJ, Davies CS and HolzRK, 1973, Detection of urban blight using remote sensing techniques, *Remote Sensing Earth Resources*, **2**: 213–226.

UNCHS HABITAT, 1984, Human Settlement Polices and Institutions issues, options, trends and guide lines, Published by United Nations, Center for Human Settlements, Nirobi, Kenya.

United Nations, Economic and Social Commission Asia and Pacific,UNESCAP, Manual on GIS for Planners and Decision Makers.

Upasana Srivastava and Nathawat MS, 2001, www.gisdevelopment.net/application/utility/transport/mi03203pf.htm

Weber Christiane, Chryssanthi Petropoulou and Jacky Hirsch, February 2005, *International Journal of Remote Sensing,* **26 (4)**: 785 - 796.

Welch R, 1982, Spatial resolution requirements for urban studies, *International Journal of Remote Sensing*, **3(2)** : 139–146.

Worboys M, 1995, *GIS: A computing Perspective*, London: Taylor and Francis.

http://www.earthtrends.wri.org

http://www.globalchange.umich.edu

http://www.interenvironment.org/cipa/urbanization

http://www.mapsofindia.com