

GEOSPATIAL DATABASE DEVELOPMENT FOR URBAN PLANNING USING SATELLITE DATA UNDER GIS ENVIRONMENT

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KEY WORDS: Urban planning, GIS, Geospatial, Image processing, Database, GUI.

ABSTRACT:

Indian cities are experiencing an accelerated pace of growth since independence and are now emerging as centres of domestic and international investments in an era of economic reforms, liberalisation and globalization. This has created opportunities for technologists and planning professionals to guide and develop the process of planned development and management utilizing modern technologies. The availability of high resolution data from remote sensing satellites has revolutionized the process of thematic mapping and geospatial database creation, specially, in the context of urban and regional planning. Further, Geographic Information System (GIS) has emerged as a powerful tool in integrating and analyzing the various thematic layers along with attribute information to create and visualize various planning scenarios for decision making. The increasing demands in urban planning and management sectors call for integrated application of remote sensing and GIS for sustainable development of urban areas. The present work deals with the development of geospatial database for urban planning of Allahabad city of Uttar Pradesh State in India through the use of satellite data and other collateral data under GIS environment. IRS-1D LISS-III digital data has been used for the extraction and analysis of the land utilization pattern of Allahabad city. The various thematic layers generated include land use pattern, road network, water supply, solid waste disposal, soil map, ground water potential map, *etc.* and these have been integrated with socio-economic and demographic data of the city to model the urban growth of the city.

1. INTRODUCTION

Urbanisation is a form of metropolitan growth that is a response to complex sets of economic, social, and political forces and to the physical geography of an area. Urban planning is basically resource development, resource management and resource generation exercise. The efficiency of urban settlements largely depends upon how well they are planned, how economically they are developed and how efficiently they are managed (Tiwari, 2003). Development of local economies, and therefore urban expansion, is driven by a number of factors, including transportation networks (land, water and air), population increases (both in term of local birth rate and influx from other areas) and the amount of available land for developments (Markon, 2003).

The proper planning, design and management of urban land use demands a careful balancing of many goals, *viz.*, search for desirable land uses, effective and sustainable management practices, coupled with interactions among the environment, economy and society. One of the main reasons underlying the growing interest in multi-criteria analysis for land use management is the need for an integrated approach to such complex problems.

The urbanization may result in the loss of natural resources, open space and agricultural lands. The efficiency and sustainability of land management will be

maximised when systems of land use are well-matched to the resources of a given area. The knowledge of spatial distribution and behaviour of land resources is indispensable for making land management decisions for a region. Land cover can be determined either by ground-based survey or from remote sensing data. Urban land environment represents one of the most challenging areas for remote sensing analysis due to high spatial and spectral diversity of surface materials (Carleer and Wolff, 2006). Further, geospatial database design under GIS environment is very important in the development of planning support systems. However, the design methodology of spatial database hasn't been developed adequately in urban research compared with the predictive modelling and simulation.

2. REMOTE SENSING FOR URBAN PLANNING

Considering the fact that natural resource assessment at regional level are time-consuming, costly and often exceed practical possibilities, one of the important aims of such activities is to efficiently study the geographical patterns of land resources and to observe spatial interactions and relationships among physical variables from one place to other. This involves use of remotely sensing techniques for continuous updating of the land use/ land cover of the area of interest and for identifying environmental constraints for the development of most

probable land use practices in that area. Further, the potential land degradation can also be examined based on the measured environmental variables, especially when a particular land use type is to be adopted. These aspects can be dealt with simultaneously also by establishing a simple modelling framework within a standardized system, whose procedure and outputs can be useful for planning at a predefined scale (Baja *et al.*, 2002).

The use of remote sensing techniques in the field of urban development practices is very common because of some specific and useful features that can be summarized as:

- synoptic view of large areas;
- usable in inaccessible areas;
- fast data acquisition;
- making the invisible visible (spectral range);
- time-stamped coherent spatial information;
- digital (semi) automatic processing possibilities.

Satellite remote sensing data is used to study and monitor land features, natural resources and dynamic effects of human activities on urban areas. A broad base map of the city and adjacent regions indicating physical features may be prepared quickly with the help of satellite imageries. Using the ground truth or interpretation key, the remote sensing data is analysed, interpreted and maps related to existing features, land use, resource analysis, *etc.* could be generated.

The information derived from remote sensing data has to be reliable and therefore must carry some sort of quality label. The usefulness of this quality label is visible when combining different data sets in a GIS or when using it as input for different spatial models (Hagman, 1998).

3. ROLE OF GEOGRAPHIC INFORMATION SYSTEM (GIS)

A GIS is an information system that is designed to work with data referenced by geographic coordinates. A GIS can be thought of a chain of operation for working with spatial data, their storage and analysis to the use of the derived information for some decision-making process. GIS can play an extremely important role in resource management, environment monitoring, land use and planning activities (Xinhong and Hua, 1992).

Remote Sensing provides reliable, timely, accurate, and periodic data while GIS provides various methods of integration tools to create different planning scenarios for decision making. Advances in GIS-based tools and databases have made it easier to construct and model the urban pattern of an area (Gupta *et al.*, 2001). At the same time, increasing concerns over the impacts of developments of urban patterns has forced planners to undertake efforts to consider and analyze land use from a regional perspective point of view. Hence, there is an urgent need to adopt remote sensing and GIS based

approach in urban development and monitoring process for implementing pragmatic plan of urban development.

GIS and remote sensing technologies have the capabilities to provide necessary physical input and intelligence for preparation of base-maps, formulation of planning proposals and to act as monitoring tool during implementation phase of any urban planning scheme. Thus, GIS and remote sensing are emerging as a powerful land related technologies for monitoring and management of land.

4. OBJECTIVES OF THE PRESENT WORK AND STUDY AREA

The main objective of the present work is to develop a comprehensive geospatial database for urban planning for Allahabad city of Uttar Pradesh State, India through the use of satellite and other collateral data under GIS environment.

The city of Allahabad, taken as the study area for the present work, is covered between 25°24'00"N to 25°32'00"N latitudes and 81°45'00"E to 81°55'00"E longitudes. Total area of the city is about 97 km² and the population of the city is 10,49,579 as per 2001 census records. The maximum temperature is 46°C and minimum temperature 1.1°C while the annual rainfall is 1935.5mm. The municipal area of Allahabad city is shown in Figure 1. The study area falls in Survey of India (SOI) topographical maps 63G/14 and 63G/15 at 1:50,000 scale.

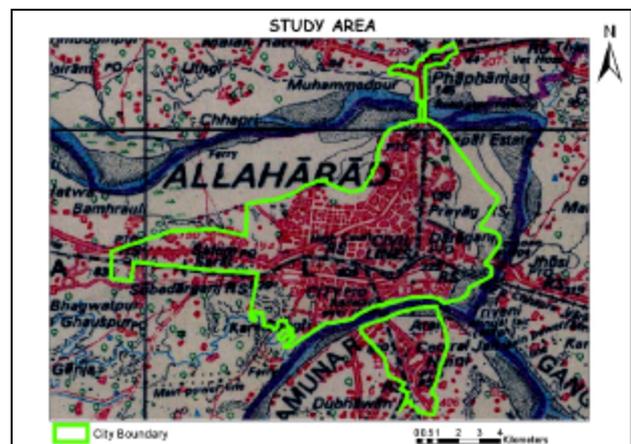


Figure1. Municipal Area of Allahabad City

5. METHODOLOGY ADOPTED

For the development of geospatial database for Allahabad city, ArcGIS 8.3 GIS software has been used. The land use/ land cover map has been prepared from IRS-1D LISS-III data of 2nd Dec. 2000 using digital image processing techniques. The Erdas Imagine 8.5 software has been used for this purpose. The spatial and non-spatial databases have been created separately and then

linked together through the use of common identifiers under GIS environment. A computer program has been developed in Visual Basic, implementing the ArcObjects of ArcGIS to develop the menu driven Graphical User Interface (GUI), incorporating the various elements of geospatial database. The development of GUI will make geospatial database more user-friendly and interactive.

6. DEVELOPMENT OF GEOSPATIAL DATABASE

The details of thematic maps created along with their attributes for the development of geospatial database for Allahabad city are discussed under subsequent heads.

6.1 Creation of Spatial Database

Knowledge of spatial land cover information is essential for proper management, planning and monitoring of resources. An urban plan must incorporate an integrated approach of spatial modelling using remote sensing and GIS. This helps in evolving efficient and economical models for development and location of industries, education, housing, water supply, service facility and disposal system, etc.

6.1.1 Land Use/ Land Cover Map:

Land utilization pattern of Allahabad city has been obtained by digitally processing the LISS-III image of IRS-1D satellite acquired on 2nd December 2000 (Figure 2). In Allahabad city, seven land use/ land cover classes have been delineated: urban/ built-up, vegetation, forestland, barren land, sandy area, and water bodies. The water bodies have been identified as river Ganga and river Yamuna and classified accordingly. A spectral based strategy with supervised classification was undertaken with the assistance of visual analysis of a displayed color composite. Ground data collection is conducted to study land use patterns and characteristics in relation to their spectral response pattern on the satellite image. Ground data was necessary to select training areas before spectral based classification techniques were used to derive thematic information.

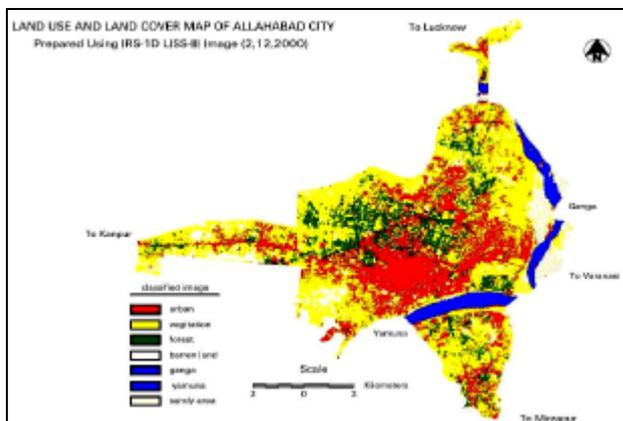


Figure 2. Land Use/ Land Cover Map of Allahabad City

The overall classification accuracy obtained for IRS-1D LISS-III classified image is 88.00% and the Kappa

coefficient comes out to be 0.86. The spatial extent of each land use/ land cover class has been given in Table 3.

Table 3. Area of Land Use/ Land Cover Classes

| S. No. | Land Use/ Land Cover Classes | Area (in ha) | Area (%) |
|--------|------------------------------|--------------|----------|
| 1 | Urban/ built-up | 2354.74 | 24.19 |
| 2 | Vegetation | 4645.80 | 47.72 |
| 3 | Forest | 1126.65 | 11.57 |
| 4 | Barren land | 728.75 | 7.49 |
| 5 | Water (Ganga) | 325.77 | 3.35 |
| 6 | Water (Yamuna) | 190.80 | 1.96 |
| 7 | Sandy area | 362.22 | 3.72 |

6.1.2 Road Network Map:

The road map of Allahabad city has been prepared from City Development Plan 2001, obtained from Nagar Nigam, Allahabad and updated by limited field surveys. The road network of Allahabad city has been divided in two categories firstly, major roads, including the highways crossing the city, and secondly streets, comprising of the roads joining the internal habitations of the city.

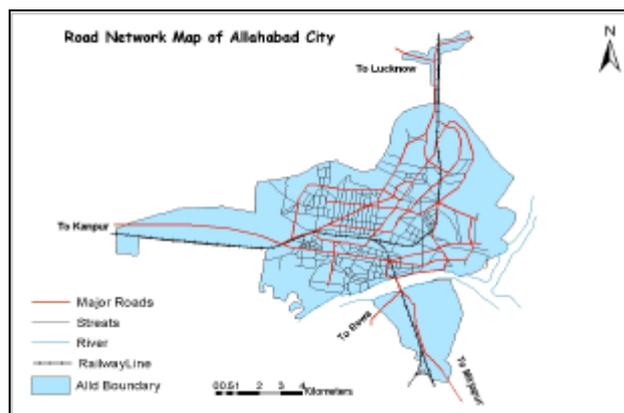


Figure 4. Road Network Map of Allahabad City

6.1.3 Water Supply Map:

The water supply map along with the location of water supply reservoir for Allahabad city has been prepared from the data provided by the Jal Sansthan, Allahabad.

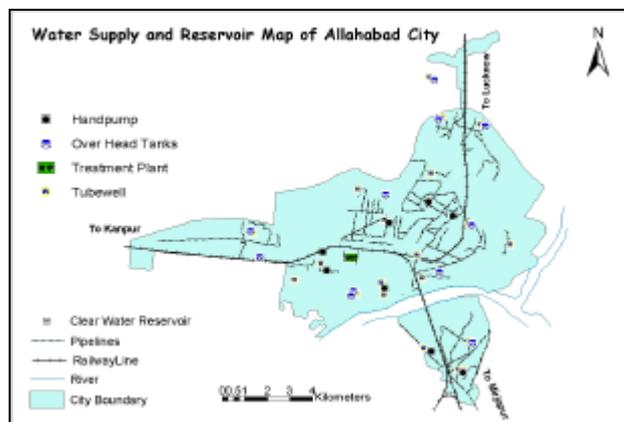


Figure 5. Water Supply Map

6.1.4 Solid Waste Disposal Map:

The solid waste disposal map of Allahabad city has been prepared from the data obtained from the Nagar Nigam, Allahabad. There are six disposal sites identified in the vicinity of Allahabad city, namely, Sulem Sarai, Kareli, Naini, Alopi bagh, Chandpur salori and Phaphamau.

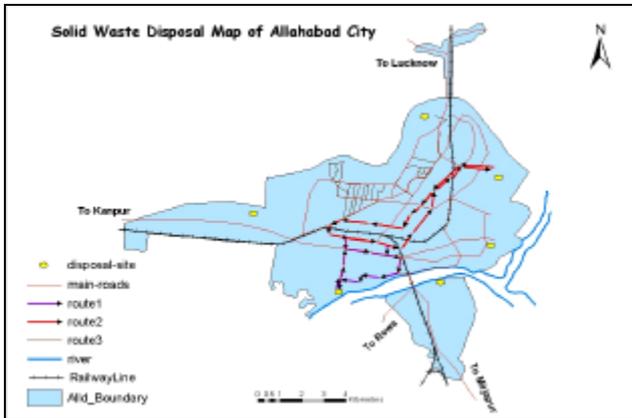


Figure 6. Solid Waste Disposal Map

6.1.4 Soil Map and Ground Water Potential Map:

The soil map and ground water potential map of Allahabad city have also been generated for making the spatial database more comprehensive.

6.2 Creation of Non-Spatial Database

The non-spatial database comprises of demographic and socio-economic data which has been obtained from Census 2001 and limited field visits. The non-spatial data has been entered in tabular format.

6.3 Integrated Geospatial Database

For the development of integrated geospatial database, the spatial database has to be properly linked to non-spatial database through the use of common identifiers. The various elements of spatial database have been properly linked with their corresponding attributes. Thus, the attribute data in tabular format has been integrated with the city map of Allahabad by joining the tables with thematic layers. The integrated geospatial database has thus been generated for Allahabad city under GIS environment.

7. DEVELOPMENT OF GRAPHICAL USER INTERFACE (GUI)

An ActiveX DLL project in GIS has been created using Visual Basic 6.0 and ArcObjects of ArcGIS software to develop a menu driven application interface for planners and decision-makers for accessing the geospatial database in an interactive manner. The ArcObjects of ArcGIS provide an infrastructure for application customization that lets one to make user-specific and user-friendly module framework to serve the specific needs of the end-

user (Burke, 2004). The ActiveX DLL project comprises of various modules, class modules and forms built to complete GUI application for incorporation in ArcGIS.

The GUI developed is menu driven and easy to use. It can be used easily by a person having basic computer skills but not possessing in-depth knowledge of GIS for extracting the information as per the requirements of an application. The main toolbar of the GUI developed in the present work has been shown in Figure 7 which highlights the use of the geospatial database.



Figure 7. Main Toolbar of GUI Developed

The developed GUI comprises of various menus and buttons to incorporate the spatial and non-spatial database which have been linked together. The GUI menu enlisting the spatial database containing land use/ land cover map, road network map, water supply map and solid waste disposal map, etc. is shown in Figure 8.



Figure 8. Spatial Database Menu of GUI

Further, the developed GUI is integrated and implemented in ArcGIS, through the DLL file generated in Visual Basic and is shown in Figure 9.

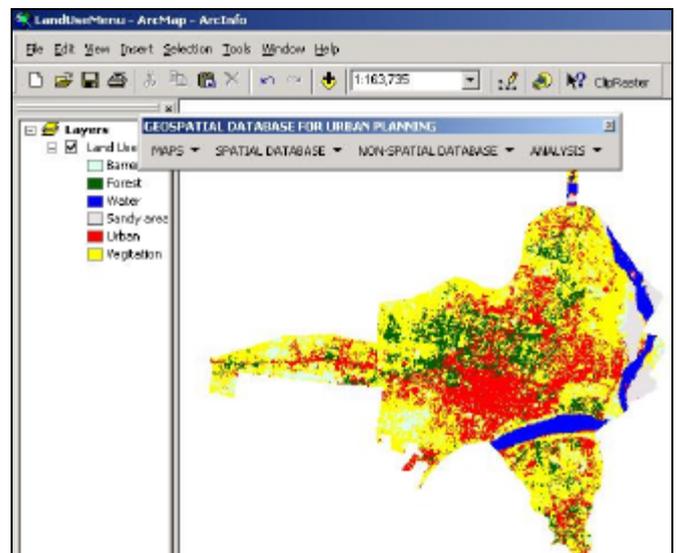


Figure 9. GUI Implemented in ArcGIS

8. CONCLUDING REMARKS

A GIS and remote sensing based geospatial database has been developed to assess, map and monitor the urban land utilization pattern in Allahabad city. The geospatial database is modular and can be updated to accommodate additional information about the city in the form of new thematic layers in future so as to make it more comprehensive.

The GUI developed by incorporating the various components of geospatial database and implementing it under GIS environment will help the planners of Allahabad city in making more informed decisions in the field of urban planning and management. The menu driven and user interactive GUI developed is expected to increase the acceptability and utilization of integrated geospatial database among planners and decision makers.

The GIS based geospatial database framework developed in the present work may be adopted for other urban cities by making modifications in the input parameters.

Disclaimer

Trade and Product names are mentioned for completeness and no endorsement is intended by the authors or the institute concerned.

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