A multi-scale Urban Analysis Using Remote Sensing and GIS

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Abstract

Urban planning was very much a design and engineering exercise with the state as a single stake holder. Mega cities with millions of population, has undergone a series of physical as well as socio-economic changes over the last 60 years. In India, Hyderabad experienced a high rate of urbanization facing structural, environmental, social and economic problems. To provide a holistic perspective on the urban characteristics, an interdisciplinary research approach is used. GIS-Geographic Information System and Remote Sensing provide the advance techniques and methods for studying urban land development and assist urban planning.

Keywords: GIS, Remote Sensing, Multi-Scale Urban Analysis, Land Use Change, Urban Growth, Urban Planning.

1. INTRODUCTION

Mega cities the largest category of urban agglomeration, attract considerable attention because of their population size, economic, socio-cultural, environmental and political influence and geographical complexity. Until 1975 there were just three mega cities in the world. The number of so-called mega cities increased in the period from 1975 until today from 4 t0 22, mostly in less developed regions [11].The number of cities increased to 27 mega cities until 2015 [8].The population development of the world is expected to increase continuously from 6.7 billion to 9.3 billion in 2050. But a heavy increase of mega cities creates a serious problem in India. The population of India (today 1.2 billion) has grown two and half times, but the urban population has grown nearly five times. The number of Indian mega cities will double from the current three (Mumbai, Delhi and Kolkata) to six by the year 2021, (new additions will be Bangalore, Chennai and Hyderabad), when India will have the largest concentration of mega cities in the world [4].

Then the number of six mega cities (Mumbai, Delhi, Kolkata, Bangalore, Chennai and Hyderabad) is increased by twelve by the year 2015 (new Ahmadabad, Pune, Surat, Kanpur, Jaipur and Lucknow) [17]. With the rapid increase of urban growth, makes us to face lot of socio-economic, environmental and political problems. This phenomenon will necessitate advanced methodologies such as space technologies, which help city planners, economists, environmentalists, ecologists and resource managers solve the problems which accompany such growth [9]. Urban planners need information about the rate of growth, pattern and extent of sprawl to provide the basic amenities such as water, sanitation and electricity etc. Since planners currently lack such information, most of the sprawl areas lack basic infrastructure facilities.

On the last decade, earth observation sensors developed to a stage where global maps have been made possible on low resolution (LR) from 250m to 2 Km [14]. Examples are global urban extent maps based on e.g., DMSP-OLS night-time lights imagery [6] ,MODIS data [3][15].A list, analysis and comparison of the various available global data sets is presented and discussed by Potere and Schneider [13]. However, most of them are provided for a single time step, and the cause geometric resolution is a clear restriction tracing the small-scale urban outlines, extents and patterns. Even though higher resolution sensors systems are available e.g., Land sat, spot, Rapid Eye, IRS, IKONOS, Quick Bird, World View-I and II. The provision of a global coverage or at least of a large amount of cities – is not an easy task. Limitations such as cloud coverage, on bound storage capacity, sensor utilization and sharing of the same source with other EO projects cause a several years lasting acquisition period. Furthermore, data costs and processing effort are significant. Thu, a global coverage at the scale covered by the medium (MR: here defined as on 10m to 100m) and high resolution (HR: 1M-10m) to very high resolution (VHR: <1m). EO sensors are inexistence.

Research studies on long term monitoring of the spatial effects of the urbanization are mostly based on MR (Medium Resolution) data from sensors such as Land sat or spot, having lower geometric resolution and thus allow for fewer thematic details. Different studies have also shows that radar imagery is an excellent basis for classifying, monitoring and analyzing urban conglomerations and their development overtime especially in cases of large area mapping [5].Using of MSS[Multi Spectral Scanner) data ,ETM (Enhanced Thematic Mapped data) and & Terra SAR-X Strip map data is used for monitoring urbanization in mega cities from space for analysis of 22 to 27 mega cities and their number is constantly increasing [8].Temporal and spatial urban sprawl, re-densification and urban development in the tremendously growing six mega cities to 12 mega cities in India, and became the largest urban agglomerations [19].

In India, by using Quick bird data of VHR (Very High Resolution <=1M i.e., 0.61M) with a sub-meter geo-metric resolution is applied for the multi-scale urban analysis of the Hyderabad metropolitan area of deriving parameters such as houses, streets, shadows, vegetation, bare soil etc.,[17].For the analysis of the urban patterns, first we have to classify the obtained data. The classification of the various land-sat scenes is based on an object-oriented classification procedure [16]. The first step is a multi-resolution segmentation. The second step is a hierarchical thematic classification procedure allowing mapping four different thematic classes, namely ‘water’, ‘vegetation’, ‘undeveloped land’ and ‘urban’ [2].

In this paper focused on the multi-scale approach with remote sensing, to support urban management with area-wide and up-to-date datasets in Hyderabad.

The main objective of this paper is:

- Landsat data enable to monitor the entire urban area and its extension as overview level.
- A time series allows for urban change detection to study urban growth and its characteristics overtime.
- At the far end of the multi-level approach Quick bird data provide highly detailed information on the structural characteristics of the urban morphology.

Further on, it will be illustrated how remote sensing can contribute basic information for improving technical supply and disposal infrastructure, e.g. for water, transportation, energy, sewage water, waste, traffic etc.

2. STUDY AREA

India is a small country, whose population is concentrated predominantly along the Mediterranean climate, is close proximity to its major cities Delhi, Kolkata, Mumbai, Chennai, Bangalore, Hyderabad figure(1). The study focuses on Hyderabad city, is a sprawling metropolis with a population of 6.8 million and growth rate of 2.5 percent per year. The population of the city can be reached to 10 to 13 million in 2020 turning it into one of the megacities of tomorrow [12].

“Megacities are undergoing new dynamics and, as a consequence are facing new spatial and organizational challenges” [1]. The performance in megacities is seen as a key factor regarding global sustainable development .First targets for future development are set in Hyderabad’, master plan and in the “City Development Strategy” of 2003 [12]. The city has faced many problems such as

- Transport system
- Water supply
- Pollution of air, water, sound etc
- Inner city infrastructure etc

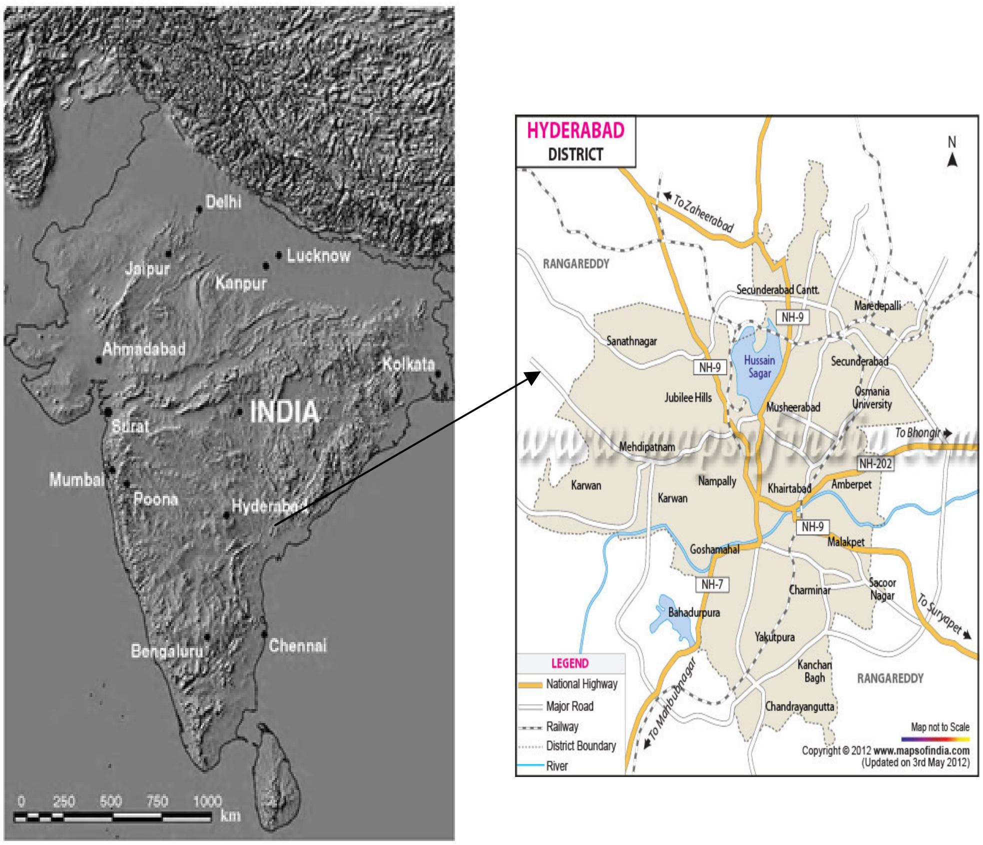

FIGURE 1: Location of Hyderabad in India.

3. DATA AND METHODS

A. Data

It started with the Multispectral-scanner(MSS) featuring a geometric resolution of 59 meters and a spectral resolution of four bands(green, red, two near infrared bands).Since 1982 the thematic Mapper (TM) has operated with 30 m geometric resolution and seven spectral bands. Since 1999 the Enhanced Thematic Mapper (ETM) has operated with an additional panchromatic band and 15m geometric resolution. Since 2002 Ikonos data of with 1m geometric resolution and since 2005 Quick bird data with 0.61m geometric resolution for finding the illegal constructions in the inner city [17].With its field of view of 185 KM the satellite is able to survey the large metropolitan areas of the study sites-thus covering in dependence of their spatial position entire areas and no cloud coverage.

The Landsat images 1997 and 2007 [22] [21] are collected from NRSC; Hyderabad is used for to detect the urban growth. The other Quick bird data of the year 2010 is also collected from NRSC; Hyderabad [20] is used for high resolution analysis.

The level of description with Land sat features is not flooded with microscopic detail, but re-gives nevertheless the specific features of the urban system. For this purpose, the requirements for the differentiation of classes are limited to the classification of built-up and non-built-up areas.

B. Methodologies for Land Use / Land Cover Classification

Landsat data of Hyderabad for different years were used for the detection of recent changes of the urban extension. The data was enhanced before classification using histogram equalization in ERDAS Image 9.2 to improve the image quality and to achieve better classification accuracy. A land cover classification extracting the classes' built-up areas, non-built-up areas, vegetation and water was performed separately on both images. The main goal is to identify the urban built-up areas to measure the changes of the urban extension over the time interval. For that purpose the classification methodology is based on an object-oriented hierarchical approach. The object-oriented methodology was used to combine spectral features with shape, neighborhood and texture features [17].

Post classification comparison was found to be the most accurate procedure and presented the advantage of indicating the nature of the changes [10] .An automated object-oriented for an extraction of detached houses, of main street infrastructure, of vegetation areas, of bare soil and of water areas. The methodology presented by [17] was applied to the Quick Bird data of Hyderabad.

A comparative analysis of land cover classification analysis of land cover classifications for times t1 and t2 performed independently was therefore implemented to monitor and analyze the land cover changes in the metropolitan area of Hyderabad. Pixel wise change detection was implemented in the flow chart figure (2) checking the land cover classes individually.

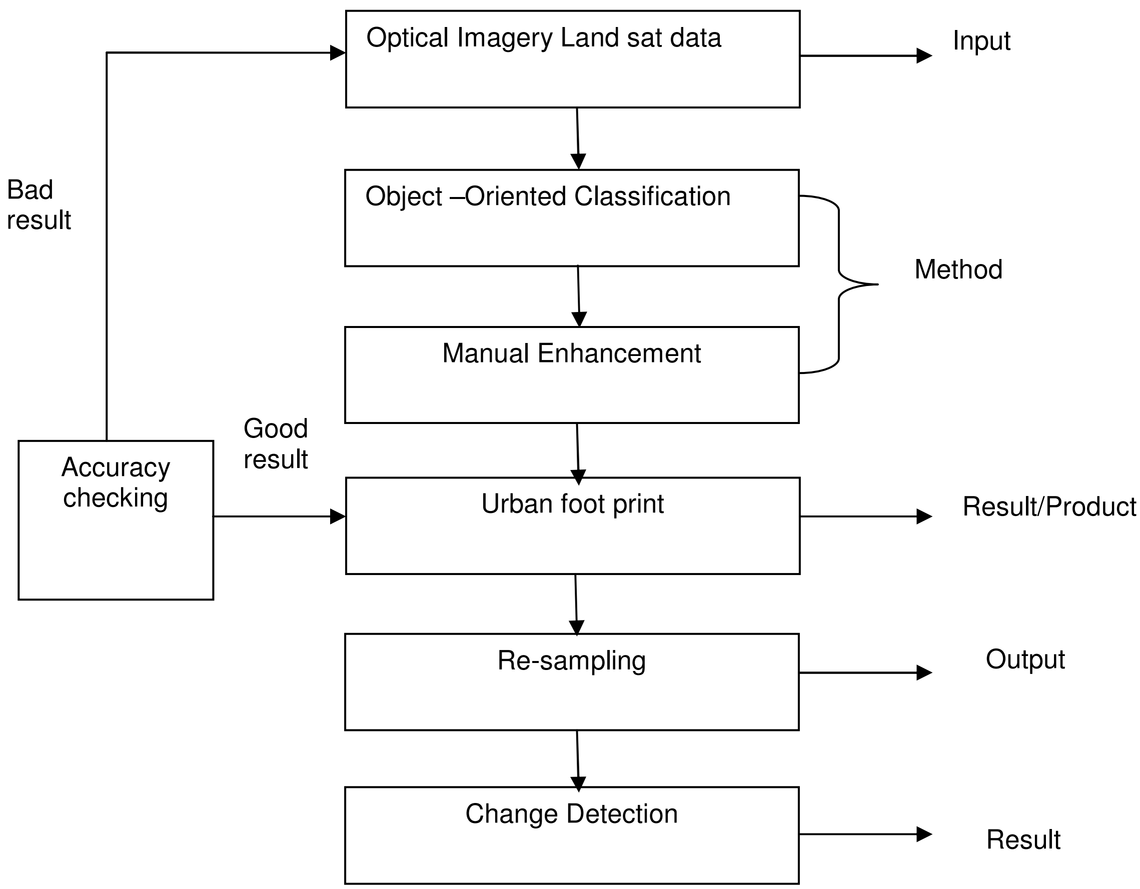

FIGURE 2: Flow Chart of Methodology for Land Use/Land Cover and Change Detection.

4. RESULTS, CHANGE DETECTION AND DISCUSSIONS

For the mega cities of the world featuring four individual urban foot print classification at four time steps in the mid-1970's, around1990, 2000 and 2010. The change detection allows identifying, localizing and quantifying the pattern and dimension of urban sprawl overtime. Since 1975 the population development and thus, the rate of urbanization in the mega cities outside the high developed countries were enormous [8]. At a first glance, a number of trends are immediately clear in terms of spatial dynamics of urbanization over the time period observed is the highest in developing countries. Beyond this, the spatial extents in developed countries are noticeably larger with respect to the absolute population. The first and the most natural analysis is the measurement of spatial urban expansion over time. The quantification of urban growth for the metropolitan areas of the mega cities are calculates as relative growth.

The urban analysis aims at a holistic understanding of the dynamics of urban growth process. The different perspectives on the city of Hyderabad are caused through the different data types. In contrary the capabilities of the Quick Bird data with its high geometry resolution allow highly detailed analysis of the urban structure and the neighborhoods [17]. The different remote sensing data contribute to a multi-level perspective within an interdisciplinary GIS database to support the information basis for sustainable urban development.

A. Remote sensing

Here we used the images of Hyderabad of the years 1997 and 2007 for the detection of recent changes of the urban extension. The contribution of remote sensing to the planning of sustainable urban development is two-fold. On the one end hand a spatial overview on the extension of the city and its structure change over time is presented. On the other hand a highly detailed analysis of the urban structure.

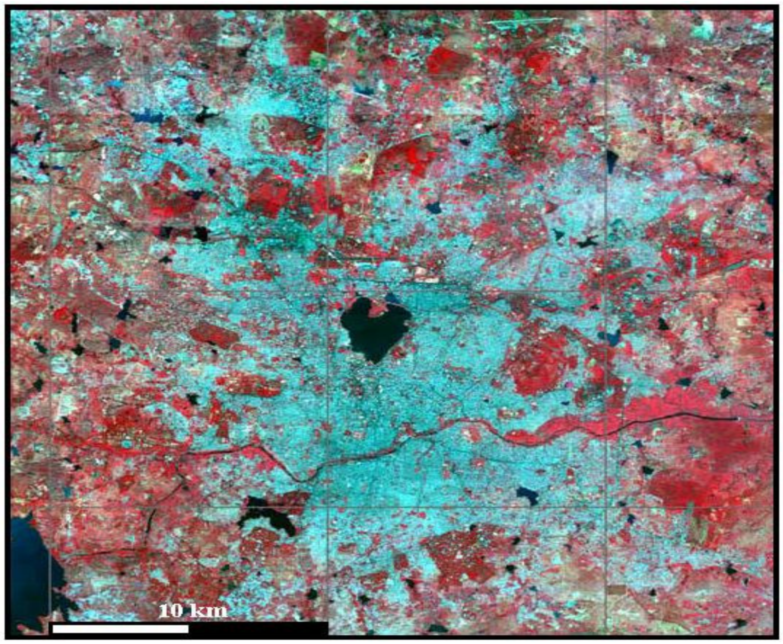

FIGURE 3: Landsat Imagery of Hyderabad, 2007.

The main goal is to identify the urban built-up areas to measure the changes of the urban extension over the time interval. A comparative analysis of land cover classification for times t1 and t2 performed independently was therefore implemented to monitor and analyze the land use patterns in the metropolitan area of Hyderabad. Pixel wise change detection was implemented checking the land cover classes individually of the two available years.

In figure (4), the spatial expansion of the urban built-up areas of Hyderabad between 1997 and 2007. In particular, the urban sprawl in the periphery and densification process in Hyderabad. New developments arise on the outskirts of Hyderabad. Nevertheless, focal points emerge in the northeast as well as in the southeast shows in the results.

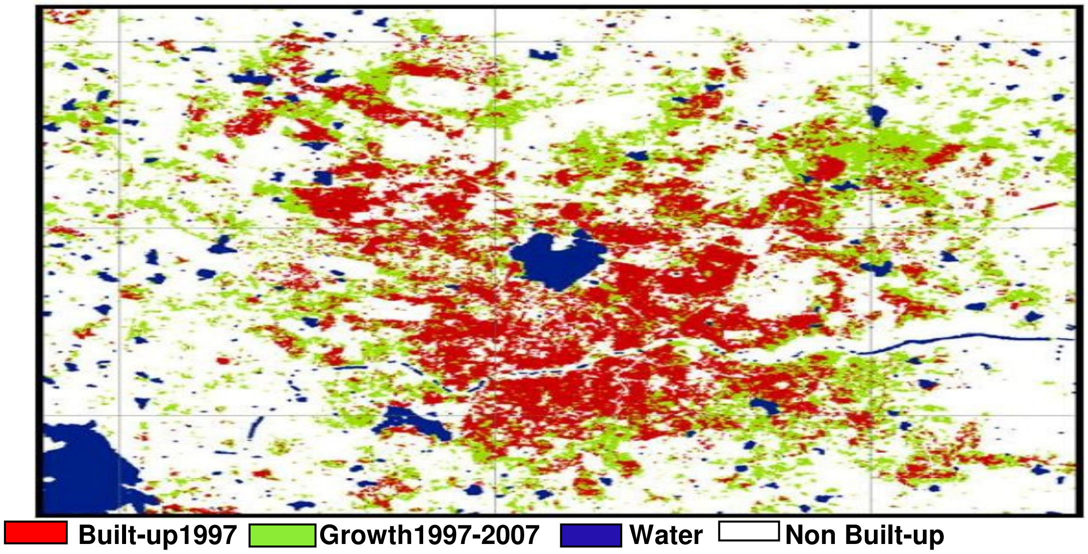

FIGURE 4: Urban Growth in Hyderabad Between 1997 and 2007.

In 1997, the urbanized area was 130km2. By the change detection, the urbanized areas were increased of about 2.5 times as large as in 1997 was measured. In the olden days only low resolution data is available. For a large scale analysis of urban growth in the metropolitan area of Hyderabad high resolution satellite image i.e. QuickBird data, Ikonos data were came up. That satellite image can support a detailed analysis of the small-scale urban morphology. In addition to this example a satellite data of another time period i.e. 2010, an automated object-oriented classification approach was implemented for an extraction of detached houses, of main street infrastructure, of vegetation areas of bare soil and of water areas. The methodology presented by [17] was applied to the QuickBird data of Hyderabad.

The methodical framework was inherited, with adjustments on the spectral peculiarity of the particular sense. For validation of the classification results an accuracy assessment has been carried out. The accuracy shows an average of more than 80% of houses have been classified correctly. This analysis of the current status of the built-up environment provides useful spatial information for a sustainable urban management. In future enables the calculation of the built-up density and provides necessary information for the analysis of the location and the carrying capacity of the street infrastructure as well as the analysis of accessibilities. The main infrastructure was extracted for an assessment of the street network performance against built-up densities. Highly dense built-up areas alternate with less dense areas, or even open spaces. The urban land covers classification of the heterogeneous urban structure in Hyderabad shown below.

FIGURE 5: QuickBird Imagery of Hyderabad, 2010.

Noticeable are the different urban morphologies which are a result of the various building sizes, shapes or alignments. The shape features enable a basic differentiation between residential and commercial usage.

Remote sensing is a feasible instrument for efficient and cost-effective analysis of the urban land cover overtime. Urban structures reflect the distribution of the population, the level of prosperity, and different units as well as infrastructure. These results from remote sensing are indispensible up-to-date spatial information to support substantial urban planning and decision making.

B. Interdisciplinary Integration

The infrastructure for housing, vegetation, water bodies etc is not sufficient, but we want spatial information for future planning. This infrastructure is not directly be measured from space, we also collected data by field surveys showing the urban structure, social structure, mobility patterns, energy and water flows. These data will be combined with remote sensing in order to expand this local information to a wider area. The results will be organized in a common GIS database. A detailed analysis of demand is a prerequisite for technical infrastructure planning of both supply and disposal services, e.g., of water, energy, sewage water and waste. The development often lack a cross cutting analyses also assessing the impact on different sectors. A common database is a first step to provide necessary information. Procedures for cross cutting analyses and evaluation have to be developed and introduced. The first cross analyses with existing data coming from the master plan in selected neighborhood show already the frictions. But available data from the city administration are not up to date and new illegal and informal constructions can be found all over the city.

Since large as well as small and medium sized man made constructions which are numerous in the city of Hyderabad are important users of technical infrastructure, a detailed knowledge of their demand and spatial distribution would allow an infrastructure planning that a better adapted to the real needs. It can also serve as basic information for improving technical equipment concerning traffic in the roads, water use, waste, energy etc and thus achieving resource savings and emission reductions. Therefore, a GIS based inventory and including information on their demand of supply and disposal services is being developed for a part of the city of Hyderabad. Remote sensing provides a first indication of the position of urban growths arise on the outskirts of Hyderabad.

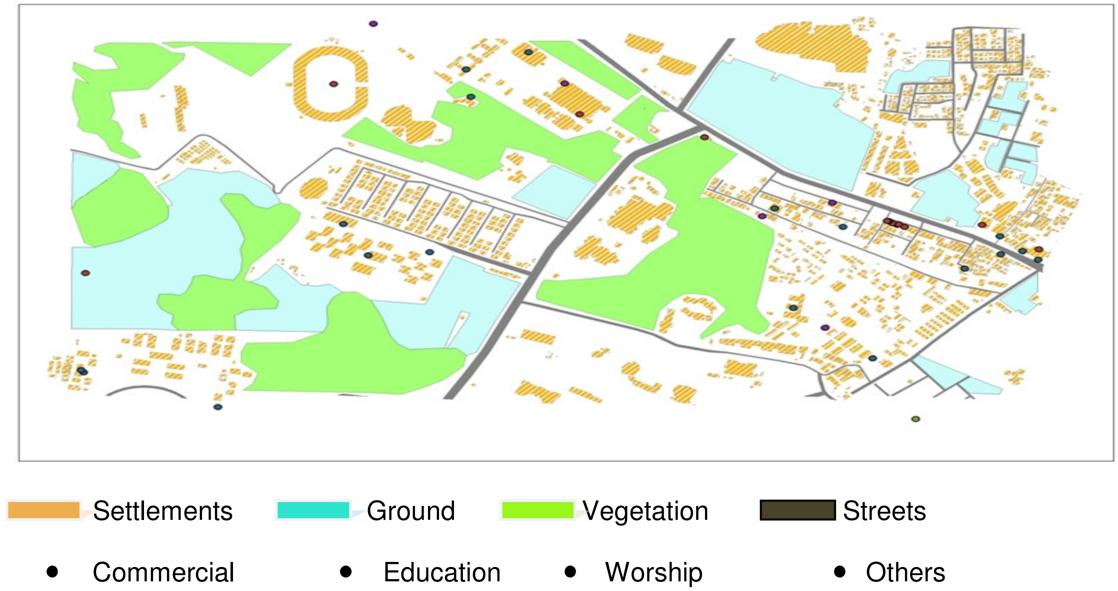

FIGURE 6: Analysis of services in Telecom colony based on remote sensing data supported by site visits.

For an inventory of different built-up areas clearly, the remote sensed data is supplemented by information provided by local partners are collected in surveys and site visits which allows in the end an assessment of supply and disposal needs. A possible example of the application of remote sensing combined with site visits to analyze the situation in the "Telecom colony" neighborhood, at Hi-tech city, e.g. education, worship, commercial etc .The land use data (green and orange) in figure (6) is derived from remote sensed data and represents the basis for a mapping sensed data and represents the basis for a mapping of the services. Hence, the interdisciplinary approach enables a more holistic view on the urban functions and structures. Beside the basic data about the situation today also monitoring is a big issue. Therefore one of the basic questions is what kind of data is really necessary and can be kept up to date with a reasonable effort. Taking into account the rapid changes, methods like remote sensing are expected to bring a substantial contribution.

5. CONCLUSION

To fight with the problems faced by the rapid urban growth, various scientific perspectives are necessary for a holistic assessment of urban situations. The major problems associated with the urban centers in India are that of unplanned expansion, changing land use / land cover areas [4].

For this, remote sensing imagery, with its repetitive and synoptic viewing capabilities, together with GIS, is important tools to map areas and monitor the changes in the urban growth. High-resolution satellite data is applied for the multi-scale urban analysis of the Hyderabad metropolitan area of deriving parameters such as houses, streets, shadows, vegetation, bare soil etc., [17]. This paper focused on the multi-scale approach with remote sensing, to support urban management with area-wide and up-to-date datasets. The Land sat analysis enabled the monitoring of the urban growth overtime to understand the dynamics and characteristics of the metropolitan area of Hyderabad. This includes also information about the direction of urban growth.

Thus, remote sensing and GIS provided to be a very useful basis for a more detailed analysis of the spatial distribution, an emerging megacity which is prerequisite for a reasonable planning of technical infrastructure. The officials of various government departments should be given through exposure and training of remote sensing and GIS for its application implementation in the urban management plans. This multilayer spatial information allows analyzing and anticipating developments to support future planning strategies.

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