MEASURING URBAN SPRAWL THROUGH SHANNON'S ENTROPY- AN APPROACH USING REMOTE SENSING AND GIS

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Abstract: The impact of population growth on urban sprawl has become a topic of discussion and debate. In India, unprecedented population growth coupled worth unplanned development activities has resulted in urbanization. The urbanization takes place either in radial direction around a well-established city or linearly along the highways. The growth rate has also indicated an increasing trend. In addition, the pressure of continuously growing metropolitan city is also changing the structure of the town and its surrounding neighborhood. I have tried to investigate the changes in land use pattern of Gurgaon region that have occurred over the past few decades, and have tried to associate them with population growth, urbanization and industrialization of the countryside. This part of the project presents the entropy method to analyze urban sprawl based on the integration of remote sensing and GIS. The advantages of the entropy method are it simplicity and easy integration with GIS. GIS (Geographical Information System) is a computer based integrated database management system that stores a large volume of spatial data along with its attribute or non-spatial data which are captured, stored, retrieved, processed and analyzed to provide answers to queries of a geographical nature as and when required.

Index Terms - Urban Sprawl, Remote Sensing (RS), Geographical Information Systems (GIS), Shannon's Entropy, Spatial Analysis.

I. INTRODUCTION

In India, unprecedented population growth coupled with unplanned developmental activities has led to urbanization, which lacks infrastructure facilities. This also has posed serious implications on the resource base of the region. The urbanization takes place either in radial direction around a well-established city or linearly along the highways. This dispersed development along highways, or surrounding the city and in rural countryside is often referred as sprawl (Theo bald, 2001). Some of the causes of the sprawl include population growth, economy and proximity to resources and basic amenities. The direct implication of such urban sprawl is the change in land use and land cover of the region. Patterns of sprawl and analyses of spatial and temporal changes could be done cost effectively and efficiently with the help of spatial and temporal technologies such as Geographic Information System (GIS) and Remote Sensing (RS) along with collateral data (such as Survey of India maps, etc.). GIS and Remote Sensing are land related technologies and are therefore very useful in the formulation and implementation of the land related component of the sustainable development strategy. The spatial patterns of urban sprawl over different time periods, can be systematically mapped, monitored and accurately assessed from satellite data along with conventional ground data (Lata et al., 2001). Mapping urban sprawl provides a "picture" of where which type of growth is occurring, helps to identify the environmental and natural resources threatened by such sprawls, and to suggest the likely future directions and patterns of sprawling growth. Remote sensing and GIS can be used separately or in combination for application in studies of urban sprawl. In the case of a combined application, an efficient, even though more complex approach is the integration of remote sensing data processing, GIS analyses, database manipulation and models into a single analyses system (Michael and Gabriela, 1996). Such an integrated analyses, monitoring and forecasting system based on GIS and database management system technologies requires an understanding of the problem and the application of available technologies. Remote sensing applications are growing very rapidly with the availability of high-resolution data from the state of the art satellites like IRS-1C/1D/P4 and LANDSAT. The remote sensing satellites with high-resolution sensors and wide coverage capabilities provide data with better resolution, coverage and revisit to meet the growing applications needs. The image processing techniques are also quite effective in identifying the urban growth pattern from the spatial and temporal data captured by the remote sensing techniques. The physical expressions and patterns of sprawl on landscapes can be detected, mapped, and analyzed using remote sensing and geographical information system (GIS) (Barnes et al., 2001) with image processing and classification

A. Statement of the Problem Statement:

The impact of population growth on urban sprawl has become a topic of discussion and debate. In India, unprecedented population growth coupled worth unplanned development activities has resulted in urbanization. The urbanization takes place either in radial direction around a well-established city or linearly along the highways. The growth rate has also indicated an increasing trend. In addition, the pressure of continuously growing metropolitan city is also changing the structure of the town and its surrounding neighborhood. I have tried to investigate the changes in land use pattern of Gurgaon region that have occurred over the past few decades, and have tried to associate them with population growth, urbanization and industrialization of the countryside. This part of the project presents the entropy method to analyze urban sprawl based on the integration of Remote sensing and GIS. The advantages of the entropy method are it simplicity and easy integration with GIS.

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II. OBJECTIVE

The objectives of the study are as follows:-

- To prepare land use and land cover maps.
- To study Shannon's Entropy to find pattern of urban sprawl.

III. DATA BASE

A. DATA SOURCES:

Various types of data sources have been used in this report. The sources of data have been used as per the requirement of the objectives of the study. The sources of data collected can be put under the following two categories:-

(a) PRIMARY SOURCES:

The primary data was collected from the field survey during November -2015 through observation. Field survey was undertaken to collect information on attribute regarding the location, purpose, and area.

B. MATERIALS AND METHODS:

The study Gurgaon, Haryana using conventional sources of data such as topographical sheets, guide maps, field survey as well as Remote Sensing and GIS. Efforts will also be made to put this Database into GIS format as a decision supporting tool so that various trend answers to queries could be derived conveniently quickly and precisely. Situated to requirement of theme under study different methodology and techniques have been used. The technologies of Remote Sensing, GIS and Google earth ,(GPS) have been applied in this study. The entire work has been done by using GIS and Remote Sensing software Arc map 9.3.1 version. The interpretation was aided by ground truth and local knowledge. Base map of Chandigarh was georeferenced using (Ground Control Points) on Google Earth. Digitization was done in Arc Map 9.3.1 version software.

C. Aim of study

The broad aim of this study is to apply the application of Remote Sensing & Geographical Information System. Remote Sensing technology will be applied for generation of spatial data; Geographical Information System will be used to analyze data, to prepare selected inputs for the formation of the development plan of area, to understand growth of urban sprawl through different years and changes of land use/land cover.

IV. STUDY AREA:

Gurgaon is a district major city in Haryana and the heart of a main industrial area. Gurgaon, situated in the National Capital Region has developed into a big and successful town because of its surrounding area to New Delhi - the Indian capital. Gurgaon Haryana is a large, fast-growing city and main industrial area found about 30 km from the city of New Delhi and only about 15 km from New Delhi's International Airport. Gurgaon Haryana enjoys all the services available to Delhi. Gurgaon Haryana is home to offices of lots MNCs and is well connected by rail and road to Delhi, Faridabad and Jaipur. Gurgaon Haryana is known as the Millennium City. Gurgaon Haryana is one of the main satellites of Delhi, forming a part of NCR (National Capital Region). Historically speaking, the name Gurgaon appears to have its origins in the word "Guru-Gram" later changed to 'Gaon'. According to myth, it was a family village gifted by Kauravas and Pandavas to their guru Dronacharya. It is also known as the Cyber City. It's no wonder then that the city has seen its market booming over the last ten years. This Gurgaon city accounts for a major piece of income tax for Haryana. Gurgaon in Haryana has been mostly a business city, home to many industries, and so there aren't any places of historical significance. However, you could trip a couple of places around the city. You could trip theSheetala Devi Temple, committed to the goddess of small pox. Damdama Lake, south of Gurgaon, presents picnic spots, boating and rides on a hot air balloons

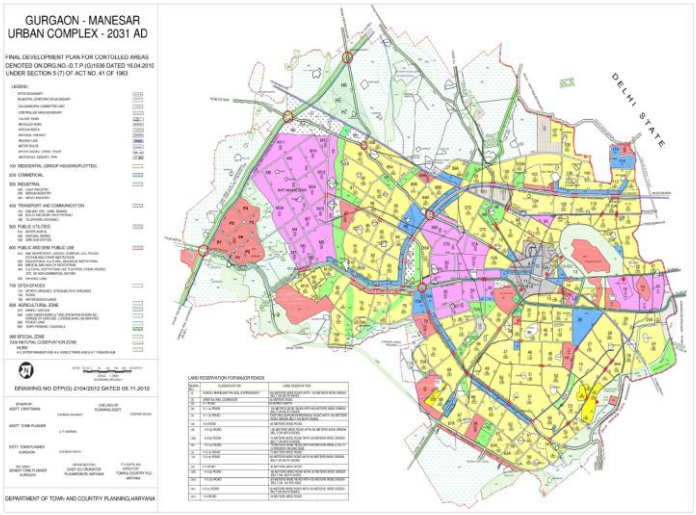

Figure 1

Source: Department of Municipal Corporation, Gurgaon(2015).

V. GEOGRAPHICAL INFORMATION SYSTEM

A. Remote Sensing:

Remote sensing is defined as "collecting and interpreting information about a target without being physical contact with object". Aircraft and satellites are the common platforms for Remote sensing observations. The term Remote Sensing is commonly restricted to methods that employ electromagnetic energy (such as light, heat and radio waves) as the means of detecting measuring target characteristics. It also gives a view of the area and also the difference in tone, texture, shape and pattern for difficult units. Experience shows the Remote sensing technique gives a lot of information that are very difficult to get from the field.

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The Geographical Information System is defined as "An automated tool to capture, store, retrieve, manipulate, display and query of both spatial and non-spatial data to generate various planning scenarios for decision making Geographical Information System is essentially a comprehensive spatial decision supporting system of computer software and hardware, tool to merge spatial geo-referenced data with non-spatial attribute data for deriving meaningful information to be useful for Urban Planning and management. The assessment of physical parameters of land is possible by analyzing these parameters, and which is very much amenable to Geographic Information System (GIS) Analysis.

VI. MEASURING URBAN SPRAWL

To understand the complexity of a dynamic phenomenon such as urban sprawl; land use change analyses, urban sprawl pattern and computation of sprawl indicator indices were determined. The characteristics of land use land cover, roads and railway network and the administrative boundaries from the topographical sheets and master plan 2031 were digitized. Urban sprawl over the period of decades (1989-15) was determined by computing the area of all the settlements from the digitized topographical sheets of 1971-72. The topographical sheets were first geo-registered. Since urban sprawl is a process, which can affect even the smallest of villages, each and every village was analyzed.

Land Use of Gurgaon, Haryana

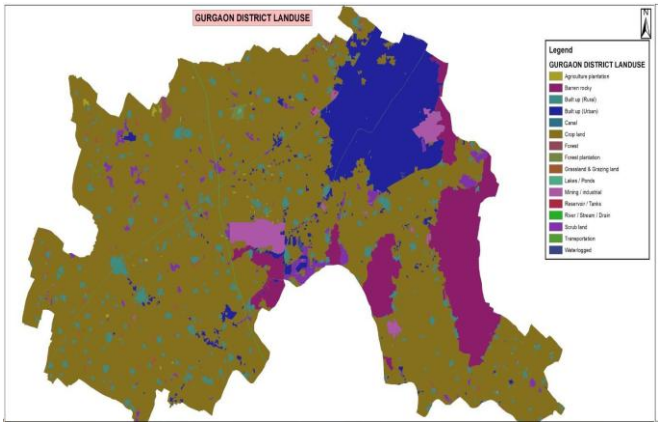

Figure 2

A. Built up Area as indicator of Urban Sprawl

The percentage of an area covered by impervious surfaces such as a asphalt and concrete is a straight forward measure of development (Barnes et at, 2001). It can be safely considered that developed areas have greater proportions of impervious surfaces, i.e. the built-up areas as compared to the lesser-developed areas. Sprawl is characterized by an increase in the built-up area along the urban and rural fringe, This attribute gives considerable information for understanding the behavior of such sprawls. This is also influenced by parameters such as, population density, population growth rate, etc. Pattern recognition helps in finding meaningful patterns in data, which can be extracted through classification. By spatially enhancing an image, pattern recognition can also be performed by Visual Interpretation.

B. Impact of Population on Urban Sprawl

Increasingly, the impact of population growth on urban sprawl has become a topic of discussion and debate. Typically conditions in environmental systems with gross measures of urbanizations are correlated such as population density with built-up area (Smart Growth America, 2000; The Regionalist 1997; Berry, 1990). The relation of population growth and urban sprawl is that the population growth is a key driver of urban sprawl. In India alone currently 35.73% of the population (Census of India, 2011) live in the urban centers, while it is projected that in the next fifteen years about 33% would be living in the urban centers.. It is quantified by considering the impervious or the built up as the key feature of Sprawl, which is delineated using topographical sheets or through the data acquired remotely. Most studies of the impacts of urbanization do not differentiate among various urban patterns.

VII. SHANNON'S ENTROPY

What is Shannon's Entropy?

This part of the Study presents the Entropy method to analyze Urban Sprawl based on the integration of Remote sensing and GIS. The advantages of the Entropy method are it simplicity and easy integration with GIS. The measurement of Entropy is devised based on the two-location factors distance from town centers and distance from roads, to reveal and capture spatial patterns of Urban Sprawl. The application of the method in Gurgaon city, Haryana, one of the fastest growing cities has demonstrated that it is very useful and effective for the monitoring of urban sprawl. It provides a tool of the quantitative measurement that is needed for rapidly growing regions in identifying internal variations and temporal change of Urban Sprawl patterns.

A. Need of Entropy

Rapid urban development and increasing land use changes due to increasing population and economic growth in selected landscapes is being witnessed of late in India and other developing countries. The measurement and monitoring of these land use changes are crucial to understand land use cover dynamics over different spatial and temporal time scales for effective land management. Today, with rapid urbanization and industrialization, there is increasing pressure on land, water and environment, particularly in the big metropolitan cities.. Urban sprawl has been criticized for inefficient use of land resources and energy and large-scale encroachment into the agricultural lands. There are many problems associated with fragmented conversion of agricultural land into urban use. The cities are expanding in all directions resulting in large-scale Urban Sprawl and changes in urban land use. The spatial pattern of such changes is clearly noticed on the urban fringes or city peripheral rural areas, than in the city centre.

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Inadvertently this is resulting in increase in the built up area and associated changes in the spatial urban land use patterns causing loss of productive agricultural lands, forest cover, other forms of greenery, loss in surface water bodies, depletion in ground water aquifers and increasing levels of air and water pollution.. There has been lot of debates on how to confine urban sprawl and conserve agricultural land resources (Bryant et al., 1982; Ewing, 1997; Daniels, 1997). There is a demand to constantly monitor such changes and understand the processes for taking effective and corrective measures towards a planned and healthy development of urban areas. In the present study 'Entropy Approach' for studying the Urban Sprawl patterns of Gurgaon over different time scales has been attempted.

B. Calculation of Entropy Value

Although various studies have been dedicated to the measurement or urban form, they have limitations in capturing the characteristics of Urban Sprawl. There methods are just developed in the context of image analysis or fractal theory (Webster, 1995; Batty and Longley, 19940; Here an alternative technique, Entropy, specifically to measure the extent or urban sprawl is developed with the integration of remote sensing and GIS. The measurement is directly carried out with in GIS to facilitate the convenient access to GIS spatial database. The measurement is based on Entropy theory, as Shannon's entropy (E) can be used to measure the degree of spatial concentration and dispersion exhibited by geographical variable (Xi) (Theil, 1967; Thomas, 1981). Entropy is calculated by:

$$E = \sum_{i}^{n} p_i \log(1/p_i)/\log(n) \qquad (1)$$

Where $p_i = x_i / \sum_{i}^{n} x_i$ and x_i is the observed value in the ith zone in a total of n zones. It ranges from 0 to 1. If the distribution is maximally concentrated in one region, the lowest value, zero will be obtained. The major difference between entropy and traditional indices of spatial dispersion is that its value is invariant with the value of zones, the number of observations.. In this study, the buffer function of GIS will be used to define buffers or zones for calculating entropy. This can allow some independent variables form GIS database to be easily embedded in entropy. Other morphological approaches have limitations to explore spatial relationships between urban sprawl and spatial factors because those methods are not directly developed within GIS. The information from GIS database is important because urban sprawl is always dependent on other geographicalvariables.
Since entropy can be used to measure the distribution of a geographical phenomenon, thus the measurement of the difference on entropy between time (t+1) and (t) can be used to indicate the change in the degree of dispersal of land development or Urban Sprawl.

$\Delta E = (t+1)-E(t)$ (2)

The dispersal of urban areas from a town center will lead to an increase in the entropy value the change of entropy can be used to identify whether land development is toward a more dispersed (Sprawl) or compact pattern. The following section will discuss how to use the entropy method to measure the rapid urban sprawl in a fast growing region with the integration of Remote Sensing and GIS.

C .The Application

It is easy to find that the urban sprawl is affected by some location factors-distance to urban centers and roads. Entropy should be calculated based on the distance variables to address the distance decay properties or urban sprawl. The influences of these locations factors were measured using the buffer functions of GIS. Types of buffer zones are devised to calculate densities of land development with regard to the distance variables. Entropy based on the buffer functions is given as:

$$E = \sum_{i}^{n} PDEN_i \log(1/PDEN_i)/\log(n) \qquad (3)$$

Where $PDEN_i = DEN_i / \sum_{i}^{n} DENi$ and DENi is the density of land development. DEN_i equals to the amount of land development divided by the total amount of land in the ith buffer in the ith buffer in total of n buffer
The thematic layer of urban sprawl of each period was obtained by the classification of multi-temporal satellite images. The thematic layers of buffers were created respectively based on the proximity to town centers using the buffer functions of GIS. The overlay of the urban images and the buffer images can capture the densities of urban sprawl in each buffer With the help of GIS, the area of land use under each buffer was found out. Three typical urban sprawl patterns can be identified in the city from the analysis The first type is concentrated (Low Development) as represented by Hongmei. The second type is Dispersed (Medium Development) as represented by Dalang which exhibited some dispersal away from the town center. The third type is Highly Dispersed (High Development) as represented by Tangsha. It has an upward increase in the density of land development and dispersal of urban development away from the town center. There three types of urban sprawl patterns can be reflected from the Entropy. In the first type of urban sprawl (concentrated), most of the land development is near the town center and the entropy is relatively small. Area farther away format the town center is not so favorable for land conversion and most of the land development is carried out only with in the distance very close to the town center. There is more spread land development in the second type (Dispersed) .the entropy is higher than that of the first type. For the third type or urban sprawl (Highly Dispersed), land development spreads over the urban fringe and to the surrounding rural area and the entropy is the highest among the three types of urban sprawl.

VIII. LAND USE AND LAND COVER MAPPING

What is land use and land cover?

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A. Land use: "The term land use relates to the human activities or economic function rated with a specific piece of land" (Lillie sand and Kiefer). In other words the land use denotes the multifaceted use of the land, which include both use and misuse of the land.

B. Land cover: "The term land cover relates to the type of feature present on the surface of the earth" (Lellesand and Kiefer). In other words land cover can be described as ground blanket of natural and culture landscape. It consists of vegetation, soils, snow, rocks, 'settlements etc. In view of the land use mapping the definition chosen must be that which is most useful in reviewing planning policies.

C. Why is land use as it is?

While knowledge of what currently exists is often a necessary condition for answering questions related to the use of land, it is rarely a sufficient one. To know how a particular parcel of land came to have its present use- for example, turning from forest to enclosed farmland to huge, hedge less fields or from green field to urban sprawl to decaying inner city slum-demand at a minimum a longitudinal profile of changes in use through time. Some such data exist of particular time periods and place. But even this sort of information generally available only on an incomplete and fragmentary Basis-may be insufficient for some explanatory purposes. In order to understand 'Why' land use changes as well as 'how the changes occur, it may be necessary to have information on who currently owns and who has owned the land in question. In general terms, these contentions are indisputable for both understanding past and present land use patterns and in any attempt to predict the future role and use of land.. Land use map is a most important map, which provides planers about present status of land use information of area. The increased importance of urbanization and the growth of urban areas from the 19th century to the present day have led to an increased study of patterns, extent of urban land use, conversion of rural to urban land, conversion and preservation of rural areas.

IX. EXISTING LAND USE CATEGORIES

These are descriptive land uses and do not reflect the actual zoning of the property.

Agricultural: This category includes land for the use for farming or for the raising of livestock. Agricultural activities include crop propagation, dairying, stock animal, and poultry.

Agricultural/Residential: This category includes land for farming as described above with residential uses on site usually single family detached residences.

Commercial: This category includes a wide range of commercial uses and service uses including retail, service businesses, restaurants, professional offices and medical related uses (except hospitals.

Industrial/Transportation/Landfill/Manufacturing: This broad category includes areas deemed appropriate for light/heavy industrial uses, which are generally not compatible with residential development. These uses include heavy manufacturing uses whose primary objective is for compounding, processing, packaging and assembling of products, construction, contracting, transportation, utilities, wholesaling, warehousing and mineral extracting uses.

Community Facilities: These land uses serve and meet community needs through a wide range of recreational facilities, funeral parlors, indoor recreation facilities, outdoor recreation facilities, residential care facilities, hostels, disability housing, childcare centers, parks, and cultural facilities.

Institutional: Uses that include churches, places of sacred and religious affiliation, cemeteries, hospitals, civic or religious uses, schools, public/private schools.

Green Space/Open Space: This category includes land for the use of nature preservation and passive recreation such as Hayes Arboretum and along the Whitewater Gorge. The category includes public parks, retention areas, lakes, golf courses, and greenbelts.

Water Tower: Land dedicated to a water tower structure or use.

Vacant Land: Vacant land is land that is undeveloped, but is not used for recreational or park purposes. The land has no buildings or usable structures. This category includes vacant land zoned for apartments and other residential buildings, commercial and industrial land, vacant streets and alleys, and industrial railway land.

X. IMPORTANCE OF LAND USE STUDY

Actually, land is most important natural resource and non-renewal in nature. Most of the human activities are based on land. 70% of the total area of the earth is covered by water and only less than 30% area lies on land surface. Even among this much land, hot and cold deserts, swamps, rock cliffs etc cover most parts. The world population and urbanization on the other hand is increasing day by day. For this reason the available resources has to be utilized to its optimum level with proper management. Thus the land use study is an essential for the making and for his environs.

XI. ROLE OF REMOTE SENSING IN LAND USE AND LAND COVER MAPPING.

Remote Sensing plays a vital role in variety of ways as enumerated as under:

- Identification and delineation of land use and land cover categories of are going.
- Preparing an inventory of land use/land cover resources of a region

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- Monitoring and mapping of land use/land cover resource of region.
- Generating DEM for suitable representation of surface feature with respect to the terrain morphology.
- Change detection analysis of land use and land cover of the region.
- Drawing census and generating statistical maps
- Land use/Land cover management for better/optimal utilization of natural resources.
- Land suitability analysis and generating an action plan for the area.
- Events mapping such forest fire, flood fury etc.

XII. ROLE OF GIS IN LAND USE AND LAND COVER MAPPING

In recent years, professionals from many fields have been developing and exploring the use of advance computer aided techniques for processing and manipulating geographic data. Much of this development has occurred independently in each field of interest such as in Urban Planning, Rural Planning, Geology, Cartography etc. those involved in urban planning have seen the advantages of being able to integrate data from various sources to produce powerful analytical Geographical information system (GIS). The use of GIS techniques allow quite complex quantitative and spatial relationship to be made and displayed in graphical form and improve the clarity of the planning and decision making process. This technique is a powerful tool, useful not only to monitor the current growth and development of a region or city, but also as basis for the construction and application of models to meet the specific objectives for development envisaged for the local situation. While the need for such database has long been felt and called for the establishment of working systems has been slow in coming. Positive steps need now to be taken to emphasize and develop application of Geographical Information System technology in the structure of urban and regional planning.

XIII. LAND USE AND LAND COVER CLASSIFICATION SYSTEM

Importance of Land Use, Land Cover Map of City

Knowledge about land use and land cover has become increasingly important as

1. The Nation plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands
2. Land use data are needed in the analysis of environmental processes and problems that must be understood
3. One of the prime prerequisites for better use of land is information on existing land use patterns and changes in land use through time. In this dynamic situation, accurate, meaningful, current data on land use are essential.
4. Current land use and land cover data are needed for equalization of tax assessments in many States.

A. Designing a Classifications System with Remote Sensing technique.

There are different perspectives in the classification process, and the process itself tends to be subjective, even when an objective numerical approach is used. There is, in fact, no logical reason to expect that one detailed inventory should be adequate for more than a short time, since land use and land cover patterns change in keeping with demands for natural resources. Each classification is made to suit the needs of the user, and few users will be satisfied with an inventory that does not meet most of their needs. In attempting to develop a classification system for use with remote sensing techniques that will provide a framework to satisfy the needs of the majority of users, certain guidelines of criteria for evaluation must first be established. The size of the minimum area which can be depicted as being in any particular land use category depends partially on the scale and resolution of the original remote sensor data or other data source from which the land use is identified and interpreted. It also depends on the scale of data compilation as well as the final scale of the presentation of the land use information.

B. Classification criteria:

A land use and land cover classification system, which can effectively employ orbital, and high-altitude remote sensor data should meet the following criteria (Anderson, 1971):

1. The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data should be at least 85 percent.
2. The accuracy of interpretation for the several categories should be about equal.
3. Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.
4. The classification system should be applicable over extensive areas.
5. The categorization should permit vegetation and other types of land cover to be used as surrogates for activity.
6. The classification system should be suitable for use with remote sensor data obtained at different times of the year.
7. Effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensor data should be possible.
8. Aggregation of categories must be possible.

XIV. CONCLUSION

Rapid urban development and increasing land use changes due to increasing population and economic growth in selected landscapes is being witnessed of late in India and other developing countries The measurement and monitoring of these land use changes are crucial to understand land use cover dynamics over different spatial and temporal time scales for effective land management The cities are expanding in all directions resulting in large-scale urban sprawl and changes in urban land use. The spatial pattern of such changes is clearly noticed on the urban fringes or city peripheral rural areas, than in the city center. There is a demand to constantly monitor such changes and

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understand the processes for taking effective and corrective measures towards a planned and healthy development of urban areas. In the recent times, Remote sensing data is being widely used for mapping and monitoring of urban sprawl of cities from the study which has been done, we get very clear cut idea that Remote Sensing and Geographical Information System have proved to be very powerful technique in measuring Urban Sprawl. This technique can be applied in other fast growing developing cities of India .India has undergoing this kind of unplanned development It is must to monitor them Having the advantage of availability of our own Indian Satellite IRS 1C , IRS 1D Cartosat of high resolutions, we can use the Satellite Data for Urban Studies

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