Potential Use of High Resolution IRS-1C Satellite Data and Detection of Urban Growth in and around of Tiruchirapalli City, Tamil Nadu State, India

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Key words: IRS-1C Satellite Data, Tiruchirapalli Town, India, Urban Growth, Land Use.

ABSTRACT

The Tiruchirapalli City is situated at the bank of Cauvery River, constitute the densest part of urban environment. It is centrally located in the Tamil Nadu State of India. The present study is to investigate the rate of urban growth in the Tiruchirapalli City on the basis of several villages. For this purpose of determination of visible surface topography with high spatial frequency and precision, the IRS- 1A & 1C (1989, 1997) data, Aerial Photographs (1979) and Survey of India topographic maps (1928, 1971) were used. The urban change analysis and prediction, image interpretation techniques such as supervised classification and change detection techniques were used. The results show that Tiruchirapalli has lost agricultural land to urban uses during a period of 60 years. The artificial areas grew since 1971 up to 1998 very strong with nearly linear rate. The biggest development between1986 and 1998 happened at east, south and west directions of the Tiruchirapalli City. These changes are due to very big increase in residential a surface, that is from 1921 up to 1980, on all places residential area was created around the existing old structures. The increase of residential and business area forces the loss of agricultural fields and water tanks. This has been largely observed along the east dimension of growth of city where the development–axes of artificial increase. There is no great change in the development of transport network but, the notable changes in road development are observed around the newly developed urban areas. These changes are due to the knowledge of unplanned developments in the urban areas of Tiruchirapalli City and can be planned well.

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1. INTRODUCTION

Nowadays, most of the world population lives in cities and metropolis. However, it is often the case that settlements grow irregularly under the pressure of masses coming to cities and these do not develop according to well-defined plans. Hence, it is necessary to monitor urban areas with frequent update. Land use in urban areas continuously change over time and geographic location, and the urban planners must be able to update their databases to reflect current land-use. An urban environment can be characterised by two main classes, namely built up areas (developed) which comprise of industrial, residential, commercial, parking areas, etc and non-built up areas (reserved) e.g. gardens, sports field, green areas, urban agriculture, etc. Town planning departments attempt to design plans (building and land use) depicting the type and extent of the permitted use of land and the corresponding constraints, whereby any change is expected to conform to these plans. However, it is not uncommon to unveil that these plans particularly in developing countries are not adhered to due to problems associated with budgetary allocation, which implies that the necessary infrastructure is not implemented.

Remote sensing methods have been widely applied in mapping land surface features in urban areas (e.g. Haack et al. 1997, Jenson and Cowen 1999). With the availability of multispectral images in digital form and the advances in digital processing and analysis, remote sensing has become a new perspective for the land use change detection. A number of automated change detection techniques have been developed. These include, image differencing, image rationing, image regression, vegetation index differencing, change vector analysis, principal components analysis, post-classification comparison and multidate classification (Singh, 1989; Jensen, 1996). The characterization and classification of urban areas has received attention since the early Landsat program (Gordon, 1980, Forster, 1980, 1983, Jensen and Toll, 1982, Ridd et al., 1983, Moller-Jensen, 1990). With the introduction of Thematic Mapper (TM) and SPOT panchromatic (SPOT-P) data came the opportunity for a variety of data combinations (Welch and Ehlers, 1987, Chavez et al., 1991), introducing more detailed investigations of urban environments. The opportunity for urban growth analysis has concurrently improved with the technology (Martin 1989, Fung and Zhang 1989, Gong and Howarth, 1990, Gong et al., 1992), allowing for analysis at larger scales. The socioeconomic, natural, technological and social processes are profoundly affected the evolving urban spatial structure within which they operate. Therefore municipal authorities are interested in effective methods for frequent area-wide mapping of urban surface cover types as a basis for ecological urban planning. For this purpose automated mapping approaches are needed which are capable of producing primary digital information which can be directly integrated into a

GIS. These informations can support the ecological evaluation of urban structures during planning processes. In this study, the changes from rural to urban in Tiruchirapalli Town, India were detected over the period 1928 to 1998 using Survey of India topographic maps, Aerial photos and IRS-1C satellite images. This paper examines the urban growth of Tiruchirapalli town, India through a texture algorithm that distinguishes built from non-built features.

2. STUDY AREA

The area of Tiruchirapalli town, India (Fig.1) consists of a major city surrounded by towns, continuously growing in size and population. The cities have a high density of buildings and have not developed according to periodic urban plans, thus resulting in clusters of buildings with different sizes and shapes. The agricultural fields surround the cities and it is relatively flat in the eastern and the northern part. Industrial and residential areas with high population density are located in the northern part; residential areas both densely and sparsely built-up are located at the southern edge of the city. The urban area is built on a relatively flat surface even though some hills with reasonable slopes are present in the city centre. These small houses can not be seen on IRS-imagery but as far as they are known or found by field checks, they will be mapped in any case. The growth of population in the city between 1961 to 1991is as follows (Table.1). This enormous urban growth requires precise detection with good management, prediction and planning.

Sl.No.	Year	Total Population	Variation	% of Variation
1.	1961	249862	30941	11.40
2.	1971	307400	57538	14.12
3.	1981	362045	54645	16.60
4.	1991	387223	25177	17.70

Table 1. Growth of Population in the Tiruchirapalli city during 1961-1991 periods.

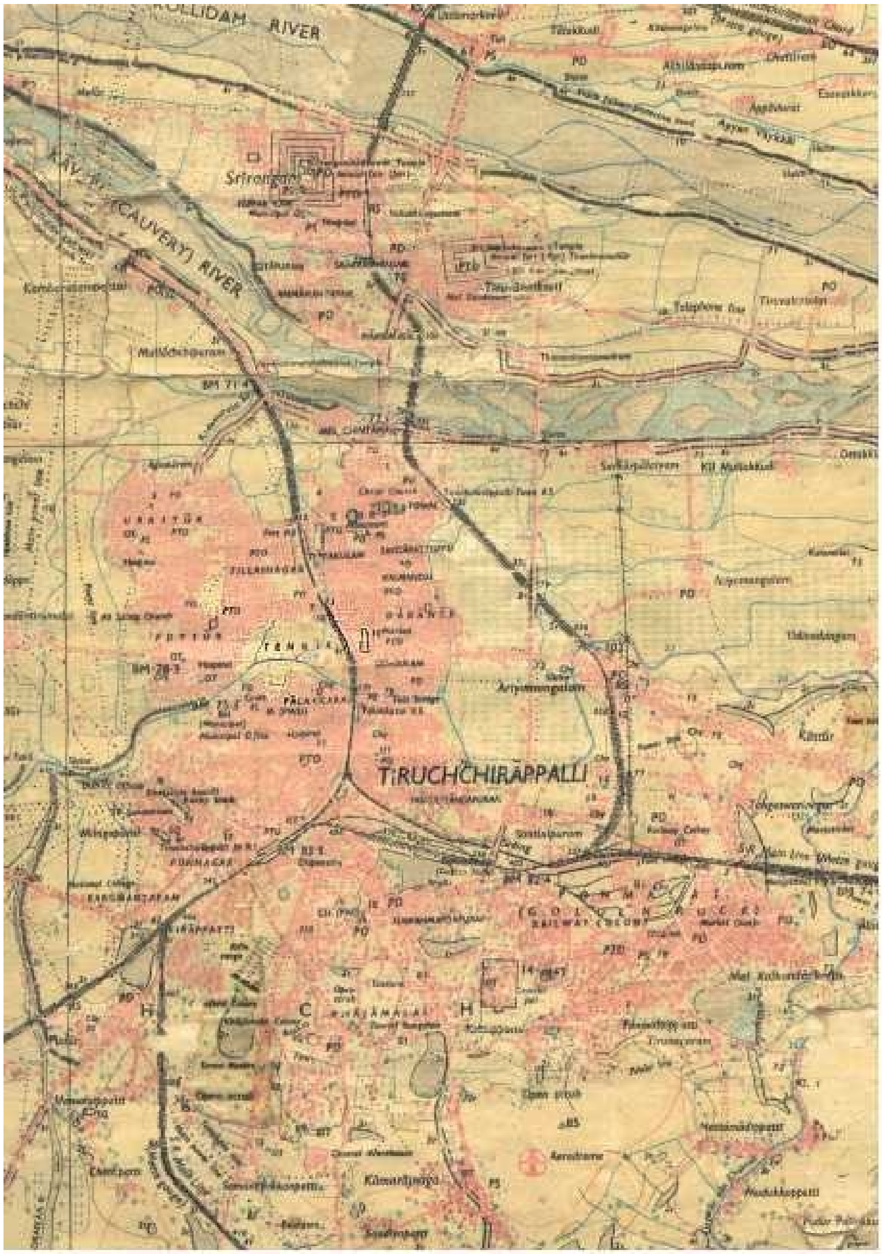

Figure.1 Tiruchirapalli town, India in the Survey of India maps (1971).

3. OBJECTIVES

The main objectives of this present study are,

1) To define the boundaries of urban growth, which will give a clear vision of the current situation for urban growth in Tiruchirapalli town. Mapping will show where urban expansion has occurred and the size and trend of that growth within the period of study.
2) To produce an urban change map that will show the changes of land use in the city within that period.

3) To produce up to date satellite image-based urban sprawl maps.

4. DATA USED

Use of aerial photographs and ground survey methods have proved to be expensive and counterproductive, hence unaffordable to most municipal budgets in developing countries. Furthermore, this is hampered by security restrictions. Consequently the underlying criteria in choosing a technique and tools should be cost-effectiveness, adaptivity to the conditions of the developing countries in terms of timeliness and information content. For urban applications, maps used for planning purposes by local governments are usually in the range of 1:10,000 to 1:50,000 which implies that satellite imagery are good candidates particularly where security restrictions, costs and time prohibit the use of aerial photography. However, use of the very high resolution satellite imagery e.g. Ikonos, are still out of reach for most municipal applications due to cost constraints and therefore sources from Spot, IRS and Landsat TM images will continue to be explored. In this study, the basis has been the application of enhanced IRS satellite data is used to generate land use information that is verified against manually interpreted urban use data and subsequently used to detect unplanned developments.

The available sources included in the study with limited field checks are, 1. Survey of India topographic maps of 1928, 1971, 2. Aerial photographs of 1979, (NRSA, 1:4,000), 3. IRS-1A LISS-II, 1989 (1:50,000), 4. IRS-1C PAN, 1997(1: 20,000) and 5. Maps of State Town and Country Planning Office (1980) and building plans, which show among other information the extent and permitted type of use.

5. METHODOLOGY

Two Indian Remote Sensing satellite images were analyzed in this study for detecting the general land use changes occurred between 1989 and 1997 with the aerial photographs acquired in 1979. The change detection was also carried out from the Survey of India topographic maps of 1928 and 1971. Aerial photographs were used to evaluate classification and change detection error through pre-processing, knowledge base development and subsequent image interpretation and prediction of designated areas for development and reserved and assessment of the results. We defined standardized operating procedures with 3 steps: fist a normal affin-transformation to place the scanned map near to the real position to enable a good orientation and to detect more easy the displacement in the next step. Then we run the partial transformation to get perfect neighborhoods and to eliminate mistakes of scanner and paper sheets (an sometimes also of the print). If necessary a third affin-transformation, to move the image to the other coordinate system (from one to another strip or ellipsoid), has taken place. The correct coordinates will be calculated by the map-corner-coordinates or by the grid on the map-sheets. Some maps 1:5000 as a DXF-data set are available but the date of processing can not be detected accurately. But even to complete the data set they can be used for validation and georeferenciation. The different building plans covering the area of study were used in combination with the 1980 to showing the extent and type of the permitted urban land uses i.e. zoned planned land uses.

6. MAPPING OF URBAN GROWTH

In general, the mapping of urban areas by remote sensing is a rather complex process due to the heterogeneity of the urban environment, typically consisting of built up structures (e.g. buildings, transportation nets), several different vegetation covers (e.g. parks, gardens, agricultural areas), bare soil zones and water bodies (Barnsley et al., 1993). Traditionally, visual interpretations of high-resolution air photos could provide comprehensive information for mapping of urban areas. The basis of the data analysis was the interpreter's knowledge of spatial arrangements of urban land cover features (e.g. texture, pattern, shapes, densities) that were used to characterize several urban structures and feature types (Bowden et al. 1975; Haack et al. 1997). Furthermore, the improvements in spatial and spectral sensor resolutions during the last several years can be considered to be a new era in urban remote sensing (Hepner et al. 1998, Tanaka & Sugimura 2001). Several studies have demonstrated the potential of remote sensing methods as source of information specifically useful for analysis of the urban/suburban environment with focus on land cover/use, socioeconomic information and transportation infrastructure (Barnsley et al., 1993; Rao 1996, Henderson and Xia, 1997; Jensen and Cowen, 1999, Donnay et al. 2001).

In the present study, to detect the change, 4-land use databases by mapping the urban development of the last 60 years and the actual situation on the base of aerial photographs and satellite data have been undertaken. The change data will be related with additional data sets such as other maps, economical data, demographic statistics and existing analyses in the literature. The goal is, to combine the existing statistical data with the land use-database to get spatial results. Existing studies will be implemented by the ancillary data sets and as far as possible integrated in the spatial analyses.

6.1 Images Interpretation

The selection of the appropriate land use/cover scheme was not an easy exercise. Specialists who have inventoried a geographic region have developed a number of classification schemes. The *U.S. Geological Survey Land Use/Land Cover Classification System* was developed by Anderson and others and is a resource oriented (land cover). In contrast, the *Standard Land Use Coding (SLUC) Manual or the Michigan Land Use Classification System* are *human* oriented *(land use) (Jensen 1996*). These schemes use hierarchical class systems. For the present study none of these was used because most of the specified classes could not be applied in the area of study, (with its different environmental criteria). Another problem was the spatial resolution of remotely sensed data, which in Tiruchirapalli prevents detailed classification (Figure.3). Four classes were therefore chosen for application: (1) Water bodies, (2) Agricultural lands regardless of type of crops and their level of intensity, (3) Urban Fabric, including all buildings and built-up areas regardless of use or pattern (4) non-built up land. They are further interpreted as follows.

1. Water bodies: 1.1. Rivers & Streams, 1.2. Tanks
2. Agricultural lands regardless of type of crops and their level of intensity,
   2.1. Cultivated, 2.2 Uncultivated, 2,3. Barren land / rocky outcrop

3. Urban Fabric, including all buildings and built-up areas regardless of use or pattern
   3.1. Residential, 3.2. Commercial and services, 3.3. Industrial, 3.4. Transportation, communications, and utilities, 3.5. Industrial and commercial complexes, 3.6. Mixed urban or built-up land.
4. Non-built up land: 4.1 Waste land

A supervised classification approach was applied initially relating to the analyst's experience of the study area, but this failed to provide adequate separation between the target classes because of the small spectral variation between important classes.

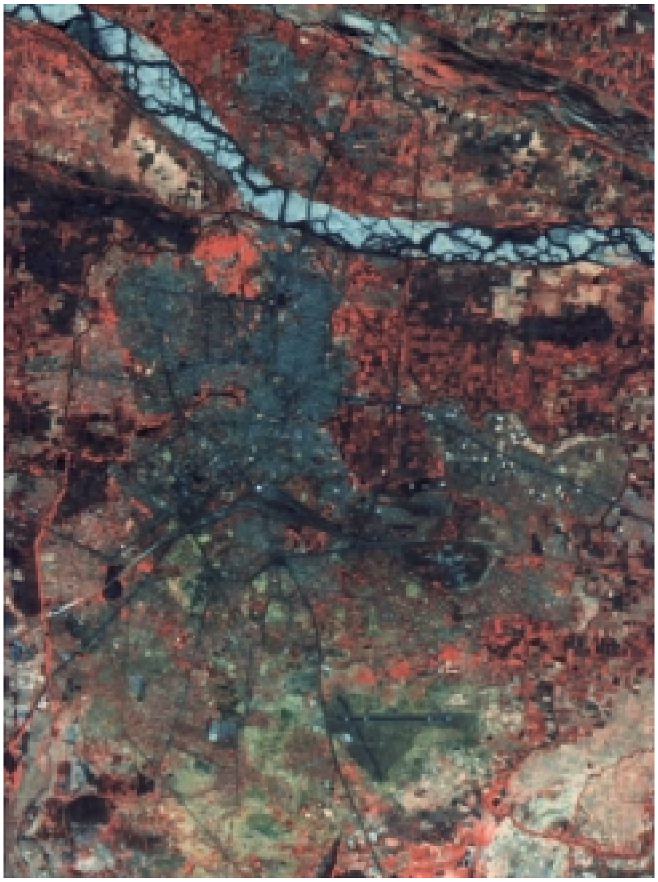

Figure.2 Tiruchirapalli urban environ in IRS-1C satellite data.

6.2 Thematic and Derived Maps

As geodetic reference base, we are using scanning and geo-referencing the topographical maps 1:50.000. As a part of the ancillary data set, city-plans and other maps were pre-processed for the interpretation. The reference urban use database is derived from imagery of IRS-1A LISS II and 1C PAN. Big structures are good visible in the imagery, the smaller once can be interpreted only by using additional information from maps, city plans and field-checks. Within the analyses of the results, the acquired aerial photos and ancillary databases were integrated, as far as they fit into spatial analyses. Other, non-spatial data are pre-processed in a database and analyses by statistical means like trend-analyses, relations etc.

6.3 Change Detection

Examining the fraction images calculated for one cover type for different dates basically does change detection. By subtracting the older fraction image from the younger one, changes, which represent an increase, have high values. The selection of an appropriate change detection algorithm is very important (Jensen 1996). There are many algorithms that can be used to perform change detection. At least seven change detection algorithms are commonly used (Jensen 1996) but these techniques have disadvantages such as (1) Parts do not provide quantitative information on the size of land use change from one land cover category to another, (2) The analyst can not label the change classes in parts (3) Some need a number of complex steps to perform change detection. In this study, two remotely sensed images (1987,1997) were rectified, registered and classified into four classes. Band rationing or image differencing (Jensen 1996) identified the amount of change between two images. Image differencing involves subtracting the *rectified* imagery of one set of data from that of another. In the modified method, the *rectified and classified* images were subtracted. The subtraction results in positive and negative values in areas of radiance change and zero values in areas of no change (Jensen 1996). In order to highlight those areas where building activities have taken place, in a first step the fraction images for built-up areas calculated for 1989 are subtracted from those calculated for 1997. Figure 2 illustrates fraction image for built-up areas of 1997 with urban as well as bare fields. The images of both dates were analyzed visually through in-memory image overlay operation. The four major types of above said land use change classes were identified with the field checks. The method is based on a single classification of a combined data set of two or more dates to identify areas of change (Singh, 1989). The classes showing the change information are expected to have significantly different statistics from no-change classes. The advantage of the technique is that only one single classification is applied to whole data set. The year wise change made during the interpretation is illustrated in Figure 3.

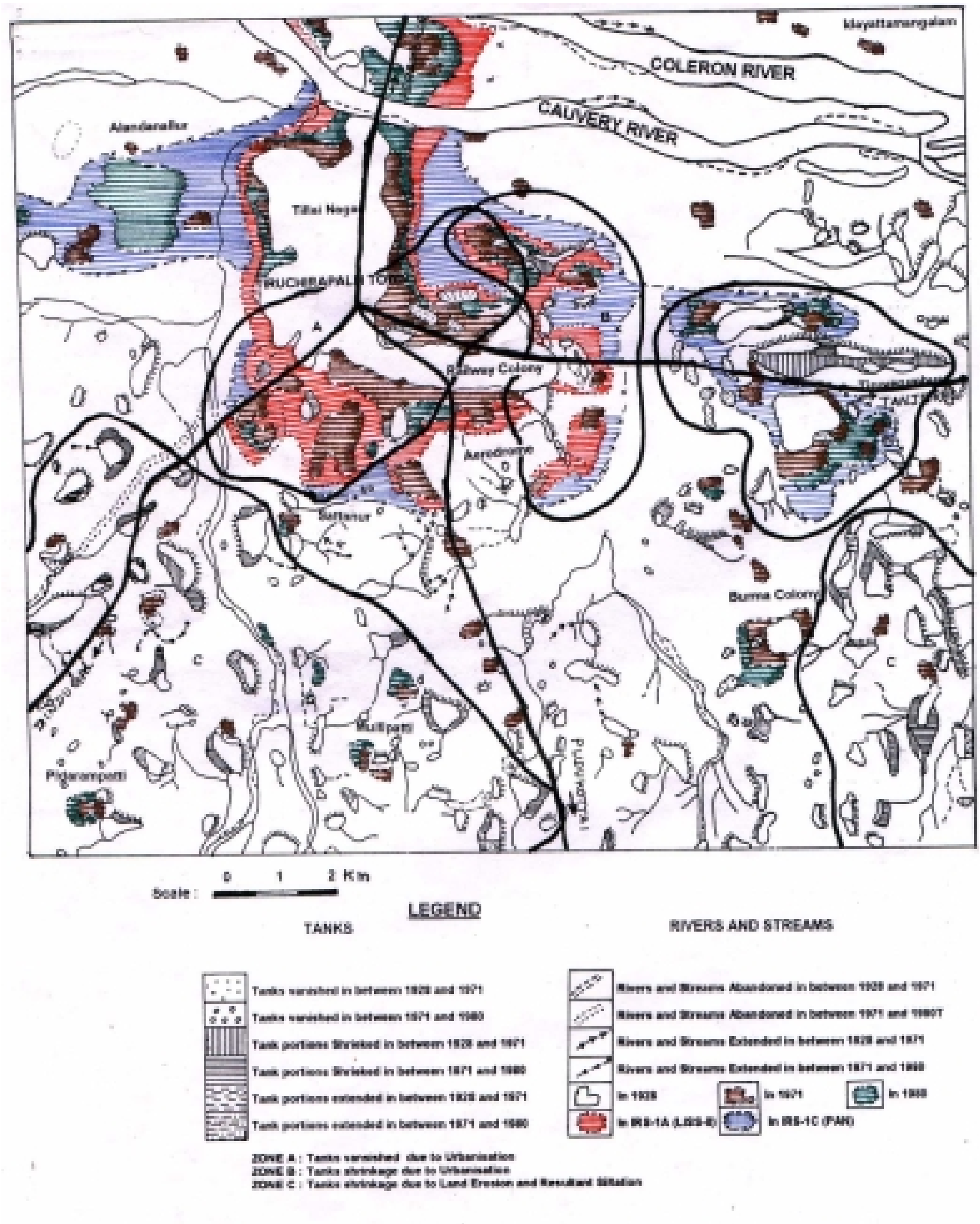

Fig.1 Urban growth of Tiruchirapalli town, Tamil Nadu, India

Figure.3 Urban Growth of Tiruchirapalli town, Tamil Nadu, India.

7. RESULTS AND DISCUSSION

The city as demarcated from the Aerial Photographs and IRS data for 1928 and 1971, has experienced rapid growth. The figure 3 shows the size and percentage of urban use change in Tiruchirapalli area. The major changes can be divided into two categories; (1) Increased change (positive) which includes urban fabric and (2) Decreased change (negative) which includes green lands and water bodies. The summary of these changes has been put in a form of “ from-to” as shown in legend of Figure 3. Based upon the analyst’s experience of the area of study, the areas of change between 1980 and 1991 (Figure.3) and these may be summarized as follows:

1. The changes in the urban limit from Survey of India Toposheets shows that the tanks are vanished and rivers and stream portions are abandoned during 1928-1971.
2. Interpretation of aerial photos (NRSA, 1:20,000) of 1979 with reference to map prepared by the Town and Country Planning office of Tiruchirapalli reveals that the changes or shrinkage in tanks are due to growth of urban land in the town and
3. The interpretation of urban land use for Tiruchirapalli town using IRS-1A LISS-II (1:50,000; 1989) and IRS-1C PAN (1:25,000; 1997) satellite data show the change of extension as well as shrinkage in tanks and streams in and around Tiruchirapalli town. The growth of town has been identified in the direction across to river Cauvery.
4. The secondary data source confirms that the changes are due to increase of population and industry in the study area.
5. A great part of town has been built up due to accommodate urban expansion demands.
6. Most of urban expansion goes toward the eastern and southern parts of the city where the agricultural land has been lost for increased urbanization.

This study presents detecting the overall urban growth changes at an urban fringe through multidate image interpretation of IRS images. The results of this study show the trend and size of urban growth in Tiruchirapalli town most of the new urban development in the city goes towards the east and southern parts where the big areas of needed land available. However, most of this urban expansion is not planned by the government so that, the rest of theses areas have to be planned properly to be prevented from the disadvantages of urban growth in the developing countries. Also, there are a significant expansion in the eastern and south eastern areas of the city where the cultivated land are, so that a new plan is needed to direct the growth to the western areas to protect these areas.

In relation to urban remote sensing applications, the results obtained from this application of IRS images data indicate that the use of this type of high resolution satellite data are very useful for mapping land use and change detection analysis especially in urban areas which face a continuos growth, the traditional methods can not cope with this dynamic phenomenon. The proposed scheme could help the studies, which use a remotely sensing data as a main input. Temporal urban mapping relies on modern mapping techniques, such as remote sensing and geographic information systems (GIS), to capture information from both historical and modern records. The multidate interpretation was found to be an effective technique to detect overall urban use changes both in size and nature providing the general development trend in the study area. The study demonstrates that the area experienced a significant rural-to--urban conversion in the 25-year period between 1980 and 1997and this trend will seem to continue.

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