Urban Sprawl Change, DEM and TIN Model of Madurai Corporation Area in Tamilnadu State (India) from 1980 to 2015, Using Remote Sensing and GIS

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Abstract

In the last 35 years, there has been rapid change in the land use and land-cover aspect of Madurai city corporation area, Tamil Nadu state. The major change is the conversion of agricultural and forest lands into urban areas mostly in an un-planned manner making urban sprawl characterizing the urban change dynamics. The principal aim of this research is to apply satellite remote sensing data, and geospatial tools to detect, analyze and quantify the urban land use changes of Madurai city corporation area.

Madurai city is located in Madurai District roughly in the central part of Tamil Nadu State in India. It is located between 9°45’ and 9°59’ N. Lat., and 77°58’ and 78°11’ E. Long. The ultimate objective of the research is to detect the land use/land-cover change of Madurai city corporation area from 1980 to 2015. Satellite images of Madurai Corporation at different periods, 1980, 1990, and 2015 were analysed. The software programs that have been used in this study to process, quantify, analyze and change detection are ArcGIS 9.3 and ERADAS 8.5. The change detection procedure enabled the identification of areas of significant change. The land cover-land use classes identified are forest, scrub, barren land, settlement, commercial and industrial area, water body, river and airport.

Keywords

Urban Sprawl, Madurai Corporation Area, DEM&TIN Model, Remote Sensing

1. Introduction

The history of urban growth indicates that urban areas are the most dynamic places on the Earth’s surface. Despite their regional economic importance, urban growth has a considerable impact on the surrounding ecosystem (Yuan et al., 2005). Most often the trend of urban growth is towards the urban-rural-fringe where there are less built-up areas, irrigation and other water management systems. In the last few decades, a tremendous urban growth has occurred in the world, and demographic growth is one of the major factors responsible for the changes. By 1900 only 14% of the world’s population was residing in urban areas and this figure had increased to 47% by 2000 (Brockerhoff, 2000). The report also revealed that by 2030, the percentage of urban population is expected to be 60%. Urban growth is a common phenomenon in almost all countries over the world though the rate of growth varies. Currently, these are the major environmental concerns that have to be analyzed and monitored carefully for effective land use management. The rapid urban growth and the associated urban land cover changes have also attracted many researchers.

1.1. Geographic Information System

A substantial amount of data from the Earth’s surface is
collected using Remote Sensing (RS) and Geographic Information Systems (GIS) tools. RS provides an excellent source of data from which updated land use/land cover (LULC) information and changes can be extracted, analyzed and simulated efficiently. RS in the form of aerial photography provides comprehensive information of urban changes (Bauer et al., 2003). It is not, however, without limitations: costs of the acquisition and the analogue data format are the most obvious problems. The cost of acquiring data causes many analysts to remain sceptical about the potential of remotely sensed data (Rowlands and Lucas, 2004). It should also be noted that LULC mapping using remote sensing has long been a research focus of various investigators (Civco et al., 2002).

Recent advancement in GIS and remote sensing tools and methods also enable researchers to model and predict urban growth more efficiently than the traditional approaches. Several modelling approaches have also been developed to model and forecast the dynamic urban features. One of the approaches is the Cellular Automata-CA. CA is a dynamical discrete system in space and time that operates on a uniform grid-based space by certain local rules. The CA is consisting of cells and transition rules are applied to determine the state of a particular cell. Its ability to represent complex systems with spatio-temporal behavior from a small set of simple rules and states made it very interesting for urban studies (Alkehder and Shan, 2005). In this study an integrated approach of, RS and GIS modeling has been applied to identify and analyze the patterns of urban changes and provide quantitative and spatial information on developments of urban areas.

1.2. Urban Sprawl

Many organizations have attempted to provide a definition, but it turns out that the definition depends on that organization’s perspective, usually polarized between a pro-growth and an anti-sprawl viewpoint. There are different types of urban sprawl. The type of sprawl determines the characteristics. The various definitions for urban sprawl suggest that there are different characteristics of sprawl. The most common ones cited are; 1) Single use zoning 2) Low density land use, 3) Car dependent communities and 4) Leap-frog development.

1.3. View of Urban Sprawl

Separation of land used for different purposes is a typical characteristic of urban sprawl. Sprawl has physical separation of space used for different purposes such as housing subdivisions, shopping centres, office parks, civic institutions and road-networks etc. Urban sprawl is perceived as economically inefficient, environmentally irresponsible and aesthetically ugly. Bruegmann (2006) calls it a logical consequence of economic growth and the democratization of society, with benefits that urban planners have failed to recognize. People have different perception about about the sprawl. Some think sprawl has enabled man to satisfy his social, economic and environmental needs while others think it is generating unnecessary tension on land use. This has raised a lot of debates about urban sprawl phenomena.

1.4. Overview of Urban Sprawl and Change Detection

Urbanization, which may be broadly defined as the process of expanding urban influence, has been taking place for more than 6000 years, has increased markedly since the beginning of this century. The process of urbanization in India has been slow but steady. As per 2001 census, only less than 1/3rd of India was urban. Predominantly its urban growth has been due to the enlargement of existing towns at every level and not significantly due to the addition of new towns. One distinctive feature of India’s urbanization is increasing metropolitanization. India’s big cities now account for a large share of total urban population. In 2001, the share of metropolitan cities was 37.8 % up from 32.5% in 1991 and 26.4% in 1981.

Bock et al. (2005) have shown the use of random sampling method for accuracy assessment by means of error matrix based on stratified and randomly selected points across the classified image. Instead of purely random method, stratified random sampling is usually recommended so that the sampling points are fairly spread in each LULC change class.

Gupta (2005) conducted a research to reveal urban/agriculture changes using multi-scale analysis in Dehradoon city in India. The authors of this paper have compared the results of five different techniques of band combination, subtraction, band division, principal component analysis and classification to find the changes in Dehradoon city, India. The research concluded that in the case of multi-resolution data, direct comparison of two multi-level image dates is restricted because various spectral and texture phenomena exist at different scales and resolutions.

Caetano et al (2005) have expressed that accuracy assessment is a process used to estimate the accuracy of image classification by comparing the classified map with a reference map. It is critical for a map generated from any remote sensing data. Although accuracy assessment is important for traditional photographic remote sensing techniques, with the advent of more advanced digital satellite remote sensing the necessity and possibility of performing advanced accuracy assessment have received new interest.

Santos et al (2006) study states that the statistical properties
of training datasets from ground reference data are typically used to estimate the probability density functions of the classes. Each unknown pixel is then assigned to the class with the highest probability at the pixel location. However, a pixel-based method is associated with the mixed-pixel problem and it might not clearly show the required classes of interest, although they are the most commonly used technique. Hence, change detection using this approach may not be effective.

Fan et al (2007) in their studies overall, producer’s and user’s accuracy were considered for analysis. The Kappa coefficient, which is one of the most popular measures in addressing the difference between the actual agreement and change agreement, was also calculated. The Kappa statistics is a discrete multivariate technique used in accuracy assessment.

Lu and Weng (2007) and a number of researches have been conducted using different classification algorithms. It should be noted that valuable surface information extraction and analysis is also well performed using image classification. Image classification is the process of assigning pixels of continuous raster image to predefined land cover classes. It is a complex and time consuming process, and the result of classification is likely to be affected by various factors (e.g. nature of input images, classification methods, algorithm, etc). In order to improve the classification accuracy, thus, selection of appropriate classification method is required. This would also enable analyst to detect changes successfully. These include artificial neural networks, fuzzy-set theory, decision tree classifier, etc. The pixel-based approach is referred to as a “hard” classification approach and each pixel is forced to show membership only to a single class. Soft classification approach is thus developed as an alternative because of its ability to deal with mixed pixels.

Rymasheuskaya (2007) in recent study has proved that both image differencing and post-classification comparison confirms their ability to be used for detecting land cover changes over northern Belarusian landscapes. Other not so common change detection techniques in the category of spectral change detection are Change vector analysis and composite analysis.

Abbas et.al (2010) has studied the changes in land use and land cover in Kafur local government area of Katsina state, Nigeria over a 13 year period. The study made land use and land cover map of the study area for 1995 and Google earth imagery of 2008. The image and the map were digitized in to GIS environment using ArcView 3.2 GIS software for analysis. A paired t-test analysis was also used to see if there was significant change in the land use and land cover between 1995 and 2008. This paper highlights the land use and land cover types, the change over the years and the cause of the change. The importance of remote sensing and GIS techniques in mapping and change detection was also highlighted.

Prakasam (2010) Land use and land cover is an important component in understanding the interactions of the human activities with the environment and thus it is necessary to be able to simulate changes. In this paper an attempt is made to study the changes in land use and land cover in Kodikanal Talus over the 40 years period (1969-2008). The study has been done through remote sensing approach using SOI Taluk map of Kodikanal (1969), and land sat imageries of 2003 and 2008. The land use and land cover classification was performed based on the survey of India, Kodikanal taluk map and satellite imageries. GIS software is used to prepare the thematic maps.

Sumathi et al (2011) has studied the aims to find out the land use and land cover of Pudukottai district of Tamilnadu, India. The total area of the district is 4,663 sqkm. The study has made use of satellite imagery for identifying the land use and land cover of Pudukottai district. In this study Arc-GIS software was used to demarcate the land use and land cover pattern. The district has been divided into five classes in level I and 11 classes in level II.

Tamilenthi et al (2011) The study attempts to identify such sprawls change for 1973-2010. The study was carried out Salem Corporation, Tamil nadu, India using the techniques of GIS and remote sensing to identify and detect the urban sprawl. The spatial data along with the attribute data of the region aided to analyse statistically and forecasting. It is found that the Old Suramangalam cluster or north west cluster extends from Andipatti to Burns colony. The Kalarampatti to NGGO colony/Chinnakkollapati extensions is second cluster which occupies in the north eastern part of the corporation. This implies that by 2020 and 2050, the built-up area in the region would rise beyond the corporation limits and hence the corporation limit will be extended.

Sunarakumar et al (2012) Study attempted to identify such urban sprawl change for 1973-2009 from the Land sat images of Vijayawada city. Remote sensing has the capability of monitoring such changes, extracting the change in information from satellite data. The images of 1973 MSS, 1990 TM, 2001 ETM+ and 2011 ETM+ which are rectified and registered in Universal Transverse Mercator (UTM) are obtained. The land use and land cover maps of the study area are developed by supervised classification of the images. There are five land use class have been identified as Urban (built-up), Water body, Agricultural land, Barren land and Vegetation.
1.5. Aims and Objectives of the Present Study

The principal aim of this research is to apply remotely sensed data, geospatial tools to detect, quantify, analyze, and urban land use changes.

The following were the specific objectives of the research:
1. Quantify and investigate the characteristics of urban land use over the study area based on the analysis of satellite images.
2. Identify whether there have been and will be significant urban land use changes.
3. To analyze the land use and land cover pattern for the specific periods.
4. To detect land use and land cover pattern for the study period.
5. To create DEM and TIN model for the study area.

2. Materials and Methods

2.1. Study Area

Madurai Corporation Area (MCA) located in Madurai District in the Southern part of the Tamil Nadu State is located between 9°45’ and 9°59’ North latitude and 77°58’ and 78°11’ East longitudes, covering an area of 293.77 sq.km. The MCA supports a population of 1,48,648 persons (1981 census). It is classified into seven firkas consisting of 43 village panchayats 3 town panchayats and 1 township. The study area consists of plain section with a few rock outcrops.

The geology of the study area comprises the archaen rocks with quartzites, complex gneiss and charnockites. A small section of the Vaigai river flows in the northern part of this panchayat union. The study area has only one canal namely Nilaiyur Channel a branch Canal of the Periyar canal which takes off from river Vaigai. The study area experiences semi-arid tropical monsoon type of climate with an average temperature of 28.1°C. Analyzing the season wise distribution pattern of rainfall a significant amount of rainfall was received during the North East monsoon accounting for about 44.2 percent of the total rainfall. This is followed by the Southwest monsoon (38.10 %) and summer (15.7%). Winter months have received a low amount rainfall. Thus the monsoon seasons have received about 82.3 percent of the total rainfall. The annual rainfall amount fluctuates from year to year. The rainfall variability is about 25 percent and as such rainfall is less reliable. Hence the need arises to substantiate the water requirements for crops through irrigation. Well and tank irrigation plays a significant role in the agriculture of the study area (Fig.1).

Fig. 2.1. Study area- Madurai Corporation, TN State.

The study area has a total population of 1,48,648 persons (1981 census) with a density of about 506 persons per sq.km, which is higher when compared to the population density of Madurai District (359 persons per.km2 ) the concentration of population is more near the Madurai Urban Agglomeration.

The total population about 59.6 percent lives in rural
settlements and 40.4 percent, in urban settlements. The literacy level (51%) recorded in Thirupparankundram Panchayat Union for the 1981 census is higher than that of Madurai district (46.6%) and Tamil Nadu State (45.8%). Regarding occupational structure about 38.3 percent are classed as workers. About 46.6 percent of the workers are engaged in agricultural activities. About 22 percent of the workers are classed as cultivators and about 24.6 percent of workers are classed as agricultural labourers. About 45.6 percent of the workers are engaged in other than agricultural activities.

Table 2.1. Data Sources.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Satellite</th>
<th>WRS:2 Path /Row</th>
<th>Resolution</th>
<th>MMYY</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Landsat - 7 TM</td>
<td>143/53</td>
<td>30 x 30</td>
<td>Feb, 1980 &amp; April, 1990</td>
<td>GLCF</td>
</tr>
<tr>
<td>2</td>
<td>Landsat - 8 ETM</td>
<td>143/53</td>
<td>30 x 30</td>
<td>Feb, 2015</td>
<td>GLCF</td>
</tr>
<tr>
<td>3</td>
<td>Topographic map</td>
<td>58 K</td>
<td>1.25,000</td>
<td>1990</td>
<td>GLCF</td>
</tr>
<tr>
<td>4</td>
<td>Administrative Map of Madurai corporation</td>
<td>9°45' to 9°59' N, 77°58' to 78°11' E</td>
<td>1.30,000</td>
<td>2010</td>
<td>Madurai corporation, Madurai.</td>
</tr>
</tbody>
</table>

2.2. Methodology

In order to detect areas that have changed as a result of the expansion of the urban fringe, the procedures as shown in the flow chart were followed. The first thing to consider is the processing of the remotely sensed data to extract change information. Basically, the main processes involve are pre-processing (geometric registration and radiometric correction), followed by image classification, change detection and finally assessing the statistical accuracies of the classification in change detection process.

2.3. Flow Chart for the Methods Employed

![Fig. 2.2. Work Flow chart.](image)

2.4. Sources of Data

For the study, Landsat satellite images of Salem city were acquired for 3 Epochs; Landsat LISS-III 1980, 1990, and 2015. The Epochs were obtained from Global Land Cover Facility (GLCF) an Earth Science Data Interface.

The Landsat data were acquired from the global land-cover website at the University of Maryland, USA. URL: http://glcfapp.umbiacs.umd.edu:8080/esdi/index.jsp. It is also important to state that city Administrative map was obtained from Madurai corporation office.

2.5. Tools Used in the Study

Various software programs have been used in this study to process, quantify, analyze and model the spatial dataset. For the preliminary data processing, extracting the study area and mosaicking satellite images, ERADAS 2013 and ArcGIS 9.3 version was used.

2.6. Limitations of the Study

The present research is not completely free of limitation. First of all, considering the technical aspects of the satellites images used are restricted to certain spatial and spectral resolution. The effectiveness of the Object Oriented method has a great impact on the resolution. Secondly, for accuracy assessment, a true high quality reference data or ground truth data with the same number of classes was not available. Thirdly, due to time limitations, the choice of data, aerial extent of study area and number of methodologies used are also restricted.

2.7. Clustering to Detect the Land Use Classes

In clustering, the pixels were grouped into classes based on similar spectral characteristics. It analyses the images and organizes the pixels into clusters with similar characteristics without consideration of what these pixels represent in reality. Here it is assumed that pixels with similar characteristics represent the same land-use. It is very likely that the same land-use type can be represented with several clusters.

2.8. Aggregation of Clusters

The clustering procedure is just grouping of pixels of similar spectral characteristics. In order to get informational classes, the clusters were grouped. Vector files with ground truth data were used to detect which land-use classes the different clusters that have been created by isoclust (Grouping same
The images were reclassified to create a land-use map for 1980, 1990 and 2015 respectively.

### 3. Results and Discussion

#### 3.1. Land Use-Land cover

To achieve this study the two different land-covers and land use classes were analysed. These values quantify the percentage change in each land cover category. The change ‘from to’ makes post classification change detection so unique. The other task is the detection of the urban expansion as described in the post classification change detection processes.

The results indicate a moderate growth of towns in the study area. The town is recorded with moderate to fast urban growth. This was owing to the industrial concessions given to peripherals and fringe areas and backward regions. Town expansion is attributed to the commercial and industrial activities. The intra-regional variations in growth are mainly associated with acceleration of economic activity, transportation network, administrative and government interventions.

#### 3.2. Change Detection

An important aspect of change detection is to determine what is actually changing to what i.e. which land use class is changing to the other. This information will also serve as a vital tool in management decisions. This process involves a pixel to pixel comparison of the study year images through overlay. In terms of location of change, the emphasis is on built-up land. The Fig. 3.1, 3.2 & 3.3 show the state LULC during 1980, 1990 and 2015 respectively. The observation here is that there seems to exist a growth away from the city centre due to high land value closer to bus stand. Table (3.1) shows the changes within the various land-cover classes which explain the trend of the changes.

![Fig. 3.1. Land use-Land cover, 1980.](image-url)
Fig. 3.2. Land use - Land cover, 1990.

Fig. 3.3. Land use - Land cover, 2015.
3.3. Direction of Change of Urban Sprawl

Defining this dynamic phenomenon and predicting the future sprawl is a greater challenge than the quantification of sprawls. Although different sprawl types were identified and defined, there has been an inadequacy with respect to developing mathematical relationships to define them. This necessitates characterization and modelling of urban sprawl, which will aid in regional planning and sustainable development. Urban sprawl dynamics was analysed considering some of the causal factors. Fig. 3.4, 3.5, 3.6 & 3.7 show direction of spread of urban areas.

Fig. 3.4. Urban sprawl, 1980.

Fig. 3.5. Urban sprawl, 1990.
3.4. Performance of NDVI

It can be seen from its mathematical definition that the NDVI of an area containing a dense vegetation canopy will tend to have positive values (0.3 to 0.8) while clouded fields will be characterized by negative values of this index. The brighter areas which represent change in vegetation are the result of evolution of urban/barren areas. The NDVI estimate hence is vital in identifying changes in urban areas by investigating the changes in the vegetation cover. There is a clear
indication (Fig. 3.8, 3.9 & 3.10) that water cover and existing urban/barren areas did not change and such have zero or a very low value.
3.5. TIN Model

The TIN model represents a surface as a set of contiguous, non-overlapping triangles. Within each triangle the surface is represented by a plane. The triangles are made from a set of points called mass points. Mass points can occur at any location, the more carefully selected, the more accurate the model of the surface. Well-placed mass points occur where there is a major change in the shape of the surface, for
example, at the peak of a mountain, the floor of a valley, or at the edge (top and bottom) of cliffs. The TIN model is attractive because of its simplicity and economy and is a significant alternative to the regular raster of the GRID model. Polygon features are integrated into the triangulation as closed sequences of three or more triangle edges. Including break lines and polygons in a TIN gives you more control over the shape of the TIN surface (Fig.3.11).

3.6. Digital Elevation Model (DEM)

DEM, in Satellite remote sensing can provide operationally, digital elevation models through radar interferometer or stereoscopic optical satellite images and is further analyzed through Geographical Information System (GIS) technology to define watersheds, stream networks and order. DEMs are efficient and effective methods used to determine the features of drainage networks such as, size, length, and slope of drainage network and to determine characteristics of basin and sub-basin. Moreover, from the DEM many significant values like slope, direction, flow length are estimated and above all provides good visual perception for the common people too. Fig. 3.12 is the DEM of the study area.

![DEM-MADURAI CORPORATION](image)

Fig. 3.12. DEM for the study area.

3.7. Discussion

The change detection is to determine what is actually changing to what i.e. which land use class is changing to the other. This information will also serve as a vital tool in management decisions. Fig. 5.1, 5.2 & 5.3 show this change assessed from data of 1980, 1990 and 2015 respectively.

In order to determine the “urban sprawl” the images for 1980, 1990 and 2010 were classified (Figs.5.4, 5.5 & 5.6). This process involved a pixel to pixel comparison of the year wise images through overlay. It is clear that the spread is towards the sub urban area. The result implies that, the land cost and the industries around MCA may be the attracting force for most people to acquire a residence closer to this vicinity as result of many socioeconomic reasons. In terms of location of change, the emphasis is on built-up land.

The NDVI of an area containing a dense vegetation canopy will tend to have positive values (i.e., 0.3 to 0.8) while clouds cover will provide artifact of negative values. There is a clear indication (Figs. 5.7, 5.8 & 5.9) that water cover and existing urban/barren areas did not change and such have zero or a very lower value. The brighter areas, which represent change in vegetation, are a result of evolution of urban/barren area shift. NDVI differencing, hence is vital in identifying changes in urban areas by investigating the changes in the vegetation cover.

The urban area of MCA has increased tremendously within the last 35 years. This resulted from rural-urban migration. MCA is one of the most developing cities in Tamilnadu, after
Chennai. Education institutions, industries and factories are located and newer ones are coming up here. As a result, rural-urban migration characterizes MCA. The overall percentage increased during the period of 35 years about 583.71%, 413%, 651.31% and 36.36% (i.e., Scrub, Settlement, Comm. & Industrial areas and Airport respectively). There has been decrease in the Forest, barren land, Water body and River with 60.76%, 61.68%, 37.86% and 36.36% respectively.

Table 3.1. Land use land cover change 1980-2015.

<table>
<thead>
<tr>
<th>Class</th>
<th>1980 (Ha)</th>
<th>2015 (Ha)</th>
<th>Area change, (Ha)</th>
<th>Area change, (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>9851</td>
<td>3865</td>
<td>-5986</td>
<td>-60.76</td>
</tr>
<tr>
<td>Scrub</td>
<td>5299</td>
<td>30931</td>
<td>+25632</td>
<td>+583.71</td>
</tr>
<tr>
<td>Barren land</td>
<td>53018</td>
<td>20313</td>
<td>-32705</td>
<td>-61.68</td>
</tr>
<tr>
<td>Settlement</td>
<td>3176</td>
<td>16293</td>
<td>+13117</td>
<td>+413.00</td>
</tr>
<tr>
<td>Com.&amp;Ind.area</td>
<td>76</td>
<td>571</td>
<td>+495</td>
<td>+651.31</td>
</tr>
<tr>
<td>Water body</td>
<td>1051</td>
<td>653</td>
<td>-398</td>
<td>-37.86</td>
</tr>
<tr>
<td>River</td>
<td>700</td>
<td>531</td>
<td>-169</td>
<td>-24.14</td>
</tr>
<tr>
<td>Airport</td>
<td>21</td>
<td>33</td>
<td>+12</td>
<td>+36.36</td>
</tr>
<tr>
<td>Total</td>
<td>73191</td>
<td>73191</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

4. Conclusion

The results of this study were based on Image classification and its interpretation. The interpretation of multi-date satellite helped in the preparation of urban sprawl map of the study area. The mapping of the urban development of MCA shows the development of urban lands had brought changes in other part of the city as well.

The urban area of MCA has increased tremendously within the 35 years. This resulted from rural-urban migration. MCA is one of the most developing cities in Tamilnadu, after Chennai and is a hub of Educational institutions, industries and factories. The overall percentage increased during the period of 35 years are about 583.71%, 413%, 651.31% and 36.36% , in respect of Scrub, Settlement, Comm.& Industrial areas and Airport respectively. Same period reported a decrease in the Forest, barren land, Water body and River to the tune of 60.76%, 61.68%, 37.86% and 36.36% respectively.

The decrease in agricultural/Scrub area is due to conversion of urban land use or discontinuation of agricultural lands. The Barren land has been increase as cultivable land is left with discontinuation of cultivation due to lack of irrigation facility and seasonal variations are made them to be available as such. Similar studies can be under taken for other major cities also to estimate to make necessary arrangement to plan accordingly to preserve the natural environment.

References


