Urban sprawl and its impact on the land cover - a geospatial study

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Abstract
The present study was aimed to estimate the urban sprawl in a historical city of India using series of satellite data between 1968 and 2005 (37 years) and GIS. The total area of the Tiruchirappalli city was 1991.96 ha during 1968 and it was expanded into 4335.98 ha (117.67%) during 2005. The average growth rate per year was 63.35 ha. This 117.67% growth was at the cost of agriculture land (97.81%) and water body (2.19%). The satellite data used in this study were found to be good source of information for this kind of analysis and further studies are need to estimate the impact of this city expansion on agriculture yield and ground water.

Keywords : Urban sprawl, Tiruchirappalli, India, Geospatial technique

1. INTRODUCTION

Land use and land cover changes have environmental implications at local and regional levels and sometimes are linked to global environmental process (Foody, 2002). Urbanization, the conversion of land, which are under other land use types into uses associated with growth of populations and economy is a main type of land use and land cover change in human history (Weng 1999) and these changes are estimated to have significantly altered ~ 80% of earth’s land area over the last several centuries (Vitosek et al. 1997). Industrialization and urbanization are important factors for socio-economic growth of a region, which causes environmental changes (Elmazir et al. 2004).

In India, land use and land cover patterns have undergone essential change due to various reasons. Especially in the Urban areas, the changes in land use is in tremendous speed. The immediate effect of urbanization severely affect two important sectors namely the agriculture and water in India, which influence many environmental effects.

The remote sensing and geographic information systems (GIS) has been widely applied as a powerful and effective tool in detecting urban land use and land cover change (Ehlers et al. 1990, Treitz et al. 1992, Harris and Ventura 1995). The available range of satellites with increasing spatial, spectral and temporal resolutions make it possible to detect the land use and land cover changes in general and urban land processes in particular in any region on the globe more accurately. GIS technology on the other hand helps to store, query and analyse and displays spatial and non-spatial digital data from various sources for urban sprawl and its impact on other resources (Weng 1999).

The present study was taken up to map the urban growth pattern in a city using temporal satellite data and to estimate its impact on the environment, particularly in the agriculture sectors and water body.

2. STUDY AREA

Tiruchirappalli, a famous historical and cultural city of India, was a capital city of Cholas kingdom during 300 BC. It has more cultural heritage. The city is situated at the centre of Tamil Nadu state, on the banks of the Cauvery River. Geographically it is between 78° 39' -
The city experiences mild winters and humid summers with mean maximum and minimum temperature of 41.1°C and 18.6°C respectively. The mean annual rainfall is 821.4 mm. As per the 2001 census, the total population is 2.4 million (NIC 2008). There are 685 factories, 145 large scale and 802 small scale industries. The city has 32 science and engineering Colleges and more than 1500 schools. The city also has world famous temples called Sri Rangam. The city is well connected with airways, railways and road transport. As a result of these facilities, many people from neighbouring regions move into this city causing unlimited expansion. To cope up with the urban expansion, the neighbouring agriculture lands are getting converted into residential area. As the newly developing sub-urban areas occupy the agriculture land, the irrigation system is also affected severely.

3. MATERIALS AND METHODS

The Survey of India (SOI) topographic map (1968), a time series geo-corrected Landsat MSS data for the year 1973 and TM 1990, uncorrected IRS 1C LISS III data for 1999 and 2002 and Quikbird satellite data for 2005 (Table 1 and Fig. 2) were used.

The Landsat MSS and TM data, downloaded from the Global Land Cover Facility (GLCF) were already geometrically corrected into Universal Transverse Mercator (UTM) projection system with Datum 44. The uncorrected LISS III satellite data of 1999 and 2002 were corrected geometrically using AUTOSYNC module of ERDAS IMAGINE 9.2 software taking the geo-corrected Landsat TM 1990 data as a reference with 0.52 pixel Route mean square error (RMSE).

The scanned SOI topographical map was geometrically corrected using the latitude and longitude values available at the corners with 0.2 pixel RMSE in Polyconic projection first and later it was reprojected into UTM projection system with Datum 44.

The Quickbird satellite data were collected from the Google earth as screen shots with overlaps and side laps and were merged together using Adobe Photoshop. Later it was geometrically corrected using the ground control points (GCPs) from Landsat TM, IRS LISS III and SOI topographical maps using AUTOSYNC module with 0.35 pixel RMSE.

All the spatial data were brought into Universal Transverse Mercator (UTM) projection system with Datum 44 for seamless integration into GIS domain. The table 1 shows the details of satellite data used in the study.

The city boundary was derived from the SOI topographical map (1968). The boundary includes the built-up land of the city. This built-up category covers the residential, commercial, transport, industrial, educational and pilgrim areas. Using onscreen visual interpretation (Head-up interpretation) (Jayakumar et al. 2002) cum delineation, the
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fig. 2a. False color composite of Landsat MSS 1973 (Bands 4,3,2 in RGB)

fig. 2b. False color composite of Landsat TM 1990 (Bands 4,3,2 in RGB)

fig. 2c. False color composite of IRS 1C LISS III 1999 (Bands 3,2,1 in RGB)

fig. 2d. False color composite of IRS 1C LISS III 2002 (Bands 3,2,1 in RGB)

fig. 2e. Natural color image of Quickbird 2005 (Bands 3,2,1 in RGB)

The perimeter of the city boundary from each satellite data was derived. As the pixel resolution of Landsat MSS data was 80 m, it was bit difficult to delineate the city boundary from other land use classes in few areas where the houses were sparsely distributed. However, it was cross checked with the SOI topographical maps and corrected. The delineation of city boundary from Landsat TM and LISS III data was delineated easily as the pixel size is less than 30 m and moreover, the built-up land has very specific tone and texture characteristics. For doubtful areas, Quickbird data was cross checked and moreover the city is the home town of one of the authors.

After delineating the city boundary from each satellite data, the area was worked out and tabulated. The water body areas (natural pond) were traced from SOI topographical map and overlaid on each satellite data to check the impact of the city growth on these water bodies in different periods. In order to check the area of water body converted into built-up land, union analysis was carried out between water body layer of 1968 and each city boundary layer individually and area was calculated.

As the city is situated at the banks of perennial Cauvery River, agriculture is intensive in this region all through the year especially in the northern and western side. Agriculture is poorly practiced in the southern and eastern side of the study area. There is no other land use around this city except agriculture. Therefore, the city expansion

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fig. 3. Status of Tiruchirappalli city and water body during 1968

fig. 4. Expansion of Tiruchirappalli city in different periods.

Table 2. Growth of city and reduction of water body area in different periods

<table>
<thead>
<tr>
<th>Between periods</th>
<th>City area Increase/decrease (ha)</th>
<th>Water body Increase/decrease (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968 - 1973</td>
<td>228.56</td>
<td>- 1.42</td>
</tr>
<tr>
<td>1973 - 1990</td>
<td>596.16</td>
<td>- 22.78</td>
</tr>
<tr>
<td>1990 - 1999</td>
<td>857.48</td>
<td>- 17.05</td>
</tr>
<tr>
<td>1999 - 2002</td>
<td>210.70</td>
<td>- 3.32</td>
</tr>
<tr>
<td>2002 - 2005</td>
<td>478.12</td>
<td>- 6.84</td>
</tr>
<tr>
<td>1968 - 2005</td>
<td>2344.03</td>
<td>- 51.41</td>
</tr>
</tbody>
</table>

is at the cost of the agriculture land.

4. RESULTS AND DISCUSSION

The total city area during 1968 was 1991.96 ha (Fig 3 and 4). It was 2220.52 ha during 1973 and the increase of between 5 years was 228.56 ha (Table 2).

Between 1973 and 1990 the city has extended further to 596.16 ha (Table 2). When compared to 1968-1973 (45.71 ha/yr), the city expansion is limited during 1973-1990 (35.07 ha/yr). Maximum city expansion was observed during 2002-2005 where 159.37 ha/yr increase was recorded. Between 1968 and 2005 (37 years) the city expansion was estimated to be 2344.03 ha which is 117.67% increase compared to 1968 (1991.96 ha). On an average, the city expansion per year was 63.35 ha during the 37 years. The spatial expansion of city area between 1968 and 2005 is given in figure 5 and the comparison between periods is given in figure 6.

The expansion of Tiruchirappalli city affected two land use categories names the water body and agriculture land. The total water body during 1968 was 318.65 ha and it was decreased to 267.24 ha during 2005 (Fig. 7). Totally 51.41 ha water body area was converted into residential area, which is estimated to 16.13% decrease to the total area of 1968 (Table 2). The reduction rate between the
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fig. 7. Decrease of area of water body in different periods

37 years was 1.39 ha/yr. The conversion of water body area into residential area is given in figure 8.

Among 37 years total area of city expansion (2344.03 ha), 2.19% area is from water body area and the remaining

fig. 8. Conversion of water body into residential area a) and b) Portion of Tiruchirappalli city from Survey of India (SOI) topographical map of 1968. c) and d) Corresponding city area from Quickbird satellite natural color image where, the blue outline indicates conversion of water body into residential area. e) Enlarged view of a portion marked in red color of figure c.

fig. 9. Quickbird natural color satellite image shows the conversion of agriculture land into residential area
97.81% is from agriculture land. The Tiruchirappalli city region is surrounded totally by agriculture lands. Figure 9 shows the spreading out of residential area in the agriculture areas.

Any development in an area including urban sprawl cause changes to neighboring land cover and it is inevitable. As far as the present study is concerned, majority of agriculture area on the western and northern sides of the study area has been converted into residential area though there is considerable amount of less intensive agriculture lands available on the southern and eastern sides of the study area. As the agriculture areas at the western and northern sides are closer to River Cauvery, water is available all through the year and active agriculture is practiced in these areas. Therefore, conversion of active agriculture lands into residential area might cause severe problems to the food security in these areas in the near future.

In the present study the growth of Tiruchirappalli city between 37 years was spatially mapped and estimated using appropriate datasets. The expansion of area is at the cost of agricultural land and water body area. This primary result of this study gives an outline of growth rate of the city, the land use changes and the impact of city growth on agriculture and water body.

As we don’t have the agriculture pattern and yield from these regions for different years, we could not compute the decreased agricultural yield however, we could unquestionably conclude that the expansion of city has affected the agriculture areas considerably. The residential expansion over water body might definitely have affected the underground water table considerably. Moreover, every year during fall season, few low lying residential areas especially the newly expanded areas in the agriculture land and water body experience flood damages. Although we could not certainly conclude, due to lack of data and analysis, this flood damage is because of expansion in the agriculture and water body areas, to some extent we can assume that it may be a reason.

5. CONCLUSION

This study was carried out to estimate the growth of a historical Tiruchirappalli city in India. The series of satellite data were found to be good source of information for this study. The result gives a clear picture of the total area of the city and the growth rate. Moreover, it also portrays the impact of city expansion on agriculture land and water body in terms of area clearly. However, further in depth studies are needed to estimate the effect of city growth on agriculture yield and environment. Moreover, the modelling of trend of urban sprawl and its prediction might also be considered in the future studies.

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REFERENCES