

MAPPING OF URBAN GROWTH IN THANJAVUR CITY USING SHANNON ENTROPY ANALYSIS

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Abstract

Thanjavur city is agriculture based one and it is engulfing into a higher urban growth rate. In this context, the present study analyses the urban growth of Thanjavur city between 1970-2014 using geospatial data with Shannon entropy analysis for identifying the direction of growth. Based on the analysis, the buffer zones are created and growth has been characterized as first, second and third level of sprawl. The study concluded that the city is sprawling rapidly towards southern part, also observed it affect the agricultural land as it leading to conversion of land into built up areas.

Keywords: Urban Sprawl, Urban growth, CBD, Shannon Entropy analysis

1.0 Introduction

Due to modernization and scientific development there will be urban growth naturally in Worldwide. Awkward and irregular spatial growth of a town or city mainly due to the increase of population can be termed as urban sprawl. Hence, if any area which is under the jurisdiction of a municipality corporation, cantonment or any notified town, which exceeds its administrative boundary and grows outward without any check it is considered to be a sprawl. The area, which the increasing population occupies, will indicate the nature and type of the sprawl. The infilling of vacant lands within any area is an example of under bound sprawl. The term 'sprawl' does 'suggest lack of direction' and haphazard growth hence there is an inbuilt need for planning the sprawl and giving a suitable direction. As per the statistics in 2007, the world's urban population is likely to be increased 3.3 billion to 6.4 billion in 2050.

To define urban sprawl is still a complex one and its associated problems like loss of agricultural lands, increasing built up area, pollution, and traffic congestion etc., makes urban sprawl as one of the current social problems and to take immediate measures to decrease further complexity. The dynamic process of the urban sprawl gives fruitful information for the planners to provide basic amenities of the area. Monitoring urban sprawl dynamics is important to take good measures for planning the urban development. Urban planners should know about the urban growth trend in order to develop future urban planning. In

this context the Thanjavur city has been taken for the study and analyses the temporal changes of the urban sprawl using geospatial data, statistical techniques i.e. Shannon entropy analysis along with GIS.

2.0 Review of Literature:

Sagar Mali et al (2013) have explained ward wise population data integrated with ambulance, blood bank, education sector, hospital and road network to identify areas with high amenities and area lacking amenities. **Govinda Vanum and Kiros Meles Hadgu (2012)** used Shannon's entropy to determine the compactness or dispersion and also tabulated ward wise, zone wise and one km buffer wise entropy values. It is also evident that high per capita built up is an indicator of urban sprawl. **Sagar Mali et al (2013)** have explained ward wise population data integrated with ambulance, blood bank, education sector, hospital and road network to identify areas with high amenities and area lacking amenities. **Srimanta Gupta et al (2013)** briefly explained about influencing factors of urban sprawl and to sum up their influences on sprawl, a multivariate regression analysis has been undertaken and it is predicted to be getting more dispersed in 2021 with a 24.6% increase in built up land. **Vinay Kumar and Srivastava (2009)** have delineated macro level changes in urban area on regional scale and observed that the urban sprawl has been consumed surrounding agricultural and flat upland hindered the further development of the study region. **Rajashree et al, (2007)** have studied the population growth analysis, and ward wise occupancy analysis, further quantification of urban expansion was done based on spatial extent of urbanization, density analysis and Shannon's entropy values and jaggedness degree. **Sulochana Shekhar (2005)** studied changing space of Pune with GIS perspective, pattern of urban sprawl, analysis of spatial and temporal changes and quantified the urban sprawl in terms of change in built-up area. **Burton Stein (1960)** have characterized the main factors which were resulted in urban growth in Thanjavur were emergence of religious centers, holding of fairs, commercial activities and the initiatives taken by the kings and ministries in the creation of urban centers.

2. Study area:

Thanjavur is a historical city located in the centre of Cauvery delta region surrounded with agricultural land, and having 10°48' North latitude to 10° 8' North latitude and 79° 09' East longitude to 79° 15' East longitude covering SOI top sheet no 58N/1 and 58N/2 and shown in Fig 1. The town spreads over an area of 36.33 sq.km area and it is well connected by roads and railway network with the adjoining district viz, Tiruchirapalli, Thiruvavur and Pudukottai. The climate is fairly healthy with average annual temperature of 31° Celsius and mean rainfall amount of 104 cm. The city population in 1970 is about 1,40,547 and in 2011 it is increased to 2,22,943.



Fig 1- Study Area Map

3.0 Methodology

The methodology involves, the year 1971 built up areas were mapped from the topographical data and converted in to digital format. Next, for 2014, the built up areas were mapped from IRS P6 satellite data. Then, Central Business District (CBD) were identified and 10 buffer zones were created using ArcGIS. From the CBD the Shannon's entropy statistical method was executed to measure the compactness or dispersion of built up area growth between 1970- 2014. Finally, the changes were mapped and measured to find out the growth direction.

4.0 Mapping of Built up areas

The study of land use pattern changes in urban area over period is important task for determining the trend of urban growth.

4.1 Mapping of built up areas for 1970

From the topographical data, the built up areas and its surrounding adjacent villages were mapped and converted into GIS databases and shown in Fig 2. To find out the growth and the built up area was calculated as 4.23 sq.km, it has been observed that the core area having high built up density comparing to the rest of the areas.

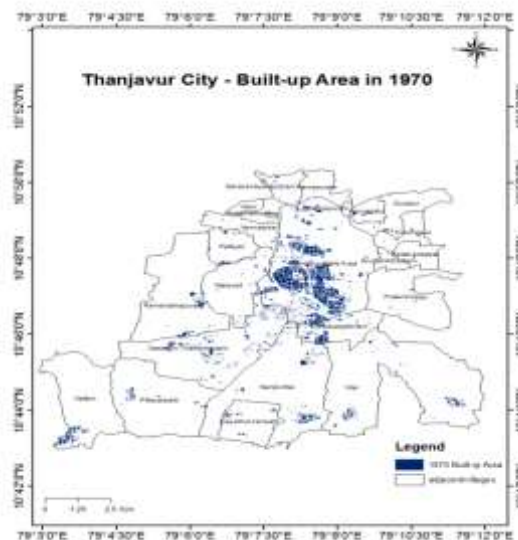


Figure 2 - Mapping of 1970 built up areas

4.2 Mapping of built up areas for 2014

From the IRS P6 LISS IV data of 2014, the built up areas were mapped and converted into GIS databases and shown in Fig 3. It has been observed that the built up area was calculated as an area of 27.27sq.km and the southwestern part is having high built up density.

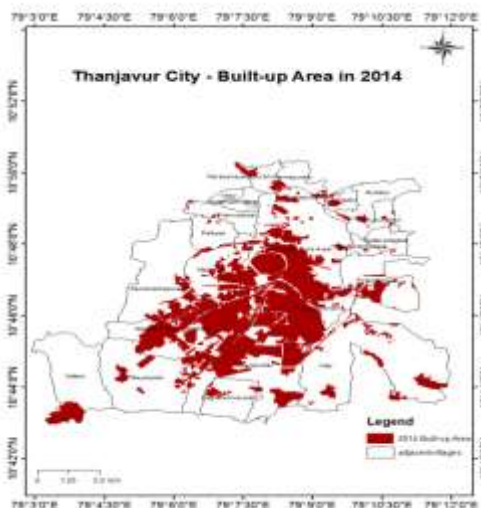


Figure 3 - Mapping of 2014 built up areas

4.3 Creation of buffer zones:

The division approach increases the number of zones and would provide an improved insight into the urban expansion of the study area. The division method considers the effect of the distance to the CBD from each zone and urban growth direction; this approach is preferred by urban planners and decision makers (Congalton 1991). Moreover, the distance to the CBD is a significant factor because the density of urbanized area changes with this distance. The level of sprawl in each zone is different from other zones. Furthermore, the sprawl varies within each direction, thus leading to different patterns of urban growth (Alshariff 2015). The study area buffered zones were created using GIS at an interval of 0.5 Km from a point chosen at Thanjavur old town based on CBD (Central Business District) concentration of commercial activity within a city up to 5 km around it. Based on the CBD 10 buffer zones were created and individual buffer zone wise built-up areas are calculated to determine the Shannon's entropy for the detection of urban sprawl. For satisfying these criteria buffer zones are created and further entropy analysis are made.

4.4 Zone wise Built-up Area in 1970

The buffer rings of CBD is overlaid with the total built up area and shown in Fig 4 and each buffer zones are calculated individually and the resultant zone wise built-up area are tabulated in the Table 1. It is observed that the higher concentration of built up area are found in the third buffer zone area having 1.05 Sq.Km with 24.82 percentage, whereas the lower concentration observed in ninth buffer zone i. e 0.06 Sq.Km constituting of 1.41% .

Table 1 - Zone wise Built up Areas in 1970

Buffer Zone Number	TGA (Sq.Km)	BUA (Sq.Km) in 1970	% of BUA
1	0.79	0.32	7.56
2	2.36	0.98	23.16
3	3.93	1.05	24.82
4	5.50	0.83	19.62
5	7.07	0.37	8.74
6	8.64	0.24	5.67
7	10.21	0.13	3.07
8	11.78	0.13	3.07
9	13.35	0.06	1.41
10	14.93	0.11	2.60
Total	78.55	4.23	100

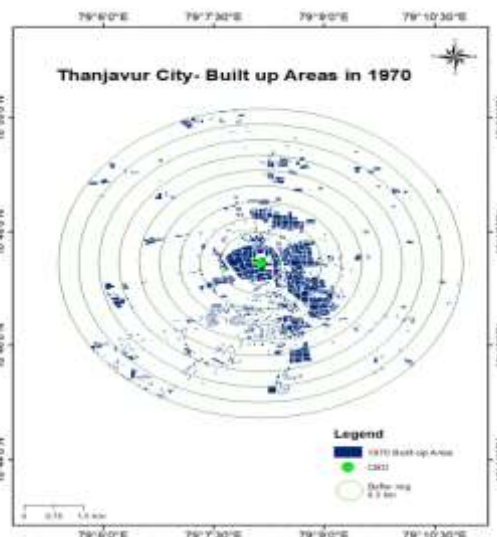


Figure 4 - Built-up Area in 1970

4.5 Zone wise Built-up Area in 2014

The buffer rings created are overlaid with the built up area and shown in Fig 5. Then zone wise areas were calculated individually and the resultant zone wise built-up area are tabulated and shown in the Table 2. It is found that the higher concentration in the fourth and eighth buffer zone having 3.63 and 3.66 Sq.Km respectively and whereas lower one found in first buffer zone having 0.53 Sq.Km only. The fourth and eighth zone constitute with 13.4% and 13.3% built up area with high percentage and in the first zone lowest percentage of 1.9 has observed in 2014.

Table 2 Zone wise Built up Areas in 2014

Buffer Zone Number	TGA (Sq.Km)	BUA (Sq.Km) in 1970	% of BUA
1	0.79	0.53	1.94
2	2.36	1.89	6.93
3	3.93	3	11.00
4	5.50	3.63	13.31
5	7.07	3.18	11.66
6	8.64	3.42	12.54
7	10.21	2.87	10.52
8	11.78	3.66	13.42
9	13.35	2.65	9.71
10	14.93	2.44	8.94
Total	78.55	27.27	100

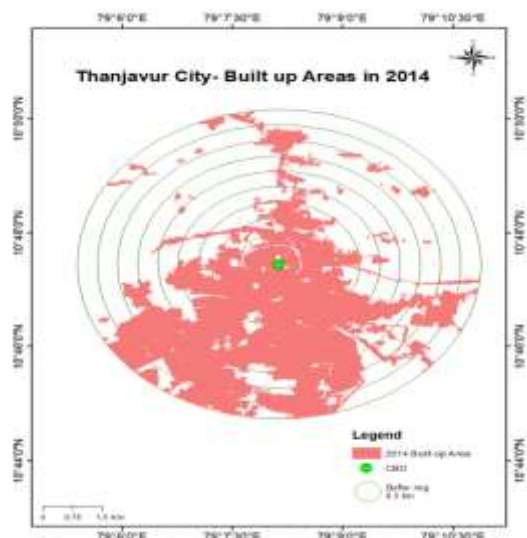


Figure 5- Built-up Area in 2014

5.0 Entropy Analysis:

The term Entropy is most frequently used describing the quantity efficiency of elements, it is related to the expansion of the spatial variable in a given area or limit. This method is useful to measure various distinguish types of sprawl. The Entropy method is beneficial with GIS due to its simplicity and uncomplicated integration. The Shannon's entropy approach (Yeh and Li, 2001 and S. Shekhar 2005) was quantified to detect the urban sprawl phenomenon. Entropy value varies from 0 to 1, if the distribution of built-up is most concentrated in one area; the lowest entropy value is 0. Distribution of built-up across space will give the maximum entropy value 1.

This Entropy (E_t) method is

$$E_t = \sum_{j=1}^m P_{Dj} [\log (1/P_{Dj})] / \log (m)$$

$$\text{Where } P_{Dj} = D_j / \sum_{j=1}^m D_j$$

D_j is the density of land growth. That equals to quantity of built-up land divided by the total quantity of land in the j^{th} zone in the total of m zones. While using Entropy to measure the distribution of a physical occurrence, the difference on entropy among two different time periods of time can be used to indicate the change in the amount of circulation of urban sprawl.

$$\Delta E_t = E_t(y+1) - E_t(y)$$

Where ΔE_t is the difference of the relative entropy values between two time periods, $E_t(y+1)$ is the relative entropy value at time period $y+1$, $E_t(y)$ is the relative entropy value at time period.

In the study area, Shannon entropy was calculated from the built up area for each individual zone, the value of entropy for total 10 buffer rings and shown in Table 4 for the year 1970. Same way for the year 2014 entropy was calculated and shown in Table 5.

$$\text{Log}(10) = 1 \text{ for year 1971 was } E_t = 0.71/1 = 0.71$$

$$\text{Log}(10) = 1 \text{ for year 2014 was } E_t = 0.95/1 = 0.95$$

The graphical representation of Shannon entropy analysis Shows in Fig - 6

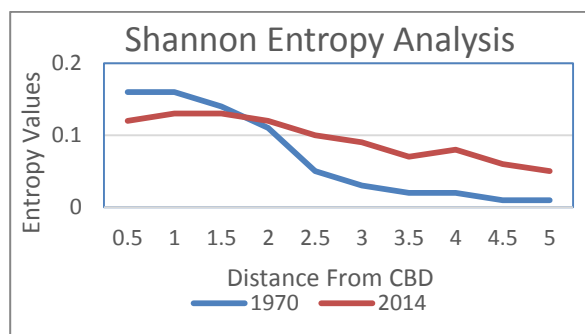


Fig - 6 Shannon Entropy Analysis

Table 3 Shannon Analysis for 1970

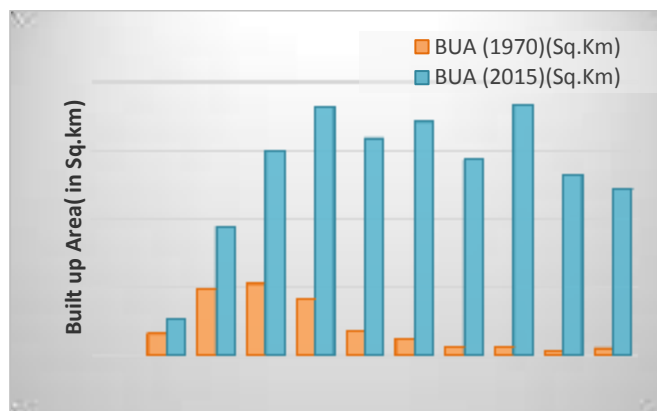
Buffer rings	Built up Density(PDj)	1/PDj	Log (1/PDj)	PDj*Log (1/PDj)
1	0.3	3.38	0.53	0.16
2	0.31	3.26	0.51	0.16
3	0.2	5.07	0.71	0.14
4	0.11	9.03	0.96	0.11
5	0.04	25.77	1.41	0.05
6	0.02	48.76	1.69	0.03
7	0.01	104.42	2.02	0.02
8	0.01	122.32	2.09	0.02
9	0	292.93	2.47	0.01
10	0.01	186.22	2.27	0.01
	1			0.71

The relative entropy was worked out for 1971 and 2014
 $\Delta E_t = 0.95 - 0.71 = 0.24$

The entropy value obtained for 1970 is lower than that of 2014.

Table 4 Shannon Analysis for 2014

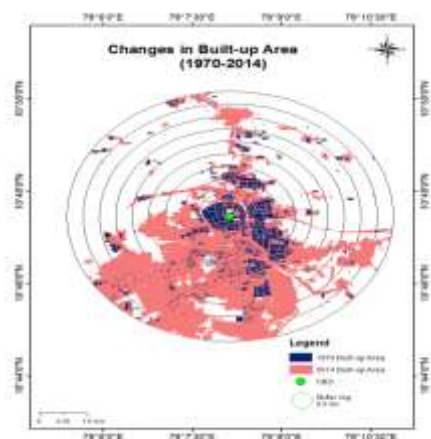
Buffer Rings	Built up Density (PDj)	1/PDj	Log (1/PDj)	PDj*Log (1/PDj)
1	0.14	6.96	0.84	0.12
2	0.17	5.87	0.77	0.13
3	0.16	6.16	0.79	0.13
4	0.14	7.12	0.85	0.12
5	0.10	10.44	1.02	0.10
6	0.08	11.86	1.07	0.09
7	0.06	16.71	1.22	0.07
8	0.07	15.12	1.18	0.08
9	0.04	23.66	1.37	0.06
10	0.03	28.78	1.46	0.05
	1.00	1.00	0.00	0.95


Figure 8- Changes in built-Up Area

5.1 Comparative Analysis

The built-up area as a potential and fairly accurate parameter of urban sprawl has resulted in making considerable hypothesis. For which the study area 1971 and 2014 built up areas were integrated using GIS and shown in Fig 7. It has been observed that the central part of the town up to 0.5 km occupied most of its space by built ups in 1971. In 2014, some area is engulfed by built up areas, when compared to other zones, whereas the outer part is largely confined to more built up land.

The zone wise changes of built up areas are graphically represented in Fig 8, and observed that in 1971 highest built up density was up to 1.5 Km from the CBD. But in 2014 central portion of the city only retaining the built up density of 1971, while remaining areas up to 5 km from CBD, the density was increased.


Figure 7- Changes in Built-up Area (1970- 2014)

6. Results and Discussion:

From the study area built up area was calculated as an area of 4.23 sq.km in 1971 and 27.27 sq.km in 2014, it has been observed that the core area having high built up density comparing to the rest of the areas in 1971, where as in 2014 the areas were increased that too in the south western part having high built up density. Concluded that proving drastic increases in and around Thanjavur city of 5 km buffer area.

Based on the buffer analysis, in 1971, higher concentration of built up area are found in the third buffer zone area having 1.05 Sq.Km with 24.82 percentage, whereas the lower concentration observed in ninth buffer zone only 0.06 Sq.Km constituting 1.41% . In 2014, the higher concentration found in the fourth and eighth buffer zone as 3.63 and 3.66 Sq.Km respectively and whereas lower one found in first buffer zone having only 0.53 Sq.Km. The fourth and eighth zone constitutes with 13.4% and 13.3% built up area with high percentage and in the first zone, lowest percentage of 1.9 is observed in 2014. The driving force behind urban sprawl in Thanjavur municipality is population growth

The Shannon entropy values for 1971 and 2014 are 0.71 and 0.95 respectively and the relative entropy value obtained 0.24, it shows that the higher dispersion in settlement pattern in the study area. It is clearly noticed that in south-West direction urban growth is taking place towards mainly in the adjacent villages of Nanjikottai ,Neelagiri Terkuthottam, Pillayarpatti and Melaveli, Whereas in the East direction near Pulianthoppu and some parts of Vilar. According to the recent census, the villages like Nanjikottai, Neelagir Pudukattinam and Vilar are upgraded to census town due to the high population growth in recent decades.

The study shows a discontinuous spread of settlements in the Northern part, leap frogging into each other along the

national and state highway and, fast spreading into the hinterland and converting the viable agricultural lands into urban development, which led to the rapid expansion and sprawling of the younger settlements resulting in land cover changes from rural to urban. And also the study provide the quantitative and qualitative data for future effective planning and decision making for more indigenous and sustainable development of the settlements in and around Thanjavur Municipality.

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