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Mapping Urban Sprawl and Measuring Urban Density using Shannon Entropy: A Case Study of Salem City and its Environ

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Abstract: ***Urbanization refers to increase in population of the city which is being influenced by social, political and economic characteristics of the city. As the population of the city increases, the boundary of the city expands to some extent leading to urban fringes. Urban sprawl is the haphazard patchwork of development resulting in an improper development in any city. It is necessary to monitor the growth of the city to prevent this kind of improper development. Identification of urban growth and its density of the city helps in better planning and management of the city. This requires analysis of spatial and temporal data for analyzing the trends over a period of time. The present study uses Remote Sensing and Geographic Information System techniques to monitor the urban growth and Shannon entropy to measure dispersion of built-up land growth in the city. The study area has been divided into concentric circles of 1 km buffer and the urban growth is analyzed based on urban built-up density with respect to each circular buffer zones. The study also proved the potential of RS and GIS techniques in the Spatial-temporal analysis of urban growth trends and their consequences in the lands adjoining to urban areas.***

Keywords: Urban sprawl, Urban growth, Shannon entropy, Remote sensing and GIS

1. Introduction

As the population of the city increases, there is a change in landuse and land cover practices leading to urbanization. The agricultural lands, water bodies and forests are replaced by Built-up lands. These changes have been increasing since two decades because of population growth, increasing employment opportunities and globalization. [5]. This unmanageable population growth leads to improper development in the city and causes serious impacts to the environment such as pollution, scarcity and unemployment.

This improper and uneven development results in urban sprawl which is quite increasing for the past two decades in India.It is to be considered as the uneven growth from the centre to the outskirts of the city. [5].Geospatial techniques have been used to analyze the changes in urban area over a period of time. The temporal spatial data allows to visualize the changes in land use practices in an area and to find out the driving factors which influences the changes and helps in making decisions accordingly [1]. The driving factors which influences urban sprawl can be of anthropogenic or natural.

The anthropogenic factors include roadways and railway lines which directly influence the urban sprawl. The natural features such as mountains and river network acts as barriers of urban sprawl in a city. Shannon's Entropy is used to measure the dispersion of urban growth along the city spatially. It is the proportion of the maximum possible dispersion in which a variable is spread between categories or spatial zones. [1] -[5]. This study involves the analysis of spatial and temporal changes in Salem city and uses Shannon entropy to find out the built-up area density of the Salem city.

2. Data and Methods

2.1 Study Area

Salem is a famous city in Salem district in Tamil Nadu. It is located about 160 kilometers northeast of Coimbatore, 186 kilometers southeast of Bangalore and about 340 kilometers southwest of the state capital, Chennai. It covers 91.34 km^2. The name Salem is derived from the word "Sela"or"Shalya" which refers to "the country surrounded by hills".The city is surrounded by Nagaramalai on the north, Jarugumalai on the south, Kanjamalaion the west, Godumalai on the east and the Shevaroy hills on the northeast. Kariyaperumal Hill is on southwestern Salem. This study is undertaken to measure the urban sprawl in Salem city, Tamil Nadu, India through Shannon entropy approach because Salem is the sixth largest city in Tamil Nadu by population.Itwill reveal the changes in urban area of Salem city and its reasons.

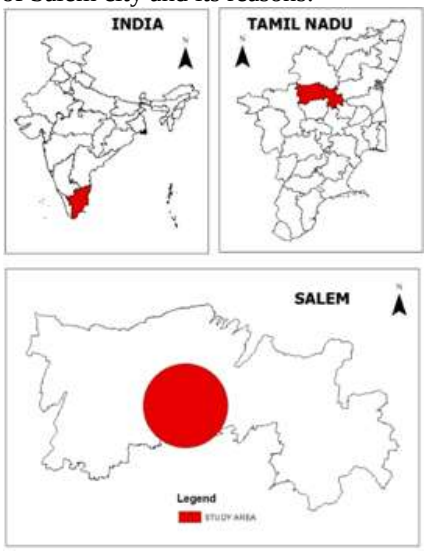

Figure 1: Location Map of Study Area

2.2 Data used

The Dataset includes Satellite Images and Toposheets.The toposheets were used for the years 1932, 1944, 1972 and 2006(OSM) and the satellite images have been listed in the table 1.

Table 1: Satellite images used for this study

Years	*Satellite data*	*Date*
1992	Landsat 5	8th Dec 1992
2000	Landsat 7	10th April 2000
2011	Landsat 5	12th Feb 2011
2017	Landsat 8	17th April 2017

2.3 Methodology

The pre-processing of the satellite images was done in ERDAS imagine 2014.The satellite images and toposheets were classified into two main classes such as built-up and Nonbuilt-up area. The areas were classified by manual digitization. The total area of built-up and Nonbuilt-up was calculated. The CBD(Central Business District)has been chosen in the study area and it was divided into 15 concentric circles by creating buffer for each 1 km using multiple ring buffer tool in Arc-GIS Software. Then the classified image and the buffer layer were intersected to find out the growth in urban area in every 1 km. The built-up area in every zone was calculated for a year. This was followed for all the years which had been chosen for this study. Then the further processes like masking, digitization, classification, area calculation and map preparation were done in Arc GIS software.
Shannon Entropy has been computed to analyze the urban sprawl during the years 1932 and 2017 in the Salem city. Shannon entropy is a measure to determine the compactness or distribution of built up land growth in the urban areas.

$$En = \sum_{i}^{n} \mathrm{Pi}\log(1/\mathrm{Pi}) / \mathrm{Log}(n)$$

Where,
En-is the relative entropy
Pi-probability or proportion of built-up in the zone
N-Number of zone

$$Pi = Xi / \sum Xi$$

Where,
Xi-is the urban Area within the particular zone
∑Xi– is the total Area of the zone

The value of Shannon entropy ranges from 0 to log n. Value of 0 indicates that the distribution is very compact while values nearer to 1 indicates that the distribution is much dispersed.

3. Results and Discussion

The following various significant methods have been used to identify urban sprawl of Salem city of the study area.

3.1 Built-up Area Change Analysis

The remote sensing is a powerful and useful tool for studying urban related issues like land use /land cover change detection, urban growth analysis, urban planning, etc. In the present study, ArcGIS software has been used for analyzing multi-temporal Landsat images and toposheets of Salem city. The built-up area has been extracted from toposheets (1932, 1944, 1972 and 2006) and satellite images (1992, 2000, 2011 and 2017) using manual digitization. The area is divided into two major classes viz.; Built-up area and non-built-up area.

The bar chart 2 shows the total Built-up area and Non built-up area of Salem city.The built-up area of Salem city was 2167.903 ha in the year 1932, 3159.509 ha in the year 1944, 5084.935 ha in the year 1972, 5486.753 ha in the year 1972, 5733.032 ha in the year 2000, 8998.039 ha in the year 2006, 10004.1 ha in the year 2011, and 10464.89 ha in the year 2017. The total Built-up area has been increased from 2167.903 ha to 10464.89 ha. This indicates that the Built-up area is rapidly growing from the year 1932 to 2017.

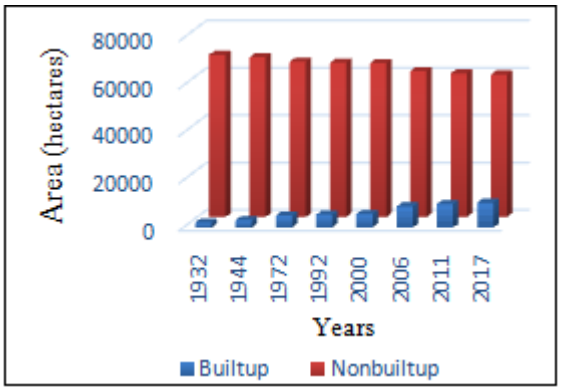

Figure 2: Built up and Non Built up area of Salem city

The built-up area in Salem city has kept increasing for every one kilometer and its shown in the figure 3,4,5,6.

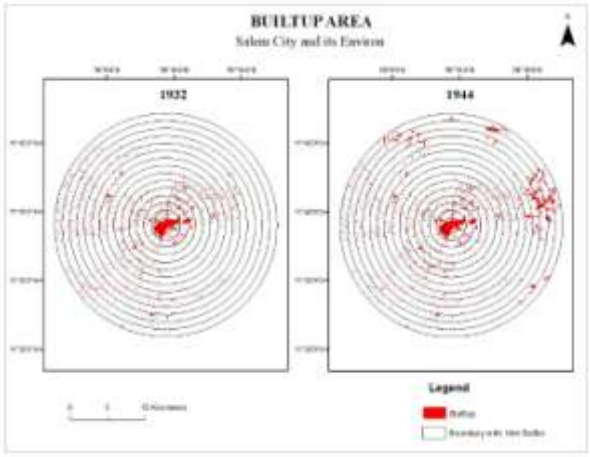

Figure 3: Built up area of Salem city and its environ in the year 1932 and 1944

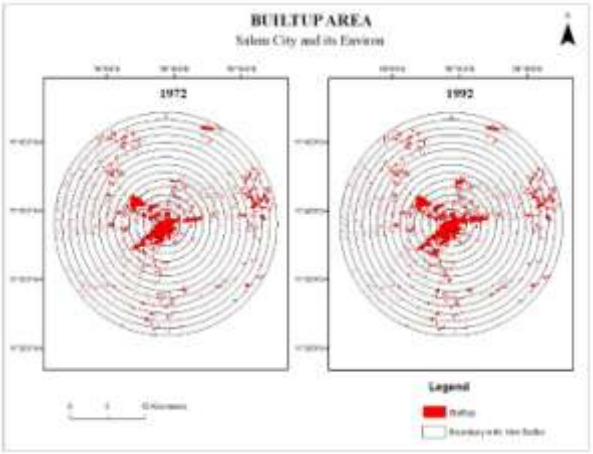

Figure 4:Built up area of Salem city and its environ in the year 1972 and 1992

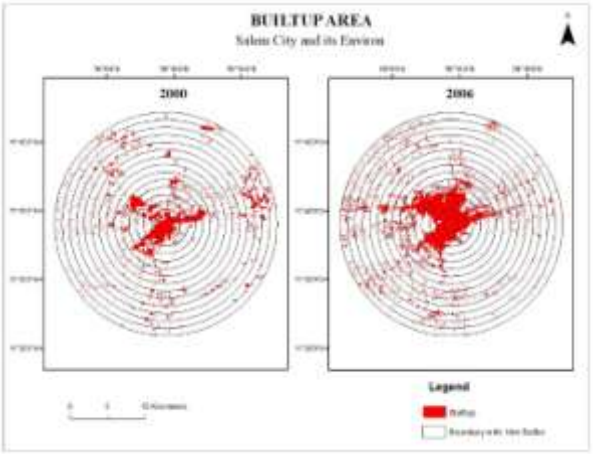

Figure 5: Built up area of Salem city and its environ in the year 2000 and 2006

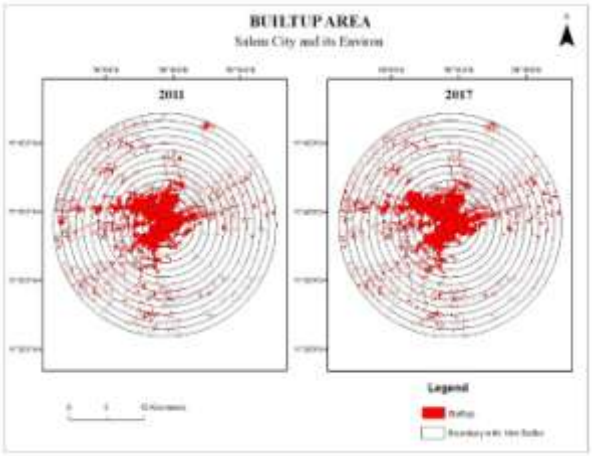

Figure 6: Built up area of Salem city and its environ in the year 2011 and 2017

3.2 Measuring Urban Density

To measure the urban density, the entire city area has been divided into 15 bufferrings (1 km each) from CBD and the built up area was calculated in each buffer zone.Finally, the entropyvalue was calculated for each zone in the study area for all the years. The figure 7shows the entropyvalues in each zone for the corresponding years. In which the entropy value increase with increasing distance from the city centre indicates the sparse urban built-up area. The entropy value for the year 2017 is very less that shows high density built up area.

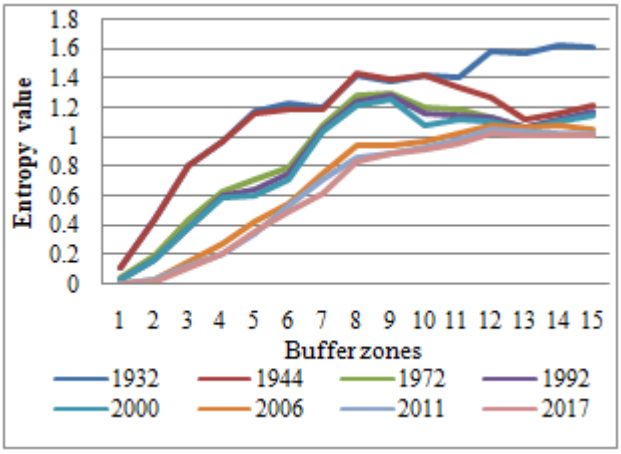

Figure 7: Entropy values in Each Buffer

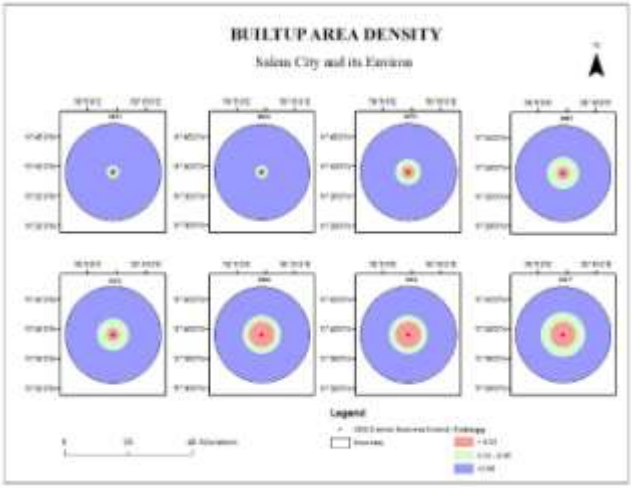

Figure 8: Built up Area density for Salem city and its Environ

Figure 9: Types of Built up area based on density

In all the years, concentric circle buffer zone with entropy values less than 0.33 indicates dense urban area which would be the zones of uniformity; those comes between 0.33-0.66 would be the zones of organized urban development and those above 0.66 would indicate the zones of chaotic urban development and it is dispersed built up area which is shown in figure 8 and 9.

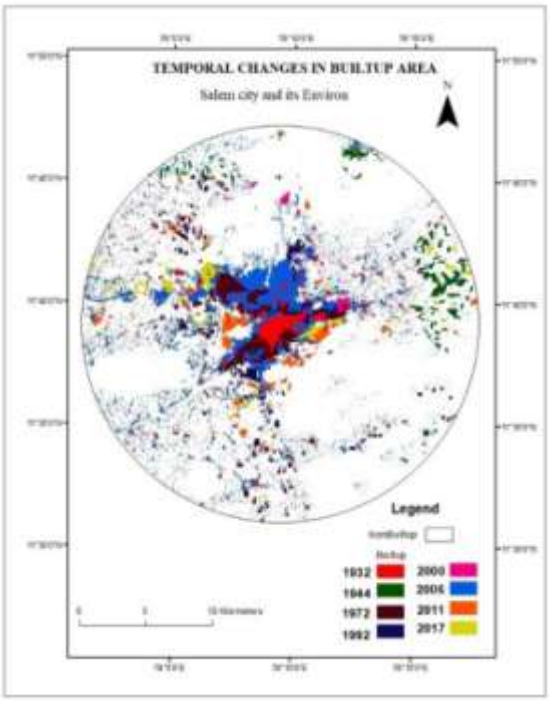

Figure 10: Temporal Changes in Built up Area of Salem city and its Environ

Figure 10, represents built-up area change detection analysis which denotes the temporal changes in Salem city.Southern East part of Salem city has been covered by hills that is the major reason for the expansion of built-up area in opposite direction of Salem city.

4. Conclusion

Measurement of urban built-up density shows its importance in monitoring urban growth expansion over the different periods. This approach is quite helpful in monitoring the urban dynamics. The concentric circle approach is more appropriate for identifying the growth as well as its dispersion. For the sustainable urban development, proper infrastructure development is required. This study concludes that measurement of built-up density using Shannon's entropy can be effective in monitoring the spatial urban growth dynamics.

Remote sensing and GIS based techniques are used to distinguish built-up and Non built-up areas. The present case study is focused on extraction of urban area in Salem city in terms of increasing urban density from the mean Centre of 1km city buffer using the temporal Landsat images and the toposheets for the year 1932, 1944, 1972, 1992, 2000, 2006, 2011, and 2017. The study area has been classified and the built-up area has been extracted. The extracted urban built-up area shows the growth of Salem city from 1932 to 2017. Shannon entropy approach has been adopted for measuring the urban built-up density. Fifteen concentric buffer rings of 1 km area where drawn from city Centre to obtain the actual built-up area density. Shannon entropy values have been calculated for each buffer and on the basis of maximum and minimum value, three cumulative classes have been derived. The entropy value nearer to 0 shows the compact built up area and more density and the value nearer to 1 or above represent decreasing density or compactness.

The approach adopted in the study clearly demonstrate the potential of GIS and remote sensing techniques in measuring changes in urban built-up area in city buffer. This study not only provides the scientific way to understand the future urban growth but it also provides acost and time effective methodology to assess built-up land use. Hence it would be useful for decision making process and also helpful for planners and authorities to formulate suitable plan for sustainable built-up/urban development in the region.

References

[1] H.S.Sudhira, T.V.Ramachandra, Karthik S. Raj, K.S.Jagadhish, "Urban growth analysis using spatial and temporal data,"Journal of the Indian society of Remote Sensing,31,pp.299-311,2003.
[2] Milappunia, Laxman Singh, "Entropy Approach for assessment of Urban Growth: A Case Study of Jaipur, India," Journal of the Indian Society of Remote Sensing, 40, pp. 231-244, 2012.
[3] Nilanjana Das Chatterjee, Soumendu Chatterjee, Ansar Khan, "Spatial Modeling of Urban Sprawl around Greater Bhubaneswar City, India," Springer International Publishing, 2015.
[4] NishaRadhakrishnan, Satish Kumar Eerni, Sathees Kumar, "Analysis of Urban Sprawl Pattern in Tiruchirappalli City using Applications of Remote Sensing and GIS," Arabian Journal for Science and Engineering,39, pp. 5555-5563, 2014
[5] T.V. Ramachandra, Bharath H. Aithal and M. V. Sowmyashree, "Urban Structure in Kolkata: Metrics and Modelling through Geo-Informatics," Applied Geomatics, 6, pp. 229-244, 2014.
[6] RamakarJha, Vijay P. Singh, And V. Vatsa, "Analysis of Urban Development of Haridwar, India, using Entropy Approach," KSCE Journal of Civil Engineering, 12, pp.281-288, 2008.
[7] SassanMohammady, Mahmoud Reza Delavar, "Urban Sprawl Assessment and Modeling using Landsat images and GIS," Springer International Publishing Switzerland, 2016.
[8] Shaily Raju Gandhi, Shasshikant A. Sharma and Anjana Vyas, "Urban Growth Analysis using Shannon Entropy-A Case Study of Rajkot City (Gujarat)" published in Journey of Geomatics (2015).
[9] Amrit Kamila and Subodh Chandra Pal, "Urban Growth Monitoring and Analysis of Environmental Impacts on Bankura - I & II block using Landsat Data," International Journal of Advanced Remote Sensing and GIS, 4(1), pp.965-975, 2015
[10] J. Antony Vinoth Kumar, S.K. Pathan, R.J. Bhanderi, "Spatio-Temporal Analysis for Monitoring Urban Growth- A Case Study of Indore City," Journal of the Indian Society of Remote Sensing, 35(1), 11-20, 2007.
[11] Bharath H. Aithal& T. V. Ramachandra, "Visualization of Urban Growth Pattern in Chennai using Geoinformatics and Spatial Metrics," Journal of the Indian Society of Remote Sensing, 44, pp. 617-633, 2016.

[12] B. Bhatta, "Analysis of Urban Growth Pattern using Remote Sensing and GIS: A Case Study of Kolkata, India," International Journal of Remote Sensing, 30, 4733–4746, 2009.
[13] Reid Ewing, Rolf Pendall, Don Chen, "Measuring sprawl and its transportation impacts," Journal of the Transportation Research Board, pp. 175-183, 2003.
[14] Francis Mwakapuja, EvaristoLiwa and JaphetKashaigili, "Usage of Indices for extraction of built-up areas and vegetation features from Landsat TM image: A Case of Dares Salaam and Kisaraweperi-Urban Areas, Tanzania," International Journal of Agriculture and Forestry, 3(7), pp. 273-283, 2013.
[15] S. Farooq and S. Ahmad, "Urban Sprawl Development around Aligarh City: A Study Aided by Satellite Remote Sensing and GIS," Indian society of remote sensing, 36, pp. 77–88, 2008.
[16] Kass Green, DickKempka, Lisa Lackey, "Using Remote Sensing to Detect and Monitor Land Use and Land Cover Change," Photogrammetric Engineering and Remote Sensing, 60, pp. 331-337, 1994.
[17] Masroor Hussain, Dongmei Chen, Angela Cheng, Hui Wei, David Stanley, "Change Detection from Remotely Sensed Images: From Pixel-Based to Object-Based Approaches," ISPRS Journal of Photogrammetry and remote sensing, 80, pp. 91–106, 2013.
[18] Chunyang He, Peijun Shi, DingyongXie, Yuanyuan Zhao, "Improving the Normalized Difference Built-Up Index to map Urban Built-Up Areas using a Semiautomatic Segmentation Approach," Remote sensing Letters, 1, pp. 213–221, 2010.
[19] Martin Herold, Philip E Dennison, "Spectrometry for Urban Area Remote Sensing: Development and Analysis of a Spectral Library from 350 to 2400 nm," Remote sensing of environment, 91, pp. 304–319, 2004.
[20] Martin Herold, Margaret E Gardner, Dar A Roberts,Philip E Dennison, "Spectral Resolution requirements for Mapping Urban Areas," IEEE transactions on Geoscience andRemote sensing,41, pp. 1907–1919, 2003.
[21] Martin Herold, Joseph Scepan, Keith C Clarke, "The use of Remote Sensing and Landscape-Metrics to Describe Structures and Changes in Urban Landuses," Environment and Planning, 34, pp.1443–1458, 2002.
[22] JiHong Li,RongXuQiu, Le Xiong andJiadong Xu, "A Gravity-Spatial Entropy Model for the measurement of Urban Sprawl," Science China Earth Sciences, 59, pp.207-213, 2016.
[23] Mathew Luck, Jianguo Wu, "A gradient analysis of urban Landscape Pattern: A Case Study from the Phoenix Metropolitan Region, Arizona, USA," Landscape Ecology, 17, pp. 327–339, 2002.
[24] Mahdi SabetSarvestani, Ab. Latif Ibrahim, PavlosKanaroglou, "Three decades of Urban Growth in the city of Shiraz, Iran: A Remote Sensing and Geographic Information Systems Application." Cities 28(4), pp. 320–329, 2011.
[25] Yue W Z, Liu Y, Fan P L. (2013), "Measuring Urban Sprawl and its drivers in large Chinese cities: The case of Hangzhou". Land Use Policy, 31:358–370.