

Assessment of urban growth using Shannon's Entropy Index: A case study of Chennai, Detroit of India

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Abstract

The Remote Sensing (R/ S) and Geographical Information System (GIS) play a vital role to evaluate and study the urban expansion pattern. In this study, the Chennai city was selected to perform the urban sprawl study. Five different periods of satellite imageries for the time elapsed between 1994 and 2016 were used. The main aim of this paper was to identify the urban sprawl of Chennai as a patterning process. The extended areas of urban in the period of 1994, 2001, 2006, 2011 and 2016 were extracted by the sub-pixel classification method from the satellite imageries. Furthermore, Shannon's entropy index was used for assessing urban expansion. The findings of this study proved that Chennai city has sprawled by urban expansion during the period between 1994 and 2016. Likewise, the dispersion rate of urban sprawl for the periods of 1994, 2001, 2006, 2011 and 2016 were 0.671, 0.679, 0.688, 0.693 and 0.695 respectively. Consequently, this uncontrolled dispersed urban development had resulted in the study area losses their green space.

Keywords: Detroit of India, Geographical Information System (GIS), Remote Sensing (R/ S), Shannon's entropy, Sub-pixel classification, Urban sprawl

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INTRODUCTION

At present, the developed and developing countries' cities are experienced prompt change. They are increasing in area, population density and at the same time they are obtaining a new character as their people execute new tasks in the physical environment, that increasingly reflect the use of new technology (Allefsen, 1962; Milap Punia and Laxman Singh 2012). Prompt expansion of urban area creates a huge level of changes in the landscape have been recently observed in many developing countries including India as a result of rapid economic advancements (Yeh and Li, 2001; Mohapatra *et al.*, 2014; Derya Ozturk, 2017). It is considered as the greatest significant changes in Land Use and Land Cover (LU/ LC) changes (Weng, 2001). The result of a large scale of urban sprawl, the surrounding natural land parcels such as agricultural fields, forests or wetlands were encroached (Xu *et al.*, 2000). Changes of these other natural land use features into these impervious built-up lands can put important impacts on the

ecosystem, thus affecting the hydrologic system, biodiversity and climate and as a result that may have the negative effect such as urban temperature island phenomenon (Jyotishman Deka *et al.*, 2012). In view of fact that urban development is an inescapable process, efforts can be prepared to direct it in the appropriate way by urban land use planning so as to produce the natural resources and the rights of the people (Soffianian *et al.*, 2010). Thus, precise mapping of urban surroundings and monitoring urban expansion is becoming gradually increasing significant at the level of global (Guindon and Zhang, 2009). For urban sprawl, a mapping is expensive and time-consuming when we are using conventional surveying methods. Hence, Shannon's entropy index along with R/ S and GIS have been used as another new method for urban sprawl related studies (Yeh and Li, 2001; Sudhira *et al.*, 2004; Punia and Singh, 2011; Jyotishman Deka *et al.*, 2012; Derya Ozturk, 2017; Vivek Garg and Alok Sharma, 2018).

The former researchers, in their studies different methods were applied for zone divisions to calculate the entropy index. For example, the city center based created the buffer zones; pie selection based dividing the study area into zones and administrative boundary depends on dividing the zones. In the present study, the Chennai city was divided into five zones based on the Taluk boundaries. The core aim of this study was to show the combined use of R/ S and GIS with Shannon's entropy in addressing a basic urban sprawl issue of the Chennai city. The precise objective is to evaluate the urban growth patterns in the studied area in the period between 1994 and 2016.

MATERIALS AND METHODS

Study area: Chennai city (Detroit of India), the capital of the Tamil Nadu was selected as a study area in this study. It is the main economic, commercial, financial and business centre of Tamil Nadu. Chennai city is geographically located in between 80°10'5.079"E to 80°18'39.522"E Longitude and 12°56'56.547"N to 13° 8'17.583" N latitude along the Bay of Bengal coast in the western part of the study area. The study area is divided into five Taluk namely: Egmore - Nungambakkam, Mambalam - Guindy, Mylapore - Triplicane, Perambur - Purasawalkam and Fort - Tondiarpet as shown in Fig. 1.

R/ S and GIS are a unique phenomenon that can play a major role in effective and well-organized mapping and monitoring a vast change of land-use and land-cover. Thus, to achieve the above-mentioned aim the following methodology has been adopted. For this study, different sensors of Landsat satellite imageries have been used. Sub-pixel classification technique has been employed to built-up area classification for every period of satellite images. It deals with performing feature in the classification by breaking the pixel into more pixels based on the unmixed spectral by identifying the abundance of classes using a fuzzy logic algorithm. Actual built-up area calculated for every period which was used to compute the Shannon's Entropy Index. It was computed for understanding urban growth. It helps to determine whether the growth and urban expansion was more dispersal (sprawl) or compact in nature.

Shannon's Entropy Index is given below

$$H_n^1 = -\sum P_i * \log P_i \dots\dots\dots(1)$$

$$H_n^1 = \sum P_i * \log (1/P_i) \dots\dots\dots(2)$$

Where,
 Pi is the proportion of the built-up value in the ith Zone (Taluk)
 n represents the total number of Taluks
 log n represents the maximum limit of entropy i.e. equal to log 5 = 0.69897.

The outcome of Shannon's Entropy index ranges between 0 and log(n), where the index ranges are closer to zero indicates the urban distribution is compact else if the values are nearer to log n represents the spreading of sprawl. Values of entropy index closer to log n disclose the dispersion of the settlement area, which denotes the incidence of urban expansion and heterogeneity of other land uses. The change of entropy values in every period represents land development is toward a divergent or compact pattern. The detailed workflow of this study is shown in Fig. 2.

RESULTS AND DISCUSSION

The five different periods of satellite images were classified into two classes. The first one is the built-up area and another one is non-built up area. The former researchers in their studies supervised classification technique was employed for satellite image classification process (Jyotishman Deka et al., 2012; Abdelkader El Garouani et al., 2017; James Magidi and Fethi Ahmed, 2017). In the present study, the sub-pixel classification method was adopted for classifying the built-up areas. Fig. 3 shows the classified built-up area for the year of 1994, 2001, 2006, 2011 and 2016. It clearly represented the urban growth of Chennai city in differ-

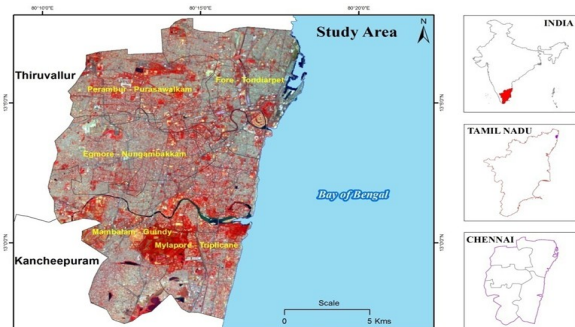


Fig. 1. Study area: Chennai City showing the Taluk boundary with Satellite image background.

Table 1. The Shannon's Entropy Index of Egmore – Nungambakkam, Mambalam – Guindy, Mylapore – Triplicane, Perambur – Purasawalkam and Fort – Tondiarpet Taluks.

Taluk	1994	2001	2006	2011	2016
Egmore - Nungambakkam	0.133	0.141	0.142	0.141	0.140
Mambalam - Guindy	0.132	0.132	0.129	0.138	0.142
Mylapore - Triplicane	0.114	0.114	0.133	0.132	0.132
Perambur - Purasawalkam	0.134	0.134	0.130	0.130	0.131
Fort Tondiarpet	0.158	0.158	0.156	0.152	0.150
Total	0.671	0.679	0.688	0.693	0.695

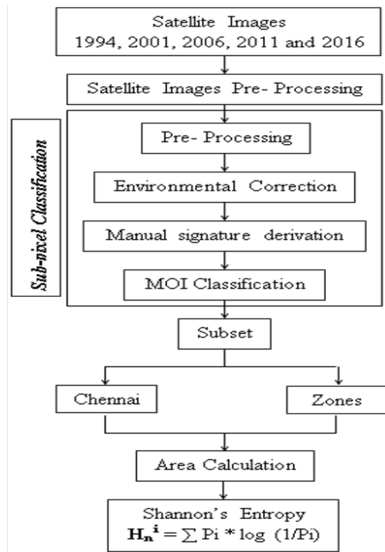


Fig. 2. Detailed workflow for assessing the Urban sprawl of Chennai city.

ent periods. In the sub-pixel classification method, a pixel was sub-divided into eight classes based on the occupied percentage of the urban area. In this classification method, only 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80-89 and 90 to 100 percent of occupied urban area were assessed which is represents in light yellow to dark red colour in Fig. 3. The actual built-up area of study area calculated from eight classes and then combined to obtain a total built-up area. Taluk-wise calculated entropy index and year wise graphical representation or Shannon's entropy index of the study area are shown in Table 1 and Fig. 4 respectively. It clearly demonstrates the urban sprawl was gradually increased from 1994 to 2016.

The calculated Shannon's entropy index of Chennai District for the year of 1994, 2001, 2006, 2011 and 2016 is 0.671, 0.679, 0.688, 0.693 and 0.695 respectively. The above mentioned all periods of the index value was nearly equal to the upper limit of the entropy value 0.69897. It is the greatest evidence for the urban expansion of the Chennai city comes under the more dispersal.

Conclusion

Chennai city had experienced a rapid rate of urban growth over the period of time. This study had taken efforts to identify the urban sprawl for the period between 1994 and 2016. The spatial urban expansion dynamics had efficiently captured by R/S and GIS techniques using entropy index approach. In this study, satellite imageries play a vital role in mapping and quantifying the temporal urban extension area. The proposed methodology of classification in this study helps to get a more accurate built-up area. For all periods, calculated Shannon's entropy index of Chennai city is gradually increased indicating the greatest evidence for

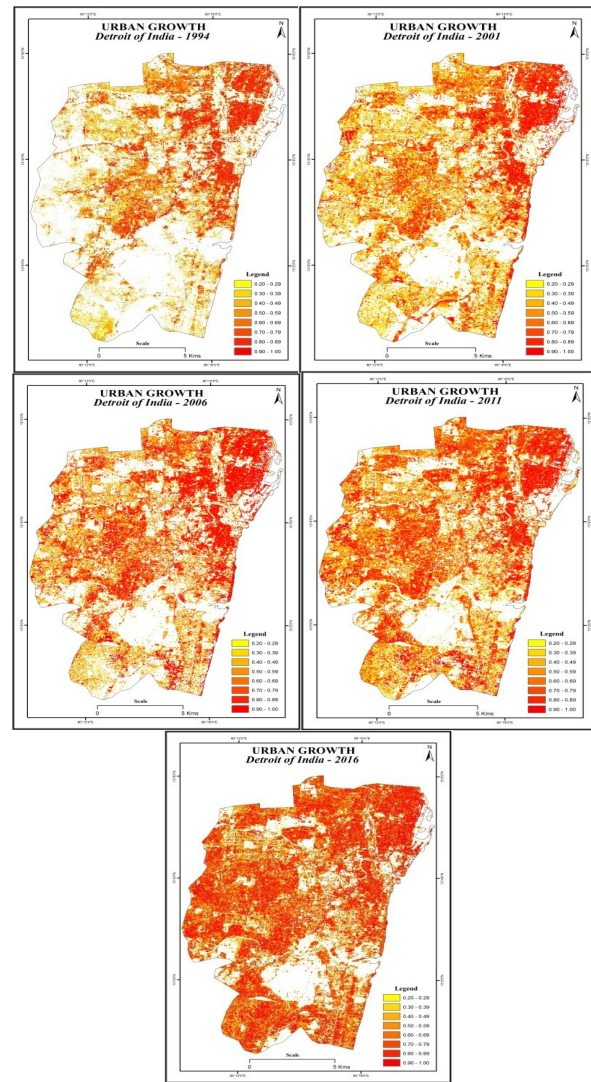


Fig. 3. Sub-pixel classification outcome for the year of 1994, 2001, 2006, 2011 and 2016.

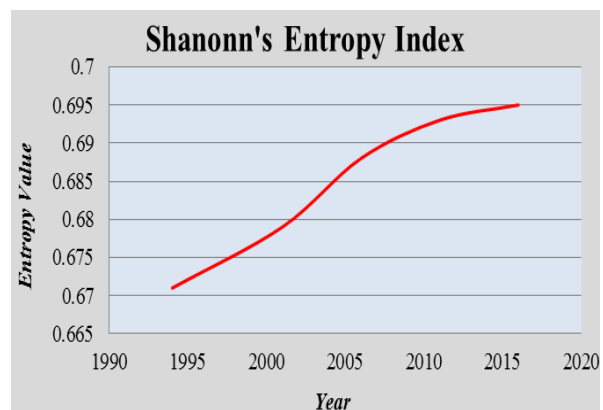


Fig. 4. Different periods of Shannon's Entropy Index of the Chennai city.

urban sprawl in the Chennai city. It will automatically affect the other most important factors of LU/LC. The outcome of this study helps in taking proper measure of sustainable development.

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