An Analysis of Spatio-temporal Characteristics of Urban Sprawl in the Mysore City

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Abstract

Rate of urbanization is now more in the developing countries than developed countries. Mismanaged rapid urbanization leads to scattered growth resulting in urban sprawl. The urban sprawl characteristics such as spatial structure and pattern should be quantified to developcounter strategies to evade possible adverse impacts. The study aims to analysethe spatio-temporal characteristics of urban sprawl in the Mysore LPD using landscape metrics for the years 2000 and 2016 byemployingFragstats 4.1 software.The study adopted the combined approach of remote sensing, GIS and landscape metric to visualize the spatial structure and pattern of urban sprawl.The indices of landscape metrics used in the study are Number of Patches (NP), Patch Density (PD), Landscape Shape Index (LSI), Clumpiness Index (Clumpy), Percentage of Like Adjacencies (PLADJ). During the study period, NP,PD and LSI has increased indicating fragmented urban growth and Clumpyand PLADJhave declined showing dispersed urban growth in Mysore LPD with more aggressive towards south direction of the city.Measures should be initiated by concern authorities to evade possible threats of scattered fringe development in orderto achieve sustainable urbanisation.

Keywords: Landscape Metrics, Remote Sensing, Geographic Information System, Number of Patches, Patch Density, Landscape Shape Index, Clumpiness Index, Percentage of Like Adjacencies.

1. Introduction

The rate of urbanizationis now more in the developing countries than developed countries. Urban population has increased from 17.8% in 1950 to present 40% in the developing world. It is estimated increase to almost 60% by the year 2030 (Zhang, 2015). Rapid urbanization in developing counties leads to scattered growth towards their peripheries (Darío, 2014). Unlimited and non-contiguous low-dense suburban growth of both residential and non-residential developments is known as urban sprawl which is characterised as spatially segregated land-use, total reliance upon the automobile etc. (Sierra club, 1998; Torrens and Alberti, 2000; Angel et al., 2007; Sudhira and Ramachandra, 2007). Sprawl encroaches water bodies (Ramachandraiah and Sheela Prasad, 2004), acquires prime cropland, grassland and wasteland (Shalaby et al., 2012; Singh, et al., 2014; Gumma et al., 2017; Li et al., 2018), fragment the wetland (Murungweni, 2013), threaten the wildlife (Pijanowski et al., 2002), convert the forest into impervious surfaces etc. (Gonzales, 2016).

In view of this, quantifying the characteristics of phenomenon like sprawl has received a wide attention among the policy makers, town planners and academicians. The conventional methods of surveying and mapping techniques are expensive and time consuming for estimation of urban growth and sprawl. Hence, use of Remote Sensing and Geographical Information System become indispensable as these techniques are cost effective and technologically sound (Yang and Liu, 2005; Haack and Rafter, 2006). Wide statistical techniques along with Remote Sensing and Geographical Information System are used in most of the urban growth and sprawl studies (Lo and Yang, 2002; Jat et al., 2008). In developed countries and recently in developing countries like China and India studies on urban growth and sprawl dynamics have been attempted (Lata et al., 2001; Sudhira et al., 2004). There are scores of metrics available to describe and detect the landscape pattern and drivers beyond such growth. Basically, landscape metrics are used for studying the forest patches (landscape ecology) (Trani and Giles, 1999; Civco et al., 2002) but now a day these metrics are widely using for capture the landscape properties in terms of spatial pattern and structure at landscape level (Yeh and Li, 2001; Chatterjee et al., 2016). Landscape metrics are mathematical indices developed to quantify the structure and composition of a landscape from the categorical map describing that landscape (Rossi and Dobigny, 2019). These indices are calculated based on patch type, area, edge and neighbour type etc. of a landscape (Sudhira and Ramachandra, 2007).

Mysore is second largest and second fast-growing city of Karnataka state, India. In recent decades, several large public residential and more than 2500 private residential layouts have cropped up. People from both semi-urban and rural hinter land of Mysore are migrating to the city which intensifies the demand for housing and infrastructure. Compared to inner-city locations, city outskirts offers affordable and low costs housing sites causing scattered fringe development which is seen as one of the potential threats to sustainable urbanisation.

2. Objective

Thestudy aims to analyse the spatio-temporal characteristics of urban sprawlin the Mysore Local Planning Districtusing landscape metrics for the years 2000 and 2016 in Fragstats 4.1 software.

3. Study Area: Mysore Local Planning District

The study area of the present research work is Local Planning District of Mysore city,headquarter of the Mysore District of Karnataka state, India. It spreads over an area of 507.72 sqkm. It lies between 12° 14' 41" to 12° 22' 25" N latitudes and 76° 34' 20"to 76° 43' 23" E longitudes. The Mysore district shares boundary with Tamil Nadu state to its southeast, the Kodagu district to its west,Mandya district to its north, Hassan district to its northwest and Bangalore district to its northeast. Mysore has the highest elevation located on the top of the Chamundi hill (1050 m) and the minimum contour value is 725 meters. The northern part of the city is drained by river Cauvery and the south is drained by the riverKabini. The Mysore city blessed with several tanks and lakes across the city and in its outskirts. The population of the city has been growing swiftly from 60,312 in 1871 to 9,14,919 in 2011.

The total area under MUDA limit was 7,142.93 hectares in 2001 which has increased to 14,034.67 hectares by 2011. In Mysore city, residential area was 39.9% in 2001 which rose to 43.45 in 2011; commercial land use was 3.02% in 2001 which decreased to 2.45% whereas industrial land use remains almost same. Despite of MUDA limits increase, water body’s cover has declined from 2.02% to 1.27% during 2001 to 2011. Agriculture land use has increased from 2.27% to 6.41% due to inclusion of neighboring villages into MUDA limits (MUDA CDP 2011).

In the last two decades, Mysore cityhas seen massive increase of built-up from 80.71 sqkm in 2000 to 226.72sqkmin 2016 which triggered a drastic land-use land cover changeespecially at outskirt of the city (Manjunatha and Chandrashekara, 2020).

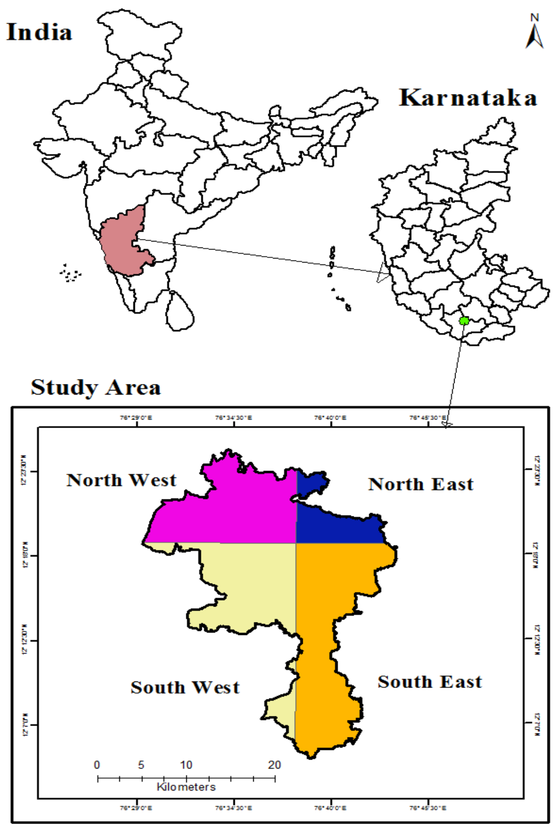

Figure – 1: Study Area: Mysore Local Planning District

4. Methodology

The required spatial informationhas been collected from the Karnataka State Remote Sensing Application Center (KSRSAC). The data in vector format and its respective satellite imageries for the years2000 and 2016 has been collected from KSRSAC. The spatial data used in the study are IRS 1C/1D: LISS - III of 2000 and Worldview-1 of 2016. The pre-processing of raw satellite images and accuracy assessment ofland use and land cover classification were performed by KRSAC, thus the obtained data is errorfree and within acceptable level. The collected data from KSRSAC was clipped using Mysore Urban Development Authority (MUDA) proposed boundary in CDP 2011 for the years 2000 and 2016 in ArcGIS 10.1. The entire study area (Mysore LPD) has been divided into four sections as a) North-East, b) North-

West c) South-Eastand d) South-West directions/zones with considering the K.R. Circle as center point (Central Business District) of Mysore city. Further, urban sprawlcharacteristics such as spatial structure and pattern have been quantified through the calculation of selected indices of landscape metrics using Fragstats 4.1 software for two time periods i.e. 2000 and 2016 (Table-1). The landscape metrics used in the study are Number of Patches (NP), Patch Density (PD), Landscape Shape Index (LSI), Clumpiness Index (Clumpy) and Percentage of Like Adjacencies (PLADJ), the details as follows.

Number of Patches (NP): The patch refers to built-up/urban pocket distributed across the particular landscape which depicts the level of fragmentation of growth. Less number of patches indicates compact urban growth whereas more number of patches indicates disaggregated growth.

Patch Density (PD): Patch density is the number of urban patches divided by total landscape area. Patch density increases with increasing number of patches in a landscape. Increasing of urban patch density indicates sprawl whereas decreasing values characterize aggregated growth.

Landscape Shape Index (LSI): Landscape shape index quantify landscape configuration by considering shape complexity of patches thereby measure aggregation/clumpiness or dispersion of patches across the landscape. If landscape contains single compact area, the LSI will be less; if patches are dispersed with complex shapes the LSI will be high. When Landscape Shape Index (LSI) is equal to 1, it shows aggregated/compact growth of corresponding class whereas increase of LSI without any limit indicates more disaggregated/dispersed growth.

Clumpiness Index (Clumpy): It is a measure of patch aggregation/compactness. Decreasing trend with values closer to zero indicates more disaggregated patches whereas near to one indicate more aggregated patches/ growth.

Percentage of Like Adjacencies (PLADJ): It shows distribution of patches having like adjacency thereby it depict urban growth patterns and spatial structures. This metric considers the number of similar i.e. built-up, adjacencies divided by the total number of built up patches. If the value is 100 indicates presence of only one class in the landscape (it means all adjacencies belongs to the same class). If PLADJ is zero indicates more disaggregation or towards higher fragmentation growth (it means no like adjacencies present in the landscape).

Table -1: Selected indices of Landscape metrics

Name of the Metrics	Formula	Units	Range
Number of Patches (NP)	$NP = N$ N = total number of patches in the landscape	None	NP ≥ 1, without limit.
Patch Density (PD)	$PD = \frac{n_i}{A}(10,000)(100)$ n_i = number of patches in the landscape of the path type (class) i A = total landscape area (m_2)	Number per 100 hectares	PD > 0, constrained by cell size.
Landscape Shape Index (LSI)	$LSI = \frac{.25\sum_{K=1}^{m} e_{ik}^{*}}{\sqrt{A}}$ e_{ik}^{*} = total length (m) of edge in landscape between patch types (classes) I and k; includes the entire landscape boundary and some or all background edge segments involving class i. A = total landscape area (m_2)	None	LSI ≥ 1, without limit.
Clumpiness Index (CI)	$G_i = \left(\frac{g_{ii}}{\sum_{k=1}^{m} g_{ik}}\right)$ $CLUMPY = \begin{bmatrix} \frac{G_i - P_i}{1 - P_i} for G_i \geq P_i \\ g \\ \frac{G_i - P_i}{1 - P_i} for G_i \lhd P_i; P_i \geq .5 \\ \frac{P_i - G_i}{-P_i} for G_i \lhd P_i; P_i \lhd .5 \end{bmatrix}$ g_{ii} = number of like adjacencies (joins) between pixels of patch type (class) i based on the double-count method. g_{ik} = number of adjacencies (joins) between pixels of patch types (classes) i and k based on the double-count method. P_i = proportion of the landscape occupied by patch type	Percent	-1 ≤ CLUMPY ≤ 1

	(class) i.		
Percentage of like adjacency (PLADJ)	$$PLADJ = \left(\frac{g_{ii}}{\sum_{k=1}^{m} g_{ik}} \right)(100)$$ g_{ii} = number of like adjacencies (joins) between pixels of patch type (class) i based on the double-count method. g_{ik} = number of adjacencies (joins) between pixels of patch types (classes) i and k based on the double-count method.	Percent	$0 \leq PLADJ \leq 100$

5. Results and Discussion

To analysis the urban sprawl characteristic**s** such as **s**patial structure and pattern of emerging Mysore urban agglomerate, Number of Patches (NP), Patch Density (PD), Landscape Shape Index (LSI), Clumpiness Index (Clumpy), Percentage of Like Adjacencies (PLADJ) has been computed and discussed as follows.

Table - 2: The results of selectedlandscape metrics of Mysore LPD and its four directions

Direction	Years	NP	PD	LSI	CLUMPY	PLADJ
North-East	**2000**	08	0.16	3.25	0.98	98.58
	2016	456	23.87	44.00	0.31	74.75
North-West	**2000**	27	0.19	5.82	0.97	98.33
	2016	1477	30.99	79.97	0.25	70.09
South-West	**2000**	34	0.24	5.92	0.97	97.92
	2016	2555	55.70	83.59	0.33	62.91
South-East	**2000**	60	0.32	10.21	0.95	96.07
	2016	2946	52.92	95.79	0.33	55.21
Mysore LPD	**2000**	129	0.22	11.59	0.97	97.96
	2016	7434	38.26	76.84	0.31	66.57

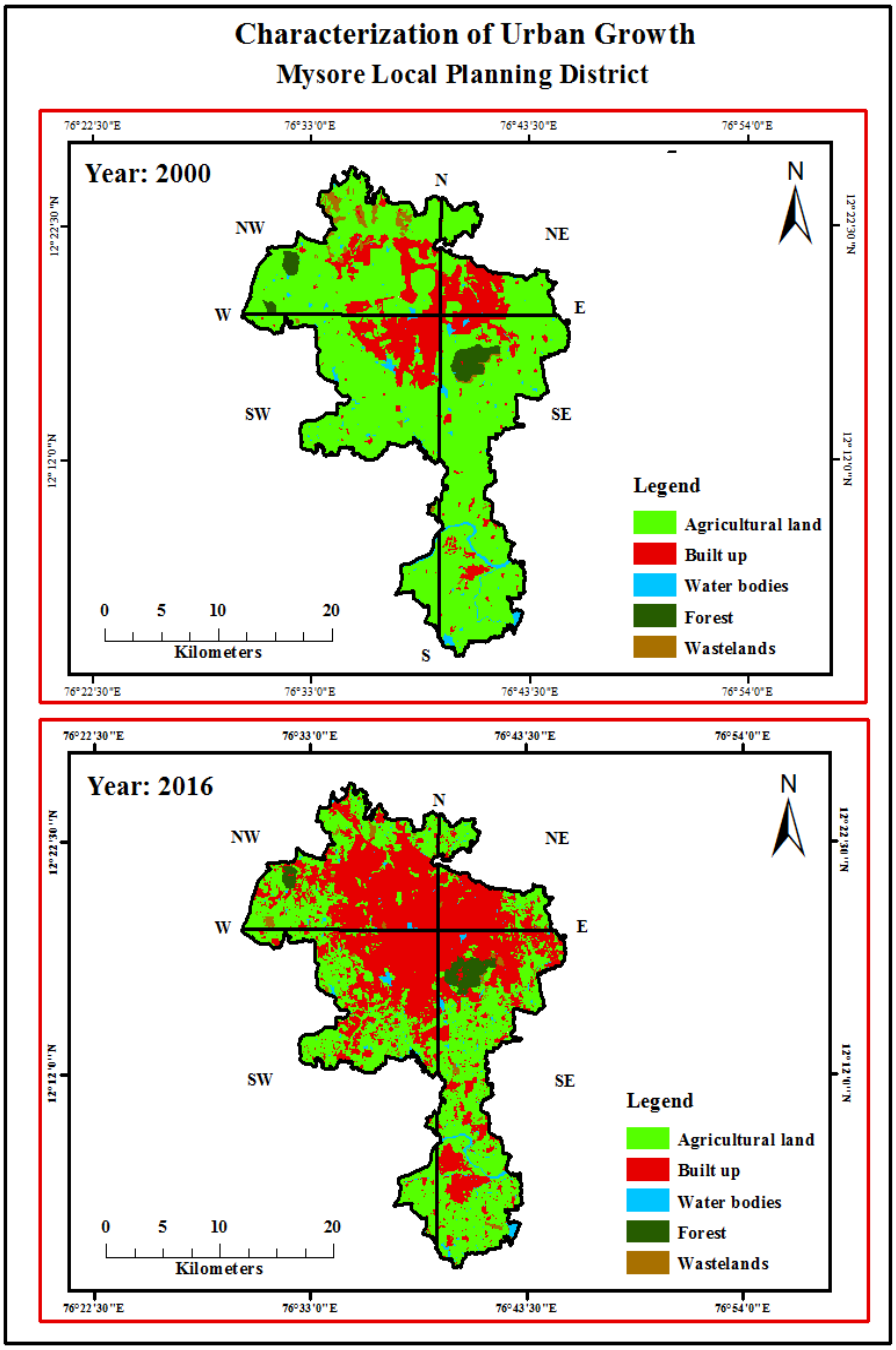

Figure-2:Characteristics of urban sprawl in Mysore LPD and its four directions.

There has been massive increase of **number of patches** from 129 to 7434 in Mysore LPD with highest such urban patches are seen towards South-East direction followed by South-West direction, indicating urban growth becoming fragmented in Mysore LPD and it is more intensive towards southern direction of the city. The **patch density**has also increased from0.22 to 38.26 in the Mysore LPD with highest increase is seen towards South-West direction followed by South-East direction indicating sprawling urban growth. Similarly **Landscape shape index** has increased from 11.59 to 76.84 with highest towards South-East direction followed by South-West direction implying dispersed urbanization. However, **Clumpiness index** has declined from 0.97 to 0.31 in Mysore LPD with highest is seen towards North-West directionindicating random/haphazard distribution of urban patches. Similarly **Percentage of Like Adjacencies** has also declined from 97.96 to 66.57 in Mysore LPD with highest is seen towards South-East direction followed by South-West direction indicating more different patch adjacencies implies scattered urban growth.The result hints that urban growth is scattering with more aggressive towards southern direction of the city.

6. Conclusion

The study demonstrates that aggregated Mysore city becoming a scattered urban landscape evidenced by increased number of patches, patch density, LSI and decreased Clumpy and PLADJ Indices. Scattering is more aggressive towards southward direction of the Mysore city. Emergence of Mysore-Nanjanguducorridor as a commercial hub, presence of airport etc.in the south direction leads to more scattering towards south. The study proved that landscape metrics in conjunction with remote sensing and GIS emerged as better tool to capture dynamics of urban sprawl. The concern authorities should initiate measures to counter the possible threats of scattered fringe developmentin order to achieve sustainable urbanization in the Mysore city.

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