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Measuring spatial pattern of urban sprawl in the Mysuru local planning district using Shannon Entropy, 2000-2021

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Abstract

Mysuru is emerging as urban agglomerate and has become a new hotspot for long-term investors in land and home seekers. Hence, urban growth in Mysuru has become scattered at fringe (urban sprawl) due to availability of low-cost housing sites threatening its sustainability. The objective of the research is to evaluate the spatial distribution of urban expansion within the local planning district of Mysuru. The study used the satellite imageries such as IRS1C/1D: LISS - III of the year 2000 and Worldview-1 of the year 2021, which were collected from the Karnataka State Remote Sensing Application Center. The Shannon entropy technique has been employed at landscape level using Fragstats 4.1 software to detect the direction-wise pattern of urban sprawl. The study reveals that Mysuru cityis transforming from an aggregated compact city to a sprawling city. Additionally, the investigation demonstrates that urban sprawl has been progressively moving towards the outer zones of the city, away from the inner areas, during the last 20 years. The study has implications for planning measures to mitigate and minimize the adverse impact of sprawl to achieve sustainable urbanization and also stresses on the need to have a solid policy framework to deal with future urban growth in the city.

Keywords: *Urban sprawl, Shannon entropy, sustainability, remote sensing and GIS.*

Introduction

Karnataka is among the highly urbanized and industrialized states in India that is experiencing rapid urbanization. The urban population increased from 22.95 percent in 1951 to 38.67 percent in 2011 (Census of India, 2011). The level of urbanization in Karnataka has always been higher than the country's average. After Tamil Nadu, Maharashtra, and Gujarat, Karnataka is the fourth major state in India in terms of the level of urbanization it has achieved. The number of urban agglomerations and towns in Karnataka increased from 252 in 1991 to 314 in 2011 (Census of India, 2011). It is projected that by 2025, 50 percent (40 million) of Karnataka's population lives in urban areas. A notable aspect of urbanization in Karnataka is the concentration of the urban population along significant transportation routes, namely the Bangalore-Belgaum, Mysuru-Kolar, and Mangalore-Karwar (coastal stretch) corridors. These three corridors are home to over 65 percent of Karnataka's urban population. (Eswar and Roy, 2018). Mysuru is the second-most populous city in Karnataka after Bangalore. Between 1961 and 2011, the population of Mysuru city has surged from 254,000 to 893,000.

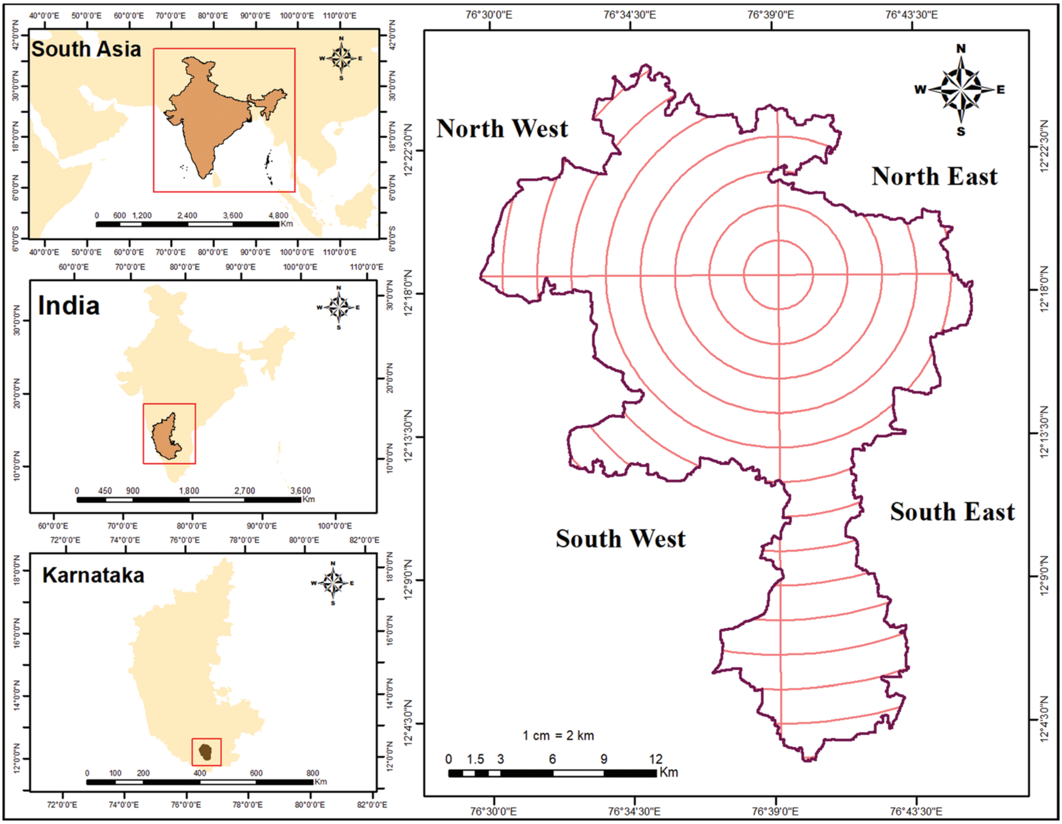

Fig. 1: Study area: Mysuru local planning district

Mysuru is fast-growing heritage city that has many educational institutions, research institutes of national importance, presence/ establishment of IT industries, emergence of The Mysuru-Nanjangud industrial corridor is a well-known tourist spot that draws in over 2.5 million visitors annually. Spatially limited Mysuru has begun to expand in leaps and bounds after incorporating Nangangud town to its local planning area. In this city, built-up has been increased from 80.71 km^2 to 226.72 during the first two decades of the present century (Manjunatha and Chandrashekara, 2020). The city is fast emerging as an urban agglomerate and has become a new hotspot for long-term investors in land and home seekers. Due to the availability of inexpensive land for housing, the outskirts of the city are experiencing dispersed expansion, which is viewed as a potential menace to sustainable urban development when compared to locations within the city. Such growth encourages more use of private vehicles leading to problems like crowded roads, increased travel time, excessive fuel consumption, traffic jams, delays and accidents, emission of greenhouse gases etc., leading to formation of urban heat islands all of which seriously affect human health (Wikström and Dolmén 2001; Wang & Debbage, 2021). Additionally, scattered urban growth also has been responsible for

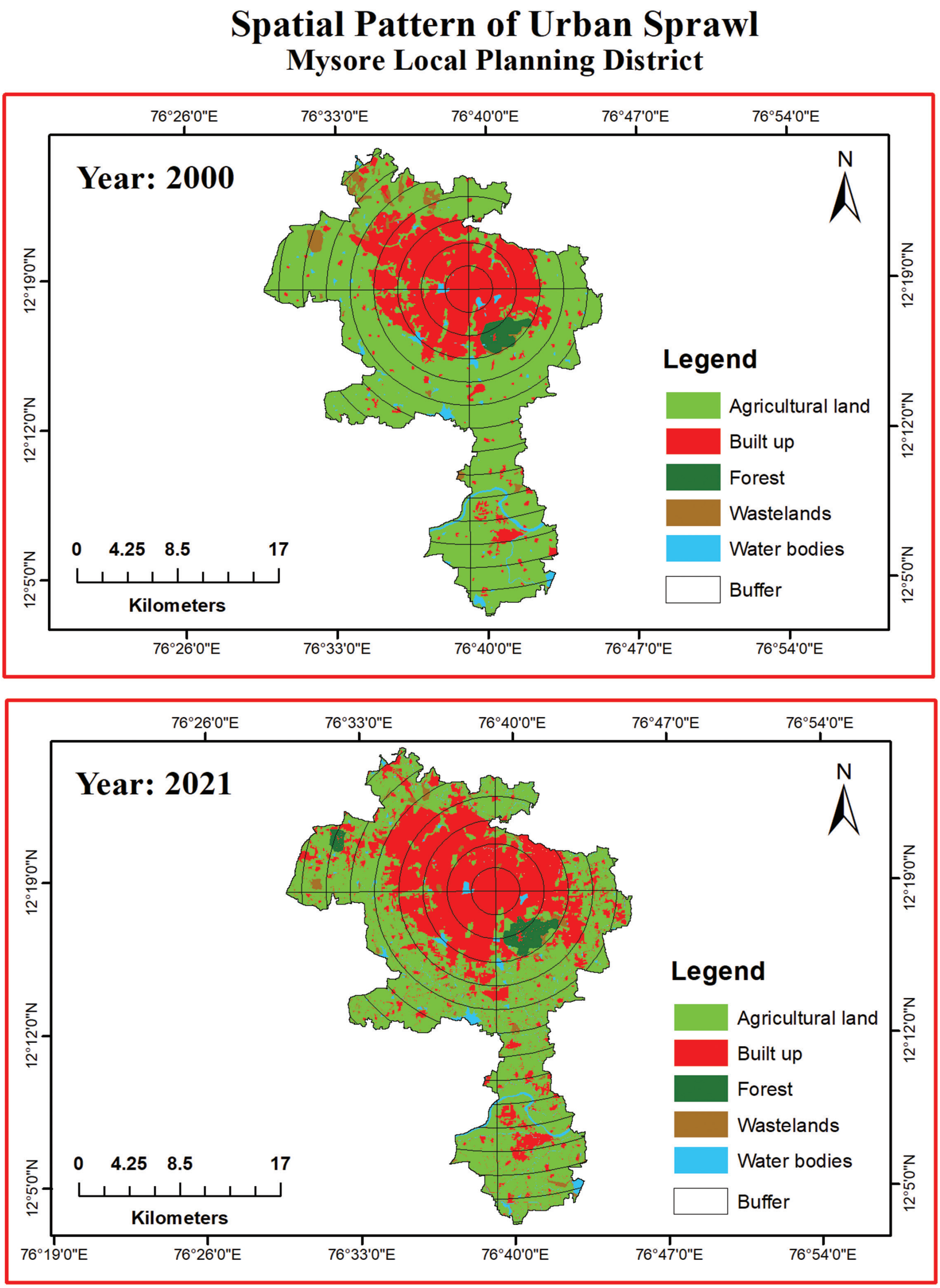

Fig. 2: Four directions and buffer arcs/zones of the Mysuru LPD

declining of prime agricultural area, soil, decline of groundwater re-charge potential, damage to rich biodiversity and fragile ecology (Mundoli et. al. 2014; Lai et. al., 2015; Kadhim, et. al., 2016; Garouani et. al., 2017).

Harvey and Clark (1965) defines "sprawl" characterized as uninterrupted residential expansion at the periphery of a metropolis, ribbon-like development of low density alongside highways, and sporadic development within previously undeveloped areas, resulting in a fragmented spatial pattern. The Sierra Club (1998) defines sprawl as "low-density development beyond the edge of service and employment, which separates where people live from, where they work and therefore requiring cars". Sprawl refers to the spread of low-density development that has jumped beyond the periphery of an urban area, suggesting that it lacks defined boundaries. Over the past few decades, urban sprawl has become prevalent not only in tier-I cities but also in tier-II cities of developing nations, necessitating a comprehensive examination of the issue to determine potential solutions.

To analyze the characteristics of urban sprawl, there are scores of metrics available in software that can efficiently work in conjunction with remote sensing and GIS which can be put under the broad categories of area-edge, shape, aggregation, sub-division and isolation characteristics of urban patches (Mcgarigal *et al.*, 2002; Abebe, 2013; Mallupattu and Sreenivasula, 2013; James and Ahmed, 2019). To comprehend the structure, pattern, and changes in urban growth, the built-up area is typically regarded as a key indicator, and Fragstats software is utilized to calculate landscape metrics (Modica *et al.*, 2012; Jain *et al.*, 2013). Shannon's entropy is one of the indices of landscape metrics which measures the degree of spatial concentration or dispersion of a geographical variable in an area or zone (Lata *et al.*, 2001; Sudhira *et al.*, 2004; Joshi *et al.*, 2006; Jat *et al.*, 2008; Rajeev, 2016). Visualizing the spatial distribution of urban sprawl in relation to evolving spatial and temporal dynamics is a valuable technique. This approach is often employed in conjunction with Remote Sensing and GIS techniques to model urban sprawl (Sridhar *et al.*, 2019). The procedures employed to measure urban sprawl are determined by the type of spatial data used in the study. The relative advantages of spatial methods incorporating GIS and remote sensing over statistical analysis has made us to choose this combined method. In the present study the Shannon entropy has been used to determine the phenomenon of urban sprawl in the city of Mysuru.

Study area: Mysuru Local Planning District

The research is focused on the Mysuru Local Planning District, which is home to the Mysuru District of Karnataka state, India. The area encompasses 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 (Fig. 1). The Mysuru district is situated in the southeastern region of Karnataka state and shares its borders with Tamil Nadu to the southeast, Kodagu district to the west, Mandya district to the north, Hassan district to the northwest, and Bangalore district to the northeast. The Cauvery river drains the northern region of the city, while the Kabini river drains the southern region. In addition, there are numerous tanks and lakes situated throughout Mysuru city and its outskirts.

Mysuru city has seen colossal increase in built-up area (CDP, 2011), from 80.71 km^2 in 2000 to 226.72 km^2 in 2021 with addition of 146.01 km^2. The expansion of urbanization in Mysuru has resulted in significant changes in land use and land cover, particularly in the outskirts of the city, over the past two decades (Manjunatha, and Chandrashekara, 2020). The landscape metrics analysis of urban growth reveals that urban growth in the Mysuru city has become more diverse, complex and fragmented especially towards south direction of the city (Manjunatha and Chandrashekara, 2021).

Materials and methods

The land-use and land-cover data in vector format and its respective satellite imageries were obtained from the Karnataka State Remote Sensing Application Center (KSRSAC) for the years 2000 and 2021. KSRSAC was responsible for conducting the preprocessing of raw satellite images and carrying out the accuracy assessment of land use and land cover classification. The obtained data is reasonably error free and within acceptable level of accuracy. The collected vector LULC data from KSRSAC includes the Level-I LULC information. The KSRSAC used NRSC classification system which includes standard classes such as agricultural, built-up, water bodies, forest and wasteland.

The satellite imageries collected from KRSAC were clipped using Mysuru Urban Development Authority (MUDA) proposed boundary in CDP 2011 for the years 2000 and 2021 using ArcGIS 10.1 for extracting the study area from the image. Then the entire study area was divided into four sections as a) North-East, b) South-East, c) South-West and d) North-West keeping center point as Central Business District (KR Circle) of Mysuru city. The direction wise subdivision would provide greater insights into the nature and causes of urban sprawl in Mysuru local planning district particularly with respect to the orientation of sprawl that can be perceived from it. Further, each direction has been divided into concentric circles or buffer arcs/zones from the city center (i.e., K. R. Circle) with 2 km increment by constructing the Multiple Ring Buffer in ArcGIS10.1 software. Shannon entropy has been computed at the landscape level using Fragstats 4.1 software for each buffer arcs/zone of each direction to measure the degree of urban sprawl for the years 2000 and 2021. Shannon entropy is calculated using the equation 1.

$$\mathrm{SHDI} = -\sum_{i=1}^{n} \left(P_i \times \ln P_i \right) \qquad \text{(Eq. 1)}$$

Where, Pi = The proportion of a particular patch type occupying the landscape (class) ln = Log of total number of the zones.

Shannon Entropy values range from zero to log(n) or ln. The 0 indicates maximally concentrated and Log(n) or ln value indicates dispersed urban growth or sprawl. Higher entropy value indicates occurrence of sprawl (Shannon 1948). The log(n) value represents the number of 2 km buffer zones/arcs that covers the entire study area (n). Thus, log(n) value of all the four directions of Mysuru LPD is as presented in Table 1.

Result and discussion

Degree of urban sprawl

A common trend has been observed among all the four directions that in the year 2000, entropy value is close to 0 (far lesser than threshold value of respective direction) indicating less dispersed built-up towards

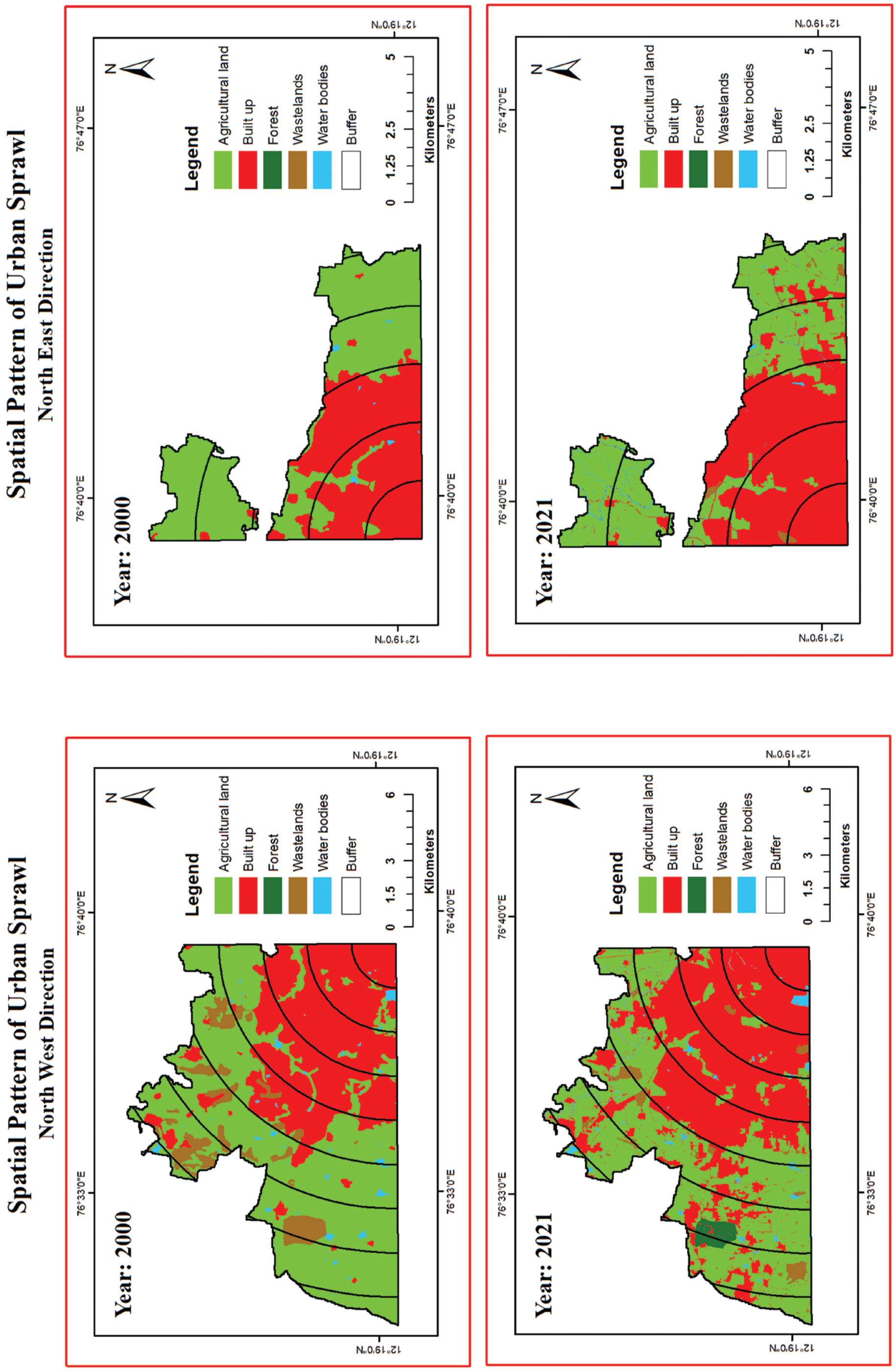

Fig. 3a: Direction-wise buffer arcs of the Mysuru LPD

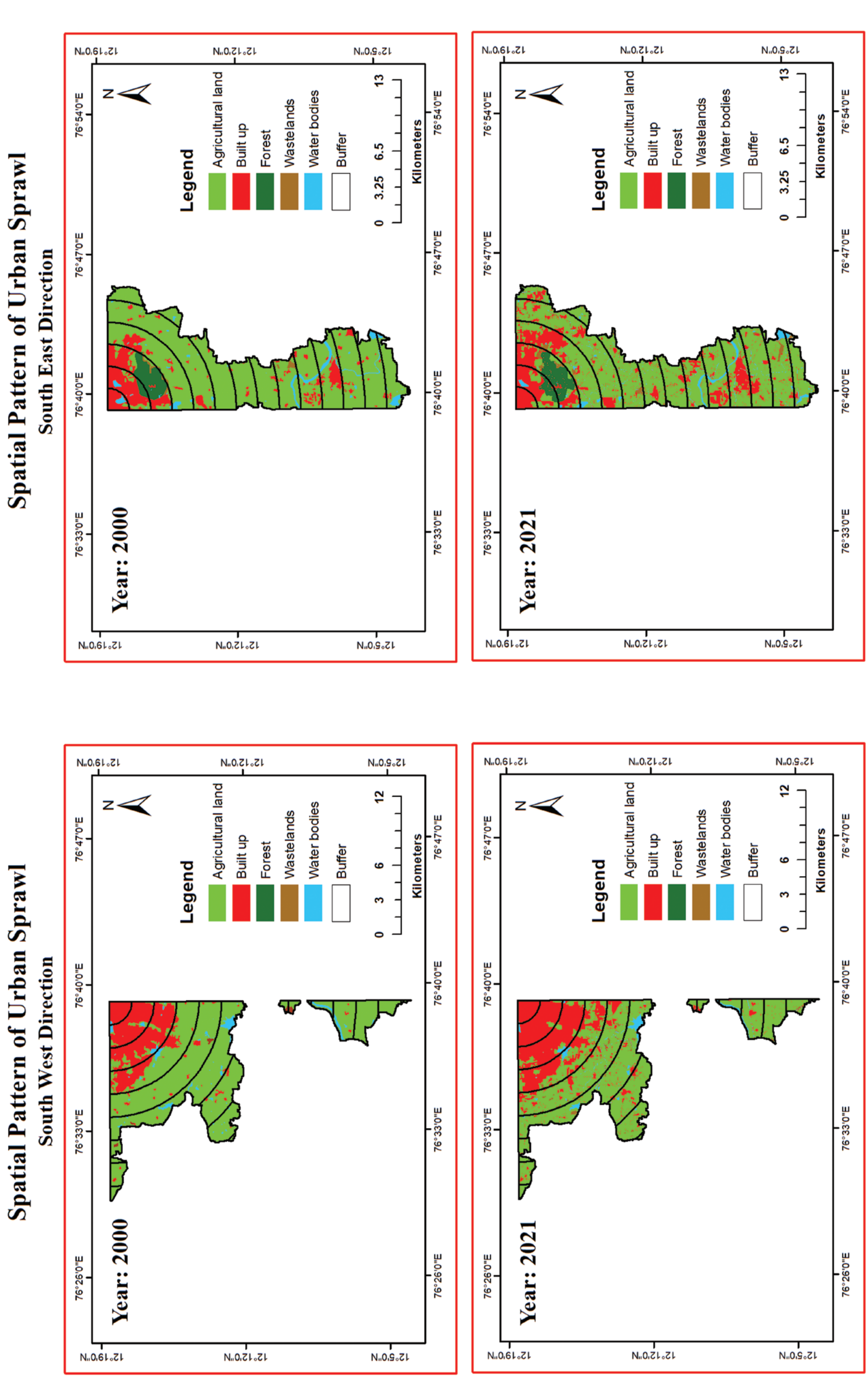

Fig. 3b: Direction-wise buffer arcs of the Mysuru LPD

Table 1: Number of buffer arcs and "ln" values

Directions	Number of buffer arcs	"ln" value
North-West	9	2.20
North-East	6	1.79
South-East	15	2.71
South-West	14	2.64

Table 2: Direction-wise Shannon entropy values and "ln" values

Directions	Shannon Entropy		"ln" value
	In the year 2000	In the year 2021	
North-West	0.51	2.07	2.20
North-East	0.33	1.40	1.79
South-East	0.53	2.46	2.71
South-West	0.58	2.54	2.64

all four directions. In the year 2021, entropy of all the four directions however increased (close to "ln" value) indicating disaggregated urban growth towards all directions with more aggressive push in southern direction of Mysuru city (Table 2 and Fig. 2).

In order to investigate the degree of urban sprawl at neighbourhood (micro level) level or in specific locality/zones, each direction was further divided into 2 km radius arcs keeping city centre as the focal point and Shannon entropy has been calculated for each arc, the details of which are shown in Table 2.

In the year 2000, the entropy value of all the buffer arcs towards all four directions is low (close to 0) indicating an overall aggregated urban growth in all four directions (Fig. 3 a & b). However, towards the North-East direction, few inner zones/arcs such as 2 and 3 (i.e., from 2 to 4 km and 4 to 6 km) and towards South-West direction, arcs 2 and 3 have relatively higher entropy value than the outer arcs (Fig. 4 to 7) indicating a gentle dispersed built-up across dominant agriculture land-use.

Over the years (in the year 2021) the entropy values of inner arcs/zones of all the directions further decreased due to infilling process of the built-up. Entropy values of outer arcs/zones of all four directions however drastically increased. Towards the North-Western direction, the entropy value of arcs such as from 6 to 8 km, 8 to 10 km, 10 to 12 km and 12 to 14 km (four arcs) (Fig. 4), similarly towards North-East direction, arcs such as from 4 to 6 km, 6 to 8 km and 8 to 10 km (three arcs) (Fig. 5), towards South-East direction, arcs like from 2 to 4 km, 4 to 6 km and 6 to 8 km and 16 to 18 km, 18 to 20 km and 20 to 22 km (six arcs) (Fig. 6) and towards South-West direction, arcs such as 6 to 8 km, 8 to 10 km, 10 to 12 km and 12 to 14 km (four arcs) have high entropy value (close to "ln" value) (Fig. 7) indicating sprawling of built-up in those zones. It is conspicuous that outer arcs/zones have more sprawling indicating shifting of sprawling tendency towards the city outskirts from inner area.

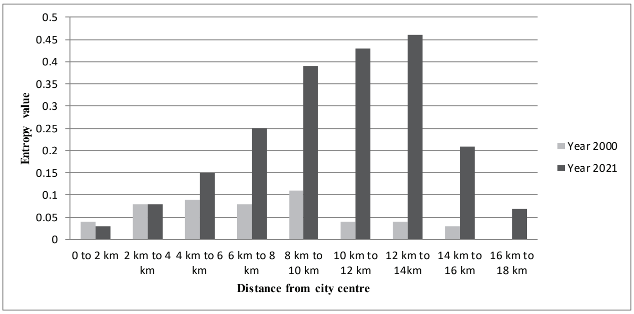

Fig. 4: Shannon entropy value of arcs of North-West direction

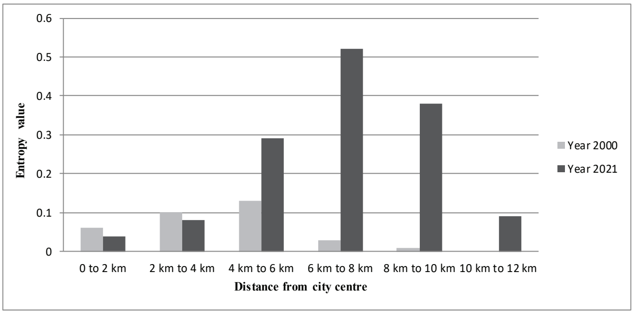

Fig. 5: Shannon entropy value of arcs of North-East direction

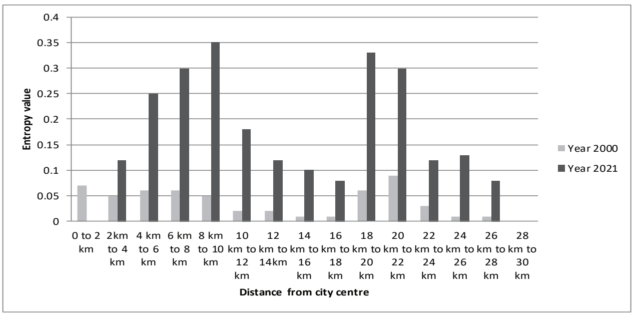

Fig. 6: Shannon entropy value of arcs of South-East direction

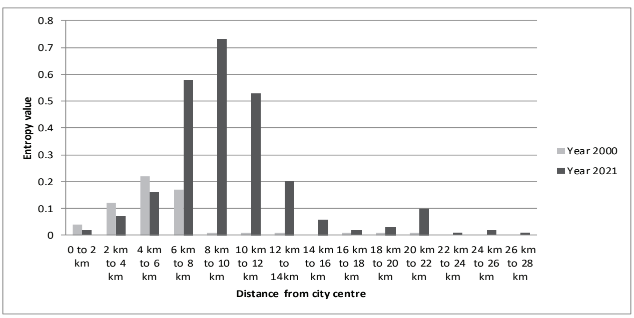

Fig. 7: Shannon entropy value of arcs of South-West direction

The calculation of Shannon's entropy values for the study area indicates a significant increase from the year 2000 to 2021, indicating a trend of urban sprawl. It can be observed from the Fig. 4 to 7 that the higher rate of sprawl is confined to a distance of 4 to 14 km from the centre of the city. This is an indication of infilling growth supported by the phenomena of urban sprawl that has occurred in the city of Mysuru during the period from 2000 to 2021 due to increased economic activities and the gravity force exerted by the neighbouring Bengaluru metropolitan city. This can be further confirmed from the south-east and north-east (Fig. 5 and 6) directional sprawling pattern.

Conclusion

The study reveals that a compact (aggregated) Mysuru transformed into a sprawling city over the last two decades. There is a tendency of shifting of sprawling from inner to outer arcs in the Mysuru city. Sprawling is more aggressive towards south of the city. The city has grown rapidly, both in terms of population and area, due to the influx of people seeking better employment and educational opportunities. This has led to a noticeable surge in the construction of residential complexes, commercial buildings, and other infrastructure facilities on the periphery of Mysuru city. Urban sprawl can have several negative impacts on the environment, economy, and social well-being. Measures should be taken to minimize the possible adverse impacts of sprawl on urban environment to achieve sustainable urban growth. To reduce urban sprawl, it is important to implement measures that promote compact and mixed-use development, smart growth policies, transit-oriented development, open space and farmland preservation, infill development incentives, zoning regulations and land-use planning. The study therefore recommends a need to have comprehensive policy framework to deal with the inevitable urban sprawl that the city of Mysuru may face in near future.

Reference

Abebe, G. A. (2013). *Quantifying urban growth pattern in developing countries using remote sensing and spatial metrics: a case study in Kampala, Uganda* (Master's thesis, University of Twente).

Census of India (2011). Office of the Registrar General & Census Commissioner, Ministry of Home Affairs, Government of India. India.

Census of India. (2011). *Census of India 2011*. Retrieved from Some concepts and Definitions: https://censusindia.gov.in/2011-prov-results/paper2/data_files/kerala/13-concept-34.pdf.

Compressive Development Plan (2011). Mysuru Urban Development Authority, Mysuru.

Club, S. (1998). The dark side of the American Dream: The costs and consequences of suburban sprawl. *Challenge to Sprawl Campaign, College Park, MD. www. tamalpais. sierraclub. org/transportation/ sprawl/Sprawl_report. what. html.*

Eswar, M. & Roy, A. K. (2018). Urbanisation in Karnataka: Trend and Spatial Pattern. *Journal of Regional Development and Planning*, 7(1), 61-69.

Garouani, A. E., Mulla, D. J., Garouani, S. E., & Knight, J. (2017). Analysis of urban growth and sprawl from remote sensing data: Case of Fez, Morocco. *International Journal of Sustainable Built Environment*, 160-169.

Harvey, R. O. & Clark, W. A. V. (1965). The nature and economics of urban sprawl. *Land Economics*, 41(1), 1–9.

Jain, S., Laphawan, S. & Singh., P. K. (2013). Tracing the Changes in the Pattern of Urban Landscape of Dehradun over Last Two Decades using RS and GIS. *International Journal of Advanced Remote Sensing and GIS*, 2(1), 351-362.

Jat, M., Garg, P. K. & Khare, D. (2008). Monitoring and modelling of urban sprawl using remote sensing and GIS techniques. *International Journal of Applied Earth Observation and Geoinformation*, 10, 26-43.

Joshi, P. K., Lele, N. & Agarwal, S. P. (2006). Entropy as an indicator of fragmented landscape. *Current Sciences*, 91, 276–278.

Kadhim, N., Mourshed, M., & Bray, M. (2016). Advances in remote sensing applications for urban sustainability. *Euro-Mediterr J Environ Integr*, 1-22. Retrieved from https://link.springer.com/article/10.1007/s41207-016-0007-4.

Lai, S., Loke, L. H., Hilton, M. J., Bouma, T. J., & Todd, P. A. (2015). The effects of urbanisation on coastal habitats and the potential for ecological engineering: A Singapore case study. *Ocean & Coastal Management*, 78-85. Retrieved from https://doi.org/10.1016/j.ocecoaman.2014.11.006.

Lata, K. M., Prasad, V. K., Badarinath, K. V. S., Raghavaswamy, V., & Rao, C. H. S. (2001). Measuring urban sprawl: A case study of Hyderabad. GIS Development 5 (12), 8-13.

Magidi, J. & Fethi, A. (2019). Assessing urban sprawl using remote sensing and landscape metrics: A case study of City of Tshwane, South Africa (1984–2015). *The Egyptian Journal of Remote Sensing and Space Sciences*, 22, 335–346.

Mallupattu, P. K. & Reddy, S. J. R. (2013). Analysis of land use/land cover changes using remote sensing data and GIS at an Urban Area, Tirupati, India. *The Scientific World Journal*, 2013, 1-6.

Manjunatha, C. S. & Chandrashekhara, B. (2020). Assessment of Changing Land Use Land Cover Pattern in the Mysuru Local Planning District (LPD) using Remote Sensing and GIS. *Science, Technology and Development*, 9(10), 206-216.

Manjunatha, C. S. & Chandrashekara, B. (2021). *Urban Sprawl, A geographical perspective with GIS approach*. Sara Book Publication. Ahmedabad-06, Gujarat (India).

Mcgarigal, K., Cushman, S., Neel, M. & Ene, E., (2002). FRAGSTATS: spatial pattern analysis program for categorical maps. Computer Software Program Produced by the Authors at the University of Massachusetts, Amherst.

Modica, G., Vizzari, M., Pollino, M., Fichera, C. R., Zoccali, P., & Di Fazio, S. (2012). Spatio-temporal analysis of the urban–rural gradient structure: an application in a Mediterranean mountainous landscape (Serra San Bruno, Italy). *Earth System Dynamics*, 3, 263–279.

Mundoli, S., Manjunath, B., & Nagendra, H. (2014). Effects of urbanisation on the use of lakes as commons in the peri-urban interface of Bengaluru, India. *International Journal of Urban Sustainable Development*. Retrieved from http://dx.doi.org/10.1080/19463138.2014.982124.

Rajeev, (2016). Measuring urban sprawl through Shannon's entropy- an approach using remote sensing and GIS. *International Journal of Science, Engineering and Technology Research*, 5(1), 24-30.

Shannon, C. E. (1948). A Mathematical Theory of Communication. *The Bell System Technical Journal*, 379–423. Retrieved from https://doi.org/10.1002/j.1538-7305.1948.tb01338.x.

Sridhar, M. B., Sathyanathan, R. & Shaji S. A. (2019). Spatio-Temporal Urban Sprawl Analysis and Evaluation Using GIS for Lucknow City. *International Journal of Innovative Technology and Exploring Engineering*, 8(6), 894-899.

Sridhar, M. B., Sathyanathan, R., & Shaji, S. A. (2019). Spatio-temporal urban sprawl analysis and evaluation using gis for Lucknow City. *International Journal of Innovative Technology and Exploring Engineering (IJITEE), 8*(6), 894-899.

Sudhira, H. S., Ramachandra T. V. & Jagadish, K. S. (2004). Urban sprawl: metrics, dynamics and modelling using GIS. *International Journal of Applied Earth Observation and Geo-information*, 5, 29–39.

Wang, M., & Debbage, N. (2021). Urban morphology and traffic congestion: Longitudinal evidence from US cities. *Computers, Environment and Urban Systems, 89*. Retrieved from https://doi.org/10.1016/j.compenvurbsys.2021.101676

Wikström, P. O. H., & Dolmén, L. (2001). Urbanisation, Neighbourhood Social Integration, Informal Social Control, Minor Social Disorder, Victimisation and Fear of Crime. *International Review of Victimology, 8*, 121-140. Retrieved from https://doi.org/10.1177%2F026975800100800202.

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