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Assessment of Urban Spatial Growth Using Geospatial Technology in Baghpat

Dr. Renu Devi
Associate Professor, Department of Geography,
D.J. College Baraut (Baghpat), C.C.S University
Email: renu.geo2010@gmail. com

Abstract: Urbanization is believed to be one of the most significant forces in human history influencing changes in land use and land cover, which is linked to population and economic growth. The necessity for urban growth leads to the occupation of nearby natural land parcels, like wetlands, forestlands, and agricultural fields. In order to maintain a systematic urban growth pattern at regional or global level, effective planning has to be first prepared at local level. The present study aims to assess the urban spatial growth with the help of Shannon Entropy approach in Baghpat city. Shannon's entropy has been used to evaluate the urban growth in the four different zones across the concentric circle of incrementing radius. The expansion of metropolitan areas can be gauged using Shannon's entropy. The gradient analysis was conducted using rectangular boxes with an increasing radius of one kilometer from the city centre for the years 2000, 2010, and 2022. From 2010 to 2022, the built-up area in the south eastern and western part of the study area has continued to increase along with the increase in the north eastern part.

Keywords*: Urbanization, Spatial Growth, Shannon Entropy, Built-Up, Gradient Analaysis*

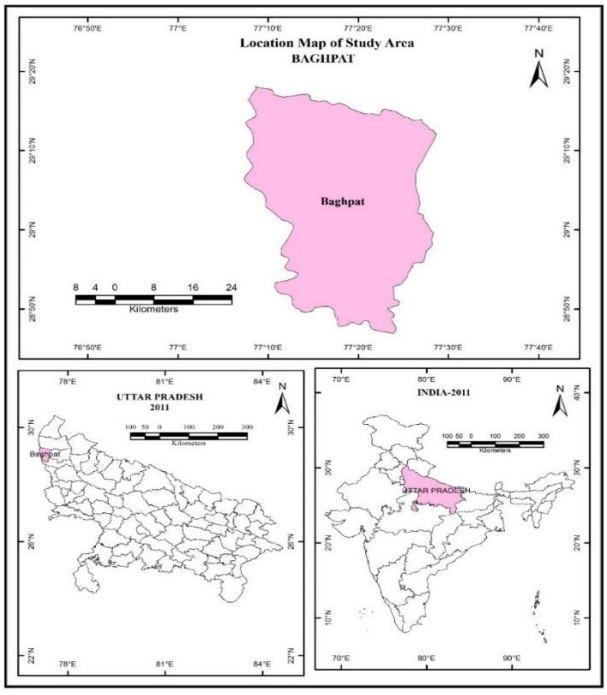
1. Introduction

Urbanization is thought to be one of the most significant forces in human history influencing changes in land cover and use, which is linked to population and economic growth (Weng, 2001). Due to the constant urbanization, land covers in metropolitan areas tend to change more quickly than other features (Jieli et al., 2010). The necessity for extensive urban growth leads to the invasion of nearby natural land parcels, like wetlands, forestlands, and agricultural fields (Xu et al., 2000). Urban heat island phenomena and other adverse effects may result from the conversion of these natural areas into impermeable built-up areas. These conversions can have a substantial impact on the ecosystem, impacting the hydrologic system, biodiversity, and climate (Xu et al., 2007). In India, an area is said to be experiencing urban expansion if there is a significant increase in population from the city centre to its periphery. The population of India's cities is now increasing at a rate of roughly 2.3% annually. Increased urban population and expansion in urban areas are unintentional outcomes of migration and unplanned population growth. As a result of population growth rates, urban expansion is a naturally occurring process that is always changing. Between 1991 and 2001, there were 4369 more

towns and urban agglomerations than there were in 3697. By 2030, the country's urban population is expected to have increased from 28.3 percent in 2003 to roughly 41.4 percent (United Nations, 2004). From 23 urban agglomerations in 1991, there were 35 urban agglomerations, or cities, with a population of one million or more by 2001. The purpose of the paper is to evaluate Baghpat's spatial growth using geospatial technologies. Metrics-based spatial analysis offers quantitative details about the landscape's composition both in space and time. Furthermore, it would be beneficial for examining the modifications made to the landscape's structures and patterns (Henebry and Goodin, 2002). In order to understand the processes of urban growth, remote sensing and spatial metrics work together to give spatial information about the growth, structure, and dynamics of urban areas (Deng et al., 2009; Ramachandra et al., 2012). The purpose of the paper is to evaluate Baghpat's spatial growth using geospatial technologies.

2. Study Area

The Baghpat District in western Uttar Pradesh is lying between the Hindon -Yamuna region, which is bordered by the Hindon river on the east and by the river Yamuna river on the west. It occupies a region of approximately 1345 km2 and is located between latitudes 28°47’ and 29°18’ N and longitudes 77°07’ and 77°30’ E. The study region has a subtropical environment with an annual rainfall average of roughly 500 mm (Fig.1).



Source: Prepared by Author

Figure 1: Locational Map of the Study Area

Geologically, the area is underlying by Quaternary alluvium. The Quaternary epoch is represented by two sedimentation cycles. Varanasi Alluvium, an older alluvium, was deposited as a result of the previous one. The more recent one is called Newer Alluvium and dates from the Late Pleistocene to the Holocene (Alam & Umar, 2013). Older alluvium covers most of the land, whereas newer alluvium is limited to areas near river courses. The area's more than 500 meters of alluvium are thought to be beneath the Delhi Rocks.

3. Research Methodology

The application of GIS and satellite data to measure urban growth trends using the Shannon entropy approach has been the subject of extensive research in recent years (Sudhira et al., 2004; Joshi et al., 2006; Sun et al., 2007; Sarvestani et al., 2011). Any geographic unit can be studied using Shannon's entropy, which functions as a spatial concentration or dispersion indicator. Urban sprawl trends are measured by a metric calculation technique that considers both temporal and spatial fluctuation of expansion regions, statistically accounting for them (Li et al., 1998).

3.1 Data Source: Satellite data from 2000 to 2022 have been used to study the dynamics of urban expansion. The Landsat series provided the data for the three time periods. Data from the Landsat 5 Thematic Mapper sensor (30 m) for the year 2000 and the Landsat 8 Operational Land Imager sensor (30 m) for the years 2010 and 2022 have been obtained from the United States Geological Survey (USGS) website (Figure 4.1).

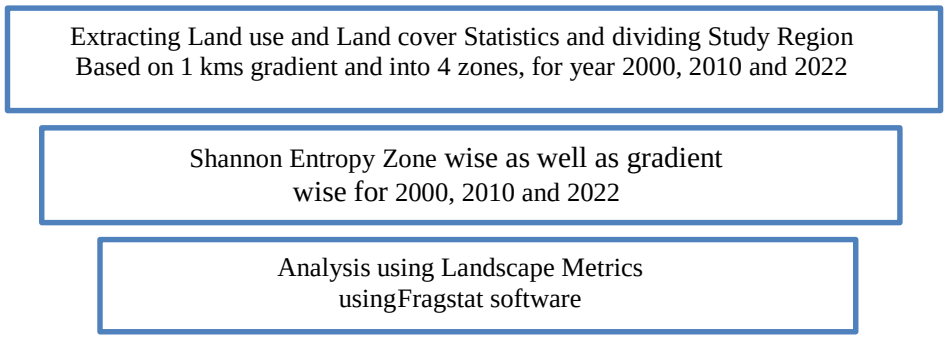


Figure 1.1: Research Methodology

3.2 Data Analysis: The Shannon's entropy and spatial metrics have been used to analyze the urban growth in the study area in gradient wise as well as in the zonal analysis, for the year 2000, 2010 and 2022.

3.2.1 Zonal Analysis: The city of Baghpat is the study area, and it has been divided into four zones for further analysis: north-east, south-west, north-west, and south-east. This is because

there are a variety of driving reasons behind urbanization, and they haven't been consistent in all directions.

3.2.2 Gradient Analysis: Each zone was divided into rectangular boxes with varied radiuses of one kilometre from the city centre. This made it easier to visualize and comprehend the local urbanization process and the elements that influence it. This aids in understanding the driving causes behind urbanization at different scales (sprawl, compact expansion, etc.) in reaction to social, political, and economic forces. Urban sprawl can be visualized using techniques like zones and concentric rings (low density, ribbon, leaf-frog growth). Time series data analysis is used to track the density of built-up areas within each circle. This helps the city's management comprehend the dynamics of urbanization and develop appropriate infrastructure and basic facilities for the residents.

3.2.3 Entropy Model: Shannon's entropy has been used to evaluate the urban growth in the four different zones across the concentric circle of incrementing radius. The Shannon's entropy was computed to detect the urban growth phenomenon following Yeh and Li (2001). Shannon's Entropy is given by:

The Shannon's Entropy Index

$$H_i^n = -\sum pi \log (pi) \quad (1)$$

$$H_i^n = \sum pi \log(1/pi) \quad (2)$$

Where n is the total number of zones and Pi is the percentage of the variable in the ith zone. The range of entropy values is 0 to Log (n), where Log (n) represents the maximum entropy value. According to Sudhira et al. (2004), the distribution is more dispersed here if the value is closer to Log (n) than it is to zero.

3.2.4 Spatial Metrics

It measures the distance and distribution of the edge length between the patches. According to McGarrigal and Marks (1995), the representation depicts the configuration of the terrain, despite the lack of spatial clarity. The edge qualities provide information that aids in measuring and comprehending the urbanisation and landscape fragmentation. For the years 2000, 2010, and 2022, the study's analysis of gradient-wise urban expansion in four directions was conducted using the chosen Fragstat spatial metrics (Table 4.2).

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Table 4.2 Description of Fragstats Metrics

	Indicator	Formula	Description
1.	Percentage of landscape (Built-up) (PLAND)	PLAND= $P_i=\frac{\sum_{j=1}^{n} aij\ (100)}{A}$ Range: 0 < %Land ≤ 100	PLAND equals the percentage the landscape comprise of the corresponding patch type. aij= area (m2) of patch ij A =total landscape area (m2).
2.	Perimeter Area Fractal Dimension (PAFRAC)	$PAFRAC = \frac{2\left[n_i\sum_{j=1}^{n}(\ln p_{ij}\cdot \ln a_{ij})\right] - \left[\left(\sum_{j=1}^{n}\ln p_{ij}\right)\left(\sum_{j=1}^{n}\ln a_{ij}\right)\right]}{\left(n_i\sum_{j=1}^{n}\ln p_{ij}^2\right) - \left(\sum_{j=1}^{n}\ln p_{ij}\right)^2}$	PAFRAC greater than 1depicts the complexity is shape

Source: Prepared by the Author based on Fragstat

The dispersion of the geophysical variable (built-up area), which represents the presence of urban growth and heterogeneity of land uses with agricultural, fallow, etc., is dictated by entropy values closer to log n. After treating each of the four zones and the concentric circles as a separate spatial unit, Shannon's entropy has been computed in each of these two locations. The lowest value, zero, will be attained if the distribution is maximum concentrated in one circle, as per the concept of Shannon's Entropy. Conversely, the maximum of log n will be assigned if the distribution among the concentric circles is even. It has been possible to determine if land development is moving towards a more compact or more dispersed (sprawl) pattern using the change in entropy.

Result and Discussion

4. Shannon's Entropy (Hn): Zonal and Gradient Analysis

Since the built-up area increased from 2000 to 2022, the study region has seen a process of urbanization over time. The expansion of metropolitan areas can be gauged using Shannon's entropy. The gradient analysis was conducted using rectangular boxes with an increasing radius of one kilometer from the city centre for the years 2000, 2010, and 2022. It has been computed zone-wise for all four directions. The process of urban growth across the rectangular boxes of 1 kms (Figure 1.2, Figure 1.3 and Figure 1.4) from the center towards the peripheries for the year 2001, 2011 and 2017 has highlighted the growth and intensification of built up area around the core of the city as well as spreading out from it in the south eastern direction and in the western direction from 2001 to 2011.

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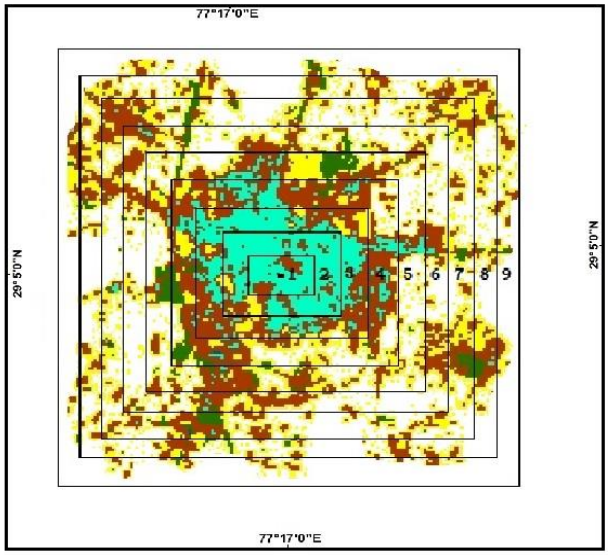

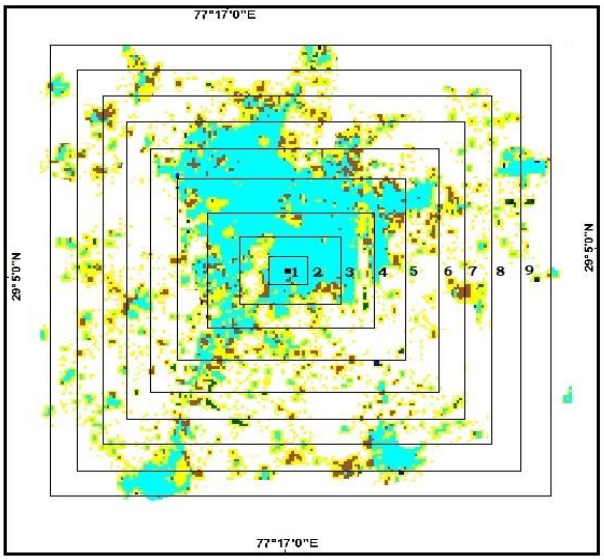

Figure: 1.2 Zonal and Gradient in 2000 **Figure 1.3 Zonal and Gradient and 2010**

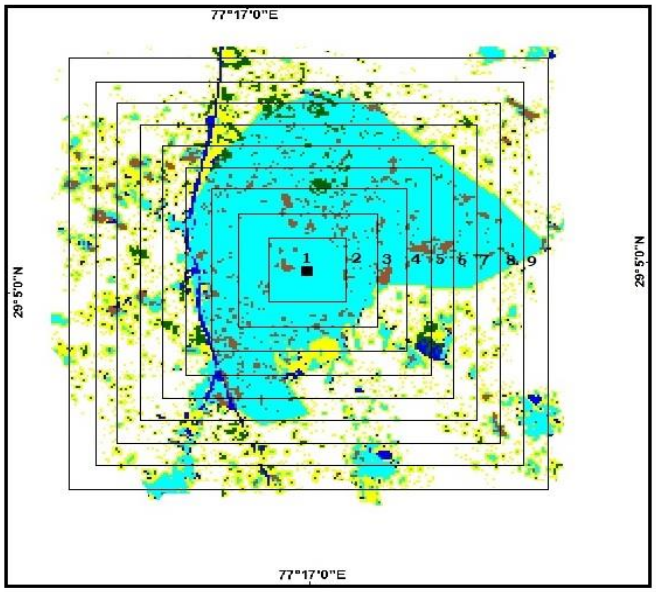

Figure 1.4 Zonal and Gradient and 2022

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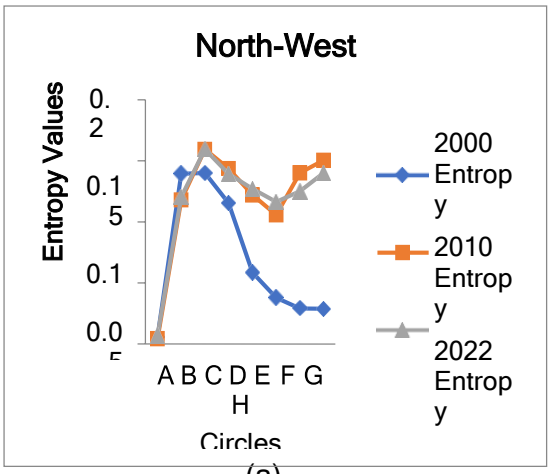
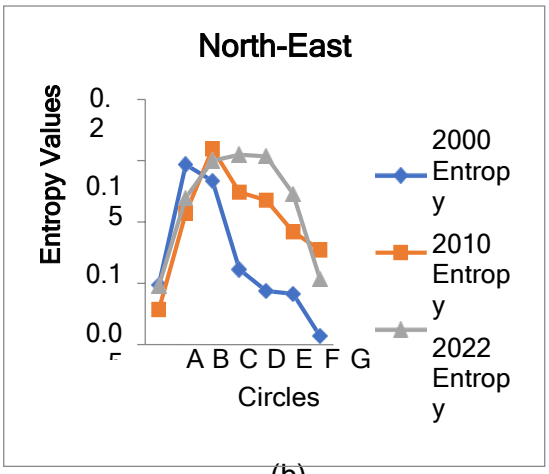
From 2010 to 2022, the built-up area in the south eastern and western part of the study area has continued to increase along with the increase in the north eastern part. The process of urbanization in the study area (Figure 4.6), could be analyzed from the growth in built up area from 2000 to 2022.

4.1 Shannon's Entropy: Zonal as well as Gradient

The following figures a, b, c, and d show the gradient analysis of Shannon Entropy from the city centre over the one-kilometer buffers in each direction. Shannon entropy has been calculated for the years 2000, 2010, and 2022 in order to allow for a comparison of the entropies and increase of sprawl over time. The entropy has increased from 2000 to 2022 in both north-east and south-east directions, towards the peripheries. The increase has been relatively marginal in the vicinity of the city centre (up to buffer C, or a distance of 6 km), but it is definitely noticeable on the periphery. The increase in entropy in the north-west direction is clearly visible between 2000 and 2010, but there has been very little increase in entropy value between 2010 and 2022.



(a)



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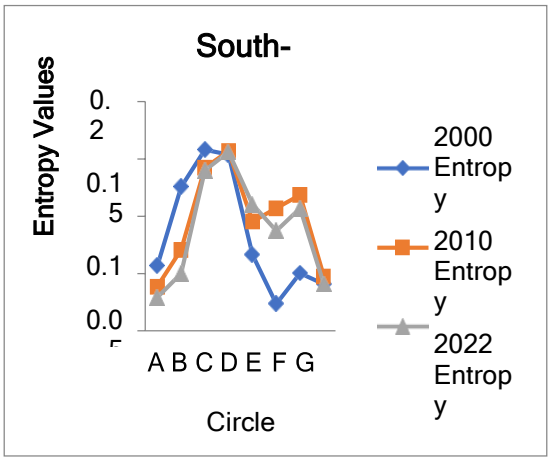
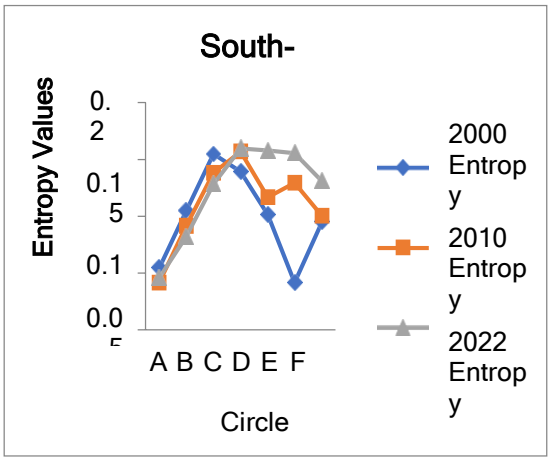


(c)



(d)

Figure 1.5 (a, b, c, d): Entropy Gradient and Direction-wise

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The northwest portion, which is a part of the cantonment area, is forested. This may be the cause of this study area's comparatively lower growth. The entropy in the city's periphery grew in a south-west direction between 2000 and 2010, but it declined between 2010 and 2022.

5. Percentage of Land (PLAND)

PLAND is the proportion of a specific class type in the terrain. PLAND is the total area of all patches of a given type divided by the entire area of the landscape, multiplied by 100 to convert the result to a percentage. The built-up percentage has been computed in the study to examine its evolution throughout time.

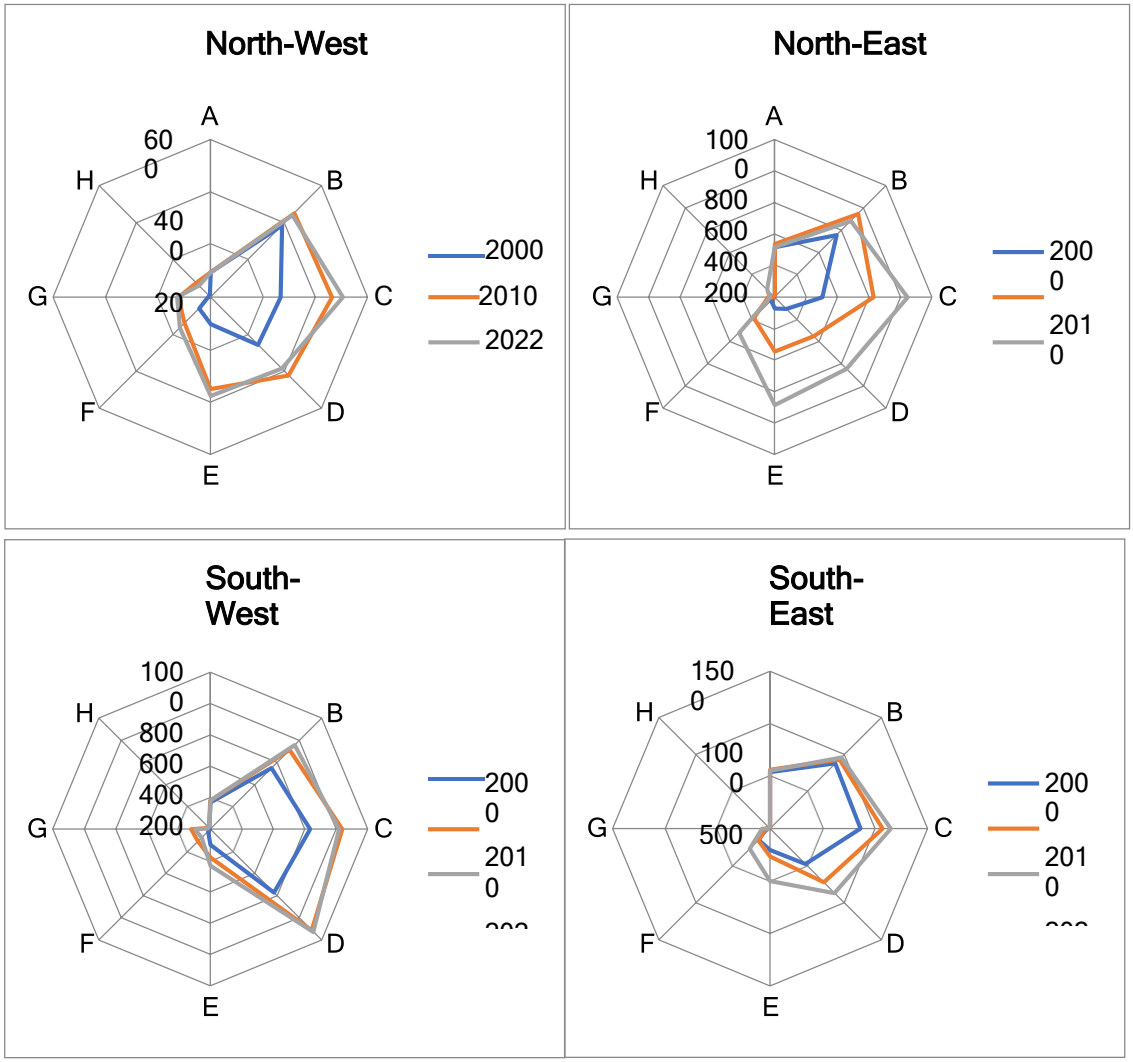

Figure 1.6 (a, b, c, d): Urban Class Area

In the year 2022, the proportion of urban landscape was lowest in the north-west and highest in the south-east (Figure 1.6 a, b, c, d). However, the city's centre has the highest patch density in all four directions, with circles ranging from three to five.

6. Perimeter Area Fractal Dimension (PAFRAC)

It comes under the category of Shape metrics. It helps in analyzing the shape of urban patches in the landscape. Its value ranges from 1 to 2. PAFRAC value approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling perimeters. As the calculation of PAFRAC involves regression analysis, it is advisable to use it only when sample size is not small. The reduction in the value of PAFRAC over time has suggested reduction in the complexity of shape of urban Patches and simple perimeter. All the four direction have complex shape as value for the three time period has been higher than 1.

7. Conclusion

The dynamics of land use and cover suggest that the study region's built-up area grew significantly between 2000 and 2022. The built-up area in the study region increased from 30.65% of the total area in 2000 to 43.77 percent in 2011. In 2022, the proportion of built-up area increased even more to 65.19 percent. Baghpat city's close proximity to Delhi and its inclusion in the National Capital Region is the main causes of this rapid rise. Since Baghpat City's changed, the administration has implemented a number of initiatives targeted at boosting the city's economy by attracting in a sizable number of institutional and commercial operations.

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Author contribution

This whole study is done by author by their own. Therefore, there is no conflict of interest.

References:

Alam, F., & Umar, R. (2013). Trace elements in groundwater of Hindon-Yamuna interfluve region, Baghpat district, Western Uttar Pradesh. Journal of the Geological Society of India, 81, 422-428.

Census of India (2011). Paper 2 of 2001: Rural–Urban Distribution of Population, Provisional Population Totals. Government of India Publications, New Delhi.

Deng, J.S., Wand, K., Hong, Y., Qi, J.G. (2009). Spatio-temporal dynamics and evolution of land use change and landscape pattern in response to rapid urbanization. Landscape Urban Planning, 92, pp. 187-198.

Hargis, C. D., Bissonette, J. A., David, J. L. (1998). The behavior of landscape metrics commonly used in the study of habitat fragmentation. Landscape Ecology, 13, pp. 167-186.

Henebry, G. M., Goodin, D. G. (2002). Landscape trajectory analysis: toward spatiotemporal models of biogeochemical fields for ecological forecasting. In: Paper Presented at Workshop on Spatio-temporal Data Models for Biogeophysical Fields, La Jolla, CA, USA.

Joshi, C., De Leeuw, J., Skidmore, A. K., Van Duren, I. C., & Van Oosten, H. (2006). Remotely sensed estimation of forest canopy density: A comparison of the performance of four methods. International Journal of Applied Earth Observation and Geoinformation, 8(2), 84-95.

Li, X., Gar-On Yeh, A., Wang, S., Liu, K., Liu, X., Qian, J., & Chen, X. (2007). Regression and analytical models for estimating mangrove wetland biomass in South China using Radarsat images. International journal of remote sensing, 28(24), 5567-5582.

Ramachandra, T. V., Bharath, A. H., Durgappa, D. S. (2012b). Insights to urban dynamics through landscape spatial pattern analysis. International Journal of Applied Earth Observation Geoinformation, 18, pp. 329-343.

Sarvestani, M. S., Ibrahim, A. L., & Kanaroglou, P. (2011). Three decades of urban growth in the city of Shiraz, Iran: A remote sensing and geographic information systems application. Cities, 28(4), 320-329.

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 Geoinformation, 5(1), 29-39.

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

Geoinformation, 5(1), 29-39.

Sun, F., Sun, W., Chen, J., & Gong, P. (2012). Comparison and improvement of methods for identifying waterbodies in remotely sensed imagery. International journal of remote sensing, 33(21), 6854-6875.

United Nations (2011). World Urbanization Prospects: 2011 Revision. Department of Economic and Social Affairs, pp. 1-138.

United Nations (2014). World Urbanization Prospects: The 2014 Revision-Highlights, Department of Economic and Social Affairs, pp. 1-27.

Weng, Q., (2001), A remote sensing–GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China, International Journal of Remote Sensing, 22(10), pp1999–2014.

Xu, B., Yang, X., Tao, W., Qin, Z., Liu, H., & Miao, J. (2007). Remote sensing monitoring upon the grass production in China. Acta Ecologica Sinica, 27(2), 405-413.

Xu, H., Wang, X., and Xiao, G. (2000). A remote sensing and GIS integrated study on urbanization with its impact on arable lands: Fuqing City, Fujian Province, China. Land Degradation and Development, 11 (4), pp. 301–314.

Xu, H., Wang, X., and Xiao, G., (2000), A remote sensing and GIS integrated study on urbanization with its impact on arable lands: Fuqing City, Fujian Province, China, Land Degradation & Development, 11(4), pp 301–314.

Yeh, A. G. O., & Li, X. (2001). Measurement and monitoring of urban sprawl in a rapidly growing region using entropy. Photogrammetric engineering and remote sensing.

Yeh, A. G., and Li, X. (2001). Measurement and Monitoring of Urban Sprawl in a Rapidly Growing Region Using Entropy. Photogrammetric Engineering and Remote Sensing, 67 (1), pp. 83-90.