Innovations

Monitoring Urban Spatial Growth Using Geospatial Technology

Dr. Aruna Paarcha

Assistant Professor, Department of Geography, Jamia Millia Islamia, New Delhi

Abstract

The global population is increasing at an alarming rate in urban areas. More than 50 per cent of the world population lives in urban areas. However, the levels of urbanization would vary across countries. India is anticipated to become the world's most populated country by 2025, superseding China. Urban population in India, has also substantially increased over the past decade, thus, urbanization is one of the imperative demographic challenges in the 21st century in our country. To analyze the process of growth in the study area methods such as Shannon's entropy and Spatial metrices have been used with the help of geospatial technology. The dynamics of Land use and cover indicated the active rapid growth in the built-up area in the study region from 2001 to 2017. The study region witnessed a rise in the built-up area from 19.64 percent in 2001 to 30.77 percent in 2011 and continued to rise to reach 35.19 percent of the total area in 2017. Over the time period of 2001 to 2017, the analysis highlighted that the process and its densification have mostly occurred in the surrounding areas of the city and with the time it has gradually moved out from the core of the city to the peripheral areas.

Keywords:1. Urbanization 2. Demographic challenges 3. Shannon's entropy 4. Spatial Metrices 5. Land use and Land cover 6. Peripheral areas

1. Introduction

Population around the world is increasing astoundingly across the landscape but the situation is more critical in urban areas where there is increase in the population at an alarming rate. Variations in the level of urbanization vary from country to country and place to place. In the last 60 years, noticeably there is an increase of 50 per cent urban population globally, which was only 28.3 per cent in 1950 (World Bank, 2011). India, after China, is the country with second highest population over the globe with over 121 million people which is equal to 17.5 per cent of the total population of the world (Census of India, 2011). India is anticipated to become the world's most populated nation by 2025, superseding China. Population living in urban areas of India also recorded an increase from 285 million to 377 million from 2001 to 2011, i.e., over the past decade. Although an increase of 3.31 per cent from 27.85 per cent of urban population in 2001 to 31.16 per cent in 2011, an addition of 92 million people to urban areas. In India, urbanization is causing one of the major demographic challenges of recent times and urbanization in 21st century can be considered as an overbearing issue. From 2010 – 2050 urban population will show a constant upward trend in its population count and the population will rise up to 497 million throughout this time period (Census of India, 2011; United Nations, 2011 and Ramachandra et al., 2012 a, b).

Indian urbanization has the most striking characteristics of unparalleled growth of class I cities. The population share of cities categorized as class I cities, have increased significantly from 26.0 to 68.7 between 1901 to 2001. Class I cities/urban agglomerations have shown a rapid increase from 30 to 48 in numbers from 2001 to 2011. Urban population has been growing in India primarily because of migration (Ramchandra et al., 2014 and Kundu, 2006). In India, migration i.e. forced migration as well as voluntary migrations are very common and migration itself is one of the major causes of growing population in urban areas. Thus, exerted pressure on the available resources of urban areas which ultimately leads to extension of city boundaries and growth or areas i.e. peri-urban. Apparently, million cities are increasing very rapidly in India. The rapid growth of these urban settlements results into the extension of their juridical boundaries engulfing their hinterland and peripheries, so that they could support their ever-increasing population.

The rapid growth of these urban settlements results into the extension of their juridical boundaries engulfing their hinterland and peripheries, so that they could support their ever-increasing population. Urban Sprawl can be termed as the progress of extension of the core city mainly because of population explosion in urban areas and subsequently, providing accommodation to its population beyond its boundary. Therefore, rapid development of cities and its peripheral areas incline its physical landscape, giving rise to numerous social, economic, environmental implications. (Mundia and Murayama, 2010; Grimm et al., 2000). Environmental consequences of rapidly growing cities have negative impacts in terms of reduction of the agricultural land, forest cover which further leads to climate change at micro and macro level. The degree and direction of sprawl growth are governed by variety of factors such as development of industries, quality of the land, connectivity, accessibility etc.

It is evident that increasing population density due to sprawl is directly influencing socio-economic environments of the cities. The degree and direction of sprawl growth are governed by variety of factors such as development of industries, quality of the land, connectivity, accessibility etc. (Xu et al., 2000; Knox, 2009; Pathan et al., 1993). Land transformation usually takes place in an unplanned manner leading to the growth of urban sprawl. Furthermore, these cities are inclined to the growth of slums and squatters where basic amenities like safe drinking water, access to sanitation facilities, and access to electricity are also out of reach for the deprived rural immigrant (Kundu et al., 1999). Sustainable development is the basic requirement of 21st century, where unorganized and unplanned growth of the urban areas are causing hindrance to its path towards sustainable development, mainly because there is no appropriate amount of infrastructure facilities available to support the population which is constantly increasing. Unplanned and inadequately managed urban areas are creating threats to the environment by the formation of sprawls, unsustainable means of productions as well as consumption patterns resulting into the degradation and pollution of the cities. Moreover, making the cities vulnerable to different types of health risks, occupational hazards, traffic accidents and hazards caused by changes in the diets and socio-economic conditions (Chaschan and Shankar, 2012; Li et al., 2012). The three pillars of sustainable development, namely, socio-economic growth and environmental conservation are backbone of urbanization.

The major goal of the conference "The future we want" organized by United Nations in Rio has been the accomplishment of sustainability of the cities. There is need of progressive model which solely meant for development of urban areas and its development which includes aspects of sustainable development, equity promotion, shared prosperity and welfare. The following emphasis was put forward in the third

United Nation conference on Human settlements (United Nations, 2014). Consequently, gaining new heights at global scale is utmost important in urban growth monitoring and urban environment mapping. For investigating the present and future demands of the cities it is very significant to have timely and precise data for critically investigating the urban development. Therefore, strategic efforts should be made towards protecting natural resources as the primary concern on one hand and to have an organized and well-planned urbanization on the other hand.

Satellite data mainly of multispectral and multitemporal have been very convenient in detecting the variations occurring over the city landscape. Moreover, for monitoring, estimating, quantifying and sprawling and growing of urban areas GIS techniques have been used (Jat et al., 2008; Yeh and Li, 2001; Punia and Singh 2011; Sudhira et al., 2004). To comprehend the features of landscape and to examine it, different landscape level metrics are available for the purpose of providing required understanding and details regarding the landscape (Gustafson, 1998; McGarigal and Marks, 1995; Hargis et al., 1998; Jaeger 2000; O'Neill et al., 1988; Ramachandra et al., 2012). The measurement of features of the landscape is done by spatial metrics units which are derived to the spatial data (Ramachandra et al., 2012; Herold et al., 2002). Information regarding the quantitative characteristics of the landscape is obtained by spatial analysis based on metrics. Moreover, information obtained plays a crucial part in analyzing the pattern and changes that have occurred on the structure of landscape (Goodin and Henebry, 2002). Geospatial technology together spatial metrics have the potential to provide spatial information related to urban growth, structure and its dynamics as well as in understanding the processes of urban growth. To provide spatial data which is correlated to urban dynamics, process, structure and its growth are obtained through remote sensing and spatial metrics together.

2. Data Used

To study the urban spatial growth, the Landsat series data has been used. The data has been obtained from (Table 1) United States Geological Survey (USGS).

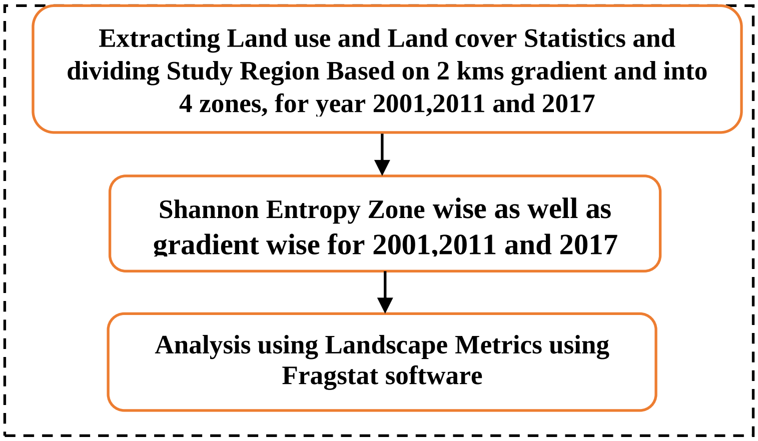
Table 1: Data used

S. No.	Satellite	Sensor	Year	Resolution (Meters)
1	Landsat 5	TM	2001	30
2	Landsat 5	TM	2011	30
3	Landsat 8	OLI	2017	30

Source: USGS

3. Methodology

The study of urban growth has been conducted with the help satellite data, with temporal data of 2001 to 2017 time period. Basically, data of three different time period has been used in the study which is obtained from Landsat series of United States Geological Survey (USGS). For the year 2001 and 2011, data of Landsat 5 Thematic Mapper sensor have been used and for the year 2017, data of Landsat 8 Operational Land Imaging sensor have been used (Figure 1).



The analysis of the growth taking place in urban area has been studied with the help of spatial metrics and the method of Shannon's Entropy. The study is carried out gradient as well as in the zonal wise, for the year 2001, 2011 and 2017.

3.1 Zonal Analysis

For examining the growth of the concerned study area, it has been categorized into four distinct zones: North-east, South-west, North-west and South-east for further analysis. Mainly because urbanization process comprises of variety of driving aspects which possibly may not be uniform in every single direction. To split the areas of the city in four distinct zones, growth of the city is expressed with respect to direction. Thus, the division of study area into four distinct zones mentioned above has been taken into consideration. Where the process of urbanization has been studied in each zone for 2001, 2011, 2017 respectively.

3.2 Gradient Analysis

To visualize the urbanization process at local level and understanding the factors affecting it, each zone has been categorized into homocentric circles (city as center) having radius of 2 km. This provides insight into the location and varying aspects where the urbanization is occurring at numerous levels with respect to the economic and social prosperity in the prevailing political conditions. Approaches, such like zones and homocentric circles help in observing the various types of sprawls. For the analyzes time series data have been used to monitor the density of built-up in each circle. Subsequently, it facilitates the study of land dynamics and cities, which facilitate in providing required number of basic amenities and infrastructure to the individuals residing.

3.3 Entropy Modeling

To evaluate the growth of study area, it has been divided into four distinctive zones of homocentric circle of incrementing radius. Shannon's model of entropy (Ramachandra et al., 2012; Sudhira et al., 2004) has been used to recognize the type and formation of growth. Shannon's Model of Entropy is given by:

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

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

Where, pi indicates the variable (built-up), in that particular zone. The range of values of entropy lies between zeros to log n. If the values are found to be closer to zero then it shows the presence of compactness and homogeneity in the growth. Whereas the values closer to log n highlights the existence of dispersion in the settlement pattern along with heterogeneity of land uses. Shannon's index of entropy has been calculated in all the four zones as well as across the homocentric circles considering each zone as well as homocentric circles as individual spatial unit. If the growth is highly concentrated in any one circle, then that zone will have the minimum value that is zero. On the other hand, highest value of index being log n point towards less concentrated growth. Thus, the index values of entropy have been very crucial in recognizing land transformation's pattern, if it's heading towards compactness, in the future.

3.4 Spatial Metrics

Geo-spatial metrics have been developed for measuring spatial pattern of growth of cities. They have been very diverse in terms of both their complexity as well as in measuring the specific features of the urban environment (Reis et.al, 2015). Over the years, the urban forms and types have been studied using spatial matrices (Ramachandra, 2014; Kasanko et al., 2006; Schneider and Woodcock, 2008; Herold et al., 2002). The computation of spatial dynamics of urban landscape has been facilitated with the application of metrics. Urban dynamics have been well understood by the analysis of selected spatial metrics. FRAGSTATS 4.2 (Marks and McGarigal, 1995) is used to calculate different metrics.

3.4.1 Area Metrics

It provides insight about the landscape composition and gives detail of area occupied with several patches of the landscape.

3.4.2 Shape Metrics

It quantifies the configuration of landscape by estimating the shape complexities at different level. To quantify shape parameter concisely in a metric is not easy. All the indices of shape are based on perimeter of area ratio and it helps in understanding heterogeneity of patches.

3.4.3 Edge/Border Metrics

It quantifies the length and distribution amount of edge between the patches as well as the configuration of landscape (Marks and McGarigal, 1995). It provides insight in the fragmentation of the landscape. The selected Fragstat spatial metrics (Table 2) have been used in the study to analyze the gradient wise urban growth in the four directions for the year 2001, 2011 and 2017.

3.4.5 Spatial Metrics

Table 2: Landscape Metrics

Description Metrics generated in Fragstat			
	Indicator	**Formula**	**Description**
1.	Class Area (CA)	CA= Area of a class Range: CA > 0, without limit	Class Area show intensity of particular patch type in landscape. Equals the sum of the area (m2) of all patches of the comparing patch type, isolated by 10,000. ajj zone (m2) of fix ij.
2.	Number of patches (Built-up) (NP)	NP = n_i Range: NP≥1	It denotes the total number of patches of a specific category.
3.	Percentage of landscape (Built-up) (PLAND)	PLAND= $P_i = \frac{\sum_{j=1}^{n} aij}{A}$ (100) Range: 0 < %Land ≤ 100	It represents the landscape of specific type in percentage. aij= area (m^2) of patch ij A =total landscape area (m^2).
4.	Patch Density (PD)	PD = $\frac{n_i (10,000) (100)}{A}$ Range: PD > 0	It is the number of patches of urban patch divide by overall spatial extent.
5	Largest patch Index (Built-up) (LPI)	LPI = $\frac{\max_{j=1}^{n}(aij)\ (100)}{A}$ RANGE : 0 < LPI ≤ 100	Its value ranges from 0 to 1. LPI approaches 0 when the largest patch of the built up patch becomes increasingly small and LPI=1 when the entire landscape of the patch type of the built up class.
6	Mean Patch Size (Class/ Landscape) (MPS)	MPS=$\frac{A}{N\ Patch}(10000)$ Range: MPS>0, without limit	It is summation of patches of a particular type divided by the number of patches in that type multiply by 10,000.
7.	Perimeter Area Fractal Dimension (PAFRAC)	$PAFRAC = \frac{2}{\frac{\left[n_i \sum_{j=1}^{n} (\ln p_{ij} \cdot \ln a_{ij})\right] - \left[\left(\sum_{j=1}^{n} \ln p_{ij}\right)\left(\sum_{j=1}^{n} \ln a_{ij}\right)\right]}{\left(n_i \sum_{j=1}^{n} \ln p_{ij}^2\right) - \left(\sum_{j=1}^{n} \ln p_{ij}\right)^2}}$	If its value is more than 1 it indicates shape complexity. %

Source: Based on Fragstat 4.2 Handbook

4. Results and Discussion

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

In the course of time it has been observed, built-up area has increased from 2001 to 2017 mainly because of ongoing process of urbanization. Shannon's model of entropy indicates growth process in cities. The computation has been performed for all four directions i.e., zone wise (Figure 2 A, B, C, D). For the year 2001, 2011 and 2017 gradient analysis has been performed with homocentric circles of incriminating buffer zones of 2kms from the center of the city. The process of urban growth across the circles of 2 kms (Figure 3, Figure 4 and Figure 5) from the city towards the outskirts for the year 2001, 2011 and 2017 has emphasized intensification and growth of built up surrounding the core area of the city as well as spreading out from it in the south eastern direction and in the western direction from 2001 to 2011. From 2011 to 2017, the built-up area in the south eastern and western part has continued to increase along with the increase in the north eastern part.

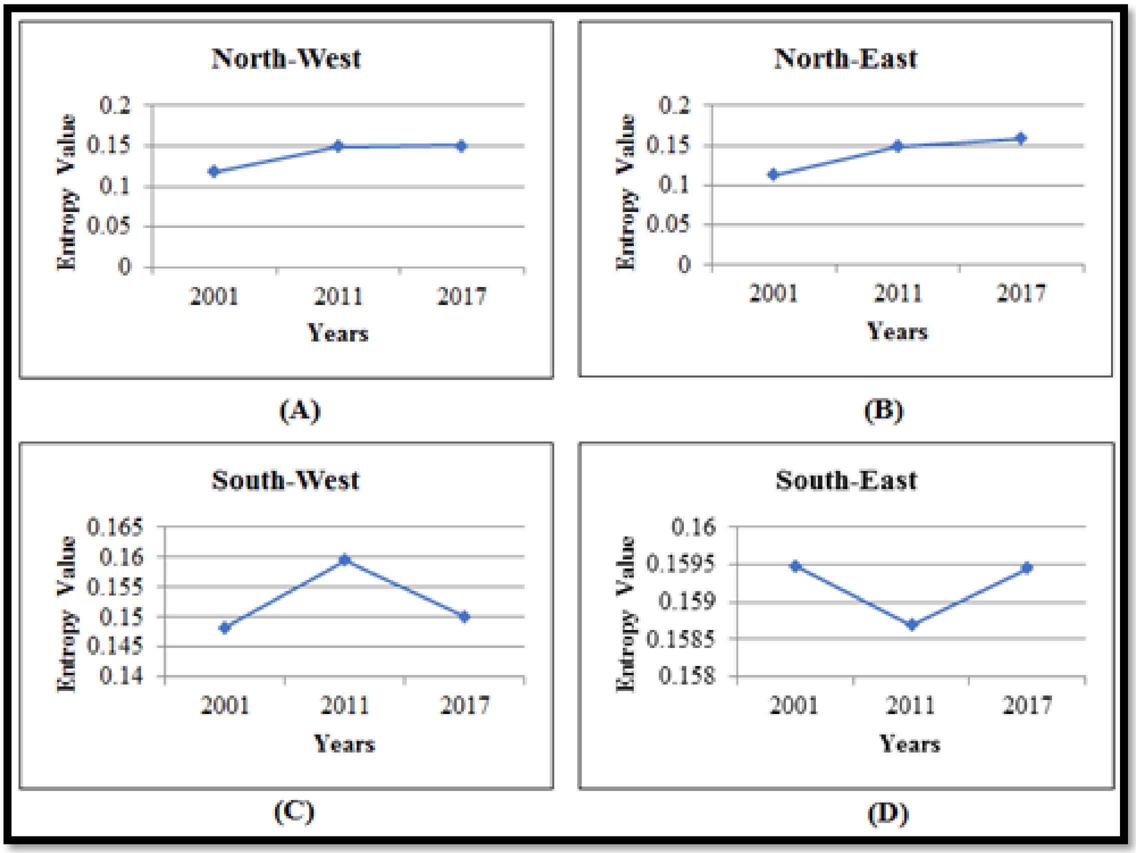


Figure 2 (A), (B), (C), (D): Shannon's Entropy Direction Wise

The process of urbanization in the study area (Figure 6) could be analyzed from the growth in built up area from 2001 to 2017.

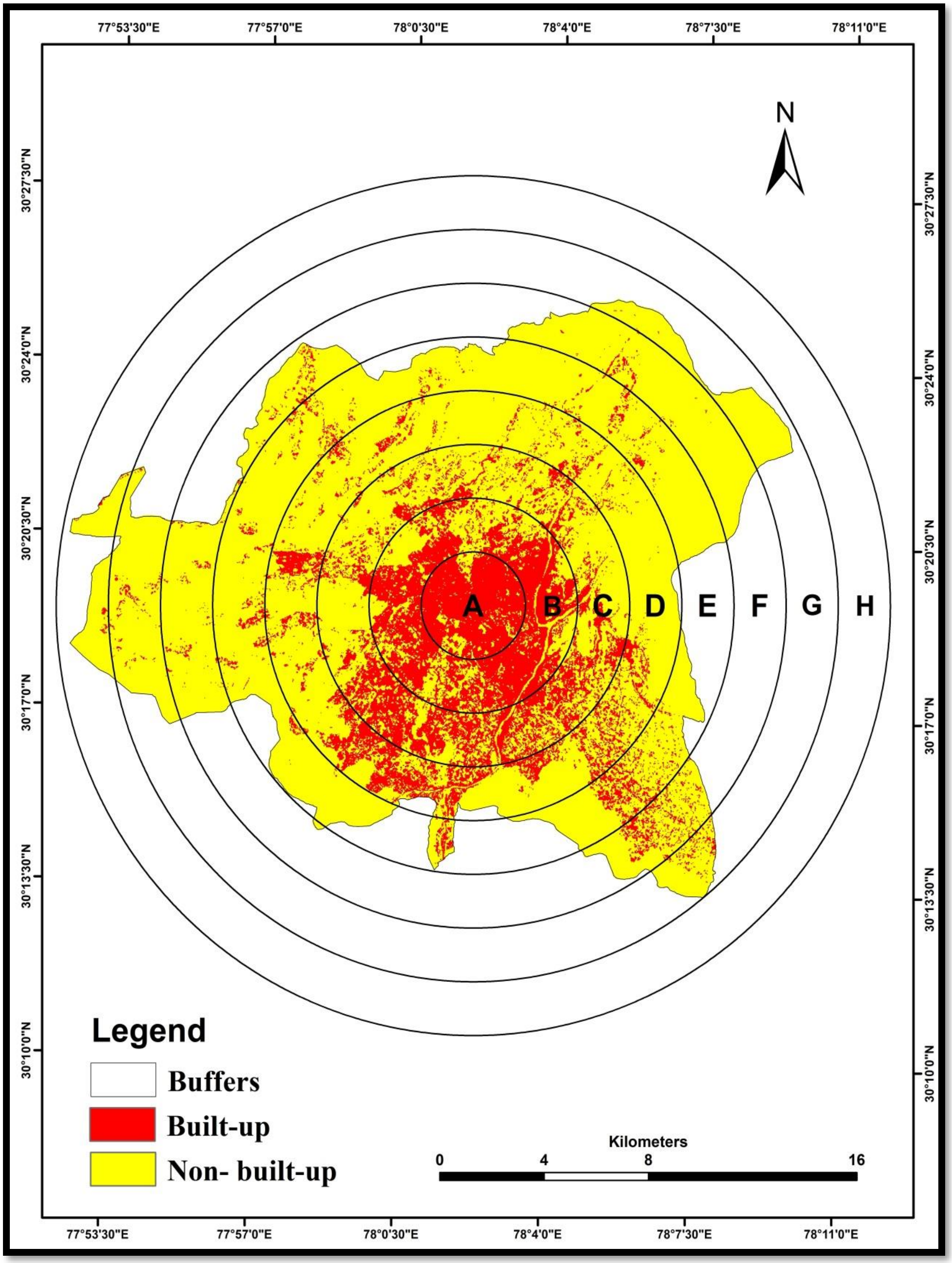


Figure 3: Circle Wise Built up and non-built-up Area, 2001

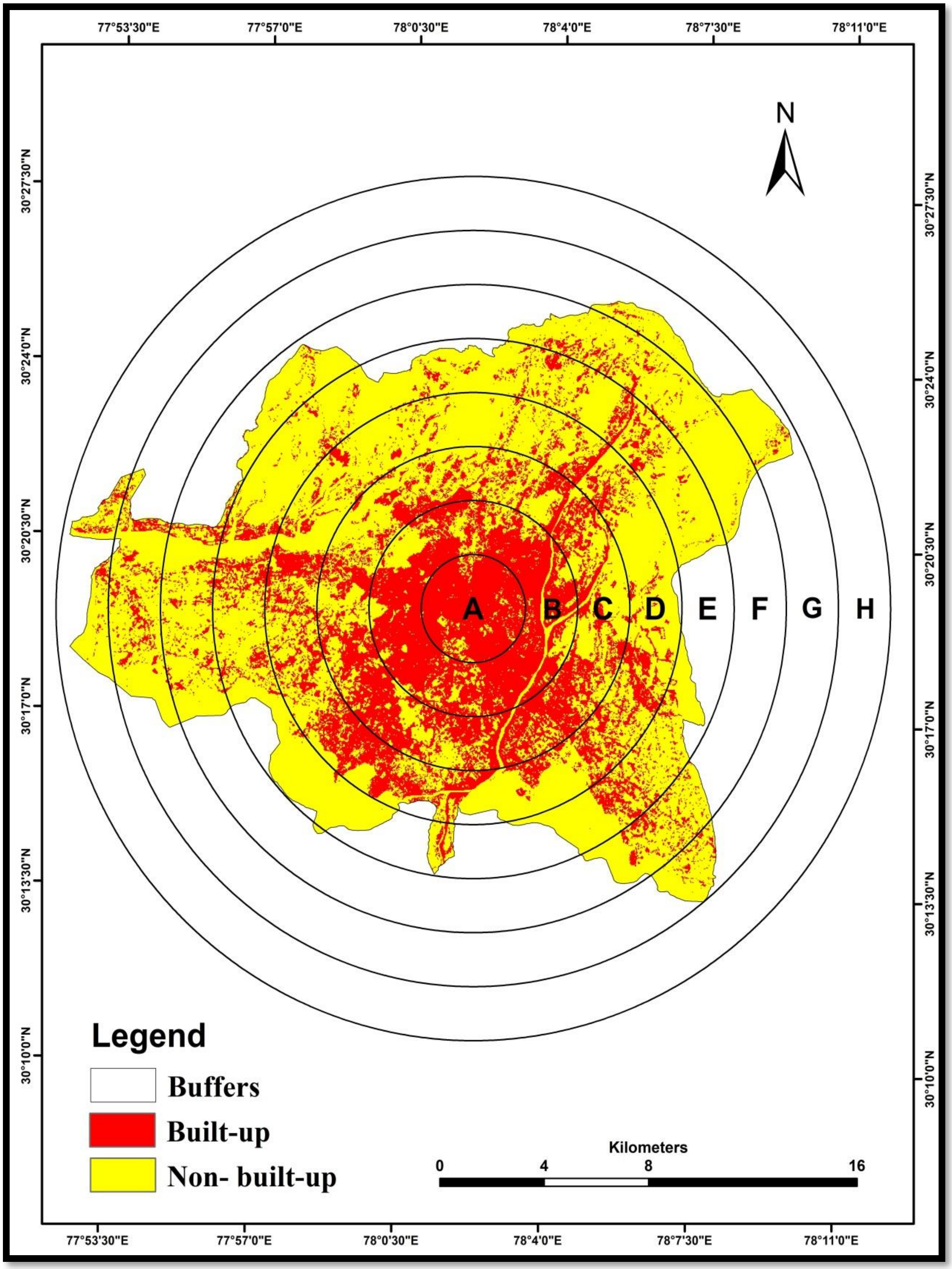


Figure 4: Circle Wise Built up and non-built-up Area, 2011

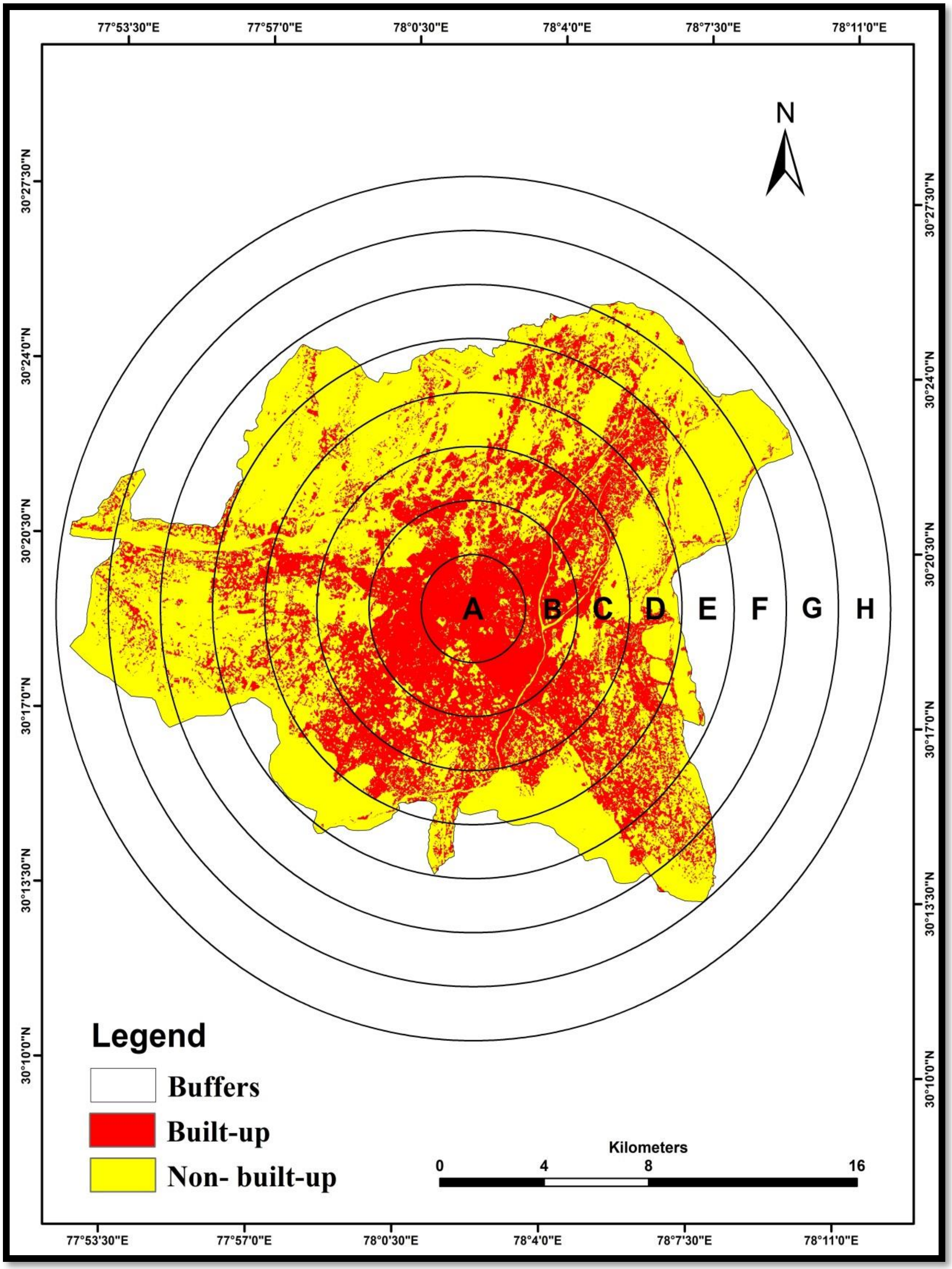


Figure 5: Circle Wise Built up and non-built-up Area, 2017

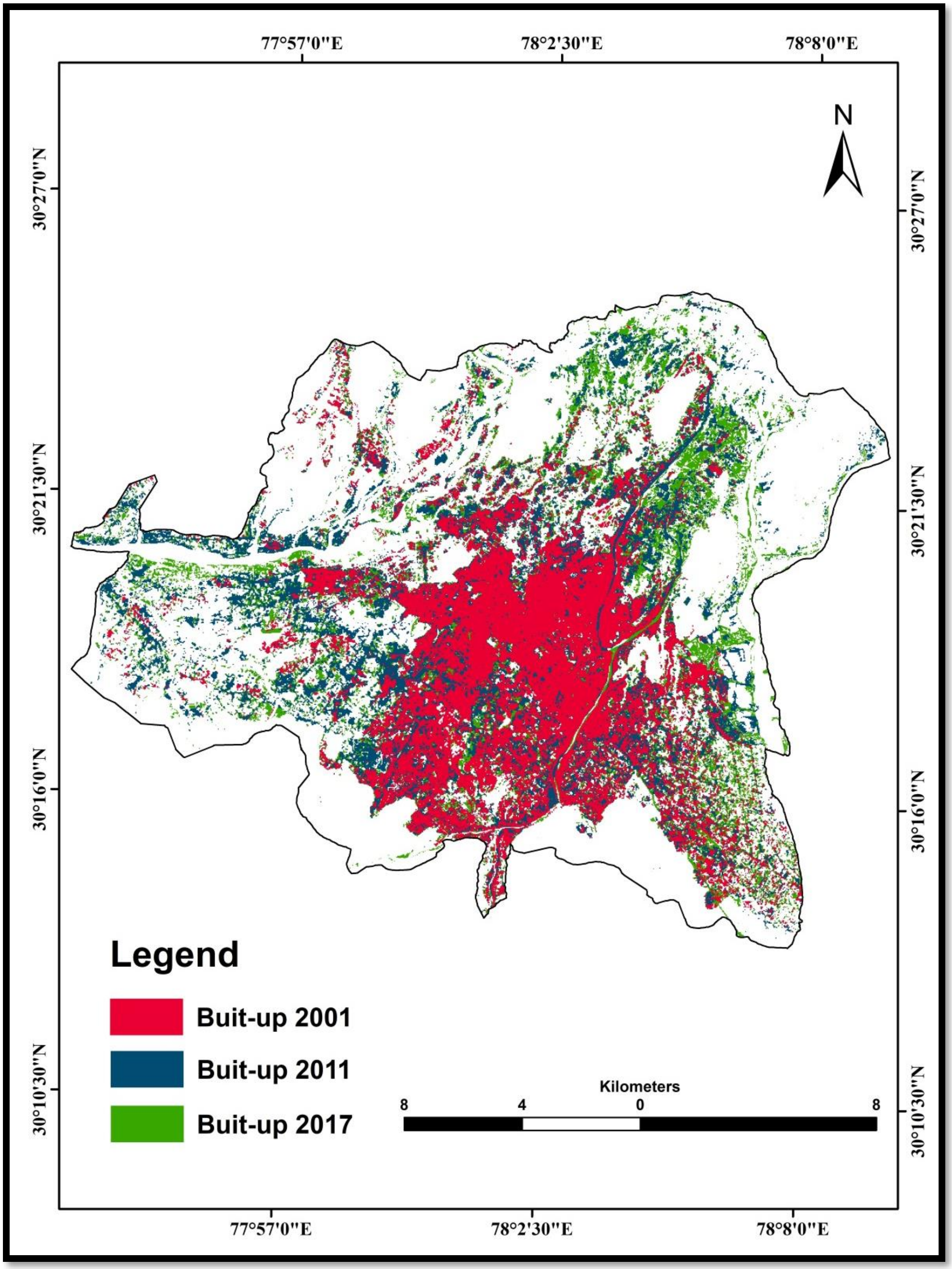


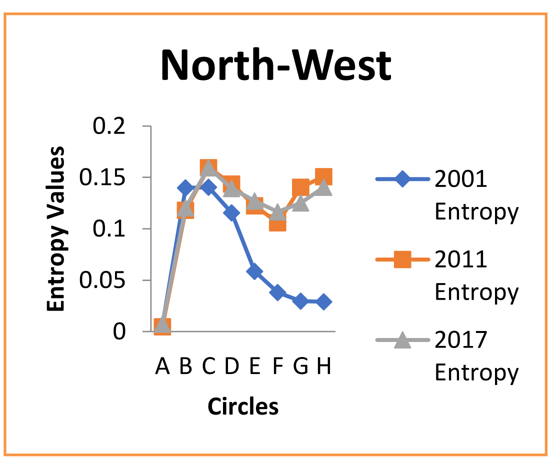
Figure 6: Built up Area Change, 2001-2017

4.1.1 Shannon's Entropy

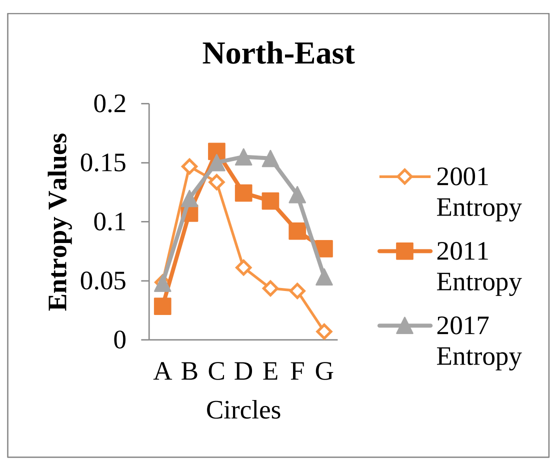
Zonal - When the Shannon's entropy was performed direction wise (Figure 2 A, B, C, D) it indicates that the sprawl as the entropy have been experiencing in the directions i.e., North-east, North-west and South-east in the study area where the entropy value has been increasing for the following directions. The only exception, where the entropy value has decreased from 2001 to 2011 but from 2011 to 2017 is the south west region. The range of values of entropy lies between zeros to log n. If the values are found to be closer to zero then it shows the presence of compactness and homogeneity in the growth. Whereas the values closer to log n highlights the existence of dispersion in the settlement pattern along with heterogeneity of land uses. It has been noticed in the south west zone from 2001 to 2011. On the other hand, decrease in the growth from 2001 to 2017, as evident by the drop in the entropy value. Subsequently, the entropy value decreased during 2001 to 2011 but it started increasing from 2011 to 2017 again for the south east zone. Therefore, it could be concluded that urban patches in the northwest and northeast direction have been getting fragmented.

4.1.2 Shannon's Entropy: Zonal as well as Gradient

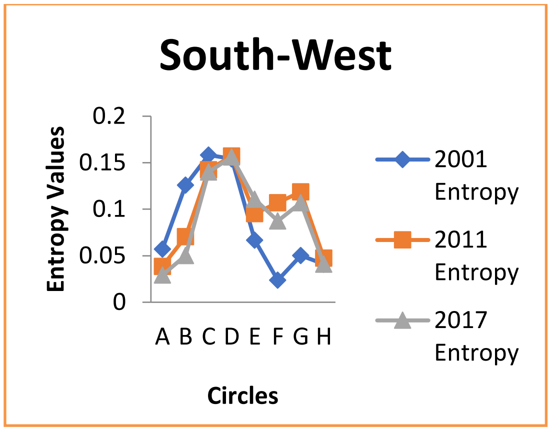
The gradient analysis of Shannon Entropy from the city center across the buffers of 2 kms in the four directions (Figure 7 A, B, C, D) has been performed. For enabling comparative assessment of the entropies and growth of sprawl, the computation of Shannon entropy has been performed for the year 2001, 2011 and 2017. Around the city core (up to buffer C, i.e. distance of 6 kms) the growth has been very minor, but the increase is clearly distinguishable in the outskirts. The entropy has increased from 2001 to 2017 towards the peripheries in South east and North east directions. In the North West direction, the entropy increase is well defined from 2001 to 2011 but from 2011 to 2017, there has been negligible growth in the value of entropy. The North West part of the study area contains forests and cantonment areas, which can be a significant factor for its minor growth. The values of entropy have decreased for year 2017 with respect to values in year 2011 in the circle G and H. In South-west direction, the entropy in the outskirts of the city has increased from 2001 to 2011 but it has decreased from 2011 to 2017.



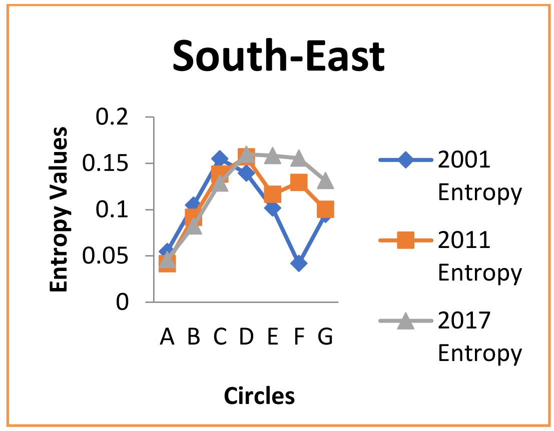
A



B



C



D

Figure 7 (A, B, C, D): Entropy Gradient and Direction-wise

As a fact that Dehradun in 2000 A.D. became the capital of Uttarakhand could be a reason for this rapid increase in the entropy from 2001 to 2011 in all the four directions in the city outskirts. Subsequently, there have been various governments' policies that aimed to make Dehradun a hub for huge institutional and commercial activities, ultimately pulling people from adjoining rural areas in search for better lifestyle and employment opportunities. On the other hand, core of the city has high land values, which poor people cannot afford. Thus, they opt to live in the peripheral areas which housing is much more affordable for the poor sections of the society.

Urban planners attempt to formulate city structure in such a way that is both i.e. socially and environmentally acceptable, which is done by designing a compact structure rather than a dispersed one. In urban sprawl, working population needs to commute daily from the outskirts towards the city center and there is high consumption of energy as well as fuel from the vehicles which emits harmful gases and it deteriorates the physical environment of the entire city. The poor urban sprawl dwellers, suffers from lack of basic facilities i.e. medical facilities, hygienic conditions and also, becomes a hub of criminal activities.

4.2 Spatial Metrics

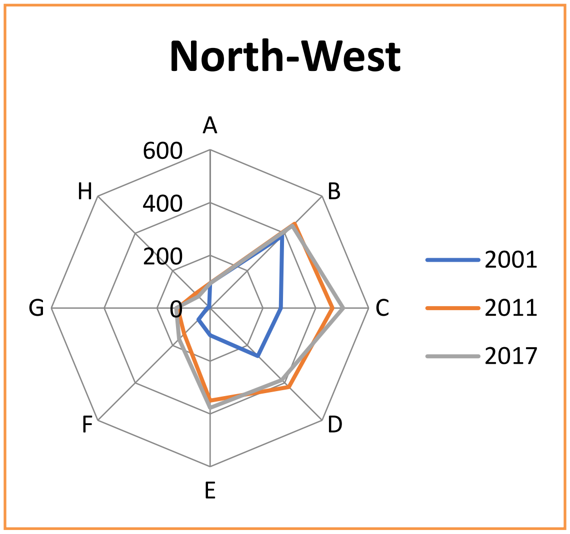
Fragstat software has been used to prepare the Landscape metrics of the study area to more insight in the growth pattern.

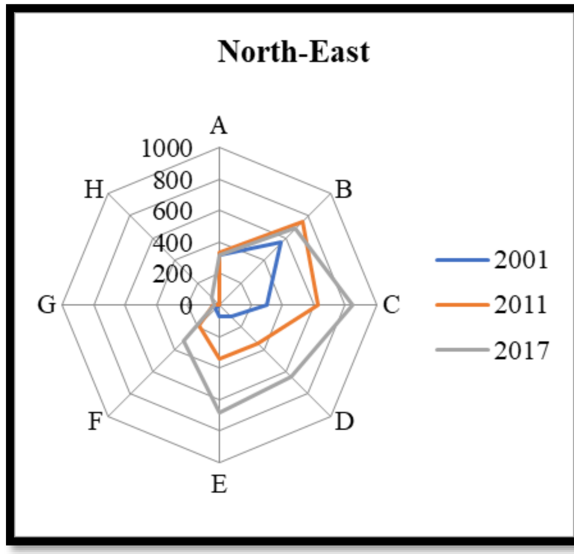
4.2.1 Class Area

For analyzing the landscape composition and computing the areas of a class in hectares class areas metrics have been used. Direction wise class area metrics has been calculated as well as gradient wise along various homocentric circles from the city center. There has been an increase in class area from 2001 to 2017. It has been evident that, in year 2017, urban growth is least prominent in North West direction, while it is more prominent in South east direction.

4.2.2 Percentage of Land

It indicates the presence of a particular class type in percentage and is called PLAND. To analyze the growth over the period of time, built-up percentage has been calculated in the study. In 2017, urban landscape percentage has been higher in the South -East direction and has been least in the North-west direction (Figure 9 A, B, C, D). But in all the four directions, maximum patch density has been recorded around the core of the city, in circles

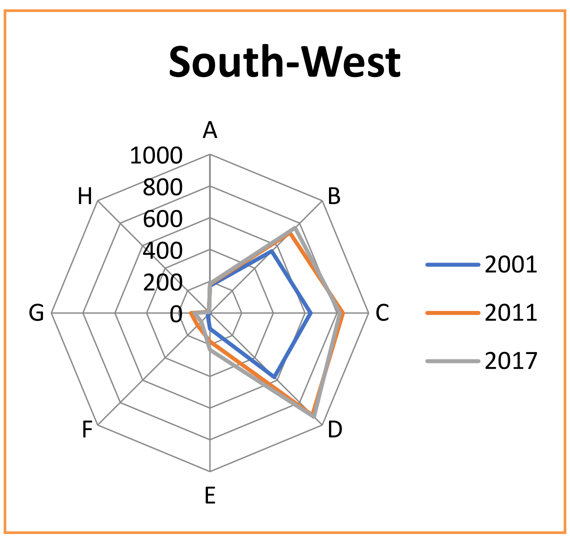




ranging from C to E.

A

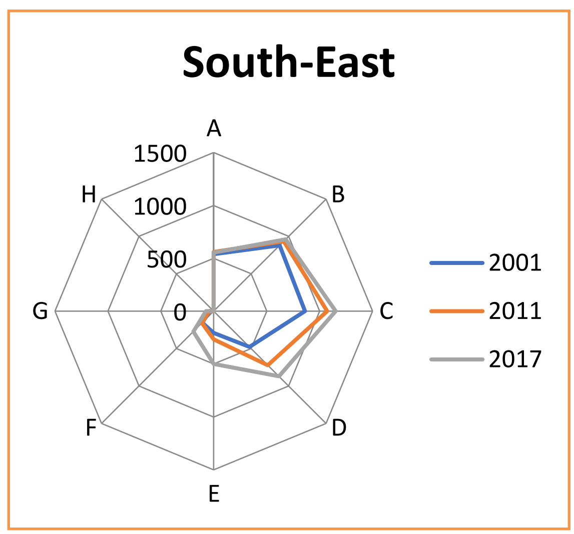
B



C

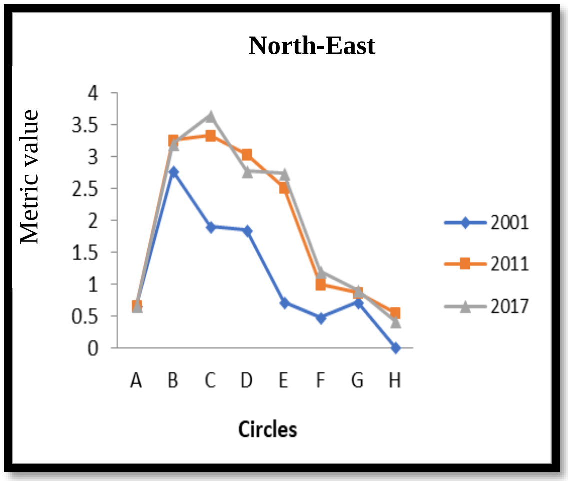
D

Figure 8 (A, B, C, D): Urban Class Area

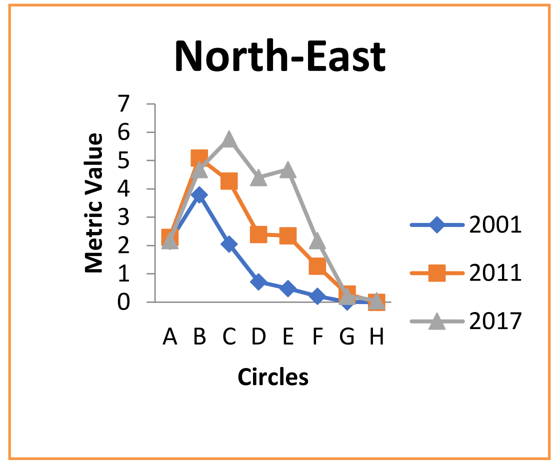


To study the growth over the period of time, built-up percentage has been calculated in the study. The urban landscape percentage has been higher in the South -East direction and has been least in the

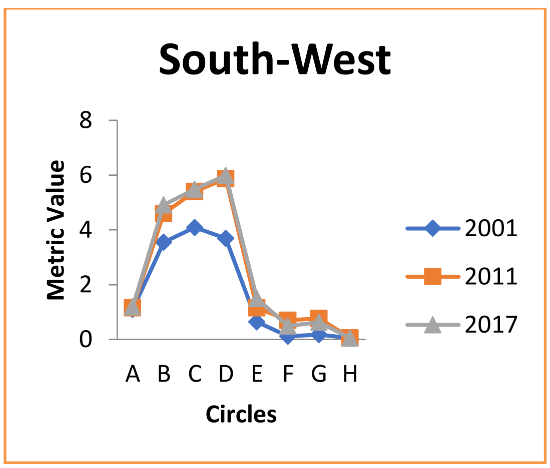
North-west direction in year 2017, (Figure 9 A, B, C, D). But in all the four directions, maximum patch density has been recorded around the core of the city, in circles ranging from C to E.



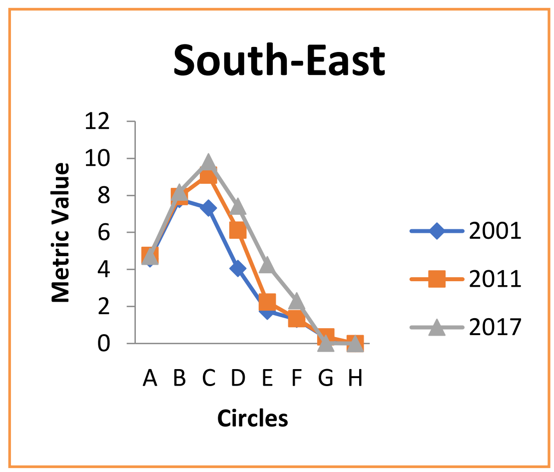
A



B



C

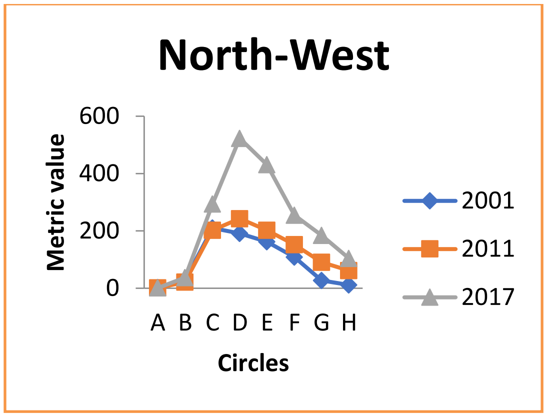


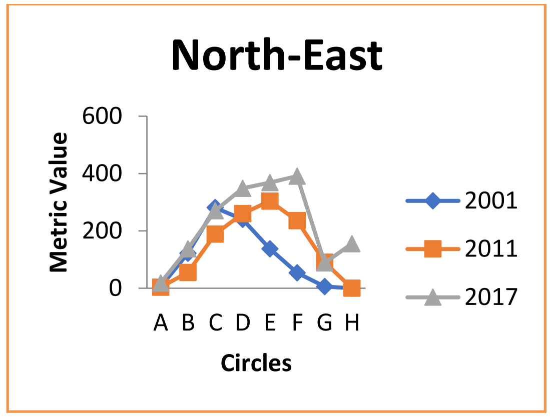
D

Figure 9 (A, B, C, D): Percentage of Landscape

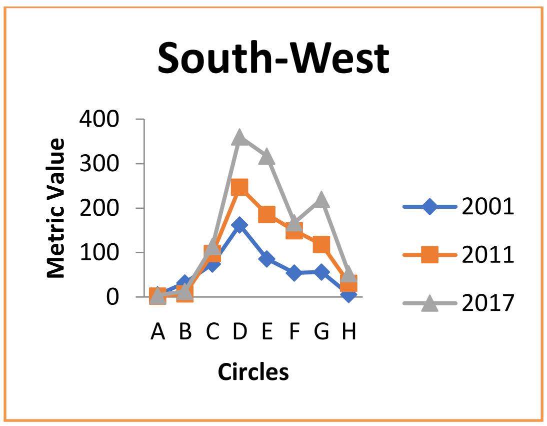
4.2.3 Number of Patches (NP)

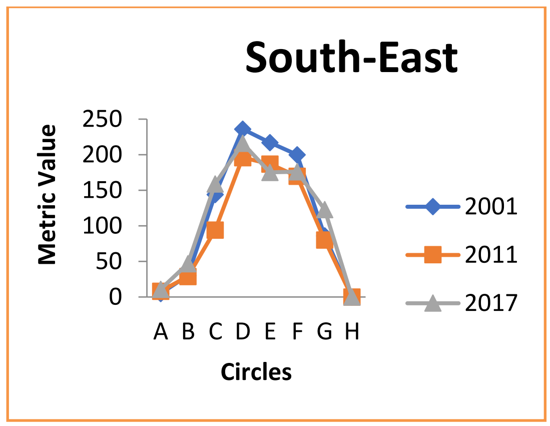
Basic parameter when it comes to record the degree of subdivisions/ fragmentation of the patch type in a landscape is denoted by this metrics. It illustrates the numeric value of patches of built in the area. A rising trend for number of patches in all directions from 2001 to 2017, except in South -East direction where total built up patches decreased from 2001 to 2017, (Figure 10 A, B, C, D) has been observed. Thus, in South-East direction, since the number of patches has decreased, it could be concluded that here less land fragmentation has been taking place and the patches have been combining to form a single compact patch.





A B



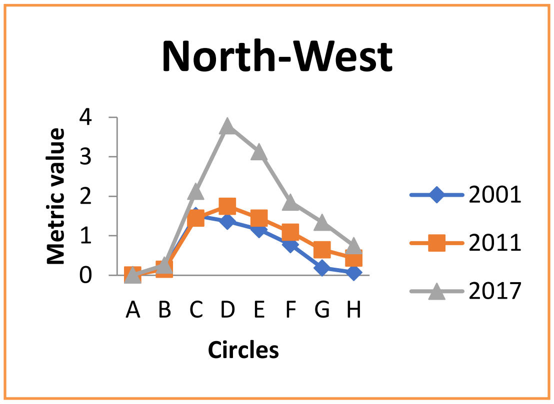


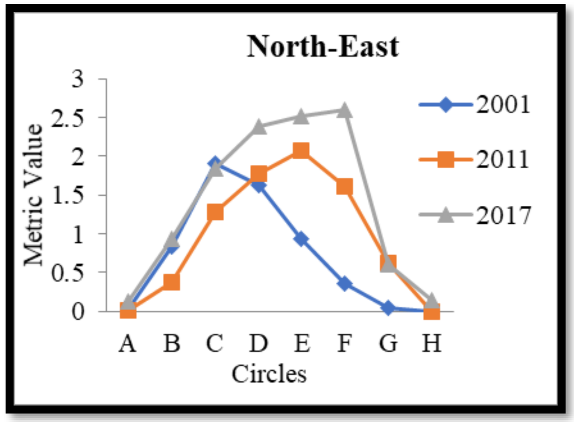
C D

Figure 10 (A, B, C, D): Number of Patches

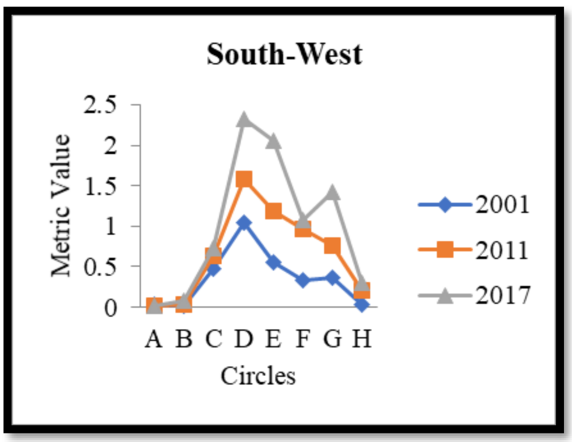
4.2.4 Patch Density

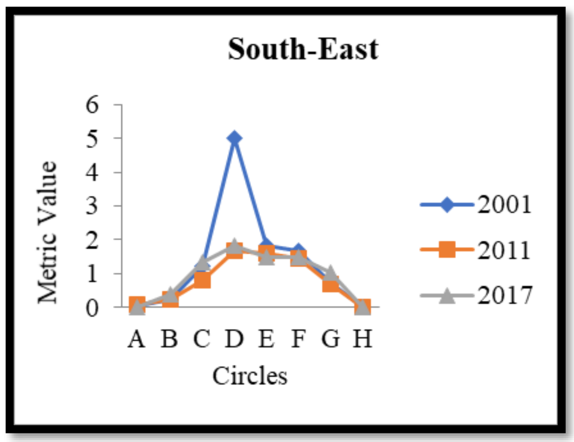
Patch Density (PD) is an essential indicator of urban fragmentation. It does not provide any informative aspect about the spatial pattern and sizes of patches. It only consists of numbers but they are of less interpretative value. There is a direction relationship between number of patches and density of patches i.e. if the value of number of patches is recorded high then it indicates increase in patch density. Thus, representing more fragmentation in the city. The similar relationship has been observed in the study area as well. Where, more fragmentation of the urban patches from year 2001 to 2017 is observed. But only in south east direction it has decreased, especially in the area lying between circle C to circle E. In the core city, patch density is low (Figure 11 A, B, C, D), which signifies its compactness around city center. On the other hand, it has been increasing in the peripheral areas. Hence, indicating steady increase in the level of sprawl in the city periphery. In south east direction, patch density values decrease, indicating smaller patches have been aggregating to form a single large patch.





A B





C D

Figure 11 (A, B, C, D): Patch Density

4.2.5 Largest Patch Index

It indicates dominance which quantifies percentage of landscape of the largest patch. LPI approaches 0 when the largest patch of the corresponding patch type is increasingly small. If the value of LPI is 100, it shows that there is presence of a single largest patch. In other words, 100 per cent of the area is covered by that single largest patch. It facilitates in assessing the urbanization process across the year comparatively. The largest urban patch has been in circle B for the North -East, North -West and South East direction, (Figure 12 A, B, C, D). Whereas, in the South-west direction the largest urban patch has been in circle C for all the three years. These metric aids in locating the growth poles over the years.

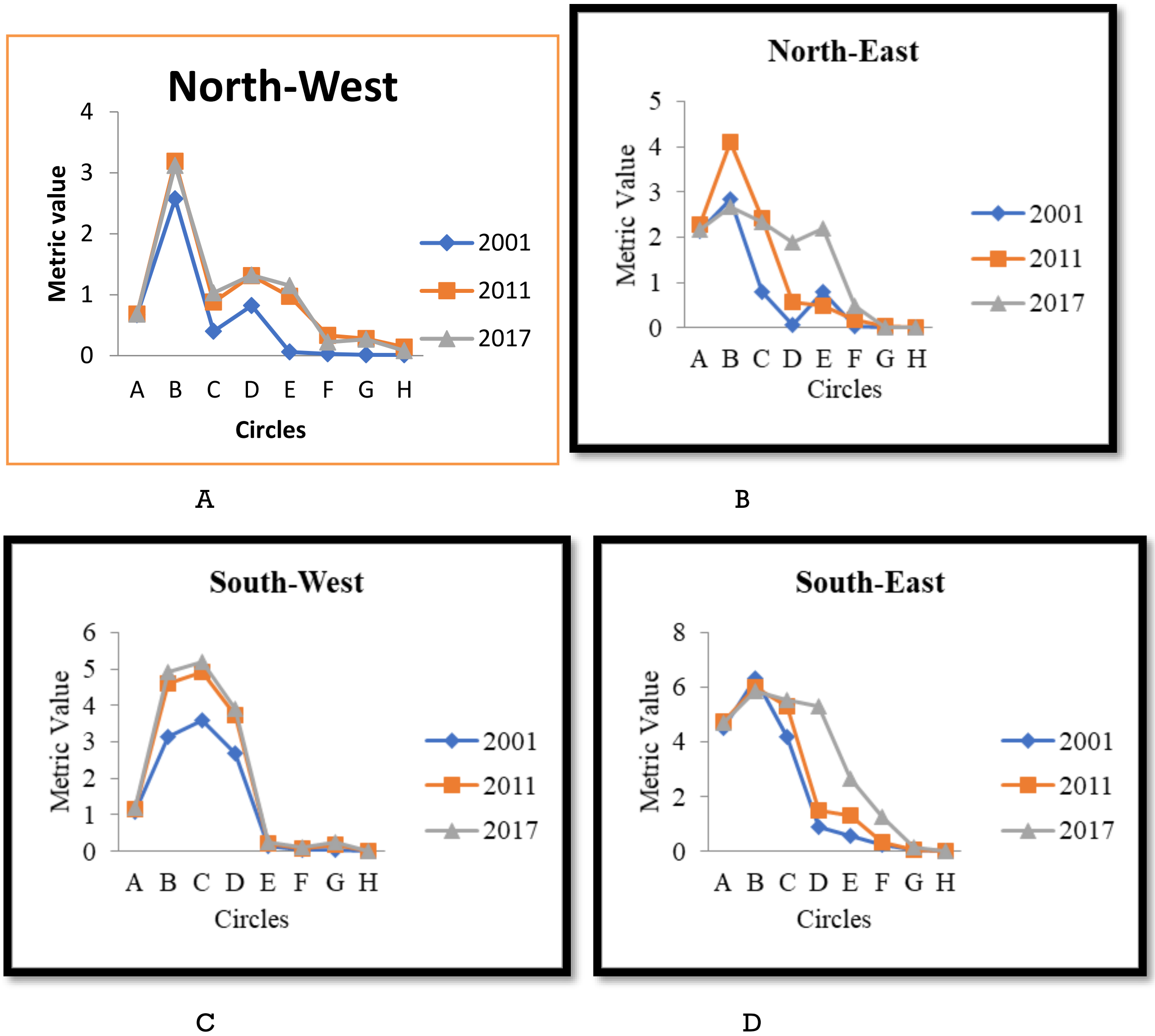
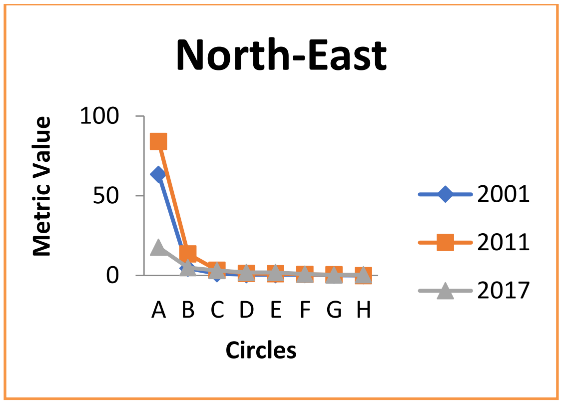


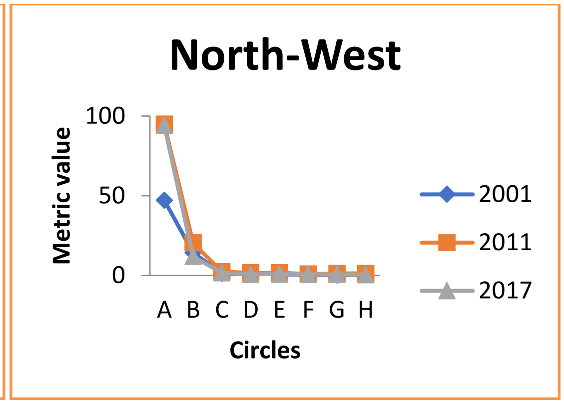
Figure 12 (A, B, C, D): Largest Patch Index (LPI)

4.2.6 Mean Patch Size

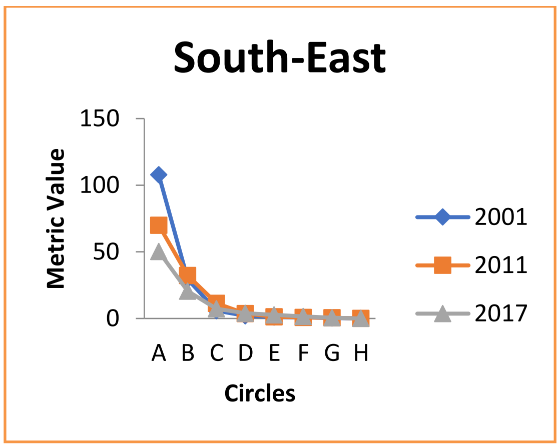
It is an index of particular class which is in inverse relation to its degree of fragmentation. Thus, more fragmentation will have lower values of MPS and higher value suggests concentrated city growth. The circles A and B are having higher values in all direction over the time period in study area and beyond C the value has decreased drastically, (Figure 13 A, B, C, D). Thus, implying that city center has more of compact nature due to aggregation, as value of MPS has been more around the city center, thus less fragmentation.



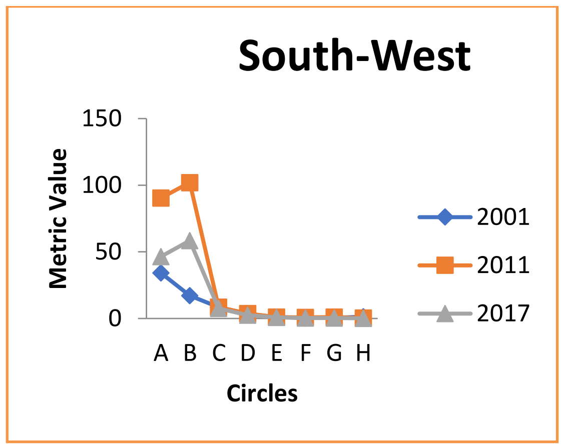
A



B



C

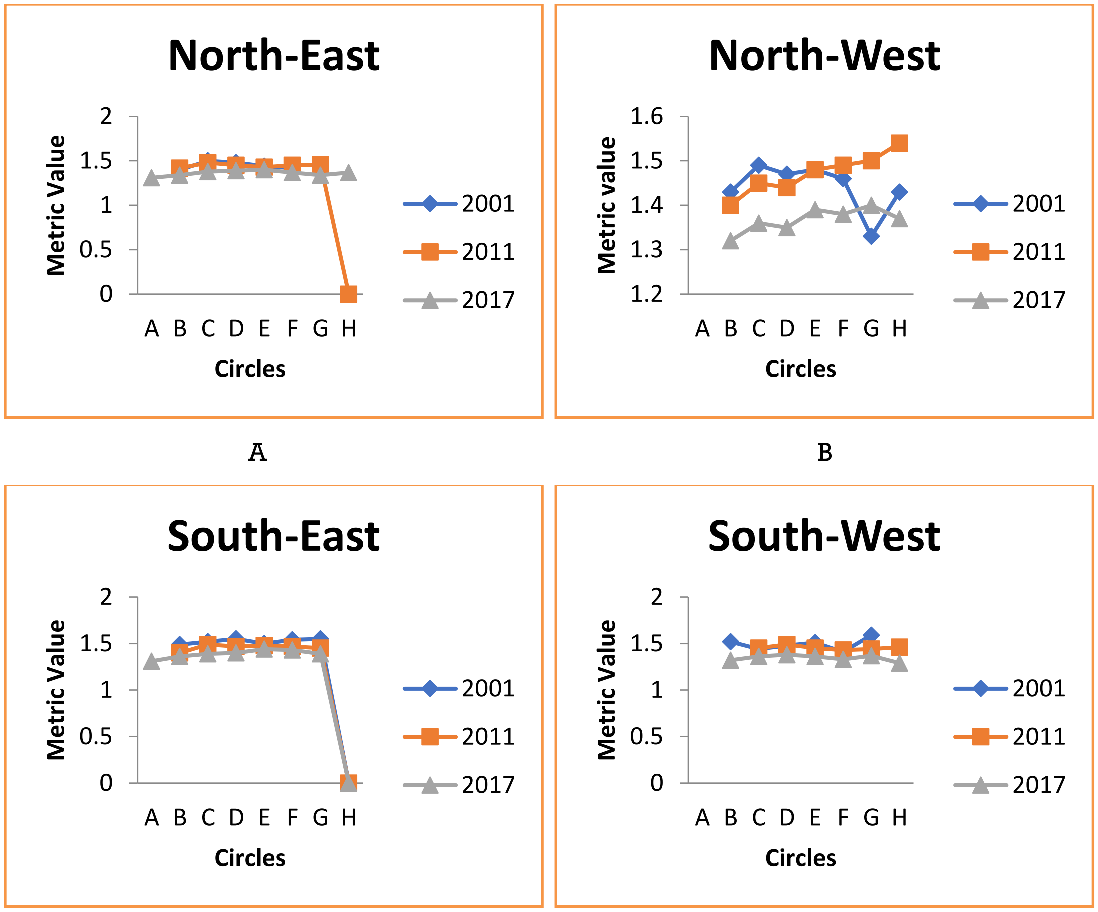


D

Figure 13 (A, B, C, D): Mean Patch Size

4.2.7. Perimeter Area Fractal Dimension

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. If PAFRAC value is close to 1 it indicates shapes having simplified perimeters for example square. But if the value is closer to 2 then it denotes complex shapes having convolution. PAFRAC calculation involves regression analysis, thus it is advisable to use it only when sample size is not small. The reduction in the value of PAFRAC over time has suggested less complicated shape of urban Patches and simple perimeter. All the four directions have complex shape as value for the three-time period has been higher than 1 (Figure 14 A, B, C, D).



C D

Figure 14 (A, B, C, D): Perimeter Area Fractal

5. Conclusion

The dynamics of Land use and cover indicated the active rapid growth in the built-up area in the study region from 2001 to 2017. The study region witnessed a rise in the built-up area from 19.64 percent in 2001 to 30.77 percent in 2011 and continued to rise to reach 35.19 percent of the total area in 2017. Uttarakhand came into valid existence in 2001 as Dehradun its capital which could be a reason for such a rapid increase. Following this shift in status of Dehradun, there have been various governments' policies that aimed to make Dehradun a hub for huge institutional and commercial activities. The prime reason behind the increase of built-up areas in the urban areas is the conversion of vegetative covers like agricultural land and forest areas.To analyze the process of growth in urban areas methods like Shannon's entropy and spatial metrics are used. Over the time period of 2001 to 2017, the analysis highlighted that the process and its densification have mostly occurred in the surrounding areas of the city and with the time it has gradually moved towards the outskirts. While comparing the entropy values of the core of the city and its outskirt areas, the values recorded on the outskirts were comparatively higher than the core area.

Other classes like crop land and open spaces paid the price in negative terms due to the process of urban sprawling. To encounter to ill effects of the urban growth on the environmental settings, the policy makers and the urban planners have to make appropriate and reliable development plans this made possible only by analyzing the rapid growth of urban areas. Meanwhile, from the analysis of the urban area, it has been concluded that there is a substantial rise in the built-up area, which mainly occur when there is reduction of natural land cover i.e. vegetation, agricultural lands, and it is replaced by impervious surfaces i.e. roads, buildings etc. Thus, giving rise to sustainable city development programme which are fulfilled with integrated approach towards planning of available resources. Dehradun, after becoming the capital of Uttarakhand state in 2000, it has developed as a regional service center for the entire region of Garhwal, thus, leading to attracting a huge population living nearby and also from different parts of India as it also started developing as an educational hub. Therefore, unprecedented growth which taking place continuously from the year 2000, has turned a boon to the city as several problems have started emerging such as lowering of groundwater table, overcrowding, chaos, congestion, mass encroachment etc. Thus, the role of the local government now has a protuberant part to perform in the planning for the development of the city in an organized and sustainable manner and to provide a healthy and livable environment to the future generations.

References

1. *Census of India (2011). Paper 2 of 2001: Rural–Urban Distribution of Population, Provisional Population Totals. Government of India Publications, New Delhi. (www.censusindia.gov.in)*
2. *Chaschan, J., Shankar, R. (2012). An analysis of urban growth trends in the post-economic reforms period in India. International Journal of Sustainable Built Environment, Vol.1, Issue 1, pp. 36-49. (www.infona.pl)*
3. *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. (www.cabdirect.org)*
4. *Grimm, N. B., Grove, J. G., Pickett, S. T. A., Redman, C.L. (2000). Integrated approaches to long-term studies of urban ecological systems. Bioscience 50 (7), pp. 571-858. (www.fs.usda.gov)*
5. *Guindon, B., and Zhang, Y. (2009). Automated Urban Delineation from Landsat Imagery Based on Spatial Information Processing. Photogrammetric Engineering and Remote Sensing, 75 (7), pp. 845-858. (www.semanticscholar.org)*
6. *Gustafson, E. J. (1998). Quantifying landscape spatial pattern: what is the state of the art? Ecosystems, 1, pp. 143-156. (www.researchgate.net)*
7. *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. (www.edc.uri.edu)*
8. *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. (www.wgbis.ces.iisc.ernet.in)*
9. *Herold, M., Goldstein, C., Clarke, N.C.K. (2002). The spatial form of urban growth: measurement, analysis and modeling. Remote Sensing Environment, 86, pp. 286-302. (www.academic.microsoft.com)*
10. *Jaeger, J. A. G. (2000). Landscape division, splitting index, and effective mesh size: new measures of landscape fragmentation. Landscape Ecology, 15, pp. 115-130. (www.link.springer.com)*
11. *Jat, M. K., Garg, P. K. and Khare, D. (2008). Monitoring and Modelling of urban sprawl using remote sensing and GIS techniques, International Journal of Applied Earth Observation and Geoinformation, 10 (2008), pp. 26–43.(www.sciencedirect.com)*

12. *Kasanko, M., Barredo, J. I., Lavalle, C., McCormick, N., Demicheli, L., Sagris, V., et al., (2006). Are European cities becoming dispersed? a comparative analysis of 15 European urban areas. Landscape of Urban Planning, 77 (1–2), pp. 111–130.(www.mdpi.com)*
13. *Knox, P. (2009). International Encyclopedia of Human Geography, pp. 112-118. (www.geography.osu.edu)*
14. *Kundu, A. (2006). Trends and patterns of urbanization and their economic implications. India Infrastructure Report, pp. 28–41. (www.pubs.iied.org)*
15. *Kundu, A., Bagchi, S. and Kundu, D. (1999). Regional distribution of infrastructure and basic amenities in urban India: issues concerning empowerment of local bodies. Economic and Political Weekly, 34 (28).(www.epw.in)*
16. *Li, X. H., Liu, J. L, Gibson, V., Zhu, Y. G., (2012). Urban sustainability and human health in China, East Asia and Southeast Asia, Environmental Sustainability 4, pp. 436-442. (www.researchgate.net)*
17. *McGarigal, K., Marks, B.J. (1995). Fragstats: Spatial Pattern Analysis Program for Quantifying Landscape Structure. PNW-GTR-351, p. 122. (www.srs.fs.usds.gov)*
18. *Mosammam, H. M., Nia, J. T., Khani, H., Teymouri, A. and Kazemi, M. (2017). Monitoring landuse change and measuring urban sprawl based on its spatial forms: the case of Qom city. Egyptian Journal of Remote Sensing and Space Science, Vol. 20 (1), pp. 103-116.(www.scrip.org)*
19. *Mundia, C. N., Murayama, Y. (2010). Modeling spatial processes of urban growth in African cities: a case study of Nairobi City. Urban Geography, 31(2), pp. 259-272. (www.tandfonline.com)*
20. *O'Neill, R. V., Krummel, J. R., Gardner, R. H., Sugihara, G., Jackson, B., Angelis, D. L. D., Milne, B. T., Turner, M. G., Zygmunt, B., Christensen, S. W., Dale, V. H., Graham, R. L. (1988). Indices of landscape pattern. Landscape Ecology, 1, pp. 153-162. (www.lapa.ufscar.br)*
21. *Pathan, S. K., Sastry, S. V. C., Dhinwa, P. S., Mukund, R. and Majumdar, K. L. (1993). Urban growth trend analysis using GIS technique-a case study of the Bombay metropolitan region. International Journal of Remote Sensing, 14 (17), pp. 3169-3179. (www.lipgen.ggfwzs.net)*
22. *Punia, M. and Singh, L. (2011). Entropy Approach for Assessment of Urban Growth: A Case Study of Jaipur, India, Journal of the Indian Society of Remote Sensing, 40 (2), pp. 231-244. (www.semanticscholar.org)*
23. *Ramachandra, T.V., Aithal, B.H. and Sowmyashree, M.V. (2014). Urban structure in Kolkata: metrics and modelling through geo-informatics, Applied Geomatics, 6, pp. 229-244. (www.infone.pl)*
24. *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. (www.wgbis.ces,iisc.ernet.in)*
25. *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. (www.wgbis.ces,iisc.ernet.in)*
26. *Ramachandra, T.V., Bharath, A. H., Sreekantha, S., (2012a). Spatial metrics based landscape structure and dynamics assessment for an emerging Indian Megalopolis. International Journal of Advanced Research in Artificial Intelligence, 1 (1), pp. 48-57. (www.thesai.org)*
27. *Reis, J. P., Silva, E. and Pinho, P. (2015). Spatial Metrics to Study Urban Patterns in Growing and Shrinking Cities. Urban Geography, June. (www.tandfonline.com)*
28. *Schneider, A., Woodcock, C. E. (2008). Compact, dispersed, fragmented, extensive? A comparison of urban growth in twenty-five global cities using remotely sensed data, pattern metrics and census information. Urban Studies, 45 (3), pp. 659–692. (www.journals.sagepub.com)*
29. *Soffianian, A., Nadoushan, M. A., Yaghmaei, L. and Falahatkar, S. (2010). Mapping and Analyzing Urban Expansion Using Remotely Sensed Imagery in Isfahan, Iran, World Applied Sciences Journal, 9 (12), pp. 1370-1378. (www.citeseerx.ist.psu.edu)*

30. *Sudhira, H.S., Ramachandra, T.V. and Jagadish, K.S. (2004) Urban Sprawl: Metrics, dynamics and Modeling Using GIS. International Journal of Applied Earth Observation and Geo- information, 5, pp. 29-39. (www.sciencedirect.com)*
31. *United Nations (2011). World Urbanization Prospects: 2011 Revision. Department of Economic and Social Affairs, pp. 1-138. (www.un.org)*
32. *United Nations (2014). World Urbanization Prospects: The 2014 Revision-Highlights, Department of Economic and Social Affairs, pp. 1-27. (www.un.org)*
33. *World Bank (2011). World Bank database. (www.data.worldbank.org)*
34. *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. (www.researchgate.net)*
35. *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. (www.asprs.org)*