ZONAL PERSPECTIVE ON SPATIO-TEMPORAL LAND USE CHANGE IN INDIA THROUGH METRICS

R. Verma[1]*, J. Zawadzka[2], P. K. Garg[1]

[1]Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee- 247667, Uttarakhand, India- (rverma2, p.garg)@ce.iitr.ac.in
[2]Cranfield Environment Centre, Cranfield University, Bedford- MK430AL, United Kingdom- joanna.zawadzka@cranfield.ac.uk

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ABSTRACT:

India is a magnanimous country having large population centres with different settlement characteristics in various states and Union Territories (UTs), which can affect climate and development of country in longer duration. As such spatio-temporal analysis of urban dynamics over different constituent land use/land cover (LU/LC) is performed in this study using open source data and software programs only. The study derives a pattern of 4 Landscape Metrics (LSMs) by mapping urban growth through continuity, complexity, centrality and compactness of built-up land use using a publically available classified Decadal Land use data of India for years 1985, 1995 and 2005, over a period of 20 years in 7 zones of India. Spatially, UTs are showing lowest values in all LSMs which may be attributed to comparatively smaller sizes of districts in UTs. Central zone of India is showing highest values of Largest Patch Index (LPI) indicating larger built-up patches in zone, as larger population resides in the central states of India. East zone is having most complex shape of urbanisation with highest Landscape Shape Index (LSI) value. West Zone is predominantly showing greater centrality values through Mean Euclidean Nearest Neighbor Distance (ENN_MN), as larger part of it comprises of dessert. Temporally, built-up patches are larger and more complex in shape but less centralized in year 2005 with Aggregation Index (AI) remaining almost same over the years. All the results are indicating a dispersed urban growth in zones of India with similar surroundings of past years.

1. INTRODUCTION

Recent decades have seen a large uprising in population of Asian cities. The increasing population gave unprecedented rise to urbanisation in these cities. Urbanisation may be coined as an event, which causes diverse change in land use of city landscape (Liu et al. 2016). This urban development can have socio-economic as well as environmental impact on cities and its dwellers (United Nations, 2018). Rapid urban development causes fast changes in land use/ land cover (LULC) and it can be in form of decreasing Urban Green Space (UGS) (Wu et al. 2016) or loss of agricultural land (Hou et al. 2019) Asian cities are being largely impacted by urbanisation in terms of environmental degradation (Alphan, 2003). It gives the need of study of urban development and LULC changes in Asian cities a vital importance. Metropolitan cities all over the world are continuously being modelled and monitored with the use of modern tools and techniques (Sapena and Ruiz, 2015). Use of Medium resolution satellite remote sensing can prove needful in studying urbanisation in development countries where spatial data is scarce (Demissie et al. 2017; Hou et al. 2016). Attempting study of countrywide urbanisation can prove challenging as presence of satellite data for whole country can be really impossible. This can be overcome by use of publically available already classified LULC data such as Decadal Land use Land cover data of India by Oak Ridge National Laboratory Distributed Active Archive Centre (ORNL DAAC) (Roy et al., 2016), Copernicus Global Land Services (CGLS- 100) LULC (Buchhorn et al. 2020), both data at 100m resolution, Sentinel2 10m Global LULC and several others.

Urban sustainability can be effectively planned in context of urbanisation by study of landscape patterns (Yang et al. 2019). Landscape Metrics can also help quantify landscape dynamics (Crews-Meyer, 2002) and its spatial distribution of change (Yang et al. 2016). Much more variation in urban fringes of Asian cities has been a general trend but Indian Cities are more irregular and convoluted in lack of state policies regarding urban sprawl (Huang et al. 2007). A Geo-spatial index can prove to be the best indicator to get the typical and intrinsic features of urban sprawl of the particular city (Jiang et al. 2007).

Qualitative and Quantitative are two aspects of urban sprawl of any city. Analysis of spatial metrics for urban sprawl is being qualitative and study of expansion parameters being quantitative aspect of urbanisation in the city (Huang et al. 2007 and Maimaiti et al. 2017). Appropriate analysis of spatial metrics for urban sprawl in any city may prove to be beneficial for its future planning and settlement policies also in addition (Berling-Wolff and Wu, 2004). Urbanisation at micro scale of neighbourhood level with temporal resolution can be best indicated by spatial metrics (Ramachandra et al. 2019). The four characteristics namely complexity, compactness, centrality and porosity of any urban sprawl can be explained best by use of spatial metrics (Ji et al. 2006 and Jiang et al. 2007). These spatial metrics introduced by McGarigal and Marks, 1995 show us the directional and yearly pattern of urbanisation. Spatial metrics show insignificant effect of spatial-temporal resolution of classified images (Wu et al. 2011).

The study has been performed over built-up land use present in 694 districts present over 28 States and 8 Union Territories (UTs) in 7 zones of India using Decadal Land use Land cover data of India for years 1985, 1995 and 2005 provided by ORNL DAAC to study spatial pattern of urbanization. The study helps in understanding the characteristics of urbanisation in India and help planning for sustainability, which is also underlined Sustainable Development Goal (SDG 11- Sustainable Cities and Communities).

2. STUDY AREA

Study area, India is seventh largest country by area in world area approximately 3.3 million km^2 and second most populous country in the world with 1.2 billion population. India, a magnanimous country comprising of 36 administrative boundaries, shows a range of diversity in population and culture inhabited by its dwellers. These large population centres have different settlement characteristics varying over different administrative levels (States/Union Territories, Districts, Sub-Districts, Villages/Towns and Wards/Blocks etc.) of India. To understand the effect of urbanisation in the seventh largest country of world, India, all of its 694 districts spread over 28 states and 8 Union Territories (UTs) in 7 zones of India namely, North, Central, East, North Eastern, South, West and UTs were taken into account (Figure 1).

India is mainly a sub-tropical humid climate country with variations in wet and dry over 6 different climatic scenarios. All these different scenarios of land use cover such as dessert, river planes and mountainous regions present in it, help in accumulation of different population centers in different regions in India. The urbanization in India is happening at a vast rate with emergence of 23 metropolitan cities and almost 53 million plus urban agglomerations, which needs to be properly supervised for giving its citizens a sustainable life for inclusive and mutual growth.

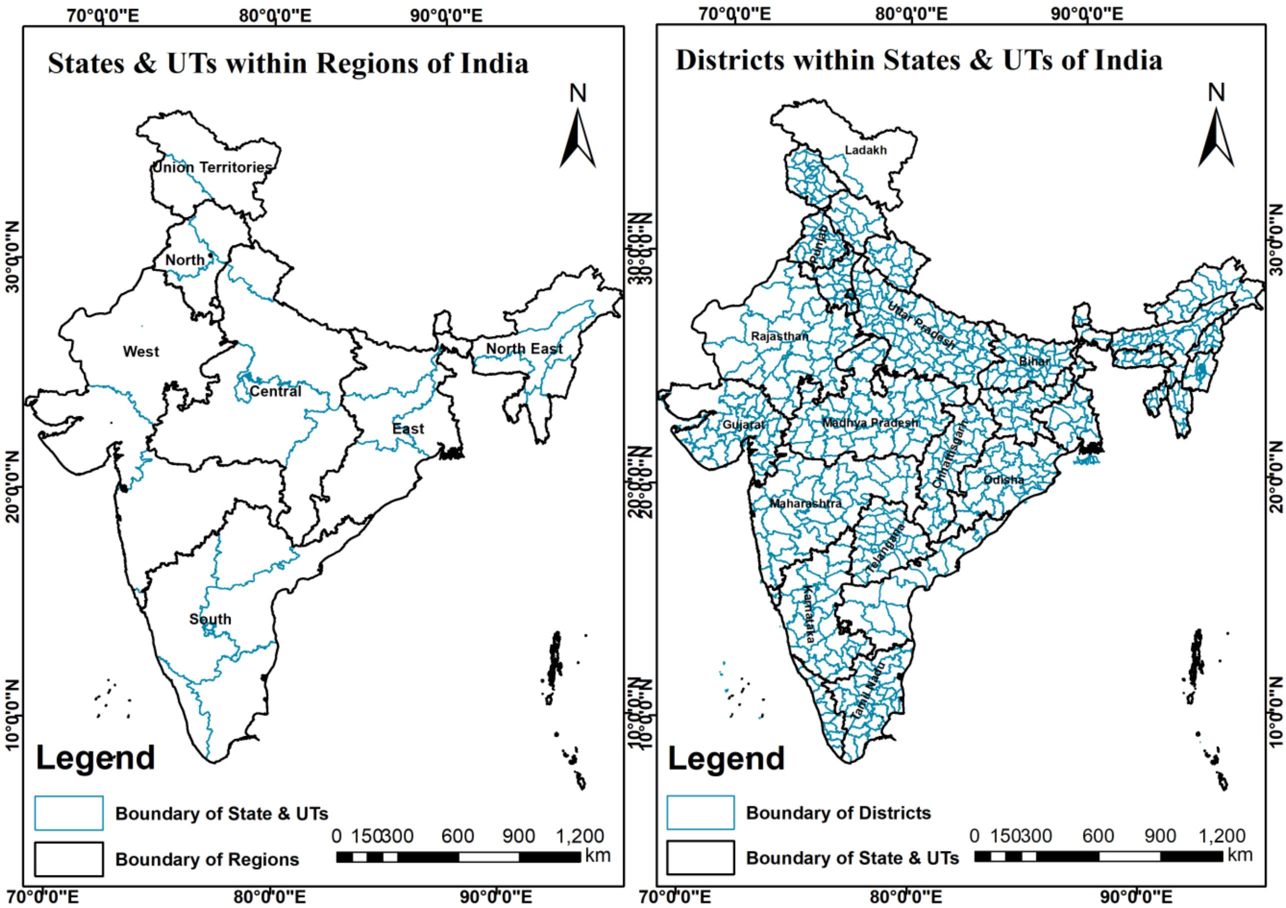

Figure 1. Study area used in study.

3. METHODOLOGY

The study has been performed to study the nature of urbanisation in different zones of India (Figure 2). It can help understand the way of urban growth in these zones and also the particular problems persisting with the urbanisation.

3.1 Data used

Decadal Land use data of India (Roy et al. 2016) for years 1985, 1995 and 2005 has been used as classified maps for study area. Decadal Land use data of India has been downloaded from Oak Ridge National Laboratory Distributed Active Archive Centre (ORNL DAAC) website. The data obtained as classified images, Decadal ORNL DAAC images are of 100 m resolution. An overall accuracy of classified image for year 2005 was found to be 94.46% and the Kappa accuracy of 0.9445. For year 1985 and 1995, accuracy of classified image was assumed to be same of year 2005 (Roy et al., 2016). All the images are clipped for study area for further analysis. ORNL DAAC decadal LULC images contain 19 land use classes in Indian Territory and study area boundary respectively and built-up land use class is used for mapping urbanisation in all three years data.

3.2 Landscape Metrics of Urbanisation

Landscape metrics help quantifying the properties of spatial distribution of landscape, patches and its classes. Complexity, Centrality, Compactness and Continuity are properties which have been quantified to describe the landscape of study area.

Landscape shape Index (LSI) has been used to measure complexity of landscape as complexity denotes the irregularity in size of patches. Centrality is quantified by Mean Euclidean

Nearest-Neighbor distance (ENN_MN). The Mean Euclidean Nearest-Neighbor distance (ENN_MN) measures the Euclidean distance of a patch from nearest patch in neighborhood. It may be the shortest edge to edge distance between patches of all class in landscape. Aggregation Index (AI) helps in quantifying the compactness of patches in landscape (Verma & Garg, 2021). Compactness measures the distribution of patches of alike properties which may depend upon patch shape and distance also. Continuity is measured as ratio of open space in comparison to total built-up area in landscape. LPI (Largest patch index) helps in determining the pattern of landscape in continuity. These indices can be calculated using FRAGSTATS (McGarigal & Marks, 1995) as listed below (Figure 4).

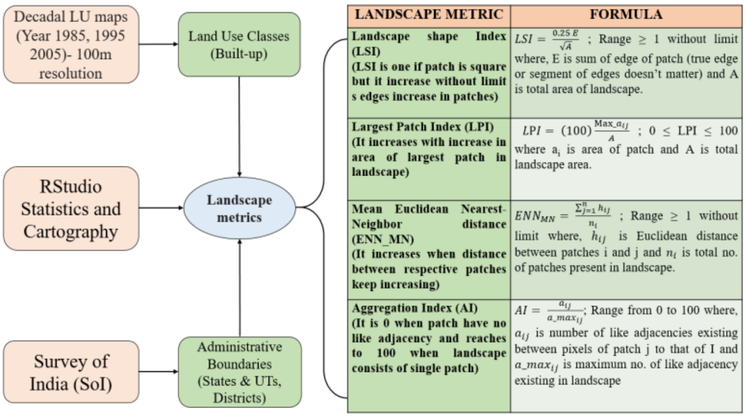

Figure 2. Flow chart showing methodology used in study.

GeoTIFF files of classified images of year 1985, 1995 and 2005 were used in batch process for finding built-up land use in each of the 694 district shapefile. Each built-up land use map thus produced for each 94 district was batched in RStudio® *landscapemetrics* library (Hesselbarth et al. 2019) for calculation of Class Landscape Metrics. Spatial pattern for built-up was analysed for urbanisation in study area over change durations for different districts, states/UTs and zones. Administrative boundaries were gathered from Survey of India (SoI) Nakshe website. Each district in spate state and UT was assigned proper Zone identification according to census data of India 2011. These administrative boundaries were used to create maps with averaged metrics values in RStudio®.

4. ANALYSIS OF RESULTS & DISCUSSION

India over the period of 20 years from 1985 to 2005 show a massive change in form of urbanisation in it due to various causes (Figure 3). This process of urbanisation has been gradual from 1985 to 1995 and from 1995 to 2005. Built-up in India increased to 40389.52 km^2 in year 2005 from 34291.06 km^2 in year 1985 and to 47134.89 km^2 in year 2005. In both change durations 1985-1995 and 1995-2005 growth in urbanisation in form of increase in built-up land use class has been around 17% of previous years. South zone in India has seen a massive growth in urbanisation in change duration from 1985 to 2005 cumulatively and also in each individual change duration of 1985- 19995 and 1995-2005 whereas North-east zone has gained the least urbanisation in each change duration. West zone saw an almost similar urbanisation to South zone in 1985-1995 but lacked significantly in 1995-2005. Central zone also saw a comparative urbanisation to South and West zone but due to less urbanisation in 1995-2005, its total urbanisation growth happened to be similar to North zone, which saw almost 4 times of urban growth in 1995-2005 than of 1985-1995.

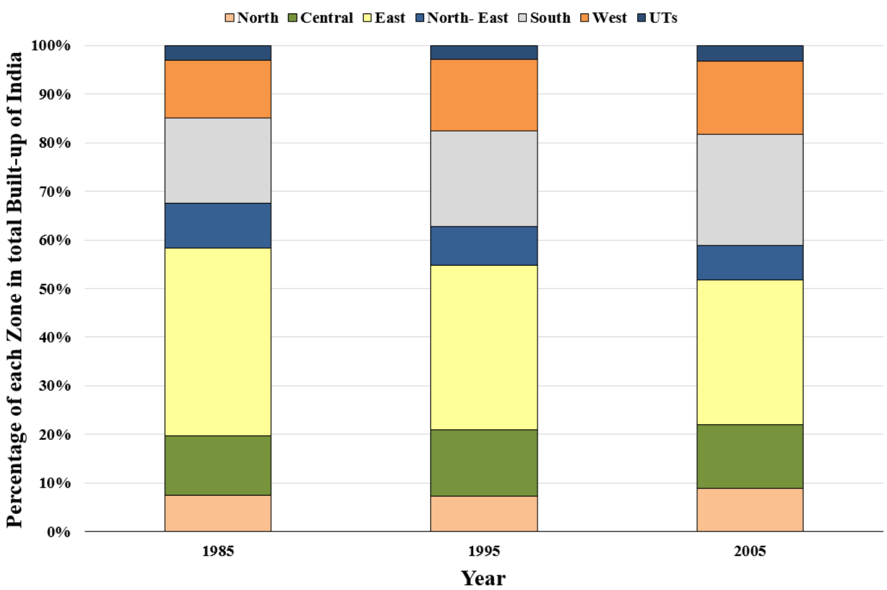

Figure 3. Year wise comparison of contribution of each Zone in Total Built-up of India.

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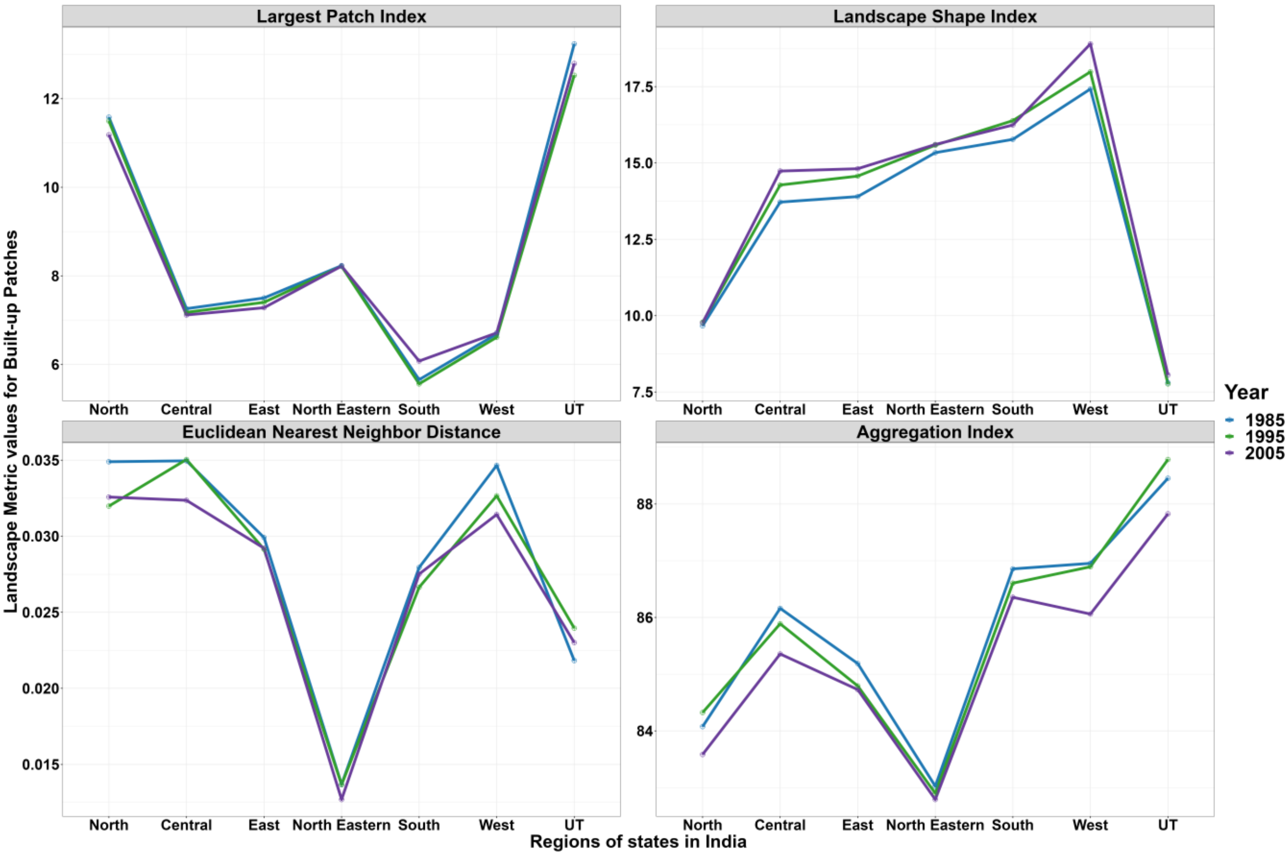

Figure 4. Year wise comparison of landscape metrics for different Zones of India.

Landscape metrics LPI, LSI, ENN_MN and AI over 7 zones of India show different properties of urbanisation over the change duration of 1985 to year 2005 (Figure 4 & 5). The properties for zones haven't changed over the years for respective zones but spatially each zone show a unique range of pattern of urbanisation in it, giving a unique geographical and demographical insights in each zone. ENN_MN and AI both show a lower range of values for Year 2005 in comparison to previous years of 1985 and 1995, whereas LSI values are greater for year 2005 in comparison to previous years. LPI values are almost similar for all 3 years of urbanisation with only a slightly higher LPI values for South zone of India in year 2005.

Lower values of ENN_MN for year 2005 show a lower centrality of built-up patches to city centres indicating more dispersion in urbanisation in year 2005. North, Central and West zones of India are showing much more dispersion in year 2005 in comparison to previous years. Urbanisation is much more dispersed in North eastern states of India, which can be attributed to mountainous geography of this particular zone. This can be related to extensification of urbanisation in these zones. ENN_MN values of zones also correlate with values of AI in corresponding zones. Lower values of AI for year 2005 show presence of dissimilar land use classes in neighbourhood of built-up land use class. This indicates intensification of urbanisation in the particular zones and in India in total. Results show that much denser urbanisation took place in year 2005 than previous years. West zone shows highest AI value. It can be attributed to presence of dessert in the most of the part of zone causing accumulation of population centres much nearer to each other. Lowest values of ENN_MN and AI fort North-Eastern zone also implies the correlation between urbanisation properties in the zones of India.

North zone shows presence of much larger patches of built-up in India and South zone shows presence of dissociated patches of built-up in its States but this has slightly reduced towards more compact structure of urbanisation in Year 2005 whereas for other zones the values of LPI remain almost same throughout the change duration of study. UTs Zone show highest LPI and AI values, as its major constituent NCT of Delhi is most densely populated city in India as per census 2011 of India.

LSI is also highest for west zone of India and lowest for North zone among all zones of states. Parts of North, Central and East Zones of India are planes of some of largest riverine belts (Ganga- Yamuna), causing accumulation of larger population centres across these rivers. These cities are much simpler in structure in comparison to North- Eastern, South and West zone cities in India and it can be attributed to much complex geographical attributes of these zones as they comprise major parts of mountainous and desserts respectively.

All these 4 metrics LPI, LSI, ENN_MN & AI represent a unique characteristics of urbanisation in India. These metrics a dispersed urbanisation in India over change duration of 1985 to 2005. It also shows formation of more complex built-up patches temporally. North & Central Regions area most distinctive zones for accumulating most of population. Most consistent region is North Eastern part of India with little or no change temporally and spatially both.

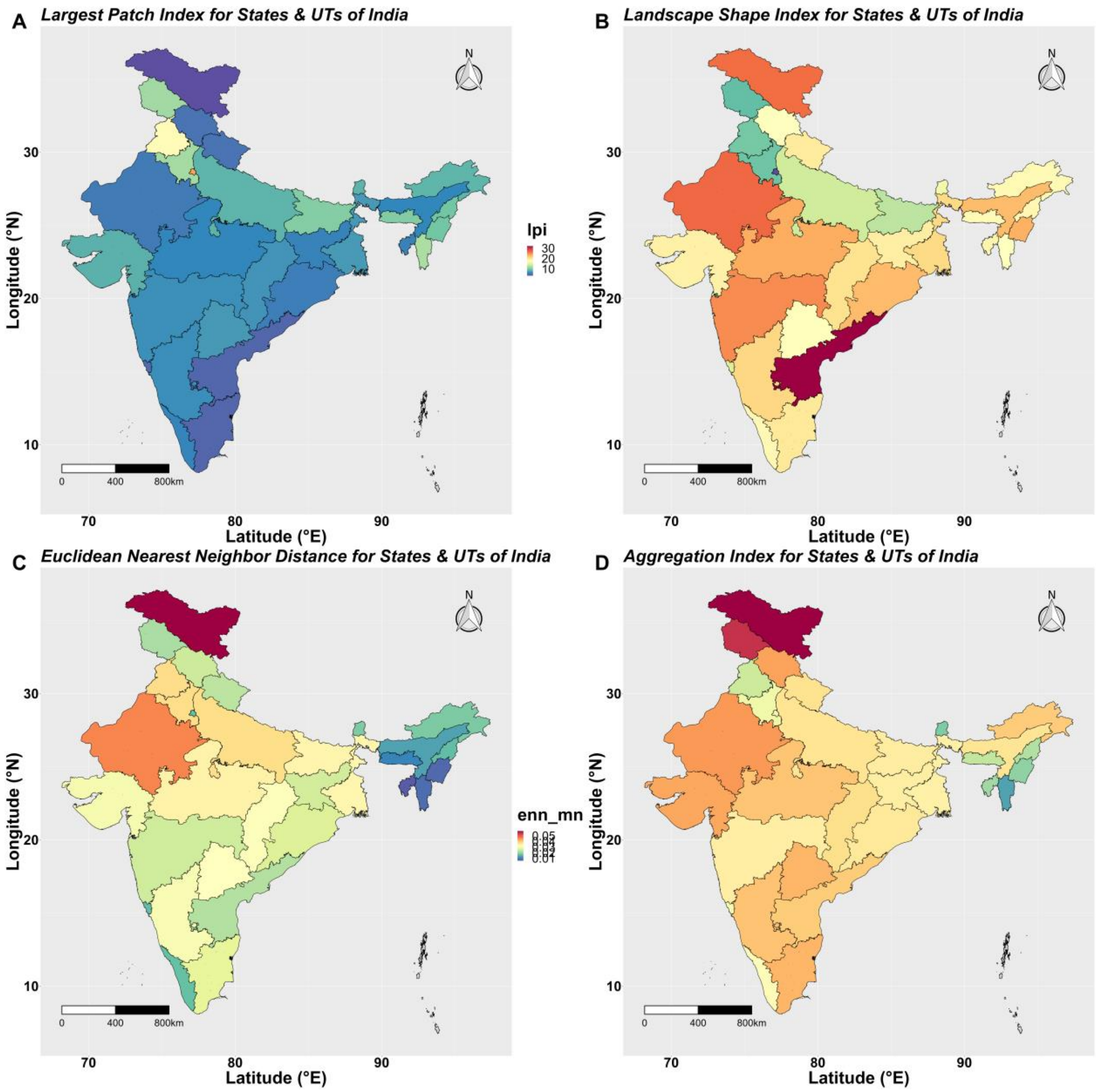

Figure 5. Spatial variation of landscape metrics for each State & UT of India.

5. CONCLUSIONS

Study shows effectiveness of Landscape Metrics in characterizing urbanisation over a change duration. Study also shows a unique perspective over urbanisation process happened in previous decades in India. Countries with large areas and diverse geographical, demographical and cultural composition like India, can have much more variations in values of landscape metrics. Zonal classification of landscape metric values show that there are several contributing factor which can affect the urbanisation in background and thus helped in idea of the impact of all the contributing factor over the urbanisation process in these zones. Zonal classification based on demography, geography and cultures maybe attributing factors in the urbanisation.

Urbanisation planning to accumulate population can be done keeping in mind the arrangement of the patches in future. Analysis of urbanisation through landscape metrics can also help it relate to other processes of urban dynamics happening in city boundaries such as Urban Heat Island (UHI) and Urban Green Spaces (UGS). This can help mitigate various environmental problem happening in city boundary and can help develop the city into a much more comfortable place to flora fauna present in it. These metrics can help improvise urban planning strategies in India for nearby future and help plan a much more inclusive and sustainable urban growth model which can help India achieve its SDGs.

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