Land Use Land Cover Dynamics in a Rapidly Urbanising Landscape

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Abstract

Landscape transformations in the rapidly urbanizing landscape are the most dynamic process affecting the local ecology and environment. The urbanized landscape do provide to its inhabitants the complex social and economic environment leading to further increase in population. Consequences of the unplanned urbanisation are enhanced pollution levels, lack of adequate infrastructure and basic amenities. This necessitates understanding of spatial patterns of the growth for an effective urban planning. This communication analyses the landscape dynamics of Belgaum City with 5 km buffer using Shannon's entropy and explores landscape patterns through spatial metrics applied to the temporal land use data. Remote sensing data acquired at regular intervals through satellite borne sensors enables the synoptic monitoring of urban growth patterns and dynamics. Spatial metrics enables the quantification of urban footprint. Assessment of spatial and temporal dynamics of the landscape and quantification of patterns through metrics helps in the understanding of urbanisation process. . This communication focuses on the monitoring of land use and land cover dynamics of Belgaum City with a buffer of 5 km. Land cover analysis is done through the slope based vegetation indices show a decline of vegetation from 98.8% (1989) to 91.74% (in 2012). Temporal land use analysis reveal that the increase of urban pockets (built up and other paved surfaces) from 0.31% (in 1989) to 6.74% (2012), the tree cover has decreased from 4.62% (in 1989) to 2.44% (in 2006). Direction wise gradient analysis through spatial metrics and the Shannon entropy highlight an increase of fragmented growth during post 2000 in all directions.

Keywords: *Belgaum, Land Use, Land Cover, Urbanisation, Urban Sprawl, Landscape Metrics, Remote Sensing, Geoinformatics.*

1. Introduction

Large scale land-use land-cover (LULC) dynamics leading to deforestation is one of the drivers of global climate changes and alteration of biogeochemical cycles. This has given momentum to investigate the causes and consequences of LULC by mapping and modelling landscape patterns and dynamics and evaluating these in the context of human-environment interactions in the rapidly urbanizing landscapes. Human induced environmental changes and consequences are not uniformly distributed over the earth. However their impacts threaten the sustenance of human-environmental relationships. Land cover refers to physical cover and biophysical state of the earth's surface and immediate subsurface and is confined to describe vegetation and manmade features [1,2,3,4,5]. Thus land cover reflects the visible evidence of land cover of vegetation and non-vegetation. Land use refers to use of the land surface through modifications by humans and natural phenomena [1,2,3,5,6]. Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it [5]. Alteration the structure of the landscape through large scale LULC has influenced the functioning of landscape, which include nutrient, regional water and bio-geo chemical cycles [3, 7].

Post-independence period, particularly during the globalization era in 1990's, the government facilitated the interactions of global industries with in-house industries. Large scale industrialization paved way for major land use land cover changes, caused by migration of people from different parts of the country, also from other parts of the globe and country for the employment opportunities. These led to intense urbanisation of major metropolitan cities with spurt in human population due to migration and also sprawl in peri-urban pockets [1,8,9,10,11,12]. Unplanned urbanisation are characterized by the loss of diversity, with changes in the coherence and identity of the existing landscapes. The drastic landscape changes are a threat or a negative evolution, as it affects the sustenance of natural resources. Urbanisation process leads to conversion of ecological land use (such as vegetation. Open area, cultivable lands, water) in to impervious layers on the earth surface. Increasing unplanned urbanisation is an important cause for depletion of resources species extension, hydro-geological alterations, loss of crop lands [3,13]. Unplanned urbanisation has various underlying effects such as dispersed growth or sprawl.

Urban Sprawl refers to an uncontrolled, scattered urban growth as a consequence of socio economic infrastructural development leading to increase in traffic, deficit of resources by depletion of the locally available resources while creating demand for more resources [3,10,14,15]. Often exceeding the carrying capacity of the land. The dispersed growth or sprawl occurs basically in the periphery and the outskirts and these regions are devoid of any basic amenities or infrastructure. Sprawl can be in the radial direction encircling the city center or in linear direction along the highways, ring roads, etc. The dispersed growth of urban pockets has been quantified through mapping of impervious surface in and around the city in the developed countries and in developing countries such as China [13,16] and India [1,14,17,18]. As per the population census, 25.73% [19] lives in the urban centers in India and it is projected that during the next decade about 33% would be living in the urban center [1,3] The extent or level of urbanisation and consequent sprawl has driven the changes in land use land cover patterns. LULC dynamics have altered the spatial landscape patterns [10] and these changes in the landscape (urban) pattern indicates the socio economic conditions and environmental impacts. The underlying phenomena of urban sprawl has been explained through the landscape index - Shannon entropy, a measure of urban growth [10,20]. It measures the degree of spatial concentration or dispersion of a geographical variable among n zones [3,14,16]. Larger value of entropy highlights the occurrence of dispersed growth or urban sprawl [1,3].

Multi resolution spatio-temporal data acquired since 1970's through space borne sensors helps in quantifying LULC dynamics through the temporal analysis of landscape patterns [1,18,21]. Evaluation of landscape dynamics qualitatively and quantitatively aids in understanding the changes and also help to determine the effect of anthropogenic activities [1,4,10,22]. The application of landscape metrics to spatio-temporal data helps in analysing the urban foot print. Landscape metrics aid in quantifying the spatial pattern of a particular landscape changes within the geographical area [1,3,14,22,23]. These metrics enables to quantify the landscape with respect to spatial dimension, alignment, pattern at a specific scale and resolution [6]. Metrics applied with the land use data help in evaluating the landscape heterogeneity and also in relating to urban growth pattern [1,23]. The spatial metrics have been used to quantify the urban form, describe the trend and growth of the land use patterns and to model the patterns of future urbanisation [3,22,23]. Gradient based spatial metrics analysis helps to visualize and understand the development in different directions and gradients with respect to the location as peaks and valleys along the direction [6,10,24].

The current focus of LULC analysis is to analyse the landscape dynamics of Belgaum City with 5 km buffer using Shannon’s entropy and exploring insights to landscape patterns through spatial metrics applied to the temporal land use data.

The rest of this paper is organized as follows. Section 2 ....

2. Study Area

Belgaum City (see Fig.1) geographically located in the North Western Part of Karnataka State. The city with the spatial extent of about 58 sq.km. Extends from 74^{0}28’29.071" E to 74^{0}34’54.92” E and 15^{0}49’23.189” N to 15^{0}54’0.142” N with an average elevation of 751m above mean sea level. Five km buffer from the administrative boundary was considered as shown in Fig. 2 (with a gross area of 38 sq.km) to account for developments in the peri urban regions. The city has about 58 Wards, with population of 488292 (2011 Census Provisional)[19] and Population Density of 84.21 persons per hectare. Population has a decadal increase of 7.31%. BUDA (Belgaum Urban Development Authority) formed during 1988 is responsible for urban development including layout and town planning [25]. BUDA consists of local planning area of 182 sq.km, which includes the Belgaum city corporation, 26 surrounding villages and regions under conurbation limit. BUDA since 1988 has developed about 19 townships [26]. Temperature varies from 18 ^{0}C (winter) to 40 ^{0}C (summer) and city receives annual average rainfall of 1418 mm. Soils in the region consist of shallow to very deep black soils, red loamy soils, lateritic soils etc. The city is surrounded by Kanburgi, Yamanspura, Kangrali.B, Kangrali.K villages in the north, Hindalga, Binakanahalli, Savagaon, Madoli in the West, Angol, Wadgaon, Madhavapura, Haldge in the South and Sindoli, Mutuge, Nilage Villages in the East [27].

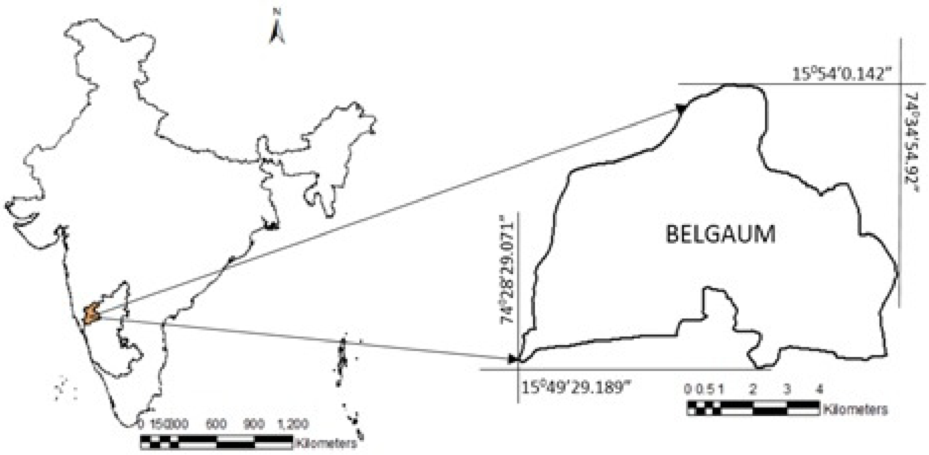


Figure 1. Belgaum City Administrative Boundary

3. Materials

Temporal remote sensing data of Landsat TM and Indian remote Sensing (IRS) were used to analyse LULC changes, urbanisation process, etc. The remote sensing data were supplemented with the Survey of India toposheets of 1:50000 and 1:250000 scale to generate base layers of the administrative boundary, drainage network, etc. Training data using pre calibrated Global Positioning System (GPS) and virtual online spatial maps such as Google Earth and Bhuvan were used for geometric correction, classification, verification and validation of the classified results (see Table I).

Table I: Materials used in Analysis *(“Self Compiled”)*

Data	Year	Purpose
Landsat Series TM (30m) and ETM	04/03/1989, 21/03/2000	Land cover and Land use analysis
IRS LISS III (24m)	01/04/2006	Land cover and Land use analysis
IRS R2 (5M)	16/03/2012	Land cover and Land use analysis
Survey of India (SOI) toposheets of 1:50000 and 1:250000 scales		To Generate boundary and Base layer maps.
Field visit data –using GPS		For geo-correction, classification of remote sensing data and validation.

4. Method

A three-step approach as illustrated in Fig. 2 was adopted to understand the dynamics of the urbanizing city, which includes (i) a normative approach to understand the LULC dynamics (ii) a gradient approach of 1km radius to understand the pattern of growth during the past four decades.(iii) Quantifying the growth over time using spatial metrics.

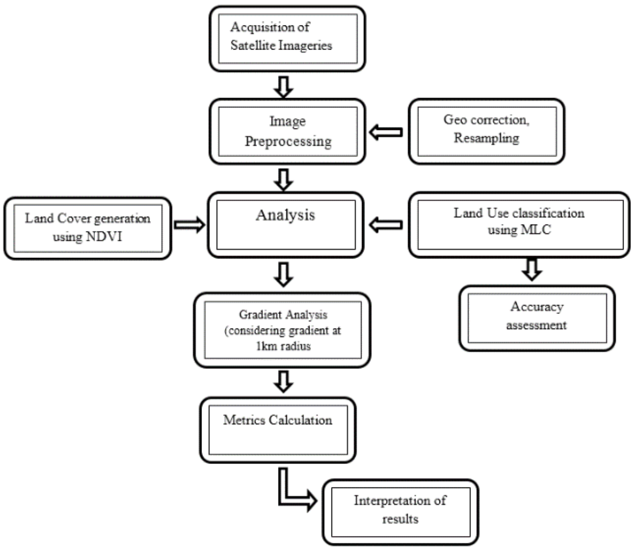


Figure 2. Procedure followed to understand the spatial pattern of landscape change *("Self Compiled")*

Various stages in the data analysis are:

4.1. Preprocessing: The remote sensing data of Landsat were downloaded from GLCF (Global Land Cover Facility, http://glcf.umiacs.umd.edu/data) and IRS LISS III data were obtained from NRSC, Hyderabad (http://nrsc.gov.in). The data obtained were geo-referenced, rectified and cropped pertaining to the study area. Landsat data has a spatial resolution of 28.5 m x 28.5 m (nominal resolution) were resampled to uniform 30 m for inter temporal data comparisons.

4.2. Vegetation Cover Analysis: Vegetation cover analysis was performed using the index Normalized Difference Vegetation index (NDVI) was computed for all the years to understand the change in the temporal dynamics of the vegetation cover in the study region. NDVI value ranges from values -1 to +1, where -0.1 and below indicate soil or barren areas of rock, sand, or urban built-up. NDVI of zero indicates the water cover. Moderate values represent low density vegetation (0.1 to 0.3) and higher values indicate thick canopy vegetation (0.6 to 0.8).

4.3. Land Use Analysis: Further to account for changes in the landscape, land use analysis were performed and categories considered are listed in Table II.

Table II: Land use categories *("Self Compiled")*

Land use Class	Land uses included in the class
Urban	This category includes residential area, industrial area, and all paved surfaces and mixed pixels having built up area.
Water bodies	Tanks, Lakes, Reservoirs.
Vegetation	Forest, Cropland, nurseries.
Others	Rocks, quarry pits, open ground at building sites, kaccha roads.

Data were classified with the training data (field data) using Gaussian maximum likelihood supervised classifier. Analysis involved i) generation of False Colour Composite (FCC) of remote sensing data (bands – green, red and NIR). This helped in locating heterogeneous patches in the landscape ii) selection of training polygons (these correspond to heterogeneous patches in FCC) covering 15% of the study area and uniformly distributed over the entire study area, iii) loading these training polygons co-ordinates into pre-calibrated GPS and collection of the corresponding attribute data (land use types) for these polygons from the field. GPS helped in locating respective training polygons in the field, iv) supplementing this information with Google Earth (http://www.googleearth.com) and Bhuvan (http://bhuvan.nrsc.gov.in) v) 60% of the training data has been used for classification, while the balance is used for validation or accuracy assessment.

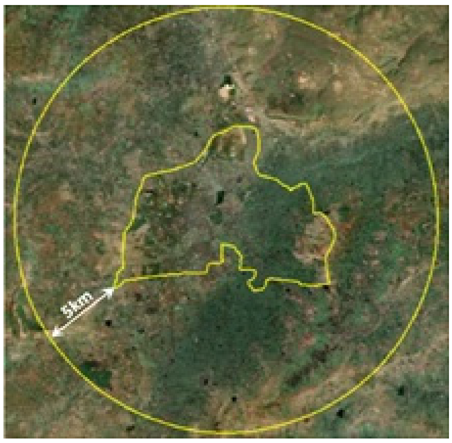


Figure 3: Study Area with 5 Km Buffer Overlaid on Spatial Data *(Source: Google Earth)*

Gaussian maximum likelihood classifier (GMLC) is used to classify the data using the training data.

GMLC uses various classification decisions using probability and cost functions [28] and is proved superior compared to other techniques. Mean and covariance matrix are computed using estimate of maximum likelihood estimator. Estimations of temporal land uses were done through open source GIS (Geographic Information System) - GRASS (Geographic Resource Analysis Support System, http://ces.iisc.ernet.in/grass). 70% of field data were used for classifying the data and the balance 30% were used in validation and accuracy assessment. Thematic layers were generated of classifies data corresponding to four land use categories.

Table III. Landscape Metrics Analysed *("Self Compiled")*

	Indicators	Formula
1	Number of Urban Patches (NPU)	$NPU = n$ NP equals the number of patches in the landscape.
2	Patch density(PD)	f(sample area) = (Patch Number/Area) * 1000000
3	Normalized Landscape Shape Index (NLSI)	$NLSI = \frac{\sum_{i=1}^{i=N} \frac{p_i}{s_i}}{N}$ Where s_i and p_i are the area and perimeter of patch i, and N is the total number of patches.
4	Landscape Shape Index (LSI)	$LSI = e_i / \min e_i$ e_i =total length of edge (or perimeter) of class i in terms of number of cell surfaces; includes all landscape boundary and background edge segments involving class i. $\min e_i$=minimum total length of edge (or perimeter) of class i in terms of number of cell surfaces.
5	Total Edge (TE)	$TE = \sum_{k=1}^{m} e_{ik}$, where, e_{ik} = total length (m) of edge in landscape involving patch type (class) i; includes landscape boundary and background segments involving patch type i.
6	Percentage of Land (Pland)	$PLAND = P_i = \frac{\sum_{j=1}^{n} a_{ij}}{A}$, P_i = proportion of the landscape occupied by patch type (class) i. a_{ij} = area (m^2) of patch ij, A =total landscape area (m^2).
7	Aggregation index(AI)	$AI = \left[\sum_{i=1}^{m}\left(\frac{g_{ii}}{\max \rightarrow g_{ii}}\right)P_i\right](100)$ g_{ii} =number of like adjacencies between pixels of patch type P_i= proportion of landscape comprised of patch type.
8	Cohesion	$Cohesion = \left[1 - \frac{\sum_{j=1}^{n} p_{ij}}{\sum_{j=1}^{n} (p_{ij})\sqrt{a_{ij}}}\right]\left[1 - \frac{1}{\sqrt{A}}\right]^{-1} * 100$ p_{ij} = perimeter of patch ij in terms of number of cell surfaces. a_{ij} = area of patch ij in terms of number of cells. A = total number of cells in the landscape
9	Edge Density (ED)	$ED = 10000 * \frac{\sum_{k=1}^{m} e_{ik}}{A}$ e_{ik} = total length (m) of edge in landscape involving patch type (class) i; includes landscape boundary and background segments involving patch type i. A =total landscape area (m^2).
10	Contiguity Index	$CONTIG = \frac{\left[\frac{\sum_{r=1}^{z} c_{ijr}}{a_{ij}}\right] - 1}{v - 1}$ c_{ijr} =contiguity value for pixel r in patch ij. v = sum of the values in a 3-by-3 cell template (13 in this case). a_{ij} = area of patch ij in terms of number of cells
11	Area weighted mean Fractal index	$AWMPFD = \frac{\sum_{i=1}^{i=N} 2\ln 0.25 p_i / \ln S_i}{N} \times \frac{S_i}{\sum_{i=1}^{i=N} S_i}$

Evaluation of the performance of classifiers is done through accuracy assessment techniques of testing the statistical significance of a difference, comparison of kappa coefficients and proportion of correctly allocated classes (Jensen, 2005) through computation of confusion matrix. These are most commonly used to demonstrate the effectiveness of the classifiers [3,18,29,30]. Further each zone was divided into concentric circle of incrementing radius of 1 km (see Fig. 3) from the center of the city for visualising the changes at neighborhood levels. This also helped in identifying the causal factors and the degree of urbanization (in response to the economic, social and political forces) at local levels and visualizing the forms of urban sprawl. The temporal built up density in each circle is monitored through time series analysis.

4.4. Urban Sprawl Analysis: Direction-wise Shannon's entropy (H_n) is computed (see eqn. 1) to understand the extent of growth: compact or divergent ([30], [10]). This provides an insight into the development (clumped or disaggregated) with respect to the geographical parameters across 'n' concentric regions in the respective zones.

$$Hn = -\sum_{i=1}^{n} Pi \log(Pi) \quad \text{...... (1)}$$

where Pi is the proportion of the built-up in the i^{th} concentric circle and n is the number of circles/local regions in the particular direction. Shannon's Entropy values ranges from zero (maximally concentrated) to log n (dispersed growth).

4.5. Spatial Pattern Analysis: Spatial metrics provide quantitative description of the composition and configuration of urban landscape. These metrics were computed for each circle, zonewise using classified land use data at the landscape level with the help of FRAGSTATS [32]. Urban dynamics is characterised by prominent spatial metrics chosen based on Shape, edge, complexity, and density criteria. The metrics include the patch area, shape, epoch/contagion/ dispersion and are listed in Table III.

5. Results

5.1. Land Cover Analysis: To understand the spatial extent of area under vegetation and non-vegetation, various land cover indices were analyzed. Among these NDVI index provide better insights to understand the extent of vegetation cover. Temporal NDVI were calculated and the results are given in Fig. 4 and in Table IV. The results indicate that the vegetation in the study region decreased for 98.8% (in 1989) to 91.74% (in 2012). Further temporal land use analyses are done to understand the changes in land uses.

Table IV. Land Cover Analysis *("Self Compiled")*

Year	Vegetation	Non Vegetation
1989	98.8%	1.2%
2000	98.41%	1.59%
2006	96.35%	3.65%
2012	91.74 %	8.26 %

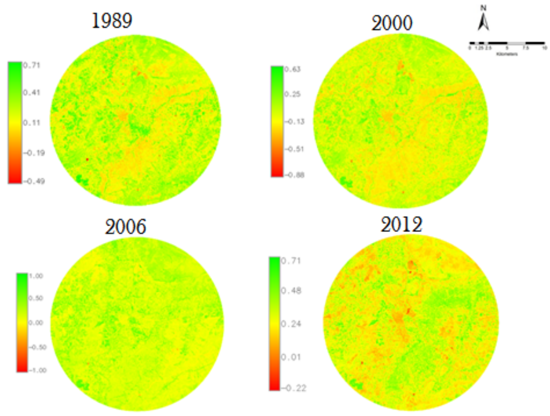


Figure 4: Land Cover Classification *("Self Compiled")*

5.2. Land Use Analysis: Temporal land use changes during 1989 to 2012 were analysed. Spatial data were analysed using maximum likelihood Classifier and the results are shown in Fig. 5 and Table V. The results of the analysis indicate that the urban impervious land use has increased from 0.31 % (in 1989) to 6.74% (in 2012); vegetation decreased from 4.62% (in 1989) to 2.44% (in 2012), while water category remained fairly constant.

Table V: Land Use Analysis *("Self Compiled")*

Year	1989		2000	
Land use	**%**	**Area(Ha)**	**%**	**Area(Ha)**
Water	0.14	53.24	0.33	125.49
Vegetation	4.62	1756.92	2.58	981.14
Built up	0.31	117.89	1.17	444.93
Others	94.9	36089.11	95.92	36477.00
Year	**2006**		**2012**	
Land use	**%**	**Area(Ha)**	**%**	**Area(Ha)**
Water	0.23	87.47	0.24	92.03
Vegetation	2.33	886.07	2.44	928.73
Built up	4.81	1829.17	6.74	2190.15
Others	92.93	35339.95	91.58	34904.41

Accuracy Assessment and Kappa Statistics: Kappa Statistics serves as an indicator of the extent pixels are correctly classified into the respective categories. The accuracy assessment was carried out for the classified data and the results are given in Table VI. The results indicated that the accuracy was above 90% and kappa values had strong agreement with the accuracy values with an average of 0.9.

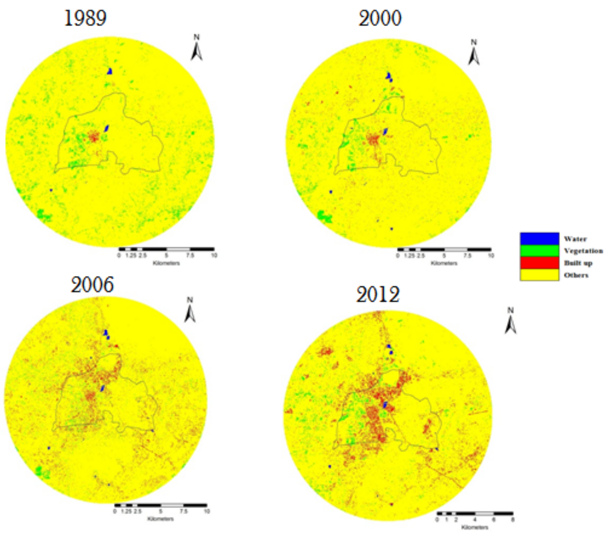


Figure 5: Land Use Classification *("Self Compiled")*

Table VI. Accuracy Assessment *("Self Compiled")*

Year	Overall Accuracy	Kappa Value
1989	94.85	0.87
2000	92.73	0.83
2006	93.64	0.92
2012	93.12	0.93

5.3. Urbanisation Analysis using Shannon's Entropy: Shannon entropy, as an indicator of urban sprawl was calculated and the results are shown in Fig. 6 and Table VII. The threshold limit of Shannon's Entropy is log11 or 1.041. The results indicated that though Belgaum and the buffer region is not experiencing urban sprawl. However increasing entropy values show the tendency of sprawl in the region.

Table VII: Built Up and Shannon's Entropy Analysis *("Self Compiled")*

Year	NE	NW	SE	SW
1989	0.0059	0.0191	0.0034	0.0088
2000	0.0283	0.0546	0.017	0.0334
2006	0.0791	0.140	0.108	0.113
2012	0.0864	0.1652	0.1154	0.137

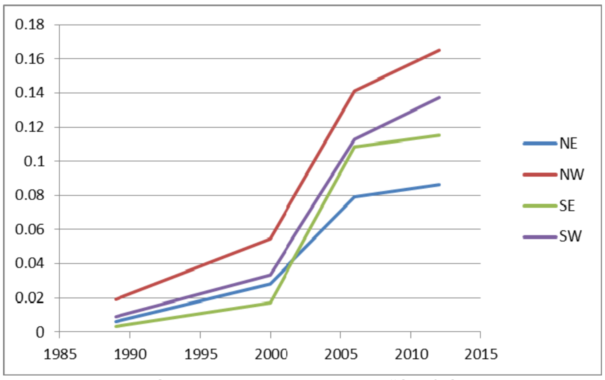
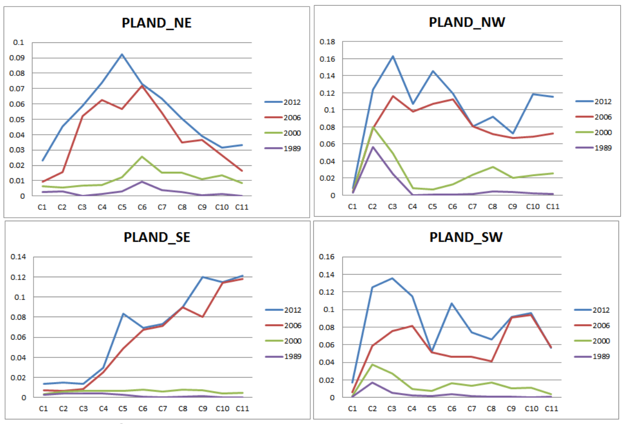


Figure 6: Shannon's Entropy *("Self Compiled")*

***5.4. Spatial Patterns Analysis*:** Spatial patterns of the landscape was analysed considering metrics based on the urban land use changes. Various landscape metrics were calculated as discussed.

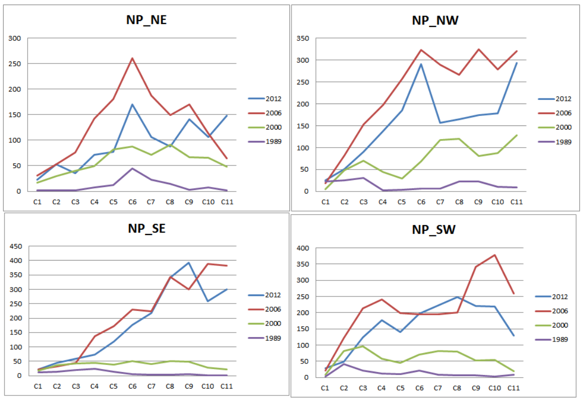
Proportion of Landscape (PLAND): PLAND indicates the percentage of urban land present in particular gradient and zone and ranges from 0 to 1, the value 1 indicates the landscape comprises of a single urban class and zero represents absence of urban class. The results of the analysis are represented in Fig. 7a, which indicates spurt in urban land use during post 2000 and especially in 2012 in almost all directions and all gradients.



X axis : Circles at every 1 km **Y axis**: Indices value

Figure. 7a: Proportion of Landscape Metric *("Self Compiled")*

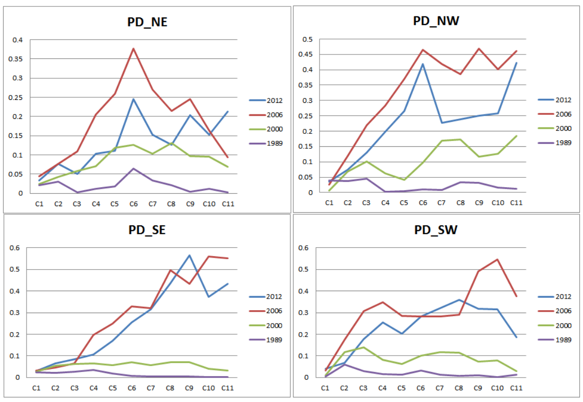
Number of Patches (NP): NP is a type of metric describes the growth of particular patches whether in an aggregated or fragmented growth in the region and also explains the underlying urbanization process. Number of Patch is always equal to or greater 1, NP = 1 indicates that there is only 1 patch of a particular class, showing aggregated growth, larger values of NP indicate fragmented growth. The results indicate that there growth of urban patches in all directions post 2000, which have increased specially in the buffer zones, due to fragments as in Fig. 7b.



X axis : Circles at every 1 km **Y axis**: Indices value

Figure 7b. Number of patches metric analysed *("Self Compiled").*

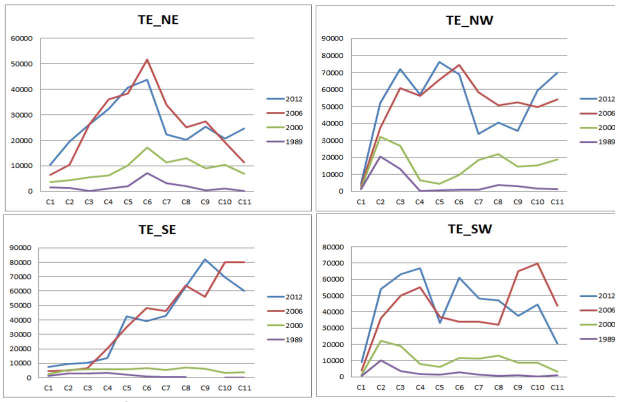
Patch Density (PD): PD is a landscape metric which is quite similar to number of patches but gives density about the landscape in analysis, The values vary from 0 to 1, 0 indicating a single homogenous patch, whereas values towards 1 indicates fragmented growth as the patches increase the patch density increases. The results as in Fig. 7c indicates an increase of NP in the outskirts, but at the core of the city, clumped patches are prominent in all directions specially post 2000. In 2012, this substantially decreased in almost all directions mainly due to patches getting clumped and forming a single patch.



X axis : Circles at every 1 km **Y axis**: Indices value

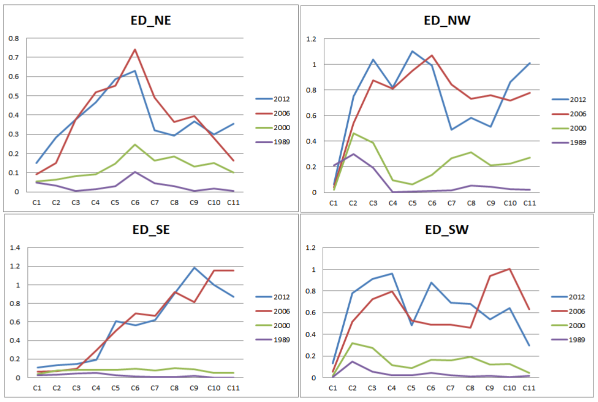
Figure 7c: Patch Density Metric *("Self Compiled")*

Total Edge (TE) and Edge density (ED): TE is the absolute measure of total length (perimeter) of each class of a particular patch in landscape in meters. TE considers true edges into consideration. Value of TE is greater than or equal to zero. Larger the edge values indicate larger continuous patches. ED is the ratio of total edge distance to the total Area. If ED is zero, it represents there is no class of the landscape. Fig. 7d explains the results of the analysis, which indicate that during 1980's the edges were smaller, which explains that the urban patch was rare in landscape and was concentrated, but post 2000 and in 2012 there are larger edges, which indicate that the urban area is continuous. This phenomenon is true in the city boundary, but the buffer region patches are yet fragmented and non-continuous. Fig. 7e explains the edge density which has the agreement with the metrics explained earlier, indicative of the fragmented patches becoming a single patch in 2012.



X axis : Circles at every 1 km **Y axis**: Indices value

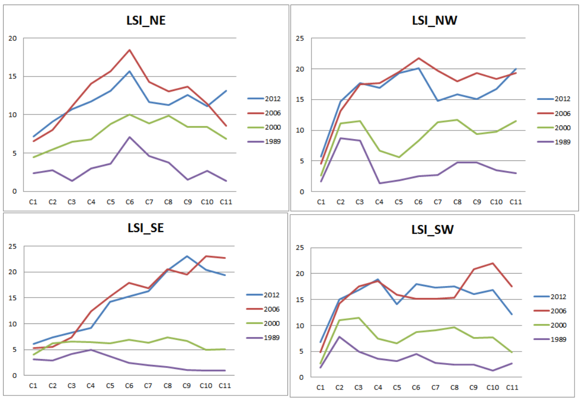
Figure 7d: Total Edge Metric *("Self Compiled")*



X axis : Circles at every 1 km **Y axis**: Indices value

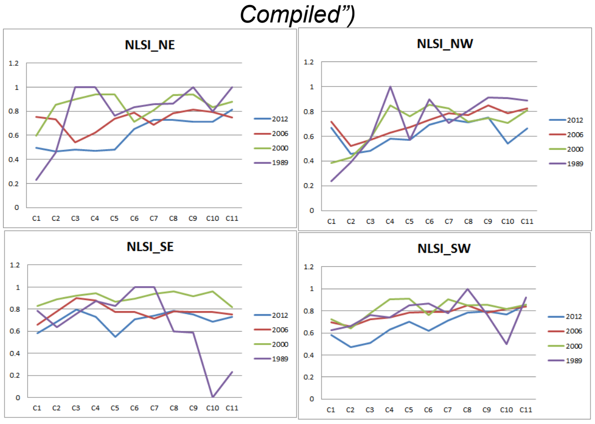
Figure 7e: Edge Density Metric *("Self Compiled")*

Landscape Shape Index (LSI) and *Normalized Landscape Shape Index(NLSI)*: LSI provides a measure of class aggregation or clumpiness depending on the shape of the class in analysis, when the value of LSI is 1, this indicates clumped growth, the increasing values of LSI indicates aggregation. NLSI is the normalized value of LSI, when zero or closer to zero indicates a clumped growth whereas NLSI towards 1 indicates aggregated growth of the landscape. Fig. 7f and 7g represents the results of LSI and NLSI. The results of both metrics puts out a fact that in 2012 landscape class shapes are becoming more complex indicative of fragmented growth, with comparison of simple shape in 1980's a clumped growth.



X axis : Circles at every 1 km **Y axis**: Indices value

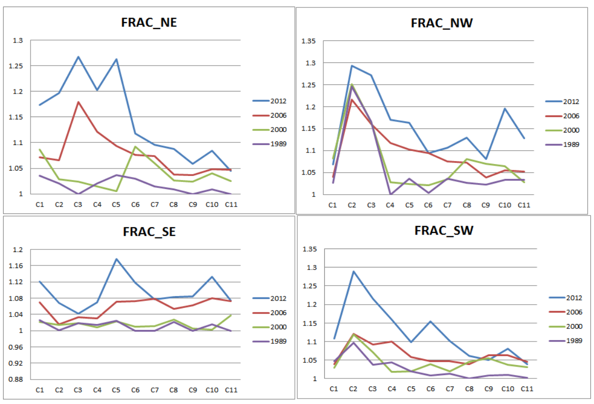
Figure 7f: Landscape Shape Index metric*(“Self Compiled”)*



X axis : Circles at every 1 km **Y axis**: Indices value

Figure 7g: Normalised Landscape Shape Index metric*(“Self Compiled”)*

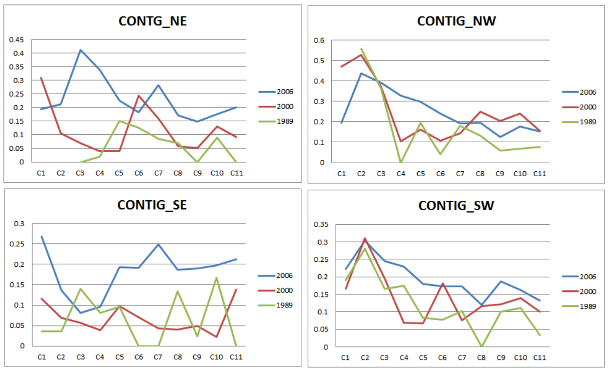
Fractal Dimension Index represents the complexity of the shape of the landscape. The values vary from 1 to 2; index values closer to 1 indicates simpler shapes of the land scape values closer to 2 indicate varying shape of the landscape. Fig. 7h explains that the complexity of shape increases in 2012 when compared to 1989 accompanied with simple shapes and perimeters.



X axis : Circles at every 1 km **Y axis**: Indices value

Figure 7h: Fractal Dimension Metrics in four directions*(“Self Compiled”)*

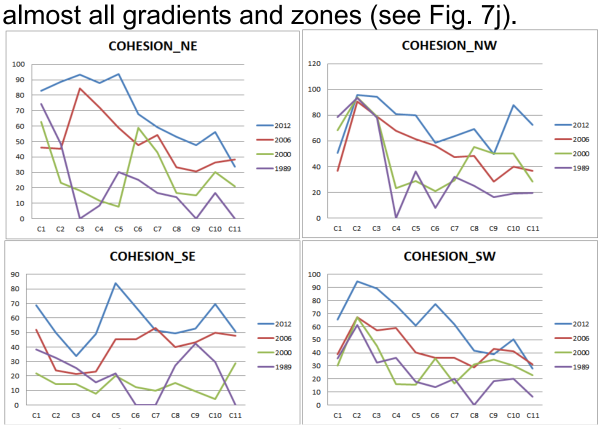
Contiguity indicates the continuity of the landscape, Contiguity index varies from 0 to 1, values closer to zero indicates single pixel, values closer to one indicates patch with large number of pixels of the particular class. Fig. 7i explains the output of the contiguity metric, explaining the dominance of the urban pixels in all directions post 2000, which was less in 1980’s.



X axis : Circles at every 1 km **Y axis**: Indices value

Figure 7i: Contiguity metric*(“Self Compiled”)*

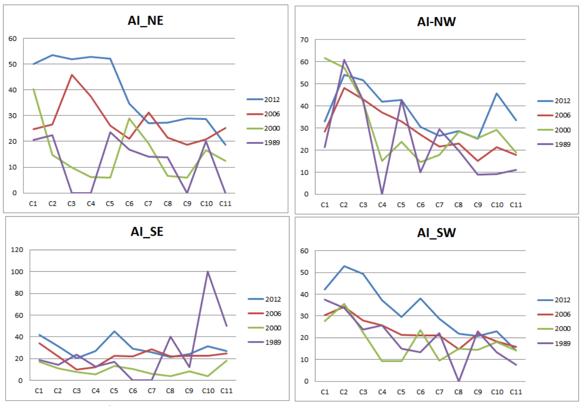
Cohesion measures the physical connectivity between adjacent patches; the cohesion value 0 indicates disaggregation and no inter connectivity between patches and higher value indicates clumped and connectivity between patches. Higher values during post 2000 illustrate of fragmented landscape forming clumped patches in almost all gradients and zones (see Fig. 7j).



X axis : Circles at every 1 km **Y axis**: Indices value

Figure 7j: Cohesion Metric *(“Self Compiled”)*

Aggregation index is a measure of disaggregation or aggregation of a landscape, the metric varies from zero to 100 percent, values closer to zero indicate disaggregation and values closer to 100 indicate aggregated growth of the landscape. Fig. 7k corroborates with the earlier metrics that post 1980’s the landscape had been fragmented which has started aggregating during post 2000.



X axis : Circles at every 1 km **Y axis**: Indices value

Figure 7k: Aggregation Index*("Self Compiled")*

6. Conclusion

Karnataka State Industrial & Infrastructure Development Corporation Limited has been greatly instrumental in the industrialisation of the State, especially in the large and medium sector and important arm of the state in bringing industrial boom in various sectors. The intense urbanisation process in Tier I cities with the associated environmental problems and poor infrastructure, basic amenities has necessitated planning of Tier II cities to minimize the consequences of urbanisation.

State government has plans to divert the new industrial establishments and activities to tier II cities. Also globalization process and subsequent opening of Indian markets has led to rapid urbanisation leading to unorganized and fragmented urban sprawl affecting the basic amenities. Belgaum city, with 5 km buffer has been analysed to understand LULC dynamics. LU was analysed through supervised Gaussian MLC algorithm. The Land cover results show decrease in vegetation cover in the region from 98.8% (1989) to 96.35% (2006). The temporal analysis of the LU shows an increase of built up area from 0.31% (1989) to 6.74% (2012), decline of tree cover from 4.62 % (1989) to 2.33% (2006).

LULC change analysis indicates an increase of urban area by 14 times during 1989 and 2012 while the vegetation has reduced by 2.45%. Shannon Entropy indicates the tendency of urban sprawl during post 2000 in all direction and predominantly in North West direction. Spatial metrics reveal concentrated urbanisation at the core of the city and is increasingly fragmented growth towards the outskirts of the city.

This type of analysis helps the town planning department and other departments, to understand and visualize the changes, extent and pattern spatially and temporally. This helps to plan the basic amenities and evolve appropriate land use polices.

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