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Status of Wetlands in Urbanising Tier II cities of Karnataka: Analysis using Spatio Temporal data

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Urbanisation is the irreversible and most dramatic transformation of land affecting ecology and natural resources. Urbanisation being a global and highly sensitive issue is in a rapid pace in developing countries such as India, especially down south where urban areas have experienced an humogonous growth potential with several supporting factors (ex: economic, climate, availability of natural resources etc.,). Karnataka has been a prime destination which has attracted the sectorial developments at various parts of the state. These sectorial developments have led to an uncontrolled growth in past decade, which has to be visualised and monitored by the decision makers and city planners. In this context evolution of Multi -temporal remote sensing has gained importance in providing required data to analyse and visualise the changes to plan and effectively use the available resources for the effective city management. This communication uses satellite data sources in order to understand the urban growth pattern and its footprints temporally in eight growing tier II cities of Karnataka. A multi-scale analysis aims to identify spatiotemporal urban types, combining gradient and directional analysis along with landscape metrics to understand the absolute parameters for the growth and to quantitatively estimate the growth of these cities. The results paint a characteristic picture of spatial pattern, and thus illustrate spatial growth and future modeling opportunities of sustainable wetlands management with urban development in Karnataka. The outcomes of this communication would illustrate the growth pattern and quantified urban growth using spatial metrics considering the 1km gradient and zonal approach. The results indicate that these has been a haphazard development in increasing gradients from the city center leading to fragmented outgrowth and aggregated growth at the center of each city. This analysis would help urban planners to understand the growth and plan for sustainable cities.

Key words: Wetlands, Urbanisation, urban sprawl, Karnataka, Tier II cities, Landscape metrics

Introduction

Landscape changes are an important aspect as they play an important role in the global environment (Wood and Handley, 2001; Firmino, 1999) earth dynamics (Vitousek, 1994) and the spatial patterns of their transformation through time are undoubtedly related to changes in land uses (Potter and Lobley, 1996). Landscape changes are diverse but very often influenced by regional policies (Calvo-Iglesias et al., 2008). The main driving factors for global environmental changes are been identified as urbanisation (Phipps et al., 1986) in the context of local policies (Lipsky, 1992; Meeus, 1993; Kubes, 1994). Urbanization being a global and highly irreversible process involving changes in vast expanse of land cover with the progressive concentration of human population. In order to address these urbanization challenges without compromising the environment values and their local sustainance, land use planning and necessary supporting data are crucial, especially to developing countries under severe environmental and demographic strains (Food and Agriculture Organization, 1995).

In India, there are 48 urban agglomerations which had urbanised to the maximum extent and are suffering under the deficit of basic amenities due to sprawling process. This has led to shifting of focus from the major urban agglomerations to tier II mega-polis, which are expected to handle the urban population. The basic infrastructure like roads, air and rail connectivity should be ensured. Apart from these, the government should also ensure adequate social infrastructure such as educational institutions, hospitals along with other facilities and the tier 2 towns must be planned to handle the growth of population over few decades, which otherwise leads to a phenomena Urban Sprawl.

Urban Sprawl is characterised by a sharp imbalance between urban spatial expansion and the underlying population growth (Bruekner, 2001). Sprawl of human settlements, both around existing cities and within rural areas, is a major driving force of land use and land cover change worldwide (Batisani & Yarnal, 2009; Gonzalez-Abraham et al., 2007). Sprawl is a process entails the growth of the urban area from the urban center towards the periphery of the city municipal jurisdiction. These small pockets in the outskirts will be lacking in basic amenities like supply of treated water, electricity, sanitation facilities. Understanding this kind of growth over past few decades is a very crucial factor that helps the administration to handle the population growth and helps to provide basic amenities and more importantly the sustainable management of local natural resources through regional planning.

The basic information about the current and historical land cover/land use plays a major role for urban planning and management (Zhang et al., 2002). Mapping landscapes on temporal scale provide an opportunity to monitor the changes, which is important for natural resource management and sustainable planning activities. In this context, “Density Gradient” with the time series spatial data analysis is potentially useful in measuring urban development (Torrens and Alberti, 2000).

This study focuses on four tier II cities of Karnataka with objectives to: (1) capture the extent and location of land use change in four prime Tier II cities in past 4 decades. (2) Understand the urban growth pattern using density gradient and zonal approach, (3) understand the spatial pattern based on three landscape metrics. The results could be used in decision support systems enabling planner to get a first idea of the urban development trends.

Materials used: The time series spatial data acquired from Landsat MSS (57.5), Landsat Series Thematic mapper (28.5m) sensors for the temporal period were downloaded from public domain (http://glcf.umiacs.umd.edu/data). IRS LISS III (24 m) data coinciding with the field investigation dates were procured from National Remote Sensing Centre (www.nrsc.gov.in), Hyderabad. Survey of India (SOI) topo-sheets of 1:50000 and 1:250000 scales were used to generate base layers of city boundary, etc. Table1 lists the data used in the current analysis. Ground control points to register and geo-correct remote sensing data were collected using handheld pre-calibrated GPS (Global Positioning System), Survey of India Toposheet and Google earth (http://earth.google.com, http://bhuvan.nrsc.gov.in).

DATA	Purpose
Landsat Series MSS(57.5m)	Land cover and Land use analysis
Landsat Series TM (28.5m) and ETM	Land cover and Land use analysis
IRS LISS III (24m)	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 –captured using GPS	For geo-correcting and generating validation dataset

Table I: Data used for the analysis

Method: A two-step approach was adopted to chart the direction of the City's development, which includes (i) a normative approach to understand the land use and (ii) a gradient approach of 1km radius to understand the pattern of growth during the past 4 decades. Various stages in the data analysis are :

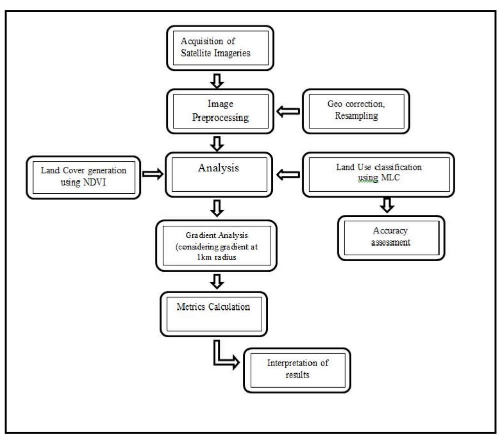


Figure 2: Procedure followed to understand the spatial pattern of landscape change

i. **Preprocessing**: The remote sensing data obtained were geo-referenced, rectified and cropped pertaining to the study area. The Landsat satellite MSS images have a spatial resolution of 57.5 m x 57.5 m (nominal resolution) and landsat TM and landsat ETM (1989 -2010) data of 28.5 m x 28.5 m (nominal resolution) were resampled to uniform 30 m for intra temporal comparisons. Data in case of non-availability of landsat data, IRS LISS3 of spatial resolution 24 m was procured from NRSC, Hyderabad (http://www.nrsc.gov.in) also was resampled to 30m.

ii. **Vegetation Cover Analysis**: Normalised Difference Vegetation index (NDVI) was computed to understand the temporal dynamics of the vegetation cover. NDVI value ranges from values -1 to +1, where -0.1 and below indicate soil or barren areas of rock, sand, or urban builtup. 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).

iii. **Land use analysis**: Land use categories listed in Table 2 were classified with the training data (field data) using Gaussian maximum likelihood supervised classier. The analysis included generation of False Color Composite (bands – green, red and NIR), which helped in identifying heterogeneous area. Polygons were digitized corresponding to the heterogeneous patches covering about 40% of the study region and uniformly distributed over the study region. These training polygons were loaded in pre-calibrated GPS (Global position System). Attribute data (land use types) were collected from the field with the help of GPS corresponding to these polygons. In addition to this, polygons were digitized from Google earth (www.googleearth.com) and Bhuvan (bhuvan.nrsc.gov.in), which were used for classifying latest IRS P6 data. These polygons were overlaid on FCC to supplement the training data for classifying landsat data.

Gaussian maximum likelihood classifier (GMLC) is applied to classify the data using the training data. GMLC uses various classification decisions using probability and cost functions (Duda et al., 2000) 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) which is the world biggest open source software project. 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.

Further each zone was divided into concentric circle of incrementing radii of 1 km 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.

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.

Table II: Land use categories

iv. **Urban sprawl analysis**: Direction-wise Shannon's entropy (H_n) is computed (equation 1) to understand the extent of growth: compact or divergent (Sudhira et al., 2004, Ramachandra et al., 2012). This provides an insight into the development (clumped or disaggregated) with respect to the geographical parameters across 'n' concentric regions in the respective zones.

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

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).

v. **Spatial pattern analysis**: Landscape metrics provide quantitative description of the composition and configuration of urban landscape. These metrics were computed for each circle, zone wise using classified land use data at the landscape level with the help of FRAGSTATS an open source software. Urban dynamics is characterised by 3 spatial metrics chosen based on complexity and density criteria. The metrics include the patch area, edge/border, shape, epoch/contagion/ dispersion and are listed in Table III.

	Indicators	Formula	Range
1	Number of Urban Patches (NPU)	$NPU = n$ NP equals the number of patches in the landscape.	NPU>0, without limit.
2	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.	0≤NLSI<1
3	Clumpiness	$CLUMPY = \begin{bmatrix} \frac{G_i - P_i}{P_i} for G_i < P_i \& P_i < 5, else \\ \frac{G_i - P_i}{1 - P_i} \end{bmatrix}$ P_i =proportion of the landscape occupied by patch type (class) i.	-1≤ CLUMPY ≤1.

Table III: Spatial Landscape Indices.

Results

Land use Land Cover dynamics:

a. **Vegetation cover analysis**: Vegetation cover of the study area assessed through NDVI . Figure 3a for Mysore shows that area under vegetation has declined to 9.24% (2009) from 51.09% (1973). Figure 3b for Shimoga shows that vegetation decreased from 89% in 1992 to 66 % in 2010.Figure 3c and 3d shows the results for Hubli and Dharwad, which shows decrease in vegetative cover by 20%. Temporal NDVI values are listed in Table IV.

b. **Land use analysis:** Land use in Mysore was assessed for the period 1973 to 2009 using Gaussian Maximum Likelihood Classifier (MLC) and results for temporal period are listed in Table V and the same is depicted in figure 4A. The overall accuracy of the classification ranges from 75% (1973), 79% (1989), 83% (1999) to 88% (2009) respectively. There has been a significant increase in built-up area during the last decade evident from 514% increase in urban area. Other category also had an enormous increase and covers 166 % of the land use. Consequent to these, vegetation cover has declined drastically during the past four decades. The water spread area has increased due to the commissioning of waste water treatment plants (ex. Vidyaranyapura, Rayankere, Kesare) during late 90's and early 2000. In Shimoga Urban category has increased from 13% (1992) to 33% (2010) (figure 4B), which is about 253 times during the last two decades.

Notable factor is that the Cultivation which is the major land use in the study region has increased to a small extent. Vegetation had decreased drastically over last two decades from 30% (1992) to about 6% (2010). Hubli showed a drastic increase in urban area which grew by 14 % in past 4 decades. Dharwad also showed a sharp increase in urban area by over 6%, All these results indicated that the water body and the watershed regions are decreasing every decade.

Mysore			Shimoga		
Year	Vegetation %	Non vegetation %	Year	Vegetation %	Non vegetation %
1973	51.09	48.81	1992	10.65	10.65
1989	57.58	42.42	1999	21.08	21.08
1999	44.65	55.35	2005	25.16	25.16
2009	09.24	90.76	2010	33.28	33.28
Hubli			Dharwad		
Year	Vegetation %	Non vegetation %	Year	Vegetation %	Non vegetation %
1989	97.0	3.0	1989	98.12	1.88
2000	94.35	5.65	2000	96.48	3.52
2005	89.73	10.27	2005	92.21	7.79
2010	78.31	21.69	2010	86.43	13.57

Table IV: Temporal Land cover details.

c. Urban sprawl analysis: Shannon entropy computed using temporal data are listed in Table VI. Mysore in recent times exhibit the dispersed growth as values are gradually picking up and the threshold value (log (8) = 0.9). However, the region experienced dispersed growth in 90's reaching higher values of 0.452 (NE), 0.441 (NW) in 2009 during post 2000's. The entropy computed for the city (without buffer regions) shows the sprawl phenomenon at outskirts. Shannon's entropy values of recent time confirms of fragmented dispersed urban growth in the city. This also illustrates and establishes the influence of drivers of urbanization in various directions. The Shimoga analysis show of sprawl in the North West, while significant growth was observed in North East, South East and South west but fragmented due to presence of cultivable land in these regions. The threshold value being (log (12) = 1.079).Hubli analysis showed the sprawl is high is the south east and south west regions with a value close to 0.5, threshold value being 1.079 and Dharwad also has growth over past 4 decade, which also shows that the value as high as 0.2, where the threshold value was 0.845. The results of Shannon entropy are tabulated below (Table VII)

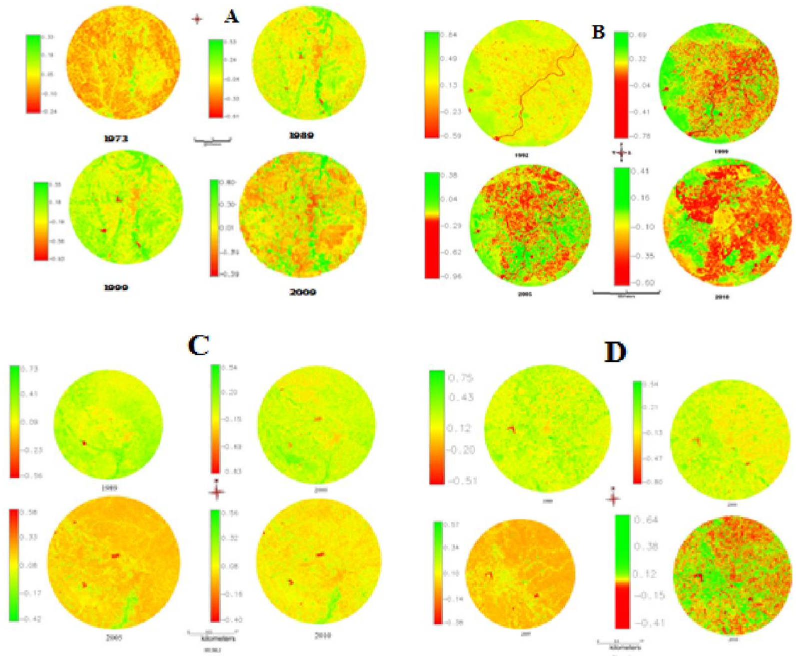


Figure 3: Temporal Land cover changes

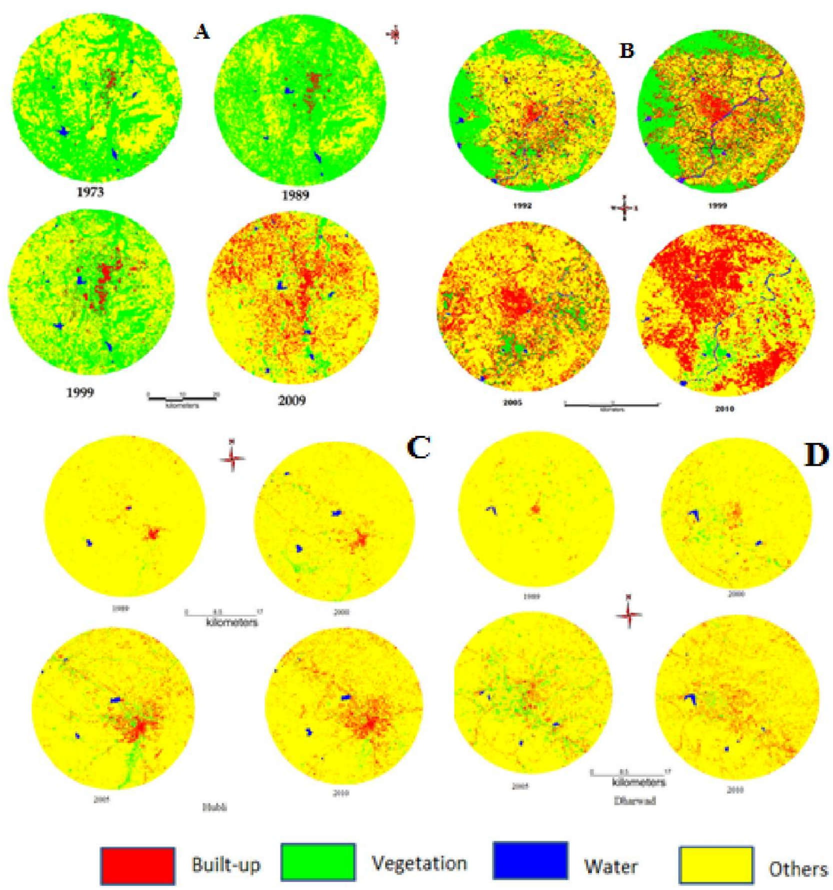


Figure 4:.Land use Changes observed temporally

Mysore					Shimoga				
Land use / Year	Urban %	Vegetation %	Water %	Others %	Land use / Year	Urban %	Vegetation %	Water %	Cultivation %
1973	1.1	53.23	0.61	45.06	1992	13.58	30.94	1.52	53.95
1989	1.2	65.89	0.39	32.60	1999	25.32	24.82	1.51	48.35
1999	3.6	41.57	0.58	54.2	2005	28.16	10.09	1.12	60.62
2009	18.68	5.76	0.12	74.84	2010	33.56	5.52	1.2	59.72
Hubli					Dharwad				
Land use / Year	Urban %	Vegetation %	Water %	Others %	Land use / Year	Urban %	Vegetation %	Water %	Cultivation %
1989	1.08	0.22	0.64	98.06	1989	0.62	1.43	0.51	97.45
2000	2.25	0.45	0.98	96.31	2000	1.93	1.41	1.13	95.52
2005	9.85	0.71	0.74	88.70	2005	3.75	1.29	0.25	94.71
2010	14.62	0.42	0.65	84.30	2010	6.47	0.69	0.47	92.36

Table V: Temporal land use details

Mysore					Shimoga				
	NE	NW	SE	SW		NE	NW	SE	SW
2009	0.452	0.441	0.346	0.305	1992	0.23	0.24	0.18	0.25
1999	0.139	0.043	0.0711	0.050	1999	0.39	0.41	0.34	0.36
1992	0.060	0.010	0.0292	0.007	2005	0.4	0.45	0.38	0.43
1973	0.067	0.007	0.0265	0.008	2010	0.43	0.7	0.42	0.47
Hubli					Dharwad				
	NE	NW	SE	SW		NE	NW	SE	SW
1989	0.027	0.02	0.055	0.011	1989	0.011	0.013	0.008	0.006
2000	0.029	0.053	0.102	0.042	2000	0.016	0.023	0.014	0.018
2005	0.146	0.09	0.21	0.059	2005	0.08	0.086	0.09	0.0745
2010	0.369	0.134	0.49	0.128	2010	0.168	0.164	0.213	0.216

Table VI: Shannon Entropy Index

d. **Spatial patterns of urbanisation**: In order to understand the spatial pattern of urbanization, Three landscape level metrics were computed zonewise for each circle. These metrics are discussed below:

Number of Urban Patches (Np) is a landscape metric indicates the level of fragmentation and ranges from 0 (fragment) to 100 (clumpiness). Figure 5A, for Mysore illustrates that the city is becoming clumped patch at the center, while outskirts are relatively fragmented. Clumped patches are more prominent in NE and NW directions and patches are agglomerating to a single urban patch. Shimoga show that center is in the verge of clumping especially accelerated in 2005 and 2010 (figure 5B), while the outskirts remain fragmented and are highly fragmented during 2005 and 2010 in North east, south east and south west directions. North west zone is losing its vegetation and cultivation class and this zone is highly fragmented in the outskirts during 2005 but is now in the verge of forming a single built up class. Figure 5C and 5D explains the state of land use in Hubli and Dharwad. Hubli and Dharwad also like other cities is tending to clumped center growth, while outskirts are highly fragmented.

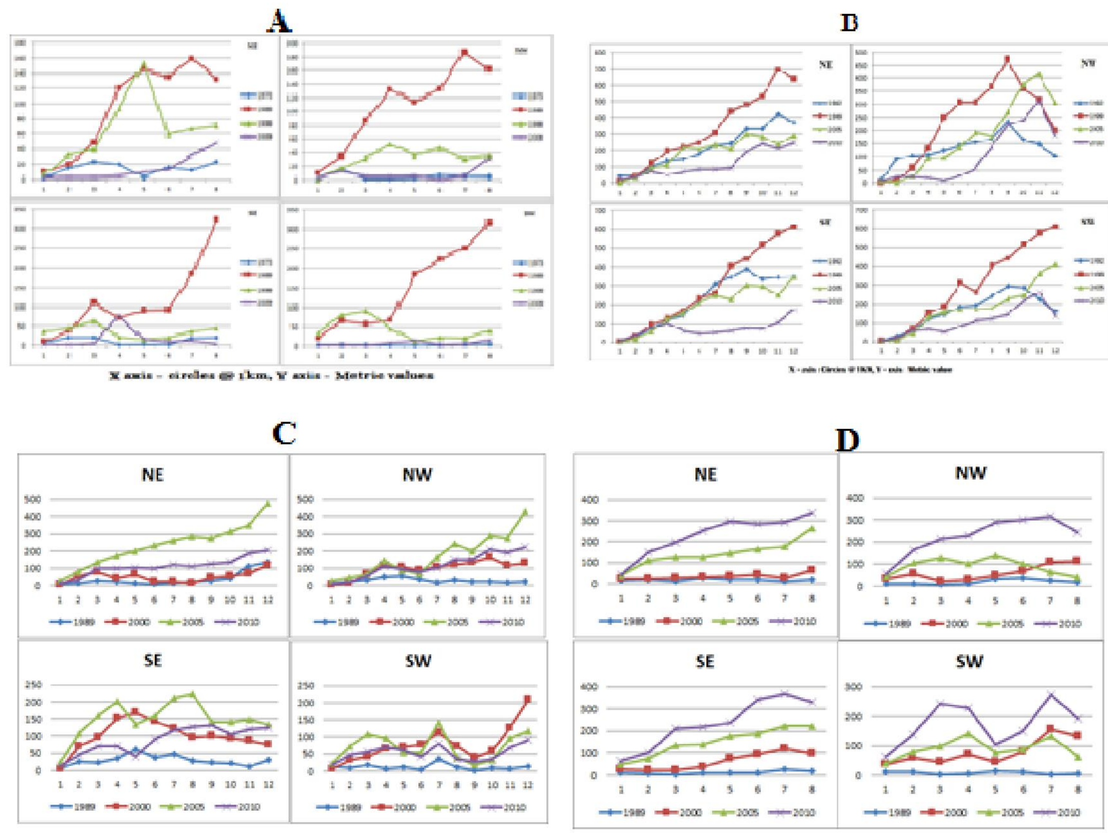


Figure 5: Number of urban patches (zonewise, circlewise)

Normalized Landscape Shape Index (NLSI): NLSI is 0 when the landscape consists of single square or maximally compact almost square, it increases as patch types becomes increasingly disaggregated and is 1 when the patch type is maximally disaggregated. Figure 6A indicates that the landscape had a highly fragmented urban class, which became further fragmented during 80's and started clumping to form a single square in late 90's especially in NE and NW direction in all circle and few inner circles in SE and SW directions. Figure 6B indicate that the urban area is almost clumped in all directions and gradients especially in north east and north west directions. It shows a small degree of fragmentation in the buffer regions in south west and south east direction. The core area is in the process of becoming maximally square in all directions. Figure 6C and 6D is the results of analysis of Hubli Dharwad region, which indicates that the city center is tensing to simple shaped compact growth, while outskirts are convoluted and fragmented.

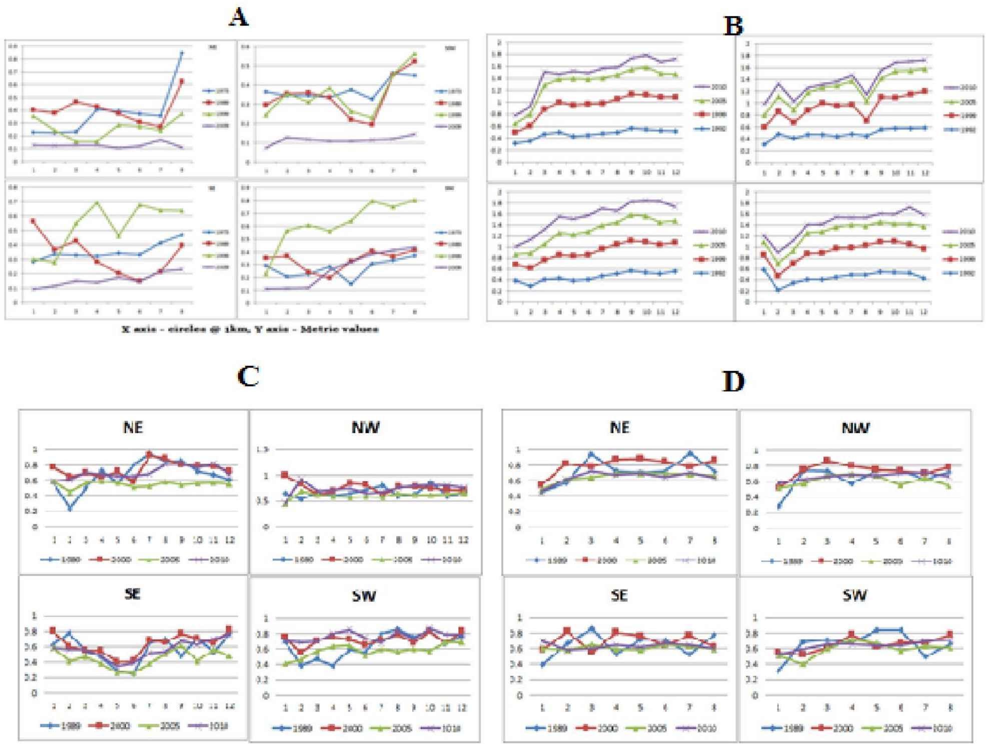
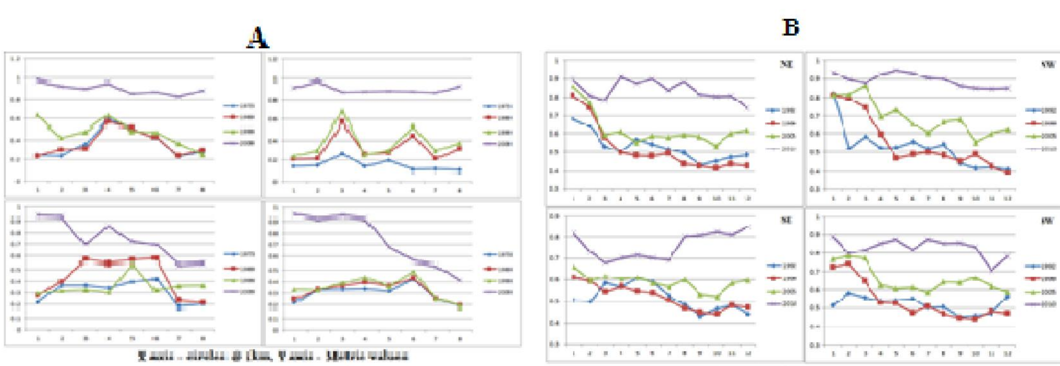


Figure 6: Normalised landscape shape index

Clumpiness index equals 0 when the patches are distributed randomly, and approaches 1 when the patch type is maximally aggregated. Mysore analysis highlights that the center of the city is more compact in 2009 with more clumpiness and aggregation in NW and NE directions. In 1973 the results indicate that there were a small number of urban patches existing in all direction and in every circle and due to which disaggregation is more. Post 1999 and in 2009 we can observe large urban patches very close almost forming a single patch especially at the center and in NW direction in different gradients (Figure 7A). Results for Shimoga (Figure 7B) are indicative of the clumpiness of the patches at the central core and buffer region and are fragmented in the outskirts. Analysis of the Hubli (Figure 7C) region showed highly fragmented outskirts, whereas Dharwad (Figure 7D) analysis showed comparatively less fragmentation



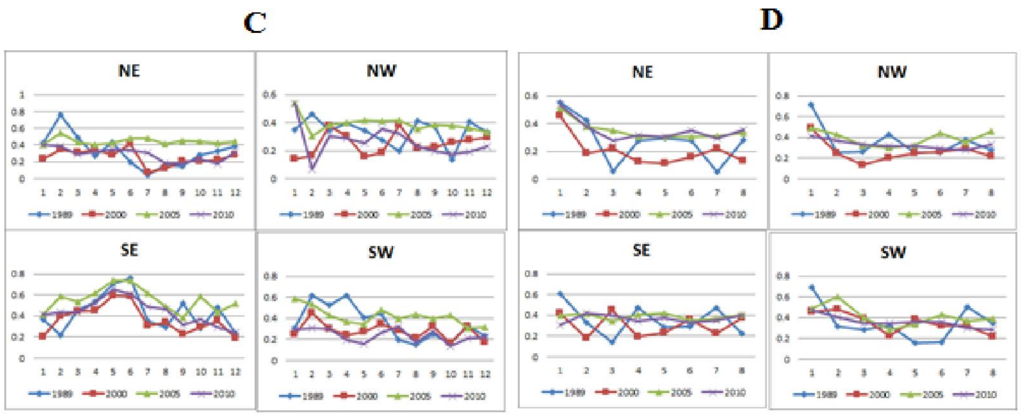


Figure 7: Clumpiness Index

Conclusion

The combined and integrated application of remote sensing, spatial metrics, and Shannon's entropy represents an innovative approach for the study of spatiotemporal change of urban forms. This paper has presented a detailed analysis of 40 years of spatial growth pattern analysis for tier II cities of Karnataka incorporating six different spatial metrics. Three different metrics represent specific spatial and temporal dynamics of urban form. All metrics have shown their sensitivity to the overall urban growth pattern in the study area. The change of urban form shows a period of urban sprawl and diffuse growth during 1990's and 2000. After 2000, especially towards 2010, spatial complexity declined as most of the urban areas grew more compact through sprawling urban patches. This analysis would help the planners and administrators to visualise the growth and plan the cities efficiently and sustainably.

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