Measuring urban sprawl in Tier II cities of Karnataka, India

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***Abstract*— Rapid irreversible urbanisation has haphazard and unplanned growth of towns and cities. Urbanisation process is driven by burgeoning population has resulted in the mismanagement of natural resources. Human-induced land use changes are the prime drivers of the global environmental changes. Urbanisation and associated sub growth patterns are characteristic of spatial temporal changes that take place at regional levels. Rapid urbanization subsequent to opening up of Indian markets in early ninety's show dominant changes in land use during the last two decades. Urban regions in India are experiencing the faster rates of urban dominance, while peri-urban areas are experiencing sprawl. Tier II cities in India are undergoing rapid changes in recent times and need to be planned to minimize the impacts of unplanned urbanisation. This communication focuses on seven tier II cities, chosen based on population. Mysore, Shimoga, Hubli, Dharwad, Raichur, Belgaum, Gulbarga and Bellary are the rapidly urbanizing regions of Karnataka, India. In this study, an integrated approach of remote sensing and spatial metrics with gradient analysis was used to identify the trends of urban land changes with a minimum buffer of 3 km buffer from the city boundary has been studied (based on availability of data), which help in the implementation of location specific mitigation measures. Results indicated a significant increase of urban built-up area during the last four decades. Landscape metrics indicates the coalescence of urban areas has occurred in almost all these regions. Urban growth has been clumped at the center with simple shapes and dispersed growth in the boundary region and the peri-urban regions with convoluted shapes.**

Keywords - Landscape Metrics, Urbanisation, Urban Sprawl, Remote sensing, Tier II, Karnataka, India

I. INTRODUCTION

Human induced land use and land cover (LULC) changes have been the major drivers for the changes in local and global environments. Land cover dynamics involving conversion of natural resources (vegetation, water bodies, green spaces) into urban space have affected various natural and ecological process. Urbanisation is a dynamic complex phenomenon involving large scale changes in the land uses at local levels. Analyses of changes in land uses in urban environments provide a historical perspective of land use and give an opportunity to assess the spatial patterns, correlation, trends, rate and impacts of the change, which would help in better regional planning and good governance of the region [1]. Urban growth is a spatial and demographic process, involving concentrated human activities in the region, which has high economic potential ([2], [3], [4]). Urban growth pattern, have a direct influence on the region's development process and often it extends its influence on the neighborhood [1], leading to dispersed growth, which is often referred as urban sprawl or peri-urban growth. Urban sprawl refers to a small clusters of medium to low-density urban growth in the outskirts without proper basic amenities ([1], [5]). This form of peri urban low density growth apart from lacking basic amenities also have a number of social, economic and environmental disadvantages [4]. Mapping the urban sprawl dynamics helps not only to identify the environmental degradation but also to visualize the future patterns of sprawling growth. Techniques have evolved for identifying and quantifying the urban sprawl ([6], [7], [4]). Apt way to capture this process is to consider the spatial and temporal changes taking place in the regions covered with impervious surfaces [8].

A quantitative and qualitative analysis of the landscape structure is essential to analyse of the patterns of landuse changes. Thematic land-use and land-cover maps generated allow us to quantify characteristics of landscape heterogeneity [9] and landscape fragmentation [10]. Spatio-temporal data (Remote Sensing (RS) data acquired through space borne sensors) with Geographic Information System (GIS) are helpful in data acquisition and analysis of LULC changes and for qualitative and quantitative results to understand the changes [11]. Temporal RS data has been used to analyze and understand the changes and impacts of human activities on the natural ecosystem [12]. Urban growth is captured based on spatial configuration and its dynamics [13]. Spatial metrics are useful for describing the landscape structure ([14], [1]) and for a wide range of applications, including the assessments of land-use change required for landscape planning and management [15], detection of changes in vegetation patterns [16], changes in landscape structure [17], for assessing the impacts of urbanization on the landscape ([1] [2] [4] [18]). Common spatial metrics have been computed for describing the structural characteristics and growth patterns of the built-up area. This review illustrates that significant research contributions ranging from gradient analyses to geospatial tool applications have been made to understand the urban growth pattern, quantification of complex patterns or processes of urban growth [19]. The present scenario in India with attribute to structure composition and rate of growth of most Indian metropolitan cities or tier 1 cities have an aggregated urban cores, huge population and have been expanding into the rural fringe areas, and planners have failed in providing the basic necessities and infrastructure [4]. Thus there has been a need of providing an alternative region for development which has been in the form of Tier II cities, which have huge space for infrastructural development capabilities with good facilities for providing basic amenities. In order to be able to provide basic amenities and infrastructure for the complex and dynamic urban environment there is an obvious need for planners and city developers to monitor and visualize the growth pattern and changing land use along the urban area and the peri urban area of the tier two cities This communication analyses the growth pattern of developing cities in Karnataka State, India. These regions have large neighborhood of various classes with diverse landscape patterns. The objectives of the study are (a) to understand the land cover and land use dynamics using temporal remote sensing data, (b) quantify urban growth, (c) to understand the urban growth patterns in different locations using gradients and (d) to assess the pattern of growth over past two decades using spatial metrics over gradient.

II. Study Area

Karnataka is one of the largest states of South India. The state covers an area of 191,976 sq. kms or 5.83% of the total geographical area of India. It is the eighth largest Indian state by area, the ninth largest by population and comprises 30 districts. According to Population census of 2001, the Population of Karnataka was 5.273 crores (52.73 million). The Population of Karnataka has increased by 17.20% compared to the population census of 1991. Karnataka lies between the Latitudes 14^{o} 49' 37.15"N to 13^{o}18' 39.29"N, Longitude 76^{o}56' 37.1"E to 77^{o}28' 15.66"E. The study focuses on tier-II cities of Karnataka which have a population of 2 - 8 lakhs, namely Mysore, Shimoga, Hubli- Dharwad, Belgaum, Bellary, Raichur and Gulbarga (Fig. 1).

Mysore is the second largest city in the state of Karnataka, ndia. The vibrant royal city of South, with numerous heritage sites, is facing the rapid urbanization. This irreversible process of urbanisation has been altering the landscape. With the government planning to develop this area under various Projects which has invited the surge of investors to invest heavily in this heritage city, especially the IT Companies. Shimoga is located in central part of the state of Karnataka, India. It lies on the banks of the Tunga River. Shimoga encompasses an area of 8477 sq. km. Shimoga district has a population of 16.43 lakh (as per 2001 Census), with population density of 194 per sq. km. Hubli – Dharwad are twin cities in Indian state of Karnataka. Hubli-Dharwad is the second-largest urbanized centers in Karnataka. The twin cities have a common governance and are governed by Hubli - Dharwad Municipal

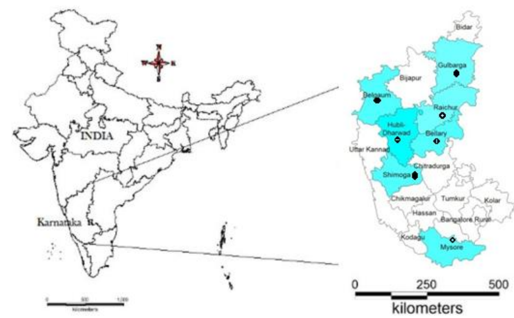

Figure 1. Study Area: Tier II Cities in Karnataka

Corporation (HDMC) with a corporation governing area of 202.3Sq km. The population of the Twin cities is about 1 million (Census 2011). Gulbarga is a biggest district in Karnataka State covering 8.49% of the area and 5.9% of State's population. Gulbarga is basically an agriculture dominated district. Raichur is one of major district in northern Karnataka, India, having 5 taluks and 37 hobli's and 120 hamlets, with an area of 8386 sq. km. and a population density of 181 persons per sq. km (2001). Bellary city is situated in the Karnataka State and has a jurisdiction over an area of 82 Sq. Kms. Population of about 0.4 million as per 2011 census (provisional). Belgaum City geographically located in the North Western Part of Karnataka State, with a gross area of 38013.27 hectares.

The city has about 58 wards, with population of 0.5 million (2011 Census Provisional) and Population Density of 84.21 persons per hectare, the population in the region has a decadal increase of 7.31%.

III. Materials and Methods

Data analysis: Preprocessing: The remote sensing data corresponding to the study region were downloaded, geo-referenced, rectified and cropped pertaining to the administrative boundary with 3km-5km buffer depending on data availability was considered. Landsat ETM+ bands of 2010 were corrected for the SLC-off by using image enhancement techniques, followed by nearest-neighbor interpolation. Data used for the analysis are listed in Table 1.

Land Cover Analysis: Among different land cover indices, NDVI - Normalised Difference Vegetation Index was found appropriate and NDVI was computed to understand the changes of land cover. NDVI is the most common measurement used for measuring vegetation cover. It ranges from values -1 to +1 depending on the earth features.

Land use analysis: The method involves 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 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, vi) collection of the corresponding attribute data (land use types) for these polygons from the field, iv) Supplementing this information with Google Earth. Land use classification was done using supervised pattern classifier - Gaussian maximum likelihood algorithm based on various classification decisions using probability and cost functions [20]. Land use was computed using the temporal data through open source GIS: GRASS- Geographic Resource Analysis Support System (http://ces.iisc.ernet.in/grass). Four major types of land use classes considered were built-up, vegetation, cultivation area (since major portion is under cultivation), and water body. 60% of the derived signatures (training polygons) were used for classification and the rest for validation. Statistical assessment of classifier performance based on the performance of spectral classification considering reference pixels is done which include computation of kappa (κ) statistics.

TABLE 1: DATA USED AND THE PURPOSE

Data	Purpose
Landsat Series MSS(57.5m)	Land cover and Land use analysis
Landsat Series TM (28.5m) and ETM	
IRS LISS III (24m)	
IRS R2 (5.6M) – LISS-IV(5.6m)	
IRS p6: LISS-IV MX data (5.6m)	
Survey of India (SOI) toposheets of 1:50000 and 1:250000 scales	Generate boundary and base layers.
Field visit data –captured using GPS	For geo-correcting and generating validation dataset

Density gradient and zonal analysis and computation of Shannon's entropy: Further the classified spatial data is divided into four zones based on directions considering the central pixel (Central Business district) as Northwest (NW), Northeast (NE), Southwest (SW) and Southeast (SE) respectively. The growth of the urban areas was monitored in each zone separately through the computation of urban density for different periods. Each zone was further divided into incrementing concentric circles of 1km radius from the center of the city. The built up density in each circle is monitored overtime using time series analysis. Landscape metrics were computed for each circle, zone wise using classified land use data at the landscape level with the help of FRAGSTATS [21]. To determine whether the growth of urban areas was compact or divergent the Shannon's entropy ([21] [1]) was computed direction wise for the study region. Shannon's entropy (Hn) given in equation 1, provide insights to the degree of spatial concentration or dispersion of geographical variables among 'n' concentric circles across Zones.

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

Where Pi is the proportion of the built-up in the ith concentric circle. As per Shannon's Entropy, if the distribution is maximally concentrated the lowest value zero will be obtained. Conversely, if it evenly distribution the value would be closer to log n indicating dispersed growth or sprawl.

IV. RESULTS

Vegetation cover analysis: Vegetation cover was assessed through NDVI, Mysore shows that area under vegetation has declined to 9.24% (2009) from 57.58% (1973). Shimoga analysis reveals that there was reduction in the vegetation cover from 89% to 66% during the past two decades in the region. In Hubli vegetation has declined from 97% (1989) to 78% (2010) in Hubli and from 98% (1989) to 86% (2010) in Dharwad. Gulbarga and Raichur analysis showed area under vegetation has declined by about 19%. Belgaum analysis indicate that the vegetation in the study region decreased for 98.8% in 1989 to 91.74% in 2012. Temporal NDVI values are listed in Table 2 and outputs are presented in Appendix 1.

TABLE 2: LAND COVER ANALYSIS (V: ARE UNDER VEGETATION IN %; NV: AREA UNDER NON-VEGETATION IN %)

In %	Mysore	Shimoga	Hubli	Dharwad
1980's	V=57.58 Nv=42.42	V=89.35 Nv=10.65	V=97.0 Nv=3.0	V=98.12 Nv=1.88
2000's	V=09.24 Nv=90.76	V=66.72 Nv=33.28	V=78.31 Nv=21.69	V=86.43 Nv=13.57
In %	**Gulbarga**	**Raichur**	**Belgaum**	**Bellary**
1980's	V=94.72 Nv=5.28	V=92.18 Nv=7.82	V=98.41 Nv=1.59	V=94.87 Nv=5.13
2000's	V=79.41 Nv=20.57	V=82.48 Nv=17.52	V=91.74 Nv=8.26	V=93.7 Nv=6.27

Land use analysis: Land use assessed using Gaussian maximum likelihood classifier. In Mysore there has been a significant increase in built-up area during the last decade evident from 514 times increase in urban area from 1973 to 2009. Shimoga also witnessed increase in the urban category from 13% (1992) to 33% (2010), which is about 253 times during the last four decades. Hubli-Dharwad also saw a significant increase in built-up area during the last decade, Hubli saw an increase of about thousand times, whereas Dharwad was about 600 times growth in urban area, Gulbarga has seen a significant increase in built-up area during the last decade evident from 21% increase in urban area. Raichur and Bellary also witnessed increase in built-up area during the last decade about 590 and 700 times during the last 4 decades. Belgaum analysis indicate that the urban impervious land use has increased from 0.31 % in 1989 to 6.74% in 2012 Consequent to these, vegetation cover and water has declined drastically during the past four decades in all cities. Temporal Land use values are listed in Table 3 and outputs are presented in Appendix 2.

Shannon's entropy computed using temporal data as listed in table 4. Mysore is experiencing the sprawl in all directions as entropy values are closer to the threshold value (log (8) = 0.9). Lower entropy values during 70's shows an aggregated growth as most of urbanization were concentrated at city centre.

TABLE 3: LAND USE ANALYSIS

Class	Mysore	Shimoga	Hubli	Dharwad
Urban	1980's=1.1 2000's=18.68	1980's=13.58 2000's=33.56	1980's=1.08 2000's=14.62	1980's=0.62 2000's=6.47
Veg	1980's=65.85 2000's=5.7	1980's=30.94 2000's=5.52	1980's=0.22 2000's=0.42	1980's=1.43 2000's=0.69
Water	1980's=0.39 2000's=0.7	1980's=1.52 2000's=1.2	1980's=0.64 2000's=0.65	1980's=0.51 2000's=0.47
others	1980's=32.6 2000's=74.84	1980's=53.95 2000's=59.72	1980's=98.06 2000's=84.30	1980's=97.45 2000's=92.36
	Gulbarga	Raichur	Belgaum	Bellary
Urban	1980's=2.62 2000's=22.52	1980's=1.44 2000's=8.51	1980's=0.31 2000's=6.74	1980's=2.12 2000's=7.42
Veg	1980's=1.54 2000's=0.49	1980's=1.62 2000's=4.81	1980's=4.62 2000's=2.44	1980's=4.61 2000's=0.48
Water	1980's=0.40 2000's=0.39	1980's=0.88 2000's=0.97	1980's=0.14 2000's=0.24	1980's=2.35 2000's=2.04
others	1980's=95.44 2000's=76.60	1980's=96.16 2000's=85.71	1980's=94.9 2000's=91.58	1980's=90.92 2000's=90.07

However, the region experienced dispersed growth in 90's reaching higher values of 0.452 (NE), 0.441 (NW) in 2009. Sprawl analysis for Shimoga reveals 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. Hubli - Dharwad is experiencing the sprawl in all directions as entropy values are gradually increasing (for Hubli: log (12) = 1.07 For Dharwad: log (7) = 0.845). Lower entropy values of 0.02 (NW), 0.011 (SW) during late 80's shows an aggregated growth as most of urbanization were concentrated at city center. However, the region experienced dispersed growth in 80's reaching higher values in NE, and SE in 2010. Gulbarga is experiencing the sprawl in all directions as entropy values are closer to the threshold value (log (10) = 1). Lower entropy values during 0's shows an aggregated growth. However, the region show a tendency of dispersed growth during post 2000 with higher entropy values 0.268 (NE), 0.212 (NW) in 2010 (and threshold is 0.77). Increasing entropy values from 1982 to 2010 shows the tendency of dispersed growth of built-up area in the city with respect to 4 directions as we move towards the outskirts and this phenomenon is most prominent in SE and SW directions. Increasing entropy values from 1973 to 2010 shows the tendency of dispersed growth of built-up area in the city with respect to 4 directions as we move towards the outskirts and this phenomenon is most prominent in SE and NE directions. The threshold limit of Shannon's Entropy is log11 (1.041). The results indicated that though Belgaum considering the buffer region has effect of urban sprawl considering the values of 1980 and 2012, and the effect is gaining strength temporally considering the threshold value of 1.041.

TABLE 4: SHANNON ENTROPY INDEX

	NE	NW	SE	SW	
Mysore	0.067	0.007	0.0265	0.008	1980's
	0.452	0.441	0.346	0.305	2000's
Shimoga	0.23	0.24	0.18	0.25	1980's
	0.43	0.7	0.42	0.47	2000's
Hubli	0.027	0.02	0.055	0.011	1980's
	0.369	0.134	0.49	0.128	2000's
Dharwad	0.011	0.013	0.008	0.006	1980's
	0.168	0.164	0.213	0.216	2000's
Gulbarga	0.086	0.065	0.046	0.055	1980's
	0.268	0.212	0.193	0.141	2000's
Raichur	0.023	0.026	0.026	0.027	1980's
	0.135	0.146	0.168	0.194	2000's
Bellary	0.04	0.03	0.08	0.06	1980's
	0.37	0.32	0.389	0.33	2000's
Belgaum	0.005	0.0191	0.0034	0.008	1980's
	0.086	0.1652	0.1154	0.137	2000's

Spatial patterns of urbanisation: In order to understand the spatial pattern of urbanization, seven landscape level metrics were computed zone wise for each circle. Prominent two metrics ([1]) are discussed below: Number of Urban Patch (Np) reflects the extent of fragmentation of a particular class in the landscape. Higher the value more the fragmentation, Lower values is indicative of clumped patch or patches forming a single class and ranges from 0 (fragment) to 100 (clumpiness). The analysis (Fig. 2) showed that all the cities except Hubli Dharwad and Belgaum are becoming clumped patch at the center, which indicates that the urban dominance and eradication of other classes present in past decades, while outskirts are relatively fragmented in all direction, but show a tendency of forming a single clumped class in the whole

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landscape considered. Hubli- Dharwad and Raichur have shown fragmentation over years both at the centre and outskirts indicative of newer urban patches in the landscape in recent decade. Further understanding this planners have to visualise the future to balance all land use to avoid unsustainable growth or complete urban dominance.

Normalised Landscape Shape Index (NLSI): NLSI calculates the value based on particular class rather than landscape and is equal to zero when the landscape consists of single square or maximally compact almost square, its value increases when the patch types becomes increasingly disaggregated and is 1 when the patch type is maximally disaggregated. Basically this metrics quantitatively captures the growth or phenomena through shape of a landscape. The analysis revealed and supported the previous metrics that the central gradients are in the process of converting to simple shapes and values are decreasing over decades, which again points to the fact of urban dominance over other land use classes in this region. However the Hubli, Dharwad and Belgaum analysis is an indicative of the yet more convoluted shapes the value being close to one than in 1980, and supports the argument that they have fragmented growth at the centre and outskirts extending to the buffer zones (Fig. 3).

V. CONCLUSION

The statistics and analysis both quantitatively and qualitatively presented here illustrate the spatial distribution of recent patterns of urbanisation in the tier II cities, Karnataka, India. Land cover analysis reveals that there was reduction in the vegetation cover during the past two decades in the study regions. Land use analysis reveals of increase in urban category increased in last two decades. Spatial analysis revealed that land use in the outskirts is fragmented. Shannon's entropy showed that there was urban sprawl in the outskirts necessitating immediate policy measures to provide infrastructure and basic amenities. Landscape metrics conform of the urban sprawl in the buffer zone, whereas the core area had mix of classes and as we go from the center towards administrative boundary the urban density intensifies. Governmental agencies need to visualize possible growth poles for an effective policy intervention. Any efforts to do so, however, must take into account the multitude of social, environmental and biophysical realities that will continue to shape the region's future. Physical urban growth in the region will undoubtedly continue, but it is required that the city planners and developers of all these cities take a note of the situation and plan for further developmental urban activities in a sound and sustainable way.

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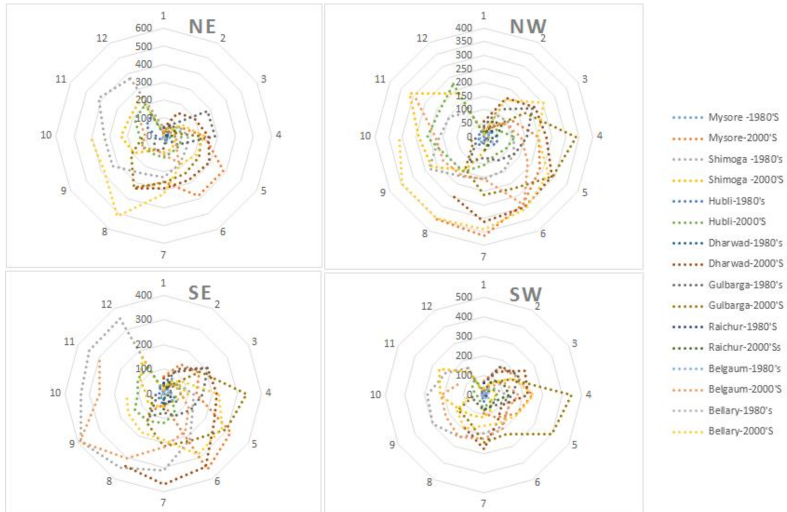


Figure 2: Number of urban patches in different zones and gradients

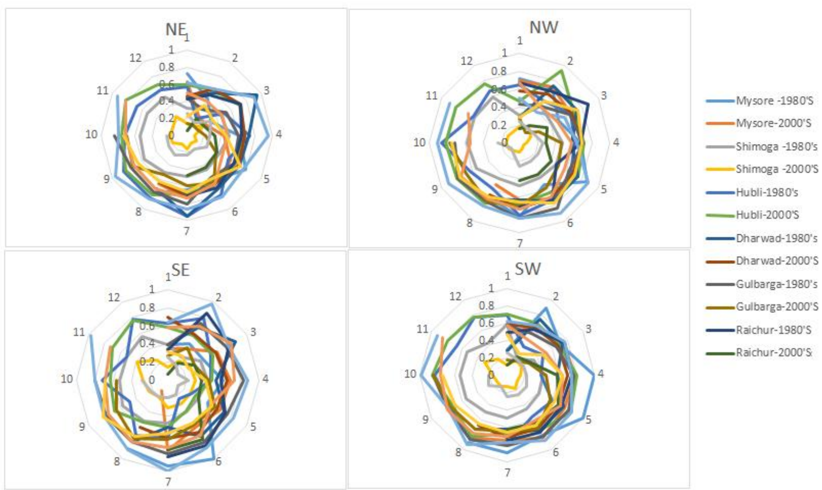
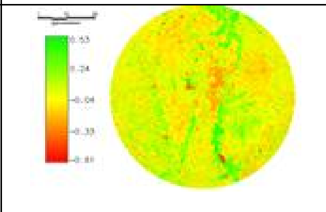
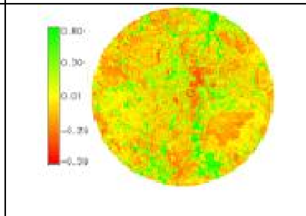
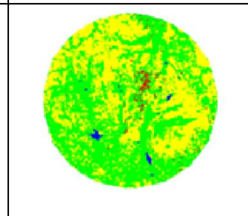
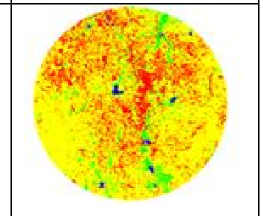
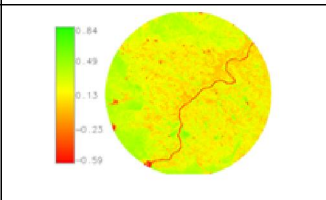
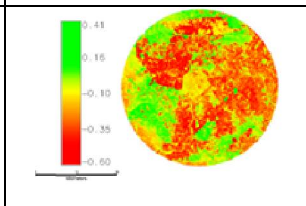
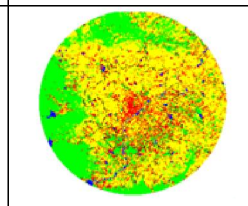
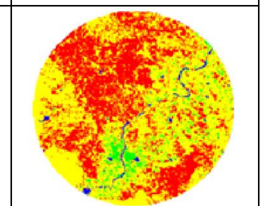
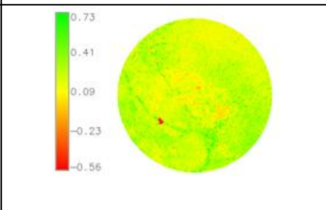
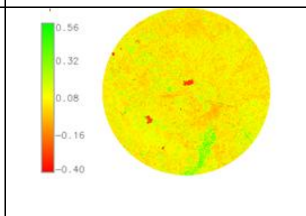
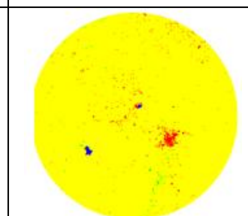
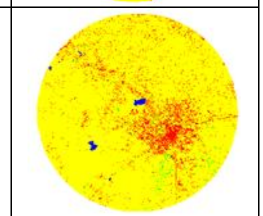
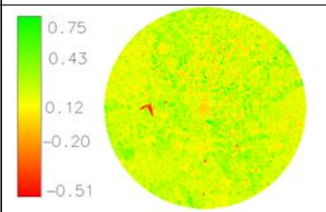
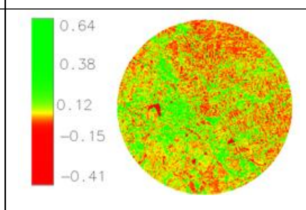
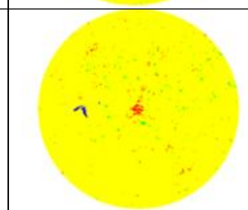
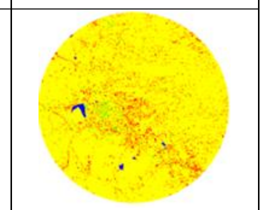
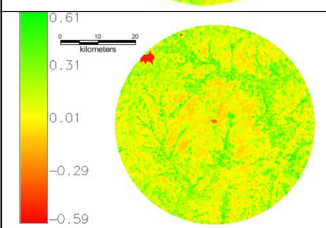
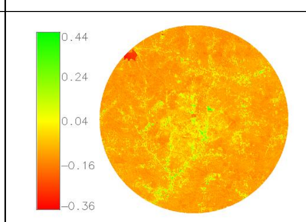
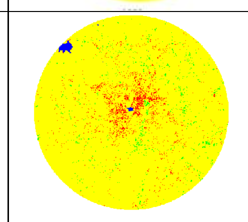
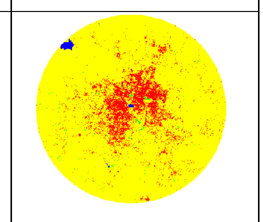
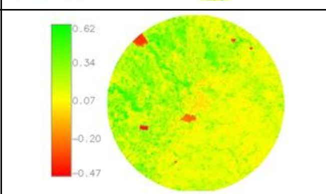
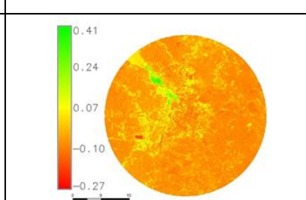
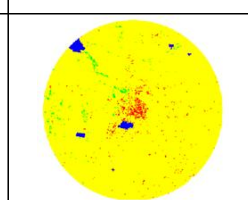
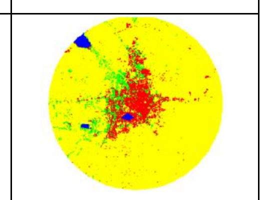
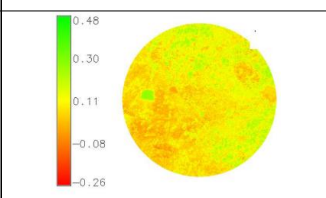
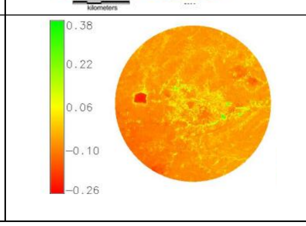
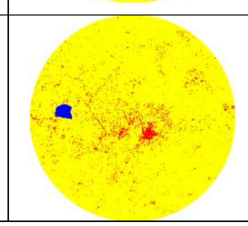
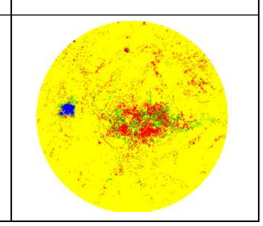


Figure 3: Normalised Landscape Shape Index in different zones and gradients

	Appendix I: Land cover		**Appendix II**: Land use	
	1980's	2000's	1980's	2000's
Mysore				
Shimoga				
Hubli				
Dharwad				
Gulbarga				
Raichur				
Bellary				

Belgaum