Spatial Pattern analysis of two urbanising Tier II cities in Karnataka using open source GIS - GRASS

Bharath H. Aithal[1,2] and Ramachandra T.V[1,2,3]*
[1]*Energy & Wetlands Research Group, Centre for Ecological Sciences [CES],*
[2]*Centre for Sustainable Technologies (astra),*
[3]*Centre for infrastructure, Sustainable Transportation and Urban Planning [CiSTUP],*
Indian Institute of Science, Bangalore, 560 012, India
http://ces.iisc.ernet.in/energy http://ces.iisc.ernet.in/biodiversity
*corresponding author: +91-080-22933099, cestvr@ces.iisc.ernet.in

***Abstract* — Urbanisation and associated growth patterns are characteristic of spatial temporal changes that take place at regional levels. Rapid, unplanned and uncontrolled urbanization causes disorganized growth. Asymmetrical growth has impacted natural resources apart from the region deprived of basic amenities. This has necessitated understanding of spatial patterns of urbanization. An understanding of the growth dynamics of urban agglomerations is essential for ecologically and sustainable feasible developmental planning. Almost a third of India's population are residing in urban. Tier II cities in India are undergoing rapid changes in recent times and need to be planned to minimize the impacts of unplanned urbanisation since major urban agglomeration have reached the saturation level of providing basic amenities and other requirements. Tier II cities in Karnataka are the most preferred destinations for industries including IT hubs, other than Bangalore. Cities such as Mysore, Shimoga, Hubli and Dharwad are fastest growing traditional regions of Karnataka, India. Hence these regions have been considered for the investigations considering buffer region around it and understanding the growth through Shannon entropy and density gradients applied zone wise and with help of landscape metrics. Shannon's entropy results shows dispersed haphazard urban growth in the city, particularly in the boundary regions of the city. Further the results of landscape metrics indicate towards a compact and simple shaped growth at the center and disaggregated and complex shaped growth at the periphery of the cities indicating that these regions are also under the influence of haphazard growth. Overall accuracy of the land use classification was 88% and was carried out using open source software's such as GRASS and QGIS. These studies help the city and state administrators and the city planners to understand the growth and visualise the further growth and plan the cities in sustainable way.**

Keywords- Urban Sprawl; Karnataka; Grass; Remote sensing; Landscape Metrics; Mysore; Shimoga.

Introduction

Cities all over India have experienced tremendous growth during the last two decades in response to globalization. in. During the past decade the population of India has almost doubled, and the urban population has grown nearly five times. The number of Indian urban agglomerations/cities having a population of more than one million in India has increased to 48 (in 2011) from 35 (in 2001). It is projected that India will have the largest concentration of urban areas by 2021 in the world [4].Urbanisation is an irreversible process of growth of human habitats with serious implication on the local ecology and natural resources. This has necessitated the understanding of spatial patterns of growth for policy interventions. Availability of temporal remote sensing data in the public domain and open source GIS has brought down the cost of spatial analysis. This helps the resource crunch city administration in the effective regional planning through visualization of problems that accompany such growth [13] [3]. Spatio-temporal data help in understanding the urban growth pattern, urbanisation rate, underlying problems of urbanisation such as urban sprawl and help in better administration through the provision of basic amenities [18].

Geospatial technologies provide a powerful tool for studying urban problems, including those related to urban/built-up land cover mapping [32], urban growth modeling [8] [7] [23], urban sprawl mapping [10] [24] [23] and environmental effects of urban development [15] [18]. Most unique feature of remotely sensed data through space borne (satellites) sensor is the availability of spatial data on a temporal scale, required to understand the time pattern changes in urban area and thus could be used to improve understanding and modeling of urban development and change processes [2] [28] [1] [7] [23] [19], and, consequently, they have been used increasingly to map urban development [22] [14] [8] [17].

The information about the current and historical land cover and land use plays a major role in urban planning and management [29] [31]. Land-cover essentially indicates the feature present on the land surface [11] [23]; [18]. Land use relates to human activity/ economic activity on piece of land under consideration [18]. Recent research and reviews in remotely sensed images processing to qualitatively and quantitatively use spatial metrics which are critical in the description, analysis, and modeling of urban form and its changes [7]. Researchers use these indices to quantify the structure and pattern of an urban environment. Recent times there are numerous studies in this direction on landscape metrics focusing on a urban area [8] [12] [7] [23]; [30] [20] [9]; [25] [26] [18]. Further, spatial patterns are understood by density gradients or concentric ring approach for the investigations of local patterns of change and effects [27], [18].

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 megapolisis, which are expected to handle the urban population. The objectives of the analysis is to: (1) capture the extent and location of land use change in two 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 landscape metrics.

Study area

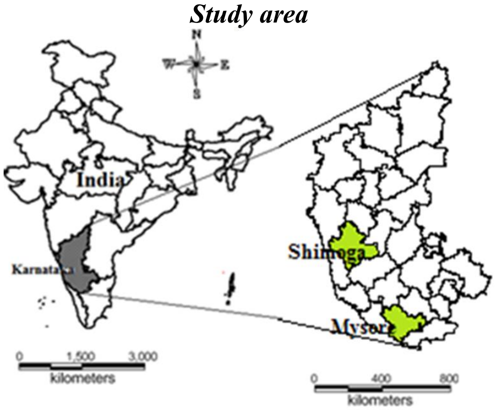


Figure 1: Study Area - Tier II cities of Karnataka: Mysore and Shimoga

Mysore city located at and with a population of about 1 million (2001 census) is the cultural capital of Karnataka, India with a hub of industrial activities., located 11°30' N to 12°50' N latitudes and 75°45' E to 77°45' E longitudes. The spatial extent of Mysore city is 128 sq. km The Mysore city with a buffer of 3km is considered for the analysis. Shimoga district is located at 13°43'N 75°15' E and 14°08'N and 75°44'E in the central part of the state of Karnataka, India. It lies on the banks of the Tunga River. The district receives an average rainfall of 1813 mm. The Shimoga city having a radius of 7km is considered for the analysis and a buffer of 5 km is considered.

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 were procured from National Remote Sensing Centre (www.nrsc.gov.in), Hyderabad. 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),

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:

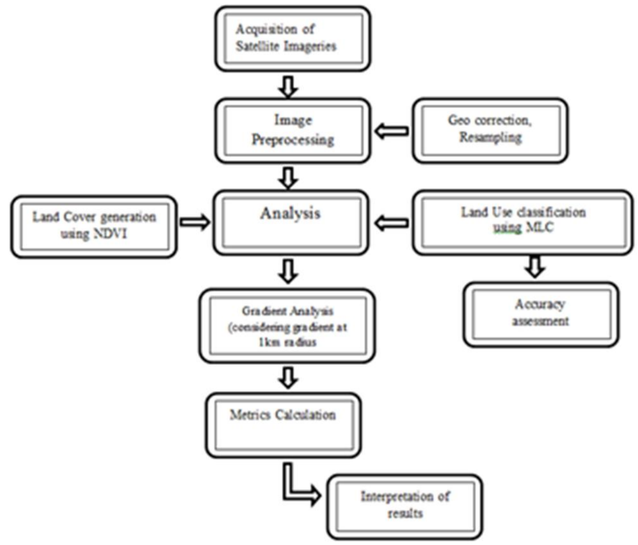


Figure 2: Procedure followed to understand the spatial pattern of landscape change

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. 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. 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 [6] 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. Evaluation of the performance of classifiers [16] is done through accuracy assessment techniques of testing the statistical significance [21], proportion of correctly allocated classes through computation of confusion matrix. [5].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.

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

Urban sprawl analysis: Direction-wise Shannon's entropy (H_n) is computed (equation 1) to understand the extent of growth: compact or divergent ([23], [19]). This provides an insight into the development (clumped or disaggregated) with respect to the geographical parameters across 'n' concentric regions in the respective zones.

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

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).

iv. **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 open source software. Urban dynamics is characterised by 3 spatial metrics chosen based on complexity and density criteria listed in Table III.

	Indicators	Range
1	Number of Urban Patches (NPU)	NPU>0, without limit.
2	Normalized Landscape Shape Index (NLSI)	0≤NLSI<1
3	Clumpiness	-1≤ CLUMPY ≤1.

Table III: Spatial Landscape Indices.

Results

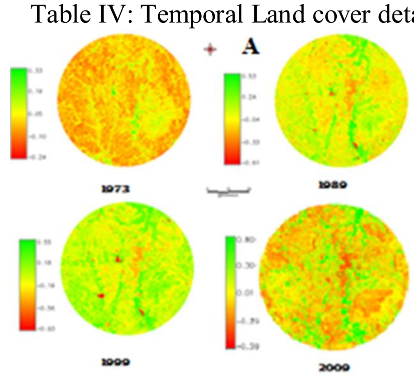
Land use Land Cover dynamics:

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. 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 was about 79%. In Shimoga Urban category has increased from 13% (1992) to 33% (2010) (figure 4B), which is about 253 times during the last two decades. Kappa statistics was calculated and is as listed in Table VI.

Mysore			Shimoga		
Year	Vegetatio n	Non vegetati on	Year	Vegetati on	Non vegetatio n
	%	%		%	%
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

Table IV: Temporal Land cover details.



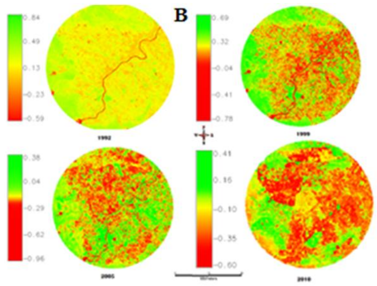


Figure 3: Temporal Land cover changes Mysore(A) Shimoga(B)

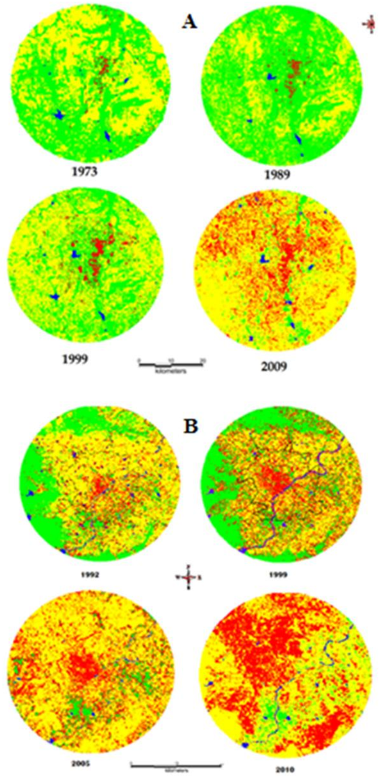


Figure 4:Land use :Mysore(a) Shimoga(b)

Mysore				
Land use Year	Urban %	Vegetation %	Water %	Others %
1973	1.1	53.23	0.61	45.06
1989	1.2	65.89	0.39	32.60
1999	3.6	41.57	0.58	54.2
2009	18.68	5.76	0.12	74.84
Shimoga				
Land use Year	Urban %	Vegetation %	Water %	Cultivation %
1992	13.58	30.94	1.52	53.95
1999	25.32	24.82	1.51	48.35
2005	28.16	10.09	1.12	60.62
2010	33.56	5.52	1.2	59.72

Table V: Temporal land use details

Year	Kappa coefficient (Mysore)	Kappa coefficient (Shimoga)
1973	0.76	0.83
1989	0.72	0.82
1999	0.82	0.84
2009	0.86	0.93

Table VI: Kappa statistics

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). Lower entropy values of 0.007 (NW), 0.008 (SW) during 70's shows an aggregated growth as most of urbanization were concentrated at city center. 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. The results of Shannon entropy are tabulated below (Table VII)

Mysore				
	NE	NW	SE	SW
2009	0.452	0.441	0.346	0.305
1999	0.139	0.043	0.0711	0.050
1992	0.060	0.010	0.0292	0.007
1973	0.067	0.007	0.0265	0.008
Shimoga				
	NE	NW	SE	SW
1992	0.23	0.24	0.18	0.25
1999	0.39	0.41	0.34	0.36
2005	0.4	0.45	0.38	0.43
2010	0.43	0.7	0.42	0.47

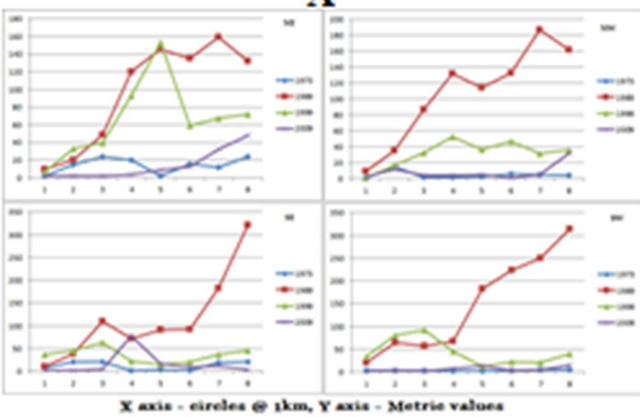
Table VII: Shannon Entropy Index

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).

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 Patch (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. 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

A



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

B

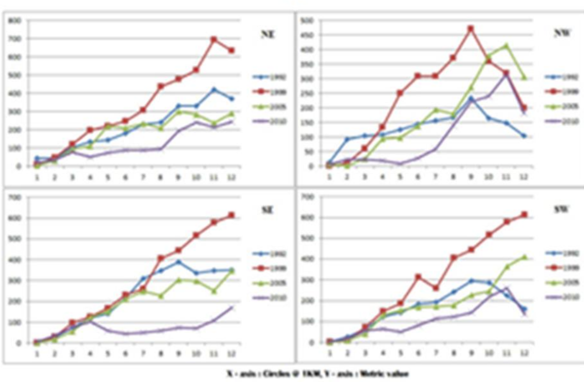
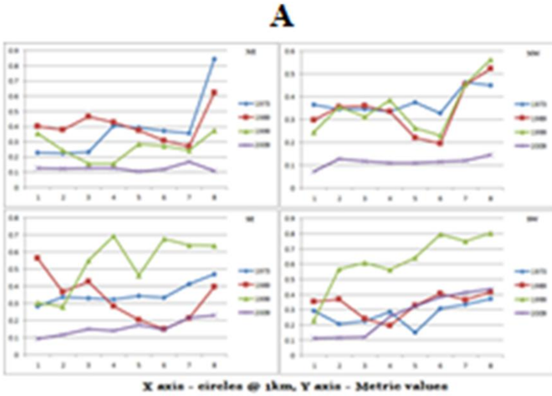


Figure 5: Number of urban patches (zonewise, circlewise)

A



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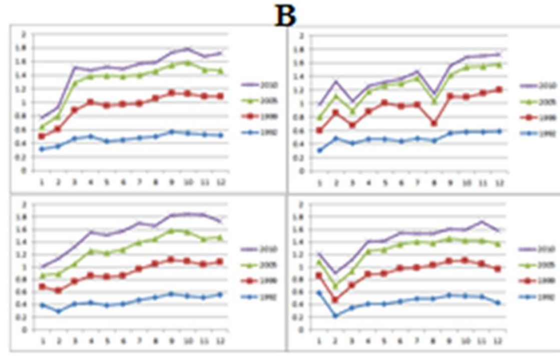
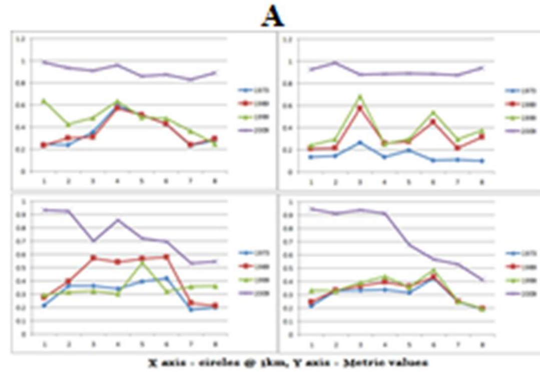


Figure 6: Normalised landscape shape index

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.

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. (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.

A



B

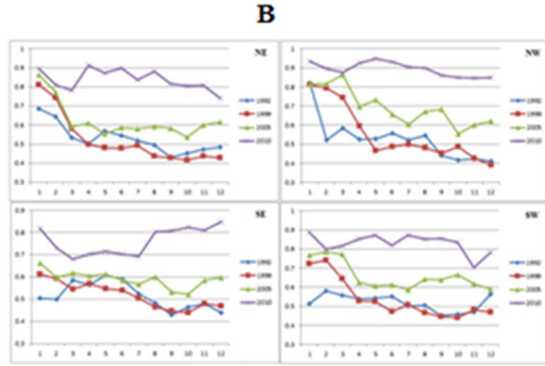


Figure 7: Clumpiness Index

Conclusion

State government's initiatives to develop Tier II cities in Karnataka as Bangalore has crossed the threshold and to provide opportunities have necessitated inventorying and mapping of spatial patterns of the growth to monitor and understand the underlying effects of urbanisation. Availability of spatial data since 1970's has aided in the temporal land use dynamics. Spatial metrics in conjunction with the density gradient approach have been effective in capturing the patterns of urbanization at local levels. The study has demonstrated that urbanisation and its spatio temporal form, pattern and structure can be quantified and compared across cities using a combination of landscape metrics and gradient analysis. The spatiotemporal patterns of change for each city revealed in this study corroborate other evidence of serious and widespread challenges for maintaining urban environmental quality, in cities both large and small.

Shannon entropy and Spatial metrics at landscape level reveal that the landscape had a highly fragmented urban class and started clumping to form a single square in late 90's and continued further in late 2000's. Local urban and rural planners need to put forward effective implementable adaptive plans to improve basic amenities in the sprawl localities.

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AUTHORS PROFILE

Dr. Ramachandra has Ph.D. in energy and environment from Indian Institute of Science. At present, Coordinator of **Energy and Wetlands Research Group** (EWRG), Convener of **Environmental Information System** (ENVIS) at Centre for Ecological Sciences (CES), Indian Institute of Science (IISc). He has made significant contributions in the area of energy and environment. His research area includes wetlands, conservation, restoration and management of ecosystems, environmental management, GIS, remote sensing, regional planning and decision support systems. During the past ten years he has established an active school of research in the area of energy and environment. He teaches principles of remote sensing, digital image processing and Natural resources management. He has published over 184 research papers in reputed peer reviewed international and national journals, 118 papers in the international and national symposiums as well as 14 books. In addition, he has delivered a number of plenary lectures at national and international conferences. He is a fellow of Institution of Engineers (India), IEE (UK), Senior member, IEEE (USA) and many similar institutions. Details of his research and copies of publications are available at http://ces.iisc.ernet.in/energy/
http://ces.iisc.ernet.in/grass

Bharath H Aithal, Electrical and Electronics Engineering graduate from Bangalore University. Currently, he is pursuing Ph.D at Indian Institute of Science. His area of interest are spatial pattern analysis, Urban growth modeling, natural disasters, geo-informatics, landscape modeling and urban planning, open source GIS, digital image processing.