Integrated approach to visualize urban growth: case study of rapidly urbanising city

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***Abstract*— Urbanisation process is a significant economic and social phenomena that occurs at an unmatched rate and scale worldwide. Rapid urbanisation and urban sprawl have been seeking much attention throughout the globe. Criticism faced by majority of the Tier-I cities in India is due to lack of proper urban planning which indirectly leads to improper land use, severe effects on natural biodiversity, large scale encroachment on wetlands leading to urban floods. This calls for an immediate action that needs to be taken by the local as well as regional governance to ensure swiftly changing landuse patterns and their ill effects. According to the researchers, the only way by which large areas can be monitored and mapped is with the aid of remote sensing and GIS tools. This communication delivers an integrated model involving metrics to understand the status of land use and land cover in the region. The focus mainly lies on understanding and modelling urbanisation pattern for the fastest growing metropolitan city on the Deccan Plateau of south eastern India. Land cover analysis for Hyderabad region reveals a drastic decrease in vegetation from 95.64% (1989), 93.28% (1999), 82.67% (2009) to 61.15% (2014). Land use analysis indicated significant urban growth of 1.75% in 1989 to 22.19% in 2014. Spatial metrics and density gradient analysis were employed to observe finer details of urbanisation pattern. This research article gives a complete visualization and urban growth statistic for Hyderabad region, helpful for government agencies and decision makers for proper urban planning and implementation of strategies with very minimal impact on the environment.**

Keywords*— *Urbanisation, Cellular automation, Markov chain, Spatial metrics, Urban modelling

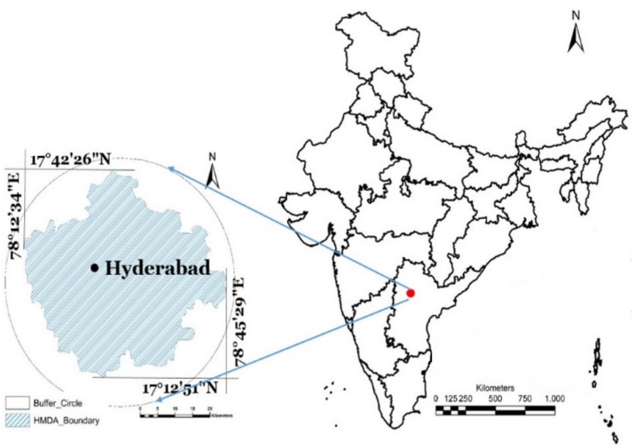
I. Introduction

Urban growth occurs when local patches of settlement are forced to agglomerate. Annual rate of urban population growth in India is about 2.3% [1]. Urbanisation process is a significant economic and social phenomena that occurs at an unmatched rate and scale worldwide. Also it has been estimated that by the year 2025, 60% of the globe inhabitants will live in urbanized areas, 72% by 2050 [2-3] in contrast with 53% of inhabitants living in urban areas at present. Urban expansions are taking place rapidly with higher rate of people migrating from rural areas to fringes and successively to core cities. Other aspects such as educational and employment opportunities, health facilities, better livelihood or higher standard of living and ease of commuting acts as major thriving force contributing to urbanisation. Haphazard dispersed development at the fringes of a city which attenuates resources as a consequence of large land use change (conversion of green lands, water bodies, parks, etc.) has become a serious issue to be addressed by the rapidly developing cities [4]. Characterizing sprawl has a varying approach and therefore making it difficult for the people to understand and measure effectively [5]. Numerous literatures [6-11] have indicated major causes for urban growth as geography of a region, economic growth, population growth and migration, industrialization, transportation, way of living etc. As on date there is a need for studying urban sprawl both temporally and spatially. With sustainability as primary goal, government and other agencies should plan, manage and develop a proper approach for designing the requirements of population growth and urban expansion. This research article employs spatial metrics, density gradient along with classified data which helps in monitoring land use changes especially to examine urban land use type [12-14]. The metrics used in this study includes: number of patches, normalized landscape shape index and clumpiness index. Various efforts have been put to understand spatio-temporal dynamics of urban growth in India. Large area of fertile and productive agricultural land were lost as a result of fragmentation due to industrialization, quarrying of sand, soil, stone etc. [15-18]. These literatures have quite well estimated changes in land use over a period of time. Findings of this research helps planners and decision makers to visualize pockets of urban growth and thereby minimizing the impacts on surrounding environment.

II. STUDY AREA

Hyderabad, the rapidly urbanizing city of Deccan plateau of India was chosen for the analysis. Presently Hyderabad is capital city for Telangana state and de facto capital for Andhra Pradesh after partition in the year 2014. Hyderabad lies on the banks of Musi River and surrounded by many water feeding lakes such as Osman sagar and Himayat sagar. With creation of special economic zones at Gachibowli, Pocharam, Manikonda etc. dedicated to information technology have encouraged companies from across India and around the world to set up operations. Erstwhile Hyderabad urban development authority (HUDA) was expanded in 2008 to form Hyderabad metropolitan area (HMA) covering 7100 km^2 and population of 7.74 million (2011). The location extents of Hyderabad region is depicted in figure 1.

Fig. 1 Study area: Hyderabad



III. DATA USED

Landsat data (30m x 30m) were downloaded from USGS Earth Explorer (http://earthexplorer.usgs.gov/). It was seen that cloud cover for all these satellite images were minimum and multiple year data were obtained for the same month to avoid seasonal variations. Imageries were also downloaded from Aster GDEM satellite. Spatial reference for all these data were WGS 1984, UTM zone 44. Data used are as listed in table 1.

Table 1 Materials and data used for the analysis.

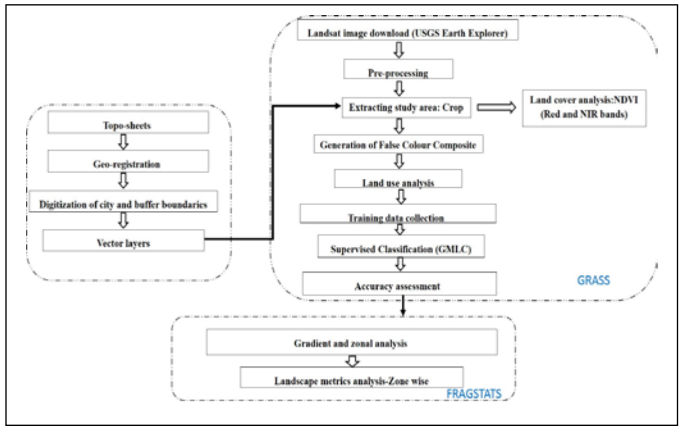
Data	Year	Purpose
Landsat	1989,1999, 2009, 2014	Land use and Land cover analysis.
Aster GDEM	2010	Extraction of Drainage lines, Slope analysis.
Google earth	--	Geo-correction, classification Validation of remote sensing data.
Survey of India Toposheets and Bhuvan data.	--	Base layers of the administrative boundary.

IV. METHOD

A. *Preprocessing*

Landsat satellite images of Hyderabad were acquired for different time period from Global Land Cover Facility and United States Geological Survey (USGS). The remote sensing data obtained were geo-referenced, corrected, rectified and cropped pertaining to the study area. The Landsat satellite images were resampled to 30m in order to maintain uniformity in spatial resolution. The study region considered included the administrative area and 10 km buffer from the administrative boundary. Multi step analysis was carried out as shown in figure 2.

Fig. 2 Methods involved in Urbanisation pattern analysis



B. *Land Cover Analysis*

Land cover analysis helps to understand the changes of the vegetation cover over the study area at different time periods. It is obtained by performing Normalised difference vegetation index (NDVI) which is formulated using NIR and Red bands. The values range from -1 to +1. Non vegetation features are indicated by the ranges -0.1 and below whereas water bodies have near zero values and vegetation features exhibit values +0.1 and above.

C. *Land Use Analysis*

Land use analysis was carried out using three bands (Green, Red and NIR) for creating false color composite (FCC) image. Training polygons and signatures pertaining to specific category were taken in FCC which covers at least 15% of the study area such that these polygons were well spread throughout. Ancillary data like GPS coordinates and Google earth data has been used to verify the ground truth. 60% of these training polygons were used for classification purpose while the rest 40% for validation and accuracy assessment. Supervised Gaussian Maximum Likelihood Classification (GMLC) was employed, since this algorithm is proved to be the eminent among other classifiers as it considers cost functions as well as probability density functions Land use classification was done with the help of open source software called GRASS (http://grass.osgeo.org/) under four categories shown in table 2. Accuracy assessment was performed to obtain error matrix. Overall accuracy and Kappa were computed.

Table 2Land use categories

Category	Features involved
Urban	Houses, buildings, road features, paved surfaces etc.
Vegetation	Trees, Gardens and forest
Water body	Sea, Lakes, tanks, river and estuaries
Others	Fallow/barren land, open fields, quarry site, dry river/lake basin etc.

D. *Density Gradient and Zonal Analysis*

To understand the growth locally specific to regions and neighborhood, the entire study area was divided into four zones i.e. North East, North West, South East and South West based on directions. In addition to zone division, each zone was divided into concentric circle from the centre with an increment of 1km (33 circles). These finely divided zones helps to interpret, quantify and visualize urbanisation pattern and agents responsible for the same at local levels spatially along with classified data [19].

E. *Landscape Metrics*

Zone wise computation of the metrics which included Number of patches (NP), Normalised land shape index (NLSI) and Clumpyness index (CLUMPY), as indicated in table 3 were performed using FRAGSTATS software.

Table 3 List of spatial metrics used

Sl.no	Indicators	Metric type and formula	Range
1	Number of patches- NP	NP = n (no. of patches in landscape)	NP>0, without limit
2	Normalised landscape shape index- NLSI	$NLSI = \frac{ei - \min ei}{\max ei - \min ei}$ 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. max e_i = maximum total length of edge.	$0 \leq NLSI \leq 1$
3	Clumpiness- CLUMPY	$\frac{Gi-Pi}{Pi}$ for $G_i<P_i$ and $P_i<5$; else $\frac{Gi-Pi}{1-Pi}$ Where, $G_i = \frac{gii}{(\sum_{k=1}^{m} gik) - \min ei}$ g_{ii}= number of like adjacencies between pixels of patch type (class) i based on double count method. g_{ik}= number of like adjacencies between pixels of patch type (class) i and k based on double count method. min ei= minimum perimeter of patch type (class) i for maximally clumped class. Pi= proportion of the landscape occupied by patch type (class) i.	$-1 \leq CLUMPY \leq 1$

V. RESULT AND DISCUSSION

A. *Land Cover Analysis*

Temporal vegetation cover analysis was done through NDVI. Figure 3 indicates the land cover changes in the year 1989, 1999, 2009 and 2014. Clear indication of vegetation declination can be seen from 95.64% in 1989 to 61.15% in 2014, whereas the non- vegetation i.e. built up, paved areas etc. have increased 4.36% in 1989 to 38.85% in 2014. To understand the land use categories like built up areas and non-vegetation areas clearly, land use analysis was performed.

Fig. 3 Vegetation cover changes from 1989 to 2014

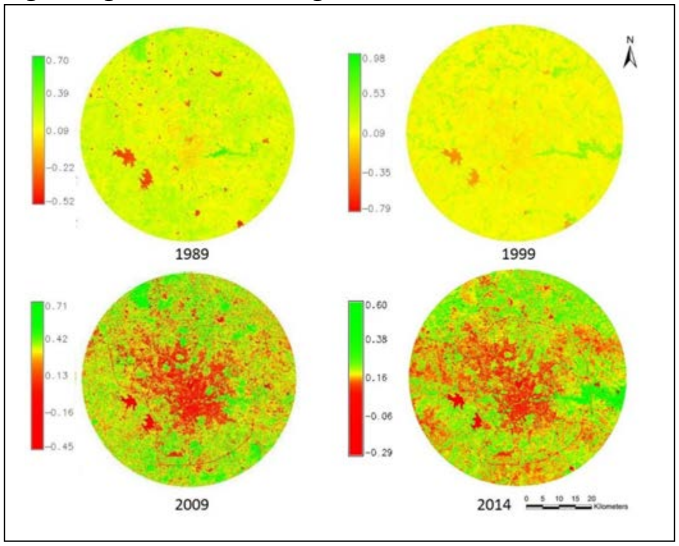


Table 5 Land cover changes 1989-2014

Year	Vegetation (%)	Non-Vegetation (%)
1989	95.64	4.36
1999	93.28	6.72
2009	82.67	17.4
2014	61.15	38.85

B. *Land Use Analysis*

GMLC supervised classification technique was employed to perform land use analysis by considering four major categories. Figure 4 represents land use dynamics for Hyderabad region in past 4 decades with significant changes in all categories. An alarming increase in built up areas were observed. Land use statistics is as tabulated in table 6. Overall accuracy obtained for the classification ranged from 87% to 94%. Both overall accuracy and kappa statistics are listed in table 7.

Table 7 Overall accuracy and kappa statistics

Year	Overall Accuracy (%)	Kappa
1989	94	0.73
1999	87	0.85
2009	90	0.90
2014	91	0.76

Fig. 4 Land use dynamics from 1989 to 2014

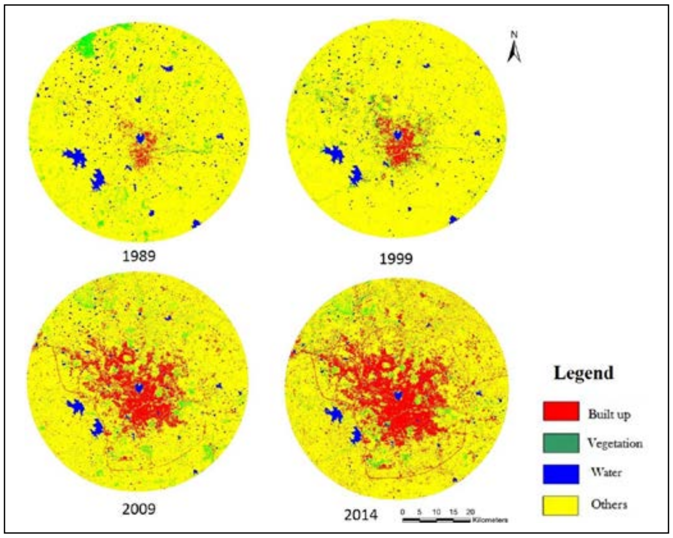
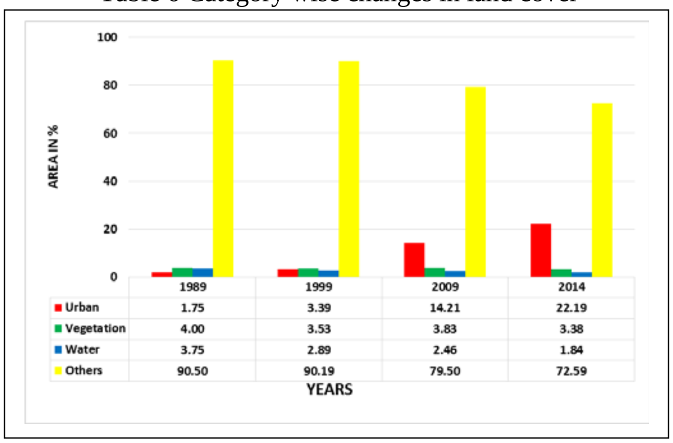


Table 6 Category wise changes in land cover



	1989	1999	2009	2014
Urban	1.75	3.39	14.21	22.19
Vegetation	4.00	3.53	3.83	3.38
Water	3.75	2.89	2.46	1.84
Others	90.50	90.19	79.50	72.59

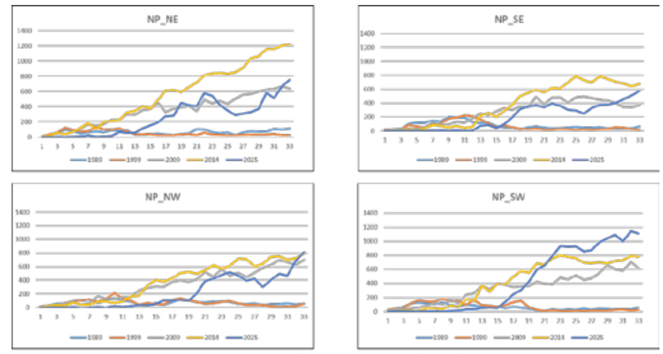
C. Landscape Metrics

Landscape metrics were calculated for each zone and gradient study region.

Number of Patches (NP) indicates count of urban or built up patches. Figure 5 shows patches have increased in all periods of time but year 2009 and 2014 shows rapid growth in all the directions pointing out fragmentation in these years appear to be more. It is to be observed that in 2014, core city area (circles 1-11), each patch has agglomerated into a single large urban patch i.e. there is a saturated urban landscape with no other landscape type.

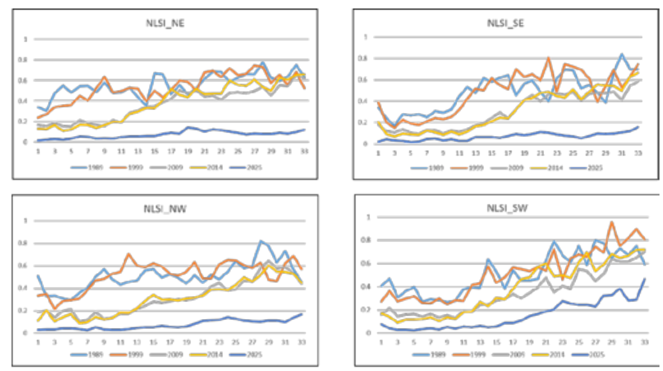
Normalized landscape shape index provides measure of class aggregation. All four zones shows lesser value of NLSI in 2014 compared to 1989 as seen in figure 6. These minimum values (NLSI < 0.5) points out that the landscape consists of a single square urban patch or it is maximally compact (i.e., almost square) in contrast with the higher values in 1999 (NLSI ≈ 1) specifying that the urban patches are disaggregated maximally with complex shapes.

Fig. 5 Number of patches – Direction and circle wise



X-Axis: Concentric circles at 1Km: Y-Axis: Metric values.

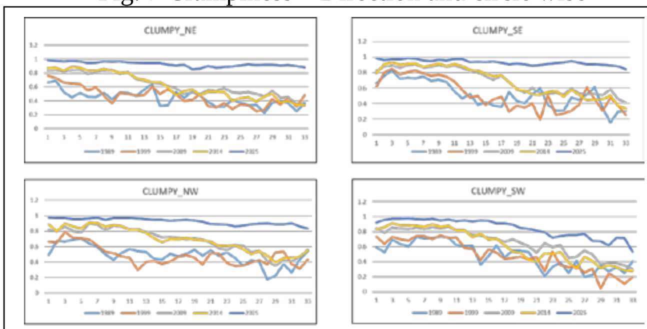
Fig. 6 NLSI – Direction and circle wise



X-Axis: Concentric circles at 1Km: Y-Axis: Metric values.

Clumpiness deals with aggregation and disaggregation for adjacent urban patches. Referring to figure 7, 1989 the values closer to 0 (circles 23-31, in NE, SE, SW directions) indicates less compact growth or maximum disaggregation. In 2014 curve shows values approaching +1 in all directions, especially in core city areas (circles 1-15) which means to say that the growth is very complex and all the patches are maximally aggregated to form large urban monotype patch.

Fig. 7 Clumpiness – Direction and circle wise



X-Axis: Concentric circles at 1Km: Y-Axis: Metric values.

VI. CONCLUSION

The escalating inappropriate growth of urban landscape has been a major concern in metropolitan cities of India due to poor environmental and living conditions in rapidly urbanizing landscapes. This research article clearly shows the land cover dynamics between the years 1989-2014, generated using vegetation index for Hyderabad. Outcome of this analysis indicate decrease in green cover suggesting increase of non-vegetative land use types. Further land use analysis demonstrated the rapid changes in landscape, especially the urban areas found to be spread over 75768 ha (2014) in Hyderabad region. Density gradient and spatial metrics output also revealed that the growth pattern of Hyderabad is sprawling in the periphery, especially along the highway road networks. The process of densification has spread out of the core during 1990's as well as they have started to get clumped during 2010's. Validated data outputs and findings of this research insists governmental agencies, planners and decision makers to emphasize more on implementing growth strategies for spatial development in future and accordingly thenecessary measures could be adapted to control or mitigate the negative potential impacts on the urban environment.

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