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Zonal-Level Urban Sprawl Analysis using Digitally-Merged Resourcesat-LISS IV and Cartosat-PAN Bitemporal Data

Prakash C.R.[1], Sreedevi B.[2], Kishore K.Y.[1], Venkatesh J.[1], Dwivedi R.S.[1] and Mahbooba Asra[1]

[1]Centre for Spatial Information Technology, Institute of Science and Technology, Jawaharlal Nehru Technological University, Kukatpally, Hyderabad, Telangana, India
[2]Directorate of Rice Research, ICAR, Rajendranagar Mandal, Hyderabad, Telangana, India

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Abstract Remote sensing and GIS along with collateral data help analyzing the growth, pattern and extent of urban sprawl. With such a spatial and temporal analyses, it is possible to identify the pattern of sprawl and subsequently predict the nature of future expansion. The article brings out the extent and spatial distribution of urban sprawl over a period of six years i.e. 2005-2011 using Resourcesat-1 LISS-IV and Cartosat-1 PAN data over Hyderabad metropolitan city, Telangana state, India. The approach comprises data preparation-radiometric normalization, geo-referencing and image fusion; on-screen visual interpretation, and change analysis in a GIS environment. The study reveals that the built-up land have expanded by 8.65% during the 6-year period. Furthermore, in terms of growth, the high density built-up land score over their low density counterpart (5.7% versus 2.96%). Such a growth could happen at the cost of scrubs, cropland and barren/rocky area to a great extent and at the expanse of water bodies to a lesser extent. An estimated 65.294 sqkm of scrubs, 40.319 sqkm of cropland and 14.523 sqkm of barren/rocky areas have been transformed into settlements. Data used, methodology employed and the results of the study are discussed in detail.
Keywords *Change Detection; Land Use/Land Cover; Remote Sensing; Urbanization*

1. Introduction

Urbanization is a worldwide phenomenon. All mega cities are rapidly growing due to various factors including population increases, industrialization and rural-urban migration. However, it is more prevalent in India due to high growth rate over last few decades (Taubenbock, 2008). Furthermore, such growths are unplanned and haphazard resulting thereby in significant impact on pressure on land, water and environment. The process is termed as urban sprawl. The urban sprawl refers to the spreading of urban developments (as houses and shopping centers) on undeveloped land near a city (Merriam-Webster, 2015). “Urban sprawl may be defined as the scattering of new development on isolated tracts, separated from other areas by vacant land” (Ottensmann, 1977). It is also often referred to as leapfrog development (Gordon and Richardson, 1997). Reliable and timely information on spatial extent, distribution and temporal behavior of built-up land apart from other features like vegetation and water resources is pre-requisite for urban planning and development. By virtue of synoptic coverage of fairly large area at regular intervals, spaceborne spectral measurements hold a great promise in deriving such information in a timely and cost-effective manner. Remote sensing techniques have proven very useful in urban mapping (Batty, 2008). Apart from spatial extent and distribution of built-up lands recently the emphasis has been more on detecting changes or studying the dynamics of such growth.

The change detection refers to the process of identifying differences in the state of an object or phenomenon by observing it at different point of time (Singh, 1989). In the context of remote sensing' the changes in the object/ feature/ phenomenon translates into corresponding changes in their spectral behaviour (reflected/ emitted/ scattered radiation) after accounting for the effects of other factors, namely atmospheric conditions, illumination and viewing angles, and soil moistures (Deer, 1995; Jensen, 1983; Singh, 1989). Owing to its high temporal frequency, digital format suitable for computation, synoptic view, and wider selection of spatial and spectral resolutions spaceborne multispectral images have been routinely used in change detection studies (Chen et al., 2012; Coops et al., 2006; Lunetta et al., 2004).

Due to the complex spatial arrangement and spectral heterogeneity even within the same class, coarser and medium resolution satellite images are inadequate for detailed change detection in urban agglomeration. High spatial resolution multispectral images have been used for automated change detection (Bouziani et al., 2010). High and very high spatial resolution satellite images, obtained from QuickBird, IKONOS, and SPOT-5, Resourcesat-1 and -2, Rapid Eye, Cartosat-1, -2, -2A, -2B etc., can provide a large amount of detailed information on terrain features in a timely manner. Study was taken up to study the sprawl of Hyderabad city during the period 2005-2011 using Resourcesat-1 LISS-IV and Cartosat-1 PAN data

2. Test Site

Covering a geographical area of around 1500 sqkm the test site - Hyderabad city –the test is bound by geo co-ordinates 17^{o}12'00" N to 17^{o}37'00" N and 78^{o}16'00" E to 78^{o}42'00" E. It has been divided into five zones, namely East zone, West zone, North zone, South zone and Central zone which includes the entire area of Municipal corporation of Hyderabad (MCH), Secunderabad cantonment and Osmania campus (OU), and parts of administrative units of Ranga Reddy, Medak, Nalgonda and Mahabubnagar districts of Telangana state. Musi River traverses the area; dividing the twin cities (Hyderabad and Secunderabad). The city experiences a hot semiarid moist climate with dry summers and mild winters. Mean annual temperature varies from 25^{o}-29^{o}C while mean summer (April - June) temperature varies from 32^{o} to 34^{o}C with a maximum of 39^{o}C in May. Mean winter (December – February) temperature varies from 20^{o}-24^{o}C. Average annual rainfall is 764 mm while PET varies from 1700-1800 mm. Soils are essentially red loam (Rhodustalf, Paleustalf and Haplustalf groups) varying from sandy loam to loamy sand with heavy compact subsoil (Staff, NBSS & LUP, 2002). Natural vegetation is tropical dry deciduous and tropical thorn forest with *Acacia*, *Azadirachta* and *Tectona* as dominant species. The region comprises of a number of water bodies namely Musi River, Osman Sagar, Himayat Sagar, Hussain Sagar, Shamirpet and Uppurguda, etc.

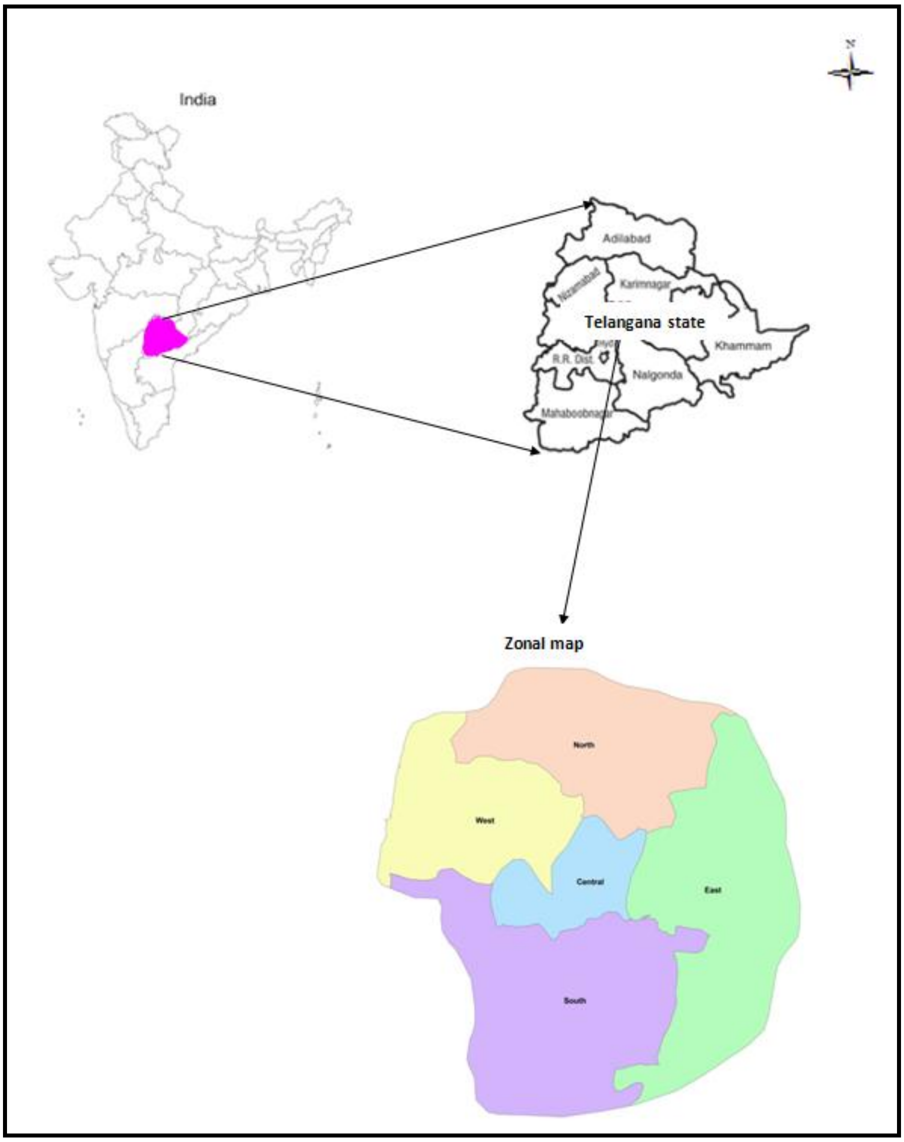

Figure 1: *Location Map of the Test Site*

3. Dataset

For realizing the objectives of the study temporal satellite images, topographic maps and Google Earth images have been used.

3.1. Satellite Data

As the study envisages zonal-level monitoring of city's sprawl, Resourcesat-1 LISS-IV multispectral data and Cartosat-1 PAN data for the period 2005 and 2011 were used. The details of the data used and salient features of the sensors are given in Table 1.

Table 1: *The Details of Satellite Data Used*

Sl. No	Satellite	Sensor Mode	Resolution	Path/Row/ Orbit	Year	Source
1	IRS P6, Cartosat-1	LISS IV- MX PAN-A/F	5.8 m 2.5 m	37852/37923 544/315 545/316	2005	NRSC
2	IRS P6, Cartosat-1	LISS IV- MX PAN-A/F	5.8 m 2.5 m	37852/37923 544/315 545/316	2011	NRSC

LISS-IV Sensor

The LISS-IV sensor is a push-broom sensor operating in three spectral bands, viz., 0.52 to 0.59 µm, 0.62 to 0.68 µm and 0.76 to 0.86 µm with a spatial resolution of 5.8 m at nadir and a 23.9km swath (Table 2). The sensor can be operated in either mono (single spectral band) or multi-spectral modes. In mono mode, a swath of 70 km can be imaged in one of the three multispectral bands. The unique feature of the sensor is its off-nadir viewing capability. The sensor can be tilted =/-26^0 off-nadir thereby providing 5day revisit for any area on the ground.

Table 2: *Salient Features of LISS-IV Sensor*

IGFOV (Across track)	5.8 mt
Ground sampling distance	5.8 mt
Spectral Bands	B2, B3, B4
Swath	23.9 km (Multi Spectral Mode) 70 km (Mono mode)
Saturation radiance (mw/cm 2 /sr/micron)	B2 – 55 B3 – 47 B4 - 31.5
Integration time	0.877714 msec
Quantization	10 bits Selected 7 bits will be transmitted by the data handling system
No. of gains	Single gain (Dynamic range obtained by sliding 7 bits out of 10 bits)

Cartosat-1 – Panchromatic Sensor

Cartosat-1 is a remote sensing satellite dedicated mostly to large scale mapping including generation of digital elevation model (DEM). There are two Panchromatic cameras operating in 0.50-0.85 µm region (in panchromatic mode) of the electromagnetic spectrum. The PAN camera is essentially a push broom scanning type of sensor with 30 km swath and 2.5 m a spatial resolution. The cameras capture near simultaneous images of the same area along the track from two different opposite angles -26^0 and 5^0 from the nadir facilitating thereby in colleting stereo images. Whereas forward looking camera (fore) is tilted at 26 degree the backward looking camera (aft) is tilted 5 degree from nadir. The PAN sensors can be steered in cross track direction to have more frequent ground coverage

3.2. Ancillary Data

The Survey of India topographic maps at 1:25,000 scale covering Hyderabad metropolitan city and its environs. Besides, Google Earth images, and mosaic of LISS-IV data acquired on 20th May, 2011 were used in map finalization.

4. Approach

4.1. Data Preparation

This step consists of geo-referencing, radiometric normalization and data fusion

4.1.1. Geo-Referencing

Remote sensing digital images have pixel as a unit-the building block of the image. Any location/feature in the image is addressed in term of scan lines (rows) and pixels (columns). Each cell is called pixel. For locating any ground feature it needs to be converted into topographic map co-ordinates (latitude and longitudes). The process of converting pixel co-ordinates into map co-ordinates (also called geo-co-ordinates) is referred to as geo-referencing or geocoding. It is achieved by identifying well distributed terrain/ ground features identifiable onto the image as well as on the digital topographic maps. These points are generally referred to as ground control points (GCPs). Remote sensing images have some inherent geometric errors resulting from earth rotation, earth curvature, terrain relief and platform attitude. These errors can be rectified by geo-referencing the image to map co-ordinates using ground control points, and suitable mathematical models such as polynomial transformation model which converts the image co-ordinates into map co-ordinates. It is achieved in several iterations until geometric registration to the tune of sub-pixel is achieved. We have used third order polynomial is used for all scenes with a sub-pixel accuracy.

The output was re-sampled to 6m pixel dimension for LISS-IV and 2.5 m in case of Cartosat-1 PAN data. Re-sampling is the process of extrapolating data values for the pixels on the new grid from the values of the source pixels using a geometric transformation. The transformation matrix is computed from the given ground control points (GCPs). This matrix consists of coefficients that are used in polynomial equations to convert the coordinates. The size of the matrix depends upon the order of the transformation. Depending upon the distortion in the imagery, the number of GCPs is defined and their locations relative to one another are calculated. Complex polynomial equations may be required to express the needed transformation. The degree of the polynomial is the highest exponent used in the polynomial. We have performed the nearest neighbor resampling approach which transfers the original data values without averaging them. The extremes and subtleties of the data values are generally preserved.

4.1.2. Radiometric Normalization

Although several atmospheric correction models are available due to paucity of the inputs required for modeling, a bulk correction approach, viz. dark object subtraction (DOS) method was followed. In this approach it is assumed that each band of data for a given scene should have contained some pixels at or zero brightness values but that atmospheric effects, especially path radiance has added a constant value to each pixel in a band. In order to compensate for this effect, the image features with almost constant brightness values, for example water bodies, was selected and histogram taken. Since water bodies exhibit almost total absorption of incidence radiation in the near infrared region, brightness values in excess of zero were subtracted from all the spectral bands of the image. Similar exercise was done for LISS-IV data of 2011 too.

4.1.3. Digital Image Fusion

The image fusion is done essentially for sharpening a lower-spatial resolution multispectral image by combining it with a higher-spatial resolution panchromatic image. In this process the spectral resolution is preserved while a higher spatial resolution is incorporated, which represents the information content of the images in much more detail (Franklin and Blogett, 1993; Pellemans et al., 1993). We have used the principal component (PC) transform to retain the spectral information of the multispectral image. The principal component (PC) transform is a statistical technique that transforms a multivariate dataset of correlated variables into a dataset of uncorrelated linear combinations of the original variables. It creates an uncorrelated feature space that can be used for further analysis instead of the original multispectral feature space. The PC was applied to the LISS-IV multispectral data. The panchromatic image (PAN) was histogram matched to the first principal component and was then used to replace the first component and an inverse PC transform takes the fused dataset back into the original multispectral feature space (Chavez et al., 1991). Replacing the first principal component with a high spatial resolution image, a multichannel dataset can be transformed into a spatial resolution image of higher ground resolution. The process is termed as Principal component substitution-PCS (Shettigara, 1992). The advantage of the PC fusion is that the number of bands is not restricted (such as for the original IHS or Brovey fusions). It is, however, a statistical procedure which means that it is sensitive to the area to be sharpened. The fusion results may vary depending on the selected image subsets (Jensen, 2005).

4.2. Visual Interpretation

Preliminary visual interpretation, ground truth collection, map finalization and change detection comprise visual interpretation.

4.2.1. Preliminary Visual Interpretation

The detection and delineation of urban LULC through visual interpretation approach, is based on image elements viz. tone/ colour, size, shape, texture, pattern shadow, association and convergence of evidence. This, in turn, is a cumulative effect of terrain relief, vegetation cover, wetness, etc. Since not only image elements but also associations in terms of terrain conditions, are taken into consideration while delineating urban LULC, instead of computer-assisted digital analysis approach, on-the-screen visual interpretation approach was employed. Owing to higher spatial resolution (2.5m) within built-up land three categories, namely high, medium and low density settlements could be tentatively delineated apart from other associated features like cropland, scrubs, barren/rocky areas and water bodies.

After geo-referencing and radiometric normalization, digital fusion of LISS-IV and Cartosat-1 PAN data, the areas likely to experience waterlogging and soil salinity and/alkalinity were broadly identified, based on their spectral behavior, and ancillary information and the terrain conditions by displaying it onto a colour monitor of the Silicon Graphics work station. Subsequently, the sample areas to be verified in the field were identified and precisely located on the Survey of India topographical maps of 1:25,000 scale.

4.2.2. Ground Truth Collection

Initially, a reconnaissance traverse of the area was made to assess the trafficability and to precisely locate sample areas. Having located sample areas, parcels of land which were interpreted as different urban LULC categories were precisely marked onto the topographical maps and observations with respect to density of settlements, terrain conditions, were made after recording their precise location with the help of a Global Positioning System (GPS) receiver model Magellan GPS ProMark-X.

Observations were, however, also made outside the sample areas randomly, in order to validate the relationship already established between image elements various LULC categories on the ground.

4.2.3. Map Finalization

The ultimate delineation of various urban LULC categories from spaceborne multispectral data was accomplished through on - the - screen visual interpretation of satellite data on a Silicon Graphics work station using ERDAS/ IMAGINE software version 8.4. To begin with the Resourcesat-1 LISS-IV and Cartosat-1PAN –merged data of 2011 was displayed onto system monitor and a blank vector layer was overlaid onto the image. Various LULC categories delineated during preliminary visual interpretation, were then located in the image, their boundaries drawn in the vector layer which was already superimposed over satellite image, vis-a-vis field observations, relief information from topographical maps, ground truth and Google Earth images. Similar exercise was carried out for delineation of various LULC categories from LISS-IV and Cartosat-1 PAN-merged data of 2005 too.

4.2.4. Map Compilation and Area Estimation

As mentioned earlier, various LULC categories were delineated using ERDAS/ IMAGINE version 8.4 software, and the vector coverage was generated and its topology built. Corrections were then carried out wherever necessary. Final coverage was unioned with the zonal boundary coverage to generate unique polygons having zones as well as LULC categories (IDs). This process helped in generating class as well as zone-wise area statistics.

4.2.5. Change Detection

The matrix operation module available in GIS analysis menu allows the comparison of two thematic maps or vector files of different years. By comparing two classified or vector sets of data, we can eliminate false positives due to radiometric differences. In an attempt to study changes in the spatial and temporal distribution of various LULC categories, LISS-IV and PAN-merged data of 2005 was used as a reference. The vector data was created in ArcGIS 9.2 using Editor tool and vector data was attributed according to different classes viz. crop land, low dense built-up land, water bodies, high density built-up land, open scrub land and barren/ rocky land by visual interpretation from resolution merge image. The matrix operation in GIS analysis menu present in the ERDAS software was used to find out changes between two seasons. The matrix operation compares all the classes of image with all classes of another image and shows the change or transformation of one class to another class.

5. Results and Discussion

As mentioned earlier, zone-wise LULC maps of the test site were prepared for 2005 and 2011, and were ultimately compiled for entire city. It is interesting to note that not only changes in the spatial extent and distribution of individual LULC category but also the kind of transformation that has taken place therein, is vividly portrayed. That is, an individual LULC category, for example, cropland whether there has been a shrinkage or otherwise in the spatial extent and distribution. If so, which category of land use land covers it has been transformed into. Since changes in LULC categories are not uniform throughout, individual zone-wise land use land cover dynamics is described hereunder:

5.1. Central Zone

The central zone of Hyderabad and its fringe areas cover an area of about 113.846 km^2. As it has already been developing since long there has been very little scope for further development. Consequently the changes in the spatial extent and distribution have been marginal. The spatial extent of cropland has shrunken during 2005 and 2011 to the tune of 0.778 km^2 (Table 3). The transformation has taken place in the south–western portion (Figure 2).

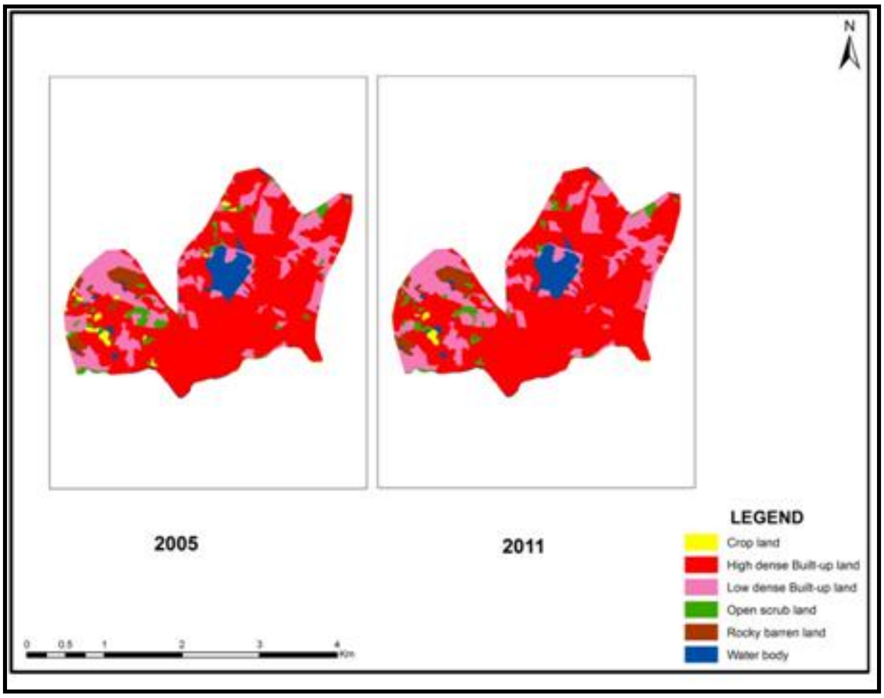

Figure 2: *Land- Use Land- Cover Maps of Central Zone during 2005 and 2011*

Similarly, open scrubs and rock outcrop have been converted into built-up land. The shrinkage in the area under these two categories accounts for 0.52% and 0.25%, respectively. In terms of hectare it comes to 59.6ha and 28.1ha, respectively. Contrastingly, both high and low density built-up land has registered an increase in their spatial extent of the order of 3.2ha and 16.6ha, respectively.

Table 3: *Temporal Behavior of Various Land Use Land Cover Categories in Central Zone*

Central Zone	2005		2011	
Class name	Area(km^2)	Area (%)	Area(km^2)	Area (%)
Cropland	1.332	1.17	0.554	0.48
Low density built-up land	25.293	22.21	25.325	22.24
Scrubs	4.175	3.66	3.579	3.14
Water bodies	5.871	5.15	5.829	5.12
High density built-up land	73.971	64.97	75.637	66.43
Barren/rocky	3.204	2.81	2.923	2.56
Total	113.846	100	113.847	100

5.2. East Zone

The city's east zone its fringe areas cover a geographical area of 412.685 km^2. It borders the rural areas along the eastern periphery. It is the peripheral area that has been converted into built-up in due course of time as the city grew up. Croplands are confined mostly to eastern periphery of the zone (Figure 3). During the period 2005 to 2011 an estimated 36.22 sqkm accounting for 8.85% of the cropland has been converted to built-up land including both low as well high density structures (Table 4). Furthermore, there has been concomitant increase in the built-up land during the same period viz., 88.729 sqkm in 2005 versus 118.81 sqkm in 2011. The increase is to the extent of 7.73%. In fact, share of growth for both low as well as high density built-up land is almost same i.e. 3.45% for low density built-up land and 3.84% for high density built-up land. Water bodies especially ephemeral, small shallow ones have been transformed to built-up resulting thereby in a decrease in their spatial extent. Water bodies covering an estimated 346 ha of area have been converted into built-up land.

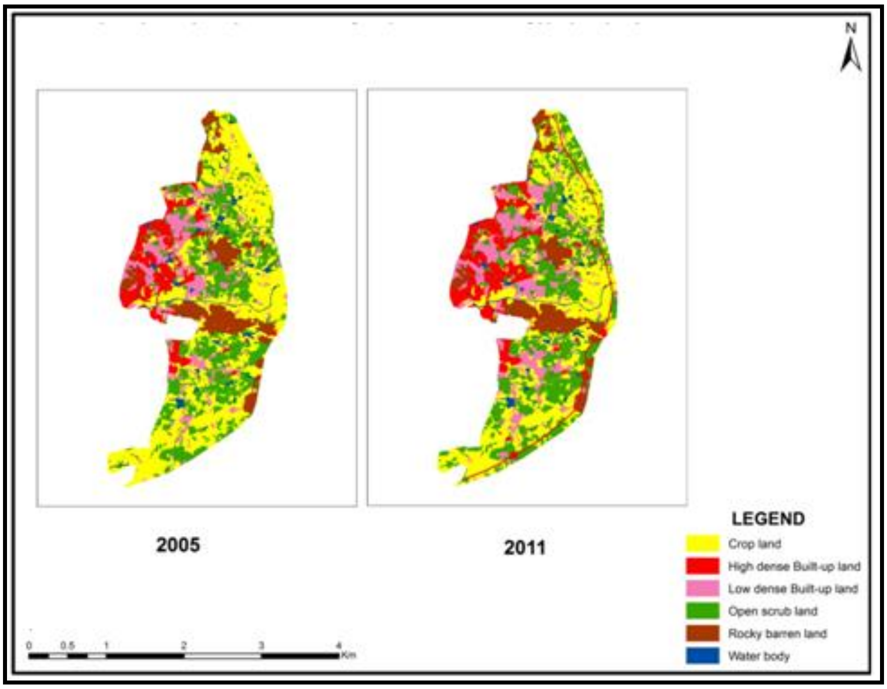

Figure 3: *Land Use Land Cover Changes in East Zone*

Table 4: *Temporal Behavior of Various LULC Categories for East Zone*

East Zone	2005		2011	
Class name	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Cropland	167.447	40.57	131.125	31.77
Low density built-up land	52.617	12.74	66.832	16.19
Scrubs	101.417	24.57	112.515	27.26
Water bodies	13.616	3.29	10.16	2.46
High density built-up land	36.112	8.75	51.978	12.59
Barren/rocky	41.476	10.05	40.074	9.71
Total	412.685	100	412.684	100

5.3. West Zone

The West zone and its fringe areas cover an area of about 241.579 km^2. Like other zones in this zone to the built-up area has been expanded at the cost of mainly cropland and barren/rocky areas. Whereas the area under cropland has shrunken by 6.03%, the reduction in the area under barren/ rocky land has been to the tune of 5.02% (Table 5). The changes in the spatial extent of cropland are quite conspicuous along the south-western fringe of the city (Figure 4). Interestingly, the built-up land has expanded from 101.746 sqkm in 2005 to 129.729 sqkm- an increase of 11.583% during 6 years period. Furthermore, the increase in the spatial extent of low density built-up has been more in comparison with high density built-up land: 3.70% and 7.89%, respectively.

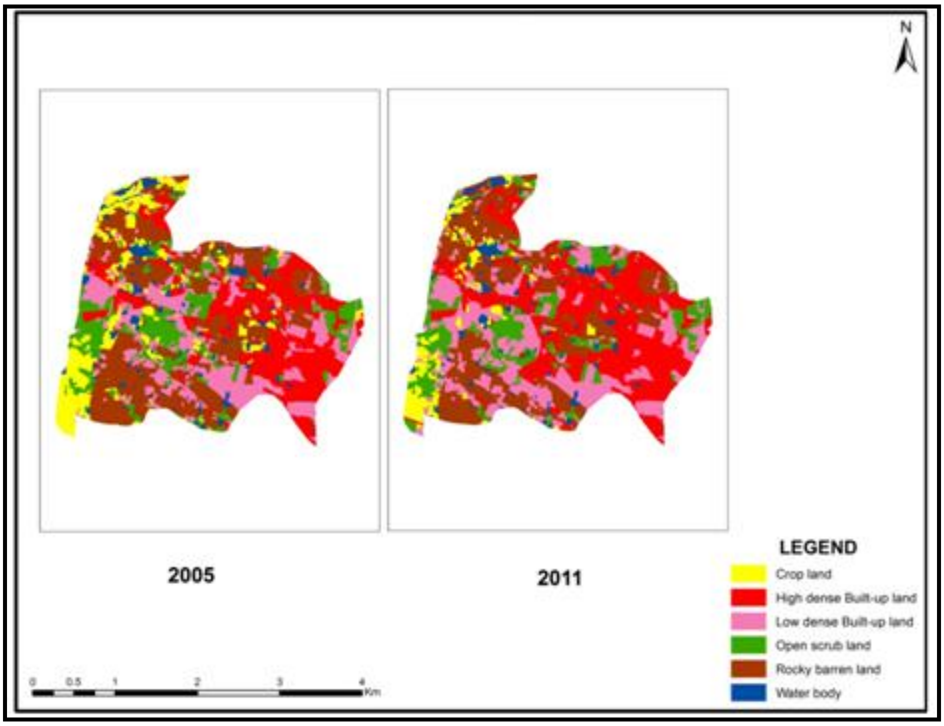

Figure 4: *Changes in LULC Categories in West Zone*

Table 5: *Temporal Behavior of various LULC Categories in West Zone*

West Zone	2005		2011	
Class name	**Area (km^2)**	**Area (%)**	**Area (km^2)**	**Area (%)**
Crop land	27.991	11.58	13.41	5.55
Low density built-up land	47.972	19.85	56.897	23.55
Scrubs	33.855	14.01	33.283	13.77
Water bodies	10.358	4.28	9.665	4.00
High density built-up land	53.774	22.25	72.832	30.14
Barren/rocky	67.629	27.99	55.492	22.97
Total	241.579	100	241.579	100

5.4. North Zone

Like other zones, in this zone to cropland and barren rocky lad have been converted into built-up land. The Built up area comprises of Low dense built up land and High dense built up land. Similarly, the area under barren/rocky which was 51.565 km^2 (17.71%) in 2005 has been reduced to was 40.58 Km^2 (13.93%) in 2011. In contrast, the area under built-up land has risen from 82.674 sqkm in 2005 to 120.916 sqkm in 2011 (Table 6). The changes in the area under cropland are more conspicuous northern periphery abutting rural area (Figure 5).

Figure 5: *Changes in LULC in North Zone*

Table 6: *Temporal Behavior of various LULC Categories in North Zone*

North Zone	2005		2011	
Class Name	**Area (km^2)**	**Area (%)**	**Area (km^2)**	**Area (%)**
Cropland	79.858	27.42	59.38	20.39
Low density built-up land	47.68	16.37	64.666	22.20
Scrubs	67.958	23.34	71.632	24.60
Water bodies	9.107	3.12	8.654	2.97
High density built-up land	34.994	12.01	46.25	15.88
Barren/rocky	51.565	17.71	40.58	13.93
Total	291.162	100	291.162	100

5.5. South Zone

The encroachment of cropland by built-up land in the southern fringe is by far the most striking feature of this zone (Figure 6). The reduction in the area under cropland during 2005 to 2011 has been to the tune of 8.42%. Shallow and ephemeral ponds have been another target for urbanization. There has been concomitant increase in built-up land to the tune of 37.884 sqkm during the period 2005 to 2011 (Table 7). However, the reduction in the area of water bodies and scrubs has been to a very limited extent.

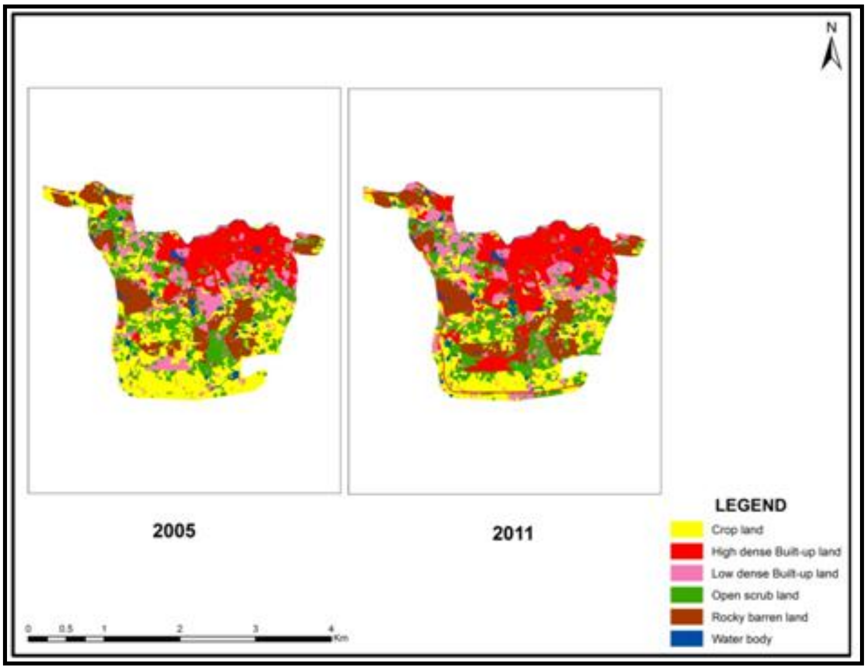

Figure 6: *Changes in LULC Categories in South Zone*

Table 7: *Temporal Behavior of Various LULC Categories in South Zone*

South Zone	2005		2011	
Class name	**Area (Km^2)**	**Area (%)**	**Area (Km^2)**	**Area (%)**
Crop land	127.92	29.77	91.753	21.35
Low density built-up land	62.449	14.53	66.296	15.43
Scrubs	83.755	19.49	82.482	19.20
Water bodies	16.31	3.79	14.959	3.48
High density built-up land	76.456	17.79	112.493	26.18
Barren/rocky	62.684	14.59	61.591	14.33
Total	429.574	100	429.574	100

5.6. Overall Changes in LULC

An analysis of the area under various LULC categories indicate that there has been an increase in the area under built–up land to the tune of 128.891 sqkm, accounting for 8.65% of the total geographical area of the city during six year period. Interestingly, the increase in the extent of high density built-up land has been more as compared to low density ones (8.7% versus 2.95%). The growth of the city's agglomeration has been at the expense of other LULC categories especially scrubs, cropland, barren/rocky and water bodies. An estimated 40.319 sqkm of cropland have been converted into built-up land including both high as well as low-density built-ups. Similarly, other LULC categories, namely, scrubs, barren/rocky and water bodies too have been used for settlements. The areas of these categories have been estimated at 65.294 sqkm, 14.523 sqkm and 0.987 sqkm, respectively.

6. Conclusions

Like any other metropolitan city, Hyderabad too has not been exception to phenomenal growth. In this process peripheral areas (rural urban fringe) with cropland and other land uses are affected the most. Our study has revealed such changes at zonal level. It has been shown that the city grew by 8.65% over a period of 6 years. The growth has been more in case of high density built-ups as compared to low density ones. Whereas the high density built-ups have grown by 5.7%, only 2.95% growth has been registered in case of low density built-ups. Furthermore, amongst the LULC categories affected most, scrubs rank first followed by cropland, barren/ rocky and water bodies. The expansion of the city at the expanse of cropland and water bodies is certainly detrimental to environmental health and also to the livelihood of rural poor.

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