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Dynamics of Rapid Urbanization of Bangalore and Its Impact on Land-Use/Land-Cover – A case study of Vrishabhavathi sub-watershed

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Abstract - *Urban growth is a global phenomenon that comes with human settlements and accompanying anthropogenic activities plays an important role in the land use and land cover change. The city of Bangalore grew to 716 Km² in 2007 with the creation of Bruhat Bangalore MahanagaraPalike (Pavan Srinath, 2014).The rapid urbanization in last four decades resulting in increase of paved area and decrease in agricultural land area which used to act as a percolation zone. It has also brought reduction in arable land, forest land and water bodies. The change of Land cover and land use in major cities is one of the major reasons for climate change.*

The paper is focused on change in Land cover and Land use that have taken place in Vrishabavathi sub-watershed (Upstream of Gali Anjaneya Temple of Bangalore) from 1973 to 2014 by using remote sensing and GIS techniques. The conclusions are drawn based on analyzing the multi-temporal and multi-spectral Landsat satellite images. The Landsat MSS satellite images for the year 1973, Landsat - thematic mapper (TM) satellite images for the year 1992, and Landsat - Enhanced Thematic mapper plus (ETM+) satellite images for the years 2001 and 2014 have been utilized to quantify the land-use /land-cover changes and the trend of urban growth in study area. The pattern of change in land use and land cover (LULCC) is obtained using four quantitative indices: Landuse/Landcover (LULC) Change Intensity Index (T_i), Dynamic Index (K_i), Integrated Index (L_d), and Rate of Change Index (A_i). These indices critically analyse the extent, rate, as well as the magnitude f change amongst the various LULC in the study area and provide a basis for comparison with other places and explain the nature of spatio-temporal dynamics of LULC as an Index of land degradation. The four indices computed for the study region determines the intensity with which the land surface and land cover is subjected change due to human activities. The Land-use/land-cover change due to new built-up area is found to be 13 % between 1973 and 1992, 3 % between 1992 and 2002, 11 % and between 2002 and 2014. The Annual growth rate of built-up area for these study years was 0.65% between 1973 and 1992 and 0.55 % between 2002 and 2014 respectively. The land-use/land-cover change statistics showed that the annual conversion rate of agricultural land and barren land to built-up area between 2002 and 2014accounted for more than 1%.

Key Words: Urban growth analysis, Land use, Land cover, Change detection, Multi-temporal satellite images, index

1.INTRODUCTION

It is generally believed that urbanization has both direct and indirect impacts on land use transformation. The urban sprawl is one of the most noticeable effects of urbanization on land use (Bhagwat Rimal, 2014). In the fast developing countries like India, there is a mass migration of people from rural to urban and also from smaller to bigger urban areas and then to metropolises like Delhi, Bangalore, Chennai, Mumbai etc. Bangalore urban areas and their urban rural linkages in recent past have experienced high dynamics of human influence and change in the land use and land cover patterns. Understanding the dynamical pattern of urbanization and identify the land use and land cover change analysis is one of the important parameter to assess the global change at various spatial–temporal scales (Lambin 1997). In addition, it reflects the dimension of human activities on a given environment (Lopez et al. 2001).

Remote sensing and GIS have proved to be effective means for extracting and processing varied resolutions of spatial information for monitoring urban growth [Masser I, 2001]. The analysis of urban growth remains a major topic using GIS and remote sensing. The spatial and temporal dimensions are major concerns of GIS and remote sensing. Modelling spatial and temporal urban growth enriches the spatial science of GIS. Methodological research into urban growth can contribute in improving current GIS, in particular its spatial analysis and modeling functions such as exploratory spatial data analysis and spatial econometrics [Goodchild, 2000, Jianquan Cheng, 2013]. Urban areas contain very complex land use structures. The objective of the study is to determine change of land use and land cover in the Vrishabhavathi sub-watershed (upstream side of Gali Anjaneya Temple, Bangalore city, A = 38 Km²).

2. STUDY AREA

Bangalore city is capital of Karnataka State. It is one of the major metropolitan cities of India and it is recognized as Capital of IT city in India. The study area Vrishabhavathi sub-watershed upstream side of Gali Anjaneya Temple is lies (Latitude 13⁰1'11" N and 70⁰32'6" E Longitude) in the Southern part of the Bangalore city, Karnataka, India. The study area is covering a total area of about 38.38 Km²(Figure1). The mean annual total rainfall is about 880 mm with about 60 rainy days/year in last 40-years. The summer temperature ranges from 18°C to 38°C, while the winter temperature range from 12°C to 25°C.The SOI Topo-sheet numbers 57/H 9 and 57/H/ 9/1 are used to delineate the boundary.

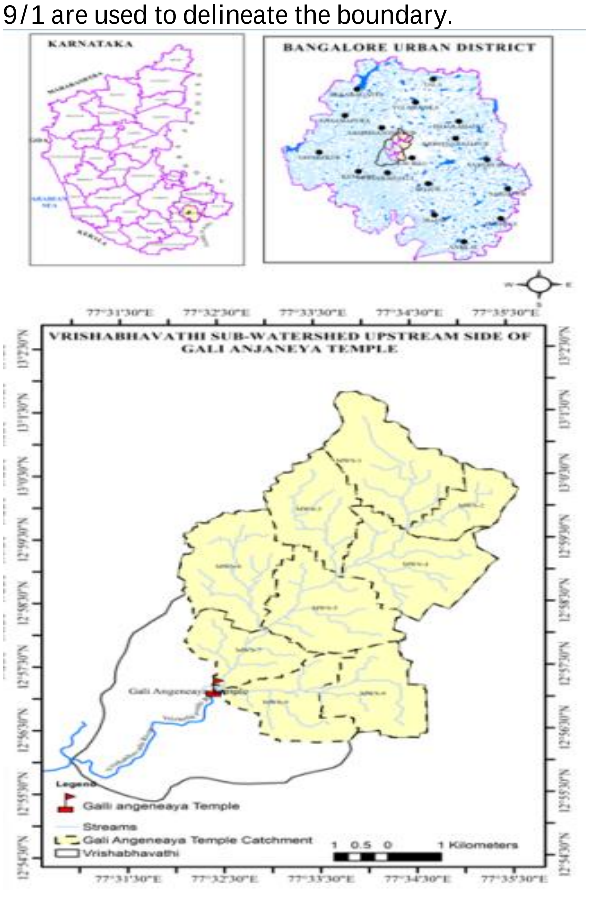


Fig. 1: Location Map of the Study Area

3. DATA USED

Landsat data (up to resolution 30m x 30m) of study area for different years were used for the detection of changes in land use and land cover pattern. The different satellite sensors are used in this paper are given below:

- Landsat MSS with 4-bands and 79mresolution acquired on 27thFeb 1973.
- Landsat TM with 7-bands and 30m resolution acquired on 14thJan 1992.
- Landsat ETM+ with 8-bands and 30m resolution acquired on 18th Feb 2002.
- Landsat ETM+ with 8 bands and 30m resolution acquired on 31stMarch 2014.

4. METHODOLOGY

The following sequence is adopted for the analysis of urban dynamics:

a) Image registration and geo-correction of the RS data of varying spatial and temporal resolutions.
b) Generation of false colour composite (FCC) using band 2 (Green), 3 (Red) and 4 (NIR) to identify heterogeneous patches.
c) Collection of training data from FCC and Google Earth images (http://www.earth.google.com).
d) Supervised classification of the RS data was done with the help of the number of distinct peaksin the histogram.
e) Land use supervised classification into 5-different classes – built-up area, water bodies, agriculture and vegetation/open space, and scrub land using Maximum Likelihood classifier using ERDAS Image 10.0. Further, the classified images were re-coded to identify the expansion of built-up from 1973 to 2014.

The accuracy assessment of the classified images using test data and Google Earth images are analysed to obtain the pattern of LULCC.

4.1 Image Classification Method

Post-classification image comparison method has been adopted in the present study. Aland cover classification extracting the classes for 'built-up areas, non-built-up areas, vegetation and water' was performed separately on both images. The image classification method [1-6] are very useful in identifying the different features from the given image. Features like built-up, water, vegetation cover, agriculture and barren land are used for obtaining the change in multi-temporal variations. The multi-temporal satellite images [3-17] provide excellent temporal variations which can be used for urban growth analysis. Different combinations of bands [13-16] are generated in order to identify built-up, vegetation, water and barren land signatures from the satellite images (signatures means similar spectral values). The supervised classification methods are used for pattern classification [12]. Supervised classification [16] identifies class information in the satellite images and similar pixels are used as 'training samples' (signature values). The classifier system is used to determine the statistical characterization of reflectance for each information class and this stage is called 'Signature analyses'. The Signature analyses involved statistical characterization of the range of reflectance on each band. The statistical characterization has been achieved for each information class. Then the image is classified by examining the reflectance for each pixel and making a decision about which of the signature it resembles accurately [4-13].

The band combinations for each image are shown below which are used to collect signatures or training samples from the given datasets:

a) Landsat-MSS 1973 data with band combinations (for false color composite (FCC) – 3, 2 and 1 band and True color composite (TCC) – 4, 3 and 2 band)
b) Landsat-TM 1992 data with band combinations (for FCC – 4, 3 and 2 band and TCC 3, 2 and 1 band)
c) Landsat-ETM+ 2002&2014 data with band combinations (for FCC 4, 3 and 2 band and TCC 3, 2 and 1 band)

Post classification comparison was found to be the most accurate procedure and presented the advantage of indicating the nature of the changes [9].An automated object-oriented procedure is used for extraction of information about detached houses, of main street infrastructure, vegetation areas, bare soil and water bodies. The land use maps pertaining to four different periods were used for post classification comparisons, which facilitated the estimation of changes in the land use category and dynamism with the changes. The post classification comparison is most commonly used to obtain the quantitative changes [5-14] with fairly good results. Post classification comparison is sometimes referred to as "delta classification" [10]it involves independently produced spectral classification results from different data sets, followed by a pixel-by-pixelor segment-by-segment comparison to detect changes in the classes. A comparative analysis of land cover classification analysis of land cover classifications for different timest1, t2, t3and t4are performed independently and used to analyze change in land cover and land use parameters in the watershed.

The four quantitative indices which are used for analysing the spatial-temporal dynamics of LULC and describe the driving force and structure of these LULC which gives better understanding of the level of land degradation due to urbanization: Landuse/Landcover (LULC) Change Intensity Index (Ti), Dynamic Index (Ki), Integrated Index (Ld), and Rate of Change Index (Ai). The formulae used for computing the indexes are as follows:

(i) Rate of change of LULC (A_i):

$$A_i = \frac{(U_{bi} - U_{ai})}{\sum (U_{bi} - U_{ai})}$$

(ii) Landuse/Landcover Change Intensity Index(C_i):

$$C_i = \frac{(U_{bi} - U_{ai})}{B}$$

Where I = (1, 2, 3, 4, 5)=No. of LULC classes
C_i =LULCC index for i^{th} landuse type
U_{ai} = i^{th} LULC area at the beginning of study period
U_{bi} = i^{th} LULC area at the end of study period
B = Total study area = 38 Km^2

(iii) Landuse/Landcover Dynamic Index (Di)

$$D_i = \frac{(U_{bi} - U_{ai})}{U_{ai}} \cdot \left(\frac{1}{T}\right) .100\%$$

U_{ai} = i^{th} LULC area at the beginning of study period
U_{bi} = i^{th} LULC area at the end of study period
T = Total study period in years

(iv) Landuse/Landcover Integrated Index (I_d):

$$I_d = 100 \times \sum_{i=1}^{i=6} A_i \times C_i$$

Where I limits (100……600)
A_i = Percentage of i^{th} level land use/land cover
C_i =LULCC index for i^{th} land use type.

5. Results and Discussion

The study area was characterized and mapped into six (5) major Land use/Land cover (LULC) classes and shown to reveal the spatio-temporal patterns of these LULC dynamics as shown in Figure 2, Figure 3, Figure 4, and Figure 5 representing the 1973, 1992, 2002, and 2014 respectively. These changes were estimated and summarized for the period of 42-yrs in Table 2, the Built-up area and scrub land showed increasing trend, while the agriculture area, barren land, and water body area showed decreasing trends. The major driving force of these LULC changes is the socio-economic factor of urbanization processes such as population, economic, technological and institutional growth which have triggered the competition for space for various urban development purposes such as residential, industrial, commercial, institutional, recreation, transportation etc. thereby increasing the built-up area as highlighted in Figure 2-5.

5.1 Land use/Land cover of study area (1973)

The land use/land cover statistics of 1973 in the study area is given in the Table 1. The Open space/Barren land was dominant in land use category in the catchment, followed by the Built-up area. Open space/Barren land being practiced almost throughout the catchment was the dominant land use with an area of17 Km^2. It comprised of 45 % of the study area. Built-up area and Agriculture area were the other major land cover classes comprising up to 30 % with a total area of 11.3 Km^2, and 17 % with and area of 6.6 % Km^2 of the study area respectively. Scrub land is spread throughout the study area. It occupied 2.5 Km^2 and constituted 7 % of catchment area. Water bodies occupied 0.5 Km^2 which constitute 1 % of the study area.

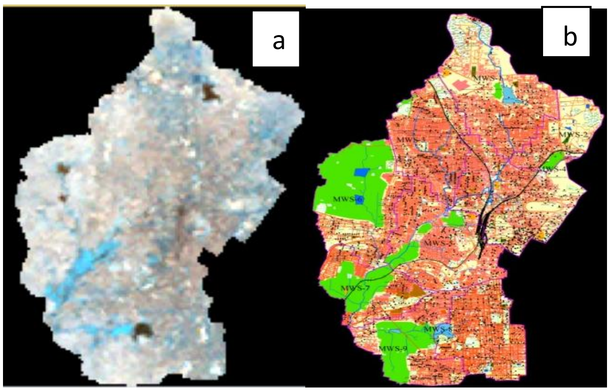


Fig 2: a) FCC and b) Classified Landsat MSS 1973 Satellite image.

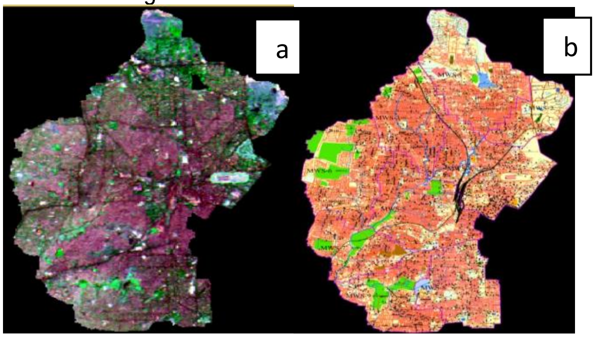


Fig 3: a) FCC and b) Classified Landsat TM 1992 Satellite image.

5.2 Land use/Land cover of study area (1992)

The land use/land cover statistics of 1992 has been generated from the satellite data and is presented in the Table 1. The data reveals that open space/Barren land is the dominant land use with a total of 17 Km^2 which constitutes 45% of the study area followed by built-up area that occupies 16.2 Km^2 which is 43% of the total area. Agriculture area and Scrub land area were the next land cover category spread over an area 2.1 Km^2 each occupying 6 % of the study area. A total of 0.5 Km^2 is occupied by the water bodies which is 1 % of the study area.

5.3 Land use/Land cover of study area (2002)

Table 1 shows the land use/land cover statistics of 2002 in the study area. Built-up area predominates followed by open space. Built-up area covers 46% of the study area followed by open space 44 % of total area. Both occupied 17.6 Km^2 and 16.7 Km^2 of the study area respectively. Water bodies occupied 0.4 Km^2 which constitute 1% of the study area.

5.4 Land use/Land cover of study area (2014)

The land cover map of 2014 shows that the built-up area was 21.7 Km^2, 57 % of the study area (Table 1). In addition, the agriculture area had reduced to zero Km^2 (Table 1). It can be observed from Figure 6 that built-up areas in 2014 have mainly been taken from open space and agricultural lands. The built-up areas have increased about 27% in the forty year period while open space and agricultural areas have reduced by more than 10%. The reduction of the open space and agricultural lands increase of urban built-up areas indicates a substantial increase in impervious surface areas. It is well noted that impervious surface areas are a major contributing factor to urban floods and urban heat island effects (Aduah et al., 2011).The results of indexes shown in Table 3 & Table 4 below of LULCC showed that Built-up area has the highest Land use Change Intensity Index of about 27.37% followed by Agriculture area, 17.34%. LULC Dynamic Index showed Agriculture area having the higher of 2.43% followed by Built-up area and Scrub land, 2.24% and 0.780% respectively. LULC Integrated Index has shown temporal variations over the years with the highest in 1992 of 446 (L_d) followed by 2002 of 422.6 (L_d) in an upper limit of 600 signifies <u>very high impact of both natural and human factors in the breadth and depth of the study area</u> and thus an indication of degradation of biophysical environment.

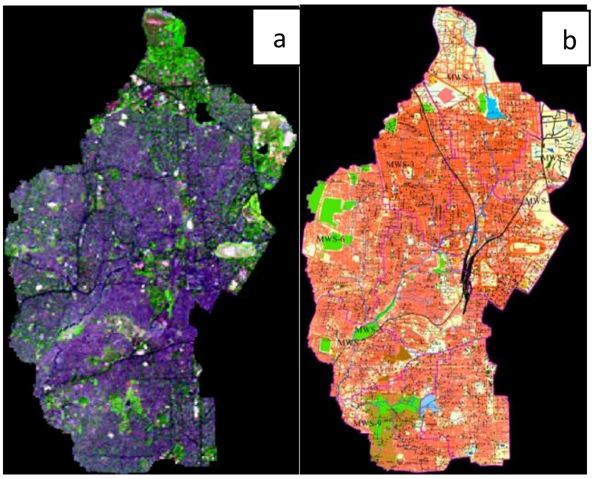


Fig 4: a) FCC and b) Classified Landsat ETM+ 2001 satellite image.

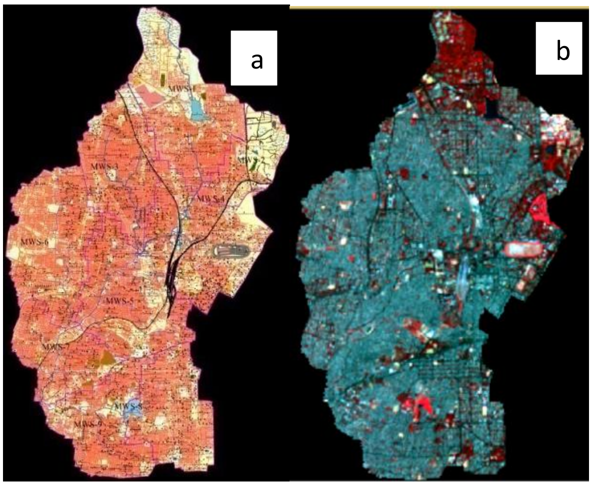
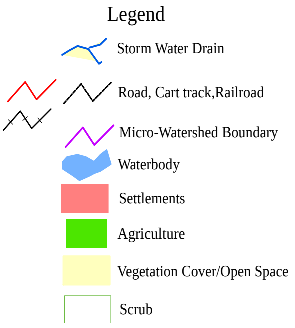


Fig 5: a) TCC and b) Classified Landsat ETM+ 2014 satellite image



5.5 Land cover analysis

Temporal land cover analysis was done through supervised classification. Figures 2-5 indicates the land cover changes in the year 1973, 1992, 2002 and 2014. Vegetation cover has dramatically decreased from 24% in 1973 to 9% in 2014, whereas non-vegetation i.e., built up, paved areas etc. have increased 76% in 1973 to 92% in 2014%. To understand the land use categories like built-up areas and non-vegetation areas clearly, land use analysis was performed.

5.6 Land use Analysis

Gaussian maximum likelihood supervised classifier employed to perform land use analysis by considering four categories. Figures 2-5 represents land use dynamics of study area in past 4 decades with significant changes in all categories. Steep increase in built up areas were noted. Decrease in Agricultural area, open space and water body is observed over last 4-decades in the study area of Vrishabhavathi sub-watershed upstream side of Gali Anjaneya Temple. These changes will alter significantly ecological and hydrological parameters and which will result in flooding at the temple even with a moderate shower in the catchment.

6. Conclusion

- The study is an attempt to understand the land use/land cover response to urban growth in the study area. The paper presents the results of Bangalore urban region for over 41- years (1973-2014).
- Analysis of data clearly show that LULC changes were significant during the period from 2002 to 2014. There is a significant expansion of built-up area noticed. On the other hand there is decrease in agricultural, water spread, and open space areas. The year 1973 had a large number of water regions in comparison with 1992 and 2014. As the urban regions is growing and it has affected the natural resources like water and vegetation.
- The four quantitative indices which are computed for the study area of Vrishabhavathi sub-watershed upstream side of Gali Anjaneya Temple are shown in Table 3 & Table 4. The LULC Integrated Index has shown temporal variations over the years with the highest in 1992 of 446 (Ld) followed by 2002 of 422.6 (Ld) in an upper limit of 600 which signifies very high impact of both on natural and human factors. It also indicates degradation of biophysical environment.

Table - 1: Land use/land cover statistics from 1973 to 2014

Sl.No.	Land Use Type	1973		1992		2002		2014	
		Area (Km^2)	% of Total Area	Area (Km^2)	% of Total Area	Area (Km^2)	% of Total Area	Area (Km^2)	% of Total Area
1	Built-up area	11.3	30	16.2	43	17.6	46	21.7	57
2	Agriculture area	6.6	17	2.1	6	1.4	4	0	0
3	Scrub land	2.5	7.0	2.1	6	2	5	3.3	9
4	Open Space/ Barren land	17.0	45	17	45	16.7	44	12.5	33
5	Water body	0.5	1.0	0.5	1	0.4	1	0.4	1

Table - 2: Land use/land cover change statistics from 1973 to 2014

Sl. No.	Land use Type	Change In Km^2 (1992-1973)	% Change w.r.t 1973 Area	Change in Km^2 (2014-1992)	% Change w.r.t 1973 Area
1	Built-up area	+4.9	+43	+10.4	+92
2	Agriculture area	-4.5	-68	-6.6	-100
3	Scrub land	-0.4	-16	+0.8	+32
4	Open Space/Barren land	0.0	0.0	-4.5	-26
5	Water body	No Change	0.0	-0.1	-25

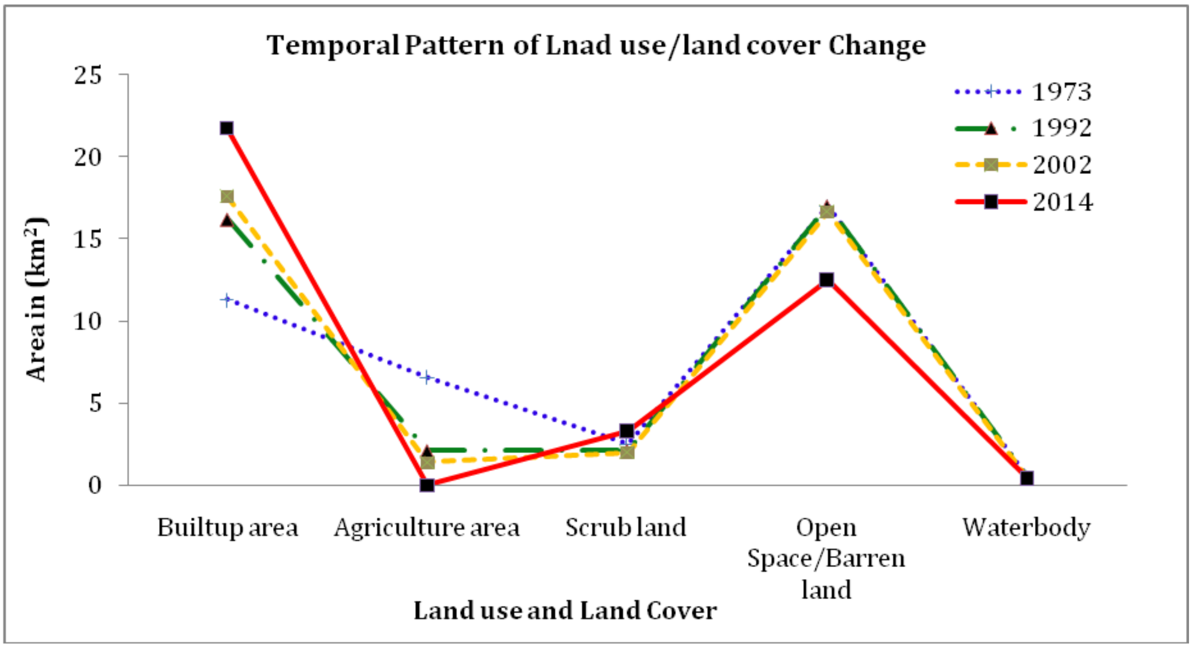


Fig. 6: Land use/land cover from 1973 to 2014

Table – 3: Summary of results and Analysis of Landuse/Landcover Changes (1973-2014)

LULC	Extent in Km^2 1973 (U_{ai})	Extent in Km^2 1992	Extent in Km^2 2002	Extent inKm^2 2014 (U_{bi})	Change in Extent in Km^2 1973 - 2014 (U_{bi} - U_{ai})	Change in Extent in % (1973 – 2014)
Built up area	11.3	16.2	17.6	21.7	+10.4	+92
Agriculture area	6.6	2.1	1.4	0	-6.6	-100
Scrub land	2.5	2.1	2	3.3	+0.8	+32
Open space/Barren land	17.0	17.0	16.7	12.5	- 4.5	-26
Water body	0.5	0.5	0.4	0.4	- 0.1	2.0

Table – 4: Summary of Analysis of Landuse/Landcover Structure Index

LULC	T_i (%)	K_i (%)	A_i	A_i (%)
Built up area	27.370	2.240	0.464	46.42
Agriculture area	17.340	2.43	0.294	29.46
Scrub land	2.105	0.780	0.035	3.57
Open space/Barren land	11.84	0.645	0.200	20.00
Water body	0.263	0.487	0.01	1.00

Table – 5: Summary of Analysis of Integrated LanduseIndex (L_d) for different years

LULC	1992				2002				2014			
	A_i	C_i	A_i× C_i	L_{di}	A_i	C_i	A_i× C_i	L_{di}	A_i	C_i	A_i× C_i	L_{di}
Built up area	0.5	5	2.5	250	0.538	5	2.69	269	0.372	4	1.488	149
Agriculture area	0.46	4	1.84	184	0.269	4	1.076	107.6	0.127	3	0.381	38.1
Scrub land	0.04	3	012	12	0.038	2	0.076	7.6	0.118	2	0.236	23.6
Open space/Barren land	0	1	0	0	0.115	3	0.346	34.6	0.38	5	1.9	19
L_d =100 ΣL_{di}				446				422.6				229.7
Water body	0	2	0	0	0.038	1	0.038	3.8	0	1	0	0

Table - 6: Land cover changes from 1973-2014

YEAR	VEGETATION(%)	NON-VEGETATION(%)
1973	24	76
1992	12	89
2002	9	91
2014	9	91

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