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LAND-USE CHANGE IN URBAN BANGALORE USING GIS AND REMOTE SENSING

SCHIMBĂRI ÎN UTILIZAREA TERENURILOR ÎN ORAȘUL BANGALORE CU AJUTORUL SIG ȘI TELEDETECȚIEI

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Abstract: Environmental changes, modifications in ecosystem structures and the loss of biodiversity affect the whole planet and have aroused worldwide public concern. Since the beginning of the 20th century, scientific and political debate on these issues, both nationally and internationally stated (Boletta et. Al. 2000) have pointed towards land-use change, which is one of the most important human and nature induced environmental changes. Generally, land-use change refers to the alteration in the physical land surface and biotic component on it. Monitoring land-use change has become an important theme of research. Land-use has enormous effects through fragmentation of natural habits (Tuner et.al., 2003; Verburg at. Al 1999; Vitousek, 1994). Bangalore is internationally recognized as a technological hub. Along the proud economical growth of this knowledge capital of India, there are noticeable blemishes in terms of its loss of ecology and threatened food security. Such changes can clearly be attributed to land-use change. When compared with its past status, the present land-use of the city clearly denotes the mounting pressure of some classes of land-use which are under stress. A balanced and sustainable growth is often only conceptual in terms of urban land-use. Using GIS and Remote Sensing, this case study for Bangalore clearly marks the awaiting problems that are caused by land-use changes. The resultant statistics also gives the scope for the future planning of land-use.

Key words: land-use change, urbanization, urban sprawl, agricultural land, ecologic loss
Cuvinte cheie: schimbări în utilizarea terenurilor, urbanizare, extindere urbană, teren agricol, pierderi ecologice

1. Introduction

In metropolitan and urban areas the problems relating to rapid transformation that take place in terms of land-use are now very pronounced. As a result, the availability of detailed, timely information on urban areas is of considerable

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importance to both the management of urban activities and to forward planning. Satellite remote sensing has the potential to provide some necessary information and the body of literature concerned with urban applications of technology continues to grow, with notable contributions on rural-to-urban land-use conversion (Jension, 1983), housing density and population estimation. Food and Agricultural Organization of United Nations (2001) estimated that the world's forests were converted to other land-uses at the rate of 0.38 per cent (i.e deforested annually) in the 1990s. The issue is more rapid and diverse in developing tropical countries. Lambin et al. (2001) remarked that tropical deforestation, rangeland modification, agricultural area shrink and urbanization are the major land-use and land-cover changes around the globe. According to Nagendra et. al. (2004) the driving force of land-use/cover change vary and their dynamic interactions result in diverse change and trajectories of change, depending upon the specific environmental, social, political and historical context from which they arise. The resulting changes from these drivers exist as a complex between subtle modification and total conversion as seen in a change in forest density and forest to agricultural land or urban area (Geist and Lambin, 2001; Meyer and Tuner II, 1992; Veldkamp and Lambin, 2001).

This research is an illustration of landscape conversion which could be monitored with the application of geoinformatics techniques. Emphasis of conversion diverts attention from land-cover modification which also has important effects on the physical landscape (Giest and Lambin 2001; Meyer and Tuner II, 1992).

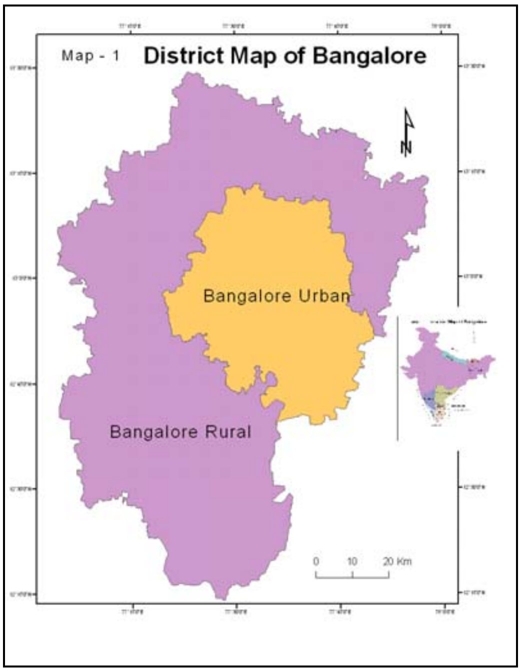

Fig. 1 Bangalore District

The complexity of land-cover changes is illustrated by functional differences within types of land-cover, structural variance between types of land-cover change, with regards to spatial arrangement and temporal pattern of change (Giest and Lambin, 2001). It is crucial to capture the understanding of land-use/cover change dynamics and their socio-economic drivers at local hot spots where they are most prominent. For a city like Bangalore (Fig. 1), that is undergoing a phenomenal growth, which becomes inevitable to have a track on growth patterns and resultant change that is imposed on the land.

2. Role of GIS, Remote Sensing and GPS in Land-use/cover Mapping

Viewing the earth from space has become essential to comprehend the cumulative influence of human activities on its natural resource base. In a time of rapid and often unrecorded land-use change, observations from space provide objective information of human utilization of landscape. Over the past two decades, data from earth sensing satellites have become important in mapping the earth's features, infrastructure managing, managing natural resources and studying environmental change. Remote sensing and GIS are providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analysis of earth-system functions, patterns and change at local, regional and global scales over time. Such data also provide vital links between intense localized ecological researches and the regional, national and international conservation and management of biological diversity (Wilkie and Finn, 1996). Allocating and managing earth's resource requires knowing its distribution in space. Maps help us measure the extent and distribution of resources, analyze resource interactions and identify suitable locations for specific action (eg. development or preservation) and plan future events. GIS helps in performing varied analysis on the data thus obtained from remote sensing. Boolean algebraic operations such as overlay analysis could bring out the interim characteristics of the land-use. GPS helps in the in-situ (ground truth verification) of the land-use represented by these technologies.

In this research context it would have been merely impossible to quantify the land-use change and its transformation in the absence of these technologies.

Geoinformatics has played an immense role in the present research in terms of quantification of change and spatial analysis of change.

3. Methodology

Urban Bangalore was taken for analysis for land-use change from the IRS IC satellite imagery of the year 2001; urban Bangalore district was clipped using the spectral signature analysis and different features were identified using hybrid classification method. The satellite imageries were classified using ERDAS imagine 9.1 image processing software. After the classification and post classification check the results were quantified for analysis and the map was composed in Arc Gis 9.2. Three four fold classification schema was used here for the classification.

4. Land-use of Bangalore urban district in 2001

In 2001, the land-use for Bangalore urban district as a whole was predominantly agrarian (Fig. 1, 2). There were rich agricultural lands and much of greenery in terms of forests. There was also an increasing component of fallow lands, waste lands and built up area around.

4.1 Agricultural lands

Agricultural lands are generally used for production of food crops and other crops. It covers an area of 1604.86 sq. Km. There is a marked absence of this land-use in the central part of the study area, mainly due to the dominance of urban built up.

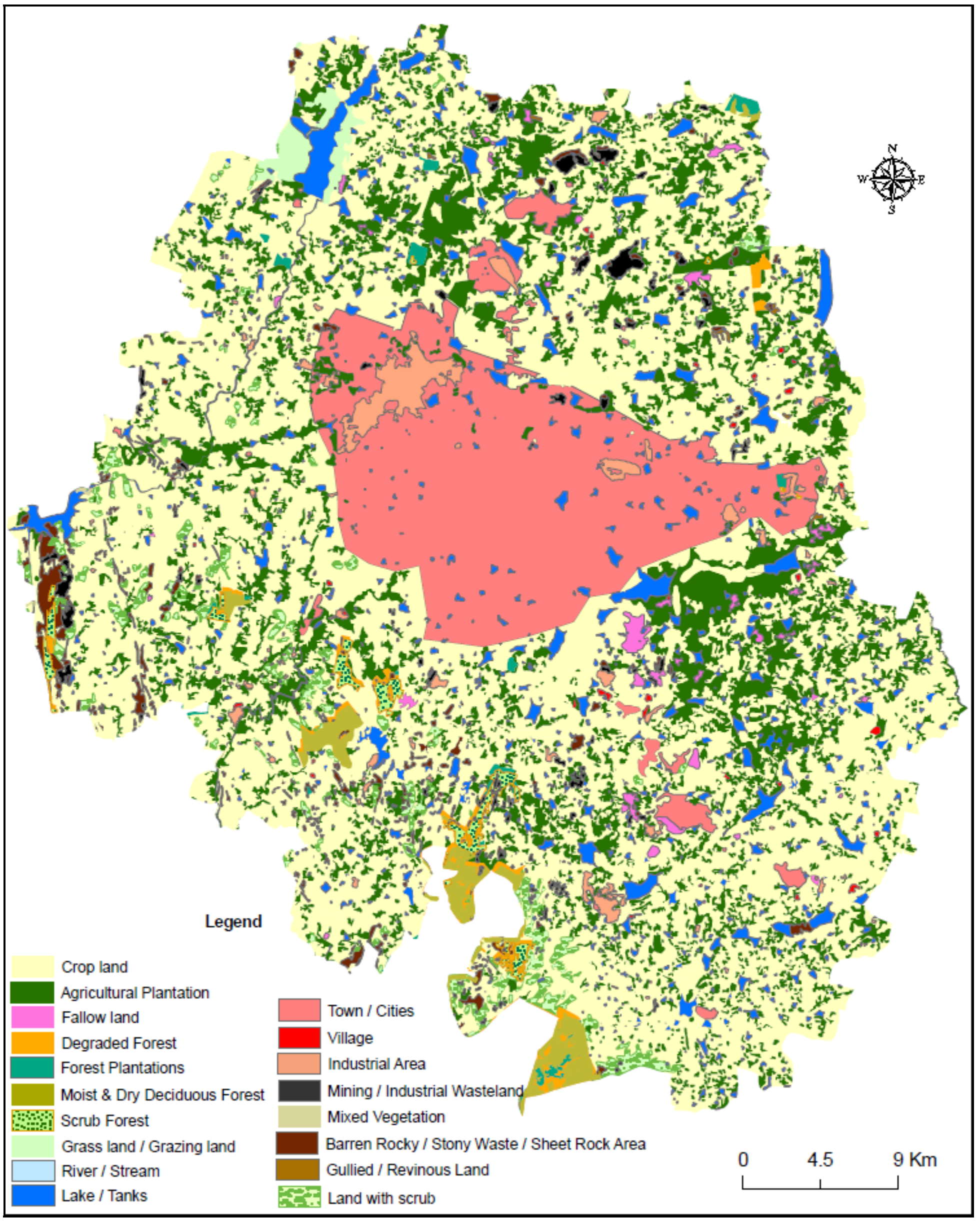

Fig. 2 Land use of Bangalore Urban District (2001)

Most of the cropped land is karif which includes standing crops during June to September months. It coincides with the south-west monsoon season. It is associated with dry land farming, limited irrigating and areas of rain fed paddy and other dry crops. Rabi crops are seen in few pockets in a scattered fashion. This includes standing crops from October to March. Double crops are seen along the margins of the study area and along the city boundaries. This includes standing crops during both karif and rabi seasons. The spectral signature of the crop land is distinct at its full growth from that of the scrub land with which it is often confused with. Using multi temporal data, a clear distinction was achieved. Next to crop land the agriculture in Bangalore is dominated by plantation lands.

They are found more in the East, North and South East. Lands which are taken up for agriculture but temporarily allowed to rest, uncropped for one or more seasons, but less than one year, is termed as fallow lands. These lands are particularly those which are seen devoid of crops at the time when the imagery is taken of both the seasons. Thus these are seen only in few pockets in the East and South near the city. Less than one-fourth of the agricultural are is in the forms of plantation lands and very negligible spread of fallow land is seen in 2001.

4.2 Forest

The area which is within notified forest boundary under Department of Forestry, bearing an association predominantly of trees and other vegetation types capable of producing timber and other forest products is called forest land. Here the vegetation density which was 40 per cent or above is classified as forest. This also perfectly conceded with the notified forest boundaries. Bangalore urban district has considerable extent of forest land running 44.25 sq. km. Degraded forest were discovered as within the notified forest boundary when the vegetative (crown) boundary lies between 10-40 per cent of canopy cover. In the progress of afforestation, Department of Forest raises trees of species of forestry importance on the notified forest lands. These are artificially planted with trees, either in open spaces or by clearing already existing forests of economically inferior species. Such kind of plantation is seen in Bangalore in the East and North. Bangalore is known for its green space and has a good ecology in the variety of trees.

4.3 Built Up

Areas of human habitation developed due to non-agricultural use and that which has a cover of buildings, transport and communication, utilities in association with water, vegetation and vacant lands are classified as built up. All man made constructions covering the land surface are included under this category. Their shape and high reflectivity differentiate them from other classes. Enhancement techniques and band combination helps in segregation of different parcels. This appears in greenish blue tint in the imagery. They were further classified as villages and towns according to the BDA (Bangalore Development Authority) / BMRDA (Bangalore Metropolitan Regional Development Authority) declaration. Thus town or city is found in the centre of the study area covering most of the BMP (Bangalore Mahanagara Palike) region. Apart from these, Kengeri in south, Anekal and Ramanagaram in South west, Haro halli, Thattekere, Kanakapura and Bididi etc. were some of the settlements classified as urban. Dod

Ballapur and Devanahalli and were classified as rural in the North. Tippur, Kodihalli, Satanuru and other surrounding major villages are classified as rural. The total built up land measures up to 309.14 sq. km, of which towns measure 313.14 sq. km., villages measure 3.15 sq. km. and industrial area measure 16.81 sq. km.

4.4 Grassland/Grazing land

These are areas where natural vegetation is dominated by grasses or grass-like plants and non grass-like herbs. Lands exclusively used for farming grass are called meadows and pastures. Such grassland is found in some parts of the North and South West of the city. The area included in this category of land-use is 12.34 sq. km.

4.5 Water bodies

This class comprises surface waters either impound in the form of ponds, lakes and reservoirs or flowing as rivers, streams, canals etc. A stream is a natural course of water flowing on the land surface along a definite channel. It may be seasonal or perennial. There are few major streams flowing in Bangalore as follows: Arkavathi river running south to north and a branch (tributary) of Arkavathi, which is also known as Vrishabhavathi. Others are minor streams such as: Kutle Hole and Antarangange hole; Rayatmala hole is also an important stream in the South. There are two reservoirs, namely Byramangala reservoir and Krishnarajasagar reservoir. The total Bangalore urban district is covered by tanks and there are 1045 tanks. A sum of 105.42 sq. km of water body area spread in Bangalore limits. The city’s water demand is covered using these sources.

4.6 Wastelands

This category consists of gullied/ravenous lands, barren/rocky/stony/sheet rock area and land with scrubs. Gullies are narrow and deep channels developed as a result of wearing away of soil by running water. Gullies deepen from rills, which are tiny channels a few centimeters deep, formed by the impact of rainfall and wearing action of runoff generated therefrom. They are more common sloping lands where they are developed by the action of concentrated runoff. Such kind of lands is found in the Eastern and Northern part of Bangalore. The next form of land which add up to waste lands are barren/rocky/stony/sheet rock area. These are lands characterized by exposed massive rocks, sheet rocks, stony pavements or lands with excessive surface accumulation of stones that render them unsuitable for producing any green biomass. Most of the Bangalore’s wasteland is this kind of land. They are seen in the Western and South-Western part of Bangalore where the ruggedness of the terrain is high. They are also noticed in some pockets in the South-Eastern parts. The area coverage of such feature extends up to 84.17 sq. km. Land with scrubs represent areas bearing association with vegetation but when the crowning cover is less 10 – 40 per cent. Such lands are seen scattered around in North-Eastern and Southern part of Bangalore. It extends up to 40.06 sq. km.

4.7 Others

All other land-use/land-cover conditions not included in any of the classes described earlier that is either an area specific or with limited aerial extent in the overall context of total geographical area of the district is included in this category. Here the mixture of scattered vegetation is included in this category. There are found in combination with the scrub land mostly in the Northern part of Bangalore. They extend to an area of 4 sq. km.

Table 1 and Chart 1 represent the land-use scenario of Bangalore Urban District in 2001. More than 60 per cent of the land was agricultural because of which it could be stated that Bangalore had predominantly agricultural in terms of land-use and such scenario can be referred to multiple ring theory where a city would be immediately surrounded by green belt that secures the food for the city. There are two predominant classes of land-use, namely agriculture and built up. A lower percentage of waste land shows the ideal utilization of land. Through this statistics, it could be inferred that the district has good ecological space but the second greater percentage of built up area shows a *blessing in disguise.* The hidden threat to all the classes of land-use through the increase of built up is felt and could be completely understood by analyzing the land-use of 2005.

Table 1.

Land-use of Bangalore Urban District in 2001

S.No	Land-use	Area in sq. km	Percentage
1	Agriculture	1604.86	73.47789
2	Forest Cover	44.25	2.025969
3	Built up	329.1	15.06772
4	Grass land	12.34	0.564982
5	Water Bodies	105.42	4.826614
6	Waste Lands	84.17	3.853691
7	Others	4	0.183138
	Total	2184.14	100

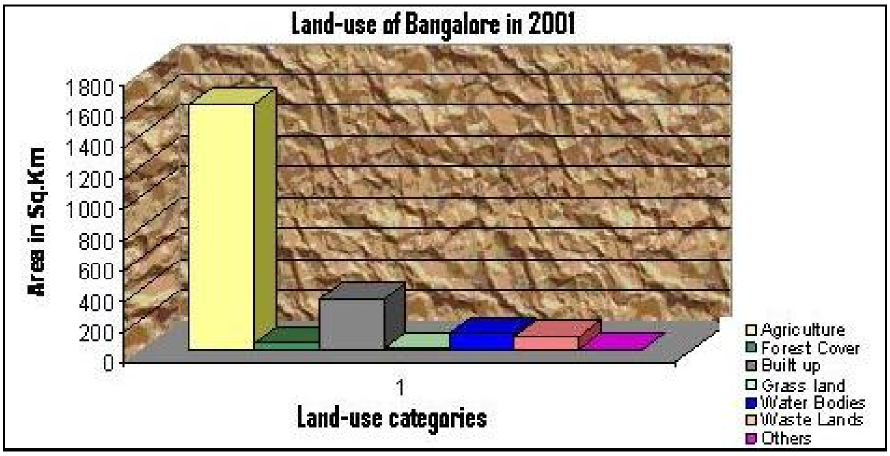

Fig. 3 Land-use of Bangalore in 2001

The model of land-use was more or less like that of the concentric ring theory as the Central Business District restricted to the centre and few satellite town scattered here and there. This was typically surrounded by industrial lands. Then there is a belt of agricultural plantations and agricultural lands. Beyond there is an extensive green belt.

5. Land-use in 2005

The land-use of 2005 saw an increasing lowering of agricultural land and a heavy shoot up of built up land. There was also an increasing loss of lake areas and forest areas. Hence, reading the overall statistics of land-use in 2005, considerable amount of ecological space loss can be identified and accounted (see Map 3).

5.1 Agriculture

There was a steady loss of agricultural land in 2005. 1072.02 sq. km was not anymore an agricultural area, as compared to land-use in 2001. This loss was accounted in terms of loss of crop land, agricultural plantation land and fallow land. The crop lands reduced by 790 sq. km., the agricultural plantation lands also reduced by 303.57 sq. km., but the fallow lands increased by 21.28 sq. km. The chart given below demonstrates that the change occurred in agricultural land-use of Bangalore in 2005 (Table 2 and Fig. 4).

Table 2.

Land-use in 2005

S.No	Land-use	Area in Sq. km	Percentage
1	Agriculture	531.98	24.3564973
2	Forest Cover	26.41	1.20917157
3	Built up	1451.41	66.4522421
4	Grass land	5.87	0.26875567
5	Water Bodies	36.45	1.66884907
6	Waste Lands	122.02	5.58663822
7	Others	10	0.45784611
	Total	2184.14	100

The decrease in crop land, plantation land and one fold increase in the fallow land clearly indicates the influence of the city on its agricultural lands. In an urban situation, it is the hinterlands where agricultural activities that are predominant supply the food materials to the inhabiting population of the city. Threat to the agricultural land implies a future threat on the food material supply and on inflation.

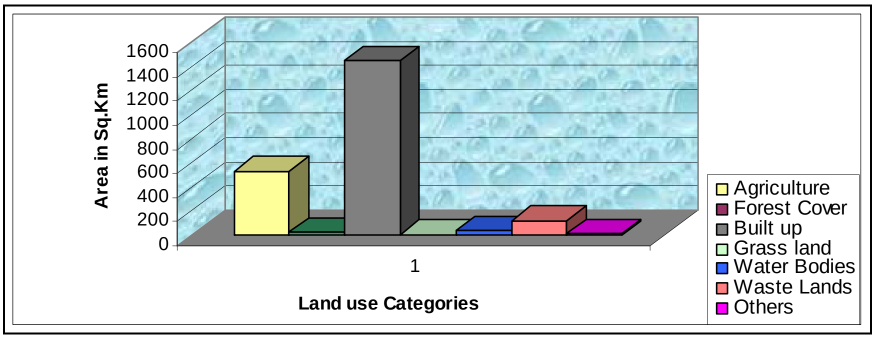

Fig. 4 Land Use in 2005

5.2 Forest

Bangalore, which had a forest area of 719 sq. km, had lost 78.82 sq. km of its land. There was an increasing graph of degraded forest area increased by 38.72 sq. km accounted from the scrub forest and moist deciduous forest. The Forest plantation shows a declining graph by a difference of 46.86 sq. km; also the scrub forest by 19.15 sq. km. The moist deciduous forest also shows a declining graph of 12.81 sq. km.

5.3 Built Up area

Tremendous increase in all the categories of the built up area was noticed in the year 2005. Areas occupied by villages increased by 23.42 sq. km, urban built up area increased by 1087.79 sq. km and industrial area increased by 11.10 sq. km. Thus on an approximation of more than triple fold rise in the built up area was accounted and this mainly due to the population rise and pressure for built up land increased.

5.4 Grass Land

There was a shrink noticed in the grass land distribution though it is very negligible. The grass lands reduced by 5.87 sq. km.

5.5 Water bodies

Regarding the water bodies, there has been a tremendous decrease in the overall area cover of water bodies in the year 2005. These areas decreased by 68.96 sq. km. The river area was reduced by 1.69 and the tank area decreased by 67.27 sq. km.

5.6 Waste Land

Waste lands also increased but the percentage of change in terms of increase is very low when compared to the other categories. Gullied land increased by an area of 2.66 sq. km. There was a decrease of 4.95 sq. km, seen in the barren rocky area distribution. There was an increasing trend of land with scrubs. In 2005 the land-use category of land with scrubs accounted for 122.02 sq. km which is an increase of 16.2 sq. km. The mining and industrial waste land also increased up to 36.14 sq. km which accounts of 21.94 sq. km when compared with 2001.

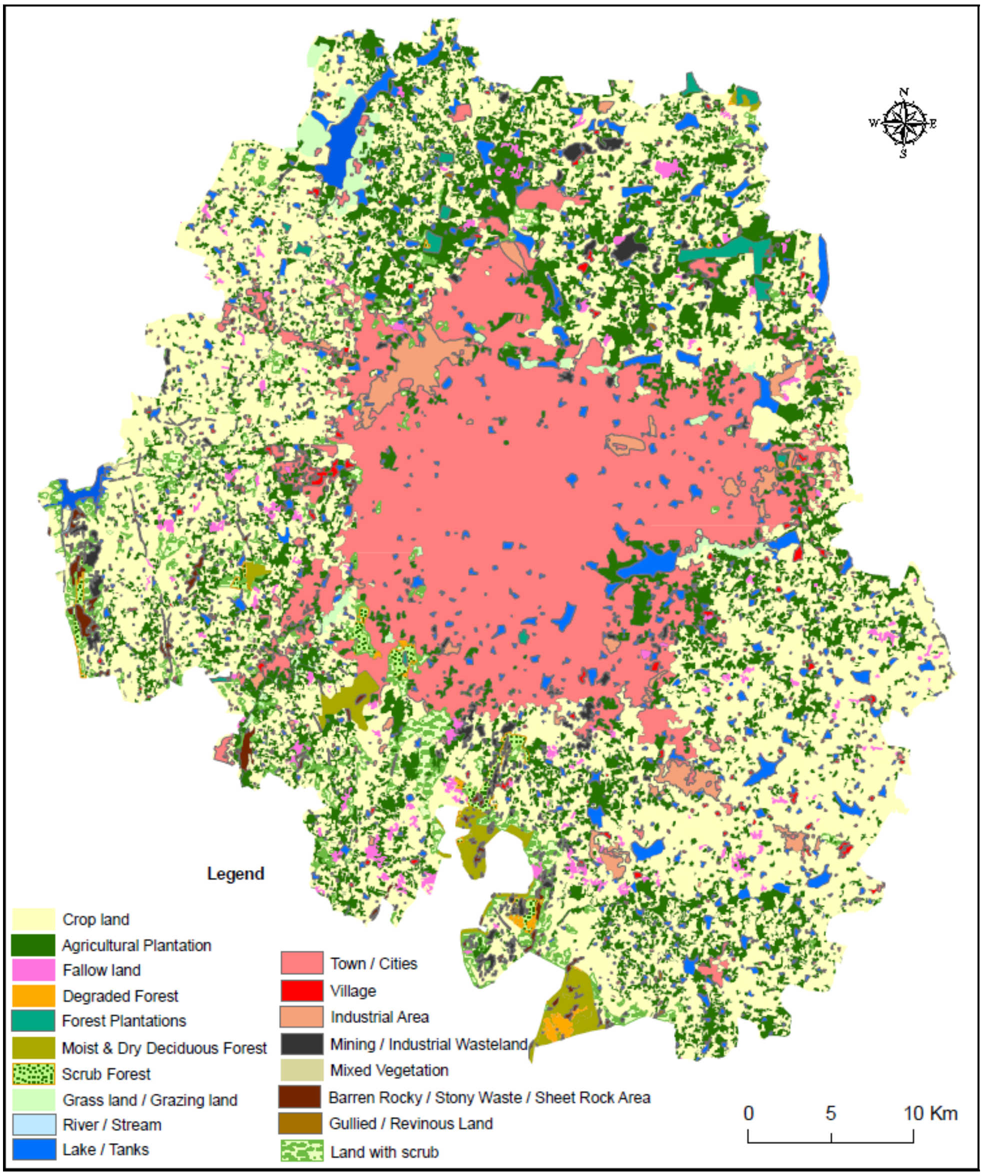

Fig. 5 Land use of Bangalore Urban District (2005)

5.7 Others

The other category of land-use which includes tree grooves and mixed vegetation has increased almost by 50% as 10.00 Sq. km. There was an approximately 5.00 Sq. km increase in the area, as compared to 2001.

6. Results

A minute comparison between land-use in 2001 and 2005 can be précised through the following table and chart (Table 3 and Fig. 6). The comparison of land-use between 2001 and 2005 shows drastic changes especially in terms of greenery loss and lake areas loss. There is a massive transformation of agriculture loss and considerable loss of the lakes which have been attributed to the increase of concrete structures of the district.

Table 3

Comparison between Land-use 2001 and 2005

No	Land-use	Area in Sq. km in 2001	Area in Sq. km in 2005	% of Land-use in 2001	% of Land-use in 2005	Increase/Decrease In %	
1	Agriculture	1604.86	531.98	73.47789	24.3565	↓	49.1213933
2	Forest Cover	44.25	26.41	2.025969	1.209172	↓	0.81679746
3	Built up	329.1	1451.41	15.06772	66.45224	↑	51.3845266
4	Grass land	12.34	5.87	0.564982	0.268756	↓	0.29622643
5	Water Bodies	105.42	36.45	4.826614	1.668849	↓	3.15776461
6	Waste Lands	84.17	122.02	3.853691	5.586638	↑	1.73294752
7	Others	4	10	0.183138	0.457846	↑	0.27470767
	Total	2184.14	2184.14	100	100		

Note: ↓ denotes decrease and ↑ denotes increase

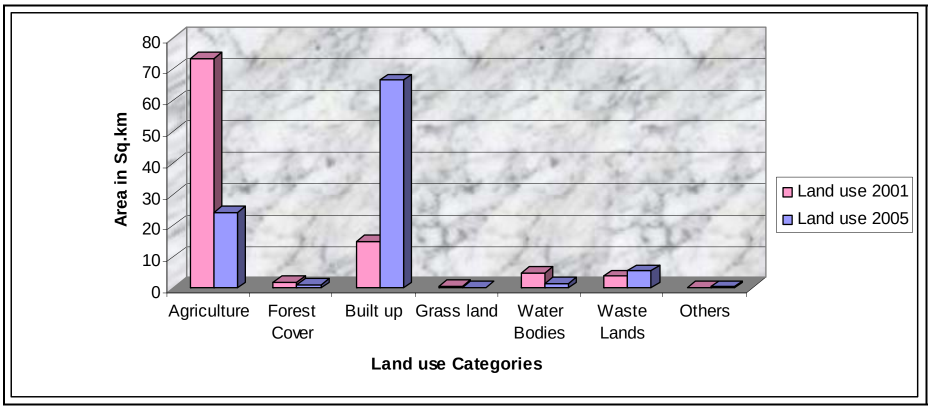

Fig. 6 Comparison between land use in 2001 and 2005

The agricultural land has decreased more than twofold, the lake area has one fold decreased and there is a considerable forest area loss can also be noted here. But the built-up has increased more than two fold and there is a notable increase in the waste lands too. All these suggest that there is an unabated ecological loss of the district which makes its charm to diminish. Thus there is an urgent need to check these losses and trace out the transformations through micro level studies. Table 3 and Chart 3 state the changes in land-use of Bangalore urban district, also giving the possibility to study the transformation of select variables of land-use, to give a clear understanding on the influence of urban built structures on the ecological space of the city. Also, the minute study of Fig. 5 suggests that the land-use resembles the multi nuclei model because of the multi-patches of nucleated settlements around the city of Bangalore.

7. Conclusions

- The important loss of ecological space like that of the decrease in the tanks, forests, agricultural lands etc. are been occupied by built up structures shows an unsustainable growth of the city.
- The agricultural land being prime victim of the urbanization, the city's demand for food crops are to be accomplished from far away. Thus, it would also increase the cost of the latter, leading to inflation. Therefore, the food security is shaken because of this process.
- The haphazard growth of urban built area can be attributed to sprawl and a close observation of its kind reveals that the city is on the line of leap frog sprawl, the worst of its kind. This may be a challenge for the future sustainable growth.
- Remote sensing and GIS are most vital tools for land-use studies and it is quite essential to adopt these cutting edge technologies to implement and reap benefits of sustainable development.

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