Assessing landscape changes of catchment area of Upper Lake Bhopal using patch analysis

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Abstract

Anthropogenic activities impart serious challenges on wetland management. The issues of Anthropogenic Activities manifest in the form of environmental degradation, point and non-point source pollution of lake water. Catchment area of upper lake Bhopal has been witnessing the same scenario; raising the question of its planning and management to control water pollution. It shows the necessity to analyse and study the pattern of land use & land cover(LULC). In order to assess the LULC pattern and spatio-temporal dynamics the changing pattern of patch number(NP), class area(CA), mean patch size(MPS), mean shape index (MSI), Shannon's Diversity index(SHDI), Simpson's Diversity Index(SDI) of all land use/land cover categories. In this research paper above mentioned parameters were measured and analyzed for landuse/landcover change from year 2003 to 2011. Area of agriculture and built up land expanded 16.18% and 4.77% while number of patches reduced by 332 and 187 for these two classes respectively. On the other hand class area of vegetation and barren land reduced 9.33% and 11.62%. Few patches of vegetation completely eliminated resulted in reduction of number of patches by 1250. Increased no. of patches of barren land by 150 shows fragmentation. Reduction in diversity indices indicates that area becomes less diversified during study period. During the period of 2003 to 2011 shape of patches of agriculture and built up land becomes more complex and that of barren land and vegetation converted to simpler shape. These indices provided meaningful insights pertaining to the spatio-temporal dynamics prevailing in the catchment area of Upper Lake Bhopal.

Keywords: Catchment,Landscape Indices,Patch parameters, spatio-temporal dynamics, Landscape dynamics.

Introduction

Economic development results in challenges of management and growth of landscape. Understanding the changing pattern of landscape is important for landscape planning and nature conservation. Quantification of changes in landscape pattern is the first step to understand the principles of ecology. Change in LULC of landscape can be expressed by words, maps or indices. This quantification by means of indices is recently developed method which has been used by different researchers to understand the landscape dynamics. This method gives opportunity to compare landscape patterns and to treat the data statistically.

Remote sensing data and GIS help in analyzing the pattern, growth and extent of urban sprawl pattern (Sudhira et al 2004). They also stated that pattern of sprawl could also be identified by modeling the extent of sprawl and subsequently nature of future sprawl can be predicted. Some landscape metrics required for quantifying sprawl was also described by him. *Turner and Ruscher (1998)* have used the size and number of patches, fractal dimension of patches, and diversity indices to quantify land use pattern in Georgia, USA. They found that

decreasing fractal dimension indicates simpler patch shapes while increasing trend of fractal dimension indicates complex patch shapes. They stated that ecological processes and resources are affected by changing patterns in the landscape. Landscape fragmentation was found statistically related with various biophysical, socioeconomic and spatial variables associated with LULC. On that basis (*Munroe et al. 2005)* studied the landscape fragmentation pattern. (*Lee et al. 2008)* attempted to understand the relationship between neighborhood and landscape structure for the city of College Station, Texas, USA using panchromatic and IKONOS multispectral images and to measure the landscape structures. They described the landscape structure using the NDVI (Normalized Difference Vegetation Index) method. Spatial pattern of the Guigang City, China was analyzed by (*Sun et al. 2006)* for 2 years 1985 and 2004 on the basis of various landscape indices such as patch fractal dimension, patch size, evenness and diversity index. They found that landscape shape was more regular and mean patch size was larger in 2004 than in 1985. Furthermore increase in Shannon's diversity index was observed in 2004 with patch evenness and patch richness. Changes in the main landscape types (industrial estate land, communal facilities land, residential land and farmland) were clearly indicated by landscape index computed for them. Transformation in land cover and land use from 1974 to 1998 in the east of Seattle, USA was quantified by (*Newell et al. 2005)* to study the impact of growth management efforts on urban fringe areas using patch parameters. They compared patch size, pattern, development type and per cent vegetative cover between 1974 and 1998 and contiguous growth was found in urban area. (*Weng et al. 2007)* analyzed changes occurring in residential pattern as a result of urban growth in an area of the City of Madison, Wisconsin, USA by using four metrics – mean patch size (MPS), patch density (PD), Shannon's evenness index (SHEI), percentage of landscape (PLAND). He found that landscape fragmentation and the degree of land use diversity are positively related to the degree of urbanization. Landscape pattern metrics with statistical data reduction techniques was used by (*Griffith et al. 2000)* to quantify landscape pattern of Kansas. They found modified Simpson's diversity index, the area weighted mean patch fractal dimension, juxtaposition and interspersion index, and the largest patch index as most important individual metrics.

Anthropogenic activities have changed the LULC pattern of Upper Lake Catchment and led to change in non-point source pollution of Upper Lake. Therefore primary aim of this paper is to study changes in landscape pattern of catchment using some landscape indices, which could provide a scientific basis for protection of Upper Lake water quality through non point source pollution.

Study Area

Bhopal is the capital of Madhya Pradesh. Upper and Lower lake together are known as Bhoj wetland. Upper lake located at 23°12' - 23°16' N , 77°18' - 77°23' E is the major source of potable water for the city. This lake is under great environmental stress due to pollution through different sources. Upper lake, have catchment of 361 sq. km. Upper lake is surrounded by Van Vihar National Park on the south, agricultural fields on the west and human settlements on the east and north. Major part of catchment is located in west and south-west of lake. This is agriculture land with few patches of built up land, tree and barren land.

METHODOLOGY

This study used two land cover classification maps derived from 2003 and 2011 Landsat data. The 2003 classification map is based on 30-m ETM image while the 2011 map is generated from 30-m Landsat TM image. The land cover classes of the classification maps include agriculture, barrenland, builtup land and vegetation. For classification, imagery acquired on 18 Jan 2003 and 16 Jan 2011 were used. A supervised classification method based on maximum decision likelihood rule was used to classify these images.

In order to quantify spatial and temporal changes in pattern within the study area, landscape indices were calculated using FRAGSTATS 4.1 software (freely available on http://www.umass.edu/landeco/research/fragstats/fragstats.html). FRAGSTATS is a software program written in C++ for use in MS Window operating system environment. It is designed to calculate landscape matrices. There are eight categories of statistics available in FRAGSTATS : 1. Area Metrics; 2. Patch Density, Size, and Variability Metrics; 3. Edge Metrics; 4. Shape Metrics ;5. Core Area Metrics; 6.Nearest Neighbor Metrics; 7.Diversity Metrics; 8. Contagion and Interspersion Metrics**.** Both spatial configuration and non-spatial composition were usually used to define spatial heterogeneity (*Giles and Trani,1999; Geneletti, 2004*). Non-spatial configuration includes Class area, patch density, Number of patches whereas the spatial composition includes patch shape and boundary characteristics.

For this study eight indices were considered : Patch number(NP), Class area(CA), Patch density(PD), mean patch size(MPS), edge density(ED), mean shape index (MSI), Shannon's Diversity index(SHDI), Simpson's Diversity Index(SDI). NP is number of all the patches within a class. CA is the summation of areas of all patches in hectares corresponding to a given class. It is calculated by measuring the area occupied by a particular class. NP and CA help together to study landscape change process. PD is the number of patches per unit area of landscape. Higher patch density shows more fragmentation. Intensity of disturbance to different landscapes can be estimated using PD. MPS of any patch type is the ratio of the total patch area and number of

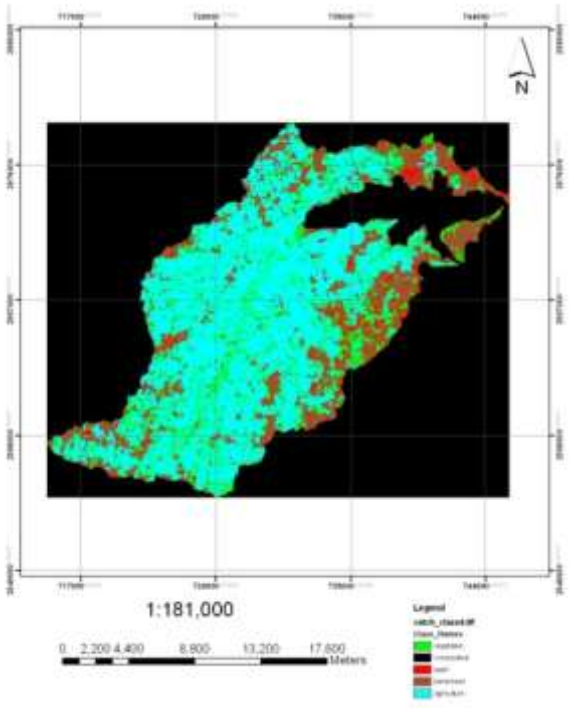

Fig 1 : Classified image 18 jan 2003

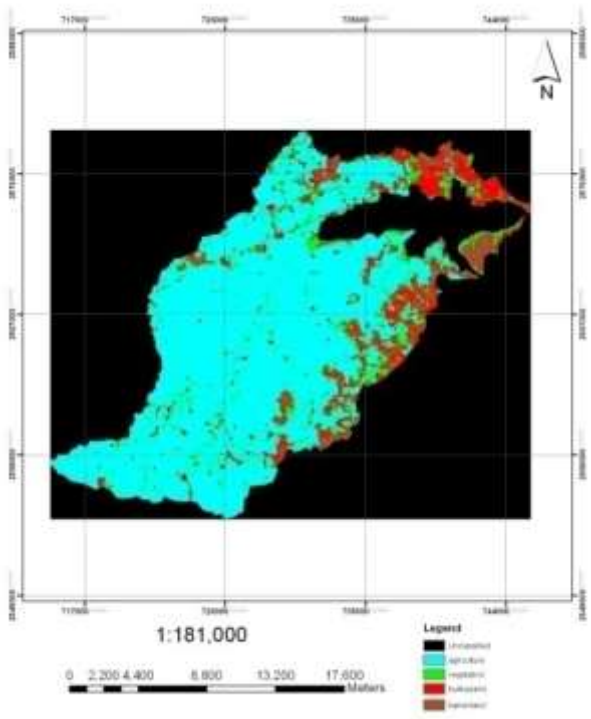

Fig 2 : Classified image 16 jan 2011

patches of corresponding class. It is used to show landscape fragmentation. ED is the ratio of summation of the lengths (m) of edge of corresponding patch type and total landscape area (m^2). ED represents spatial heterogeneity. MSI is the summation of ratio of patch perimeter and square root of area of same patch divided by no. of patches of corresponding class. MSI is a measure of the complexity of patch perimeter as compared to a perfect square. Zero value of SHDI shows one patch in landscape or no diversity. SHDI increases with number of patch types increases as proportional area of different patch types becomes more equitable.

Table1 : Landscape indices used

Indices	Equation	Explanation
Patch Number (NP)	n_i	n_i =Number of patches of individual class.
Class area (CA)	$CA = [\frac{\sum_{j=1}^{n} a_{ij}}{10000}]$	a_{ij}=area of patch j for the i^{th} land cover type A total landcover type
Mean Patch Size (MPS)	$MPS = \frac{\sum_{j=1}^{n} a_{ij}}{n_i}\left[\frac{1}{10000}\right]$	a_i =area of patch j for the i^{th} land cover type n_i = number of patches of i^{th} land cover type
Mean Shape index (MSI)	$MSI = \frac{\sum_{j=1}^{n}[\frac{0.25p_{ij}}{\sqrt{a_{ij}}}]}{n_i}$	P_{ij} = perimeter of patch j for i^{th} land cover type a_{ij} = area of patch j for the i^{th} land cover type n_i = number of patches of i^{th} land cover type
Shannon's Diversity index (H)	$H = -\sum(P_i * \log P_i)$	i =landuse/landcover category P_i =probability of I = f_i/n f=patch frequency of different LULC categories n =number of LULC categories
Simpson's Diversity index	$CA = 1 - \sum_{i=1}^{m} P_i$	i =landuse/landcover category P_i =probability of i = f_i/n f=patch frequency of different LULC categories m =number of LULC categories

Result

For this study changes in Agriculture, Barren land, Built up land and Vegetation from 2003 to 2011 were emphasized. As noted in table 3, Agriculture land expanded 27.73% (5243.847 ha) and built up land increased by 131.3% (1548.758 ha) while barren land and vegetation decreased by 58.65% (3769.59 ha) and 51.09% (3029.06 ha) respectively.

Figures demonstrates the general change of Mean Patch Size, Class Area, Number of Patches, Edge Density, Mean Shape Index, Patch Density at patch level for the four land cover classes. The NP associated with agriculture, built up and vegetation decreased by 332, 178 and 1250 respectively from 2003 to 2011. While NP of agriculture and built up land decreased, fig 3 shows increase in Mean Patch Size for these two land cover type. It suggests that expansion in CA of agriculture and built up land results in fewer but larger patches. However an increase in NP with reduction in class area and MPS for barren land shows fragmentation in barren land (BL) with conversion of BL to other land use type. Fig shows decrease in CA, NP and MPS for vegetation. It suggests that few patches of vegetation completely eliminated and converted to patches of other class. Changes in these three patch indices of all four classes show that BL and vegetation converted into agriculture and built up land. Larger patches of BL reduced to smaller patches and fragmented to increase the no. of patches. While patches of vegetation class converted to BU land and agriculture by completely eliminating few patches resulting into reduction in number of patches. Increase in MSI of agriculture and built up land indicates more complex shape of patches of agriculture and built up land. MSI of barren land and vegetation decreased from 2003 to 2011 which shows more regular shape of patches of these two classes.

Table2 : Indices at landscape level

INDEX	2003	2011
SHANNON'S DIVERSITY INDEX	1.0665	0.8487
SIMPSON'S DIVERSITY INDEX	0.5864	0.4238

Table 3: Land cover change: 2003 and 2011

Land Cover	Class Area			
	2003		2011	
	ha	%	ha	%
Agriculture	18908.74	58.28	24152.58	74.46
barrenland	6426.931	19.81	2657.337	8.19
builtupland	1179.544	3.64	2728.302	8.41
vegetation	5929.009	18.27	2899.953	8.94

Analysis of the Shannon's Diversity Index (H) yielded that there occur significant decrease in the value of H from 2003 to 2011 within the Upper Lake Catchment area from 1.0665 to 0.8487 indicating considerable increase in the gap of relative abundance of the four land use categories. It means that study area has become less diversified or proportion of agriculture and built up land increases in comparison to barren land and vegetation. The Simpson's Diversity Index computed for the catchment area for 2003 and 2011 are 0.5864 and 0.4238 respectively which also confirm the findings of Shannon's Diversity Index.

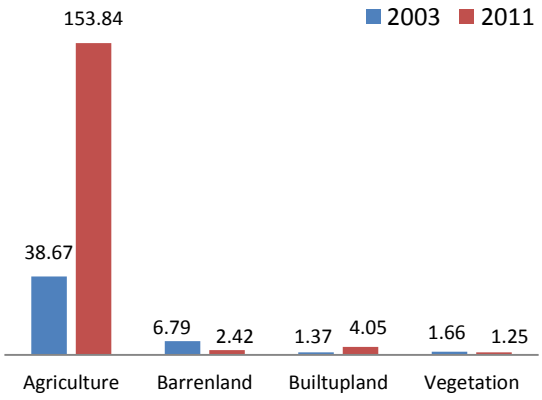

Fig 3: Mean Patch Size (ha) index

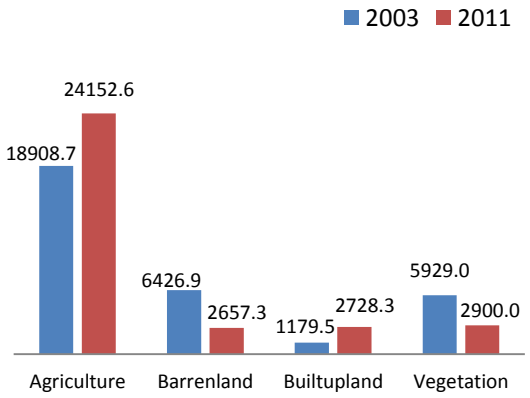

Fig 4: Class area index (ha)

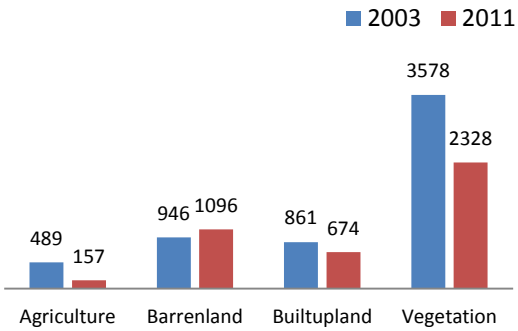

Fig 5: Number of patches

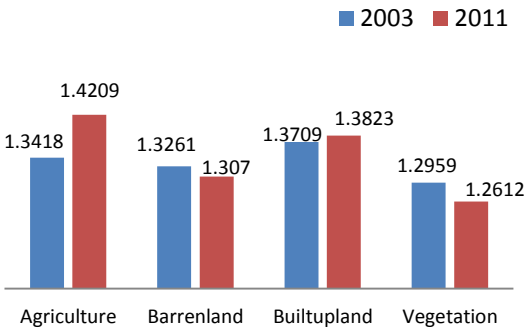

Fig 6: Mean Shape Index

Conclusion

In study area agriculture and built up land increased and number of patches decreased which shows that patches of these classes connected together with expansion in area to reduce the number of patches. Area of vegetation reduced with complete elimination of few patches. Area of barren land reduced and fragmented due to expansion

in built up and agriculture land. Shape of patches of agriculture and built up land converted to more complex while patches of barren land and vegetation converted to simpler shape.

Suitable description of indices is necessary to understand changes in landscape pattern. Several indices should be studied to get meaningful information. Important information on the changes of land use and pattern is given by different combination of indices. So the combination of several indices of each land use type shows how the changes in land use has been. Mean size of patches and number of patches are good indicator of the pattern development.

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