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Decadal Changes in Land Use/Land Cover Using Temporal Remote Sensing Data and GIS-A Case Study of Miniwada Panchayat, Nagpur District

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Abstract: The surface of the earth is undergoing rapid land-use/land-cover (LULC) changes due to population growth, various anthropogenic activities and natural phenomena. The main aim of the study is to quantitatively understand the decadal changes of LU/LC in Miniwada Panchayat using remote sensing data and GIS techniques. Supervised classification-maximum likelihood algorithm was applied in ArcGIS to detect LU/LC changes using multi-spectral satellite data obtained from Landsat TM and Landsat-8 for the years 2005 and 2015, respectively. The study area was classified into five major LU/LC classes, *viz.,* waterbodies, forest, agricultural land, fallow land and others. Change detection was performed to quantify the conversions of LU/LC from 2005 to 2015. Ground truth observations were also taken into consideration to check the accuracy of the classification. The results indicate that during the decade, the agricultural land showed 3.61% decline; at the same time, land under others (include settlement and government areas) showed an increase of 15.28%. LU/LC changes have a wide range of consequences at all spatial and temporal scales. The study reveals that the LU/LC pattern and its spatial distribution are the major rudiments for the foundation of a successful land-use strategy required for the appropriate development of any area.

Keywords: *Land use/ land cover, Landsat data, remote sensing, GIS, supervised classification*

Introduction

Land-use/land-cover (LU/LC) change is one of the most vital driving forces of global environmental change. Land use/land cover is two separate terminologies, which are often used conversely (Dimyati *et al.* 1996). Land cover refers to the physical characteristics of earth's surface, captured in the form of vegetation, water and soil. In contrast, land-use refers to the way in which land has been used by humans and their habitat, for economic activities. Land use/land cover is mutually related to one another and is dynamic. Today, the land is a limited resource due to immense agricultural and demographic pressure. This pressure results in unplanned and uncontrolled changes in LU/LC. Most ecosystems of the world have been altered or are being altered by human beings for multiple purposes - food, fuelwood, timber, fodder, litter and recreation. Many socio-economic and environmental factors are involved for the change in LU/LC, which have far-reaching impacts on a wide range of environmental and landscape attributes including the quality of water, land and air resources, ecosystem processes and function, and the climate system itself through greenhouse gas fluxes and surface effects.

Remote sensing and GIS are well-established information technologies, whose applications in land

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and natural resource management are widely recognized. These are imperative tools to obtain precise and suitable information regarding the spatial dispersal of LU/LC over large areas. Recent advancements in spatial, spectral, radiometric and temporal resolutions of satellite datasets and their availability have made it possible to perform image analysis at a much larger scale than in the past. Temporal satellite datasets have been widely used in measuring the qualitative and quantitative terrestrial LU/LC changes in cost effective and time efficient manner with better accuracy (Kachhwala 1985) in association with GIS that provides suitable platform for data analysis, update and retrieval (Chilar 2000). In the present study, an attempt has been made to analyze the extent of LU/LC changes occurred in Miniwada Panchayat, Nagpur over ten years' time period (2005-2015) using Landsat time-series datasets.

Materials and Methods

Study Area

Miniwada Panchayat is situated in Katol tehsil, about 45 km to the west of Nagpur city, Maharashtra (Fig.1). The panchayat includes three villages, namely, Miniwada, Mhasala and Malkapur, which lies between 21^0 08′ to 21^0 12′ North latitudes and 79^0 08′ to 79^0 15′ East longitudes and covers an area of 1630 ha. The elevation ranges from 407 to 472 m above mean sea level (MSL). The climate is mainly hot sub-tropical type with a mean annual temperature of 28 °C and mean annual rainfall of 980 mm. The area qualifies for 'hyperthermic' soil temperature regime and 'Ustic' soil moisture regime. The geology of the study area is covered by basaltic lava flows, commonly known as “Traps”. Columnar joints and spheroidal weathering are vital features of these rocks. The main field crops are cotton (*Gossypium spp.*), soybean (*Glycine max*), pigeon pea (*Cajanus cajan*), gram (*Cicer arietinum*), wheat (*Triticum aestivum*) *etc.* The natural vegetation comprises of teak (*Tectona grandis*), babul (*Acacia spp.*), Palash (*Butea frandosa*), Neem (*Azadirachta indica*), Mahua (*Madhuca longifolia*) *etc.*

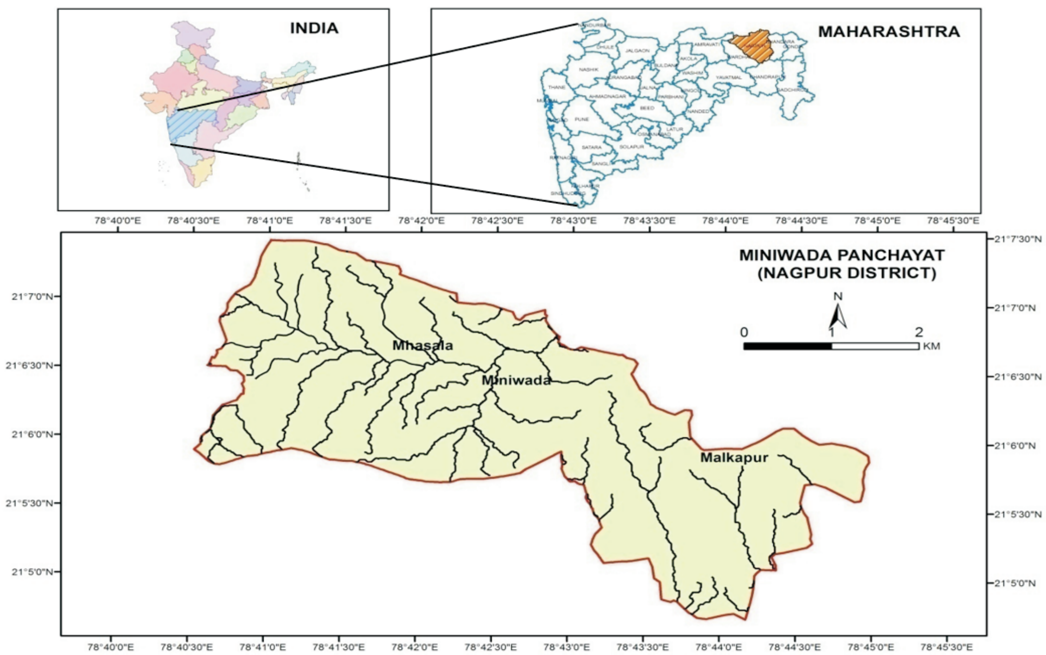

Fig. 1. Location map of the study area

Data collection and image processing

In the present study, the data used were divided into satellite data and ancillary data. Ancillary data include ground truth data collected by using hand-held GPS and Toposheets from Survey of India. Cloud free Landsat satellite imagery data of two dates were downloaded from USGS glovis (http://earthexplorer.usgs.gov/). The downloaded satellite data were preprocessed, georeferenced and projected to the Universal Transverse Mercator (UTM) projection system with WGS-84 datum. Subsequently, it was clipped on the basis of Area of Interest (AOI). Image interpretation for the development of LU/LC maps was carried out in ArcGIS 10.3 software by using maximum likelihood algorithm. The obtained maps were analyzed to detect the changes in LU/LC. Specifications of the satellite data used in the study are given in table 1.

Table 1. Satellite data specifications

Data	Date of acquisition	Bands/Colour	Path/Row	Source
Landsat TM	27/10/2005	Multispectral	144/45	USGS glovis
Landsat 8	07/11/2015	Multispectral	144/45	USGS glovis

LU/LC detection and analysis

For LU/LC classification, a post-classification detection method namely supervised classification method with maximum likelihood algorithm (MLC) was employed in the ArcGIS 10.3 Software. MLC is one of the most popular supervised classification methods used with remote sensing image data. It works based on the probability that a pixel belongs to a particular class. In this method, care must be taken to define signatures as the software uses those signatures to classify the remaining pixels. The basic theory assumes that these probabilities are equal for all classes and that the input bands have normal distributions. However, this method needs a long time of computation, relies heavily on a normal distribution of the data in each input band and tends to over-classify signatures with relatively large values in the covariance matrix. Ground verification was carried out in selected areas and based on the collected ground-truth data, the mis-classified areas were classified. The satellite data was classified by assigning per-pixel signatures and differentiating into classes on the basis of the specific Digital Number (DN) value. The delineated classes were waterbodies, forest, agricultural land, fallow land and others. For each of the pre-determined LU/LC type, training samples were selected by delimiting polygons around representative sites. Classified image pairs of two different dates were compared using cross-tabulation to determine qualitative and quantitative aspects of the changes for the periods from 2005 to 2015. A change matrix (Weng 2001) was produced with the help of ERDAS Imagine software, which gives the knowledge of the types of changes (directions) in the study area. Quantitative areal data of the overall LU/LC changes as well as gains and losses in each category between 2005 and 2015 were then compiled. It is the type of image classification, which is mainly controlled by the analyst as the analyst selects the pixels that are representative of the desired classes. To improve the accuracy of classification, post-classification refinement was therefore used for simplicity and effectiveness of the method (Harris and Ventura 1995). Visual interpretation is very important for the enhancement of classification accuracy and the overall quality of the LU/LC maps produced. Thus, visual analysis, reference data, as well as local knowledge, considerably improved the results obtained using the supervised algorithm.

Assessment of classification accuracy of 2005 and 2015 images was carried out to determine the quality of information derived from the data. For the accuracy assessment of land cover maps extracted from satellite images, a stratified random method was used to represent different land cover classes of the area. The accuracy assessment was carried out using 50 points, based on ground truth data and visual interpretation. The comparison of reference data and classification results was carried out statistically using error matrices. A non-parametric Kappa test was also performed to measure the extent of classification accuracy as it not only accounts for diagonal elements but for all the elements in the confusion matrix (Rosenfield and Fitzpatirck-Lins 1986). Kappa is a measure of agreement between predefined producer ratings and user-assigned ratings. Overall accuracy was calculated by dividing the sum of the correctly classified sample units by the total number of sample units.

Results and Discussion

The classified LU/LC maps of Miniwada Panchayat of the years 2005 and 2015 were given in figure 2. The classification results obtained through analysis of multi-temporal satellite imageries for 2005 and 2015 are summarized in table 2 and figure 3. Kappa statistics was also computed for each classified map to measure the accuracy of the results. The resulting classification of LU/LC maps of the two periods had Kappa statistics of 0.82 each. This was reasonably good overall accuracy and accepted for the subsequent analysis and change detection. Percentage of classes based on these results show the LU/LC practices observed in the study area during the period between 2005 to 2015.

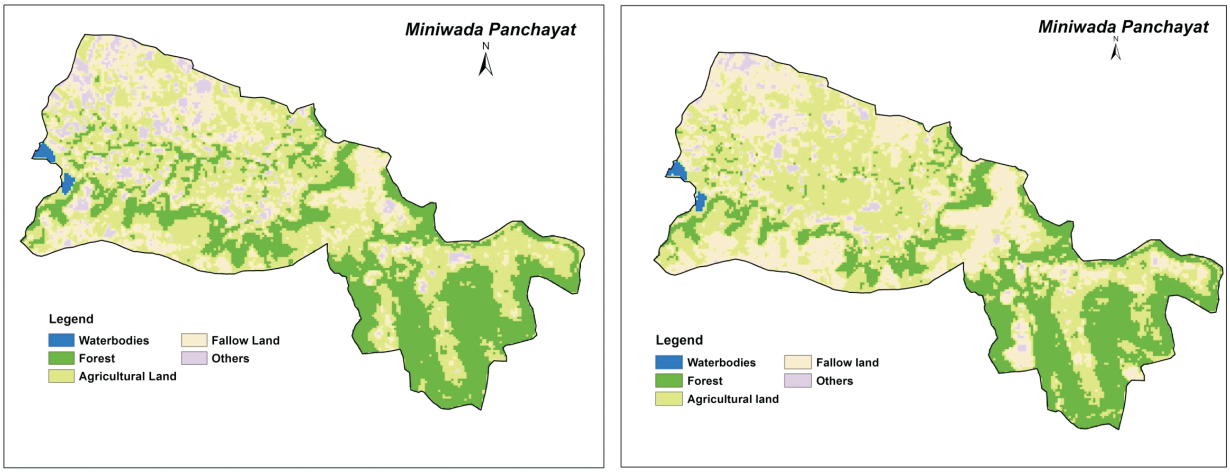

Fig. 2. Land use/land cover status of Miniwada panchayat in 2005 (left) and 2015 (right) (based on Landsat Imagery)

Table 2. Distribution of LU/LC in Miniwada Panchayat from 2005 to 2015

Land use/land cover	2005		2015		% change from 2005 to 2015
	Area (ha)	%	Area (ha)	%	
Waterbodies	7.53	0.46	6.69	0.41	-0.05
Forest	491.41	30.14	429.62	26.35	-3.79
Agricultural land	739.04	45.33	712.35	43.70	-1.63
Fallow land	336.16	20.62	416.94	25.57	4.95
Others	55.86	3.42	64.40	3.95	0.53
Total	1630	100	1630	100	

Land use change pattern

The results of the study show that the area under waterbodies, forest and agricultural land was declined. Whereas, the area under fallow land and others (settlements, government area, school) classes was increased. The area of waterbodies was decreased from 0.46 % in 2005 to 0.41 % in 2015, forest from 30.14 % to 26.35 % and the agricultural land, which was 45.33 % in 2005 and it was reduced to 43.70 %. The share of fallow land and others (Settlements, Roads, *etc.*) classes was increased from 20.62 to 25.57 % and 3.42 to 3.95 %, respectively, the changes observed in LU/LC might be due to anthropogenic activities.

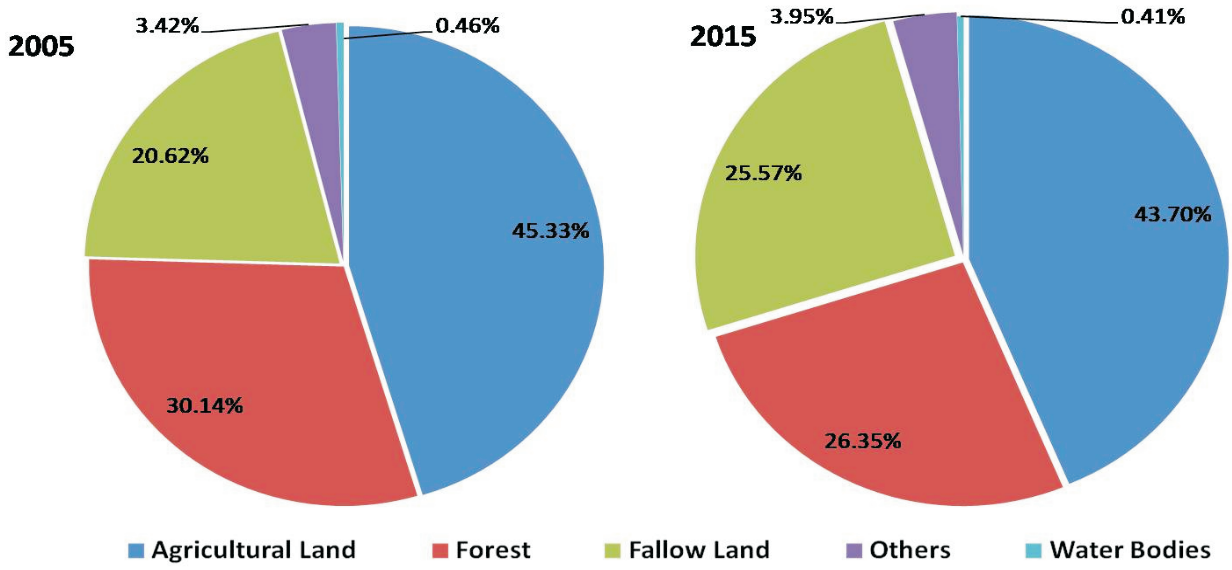

Fig. 3. Distribution of land use/land cover classes in 2005 and 2015

The comparison of each class of 2005 and 2015 showed that there had been a significant change in LU/LC during the study period of 10 years (Fig.3). During the period from 2005-2015, the percentage area covered by forest class reduced by 12.57 % and keeping the land exposed, which is the main reason for the loss of soil and making it unproductive. The major causative factors for forest decline in the panchayat could be human induced activities in forest fringe areas it includes use of forest wood for cooking, heating *etc.* The analysis shows the increase in fallow land area by 24.03 %, this might be due to socio-economic status of the farmers.

According to the information revealed by classification results, the agricultural land showed 3.61 % decline from 2005 to 2015. The other class comprising of settlement and government areas showed an increase of 15.28 % due to a large number of new housing schemes and recreational pursuits that have been developed in the past ten years. Along with these developments, there is an incline toward the construction of roads and other structures to access these areas. The area covered by the waterbodies class has also witnessed a decrease from 2005 to 2015. The percentage decrease in land area covered by this class was 11.15 %. The reason for the shrinkage was an increased rate of the surface run-off due to lack of plant roots to withhold the water. As the run-off exceeded recharge capacity of groundwater, it resulted in the lowering of the water table. Increased deforestation might be one of the reasons to deplete water.

The change area matrices (Table 3) show the nature of the change of different land cover classes or the shift in the land cover classes. Out of the 491.41 ha area under forest coverage in 2005, 428.78 ha was still under forest in 2015, but 62.63 ha was converted to fallow lands and thus, the fallow land had increased from 336.16 ha to 416.94 ha. Agricultural land decreased from 739.04 ha in 2005 to 721.35 ha in 2015 as 26.69 ha area was converted to fallow land. The area under others increased from 55.86 ha in 2005 to 64.40 ha in 2015.

Table 3 . Change area matrix of land use/land cover transitions from 2005 to 2015

			2015			
Class	Waterbodies	Forest	Agricultural land	Fallow land	Others	Total
Waterbodies	**6.69**	0	0	0	0	6.69
Forest	0.84	**428.78**	0	0	0	429.62
Agricultural Land	0	0	**712.35**	0	0	712.35
Fallow Land	0	62.63	26.69	**327.62**	0	416.94
Others	0	0	0	8.54	**55.86**	64.40
Total	7.53	491.41	739.04	336.16	55.86	**1630**

Conclusion

The study shows that the supervised classification of multi-temporal satellite images was found to be an effective tool to quantify current land use and detect their spatio-temporal changes. The observed changes varied from one LU/LC category to another with some maintaining a constant change (increase or decrease) over the two dates (2005 and 2015). Some classes underwent a decrease in the first period and an increase in the second period and *vice versa* were true for other LULC categories. Agricultural land has also decreased by 3.61 %. This depicts that the land under agriculture was cleared and might have sold out for the development of commercial and infrastructural activities. This study advocates that multi-temporal satellite data are very useful to detect the changes in LU/LC comprehensively, which have a wide range of consequences at all spatial and temporal scales in sustainable management of natural resources.

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