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EXPLORING THE SPATIO-TEMPORAL DYNAMICS OF FOREST LAND USE/LAND COVER CHANGES IN AHIRAN SUB WATERSHED OF CENTRAL INDIA

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ABSTRACT: This study analyzed spatio - temporal changes in forest land use/land cover of Ahiran sub watershed (a part of Hasdeo watershed) situated in Chhattisgarh of Central India. In the present study, Landsat Thematic Maper False Colour Composite images of the year 1999, 2006 and 2009 were interpreted for detecting the changes on forest land use/land cover. The dynamics of changes within forest land use/ land cover categories has been assessed by creating the database of the maps and subsequent analysis under GIS domain. The ground realities of changes and impact of those changes have been verified and ascertained respectively through field observations. The study revealed a total change of dense forest decrease 8.77% and non forest increase 20.9% during the year 1999 - 2009. The changes have mainly taken place in the form of its depletion/degradation of forest land cover and expansion of settlements. It is significant to note that most of the changes (70% out of total change) have occurred in the specified mining areas and among all the types of changes, forest degradation is the highest one. The impact of changes has been severe for the existing agro-ecosystem, as the productivity of agricultural crops has gone down considerably with the passage of time.
Keywords: Ahiran sub watershed, Spatio-temporal changes, Forest land use/land cover, RS & GIS.

1 INTRODUCTION

Forest land use/land cover change is a key driver of global change [1-3]. To meet the demands of large population means the need for more food production, more requirement of energy, more water requirement, better civic amenities for a reasonable quality of urban life, more infrastructure development to sustain increasing pressure and increased per capita expenditure for maintaining quality of life. This requires prudent use of land use/ land cover in the area. Land use refers to man's activities and various uses, which are carried on land (such as agriculture, settlements, industry etc). Land cover refers to the material present e.g. vegetation, water bodies, rocks/soils and other resulting from land transformations. Although land use is generally inferred based on the cover, yet both the terms land use and land cover being closely related are interchangeable [4-7].

The growing population and increasing socio-economic necessities creates a pressure on forest land use/ land cover (FLULC). This pressure results in unplanned and uncontrolled changes in land use/ land cover [8-12]. The FLULC alterations are generally caused by mismanagement of agricultural, urban, range and forest lands which lead to severe environmental problems such as landslides, floods etc [13].

Remote sensing and Geographical Information Systems (GIS) is one of the powerful tool to derive accurate and timely information on the spatial distribution of forest land use/land cover changes (FLULCC) over large areas past and present studies conducted by organizations and institutions around the world, mostly, has concentrated on the application of FLULC changes. GIS provides a flexible environment for collecting, storing, displaying and analyzing digital data necessary for change detection [14-18]. Satellite imagery is used for recognition of synoptic data of earth's surface [19-21]. Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) data have been broadly employed in studies towards the determination of land cover since 1972, the starting year of Landsat program, mainly in forest and agricultural areas [13]. The rich archive and spectral resolution of satellite images are the most important reasons for their use.

The aim of change detection process is to recognize LULC on digital images that change features of interest between two or more dates [22, 23]. There are many techniques developed in literature using post classification comparison, conventional image differentiation, using image ratio, image regression, and manual on-screen digitization of change principal components analysis and multi date image classification [24]. A variety of studies have addressed that post-classification comparison was found to be the most accurate procedure and presented the advantage of indicating the nature of the changes [25-26]. In this study, change detection comparison (pixel by pixel) technique was applied to the Forest land use\land cover maps derived from satellite imagery.

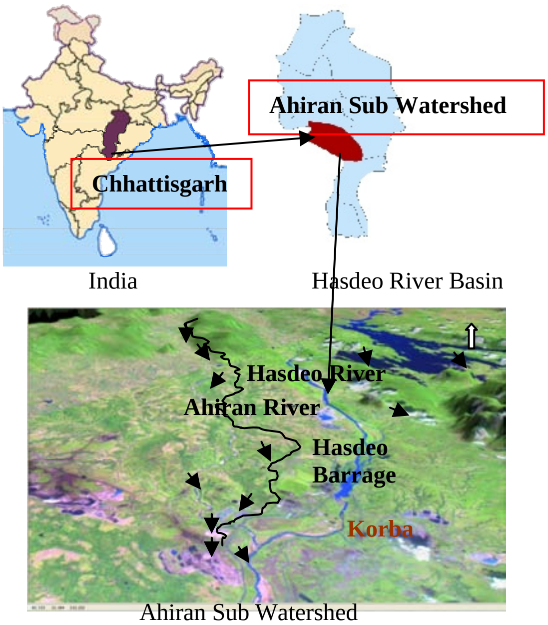

Figure 1: Location map of Ahiran Sub Watershed in Hasdeo River Basin

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The climate of the study site is monsoonic. The rainy season occurs during mid-June to September and about 80% of the total annual rainfall occurs during this period [29]. The period between December and February is characterized by cold and dry weather conditions. The summer season i.e., March to mid-June is the warm period. The annual rainfall ranges from 890 to 1240 mm per year. The mean minimum and maximum temperature ranges from 7.8°C (January) to 24.5°C during December-January and average relative humidity is maximum during August (93%) and minimum (25.5%) during April.

2 METHODOLOGY

2.1 Image Processing

LandSat TM and ETM images of scene 142/45 of year 1999, 2006 and 2009 and thematic maps were used for the study. Erdas Imagine version 10.0 and ArcGIS version 9.5 were used for the processing of the images. The raw satellite images were converted from Tag Image file format (Tiff) to img format using Erdas in order to be compatible with other Erdas Imagine files. The layers were stacked and sub-set to delineate the catchment area for classification. This was followed by georeferencing using the TM projection with reference units in square kilometer to allow compatible positioning of other themes such as forest, roads, settlement and drainage. Landsat images for assessment of the impact of Forest Land Use and Land Cover Changes on the Ahiran sub watershed which were already digitized in that format.

The band combination of red, blue and green was used to display the raw images in standard colour composites. The spectral band combination for displaying images often varies with different applications [30]. This was necessary for the visual interpretation of the images. A band combination of red, blue and green (RGB) is often used to display images in standard colour composites for forest land use/land cover and vegetation mapping [30]. In this study, the LandSat TM and ETM images were displayed in a band combination of 1, 2 and 3 (red, blue and green) which is standard for visual interpretation of vegetation mapping in the tropics.

2.2 Forest Land Cover Classification

The unsupervised classification method was used to classify the images into the various land cover categories. The unsupervised classification is a method of clustering. It is self-organizing in that the image data are first classified by being aggregated into natural spectral groupings or clusters present in the scene. It enables the specification of parameters that the computer uses to determine statistical patterns in the data. The procedure begins with a specified number of cluster means, and then it processes the image data repetitively, assigning each of the pixels to one of the class means. After each iteration the initial cluster shifts to represent the new statistical means of the clusters in the data. This happens until there is no significant change of cluster means. Then the land cover identities of these spectral groupings were determined by comparing the classified image to the ground reference data.

The statistics of the various classes were generated using the Erdas Imagine. Finally maps were composed, using ArcGIS (Version 9.5) and the maps were validated in the field to assess its accuracy. This was conducted through field visit to define how closely the classification agrees with the actual field situation. It involved the selection of samples of identified locations on the map, which were then checked in the field. In carrying field validation, GPS coordinates of 25 locations together with their respective cover classes were picked. The coordinates were geocoded in the classified maps and then the classified map was compared with the actual field situation.

2.3 Change Detection of FLULC

The most commonly used forest land use/land cover change detection methods includes : image overlay, classification comparisons of forest land use/ land cover statistics, change vector analysis and image rationing [19]. The method used in this study was the classification and comparison of forest land use/land cover statistics. This method was adopted because the study needs to find out the quantitative changes in the sub watershed areas of the various forest land use/land cover categories. Using the post-classification procedure, the area statistic for each of the land cover classes was derived from the classifications of the images for each date (1999, 2006 and 2009) separately, using Erdas Imagine software. The areas covered by each forest land use/land cover type for the various periods were compared. Then the directions of the changes (positive or negative) in each land cover type 1999 and 2006, 2006 and 2009, and 1999 and 2009 were determined [21].

3 RESULTS AND DISCUSSION

3.1 Results of land cover classification

A total of five forest land use/land cover categories were identified and classified in the study. These were Dense forest (DF), Non forest (NF), Open forest (OF), Scrubland (SBL) and Waterbodies (WBD) area as shown in Figure 2.

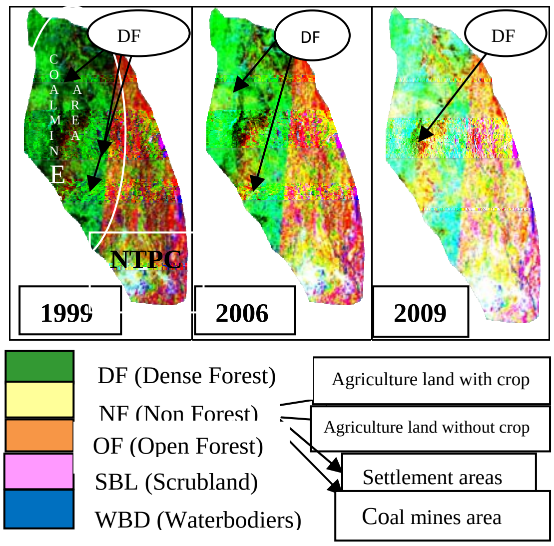


Figure 2: Spatio- temporal changes shows in Ahiran sub watershed in year 1999, 2006 and 2009

3.2 Extent of forest land use/ land cover (FLULC) categories

Table I shows that the most extensive forest land use/ land cover category of the Ahiran sub watershed as at 1999 was dense forest which covered about 11295.51 hectares (56.57%). The second most extensive forest land use/ land cover category was non forest, which covered 7131.91 hectares (35.59%). Open forest covered about 823.59 hectares (4.11%). This is followed by water bodies, which covered about 352.58 hectares (1.72%) and open area/town which covered 16.55 hectares (0.82%).

Table I: Forest land use/ land cover classes of the Ahiran sub watershed as in 1999, 2006 and 2009

FLULC	1999		2006		2009	
	Area (Km^2)	(%)	Area (kms2)	(%)	Area (kms2)	(%)
DF	205.613	22.71	177.542	19.61	126.213	13.94
NF	310.379	34.29	363.020	40.10	499.512	55.19
OF	105.768	11.69	114.154	12.62	134.992	14.91
SBL	1.004	0.11	1.891	0.20	8.413	0.92
WBD	282.466	31.20	248.603	27.47	136.100	15.0

Table I summarizes the forest land use/land cover classes of the Ahiran sub watershed. Moreover, as shown in Table I, the order of magnitude of the spatial extent of the forest land use/land cover categories in 2009 is different from that in 1999 and 2006.

3.3 Forest Land Use/Land Cover Changes (FLULCC)

Table II: Land cover changes of the Ahiran sub watershed for the periods between (1999 and 2006, 2006 and 2009 and 1999 and 2009).

FLULCC	1999-2006		2006-2009		1999-2009	
	Area (Km2)	(%)	Area (Km2)	(%)	Area (Km2)	(%)
DF	-28.071	-3.1	-51.329	-5.67	-79.4	-8.77
NF	+52.641	+5.81	+136.492	+15.09	+189.133	+20.9
OF	+8.386	+0.93	+20.838	+2.29	+29.224	+3.22
SBL	+0.887	+0.09	+6.522	+0.72	+7.409	+0.81
WBD	-33.863	-3.73	-112.503	-12.43	-146.366	-16.16

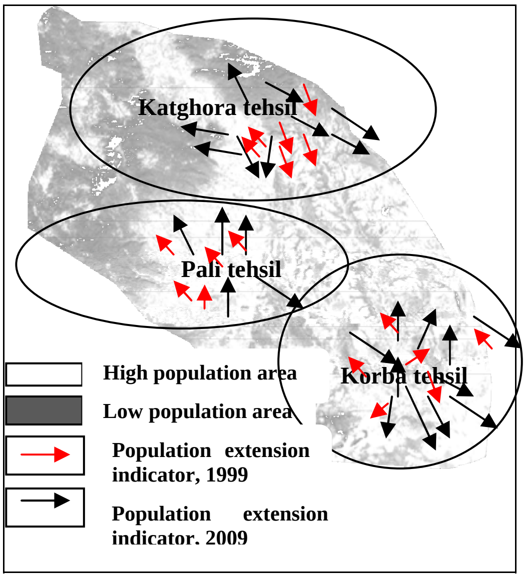
Table II shows the changes in the various forest land use and land cover categories (in km2 and %) during the periods between 1999 and 2006, 2006 and 2009, and 1999 and 2009.

In 1999-2006 the most extensive FLULCC to DF area which lost 28.071 sq kms (3.1%). It was followed by WBD with 33.863 sq kms (3.73%). Meanwhile, NF area gains 52.641 sq kms (5.81%), OF 8.386 sq kms (0.93%) and SBL 0.887 sq kms (0.09%). The landsat image study for 2006-2009, the assessment of the impact of FLULCC on the Ahiran sub watershed indicates that DF and WBD was lost from 51.329 sq kms (5.67%) and 112.503 sq kms (12.43%) area whereas, NF, OF and SBL was gained as 136.492 sq kms (15.09%), 20.838 sq kms (2.29%) and 6.522 sq kms (0.72%) area.

Finally, the order of magnitude of the FLULCC of the Ahiran sub watershed in 1999-2009 (10 years), interprets that DF and WBD area lost in high intensity of 79.4 sq kms (8.77%) and 146.366 sq kms (16.16%) whereas, NF, OF and SBL were area gained with 189.133 sq kms (20.9%), 29.224 sq kms (3.22%) and 7.409 sq kms (0.81%) respectively.

3.4 Causes of the land cover changes

The major cause identified in the study of the sub watershed is the population growth. Population growth is widely recognized as a key force behind environmental change, especially in developing countries [8]. The total population of the Ahiran sub watershed is distributed in three tehsils viz. Katghora, Pali and Korba tehsils. In Figure 3 white colour shows the high population area and black colour as low population area. The Korba tehsil has clear indication of high population area in compare to Katghora and Pali tehsil.



(Source: CoI, 2001)

Figure 3: Population status of Ahiran sub watershed in year 2009

The population extension indicator indicates that in Katghora tehsil of the sub watershed has maximum variation of population extension between years 1999-2009 in compare to other two tehsils. The main reason of population extension in this tehsil has been recorded as rich coal mines and forest availability in the forest area.
The total population of Ahiran sub watershed was recorded 413262 (CoI, 2001). In which the population of Kotghora tehsil, Pali tehsil and Korba tehsil in Ahiran sub watershed were 251645, 55649 and 105968 respectively. But in recent years the population extension indicator already shows that the population is increasing mostly from traditional settlement area to forest area due to extensive population pressure and coal mines extension (upto 70%) in forest areas. Moreover, uncontrollable farming activities as well as timber logging in the catchment also contributed to the decline

in the forest cover. This is as a result of inadequate education. The study identified that the people in the sub watershed have not been educated enough concerning the physical interactions between land use and agriculture farming. The impact of changes has been severe for the existing agro-ecosystem, as the productivity of agricultural crops has gone down considerably with the passage of time.

4 CONCLUSION

The analysis of LandSat TM images of 1999, 2006 and 2009 revealed that forest land use and land cover of the Ahiran sub watershed has changed over the years. Five broad classes of land use and land cover classes were identified and mapped from the 1999, 2006 and 2009 satellite images. These were forest, open forest, water body, open area/town and grassland. The results showed that between the years 1999 and 2009, dense forest and water bodies decreased by 8.77% and 16.16% respectively, whereas non forest, open forest and scrubland increased substantially by about 20.9%, 3.22% and 0.81%. Changes in forest land use and land cover of the Ahiran sub watershed were found to be related to population growth, logging for timber and lack of proper education.

The trend of forest land use and land cover changes detected in this study has shown general conversion of the forestland to wasteland and settlements [31, 32]. These conversions have potential consequences on the catchment characteristics, forest structure and hydrology. Since forest land cover is a function of rainfall regime, soil conditions and geomorphology [33] the conversion of the forest to grasslands and settlements would definitely lead to changes in the soil conditions and the geomorphology of the catchment [12, 34].

The conversion of forest to non forest and scrubland disrupts the forest cycle of the sub watershed by altering the balance between biodiversity, rainfall, evaporation, higher and lower plant ratio and population ratio [35, 36]. With a lower leaf area, the grass does not intercept Landsat Images for assessment of the Impact of FLULCC on the sub watershed. The shift from forest to wasteland and settlement may produce dramatic changes in the catchment peak flows as well and make the land more vulnerable to erosion leading to natural resource destruction [37]. Specific practices relating to farming and urbanization such as construction, soil compaction during logging can reduce the infiltration capacity of the soil and in turn the flow of water through the soil profile [38-39]. Moreover, the increase in farming activities in the catchment coupled with water capacity could also increase erosion and sedimentation. Therefore, these forest land use and land cover changes detected could be related to the forest land and agriculture changes in the sub watershed.

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