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Multi-temporal land use/cover change and its driving forces analysis using IRS-1D & P6 LISS3 satellite at early spring in Gej subwatershed of Hasdeo River in Chhattisgarh, India

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Abstract

The multi-temporal change detection analysis using Remote Sensing (RS) and GIS technology helps us to understand global landscape dynamics. The present work illustrates the spatio-temporal changes in land use/cover (LULC) of Gej subwatershed of Hasdeo river, Chhattisgarh, India from 2000 to 2013. (Indian Remote Sensing satellite) IRS-1D Linear Imaging Self Scanning Sensor (LISS III) image of 2000 and IRS-P6 LISS III images of 2004, 2008, 2010 and 2013 were acquired to quantify the NDVI and Land use/cover area changes from 2000 to 2013 at early spring season. Supervised classification method has been employed in IGIS 1.0 software. The image data of the study area were classified into eight different classes for LULC i.e.; dense forest, open forest, scrub, water resources, riverbed, agriculture land, settlement and barren land. The result indicates that during 2000-2013, the scrub, water resources, riverbed, agriculture land and settlement have been increased, in contrast the dense forest, open forest and barren land have been decreased. A significant positive correlation ($p \geq 0.05$) between agriculture land and scrub followed by settlement and scrub were recorded, in contrast the settlements record a negative correlation with barren land. The LULC accuracy assessment for the data analysis gives Kappa Coefficient accuracy of 97.00% and overall accuracy 99.66 %. The data base of the paper highlights the importance of change detection techniques to identify the major land cover changes, and monitoring the impact of human induced change in hydrological setting, behaviour and environment of the Gej sub watershed.

Keywords: Land use/cover, Gej sub watershed, IRS1D & P6, NDVI, Pearson correlation

Introduction

The Earth land is one of the most important natural resource which possesses flora, fauna, land and water and creates a balanced ecosystem (Turner and Ruscher, 2004). But the recent studies show that only few landscapes are in natural state on the Earth. Due to high economic development in the manner of industrialization, urbanisation, forest-agriculture land conversion, land resources have exploited to a greater extent (Longley et al., 2001). Land cover refers to the physical materials on the surface of a given parcel of land, while land use refer to the human activities that takes place or make use of land (Prakasam, 2010). The LULC pattern of an area especially in any watershed is outcome of socio economic factors and their utilisation by man, naturally in time and space (Rawat and Kumar, 2015). Rapid changes in LULC are observed throughout the earth surface due to heavy deforestation, agricultural encroachment, road construction, dams and irrigation, expansion of settlement areas, wetland modifications, mining and depleting fresh water resources (Liu et al., 2014) and coastal zone degradation (Patz and Olson, 2008). According to Lambin et al. (2000) due to deforestation more than 1.6 billion hectare of forest cover has been depleted from the earth while 1.24 billion hectare agriculture land has increased in last 300 years.

Land use/cover changes are major issues and challenges for the eco-friendly and sustainable development for the economic growth and harmful for the environment of any watershed area (Ruizluna and Berlangarobles, 2003). In the watershed, LULC changes pose risk of water quantity and quality degradation due to loss of vegetation cover which act as a barrier to the movement of materials into water system and reducing runoff (Notter et al., 2007). But these changes are sometime important for the improvement and updation of LULC dataset for effective planning and management and facilitating the foresters, farmers, local people and policy makers (Wardlow et al., 2007; Liang et al., 2013). Also understanding landscapes patterns, changes and interactions between human activities and natural phenomenon are essential for proper land management and decision improvement. In current scenario, earth resource satellite data are very applicable and useful for LULC change detection studies (Yuan et al., 2005; Brondizio et al., 1994). Watershed studies through Remote Sensing and GIS have been carried out by various workers to analyse the grass root conditions of any watershed. Linear Imaging Self-Scanning System (LISS III) data has been broadly employed in studies towards the determination of land cover since 1995 mainly in forest, water and agricultural areas (Ulbricht and Heckendorf, 2008). Several studies acknowledge the importance of data selection, radiometric collaboration and normalisation in performing accurate and reliable change detection analysis (Scheidt et al., 2008; Amin et al., 2012).

Pooja et al. (2012) have analysed LULC of Gagas watershed, Almora using SOI topographic sheets of the year 1965 and LISS III satellite data for the year 2008 over a period of 43 years. Mehta et al. (2012) presented an integrated approach of remote sensing and GIS for LULC study of arid environment of Kutch region in Gujarat in between year 1999-2009.

In the Gej sub watershed of Hasdeo river, landscapes are changing due to human intervention. An urgent need of research, to check the landscape conversion is required. So in the present paper, the drivers of LULC changes in Gej subwatershed have been studied using IRS-1D LISS III image of 2000 and IRS-P6 LISS III images of 2004, 2008, 2010 and 2013 acquired on early spring season.

Study Area

The Gej sub watershed (Fig. 1) is one of the eight sub watershed of Hasdeo river basin in Chhattisgarh, India and lies in the northern terrain of the state. It extends between 22^o 47'N to 23^o 33' N latitudes and 82^{o}34'E to 82^{o}56'E longitudes and encompasses an area of 2100 km^2. The sub watershed covers most of the area of Koriya and Surajpur district in the Chhattisgarh state and geologically characterised by steep, rough terrain, presence of Gondwana rocks and fertile land. Climatically, the study area enjoys cool and warm sub-tropical climatic conditions with good average rainfall of 1254 mm. The major stream of the Gej sub watershed is Gej river (perennial) with subsidiary Jhumka nala. The topographical condition of the area is suitable for the practice of irrigation and production of high yielding crops.

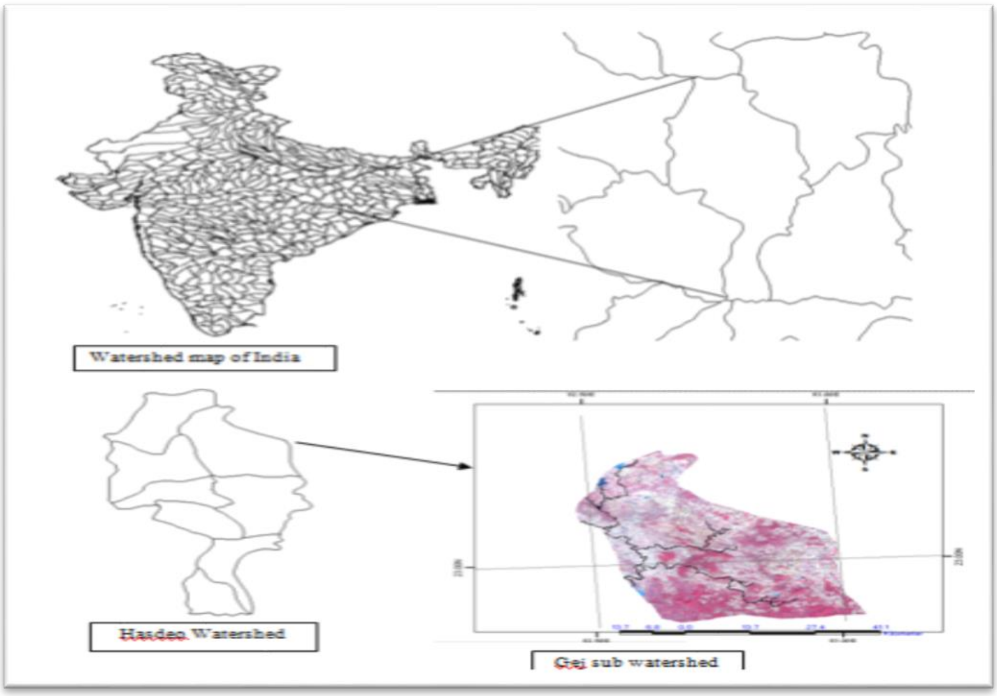


Fig. 1. Location of Gej subwatershed

Materials and Methods

Database preparation

The IRS-1D and IRS-P6, LISS III satellite data of resolution 23.5 m for the years (early spring) 2000, 2004, 2008, 2010 and 2013 (path/row: 102-56 & 103-56) have been used for the multi - temporal LULC classification of the study area. These satellite data were obtained from National Remote Sensing Centre (NRSC), Hyderabad, India and processed in IGIS 1.0 software (Scanpoint Geomatics Pvt. Ltd, Ahmedabad, India). The images were geo-referenced to rectify the alignment and co- registered to the Universal Transverse Mercator (UTM) projection system (WGS 84 datum). Open Map Series toposheets (64 J9, J13, I11, I12, I15 and I16) of 1: 50,000 scale was created and collected by Survey of India (SoI) on 1971-72 to prepare the base map of the area. Remote sensed satellite data were properly corrected to identify the real LULC change detection using multi date satellite data.

The LULC classification accuracy assessment only for the year 2000 was carried out by determining the quality of information derived from the data. Accuracy assessment of the study area was extracted from satellite image and stratified random sampling method was used to differentiate LULC classes of the area. The comparison of reference data and classification result was carried out statistically using error matrices. Kappa test was also performed to measure the extent of classification accuracy. Pearson correlation coefficient has been used to measure the correlation between the different LULC classes. The soil classification map/data has been provided by National Bureau of Soil Survey & Land Use Planning (NBSSLUP), Nagpur, India.

Generation of Normalised Difference Vegetation Index (NDVI) maps

Land use/land cover modifications, especially, changes in vegetative cover could have influence on the albedo and related to microclimate change in terms of rainfall and temperature variations (Sarma et al. 2001). The NDVI of the area is correlated with green leaf biomass, leaf area and an indicator of photosynthesis activities. In order to assess the vegetation health of sub watershed, NDVI analysis was carried out during the study. The basic formula taken for the analysis was NDVI= (NIR-R)/ (NIR+R). Where, NIR stands for Near Infra-Red band value and R stands for Red band value, recorded by the satellite sensor. The NDVI pixel value always ranges from -1 to +1. Vegetated areas generally yield high values of NDVI (i.e. positive value) because of their relatively high NIR reflectance and low visible reflectance. The NDVI maps were prepared from multi-temporal satellite data for the area.

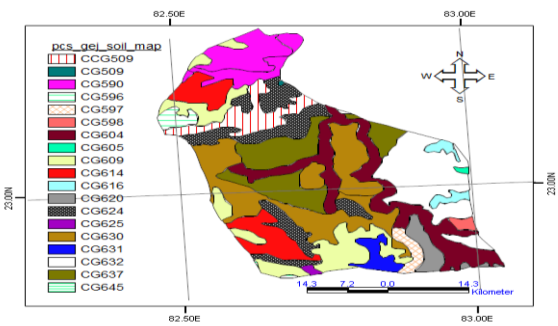
Land use land cover and its change detection analysis

The supervised classification method with maximum likelihood algorithm (Richard and Jia, 1999) was applied in the IGIS software with remote sensing image data. This method is based on pixel classes. The eight LULC classes were identified in the study area as mentioned above. Ground truthing for verification was also done in the area. For LULC change detection analysis, pixel based comparison method was used to produce change information on pixel basis and then interpretation of changes have been done (Rawat and Kumar, 2015). The Pearson correlation was carried out to further study the influence of LUCC on the water resources. The overall changes as well as gains and losses in each category for the year 2000, 2004, 2008, 2010 and 2013 were compiled and analysed. The household socio-economic pattern was also analysed in subwatershed.

Result and Discussion

Soil distribution pattern in subwatershed

In the whole subwatershed area soil distribution pattern was uneven. Eighteen soil types were identified in the area. The most common soil type found was fine loamy, loamy skeletal etc. The large proportion of the sub watershed has covered by CG 630 type soil (well drained, sloping plateau with moderate erosion, kaolinitic and hyperthermic). The eastern part of the study area has well distributed CG 632 and CG 637 type soil. These type of soil have been developed by well drained loamy soil with gentle slope. This nomenclature has been given by NBSSLUP, Nagpur, India



(Source: NBSSLUP, Nagpur)

Fig. 2. Soil map of Gej Sub Watershed area

The majority of the soils of this region are reported to be fine-loamy, kaolinitic, hyperthermic and typic halpustalfs with low soil fertility, high runoff, and low infiltration capacity. The riparian area of Gej river covers the loamy skeletal, slight deep, well drained and slightly stony type soil (CG 604). Declining soil fertility is particularly severe in the western

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part of Surajpur district because of high nutrient losses through soil erosion and extremely low fertilizer and manure inputs (figure 2). The other type of soil found in the sub watershed is hyperthermic typic ustochrepts (CG 509), loamy skeletal lithic ustochrepts (CG 596), hyperthermic typic haplustalfs (CG 597), lithic ustorthens (CG 614), vertic ustorthens (CG 616), hyperthermic udic ustochrepts (CG 645) and plinthustalfs (CG 637). Adhanom and Tashome (2016) studied Aba Midan Sub Watershed in Bambasi Wereda, West Ethiopia and stated the significant changes in the quality attributes of the soils and removal or destruction of vegetative cover and frequent tillage that lead to soil erosion and thereby declining soil fertility.

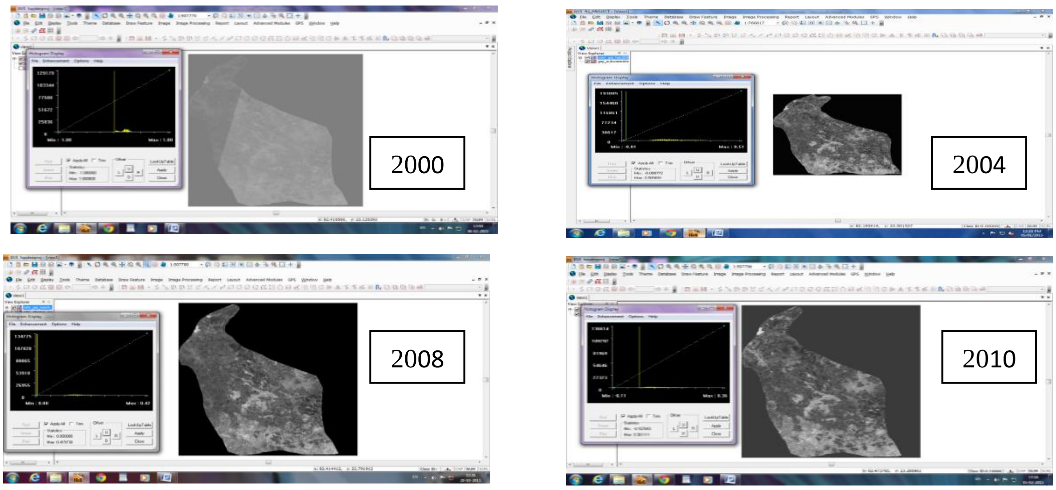
Normalized Difference Vegetation Index assessment

The NDVI maps have been generated using multi-temporal satellite data in IGIS software (Table 1, Figure 3). The different NDVI values for the sub watershed were analysed for early spring season period between 2000- 2013.

Table 1: Spatio-temporal Normalised Difference Vegetation Index (NDVI) assessment

NDVI status	*2000*	*2004*	*2008*	*2010*	*2013*
High	+0.36	+0.51	+0.39	+0.42	+0.45
Low	-0.11	-0.01	-0.02	0.00	-0.06

The NDVI value indicates that in year 2000, it varies between -0.11 to 0.36 while in year 2013 it was recorded between -0.06 to 0.45. The NDVI value for 2004, 2008, 2010 has been observed between -0.01 to 0.51, -0.02 to 0.39 and 0 to 0.42 respectively. The analysis shows the highest fluctuation in 2004 and the highest difference of the NDVI value for 2000-2013 was recorded 0.09.



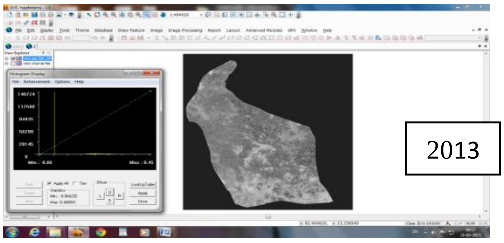


Fig. 3. NDVI of Gej sub watershed for year 2000, 2004, 2008, 2010 and 2013

The NDVI increment was due to high precipitation recorded in the area which helps to increase the vegetation cover. The changes were also found due to regular practices of soil and water conservation and different cropping pattern adopted by local villagers in the sub watershed. Ghorbani et al. (2012) in his study of Khalkhal County, Iran stated the NDVI variation from -0.44 to 0.74 in year 2002 on Landsat ETM+ images and values between -0.75 to 0.27 (2008) on IRS LISSIII images. Glenn et al. (2008) reported that in remote sensing studies bare soil value scaled at 0, and 100% vegetation will have higher values. For bare soils alone, depending on composition and wetness, NDVI varies between 0.1 and 0.2 (Carlson and Ripley 1999).

Analyses of Land Use Land /Cover change detection in sub watershed

The LU/LC maps, tabular variation and graphical representation of area changes for the year 2000, 2004, 2008, 2010 and 2013 have been shown in table 2 and in figure 4-5 respectively. The sharp decline of the riverbed area during 2000–2004 (6.05 km^2) was shown mainly due to encroachment of natural river bed at riparian areas by local peoples for vegetation cut and soil erosion. But the overall river bed has been increased during 2000-2013 by 5.06 km^2 (0.24%), it is due to increment of river width in some areas and due to increased rainfall. The water resources include river, pond, reservoir, streams etc of the study area. During 2004-2008 & 2010-2013 water resources increased by 2.53km^2 (0.12%) and 32.06 km^2 (1.52%) respectively, but during 2000-2004 & 2008-2010 it has been decreased by 0.63 km^2 (0.03%) and 28.48 km^2 (1.35%), the problem was less rainfall. Overall, the gradual increase (5.48 km^2 or 0.26%) of the water resources area during 2000–2013 has been recorded.

The area covered by barren land in Gej sub watershed show a decline trend during 2000-2013. The barren land area has been decreased during the period was 32.49 km^2 (1.54%) and the main reason of reduction was found the conversion of barren land into settlement area. The settlement area has increased during 2000–2013 by 52.10 km^2 (2.47%). The increment in settlement area was due to increment of the population settlement.

Table 2: Temporal changes of land use and land cover in the Gej sub watershed (unit: km^2).

Class/ Year	2000	Δ2000-2004	2004	Δ2004-2008	2008	Δ2008-2010	2010	Δ2010-2013	2013	Δ2000-2013
Dense forest	336.25	-27.63	308.61	-13.50	295.11	-61.38	233.73	28.90	262.63	-73.62
Open forest	332.87	11.18	344.05	29.32	373.37	5.48	378.86	-78.68	300.17	-32.70
Scrub	50.20	5.70	55.90	4.85	60.75	13.92	74.67	22.78	97.46	47.25
Water resources	50.20	-0.63	49.57	2.53	52.10	-28.48	23.63	32.06	55.69	5.48
Riverbed	38.81	-5.91	32.91	-7.80	25.10	44.09	69.19	-25.31	43.88	5.06
Agriculture land	781.34	8.65	789.99	2.32	792.31	7.38	799.69	10.55	810.24	28.90
Settlement	399.95	-4.01	395.94	20.88	416.83	16.03	432.86	19.20	452.06	52.10
Barren land	119.82	12.66	132.47	-38.60	93.87	2.95	96.82	-9.49	87.33	-32.49

Note: Δ2000-2004 represents the difference between 2000 and 2004.

In addition, scrub and agriculture land area also show increasing trend during 2000–2013 (47.25 km^2 (2.24%) and 28.90 km^2 (1.37%) respectively). The dense forest land cover show a decreasing trend by 336.25 km^2 (15.94%) in 2000 to 261.47 km^2 (12.45%) in 2013. This is mainly due to deforestation, population pressure and conversion of forest land into cultivated land. Long et al. (2007) had studied land-use changes in Kunshan, Jiangsu Province, China by using remote sensing. The outcome of their study indicated that paddy fields, dry land, and forested land in the area has moderately decreased by 8.2%, 29% and 2.6% from 1987 to 1994, and by 4.1%, 7.6% and 8% from 1994 to 2000, respectively whereas artificial ponds, urban settlements, rural settlements and construction land increased by 48%, 87.6%, 41.1% and 51.8% respectively mainly due to population requirement pressure.

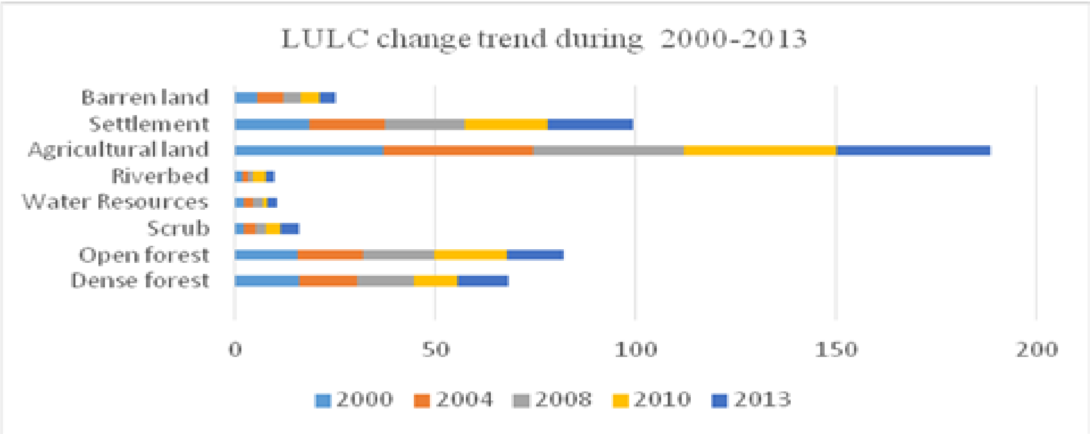


Fig. 4. Graphical representation of LULC changes (in %age) of subwatershed

The open forest area has also been decreased by 32.70 km^2 (1.55%) during 2000–2013. Overall, LULC pattern in the Gej subwatershed is characterized by the decrease of dense forest and open forest land, which is mainly converted into agriculture land and for settlement purpose. The result from the above study clearly indicates that there is a significant change in the forest area (both dense forest and open forest area). These results can become a strategic tool for forest planners and government officials to maintain the forest ecosystem health for better environmental conditions. According to Quan et al. (2006) the spatial-temporal characteristics of land use changes during 13 years from 1988 to 2001 in the special economic zone of Xiamen, China which was analysed by Landsat TM data of 1988, 1998 and 2001 indicates that in the 13 years cropland decreased by nearly 11304.95 ha. The areas of rural-urban construction and water body increased by 10152.24 ha and 848.94 ha, respectively but from 1988 - 2001, 52.5% of the cropland was converted into rural-urban industrial land. This rapid urbanization in the area during these periods contributed to changes in the rate of cropland use.

Raj et al. (2010) analyzed the LULC of Bharathapuzha basin, South India using multispectral LANDSAT imageries of 1973-2005 which showed 31% depletion in the natural vegetation cover and 8.7% depletion in wetland area. Another study conducted by George et al. 2016 showed 10% reduction in total forest area during 2000-2010 in Aluva taluka of Ernakulam district, Kerala, which was due to unprecedented rate of deforestation and rapidly rising human population pressure. The declining ratio of forest to agricultural lands and the increased intensity of land use, increases the pressure on remaining forest due to illicit cutting of trees for fire wood and for making charcoal and agricultural implements.

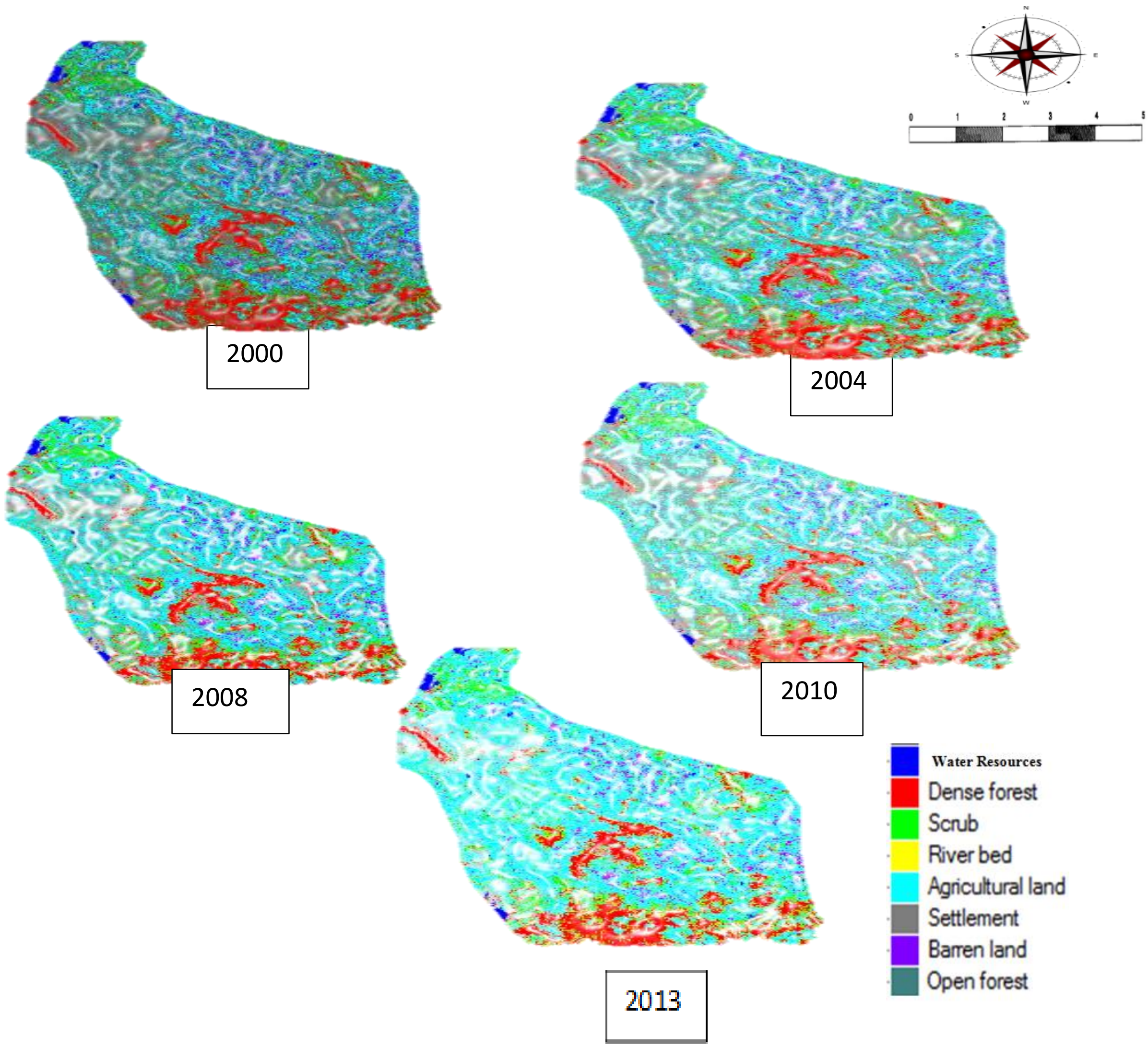


Fig. 5. Supervised classification of LULC classes of Gej Sub watershed for year 2000, 2004, 2008, 2010 and 2013 respectively

Determinants of changes in land use and land cover change

The main factors responsible for changes in LULC major part of sub watershed catchment area have been characterized by rural settlements which are agrarian in nature. Local people cultivate the area close to forest, thus there is pressure on forest land which are either converted to agricultural land, scrub or settlement area. As a result of rural settlements, people use fuel wood for cooking, which has being collected from the forest and small trees and shrubs are being destroyed thereby affecting natural vegetation of the area. Villagers also graze their domestic animals like goat, cow, buffaloes etc. in the forested area. Decreasing trend in area covered by barren land has been observed in the sub watershed catchment area which is either converted into settlement or in agriculture land.

Pearson correlation between the water resources and other LULC

Table 3: Pearson correlation (r) between different LULC of Gej subwatershed of Hasdeo River in Chhattisgarh, India between 2000-2013.

LULC class	Water resources	Dense Forest	Open Forest	Scrub	Riverbed	Agricultural land	Settlement	Barren land
Water resources	1	0.533	-0.632	0.046	-0.856	0.008	-0.073	0.048
Dense Forest	0.533	1	-0.204	-0.754	-0.732	-0.804	-0.816	0.689
Open Forest	-0.632	-0.204	1	-0.452	0.188	-0.375	-0.265	0.001
Scrub	0.046	-0.754	-0.452	1	0.413	0.993**	0.964**	-0.755
Riverbed	-0.856	-0.732	0.188	0.413	1	0.424	0.466	-0.282
Agricultural land	0.008	-0.804	-0.375	0.993**	0.424	1	0.961**	-0.753
Settlement	-0.073	-0.816	-0.265	0.964**	0.466	0.961**	1	-0.892*
Barren land	0.048	0.689	0.001	-0.755	-0.282	-0.753	-0.892*	1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Results of relationship between water resources and other LULC classes has been reported for thirteen years using Pearson's correlation coefficient (Table 3). A significant correlation between agriculture land and scrub has been found (r = 0.993) followed by settlement and scrub (r = 0.964) on 0.01 level between the year 2000-2013. The negative correlation of r= -0.892 was recorded between barren land settlement. The other classes viz; water resources and dense forest (r = 0.533) and water resources and barren land (r = 0.689) also show significant positive correlation. This indicates that scrub area has been damaged enormously for agriculture land and settlement mostly in rural areas of the sub watershed. Plantation in barren land of mining areas and rich availability of water resources in the catchment of Hasdeo and Gej river shows increment in dense forest area. Similar types of results were observed by Tian et al. (2014) in Beijing urban area and Du et al. (2014) in Jiangsu Province.

Conclusions

The study was undertaken for evaluation of multi temporal LULC change and its driving force analysis of Gej sub watershed in Hasdeo river, Chhattisgarh, India. The monitoring and evaluation of sub watershed using remote sensing data provides accurate information, which will be helpful for the proper planning and management of the sub watershed. The LULC shift in the sub watershed area was evident by the decline in the area of dense forest, open forest and barren land (3.49%, 1.55% and 1.54% respectively) and augmentation of area cover by classes of scrub (2.26%), settlement (2.67%), agriculture land (1.39%) and water resources (0.46%) in year between 2000-2013. The study indicates that the forest area (both dense forest and open forest) has decreased by 5.04% as the most prominent change signifying land degradation. The increase in the area under settlement and agriculture area has resulted in decrease of dense and open Forest area of the watershed, which may lead to a lot of environmental and ecological problems. The riparian area status in the sub watershed shows the increment in forest due to availability of water resources but decrease in agriculture land. The uncontrolled expansion of settlement and agriculture area in the sub watershed was mainly due to lack of proper management and land use planning since no any future plan report is generated prior to land development in the study area. Increase in population leads to increased agricultural activities in the catchment area due to which there is increased pressure on the water and forest resources of Gej sub watershed.

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