RESEARCH ARTICLE

Identification Of Temporal Dynamics Of Vegetation Coverage Using Remote Sensing And Gis (A Case Study Of Western Part Of West Bengal, India)

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ABSTRACT

Monitoring vegetation coverage changes using multi-temporal remotely-sensed data offers an efficient and exact evaluation of anthropogenic intervention on the natural environment. Study was conducted to explore the spatio-temporal changes in vegetation cover using the potential multi-temporal satellite data captured in 1999, 2002, 2005 and 2009 in Kangswati (Cossi) river and Dwarakeswar river interfluves area, West Bengal. Temporal changes were determined using image differencing of normalized difference vegetation index (NDVI) in that time series. The highest maximum NDVI value was found in 2009 (maximum NDVI of 0.99), and lowest value was recorded in 1999 (maximum NDVI of 0.48). By 2002 - 2005, the area of surface waterbody decreased to 0.89% and in 2009, it grew to 1.03%. In 2002 and 2005, highest percent of surface area is coved with the low density vegetation zone. By 1999 – 2005, there was decreased in trend of bare surface area, while in 2005 – 2009, there was an increased in trend. Between 1999 and 2009, the low density vegetation zone portrayed increased in trend. Assessment conducted on the generated thematic images signifies accuracies of 86.0%–92.0% were attained. However, the NDVI results indicated the vegetated area decreased and it may be due to the anthropogenic intervention.

INTRODUCTION

Vegetation or forest is the most important factors governing the ecology of an area, providing inferences to derive parameters like land use, water table, soil information etc (Bakr *et al*., 2010). Forest and wild life are essential biological components for maintaining the ecological balance of a geographical area. The importance of mapping, quantifying, and monitoring changes in the physical characteristics of forest cover has been widely recognized as a key element in the study of global change (Nemani and Running, 1996). The vegetation mapping is to recognize and characterize the different vegetation cover on the earth surface and it appraises particular vegetation characteristics and its coverage. The change in vegetation pattern has a feedback influence on the local and regional climate by reducing evaporative water losses from surface to atmosphere.

Study of vegetation characteristics over a long time periods of an area provide an inimitable opportunity to recognize vegetation dynamics, including interannual variability in vegetation composition and spatial changes (Rahman *et al*., 2011; Pen˜ uelas *et al*., 2007; Root *et al*., 2003). A difficulty often encountered in vegetation resource mapping is of demarcation of plant cover from other varieties of vegetation like bushes, agriculture, etc., when they are stirring contiguously or in the locality (Neldner *et al*., 2012; Chastan *et al*., 2006). However, the reflectance pattern from tree cover and soft stem vegetation like agriculture crops illustrates emblematic tones on the satellite imagery due to topographical and phonological variations. Consequently, because of occurrences of vegetation characteristics of transitional gradations, severance of tree vegetation from bushy or herbaceous vegetation becomes tricky. Digitally processing of remote sensing data provides tools for investigating the satellite data through various

algorithms and mathematical indices of spectral bands (Roy and Ravan, 1996; Goslee, 2011). Based on the reflectance properties, indices have been formulated to emphasize features of interest on the remote sensing data. There are numerous indices for accent vegetation-bearing areas on a satellite data, and Normalized Difference Vegetation Index (NDVI) is a general and extensively used index (Yin *et al*., 2012; Joshi, 2011; Drissi *et al*., 2009; Justice *et al*., 1985). Several change detection studies have shown that inter-date changes in vegetation properties are best identified when image data are enhanced using vegetation indices prior to image differencing (Coppin and Bauer, 1996; Fung, 1990; Mas, 1999; Radeloff *et al*., 2000).

Assessment of vegetation vigour with remotely sensed imagery has been fairly triumphant. Both mechanistic and experimental methods are extensively employed in modeling vegetation dynamics (Carmelm *et al*., 2001; Qi *et al*., 2000). The vegetation mapping is to recognize and characterize the different vegetation cover on the earth surface and it appraises particular vegetation characteristics and its coverage. The change in vegetation pattern has a feedback influence on the local and regional climate by reducing evaporative water losses from surface to atmosphere. In the present study, we explored the spatio-temporal changes in vegetation cover using the potential multi-temporal satellite data in Kangswati (Cossi) river and Dwarakeswar river interfluves area, West Bengal (India).

Study area

The study area is extended between 23°12′44.87″ N to 22°22′01.09″ N latitude and 86°50′06.83″ E to 87°49′49.65″ E longitude, and with an area of 7,512.62 km[2]. The present study represents regional diversities in terms of physiographic, agro-climatic characteristics, economic development and social composition etc. Physiographically, of the region can be categorized into three parts, *viz* Chotonagpur flanks

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with hills, mounds and rolling lands in the western part, Rahr Plain with lateritic uplands in the middle part and alluvial plain of the east with recent deposits. The area is drained by the Dwarkeswar, Silabati, Kangsawati river. Drought-affected dry areas have found in the west but the eastern part is characterized by highly wet flood-affected areas. Dense dry deciduous forest in the west is replaced by semi-aquatic vegetations of marsh lands in the east.

clouds, water and snow have better visible reflectance than those of near-infrared (NIR). Accordingly, those features acquiesces negative index values. Rock and bare soil enclosed areas have comparable reflectance in the VIS/NIR bands and consequence in vegetation indices near zero. Because of these possessions, NDVI has suit the principal tool for mapping changes in vegetation cover and analysis of the impacts of environmental phenomena.
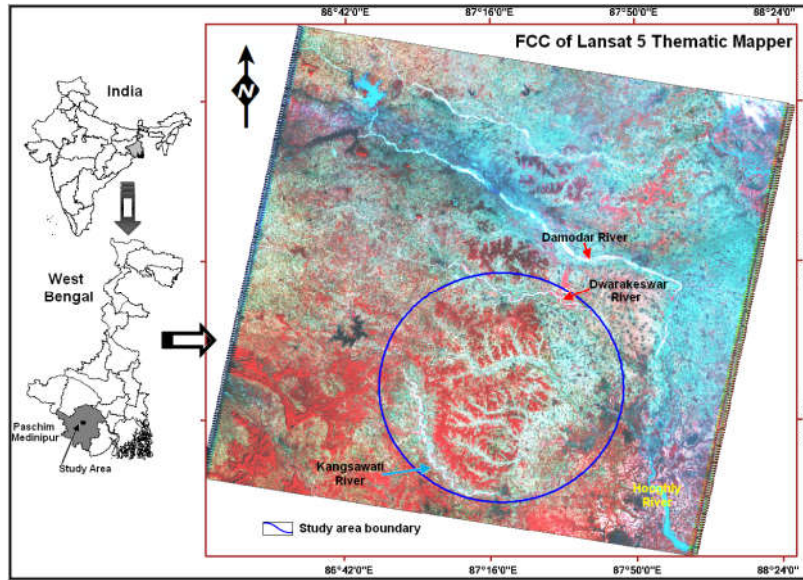

Figure 1. Map of the study area

MATERIALS AND METHODS

Image acquisition and processing

Landsat 4 and 5 imageries were used for this present study. Four periods of satellite data were selected to extract the vegetation vigor of the study area: Landsat-4 Thematic Mapper (TM) November 06, 1999; Landsat-5 TM October 29, 2002; November 14, 2005 and November 18, 2009. The details of the data were described in Table 1. All these images were rectified to Universal Transverse Mercator (UTM) coordinate system, Datum World Geodetic System (WGS) 84, Zone 45 North and based on second order Nearest Neighbour algorithm for matching the geographic projection of the reference data. The images were subtracted based on the Area of Interest (AOI) of the Kangswati and Dwarakeswar river interfluves area for further analysis.

The colour density slicing technique was pertained to the data provided by the NDVI images in order to codify the classes and compare vegetation changes of the interfluves areas and its surroundings in 1999 and 2009.

Change detection analysis

Alteration in canopy cover or vegetation biomass can be perceived by analyzing NDVI values between separated dates using image differencing. It entails subtracting one date of original or transformed (e.g. vegetation indices) imagery from a second date that has been precisely registered to the first (Banner and Lynham, 1981; Serneels *et al*., 2001). It is normally carried out on the basis of gray values. The altered region and unchanged region is established by choosing the appropriate threshold values of gray levels in the difference image. The gray value of the difference image illustrates the changes of corresponding pixels of two images.

Table 1. Details characteristics of satellite data

Date of acquisition	Scene ID	Sensor	Sun Azimuth	Sun Elevation	Spatial resolution	Cloud cover	Geometric RMSE
06th November 1999	LE71390441999310SGS00	ETM+	146.72	47.40	30 m	0.00	2.623
29th October 2002	LE71390442002302SGS00	ETM+	150.09	45.90	30 m	0.00	3.655
14th November 2005	LT51390442005318BKT00	TM	150.22	43.21	30 m	2.00	4.432
25th November 2009	LT51390442009329KHC00	TM	151.68	40.93	30 m	0.00	4.026

Normalized Difference Vegetation Index (NDVI)

Green and vigorous vegetation reflects lesser amount of solar radiation in the visible wavelength ($Channel_3$) contrasted to those in near-infrared spectrum ($Channel_4$). The Normalized Difference Vegetation Index (NDVI) is defined by Rouse *et al*., (1974) and Tucker (1979) as: NDVI = ($Channel_4 - Channel_3$) / ($Channel_4 + Channel_3$). Four NDVI continuous images, for all dates, resulted from this step with float data type (continuous real numbers). Each image at each date was recoded to only two values: 0 and 1. Zero for the non-vegetated land and one for vegetated land. The healthy and intense vegetation demonstrate a large and positive NDVI. In compare,

DIF [1999, 2000] =NDVI [1999] – NDVI [2000]
DIF [2000, 2005] =NDVI [2000] – NDVI [2005]
DIF [2005, 2009] =NDVI [2005] – NDVI [2009]
DIF [1999, 2009] =NDVI [1999] – NDVI [2009]

Accuracy assessment

Accuracy of the vegetation coverage area was established empirically, by autonomously picking fifty random samples of pixels from each resulting map, from each technique at each date, and examining their labels aligned with classes dogged from reference data. The results of the analyses were articulated in an error matrix table, previously

offered by Congalton (1991). Kappa coefficient is also calculated to measure the map accuracy (Congalton and Green, 1999).

RESULTS AND DISCUSSION

NDVI analysis results

NDVI images was created using Landsat TM and ETM+ data for each image at each date (1999, 2002, 2005 and 2009) using band 3 (R) and band 4 (NIR) and used in the analysis of variation in NDVI. Vegetation index and difference images were generated for the 10 years study period (Figure 2a). Results showed that the vegetation index map derived by NDVI transformation within each computational group were dissimilar in terms of spatial distributional pattern and statistical characteristics. The highest maximum NDVI value was found in 2009, and lowest value was recorded in 1999. The mean NDVI value of the study area is gradually increasing during the period between 1999 and 2009 (Figure 2b).

Monitoring spatial and temporal changes of vegetation coverage

The NDVI values were divided into seven main classes: surface waterbody, bare surface, very low density vegetation zone, low density vegetation zone, medium density vegetation zone, high density vegetation zone and very high density vegetation zone. The negative values of NDVI represented the surface waterbody, and the value between 0.01 and 0.100 represented bare surface. However, the positive values of 0.101 – 0.250, represented agricultural/crop land, while the higher positive value represented the vegetated areas. Figure 2a and Table 2 explain the NDVI continuous images and the area coverage for the NDVI classes by square kilometer and percentage on different dates, respectively. Results showed that in 1999, the interfluves area were 44.70% (3358.28 km^2) and 33.77% (2537.28 km^2) very low density vegetation zone and low density vegetation zone respectively. By 2002 - 2005, the area of surface waterbody decreased to 0.89% (66.72km^2) and in 2009, it grew to 1.03% (77.57km^2). In 2002 and 2005, highest percent of surface area
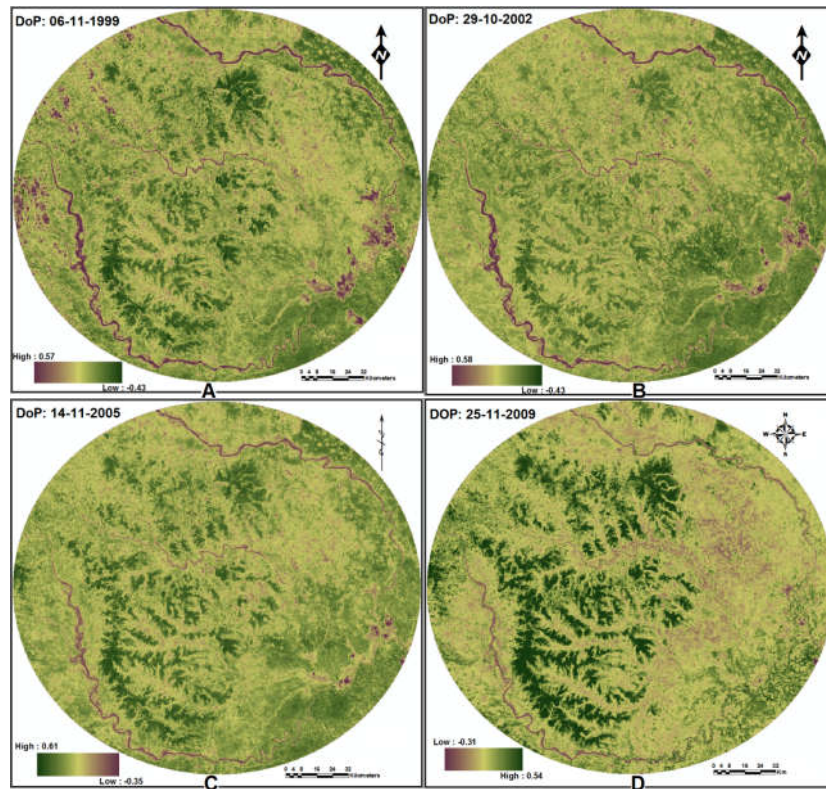

Figure 2a. Temporal coverage of vegetation characteristics during the period from 1999 to 2009
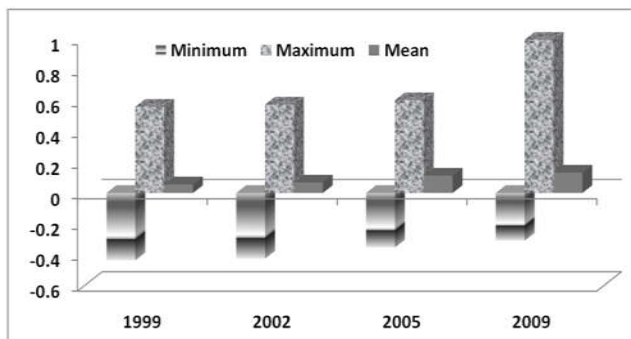

Figure 2. Vegetation characteristics derived through NDVI at different period in the study area

is coved with the low density vegetation zone (44.15% and 41.28% respectively). By 2009, very low density vegetation zone increased to 59.54% (4472.68 km^2), while the low density vegetation zone decreased (13.56%, 1018.50 km^2). High density vegetation zone is also decreased in 2009. However, very less percent of area covered with the very high density vegetation zone in the study site. According to the preceding results from the NDVI analysis, monitoring the alterations of vegetation converges between two dates were delineated. Table 3 and Figure 3a show the incessant vegetation coverage transform images using the outputs of NDVI analysis at two different dates and the differences between the areas which changed from one land cover class to another by areas, respectively. The results showed that in 1999 and 2005, interfluves area of 153.21km^2 and 122.41km^2 were decreased in surface waterbody; while in 2005 – 2009, 10.85 km^2 areas were increased. However, the overall analysis during the period between 1999 and 2009 showed decreased in trend

Table 2. Surface characteristics of vegetation vigor derived through NDVI

Surface Characteristics	NDVI Value	1999		2002		2005		2009	
		Area (sq. km)	Percent	Area (sq. km)	Percent	Area (sq. km)	Percent	Area (sq. km)	Percent
Surface waterbody	<0.00	342.34	4.56	189.13	2.52	66.72	0.89	77.57	1.03
Bare surface	0.01 - 0. 100	598.28	7.96	337.85	4.50	291.83	3.88	1415.07	18.84
Very low density vegetation zone	0.101 -0. 250	3358.28	44.70	1911.25	25.44	2117.48	28.19	4472.68	59.54
Low density vegetation zone	0.251 - 0.350	2537.28	33.77	3316.98	44.15	3101.07	41.28	1018.50	13.56
Moderate density vegetation zone	0.351 - 0.450	669.72	8.91	1713.61	22.81	1765.45	23.50	523.70	6.97
High density vegetation zone	0.451 - 0.550	6.76	0.09	43.76	0.58	169.99	2.26	5.10	0.07
Very High density vegetation zone	>0.551	0.01	0.00	0.06	0.00	0.05	0.00	0.02	0.00
Total		7512.67	100.00	7512.63	100.00	7512.59	100.00	7512.63	100.00

Table 3. Change detection analysis of vegetation vigor derived through NDVI during the period from 1999 – 2009

NDVI Value	1999 – 2002	2002 – 2005	2005 – 2009	1999 – 2009
	Area (km^2)	Area (km^2)	Area (km^2)	Area (km^2)
Surface waterbody	153.21↓	122.41↓	-10.85↑	264.77↓
Bare surface	260.43↓	46.02↓	-1123.24↑	-816.79↑
Very low density vegetation zone	1447.03↓	-206.23↑	-2355.20↑	-1114.40↑
Low density vegetation zone	-779.70↑	215.91↓	2082.57↓	1518.78↓
Moderate density vegetation zone	-1043.89↑	-51.84↑	1241.75↓	146.02↓
High density vegetation zone	-37.00↑	-126.23↑	164.89↓	1.66↓
Very High density vegetation zone	-0.05↑	0.01↓	0.03↓	-0.01↑

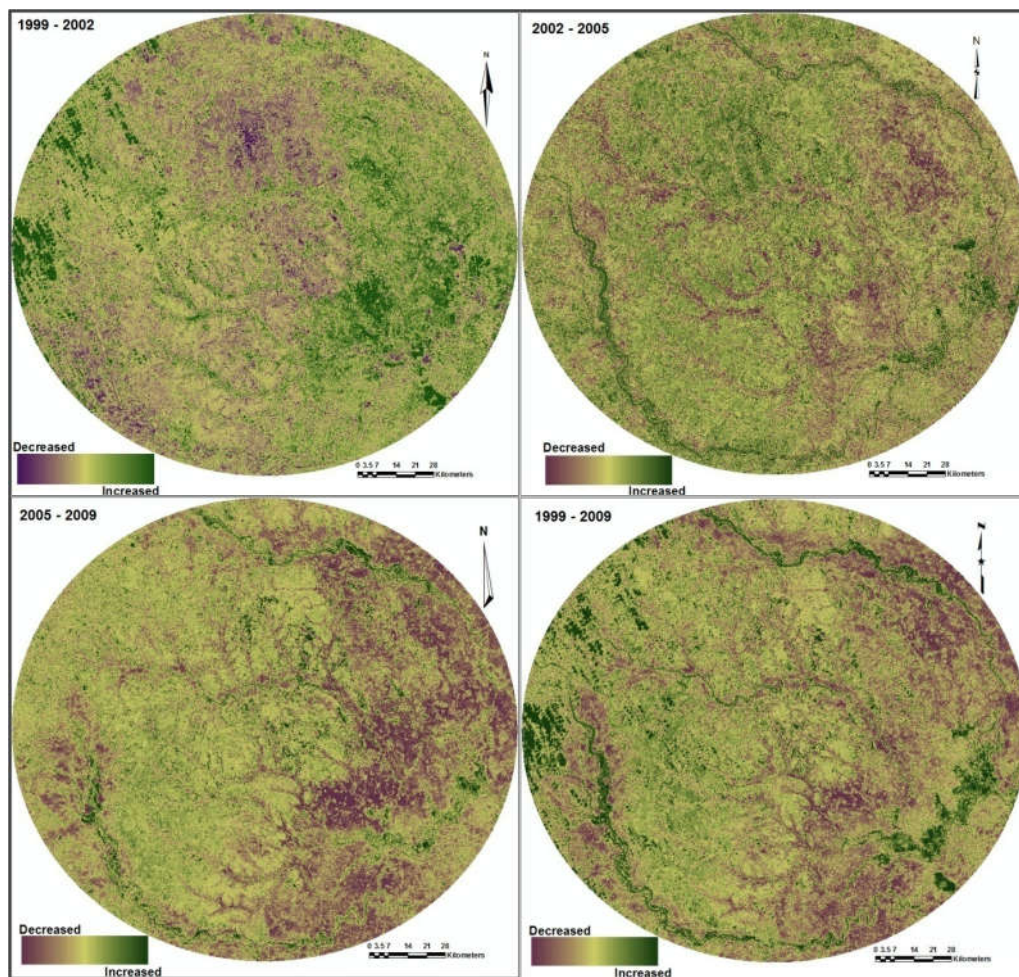↑ = Increasing in trend; ↓ = Decreasing in trend

Figure 3a. Change detection map during different periods

Table 4. Error matrices for continuous images for NDVI on different dates in Kangswati (Cossi) river and Dwarakeswar river interfluves area

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
1999					
Surface water body	2	1	1	50.00%	100.00%
Bare surface	6	8	6	100.00%	75.00%
Very low density vegetation zone	2	1	1	50.00%	100.00%
Low density vegetation zone	6	5	5	83.33%	100.00%
Moderate density vegetation zone	10	11	10	100.00%	90.91%
High density vegetation zone	7	6	6	85.71%	100.00%
Very High density vegetation zone	17	18	16	94.12%	88.89%
Totals	50	50	45		
Overall Classification Accuracy = 90.00%					
Overall Kappa Statistics = 0.8724					
2002					
Surface water body	2	1	1	50.00%	100.00%
Bare surface	7	8	6	85.71%	75.00%
Very low density vegetation zone	3	1	1	33.33%	100.00%
Low density vegetation zone	6	5	5	83.33%	100.00%
Moderate density vegetation zone	9	11	9	100.00%	81.82%
High density vegetation zone	7	6	6	85.71%	100.00%
Very High density vegetation zone	16	18	15	93.75%	83.33%
Totals	50	50	43		
Overall Classification Accuracy = 86.00%					
Overall Kappa Statistics = 0.7934					
2005					
Surface water body	1	1	1	100.00%	100.00%
Bare surface	7	8	6	85.71%	75.00%
Very low density vegetation zone	2	1	1	50.00%	100.00%
Low density vegetation zone	6	5	5	83.33%	100.00%
Moderate density vegetation zone	10	11	10	100.00%	90.91%
High density vegetation zone	6	6	6	100.00%	100.00%
Very High density vegetation zone	18	18	17	94.44%	94.44%
Totals	50	50	46		
Overall Classification Accuracy = 92.00%					
Overall Kappa Statistics = 0.8970					
2009					
Surface water body	2	1	1	50.00%	100.00%
Bare surface	7	8	6	85.71%	75.00%
Very low density vegetation zone	2	1	1	50.00%	100.00%
Low density vegetation zone	6	5	5	83.33%	100.00%
Moderate density vegetation zone	9	11	9	100.00%	81.82%
High density vegetation zone	7	6	6	85.71%	100.00%
Very High density vegetation zone	17	18	16	94.12%	88.89%
Totals	50	50	44		
Overall Classification Accuracy = 88.00%					
Overall Kappa Statistics = 0.8472					

of surface waterbody (Table 3). By 1999 – 2005, there was decreased in trend of bare surface area, while in 2005 – 2009, there was an increased in trend. Between 1999 and 2009, the low density vegetation zone portrayed increased in trend (i.e., 1114.40 km^2), it may be due to the development of settlement and agricultural land and as a result of reclamation process. From 2005 to 2009, the amend of low density and medium density vegetation zone was noteworthy. In the study area, low, medium and high density vegetation showed decreased in trend in the study area. However, some specious results were found in Table 3 and Figure 3b, such as surface waterbody and bare surface areas were increased in 2009. It may be due to fact that the ephemeral streams or irrigation/drainage canals are frequently dry/fill, especially in the monsoonal climate due to heavy rainfall and/or dry environmental conditions. Several erroneous patterns were also obtained in the 2009 results, explicitly, reduce in vegetated land. However, it may be due to anti-social activity and low economic condition in the study area played an important role to diminish the moderate to high density vegetation for their livelihood and to strengthen their economy. In reality, some portion of the study areas (Salboni, Lalgrah, Binpur etc.), vegetated land increased and non-vegetated land decreased (Figure 4).

Accuracy assessment results

To validate the accuracy of classification procedures of vegetation characteristics accuracy assessment analysis was performed. Tables 4

identify the error matrices resulted from NDVI analysis on different dates. In Table 4, the overall classification accuracy and Kappa statistics were 90.0% and 0.8724, respectively, in 1999. By 2002, the overall accuracy and Kappa statistics of NDVI classes became 86.0% and 0.7934, respectively. Accordingly, the overall classification accuracy and Kappa statistic increased to 92.0%, and 0.8974, respectively in 2009. In 2009, the impressive change among the NDVI classes made due to anthropogenic intervention, and resulting in an
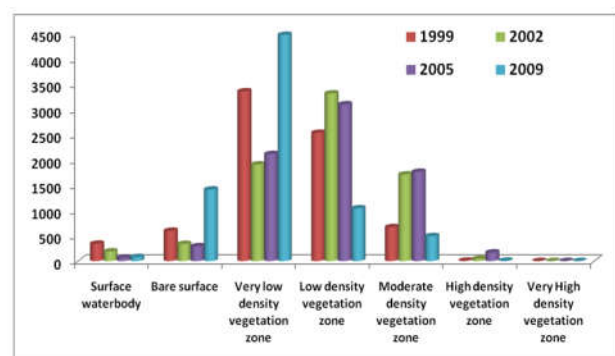
Figure 3b. Surface covered by different group of vegetation at different period (1999-2009) in the study area

Figure 4. Vegetation destruction due to human intervention

overall classification accuracy and Kappa statistics decreased to 88.0% and 0.8472, respectively. The temporal variation of vegetation coverage divulges the time period that key development and alters cropped up. During the last 11 years (1999 – 2009), a remarkable amend of vegetation vigor was observed in the Kangswati and Dwarakeswar river interfluves area. In this research, NDVI analyses were exercised to examine the characteristics of vegetation coverage during this period. According to the research results, the NDVI technique presented more consistent and precise information to scrutinize the modification of vegetation vigor in this area, except during 2009. High commission errors within the vegetation increase class may be apparent due to inter annual dissimilarity in precipitation between 2005 and 2009. However, the procedures botched to accurately differentiate fallow and newly cultivated fields from barren land during this period. The mixed classes with medium resolution Landsat Imagery necessitate information about the actual ground cover types to attain acceptable results.

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