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Research Article

LAND-USE DYNAMICS AND ENVIRONMENTAL CHANGE IN THE SUNDARBANS: EXPERIENCES FROM THE LAST FOUR DECADES

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ABSTRACT
In the Sundarbans, man-induced-disturbances pose a serious threat to the functioning of estuarine ecosystem. This rapid changing dynamics is exerting strenuous ecological footprint, wherein balance between conservation and utilization has been threatened regularly. For the last four decades construction of fisheries has appeared the most lucrative economic growth of this region. Considerable amount of agricultural land have been transformed into fisheries at the northern end, wherein river and creeks has been silted rapidly at the south. This alteration modifies the behavior of adjacent agricultural lands and obstructs natural flow of tide. Beside this, numerous creeks of the region have been modified into sweet water ponds and settlement areas, and thus creeks are failing to attend the morphological equilibrium. However, the present paper does not focus ever on the deterioration of the environment; rather an initiative has been made to study the spatiality of land-use change considering two time points – 1975 and 2004-06. It also explores the main components of environmental degradation relating to land-use change and its dynamics over time through adoption of multivariate techniques.

Keywords: *LULC, Environmental Degradation, Population Growth, Factorial Ecology*

INTRODUCTION
The detection of Land Use Land Cover change (LULC) is one of the most important indicators for environmental change that affects ecological balance of nature. These changes are often non-linear and might trigger feedback to the system that distresses the living condition and threatens the vulnerability of people (Kasperson *et al.*, 1995). Thus, not only the assessment of LULC is pertinent, but identification of prime components of LULC is also an elementary task.
Recent studies of LULC in the Sundarbans showed that transformation of agricultural lands into fisheries is the most dominant aspect of land use change (De, 2006; Danda, 2007). Since 1970s, a trend has been found to convert agricultural land into the fisheries, especially in the northern blocks. In fact, due to problems of salt water inundation agricultural lands have lost its efficiency and it becomes unproductive unless and until the salinity is washed down by the rain water. To combat with this frequent inundation, local people have adopted a new strategy.
After inundation, one or two years the lands are used as fisheries for prawn cultivation. The saline water is allowed to enter in the paddy fields in the rainy season and spawns are cultivated in water. The spawns grow in size and prolifer amidst the standing water of the plots. After harvesting it in winter, the saline water is drained off from the field and allows the rain water (during April to May) to reduce salinity for the cultivation.
This mechanism has become regular and wide spread phenomenon in the Sundarbans over the time due to lucrative economy of prawn business. But for the lucrative profit from prawn culture, the paddy fields closed to the river especially in the northern part have been transformed into fisheries permanently. The new economy has certainly brought up the change in the livelihood and life style, but it enhances salinity in the nearby paddy fields (De, 2006).
The transformation of creeks into the ponds and expansion of settlement areas are another dimensions of land-use change. This alteration disrupts the morphological system of the estuary and throws it out of equilibrium (Bandyopadhay, 2000). Apart from this, deforestation is an episodic event of LULC and still it is prevailing with a very slow rate in the settlement area of this region (De, 2006). Hence, considering all those things, an initiative has been made to assess the extent of land-use change.

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At the final stage, investigation adopts the elementary notion that in a highly populated region people are both the agents and the victims of environmental degradation. So, to get an interactive and reactive feedback an endeavor has been made to find out prime components of environmental degradation.

MATERIALS AND METHODS

To derive information about LULC, images of the analysis used for riverbank mapping have been employed. The images have been subset according to purpose of the study. Since the study requires the detection of minute changes, radiometric correction is necessary. However, no ancillary data on the atmospheric conditions during the satellite overpasses were available to account for the atmospheric differences between the two dates; so, each landsat image has been enhanced by histogram equalization method to improve the image for identifying the categories of land-use. Mainly five categories of land-use have been taken into consideration. These are – forest cover, agricultural land, fisheries, settlement area and estuarine features like**-** river, creeks, rivulets etc.

Discrimination of various features by digital analysis depends upon various factors and method used in classification. A supervised signature extraction with the maximum likelihood algorithm has been employed to classify the landsat images. This algorithm is one of the most widely used supervised classification (Wu and Shao, 2002; McIver and Friedl, 2002) and as the author has a prior knowledge about the study area, the supervised technique is preferred. Both statistical and graphical analyses of features selection are conducted, and band 2 (green), band 3 (red) and band 4 (near infrared) are found to be most effective for the discrimination of each class and so used for classification. Training site data is collected by means of on-screen selection by using Erdas Imagine 9.1. A total of 30 training sites (for two time points) are selected for two images.

An image classification cannot be completed unless and until its accuracy is tested. To determine the accuracy of classification, a sample of testing pixels from each category is selected from the classified images and their class identity is compared to the reference data. Two standardized criteria are taken into consideration to assess the accuracy of classified images. These are – overall accuracy and Kappa Coefficient (Yacouba *et al.,* 2009). The resulted value of overall accuracy is assessed at 58% (in 1975) and 66% (in 2004-06), which is insignificant to present the real picture. The derived Kappa coefficient is only 0.68 and 0.72, which are not at all reliable. Hence, the classification has been rejected, and other types of algorithm like – Mahalanabish Distance, Parallel Pipe (Erdas Imagine 9.1) as well as unsupervised classification have been employed to get a better result. But unfortunately, all are in vain. In all the cases derived values of each criterion are found insignificant. Perhaps, this problem is the manifestation of large size of the study area (4372 Sq. KM) and similarity between fisheries and estuarine features as well as between forest and planted vegetation. Thus the technique of image classification has been dropped, so likely GIS based on on-screen observation has been considered, by which features have been digitized by ArcGIS 9.3, except the settlement area. However, it is a difficult task to digitize every minute details of settlement as it is very tiny and patchy. In addition to this, the active (flows under the natural condition) and decayed creeks (flow restricted or stopped due to human interference) are digitized with the help of the information available in Google images (for 2004-06) and Toposheets (for 1975). At the last stage georeferencing of block maps has been done to delineate the block's boundary into vector form. This aims to articulate land-use change under the block-level.

Other than GIS and remote sensing, multi-variate technique has been employed to study the interactive and reactive feedback of environmental degradation. The application of Principal Component Analysis (PCA) is the most popular and accepted technique to assess the prime components of environmental degradation (Guchhait, 2005). The investigation adopts PCA technique after selection of suitable variables (by using rank correlation method) for the analysis.

Analysis

Spatial Mosaicing of Landuse Change

Land-use and land cover patterns for 1975 and 2004-06 are mapped (figure 1 and figure 2) through which four categories of land classes have been detected – forest land, fisheries, active and decayed creeks (table

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4E) under the block level. It is interesting to note here that a considerable amount of fisheries have been increased over the study period, especially in the north-eastern part of the region. This is found to occur mostly in the four blocks – Haroa, Minakhan, Sandeshkhali I and Sandeshkhali II. The reason behind this is possibly manifold. **First**, the salinity of rivers and creeks in the north-eastern part is slightly less in comparison to other parts of the region due to influx of sweet water from the river Icchamati (Nath and De, 1999). This low level salinity favours high yields of prawn seeds, and accordingly people have transformed agricultural fields into fisheries. **Second**, the fishing yield in the north-eastern part of the Sundarbans is substantially low due to its farthest distance as well as higher siltation rate in the river beds. Silted river beds become shallower over time and subsequently do not allow variety of species to enter (Mitra *et al.*, 1999). So, over the considerable period of time, river based fishing occupation has become obsolete and it is gradually replaced by fisheries. **Third**, this part has good connectivity via surface road with Kolkata which offers favorable situation for trade related activities relating to fisheries. Hence, people in the north-eastern part adopt inland fishing to remain in their indigenous culture of fishing, while people of the south still now are attached with river fishing.

Table A: Different Types of Land-use and Land Cover in 1975 and 2004-06

	1975				**2004-06**			
Block	**Forest (in Sq. Km.)**	**Fishery (in Sq. Km.)**	**Active Creek (in Km.)**	**Decay Creek (in Km.)**	**Forest (in Sq. Km.)**	**Fishery (in Sq. Km.)**	**Active Creek (in Km.)**	**Decay Creek (in Km.)**
Basanti	52.74	4.27	16.29	83.58	54.18	28.80	9.03	164.10
Canning 1	0.57	15.73	16.25	72.98	1.63	7.93	8.98	66.08
Canning 2	0.00	90.45	15.55	21.25	0.00	29.59	0.00	27.52
Gosaba	100.0	4.45	38.12	45.84	104.00	6.71	9.47	94.78
Hingulgunge	75.45	0.00	100.00	25.74	35.00	3.29	37.73	50.20
Hasnabad	0.00	3.63	27.33	52.68	0.00	30.95	12.36	61.71
Jaynagar 1	0.00	0.00	17.35	5.30	0.00	0.00	0.00	12.58
Jaynagar 2	0.00	5.03	14.15	40.73	0.52	2.35	0.00	42.17
Kakdeep	19.34	0.00	77.35	36.18	13.75	5.74	64.92	57.10
Kultali	68.03	8.99	12.01	31.80	75.53	12.02	0.00	60.06
Muthurapur 1	0.00	0.00	6.70	18.87	0.00	1.35	0.00	11.25
Muthurapur 2	16.19	2.55	30.67	61.61	12.80	9.86	4.29	87.06
Namkhana	96.44	0.00	79.77	50.76	20.56	5.90	56.52	50.63
Patharpratima	64.60	0.23	63.10	63.13	104.96	17.71	49.07	200.34
Sagar	9.74	0.00	30.42	26.05	5.19	6.61	3.78	63.29
Sandeshkhali 1	0.00	2.19	27.34	75.70	0.00	88.73	4.42	68.60
Sandeshkhali 2	0.00	11.61	17.73	100.00	0.00	27.45	2.32	88.13
Haroa	0.00	100.0	2.32	11.01	0.00	116.56	1.95	8.65
Minakhan	0.00	1.52	7.19	25.52	0.00	52.81	3.44	11.36
Total	503.1	250.65	599.64	848.73	428.12	454.36	268.28	1225.61

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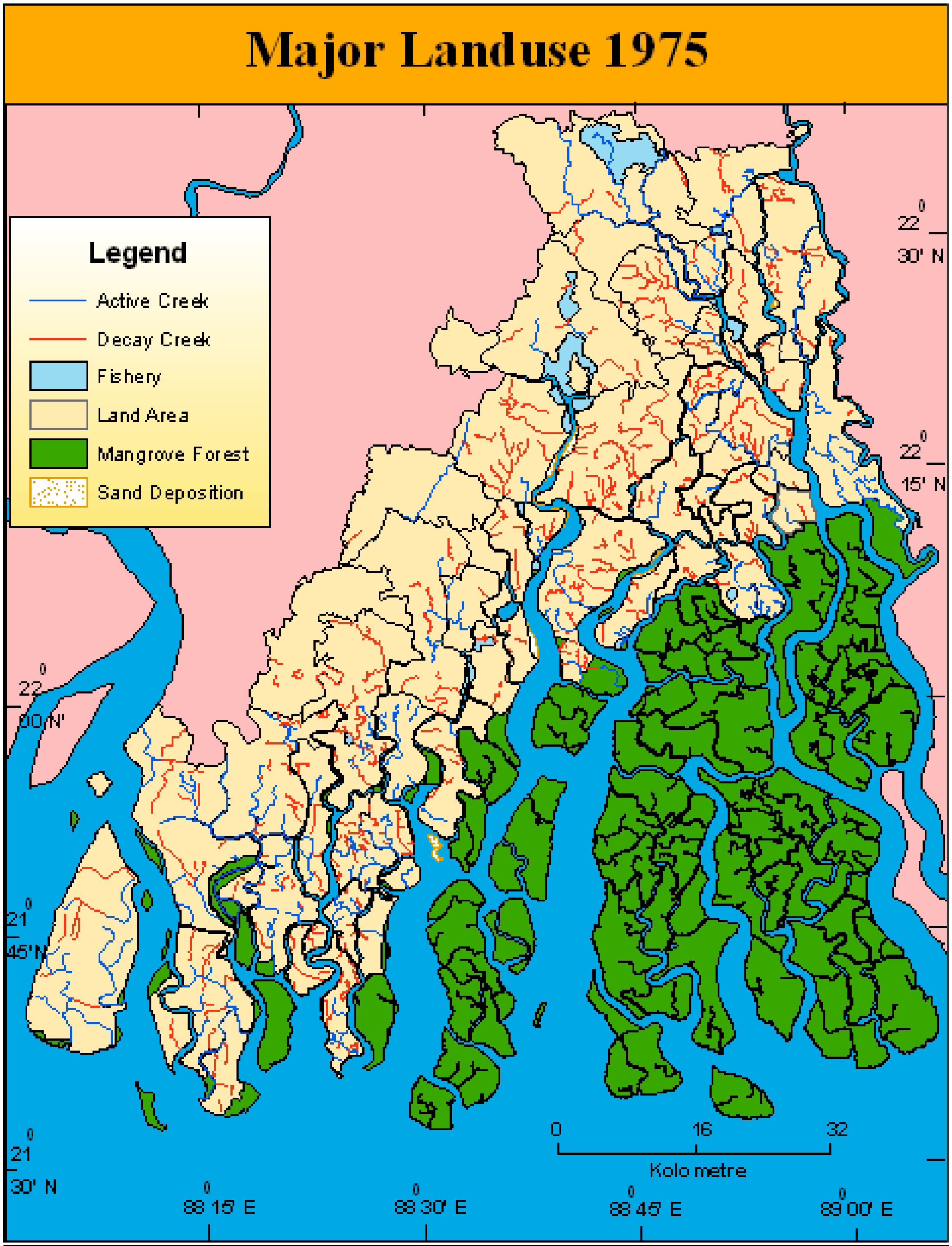

Figure 1

Another important thing is the modification of natural creeks. From 1975 to 2004-06, the amount of active creeks has been decreased from 599.64 KM. to 268.28 KM. (table A). In contrary to this, decayed creeks have been increased from 848.73 KM. to 1225.61 KM. that amounts to 39.04 % increase. This is the overall reality of the whole region, but it is significantly high in the four blocks – Patharpratima, Muthurapur II, Gosaba and Hingulgunge. So, southernmost blocks are exhibiting rigorous change in the natural flows of estuary, which might have been increased the rate of siltation of the river beds. Apart from this, some patchy deforestation is found to see in Basanti and Namkhana, whereas some natural invention of mangroves is found in Patharpratima, Kultali and Basanti as well.

Population and Environmental Degradation

It is evident in the previous analysis (Chapter Three) that the Sundarbans is almost reeling under the pressure of tremendous population growth over the last four to five decades. In an already populated region, the steady increase of population leads to environmental degradation, especially if the region's economy is dependent on the natural resource base (Guchhait, 2005).

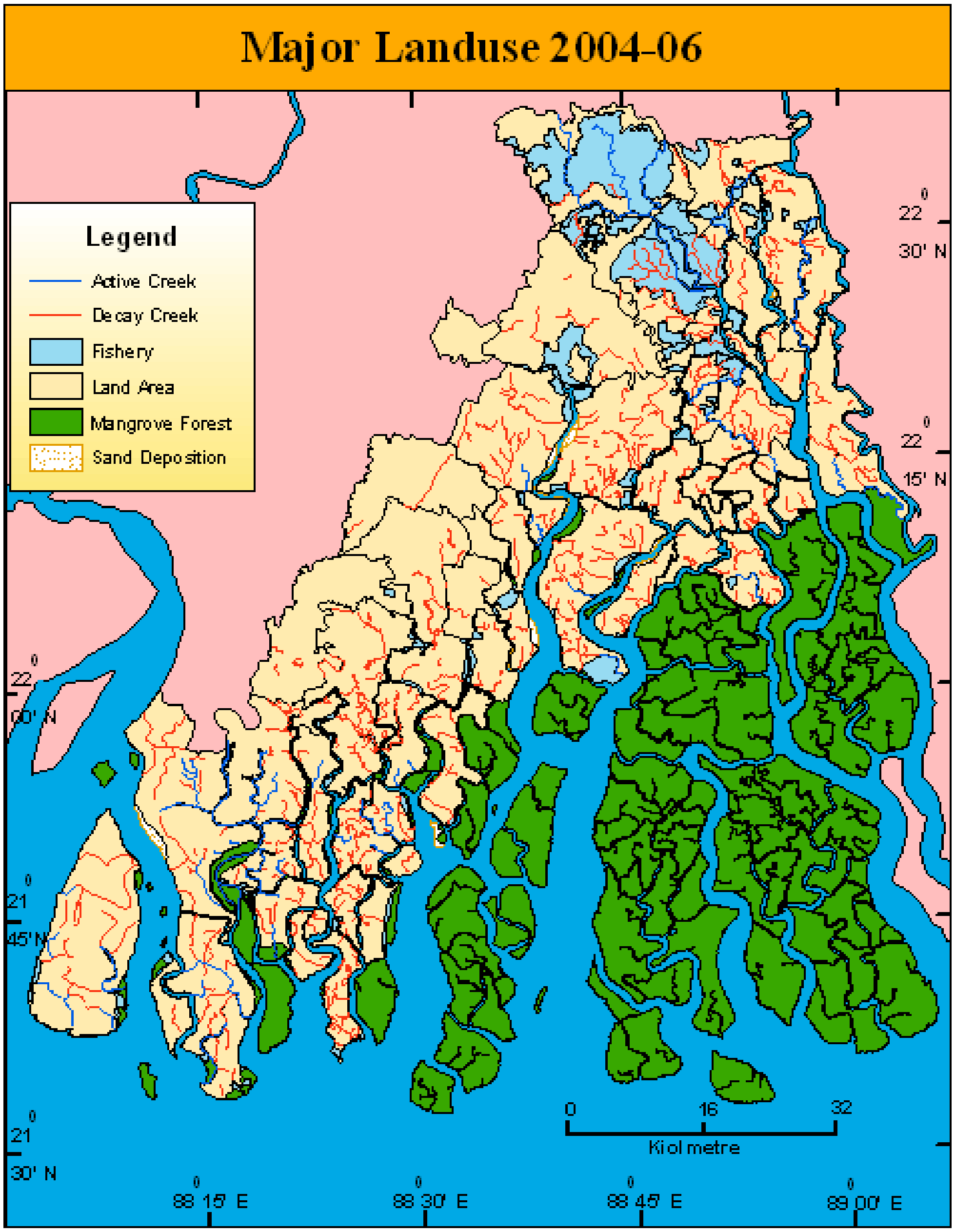

Figure 2

High rate of population growth and resultant increase of population density combine to create pressure on the carrying capacity of land, reflected by the reduction of land cover (forest) and consequent expansion of land-use.

The focus of this section pertains to the interactive and reactive feedback obtaining from the specious distinction between population and environment (Guchhait, 2005). This feedback has a spatial manifestation and, therefore, spatial association is supposed to be a strong reflection of the ground reality. With this mindset the following section sets out to enumerate the validity of the selected variables to have a glimpse about the population and environmental degradation.

Selection of the Attributes

Different factors of population-environment interface have been taken into consideration; but due to absence of well-organized data at block-level, all perspectives of environmental degradation cannot be highlighted. So, altogether twelve attributes have been considered and examined statistically by employing sphereman's rank correlation. Among these twelve attributes; literacy rate, amount of irrigated land and population growth rate have been dropped as these are showing insignificant correlation with the other attributes (at 0.005 level two tail test) in utmost cases. Therefore, nine attributes have been selected to provide a thumb-nail sketch of the prevailing situation at the macro level.

X_1 = Population Density (persons/KM^2)*
X_2 = Backward Population (combination % of SC and ST population to the total)*
X_3 = Agricultural Land (% in respect to total geographical area)*
X_4 = Forest Cover (% of forest cover surrounding as well as inside the blocks in respect to total block's geographical area)***
X_5 = Fishery Land (% in respect to total geographical area)***
X_6 = Exposure of Riverine Environment (% of surrounding rivers and creeks area in respect to total geographical area)***
X_7 = Active Creeks (in KM/KM^2)***
X_8 = Decay Creeks (in KM/KM^2)***
***Calculated from Census data, 1971 and 2001**
*****Calculated with the help of GIS based on images taken in 1975 and 2004-06.**

Population density (X_1) may be regarded as the level of crowding in which a region is definitely conducive to the environmental degradation. Coupled with this, often poverty stricken conditions probe human population to the wanton use of nature and this is axiomatically true in the Sundarbans. The poor section of the people, mainly the backward population (X_2) has been exploiting the forest as well as water resources to meet their basic needs. Dependency on agriculture (X_3) might have a positive impact on the environment as people likely to use less amount of forest as well as water resource. Reckless deforestation perhaps is responsible for the river bank erosion. Therefore, it would be useful to have a look at the extent of forest cover (X_4). The fisheries (X_5) are the expressions of land-use dynamism which might bring environment problems like – water logging, salinity increase etc. The riverine environment may cause environmental problems like salt water inundation. On the other side, it provides an ample opportunity for fishing and subsequently is being exploited by the indiscriminate catches of fishes. Thus, consideration about the exposure of riverine environment (X_6) might have a good feedback in the system. The active creeks (X_7) stand for the virginity of the estuarine ecosystem, whereas the decayed creeks (X_8) reflect the opposite. The perceptual framework mentioned here is used as a basis for examining the components of environmental degradation in selected two time points – 1975 and 2004-06.

Factorial Ecology

In order to determine to the validity of the perceived reality, the analysis proposes to introduce the multivariate technique based on multicolinearity rather than linearity since environment itself is a multidimensional concept (Guchhait, 2005). As it embarks on the few (only eight attributes) aspects, therefore only single component has been explained (table B) in two time points. In 1975, the component explains 39.33% which is slightly higher in 2004-06 (40.88%). Taking a look into the table 4F, it is clear that backward population (X_2) is not associated with the aspects of environmental degradation throughout the study period. However, the other variables are loaded significantly either in both or in single time points. The result shows the validity of population environment interface with the negative loadings in population density (X_1) and fisheries land (X_5); however the positive loadings are found for agricultural land (X3), forest cover (X4), exposure of riverine environment (X_6), active creek (X_7) and decayed creek (X_8). It clearly embarks that the blocks having lower population density and few fisheries are characterized with more forest cover, agricultural lands, riverine environment, active as well as decayed creeks. This indication of population environment interface is mostly observable in the southern blocks of the Sundarbans, whereas northern blocks bear the imprint of opposite characteristics.

Taking a dividing line of 0.60 level between heavy and light loadings, it can be affirmed that the component in 1975 is basically the expression of 'estuarine environment' (explains 39.332%) along with the dominance agricultural landscape (table B). The heavy loading in forest cover, riverine environment and active creeks indicate the existing domination of natural environment and dependency on agricultural as well as fishing occupation (as riverine environment has been loaded heavily). The phenomenon has been changed in 2004-06. Population density and fisheries which have emerged with heavy loadings in 2004-06 are quite silent in 1975. However, forest cover, riverine environment and agricultural land have appeared with same tune but their scale of loading has been declined in 2004-06. The decayed creek which responded with low value is now emerged heavily, and contrarily active creek takes its position below the dividing line. So, the components of 2004-06 can be termed as 'trend of environmental degradation' (explains 40.881%) which threatens the estuarine ecosystem of the region over the study period.

Table B: Factor Analysis for the Relationship of Population and Environment

Attributes	**PC_1 Analysis**	
	1975 (Estuarine Environment)	**2004-06 (Environmental Degradation)**
Population Density (X_1)	-0.517	-0.610
Backward Population (X_2)	0.151	0.303
Agricultural Land (X_3)	0.789	0.658
Forest Cover (X_4)	0.837	0.754
Fishery Land (X_5)	-0.515	- 0.665
Exposure of Riverine Environment (X_6)	0.882	0.799
Active Creeks (X_7)	0.804	0.438
Decay Creeks (X_8)	0.244	0.623
Eigenvalues	3.146	3.270
% of Variance	39.332	40.881

RESULTS AND DISCUSSION

Discussion

The investigation aims to capture the scenario of land-use change and its subsequent impact on man-environment interface. Since twentieth century land-use and land cover has been drastically modified and subsequently upset the morphological as well as estuarine ecosystem of the region. This trend has been coupled with tremendous population growth after 1970s. The investigation confirms such kind of drastic change through proper documentations. Regarding the components of environmental degradation; a notable change from 'estuarine environment' to 'environmental degradation' clearly embarks on the deterioration of the natural environment. All these evidences axiomatically confirm the ongoing environmental degradation of the region in the form of fishery construction at the North and modification of estuary at the South. Such alteration over time modifies natural landscape into cultural landscape and may bring unwanted environmental problems. Such gradual change will cast a strong impact on the environmental balance that will possibly endanger the next generations.

Conclusion

The analysis highlights several aspects of human interference in terms of land-use land cover change and its major components for environmental degradation. Regarding these, two basic things can be pointed out. **Firstly**, man is the agent as well as the victim of environmental degradation. An over-populated region like Sundarbans, wherein a substantial proportion of population earns their breads from the natural resources, exerts a continuous pressure on the existing resource base. Such condition has been instigated due to poverty stricken condition of the region (Kanjilal, 2000). Indiscriminate exploitation of natural resources to eradicate poverty is treated as survival strategy that poses serious threat to environmental balance. Overall, the region is reeling under pressure of resource crisis and overcrowding. **Secondly**, the excessive use of resources leads to serious crisis of natural resources. Accordingly, the resultant situation may not be able to meet the needs of people in the present day or in the near future. To mitigate the problems, out-migration could have been resulted as a part of survival strategy (Mandal, 1995). This is not a theoretical fact, rather is a grounded reality for the Sundarbans. Such problem of resource crisis generates a gradual socio-economic change of the region in one hand and on the other hand, such excessive exploitation will definitely disqualify the normal attachment of man-nature reciprocal relationship.

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