CHAPTER FOUR

Human Interference to the Estuarine Environment: An Overview of the 2nd Half of the 20th Century

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4.0.0 Introduction:

Man, being the most dominant species of the world is constantly challenging and modifying his environment. Restless transformation of the natural environment into the world of artifacts (De, 2006) alters the balance of ecosystem and produces adverse conditions in the nature. Whether this alteration is good or bad does not admit any simple answer, but the question is deadly serious one.

The lower form of human civilization exerted very minimum influence on the natural environment. While remained in the primitive life man was little more than another indigenous animal. But as soon as he altered the nature and consumed more resources, the situation underwent beyond the control leading to rapid defacement of nature. Today, man almost everywhere on the earth’s surface, exert a dynamic influence on the environment. The alarming rate of population growth and subsequent increase of resource utilization undermine the ecological balance of nature.

In the Sundarbans, man-induced-disturbances pose a serious threat to the functioning of estuarine ecosystem. It started in the British period with the clearing of forests and also construction of marginal embankments. Natural morphological system of rivers was partly modified as embankment obstructs the natural tidal flow of rivers (Kanjilal, 2000; Bandyopadhyay, 2000; Danda, 2007). But at that time life was simple, and consumption of resources was too little to affect the natural ecosystem. Man was much closed to nature than at present. Over the time the phenomenon changed gradually. With the increasing pressure of population (discussed in Chapter Three) the Sundarbans now, a crowded place is facing the rapid depletion of resources to meet the needs of population.

This rapid changing dynamics is exerting strenuous ecological footprint, wherein balance between conservation and utilization has been threatened regularly. Moreover, the utilization of land resource remains mostly under a single crop due to
scarcity of sweet water. These constraints aggravate unemployment problem and, as a result, people have to face the pangs of poverty (Mandal, 1995). Due to lack of alternative employment, men are forced to exploit water and forest resources to combat with poverty. Thus the balance of the ecosystem has been reeled under pressure and at the same time human interference is gaining priority to change the face of the nature, which was out and out virgin two hundred years ago.

4.1.0 Mode of Interference

Presently, people of this area are aware about the ecological conservation of nature and adverse effect of increasing amount of human interference. This interference is partly due to increasing need of population, while another is human greed and restless urge for resource consumption. In the Sundarbans, interference started with the reclamation process by the British Government aiming to collect more revenue from the unproductive lands. But the colonial rulers did not take into account that many of the islands were not mature enough for human settlement as those were prone to inundation twice in a day. To overcome this situation high embankments were constructed to safe the islands from day-to-day inundation in many places at the beginning. Later on, it has become permanent feature of the Sundarbans (Danda, 2007). Thus, the occurrence of tides at regular intervals was troubled to maintain its original flow and gradually morphological equilibrium of rivers was threatened. It was the first step for the alteration of natural set up in which morphological process is obstructed to a greater extent.

The second attempt of interference was concerned with the rapid clearing of forest at second phase by huge influx population, especially after 1870s. To meet the needs of population, resources had been utilized at a galloping rate. It attained a critical condition for the last thirty to forty years due to over exploitation of forest as well as water resources.

The third important modification is the change of land-use. It occurs mostly in two ways. First one is the manipulation of natural flow of tides through creeks modification by constructing embankments. By this way, people convert the creeks into several sweet water ponds for their day-to-day use as well as for little irrigation
purposes. The second one is the conversion of agricultural lands into large scale fisheries by allowing saline water through creeks into the agricultural fields. This modification in one hand makes the agricultural field saline and on the other hand altered the natural flow of creeks. Such modification in long run upset the equilibrium of rivers, as creeks are the important unit of estuarine geomorphology and ecosystem.

4.2.0 Rationale to the Problem

Justification of the present inquiry has three-fold divisions (fig. 4.1). The First one is the reclamation related interference and its rationale. The Second one is the wanton exploitation of forest resources as well as water resources; and subsequent land-use change as well as environmental degradation is the third one.

The coastline of the Sundarbans is dynamic and unstable. It is very difficult to predict about the nature of coastline shifting of this region. Some portions of coast have been retrograding and other portions have been advancing (Ahmed, 1972; Chattopadhyay, 1985; Mandal & Ghosh, 1989; Bandyopadhyay, 2000). Moreover, human interference due to reclamation of delta has altered the intensity of geomorphological process. The embankments certainly have obstructed the rhythm of tidal cycle, which could have started an accretionary phases in the islands (Bandyopadhyay, 2000). In support of this, the local people of the region opine about the increasing siltation rate in the river beds over the last four decades. Hence, the perceived reality confirms the empirical findings of the researchers. In the present chapter an attempt has been made to find out the geomorphological dynamics of the region in the 20th century with the aid of remote sensing and GIS; and at the same time it tries to relate it with the human interference.

. The Mangrove forests of this region have gained importance for the use of fire woods, timbers, and woods for paper pulp, building materials along with honey or wax. The marginal people of the region are dependent on the forest products to a great extent. Mainly, two different categories of people are dependent on it. They are the honey collector or ‘Mouley’ and the wood collector ‘Bouley’. However, their intervention is very negligible in respect to total resource as entering in the forest
Adobe is restricted by the Forest Department; but such illegal practice still are existed under the surveillance of Forest Department (Ghoshal, 2006; Pramanik, 2008). Due to unplanned exploitation of forest products mangrove-islands are almost on the verge of destruction apart from few southern most islands. In addition to this, fishermen also to some extent are responsible for the alteration of mangrove forest ecosystem. While perusing fishing operations, they spent transient life in deep rivers for seven to ten days and during this time they collect fire woods for their daily cooking from the mangrove forests. Increasing number of fishermen over time instigates a continuous pressure on forest, which in long run causes huge deforestation. In the present chapter, an endeavour has been made to quantify the forest resource with the support of remote sensing technique. Such quantification helps to analyze the changing spatiality of forest cover over the last four decades and its relationship with the human interference.

Third part of the chapter includes land-use dynamics, especially agriculture as well as fishery related transformation. 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. This alteration modifies the behavior of adjacent agricultural lands (De, 2006) 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 (Bandyopadhyay, 2000). However, the forgoing chapter 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.

![Diagram of Human Interference](Image)

Fig. 4.1
4.3.0 River Dynamics and Human Interference in the 20th Century: Documented through Maps and Images

Sundarbans delta, the most active and dynamic geomorphological unit, has been formed by the deposits of sediments washed down from the Himalaya. The fluvio-marine process between the Ganga and the Padma river system nurture the whole region through its small to large sized peripheral rivers that originate from the surrounding areas. The courses of innumerable waterways has changed the design of the lower delta since the time immemorial and made it near impossible task to define the exact limit of the area. The criss-cross design of innumerable rivers and rivulets are still unpredicted as they were in the bygone days.

Whatever may be change in the morphology of this region, the basic character remained unaltered. The prolonged sedimentation and simultaneously active erosion form the typical deltaic physiography of the region and transfix it within a morphological steady state condition (Bandypoadhyay, 2000). But human interference has altered the morphological system by constructing marginal embankments and consequently, it throws the estuary out of steady stable equilibrium (Bandypoadhyay, 2000). The present section has been made an endeavor to study the riverine dynamics of the Sundarbans, and at the same time it aims to assess the extent of human interference.

Shifting of Coastline: Earlier Works

The unsettled condition and consequent instability makes it curious about the origin of this deltaic region. Initial reports relating to river dynamics were dealt with Sagar Island (Wilson, 1846; Hunter, 1875; O’Malley, 1914). However, since the middle of the 20th century several contributions have been made (Bagchi, 1944; Roy, 1969; Mukhejee, 1969, Bandyopadhyay, 2000). However, few works (Kumar et al., 1994, Prithviraj et al., 1995, Bandyopadhyay, 2000) have been done with documentation through maps and images highlighting the recent evolutionary history of this region.
With this background, present section attempts to explore riverine dynamics with the help of maps and images. The study includes two different phase – from 1917-23 to 1965-67 and from 1975 to 2004-06. Following section provides a bird’s view of riverine dynamics and as well as a look into the matter of human interference which tries to infer its negative impacts on the natural process.

**Materials and Methods**

Riverine dynamics is a sensitive exploration in terms of geo-physical and socio-economic explanation. The results of such works are expressed in terms of area or line measurement over a specific period. Present investigation has used fifteen topographical ‘metric’ maps (15’ X 15’) with the R.F of 1: 50,000 published by the Survey of India. The year of survey of this series ranges from 1967 to 1969, except two maps of 1959-60 (No 79B/10, 79B/11). Some maps were not directly surveyed but prepared with the data available from air photographs of same duration. As the majority of area was surveyed in between 1967 to 1969, the entire study period has been expressed as 1967-69. Beside this, four 1° X 1° topographical maps with R.F of 1: 2, 50,000, prepared by Army Map Service, U.S. army have also been used (available at www.lib.utexas.edu/maps/). This series is complied form of ‘inch’ (R.F – 1: 63,360) and half inch (R.F – 1: 126,720) maps of 1923-42 and 1924 respectively. The actual inch and half inch series of the said area were surveyed in between 1905 to 1923 (Mukherjee, 2008). Most of the areas were surveyed before 1917 (Mukherjee, 2008), and so likely time period has been expressed as 1917-23. The details of topographical maps studied for the present work has been presented in the following table (table 4A).

The investigation also relies on satellite images to get an overview of river dynamics from 1970s to the beginning of the 21st century. The images of two time points have been taken into consideration – 1975 and 2004-06. The study considers three series of Landsat images – Landsat 1 (MSS series), Landsat 5 (TM series) and Landsat 6 (ETM +). The images are preliminarily georeferenced and assigned by UTM projection and WGS 84 datum model. The single scene of MSS Landsat image has been used to represent the riverbank of 1970s, whereas two scenes of TM (2004) and ETM + (2006) Landsat images have been employed for the present
situation. The details of images used in the present study are represented in the table 4B.

<table>
<thead>
<tr>
<th>Published by</th>
<th>Type</th>
<th>Year of surveying /imaging</th>
<th>Map Index</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey of India</td>
<td>Metric Series</td>
<td>1959-60</td>
<td>79B/10, 79B/11</td>
<td>Unavailable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1967-69</td>
<td>79B/8, 79B/12, 79B/15, 79B/16, 79C/1, 79C/2, 79C/5, 79C/6, 79C/9, 79C/10, 79C/13, 79C/14, 79G/2</td>
<td></td>
</tr>
<tr>
<td>Army Map Service, U.S.</td>
<td>Compiled from ‘inch’ and ‘half inch’ series in 1955</td>
<td>1905-21 (two sheets) and 1917-23 (fifteen sheets)*</td>
<td>NF-45-7, NF-45-8, NF-45-11, NF-45-12</td>
<td>*original sheets published by Survey of India</td>
</tr>
</tbody>
</table>

Table 4B: Details of Landsat Data Used in the Present Study

<table>
<thead>
<tr>
<th>Series</th>
<th>Taken by</th>
<th>Row–Path Address</th>
<th>Date of Acquisition</th>
<th>Spatial Resolution in meter</th>
<th>Spectral Resolution</th>
<th>Projection and Datum</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSS</td>
<td>Earthsat</td>
<td>148-045</td>
<td>05/12/1975</td>
<td>70</td>
<td>4</td>
<td>UTM and WGS84 datum</td>
</tr>
<tr>
<td>TM</td>
<td>USGS</td>
<td>138-044</td>
<td>04/11/2004</td>
<td>30</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>ETM+</td>
<td>USGS</td>
<td>138-045</td>
<td>18/11/2006</td>
<td>30 and 60 for band 8</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

Beside these, fifteen block maps available in the Census Report, 1961 are taken into consideration to delineate the administrative boundary of the Sundarbans. The block maps are marked with latitudinal and longitudinal extension but its accuracy standard is found to vary from one area of the map to the other.

Georeferencing all of the topographical maps of different editions has been done by using ArcGIS 9.3 version. While geocoded, sixteen nodes have been given
latitudinal and longitudinal value for an individual sheet with the help of given graticule intersection and second degree polynomial method is used to minimize the RMS (Root Mean Square) error. The same projection and the same datum model (UTM and WGS84 datum) of Landsat images have been assigned for comparative analysis. However, no comparative study has been done between the result obtained from topographical maps and Landsat images. The block maps have been georeferenced thereafter, by taking sixteen to twenty five nodes and employing second degree polynomial method. To get all the topographical maps into a single scene, they are layered into two mosaiced files representing 1917-23 and 1967-69 scenario. Finally, two Landsat images of 2004-06 (TM series) are layered into single file by using the image processing software Erdas Imagine, 9.1. The next task is the radiometric correction of the Landsat images. This process helps to identify the separating line between land and water areas. Regarding this, Histogram Equalization method has been adopted by the same image processing software.

Digitization of the raster into vector is an important task for the present investigation. By ArcGIS 9.3 version digitization of the all topographical maps and Landsat images have been done according to the purpose of the study. The demarcating line between river and land in the topographical maps marked by High Water Level (HWL) has been digitized by polygon with ArcGIS 9.3 software. It is necessary to be mentioned here that latest metric maps (1967-69) were prepared on the basis of air photographs along with ground truth verification. Delimiting HWL from air photographs is highly subjective and might be erroneous (Bandyopadhyay, 2000). But there is no way to minimize this subjective mistake through any standardized methods and error in interpreting feature boundaries is not uncommon in most large-scale map series (Bandyopadhyay, 2000). Therefore, the investigation has no way but to follow the HWL while digitizing the feature boundary. It is necessary to be mentioned here that accuracy level of old topographical maps (1917-23) vary significantly in comparison to recent, but there is no way to rectify it through any standardized method. Map to map georeferencing (by Erdas Imagine, 9.1) technique produces more error as most of the features in the maps are dynamic in nature (like river, creeks) and availability of features like – junctions, nodes are
rarely found. So, the inquiry has no choice but to accept originality of the old topographical maps.

Same kind of accuracy problem appears during the digitization of Landsat images. The spatial resolution of MSS and TM series is not smooth (within 5.0 meter, suitable for boundary identification) and significantly differs from each other. The coarse texture of the images merely is a problem for proper delimitation of river bank. Hence, digitization has been carried out subjectively by considering the colour differences of pixels and by following the transition of land and water. By such attempt, the demarcation of HWL is not at all possible as it is marked in topographical sheets. Thus digitization has been done along the line of marginal embankments.

The block maps are digitized along its boundary line and thereafter superimposed on the mosaiced files. The northern boundary of the northern blocks is taken granted as a northern limit of the Sundarbans; otherwise the vectors demarking the land and water feature are taken for the comparative analysis. The vectors of 1967-1969 have been superimposed over the vector of 1917-23 and non-overlapped area is digitized to measure the erosional area of the islands (appendix T – 4.1). In contrary to this, superimposing vectors of 1917-23 over the vectors of 1967-69, the accretional area has been calculated. The same procedure has been employed for 1975 to 2004-06. Adopting this method, island-wise (numbered from 1 to 157, fig.4.2) erosional and accretional areas have been estimated (appendix T – 4.1). The total amount of erosional and accretional areas does not provide any idea about the intensity of the process. Hence, effective measure is required to calculate the rate of erosion and accretion. Island-wise total erosion and accretion has been divided by the perimeter of the same island to estimate erosional and accretional area per kilometer (appendix T – 4.1).

To facilitate spatial analysis of erosion and accretion scenario, the islands of the Sundarbanes have been numbered (1 to 157 in fig. 4.2) and centroid location of each of the islands have been identified (Bandyopadhyay, 2000) by using ArcGIS 9.3. The perpendicular distance taken (appendix T – 4.1) from the centroids to the reference line (red colour in fig. 4.2) is measured and used for regression analysis.
Beside this, the average width of the water surfaces (including river and creeks) surrounding the island is calculated by taking the samples (2 Km interval) of linear distance from said island to the nearby islands (appendix T – 4.1). The last attempt will help to establish the relationship between river hydraulic action and erosion-accretion process.

**Analysis**

The results obtained from the investigation have been presented in the fig. 4.3 and 4.4. The comparative analysis has been summarized into two parts – from 1917-23 to 1967-69 and from 1975 to 2004-06. The following notable trends have observed from the analysis.

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![Island Index Map](image)

Fig. 4.2
Most of the southern islands, either reclaimed or non-reclaimed, are eroded from its southern margins.

Accretion is found mostly in the reclaimed area, especially in the eastern part of the region.

Non-reclaimed areas exhibit alternative pattern of erosion and accretion.

Erosion is common in both of the eastern as well as western margins of the islands, though its intensity varies depending on the fetch of the river. The islands marked by number of 138, 141, 142, 143, 146, 147 (fig. 4.2) are getting eroded from its western margin due to extensive fetch of Thakuran river. On the other hand, the islands numbered 130, 132, 140, 144, 145, 146 (146 is equally common for two instances) are eroding from its eastern margin due to presence of Matla river at the east.

The magnitude of erosion and accretion is found to decrease from ‘1917-1923 to 1967-69’ period to from ‘1975 to 2004-06’ period throughout the whole region, except some parts of the reclaimed areas.

The reclaimed areas exhibit an accretion trend, especially from the eastern to the central part of the region.

Erosion is common in the southern islands along its southern edge due to complete openness to the sea area.

Non-reclaimed areas appear with the same tune as in 1917-23 to 1967-69 is, showing an alternative pattern of erosion and accretion.

The magnitude of erosion along the eastern and the western margin of the islands is the manifestation of the fetch of the river.

The northern reclaimed islands show an accretion trend, though in 1917-25 to 1967-69 period it experienced erosional as well as accretional phase.

Based on the derived result three basic things may be concluded. First, the erosion and accretion differ significantly from the reclaimed to the non-reclaimed
areas. Non-reclaimed areas exhibit an alternative pattern of erosion and accretion indicating steady state condition of the morphological system. However, reclaimed areas are showing mostly accretional trend along with some spotted erosional areas. **Secondly**, the intensity of erosion is mainly the function of fetch of the river. **Lastly**, the southernmost islands either reclaimed or non-reclaimed exhibit erosional trend over the century. This similarity might be the reason of the rigorous marine action acting continuously that subsumes the accretional role of riverine process.

![Geomorphological Changes of the Sundarbans from 1917-23 to 1967-69](image-url)

**Fig. 4.3**
Spatial Analysis

At the last stage of this analysis the investigation unfolds the relationship between location of the islands with the rate of erosion and accretion. The previous analysis shows the existing relationship between islands situation and intensity of geomorphological process. Regression technique has been adopted to ground the reality. The study considers that the intensity of erosion and accretion is the function of centroid location (Mukherjee, 2008) of the islands. Therefore, erosion and accretion rate of two periods have been regressed in terms of distance taken from the
southern as well as eastern reference line to the centroid of the islands. The attempt has been employed in the figure 4.5, 4.6, 4.7, 4.8, which clearly voices the following:

- There is a feeble relationship between erosion rate and islands location (fig. 4.5). The southern islands are getting more eroded than the northern islands, though a significant fall of intercept value has been noticed (from 0.1075 to 0.0717) which signifies the declining trend of erosion rate. The finding grounds the earlier work of S. Bandyopadhay (2000) relating to coastline shifting of the Sundarbans in the 20th century.

- The accretion rate exhibits dynamic response (fig. 4.5) from the first half (1917-23 to 1967-69 period) to the second half (1975 to 2004-06 period). In the first half accretion rate is comparatively higher in the southern islands, but in the later half no such relationship is grounded.

- The islands in the eastern part show higher erosion rate in comparison to the non-reclaimed islands of the western part in the first half of the study period (fig. 4.7), though, no such noticeable relationship (slope value declines from 0.0016 to 0.0006) is found in the later half. Moreover, the intensity of process is decreased appreciably with the declining trend of intercept value from 0.1840 to 0.0726.
The accretion rate is found higher in the eastern part of the region, while towards the west it gradually decreases (fig. 4.8). Over the study period this relationship remains almost static that signifies rapid trend of accretion in the reclaimed parts of the region.

Thus the reclaimed areas (as it is near to the east reference line) exhibit higher erosion as well as accretion rate in the period from 1917-23 to 1967-69. But, in the second half from 1975 to 2004-06, only accretion is found higher in the reclaimed areas and erosion rate has declined considerably. On the other hand, the
process is more stable (considering two periods) as well as feeble in the non-reclaimed areas, except some incidents of intensive erosion at the southernmost islands of the region.

![Spatiality of Deposition: From East to West](image1)

**Fig. 4.8**

![Erosion Rate and Width of River](image2)

**Fig. 4.9**

It is evident from the previous analysis that the islands having wider extent of river fetch are getting more eroded. To establish the fact regression technique has been adopted where erosion rate is considered as the function of river width. This shows (fig. 4.9) a trend of positive relationship over the study period confirming the existing relationship between these two. The same technique is applied to find out
the relationship between accretion rate and river width. But no such finding can be grounded from the analysis (fig. 4.10).

![Deposition Rate and Width of River](image)

**Fig. 4.10**

**Discussion**

The riverine dynamics of estuary mostly depend on the relative dominance of the accretional fluvial process and erosive tidal and marine process (Bandyopadhay, 2000). The islands of the Sundarbans follow cyclic pattern between prograding and degrading phases which involve the different parts of the islands. The investigation shows that southern part of the estuary has been retrograding over the study period. Tremendous action of marine and tidal process lead to an erosional phase in all the southern islands either reclaimed or non-reclaimed. So, coastal retrogradation is neither associated with deforestation (Bandyopadhay, 2000) nor construction of marginal embankments. The marine and tidal processes at the south are so rigorous and the width of the river is so wider (for this study river width more than 2.5 KM produces erosional phase throughout the region) that human interference does not have any influence to the flow of natural process.

It is clear that the eastern as well as the central part of the estuary is passing through accretionary phase throughout the century. It is interesting to note that this part of the estuary is mostly reclaimed. ‘The reclamation work might have prevented
natural cycle, which could have started an accretionary phase in the islands’ (Bandyopadhay, 2000). The most noticeable thing is that the islands located just the western part of the reclaimed islands is still virgin and forested, showing an alternative pattern of erosion and accretion process, indicating the cyclic manner of delta formation (Boggs, 1987).

The work of S. Bandyopadhay shows that the construction of marginal embankments throws the estuary out of equilibrium (2000). The equation given by Wright et al. (1973) speaks that in a morphological steady state; length of a resonant macrotidal estuary \( l \) tends to equal to quarter of the tidal wave length. That signifies:

\[
1 = 0.25 L \quad \text{or} \quad 1 = 0.25T \times (gD)^{0.5}
\]

[Here, \( T = \) tidal period, \( g = \) gravitational acceleration, \( D = \) mean depth of the estuary]

Considering MHWS as a datum level, S. Bandyopadhay (2000) calculated the mean depth and shows \( l = 0.17L \). The result prompts significant derivations from the morphological steady sate condition. According to Bandyopadhay, ‘the reclamation restricts the area of tidal spill through marginal embankments, removing shallow intertidal wetlands from the reach of the estuary and subsequently increasing its mean depth as volume of tidal water masses remain constant. This alteration throws the estuary out of morphological equilibrium. The estuary thereafter responds by active in-channel sedimentation and bank erosion to decrease mean depth and to restore the steady state condition’ (Pethick, 1994).
4.4.0 Role of Man for the Change of Forest Cover: Reality of Last Four Decades

Forests are the green blankets that naturally protect the environment and preserve the natural resources. It is evident from the earlier literatures that forest of the Sundarbans is degrading with an alarming rate (Kanjilal, 2000; De, 2006; Pramanik, 2008). Those researchers have blamed the tremendous population pressure as well as lack of awareness as the prime causes of such degradation.

The Mangrove forests covering about 17 million hectares have been waning and declining significantly over the last four decades. However, the rate of degradation has been slowed down; but if such a slow rate is continued; the balance of estuarine ecosystem would be at stake. So, it is very pertinent here to assess the forest cover change with the increase of human action.

Materials and Methods

To detect the changes of forest cover, two time-points have been taken into consideration - 1975 and 2006. This duration is very much significant for the study as population influx after 1970s has been increased with an alarming rate in the Sundarbans (Guchhait & Dasgupta, 2009). For assessing forest cover LANDSAT images (cloud free) of two series have been used - Landsat 1 (MSS series) and Landsat 5 (ETM series). The images are georeferenced and the projection as well as the datum of the images are already assigned and this is identical for the both (UTM and WGS 84). Particulars of the images are noted in the table 4C:

<table>
<thead>
<tr>
<th>Series</th>
<th>Taken by</th>
<th>Row–Path Address</th>
<th>Date of Acquisition</th>
<th>Spatial Resolution</th>
<th>Spectral Resolution</th>
<th>Projection and Datum</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSS</td>
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<td>148-045</td>
<td>05/12/1975</td>
<td>70</td>
<td>4</td>
<td>UTM WGS 84 datum</td>
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<tr>
<td>ETM+</td>
<td>USGS</td>
<td>138-045</td>
<td>18/11/2006</td>
<td>30 and 60 for band 8</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>
It is important to mention here that dates of acquisition of two images are not identical. MSS image had been taken in December, while ETM+ image in November. In India mid-November to mid-February session represents winter. During this season the air remains dry and temperature is normally below the 20° C. Because of its location at the coastal edge, the variation of temperature and moisture content would be very less from November to December. So, the difference of acquisition dates of the images is insignificant and no difficulties will arise for comparative analysis.

The bands of the images have been extracted at first from the free repository of NASA (www.glcf.umiacs.umd.edu/) and thereafter converted into single scene by using image processing software Erdas Imagine 9.1 version. The processed images have been enhanced by employing Histogram Equalization method. The enhanced images are now prepared to NDVI analysis.

Several indices have been developed to find out the vegetation concentration and moisture availability with respect to space and time. Normalized Difference Vegetation Index or the NDVI is one of the most commonly used indexes, which is used to find out the vegetation concentration of an area at a particular time. Among the electromagnetic spectrum available from the Landsat image the NIR and the Red band are most sensitive to chlorophyll content of the vegetation. The chlorophyll content of the vegetation has maximum reflection for the NIR while the maximum absorbance for the Red band. Hence, the algorithm stands as

\[ \text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})} \]

The above equation indicates that the DN value of every pixel formed in the new raster i.e. the NDVI is calculated by the ratio of difference of the said bands and the summation of the same bands. Hence, theoretically the NDVI value ranges from +1 to -1.

After computing NDVI, the whole forest region has been divided into ninety eight forest islands (fig. 4.11) by drawing vector and subset the each island by Erdas
Imagine 9.1. The island-wise mean NDVI values have been derived by considering group data of NDVI in Excel 2007.

![Island Index Map for NDVI Analysis](image)

**Analysis**

The NDVI values are now employed to form map (fig.4.12 and fig. 4.13). The scale of NDVI has been represented by taking 0.05 intervals in both time points. The figures clearly depict changing intensity of NDVI value from 1975 to 2006. In 1975, a considerable amount of areas along the eastern side exhibits higher NDVI value (> 0.40). This portion of land is basically the part of core area of the Sundarbans, wherein human intervention is restricted by the Forest Department. On the other side, towards the west NDVI values decrease gradually, especially in the islands adjacent to Matla and Thakuran rivers (0.25 – 0.10). It is necessary to be mentioned here that the said two rivers are used as a fixed routes for fishing and forestry.
Fig. 4.12

The NDVI of 2006 exhibits the same tonal differences from east to west, but its intensity has been declined in respect to 1975. The NDVI of eastern part falls down below the 0.40 level and stands within 0.30 level. This is the notion of decreasing trend of forest cover over the last thirty years at the core area of the forest region. Along the western side the recorded values are found to be very low, especially in the central part of the each island. The western part is the most interfering zone, wherein NDVI appears with very light tone (> 0.10) indicating presence of sparse vegetated cover.
To get an overall picture of NDVI status, the values in table 4D have been employed into figure no. 4.14. The red curve indicates present status, whereas by green curve the NDVI of 1975 has been presented. The picture clearly depicts changing intensity of NDVI from 1975 to 2006. In 1975, the frequency of NDVI > 0.40 is higher in comparison to 2006. On the contrary, NDVI < 0.30 is more in 2006 than in 1975. These two basic changes are the prominent evidences of deforestation in the Sundarbans.
Table 4D: Distribution of NDVI Status in Two Time Points

<table>
<thead>
<tr>
<th>CLASS</th>
<th>FREQUENCY</th>
<th>Percentage</th>
<th>CLASS</th>
<th>FREQUENCY</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.1 - -0.05</td>
<td>4816</td>
<td>0.73</td>
<td>-0.1 - -0.05</td>
<td>20464</td>
<td>0.88</td>
</tr>
<tr>
<td>-0.05 - 0</td>
<td>6597</td>
<td>1.01</td>
<td>-0.05 - 0</td>
<td>29408</td>
<td>1.26</td>
</tr>
<tr>
<td>0 - 0.05</td>
<td>12652</td>
<td>1.93</td>
<td>0 - 0.05</td>
<td>34716</td>
<td>1.49</td>
</tr>
<tr>
<td>0.05 - 0.10</td>
<td>14657</td>
<td>2.23</td>
<td>0.05 - 0.10</td>
<td>54340</td>
<td>2.33</td>
</tr>
<tr>
<td>0.10 - 0.15</td>
<td>20502</td>
<td>3.12</td>
<td>0.10 - 0.15</td>
<td>100108</td>
<td>4.29</td>
</tr>
<tr>
<td>0.15 - 0.20</td>
<td>29125</td>
<td>4.44</td>
<td>0.15 - 0.20</td>
<td>117256</td>
<td>5.03</td>
</tr>
<tr>
<td>0.20 - 0.25</td>
<td>33024</td>
<td>5.03</td>
<td>0.20 - 0.25</td>
<td>191152</td>
<td>8.20</td>
</tr>
<tr>
<td>0.25 - 0.30</td>
<td>76307</td>
<td>11.63</td>
<td>0.25 - 0.30</td>
<td>323096</td>
<td>13.86</td>
</tr>
<tr>
<td>0.30 - 0.35</td>
<td>127987</td>
<td>19.51</td>
<td>0.30 - 0.35</td>
<td>449088</td>
<td>19.26</td>
</tr>
<tr>
<td>0.35 - 0.40</td>
<td>140121</td>
<td>21.36</td>
<td>0.35 - 0.40</td>
<td>614416</td>
<td>26.35</td>
</tr>
<tr>
<td>0.40 - 0.45</td>
<td>122242</td>
<td>18.63</td>
<td>0.40 - 0.45</td>
<td>351344</td>
<td>15.07</td>
</tr>
<tr>
<td>0.45 - 0.50</td>
<td>55137</td>
<td>8.40</td>
<td>0.45 - 0.50</td>
<td>45036</td>
<td>1.93</td>
</tr>
<tr>
<td>0.50 - 0.55</td>
<td>12718</td>
<td>1.94</td>
<td>0.50 - 0.55</td>
<td>1156</td>
<td>0.05</td>
</tr>
<tr>
<td>0.55 - 0.60</td>
<td>219</td>
<td>0.03</td>
<td>0.55 - 0.60</td>
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</tr>
<tr>
<td>656104</td>
<td>2331584</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![NDVI Distribution](image)

Fig. 4.14

It is clear that intra-variation of NDVI is lower in the islands, wherein NDVI mean is relatively higher. But the situation is completely different in the islands with lower mean NDVI, wherein intra-variation is higher due to sparse distribution of forest cover along with salt water bodies and barren lands. To establish the relationship between the magnitude and variation level, island-wise mean NDVI and CV of NDVI (appendix T – 4.2) has been employed into regression analysis considering that variation is the function of magnitude. The values (Mend NDVI and NDVI - CV) have been employed in fig. 4.15 and 4.16. The figures clearly reveal
negative relationship between these two variables. The slope of the equations is found to increase from \(-184.54\) to \(-201.12\). Thus, the result signifies increasing trend of intra-variation of NDVI due to continuous exploitation of forest resources. So, overall the statistical inquiry grounds the evidences of deforestation within the time span of last thirty years.

Fig. 4.15

Fig. 4.16
Focus on the Human Interference

The study remains incomplete unless and until the role of human beings are properly explored. To articulate the relationship between forest cover change and human interference two basic things have been considered here. The first one is the physical distance of the islands from the settlement area. It can hypothetically be that with the increasing distance from the settlement area, the interference would be decreased and resource remains intact. To measure this distance, centroids have been generated for each island by using ArcGIS 9.3. The perpendicular distance has been taken from the end of settlement area (marked by blue line in fig. 4.11) to the centroid of islands (appendix T – 4.2). The second consideration is the distance of islands from the resource harvesting zone. In the Sundarbans, the fishermen, wood cutters and honey collectors do not have the permission in all parts of the estuary to collect those resources. Some particular routes have been fixed by the Forest Department, in which they travel frequently. Considering this, the important routes have been identified by interrogating officers of Forest Department of Jhorkhali, Sundarbans. It may be affirmed that with increasing distance from the resource harvesting routes (marked by red line in fig. 4.11) the interference turns to decrease gradually. Accordingly, perpendicular distance has been taken from the island-centroid to the nearest resource harvesting route (appendix T – 4.2).

To establish the relationship between forest cover and human interference, the study settled in the adoption of regression technique in two time points. The NDVI values have been regressed in respect to the distance of islands from the settlement areas. The result exhibits positive relationship between these two variables (fig. 4.17 and fig. 4.18) in two time points with negligible change of slope parameter (from 0.012 to 0.013), however intercept value declines from 0.3140 to 0.2844 due to overall decrease of mean NDVI. Moving towards the south the mean NDVI value is found to be increased with a shocking rate of 0.125/10 KM. (average of two periods), which cannot be explained by action of nature, but is manifested by human action.
In the second part of the analysis, NDVI has been regressed in respect to distance between the islands and the resource harvesting routes. Results thereafter have been employed in the figure no. 4.19 and 4.20, indicating an increasing trend of NDVI away from the resource harvesting routes. The increasing rate of NDVI is found to be significant (0.0255 /10 KMs) and comparatively higher in respect to previous finding. The most important thing is to find out the substantial change of slope from 1975 to 2006. In 1975, it is 0.0028, whereas in 2006 it declines at 0.0020.
The reason behind this dynamics is not difficult to perceive. Over the time, man has encroached in the deepest part of the forest and subsequently has deforested mangrove forest region. However, the core area of the forest is the adobe of fierce animals and every step is in the clutch of death; but due to lucrative gain from the forest products man ignores all possible evils on their way. Today their intervention is no more associated with the distance factor. They venture into the deep forest to earn more and subsequently involve in the trap of wood-cutting and illegal trading. This might be the reason for lower NDVI at the core of the forest region in 2006.
Discussion

The investigation aims to establish the relationship between the role of human actions and forest cover change. Throughout the analysis this fact has been grounded with several documentations. Since 1975 to 2006, the forest cover has been depleted in the Sundarban Biosphere Reserve, especially in the core and in the eastern part. This clearly signifies the presence of human interference. The eastern part of the forest shares the boundary with Bangladesh border, through which continuous practice of illegal wood-trading is being operated. This route is a very easy way to transfer the woods and timbers to the Bangladesh, and such kind of operations perhaps is constantly decreasing the forest resources. Now, the question is that how has been such illegal activity running without the knowledge of Forest Department? Is there any nexus between the illegal trade and some forest officials? The question is deadly serious, but hardly one can answer. During field inquiries, villagers of Jhorkhali reveal a serious truth. They inform the involvement of some forest officials in illegal trading of wood with Bangladesh. The lack of proper duty provided by the forest officials is a major cause behind such socio-environmental degradation of the Sundarbans. The nature of such degradation is double-folded – one, it hampers the ecological balance; second, it generates a possibility of the common man’s involvement into moral degradation.
4.5.0 Land-use Dynamics and Environmental Change: Experiences from Last Four Decades

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 widespread 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.

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 & Shao, 2002; McIver & 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 (fig. 4.21 and fig. 4.22) through which four categories of land classes have been detected – forest land, fisheries, active and decayed creeks (table 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 & 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.

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 4E). 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.

Table 4E: Different Types of Land-use and Land Cover in 1975 and 2004-06

<table>
<thead>
<tr>
<th>Block</th>
<th>1975</th>
<th>2004-06</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forest (in Sq. Km.)</td>
<td>Fisher y (in Sq. Km.)</td>
</tr>
<tr>
<td>Basanti</td>
<td>52.74</td>
<td>4.27</td>
</tr>
<tr>
<td>Canning 1</td>
<td>0.57</td>
<td>15.73</td>
</tr>
<tr>
<td>Canning 2</td>
<td>0.00</td>
<td>90.45</td>
</tr>
<tr>
<td>Gosaba</td>
<td>100.0</td>
<td>4.45</td>
</tr>
<tr>
<td>Hingulunge</td>
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</tr>
<tr>
<td>Hasnabad</td>
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<td>3.63</td>
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<tr>
<td>Jaynagar 1</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Jaynagar 2</td>
<td>0.00</td>
<td>5.03</td>
</tr>
<tr>
<td>Kakdeep</td>
<td>19.34</td>
<td>0.00</td>
</tr>
<tr>
<td>Kultali</td>
<td>68.03</td>
<td>8.99</td>
</tr>
<tr>
<td>Muthurapur 1</td>
<td>0.00</td>
<td>6.70</td>
</tr>
<tr>
<td>Muthurapur 2</td>
<td>16.19</td>
<td>2.55</td>
</tr>
<tr>
<td>Namkhana</td>
<td>96.44</td>
<td>0.00</td>
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<td>Patharpratima</td>
<td>64.60</td>
<td>0.23</td>
</tr>
<tr>
<td>Sagar</td>
<td>9.74</td>
<td>0.00</td>
</tr>
<tr>
<td>Sandeshkhal</td>
<td>1</td>
<td>0.00</td>
</tr>
<tr>
<td>Sandeshkhal 2</td>
<td>0.00</td>
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<tr>
<td>Haroa</td>
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<td>100.0</td>
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<tr>
<td>Minakhan</td>
<td>0.00</td>
<td>1.52</td>
</tr>
<tr>
<td>Total</td>
<td>503.1</td>
<td>250.65</td>
</tr>
</tbody>
</table>

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). 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 (appendix T – 4.3).

\[X_1 = \text{Population Density (persons/KM}^2)\]
\[X_2 = \text{Backward Population (combination % of SC and ST population to the total)}\]
\[X_3 = \text{Agricultural Land (% in respect to total geographical area)}\]
\[X_4 = \text{Forest Cover (% of forest cover surrounding as well as inside the blocks in respect to total block’s geographical area)}\]
\[X_5 = \text{Fishery Land (% in respect to total geographical area)}\]
\[X_6 = \text{Exposure of Riverine Environment (% of surrounding rivers and creeks area in respect to total geographical area)}\]
\[X_7 = \text{Active Creeks (in KM/KM}^2)\]
\[X_8 = \text{Decay Creeks (in KM/KM}^2)\]

*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 (X₆) might have a good feedback in the system. The active creeks (X₇) stand for the virginity of the estuarine ecosystem, whereas the decayed creeks (X₈) 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 4F) 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 (X₂) 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 (X₁) and fisheries land (X₃); however the positive loadings are found for agricultural land (X₃), forest cover (X₄), exposure of riverine environment (X₆), active creek (X₇) and decayed creek (X₈). 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 4F). 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 4F: Factor Analysis for the Relationship of Population and Environment

<table>
<thead>
<tr>
<th>Attributes</th>
<th>PC1 Analysis</th>
<th>1975 (Estuarine Environment)</th>
<th>2004-06 (Environmental Degradation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Density (X₁)</td>
<td></td>
<td>-0.517</td>
<td>-0.610</td>
</tr>
<tr>
<td>Backward Population (X₂)</td>
<td></td>
<td>0.151</td>
<td>0.303</td>
</tr>
<tr>
<td>Agricultural Land (X₃)</td>
<td></td>
<td>0.789</td>
<td>0.658</td>
</tr>
<tr>
<td>Forest Cover (X₄)</td>
<td></td>
<td>0.837</td>
<td>0.754</td>
</tr>
<tr>
<td>Fishery Land (X₅)</td>
<td></td>
<td>-0.515</td>
<td>-0.665</td>
</tr>
<tr>
<td>Exposure of Riverine Environment (X₆)</td>
<td>0.882</td>
<td>0.799</td>
<td></td>
</tr>
<tr>
<td>Active Creeks (X₇)</td>
<td></td>
<td>0.804</td>
<td>0.438</td>
</tr>
<tr>
<td>Decay Creeks (X₈)</td>
<td></td>
<td>0.244</td>
<td>0.623</td>
</tr>
<tr>
<td>Eigenvalues</td>
<td></td>
<td>3.146</td>
<td>3.270</td>
</tr>
<tr>
<td>% of Variance</td>
<td></td>
<td>39.332</td>
<td>40.881</td>
</tr>
</tbody>
</table>

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. After all, such excessive exploitation will definitely disqualify the normal attachment of man-nature reciprocal relationship.

4.6.0 Findings

The sequence-wise analysis highlights several aspects of human interference and its subsequent impact on the natural environment. 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. 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. 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 exploitation of natural landscape projects a sense of existential distance between man and nature.
References


