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International Journal of Current Research
Vol. 8, Issue, 05, pp.32187-32195, May, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

SUNDARBAN EMBANKMENTS- A STUDY ALONG SURYABERIYA RIVER, SAMBHUNAGAR ISLAND, GOSABA, WEST BENGAL

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ARTICLE INFO

Article History:
Received 05th February, 2016
Received in revised form
23rd March, 2016
Accepted 24th April, 2016
Published online 31st May, 2016

Key words:

Reclamation,
Embankment,
Breaching,
Models of breaching.
Out migration.

ABSTRACT

The Sundarban (21° N to 21°30′N, 88° E to 88°29′E) is the largest single block of tidal halophytic mangrove forest in the world, having a diverse range of flora, fauna and hapless inhabitants. The Sundarban is facing the dire consequences of a premature reclamation for the want of agricultural land. This reclamation has come about with the construction of embankments which reduces the spill areas of the rivers and causes in channel sedimentation. This in turn raises the river bed and in comparison to that the settlements are low making them liable to get flooded whenever the embankments breach. This is a frequent occurrence here causing much hardship. This paper takes into account the incidences of embankment breaching and its possible management options in Sambhunagar island of Gosaba block in Indian Sundarban. On the basis of measurements of present embankments, data collection from satellite images, preparation of river cross profiles and questionnaire surveys, the present scenario of the extent of breach has been studied. The incidences of outmigration of people, occupational shifts and the conversion of people into environmental refugees have been identified and possible management options like construction of porcupine meshes, mangrove regeneration and construction of flood shelters have been taken into account.

Citation: Karabi Das, 2016. "Sundarban embankments- A study along Suryaberiya river, Sambhunagar island, Gosaba, West Bengal", *International Journal of Current Research*, 8, (05), 32187-32195.

INTRODUCTION

The Indian Sundarban forms a part of the single largest halophytic ecosystem of the world. The Indian Sundarban is 9630 km^2 in area. Among 102 islands, 54 are reclaimed. Physiographically, the Indian Sundarban forms a deltaic plain, criss crossed by an intricate network of tidal channels which have now been severed from their freshwater upland sources. The deltaic Sundarban forms the active part of Ganga delta (Bagchi, 1944). The economic status of about 4 million people of Sundarban is quite low as the livelihood of the people revolves around extracting resources from forests and creeks apart from agriculture. Agriculture, mainly monocropping predominates here as the saline river water is unsuitable for cultivation. Embankments, mostly earthen are the lifelines of the residents of Sundarban. These have been erected to protect the people from the saline water of the tidal rivers and to hold back the high tides which occur twice daily. Premature reclamation of the Indian Sundarban in the form of raised embankments has resulted in disequilibrium of fluvial dynamics causing shifts of thalweg line in some cases. Construction of embankments also leads to reduction of spill areas of the rivers. The sediments are deposited on the riverbed itself and the floodplain remains devoid of sediments. Thus in Sundarban, the settlements are at a lower level than the rivers and are liable to frequent flooding. Quick actions in the form of mangrove regeneration and fortification of embankments by porcupine meshes are thus necessary.

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Embankments – An overview

Embankment may refer to a levee, an artificial bank raised above the immediately surrounding land to redirect or prevent flooding by a river, lake or sea. Embankments may either be earthen or made of bricks and concrete types. These may be either be homogeneous embankments, composed of one kind of material and zoned, containing a central impervious core flanked by zones of more pervious material called shells.

Types of embankments based on location:

Three types of embankments are identified in Sundarban. They are –

- Embankment along the smaller channel margin with 2m height.
- Embankment around the island margin with a height of 2.70m.
- Embankment along wave exposed shorelines and estuary margin with 3 m height.

The dynamic hydro – geomorphic characteristics are hindrances to the proper maintenance of the embankments of the islands of Sundarban. Investigations on the textural composition show that the embankments are composed of fine sand by more than 75%. Fine sand shows less cohesion and so stability decreases resulting in more erosion by tide and wave dashing.

The height of most of the embankments ranges from 1.33 – 2.75 m above berms and the width of the summit varies from 0.8 – 1.6 m. The riverward side of the embankment ranges from 42° to 86°. The outer slope angle towards the island ranges from 34° to 71°. The triaxial compression test on geotechnical attributes of embankment materials are nearer to 2° indicating that the materials get temporary stability at a very low angle of 2°.

The riverward slope exceeds the stability angle that indicates intensive geotechnical and internal instability. River Embankment Breaching Vulnerability Index (REBVI) is calculated and its value ranges between 21.4 and 28 indicating moderately high vulnerability (Maiti, 2011).

Processes of embankment breaching

Hydraulic failure

Hydraulic failures from the uncontrolled flow of water over and adjacent to the embankment are due to the erosive action of water on the embankment slopes. Earth embankments or dikes are not normally designed to be overtopped and therefore are particularly susceptible to erosion. A well vegetated earth embankment or dike may be withstand limited overtopping if its top is level and water flows over the top and down the face in an evenly distributed sheet without becoming concentrated in any one area.

- Toe Erosion- Erosion of downstream toe of the earth slope caused by misdirected spillway outlet discharge.
- Gulling -Rainfall erosion of embankment slopes.

Seepage failure

Most embankments exhibit some seepage. However, this seepage must be controlled in velocity and quantity. Seepage occurs through its foundation. Seepage if uncontrolled can erode fine soil material from the downstream slope or foundation and continue moving towards the upstream slope to form a pipe or cavity to the pond or lake often leading to a complete failure of the embankment. This action is known as "**piping**".

Seepage can also cause slope failures by saturation of the slope material, thereby weakening the adhesive properties of the soil and its stability. Burrows or holes created by animals create voids in the embankment which weaken the structure and may serve as a pathway for seepage.

Structural Failure

These involve the separation (rupture) of the embankment material and or its foundation. Structural failure of an earthen embankment may take on the form of a slide or displacement of material in either the downstream or upstream face. Sloughs, bulges, cracks or other irregularities in the embankment generally are signs of serious instability and may indicate structural failure.

Other

Tree growth directly on the crest or top of the structure could lead to hydraulic failure should the tree be blown over. This may displace embankment material within the root ball creating a low area susceptible to flows from the impoundment.

Tree root systems may also create seepage paths through an earthen embankment and structural failure of an upstream or downstream slope could occur with displacement of a large tree implanted within the earth slope.

Models of embankment breaching

Table 1. Models of embankment breaching

MODELS	DESCRIPTION
1. CHINNESARI et al.	No erosion is seen on the upstream side of the embankment and a small head cut occurs on the downstream side which is eroded much.
2. GEORGE et al. 1989	Subcritical flow is seen on the upstream side which changes to supercritical flow in the downstream side and as a result it erodes.
3. HANSON et al.	Initial downstream erosion starts and proceeds upstream as head cut migrate and this lowers the crest.

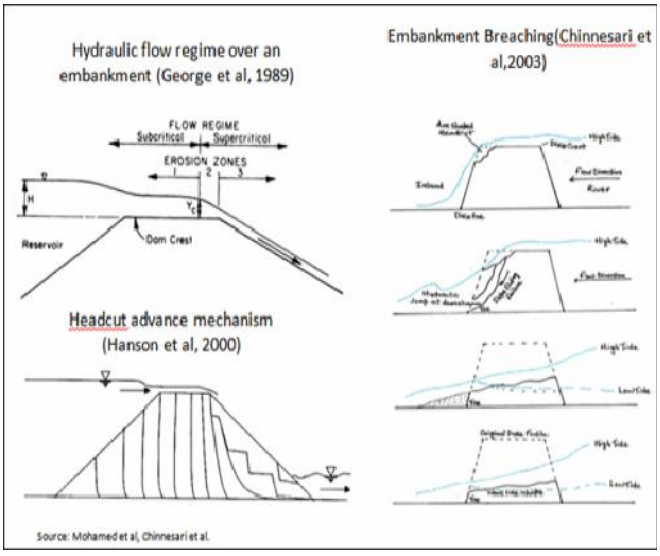

Fig. 1. Models of embankment breaching

Impacts of embankment breaching

Table 2. Impacts of embankment breaching

Direct impacts	Indirect impacts
Loss of land.	Depopulation.
Loss of wetlands.	Survival problem of the people.
Loss of settlement.	Occupational shift.
Loss of fisheries.	Environmental refugees.
Shift of bank line.	

Management of embankment breaching

Protection may take many forms, but options include

- Stone riprap.
- Gabions and gabion mattresses.
- Open stone asphalt.
- Concrete bag work.
- Concrete block work.(which can either be individual blocks or linked to form a mattress)
- Various products that may be categorized as bioengineering such as coir rolls, faggots and fascine mattresses.

Geogrids and geotextiles can also be used to reinforce grass on flood embankments.

Premature reclamation – a peril to Sundarban

Excavations prove that settlement at some places of Indian Sundarban (Nalgara – Baishhata – Manirtat near Jaynagar of South 24 Parganas of West Bengal) dates back to the Pal dynasty of 10^{th} to 11^{th} century. It is also said that "no extensive settlement into the limits of prematurely reclaimed Sundarban was in existence at any time in the past. In the inner fringe areas, which were naturally reclaimed Sundarban was in existence at any time in the past. In the inner fringe areas which were naturally reclaimed, there are ample evidences of settlements of about 300 years old" (Mukherjee, 2002). Reclamation was brought about for the collection of revenue by British officers before Indian independence. The advancement of settlement in 1770 was started by Claude Russell, the then Collector – General in Sundarban. Leases were granted as Patitabadi Taluks (tenures for wasteland reclamation). Tilman Henckell had led to the inception of a system of reclamation which led to the conversion of forest to fertile paddy fields. He wanted to create a group of peasant proprietors directly under the government. With this purpose in mind he granted about 150 leases in 1785. He established 3 stations in the heart of Sundarban, in order to assist in their development by providing markets for sale of produce. One was situated at Henckellganj, now known as Hingalganj of North 24 Parganas and the other two at Khulna, now in Bangladesh. Reclamation of the lands were brought about by demarcation of the lots bordered by streams, construction of embankment along the banks of streams which surrounded the lots, subsequent construction of strong dams across the mouths of smaller streams which ran into the block in order to keep the saline water out of reach. After the completion of these works, deforestation of the tracts, digging of tanks and construction of huts for future cultivation were followed. Initially this process of reclamation was very successful owing to high production of paddy and fishes. Prior to land reclamation the entry of saline muddy water through the tidal creeks during high tides used to raise the level of the lands, facilitating the land building process. However, embanking a length of about 3500 km of rivers which has been the primary method of land reclamation has resulted in decrease of spill areas of creeks with deposition of silt on the riverbeds thus lowering the height of adjoining lands. The low and high tide levels also rise considerably. This has resulted in the construction of another embankment far inside the island as in Basanti and Sandeshkhali of Sundarban. In these embanked islands huge quantities of water cannot be drained out to the rivers through the sluices of embankments during monsoon. These lands thus become waterlogged and gradually turn to permanent marshes. Fluctuations of heights of the adjoining lands and high tide levels and hydraulic pressure increase the chances of embankment breaching. As the height of riverbed is more, flood waters can't drain back to the rivers and flow at 1.2 m above the catchment area in Namkhana, Dwarikapur and Hingalganj. The rivers and creeks are even severed from freshwater sources and receding water leaves scouring the top soil. As a solution the fields adjoining the creeks should be flooded daily through small sluices attached to the protected embankments during high tides and most of this water is to be drained out daily during the ebb tide period. This should be done preferably during February – June after the rice harvest. The tidal water can be used for pisciculture and the deposition of silt shall increase the height of land. Also, erection of ring bunds far away from the river banks shall provide space for oscillation of rivers. (Mukherjee, 1976).

Location and drainage characteristics

The physical features of 24 Parganas district are akin to those of deltaic lands. The country is flat and is little raised above the flood level. The district can be divided remarkably into two well knit divisions.

- The northern inland tract which is fairly well raised deltaic land of old formation and
- The low lying Sundarban towards the seaboard towards south.

The northern tract is characterized by sluggish flow of water where tides fail to reach the rivers. The rivers are locked by silt. The Sundarban shows a network of tidal creeks and islands. The northern part of the Sundarban is characterized by considerable cultivation of paddy while the southern fringes laden with forests are low and make way for the sea. The village panchayat of Sambhunagar is surrounded on all sides by rivers, mainly the Suryaberiya and Hatakhali rivers. These rivers are tidal in nature like all other rivers of Sundarban where tides are experienced twice a day. Some channels and small creeks are seen inland which once had connection with the major river containing not so much water now. However during Aila the river water of Suryaberiya river joined the Hatakhali on the other side through the small channels. The total length of the tidal creeks in Sambhunagar is 69 km, the area being 40.4725 km^2 and thus the drainage density of Sambhunagar is 1.70 km/km^2.

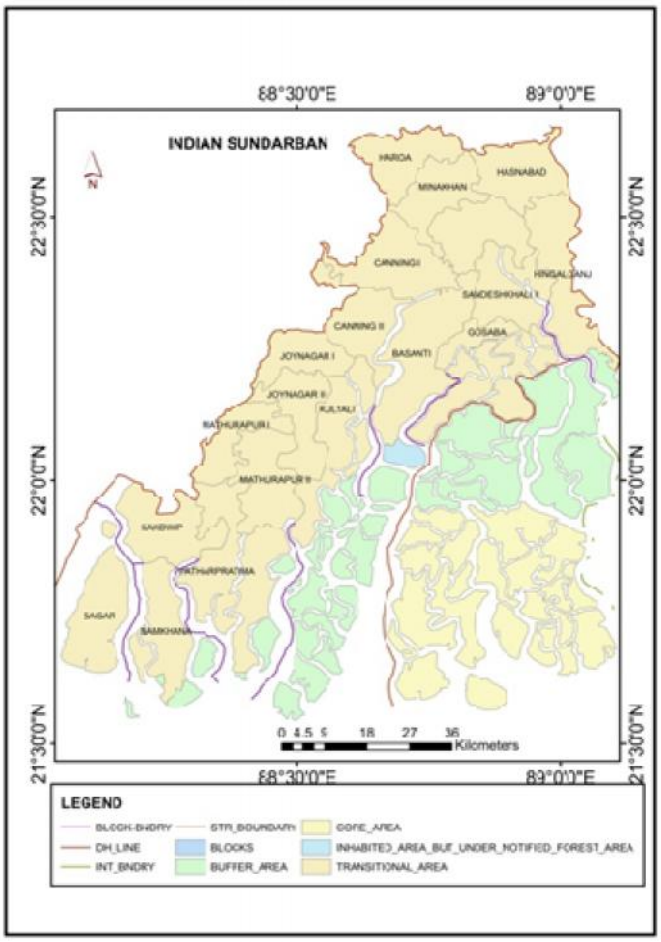

Fig. 2. Map of Sundarban Biosphere Reserve (encircled portion marks Sambhunagar)

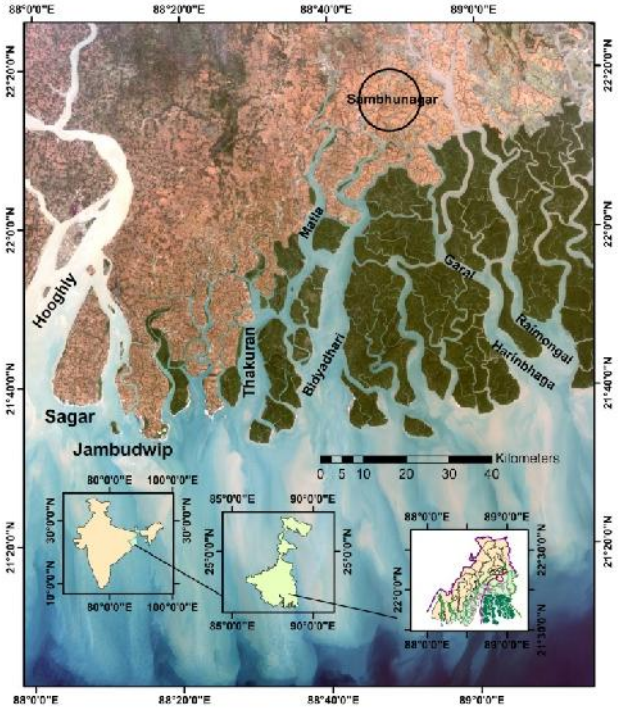

Fig. 3. Location map of the study area

Population pressure

Sambhunagar gram panchayat has six villages named – Kamalakshyapur, Bhupendrapur, Sambhunagar, Mitrapur, Jhaunkhali and Palpur. Population densities for 2001 and 2011 have been calculated to show the population pressure on Sambhunagar village panchayat as compared to the other village panchayats. This is evident from the graph that there has not been much increase in decadal population which is attributed to the repeated occurrences of embankment breaching in this area.

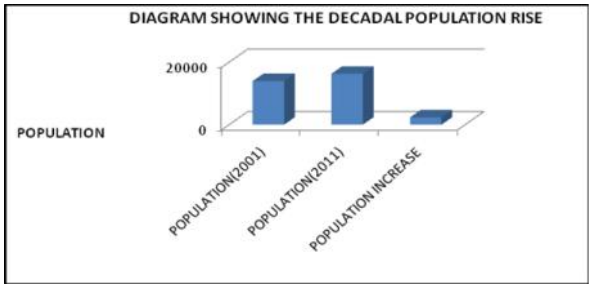

Fig. 4. Decadal population rise of Sambhunagar (2001 – 2011)

Land use and land cover characteristics

The land use and land cover map of Sambhunagar island unit for the year 2013 shows that the areas bordering the rivers and embankments are wetlands. Some amount of land is characterized by marshes while agricultural land and fallow land are sporadic in nature. Settlements are concentrated in the central and south eastern parts mostly. It can be inferred that the vegetation cover is getting thinner increasingly as the days pass which bears a negative sign for the environment and the inhabitants there. The mangrove patch needs to be regenerated to save the embankments. People are reducing the vegetation cover for the want of agricultural land which poses a threat in upcoming days.

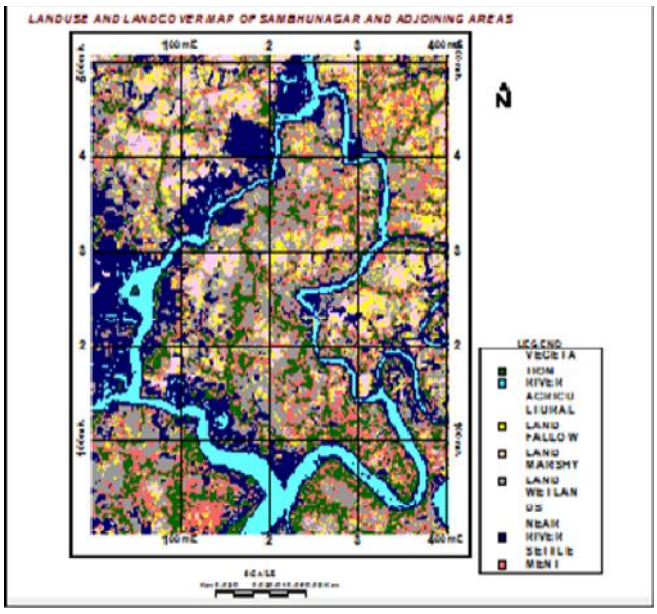

Fig. 5. Land use and land cover map of Sambhunagar (2013 – LANDSAT OLI Path – 138, Row – 45)

Hazard profile of the study area

A natural hazard is a naturally occurring event that might have a negative effect on people and the environment. Geophysical hazards encompass geological and meteorological phenomena such as earthquakes, coastal erosion, volcanic eruption, cyclonic storms and drought. Biological hazards refer to a diverse group of diseases. Floods and wildfires can result from combination of geological, hydrological and climatic factors. The following diagram shows the seasonality of hazards indicating the time when these hazards are common.

Fig. 6. Seasonality of hazards (Source : District Disaster Management Plan, S 24 Parganas, 2012)

The process of hazard analysis starts with identification and prioritization of hazard types followed by accessing probability of the occurrence of a hazard of given intensity (often associated with the physical level of damage) at a particular location. Well developed scientific methods can be used to analyze hazards which involve various steps like data collection, data analysis etc. Hazard priority scores have been found out by assessing the probability of occurrence of hazards and their intensity.

Table 3. Hazard priority score of Sambhunagar

Hazard type	Hazard priority score
Riverbank erosion and embankment breaching	8
Saltwater incursion	7
Flood during high tides	6
Strong wind	5
Storm surge	4
Drought	4
Wave action	0

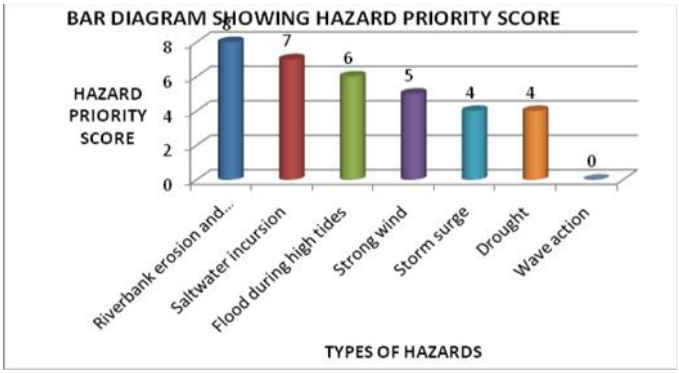

Fig. 7. Hazard Priority Score of Sambhunagar

Sambhunagar also faces the risk of rivers coming nearer to each other over the years. Some other places of Gosaba block also show this hazard of rivers coming nearer. Notable among these are sites of Sambhunagar, Kachukhali, Rangabeliya and Radhanagar Taranagar village panchayats.

Table 4. Decreasing distance between rivers

Sites of gosaba	Distance (km in soi toposheet, 79b/16,1969)	Distance (km in 2015, google earth)
Mitrapur (sambhunagar)	1.5	0.55
Kachukhali (b in map)	0.7	0.67
Kachukhali (c)	0.4	0.37
Bali	0.5	0.47
Rangabelia	0.6	0.38

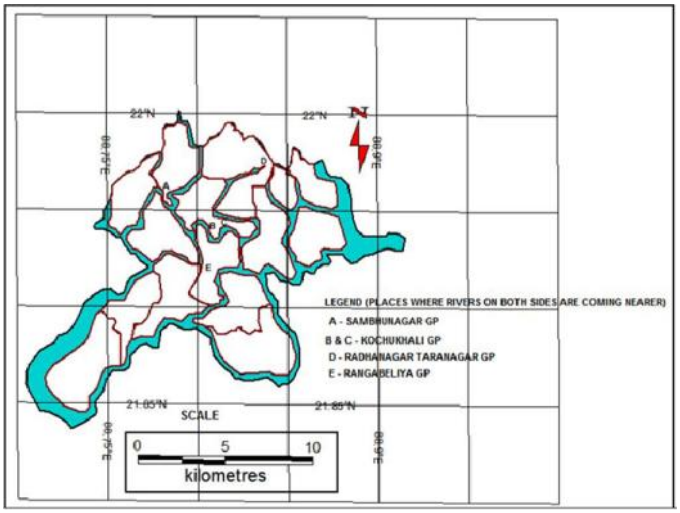

Fig 8. Sites where rivers are coming nearer

The village panchayats have capacity to vacate some people in the event of a hazard as evident from the government accounts. It has been noted that it is not possible to evacuate most of the people. Compared to other gram panchayats Sambhunagar shows a moderate capacity to evacuate people in the verge of any hazard. On this basis a bar diagram has been prepared.

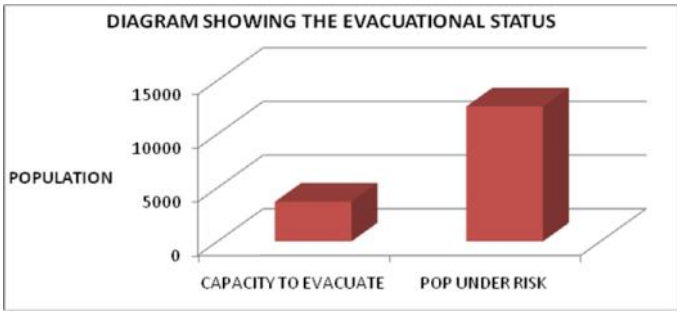

Fig. 9. Evacuation gap of Sambhunagar (Source: Evacuation Plan, S 24 Parganas, 2011)

Present extent of breaching of embankments

The extent of breaching of embankments for Bairagipara, the surveyed area of Sambhunagar has been identified from the images of Google earth. The extent of breaching from the year 2003 to the year 2009 was 0.108 km^2 and the extent of breach from the year 2010 to 2013 was 0.115 km^2. While from 2014

to 2016 the extent of embankment breaching has been reduced to 0.00175 km^2 showing a development of the situation.

Fig. 10. Embankment breaching of Sambhunagar (clockwise from left 1- 2003-09, 2 - 10-13, 3 - 14 -16 and 4 - photographic evidence)

Aila aftermath of Sambhunagar

Aila had struck West Bengal on 25th May 2009 and had left Sundarban ravaged. Even the northern parts of the Indian Sundarban were affected during Aila. Taking the mouza map of Sambhunagar the areas submerged during Aila may 2009 have been noted and computed. It was found that nearly 5.56 sq km of area of the mouzas got submerged when the Suryaberiya river joined the Hatakhali river via a small creek.

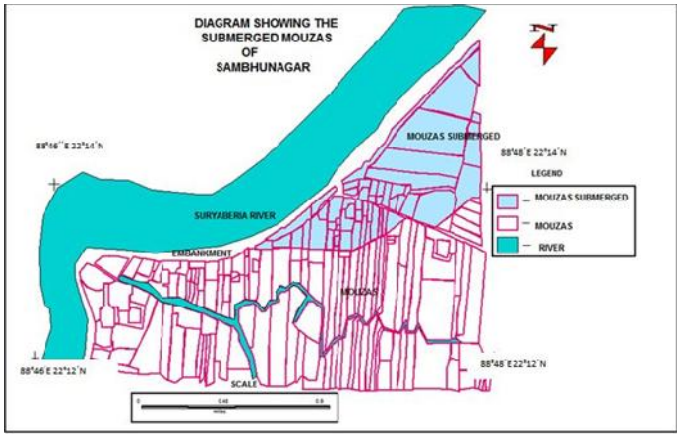

Fig. 11. Aila aftermath of Sambhunagar

Fluvial dynamics of Sambhunagar

The fluvial dynamics of Sambhunagar has been influenced by the construction of embankments towards both Sambhunagar and Chunakhali. Prior to 1960, Chunakhali opposite of Sambhunagar used to face erosion. However the construction of embankments has resulted in shifts of thalweg line causing erosion mainly towards the thalweg of the river. A total station survey was conducted on 15th April 2014 using echo sounder and GPS. The resultant profiles show the thalweg of the river and the resultant erosion. The GPS waypoints show the location of the places where the profiles were taken. Profile 1 shows the scenario of the river stretch in the middle of two embankments. The construction of embankments on both the sides has caused a disequilibrium by means of which the thalweg of the river has shifted towards Sambhunagar causing much erosion there. The right side of profile 1 points towards Sambhunagar which is facing high levels of erosion causing repeated embankment breaching and settlement shift.

Peoples' perception

Conditions of embankments

The embankments of the surveyed area are mostly earthen, with some embankments made of bricks and some armed with porcupine mesh. Out of 18 surveyed people 8 are of the opinion that the condition of embankments is worst, 5 are of the opinion that the condition of the embankments is bad and 5 are of the opinion that the condition of the embankments is moderate. Worst conditions are mainly for the earthen embankments whereas the embankments protected by porcupine mesh and other such structures are of moderate condition.

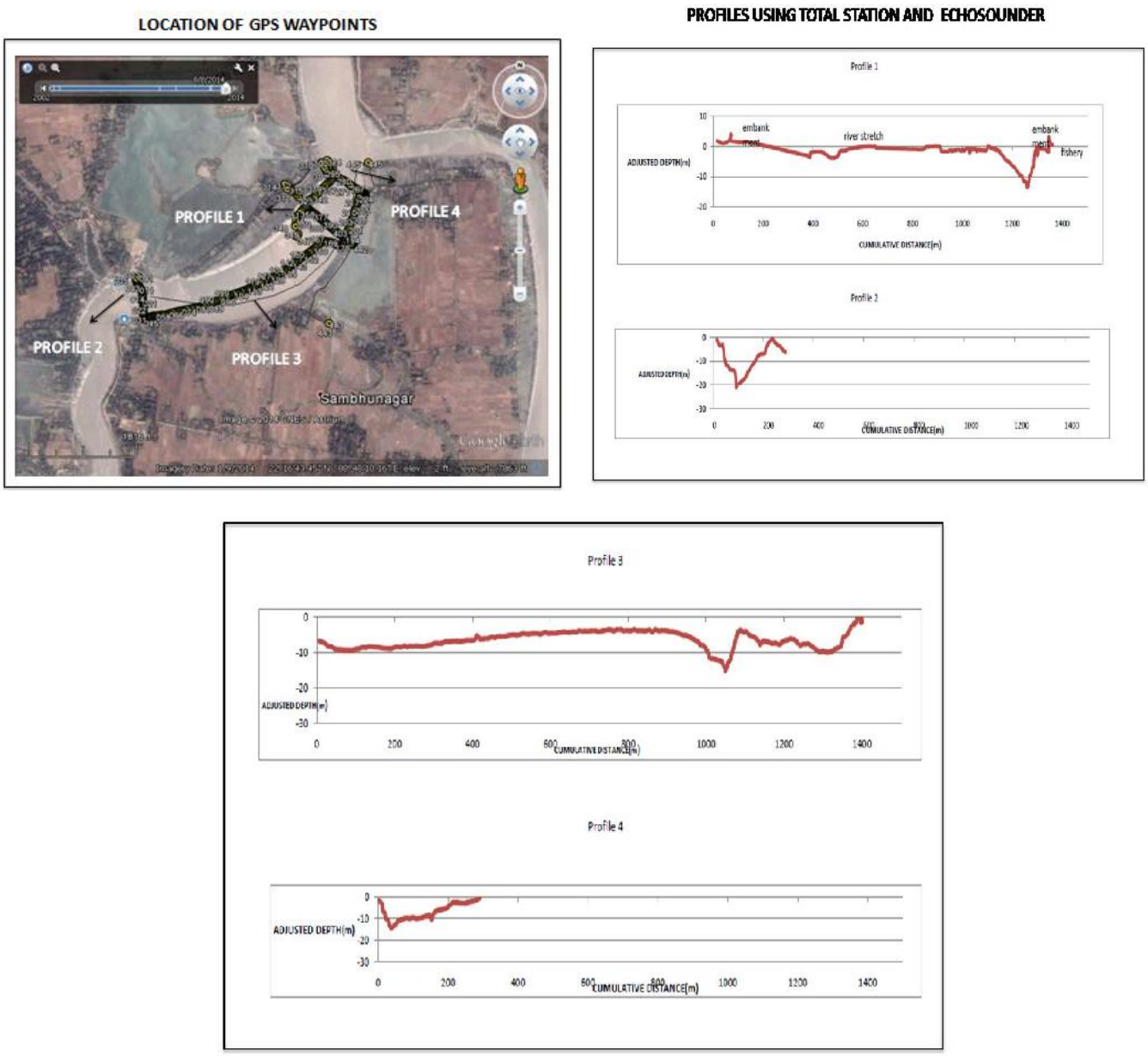

Fig. 12. Fluvial dynamics of Sambhunagar

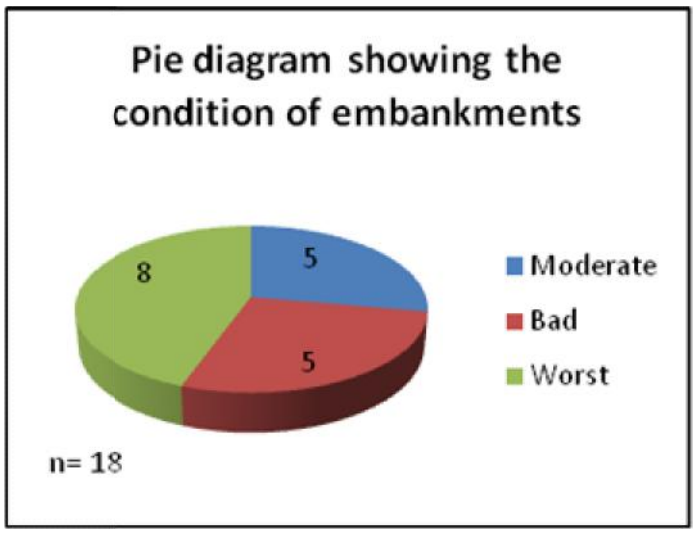

Fig. 13. Condition of embankments

Incidences of embankment breaching

The local people have opined that the embankments get breached frequently mostly during the rainy season. The breaching of embankments is associated with the saltwater incursion and land and water pollution. No governmental help is received at that time and the local people fight the situation themselves. The women keep straw on their backs when they try to prevent the breach of embankment.

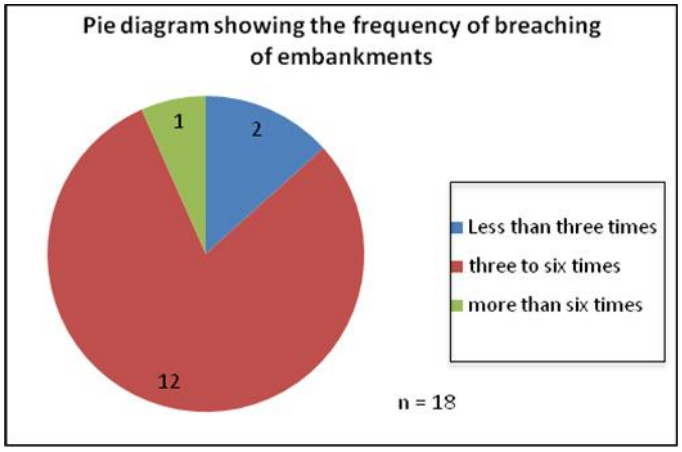

Fig. 14. Frequency of breaching of embankments

Incidences of migration

Owing to the breaching of embankments many people have lost their land and have been forced to move to much interior areas away from the river banks. Those people who have less land have out migrated to Kolkata and other places of West Bengal like Sodepur of North 24 pgs. Others have migrated to other states like Maharashtra and Kerala for jobs.

Amount of land lost due to embankment breaching

Out of the 18 surveyed people 5 people have lost less than 5 bighas of land, 3 people have lost 5 to 10 bighas of land, 8 people have lost 10 to 15 bighas of land, 1 person has lost 15 to 20 bighas of land and another person has lost more than 20 bighas of land. This indicates that mostly 10 to 15 bighas of land had been lost due to the breaching of embankments. For poor villagers whose monthly income is mainly dependent on agriculture the loss of so much land is alarming.

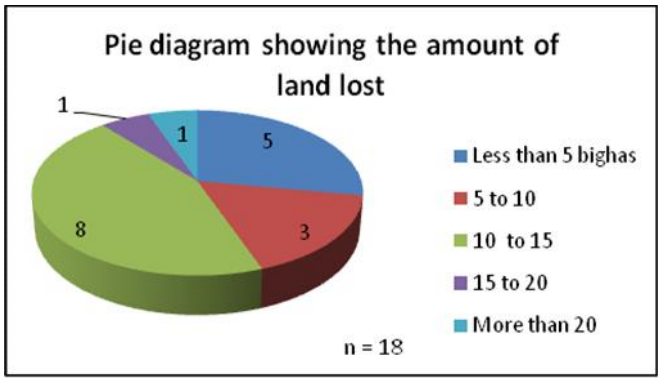

Fig. 15. Amount of land lost

Management options

The PWD and the irrigation department have constructed both earthen and brick embankments and have started a programme of aforestation and mangrove regeneration. However most of the works are unsatisfactory. Block pitching has not proven to be fruitful. No governmental or NGO aid has been received by the locals. The local people have suggested a number of measures for preventing the breaching of embankments. Out of the 18 surveyed people, 8 people have opined for the construction of porcupine mesh, 2 people have opined for the construction of guard walls, 2 persons consider the construction of concrete embankments to be effective, 3 people have opined in favour of mangrove plantation along riverside and 3 persons have considered works to be done on the riverbed to be fruitful. The local people have opined that it is necessary to prevent the toe erosion. Initiatives have been taken to construct cages and dump mud bags and bricks there to arrest breaching. Some have also opined to cut the bars of Chunakhali area so that the main flow of the river strikes the other part. However notwithstanding the inspection by the Central team no such fruitful works have been done to help the local population.

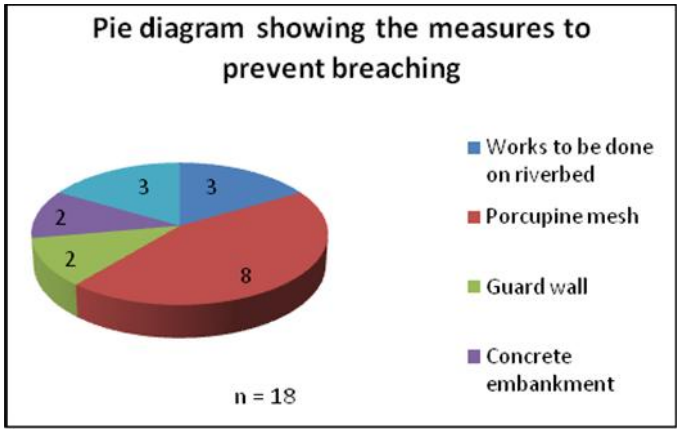

Fig. 16. Management options

Temporarily the use of concrete embankments and porcupine meshes can be an option in managing the condition of the embankments. However, with the increasing risk of repeated embankment breaching at Bairagipara of Sambhunagar and the decreasing distance between the rivers, rehabilitation of people can be cited as a long term management option.

Conclusion

Premature reclamation of Sundarban by construction of embankments has rendered a process of polderization. This has resulted in the transformation of Sundarban to a saucer shaped depression making it liable to get flooded. Repeated embankment breaching of Sambhunagar and other sites of Sundarban enhance the risks faced by the inhabitants. While, temporarily the fortification of embankments by porcupine meshes can be done the inhabitants should be rehabilitated to safer places in long term. As the creeks have been severed from the upland sources the regeneration of creeks is not possible.

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