Landscape Degradation of River Island Majuli, Assam (India) due to Flood and Erosion by River Brahmaputra and Its Restoration

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***Abstract*—Majuli, one of the largest inhabited river islands in the world, is under serious threat due to large-scale bank erosion by the Brahmaputra River. There is urgent need to preserve this socio-culturally rich island of over 0.2 million people. Erosions have been shrinking its landmass significantly and thereby causing enormous pressure on its ecosystem. Through this study, an attempt has been made to assess the effect of flood and erosion on the island, its nature, habitats and eco-system. Survey maps and satellite data are considered as major inputs to this study. Inputs from various sources in the island including associated government agencies are utilized in this study. Analyzed data indicate that the island eroded at an annual rate of 0.71 sq-km from 1914 to 1949 and alarmingly at an average rate of 3.43 sq-km in subsequent years. Recurring major floods have blanketed fertile land with unproductive silt and shrunk areas of water-bodies. Remedial measures to counter all these diminishing phenomenon and conservation of its natural resources including restoration of water-bodies are discussed. For conservation and restoration of the degraded island, people's participation is considered very essential.**

***Index Terms*—majuli, erosion, conservation, biodiversity, river island**

I. Introduction

Majuli, world's one of the largest inhabited river islands, is located in the middle reach of mighty river Brahmaputra in Assam, India. The island extends in a length of about 80 km along the East-West and about 10 to 15 km along North-South. The geographical extent of the study area (Fig. 1) is between latitudes 26 °45′ N and 27 °10′ N and longitudes between 93 °40′ E and 94 °35′ E. Average elevation of the island is about 85 m above MSL. Majuli's present population is estimated at 0.2 million with majority of its population belonging to ethnic tribal communities.

According to some geographical reports, during 18th century, Majuli had been a cluster of 15 large and a greater number of small islands. "Ref. [1]" Recurring major floods over the centuries have changed the morphology of Majuli. Coupled with these, several great earthquakes like those of 1897 and 1950 have brought Majuli to its present state. "Ref. [2]" E.A. Gait in "A History of Assam" corroborates - "There was a heavy flood in 1642, many heads of cattle were washed away. Several earthquakes occurred in the same year. It has already been stated that the great flood of 1755 is responsible for change of course of the Brahmaputra." "Ref. [3]" P. Kotoky, *et al.*, in their Research Communication stated "Majuli was formed due to head-ward erosion and channel migration of the Brahmaputra River. Majuli then was formed with 13 'chaporis' or small islands." "Ref. [4]" Dr. A. J. Baruah and Mr. R. K. Baruah, in their study on changing geographical area of the Island, indicated that "maximum shift of the north bank of Brahmaputra towards north was almost 5000 m near Auniati Satra (west of Longitude 940 E) of Majuli Island during 1914 to 1963".

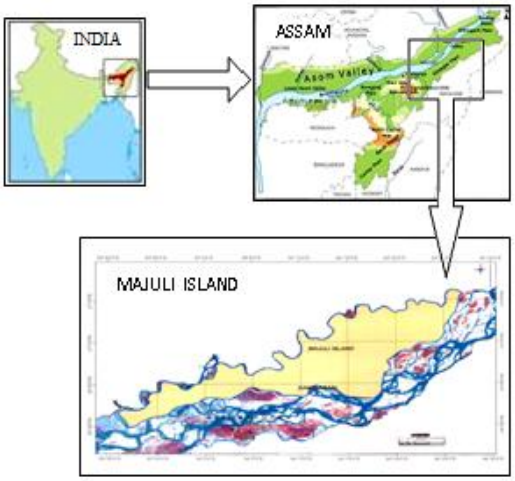

Figure 1. Key Map of Majuli Island

Present day Majuli consists of one major island, the mainland Majuli, and nearly twenty fragmented isles most of which are thinly inhabited. The Brahmaputra River, with a total catchment area of 580,000 sq-km, is characterized by its exceedingly large discharge (average annual yield of 537 billion cubic metres), enormous volume of sediment load and very highly dynamic channel morphology. "Ref. [4], [5]" Lateral changes in the channels cause massive erosion along banks leading to loss of good fertile land every year. A significantly adverse impact of bank oscillation is shifting of outfall of the tribu-

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taries and drainage channels and thereby bringing newer areas permanently under water. "Ref. [6]" Enormous silt carried by the river from seismically disturbed and geologically fragile upper catchments often changes surface geology of the island caused by recurring floods. Through this study, the trend of river bank erosion, effect of flood and erosion on the island, its nature and habitats and impact on ecosystem of the island is assessed. Government of India has been advocating for Majuli to be declared a UNESCO World Heritage Site in an effort to preserve this socio-culturally rich island. Adoption of suitable remedial and restoration measures with a scientific approach to counter all these diminishing phenomenon and conservation of its natural resources is utmost urgent.

II. Methods and Materials

There are not enough documented materials to ascertain an authentic long term trend of degradation of landmass of the island. Oldest scientifically recorded document available for this study is 100 years old authentic survey maps of 1914. Available survey maps and satellite imageries of the study area for different periods have been scanned and brought to GIS format and superimposed. Digitized layers of land mass boundary demarcation, water bodies in the island, river areas and sand-bars, built up areas, etc. have been studied. The area of Majuli Island, as per Survey of India map of 1914 (Fig. 2), has been taken as the base input for study of erosion trend. Other information for this study, like effect of flood and erosion on the island, its nature, ecosystem, demography, socio-economic condition, etc., have been obtained from local administrative authority, various reports published by different Government agencies, annals, other publications, etc. Interactions with local populace made through questioner, meetings and transact–walk to get the ground reality and also ground verification of recent as well as historical facts. Fig. 2 depicts a comparison of the geographical status of the Island on 1914 and its present status.

Geomorphology of the island has been continuously affected by floods and erosion caused by the Brahmaputra since formation of the island. But the problem became significant in the aftermath of great earthquake of 1950, with a magnitude of 8.6 on Richter Scale with its epicenter in the region. As a consequence of dramatic morphological changes of the Brahmaputra River related to the two major earthquakes in 1947 and 1950 that rocked the North-East Region of India, Majuli is threatened by massive erosion through 1950s.

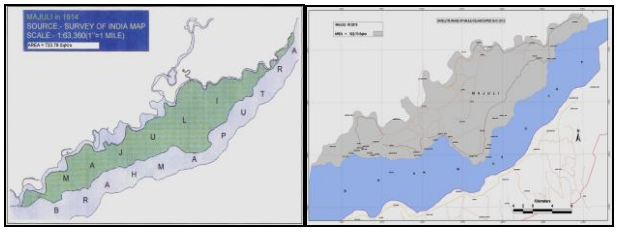

Figure 2. Majuli Island during 1914 (Left) and during 2013 (Right)

A. Erosion of Landmass by River Action

Recurring floods and erosion have shrunk area of the Island by shifting its bank-line, degraded its fertile soil with unproductive sand deposits, degraded the water-bodies in the island, and what not. Degradation of area of Majuli Island due to erosion by river Brahmaputra during the period from 1914 to 2013 is assessed from study of survey maps and satellite imageries. Quantum of land erosion in different periods have been studied from available sources as stated above and authenticated by interacting with different sections of people of the Island.

B. Wetland Degradation and Drainage Congestion

Majuli had a fairly large number of swamps and wetlands. The larger swamps owe their origin to pre-existing rivers. A number of natural drainage channels drained the Island. Present status of these natural bodies in comparison to their historical existence is assessed from study of historical reports, survey maps and subsequent studies on relevant subjects. There are definite indications of large-scale degradation of such natural bodies in the Island. Water bodies, swamps, drainage channels have been choked with sand deposits by recurring floods through breaches in embankments reducing areas of larger bodies and making the smaller ones disappear.

C. Identification of Critical Zones

Majuli Island has been delineated into different zones based on a particular locality of conglomeration of certain villages and their exposure to different causes of landmass degradation such as flood and erosion of different magnitudes. Zones are tagged as (i) most critical, (ii) moderately critical and (iii) marginally critical depending on severity of effects of flood and erosion and overall impact on population economically and socio-culturally.

III. Results

Study of various factors causing landscape degradation of one of the largest inhabited river islands in the world, indicates recurring major floods of Brahmaputra loaded with enormous silt carried from geologically fragile upper catchments as key responsible factor. River bank erosion, which is consequent to floods, is also a equally responsible factor.

A. Erosion of Landmass

"Ref. [7], [8]" Erosion of landmass of Majuli Island over a span of 100 years is depicted in Table 1 placed hereunder. Analysis of the observations of the table indicates that the area of landmass of the island was 733.79 sq-km during 1914 which had been eroded by the Brahmaputra River to 708.91 sq-km by 1949 with an average annual loss of 0.71 sq-km in a span of 35 years. Such loss of area may be attributed to erosions caused by some major floods and geological disturbances caused by the earthquakes. The most significant loss of area is observed during 1949 to 1963 which is a loss of 120.12 sq-km in a span of 14 years and averaging a phenomenal reduction of 8.58 sq-km annually and more than a dozen

times the rate of preceding 35 years. This alarming loss of land is unanimously attributed mainly to the great

TABLE I. LOSS OF LANDMASS (IN SQ-KM) IN MAJULI ISLAND BY EROSION

Year	Land Area	Area Eroded	Average Area Annually Lost	Data Source
1914	733.79	-	-	Survey of India Map
1949	708.91	24.88	0.71	Survey of India Map
1963	588.79	120.12	8.58	Survey of India Map
1988	513.89	74.90	3.00	IRS LISS III
1998	510.79	3.10	0.31	INSAT IC LISS III
2004	502.21	8.58	1.43	IRS P6 LISS III
2008	506.37	- 4.16	- 1.04	IRS P6 LISS IV
2013	522.73	- 16.36	- 3.27	IRS P6 LISS IV

Assam Earthquake of 1950 and subsequent heavily silt-loaded high magnitude floods recorded to have occurred during 1951, 1954 and 1962. The non-fluvial event like earthquake alone could have been the trigger that initiated severe erosion along the Majuli reach of the Brahmaputra. It is reasonable to believe that such huge loss of area is due to combined effects of earthquake and consequent deposition of excessive sediment in river bed transported from the geologically fragile upper hilly catchments causing the river to braid erratically.

During subsequent period of 25 years from 1963 to 1988, reduction of land area of Majuli Island was at an average annual rate of about 3.00 sq-km in spite of significant high floods during 1966, 1969, 1970, 1977, 1987 and 1988. Severity of erosion retarded during this period. The reason perhaps was stabilization of effects of earthquakes over these years. From 1988 to 2004, erosion of river banks in the island had reduced substantially to an average annual rate of 0.73 sq-km, nearly same as that of prior to 1949. During subsequent 9 years from 2004 to 2013, overall situation reversed to an annual gain of 1.04 sq-km from 2004 to 2008 and 3.27 sq-km from 2008 to 2013. Trend of erosion in the Island from 1914 is shown in Fig. 3 below.

B. Wetland Degradation and Drainage Congestion

Large number of swamps and wetlands pre-existing in the Island got reduced significantly due to floods, erosion and consequent deposition of enormous silt carried by the river during floods. A chronological status of water-bodies/swamps and drainage channels in the Island is depicted in Table II.

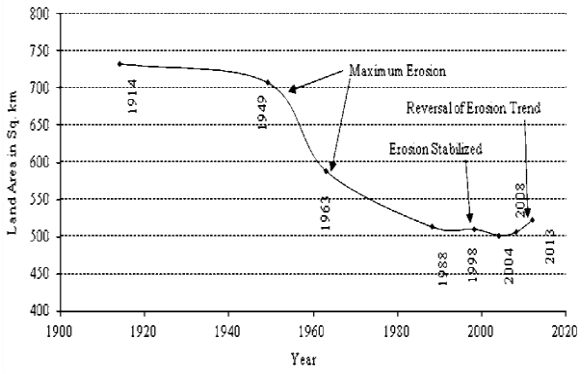

Figure 3. Trend of Erosion in Majuli Island from 1914

TABLE II. STATUS OF WATER-BODIES/SWAMPS AND DRAINAGE CHANNELS IN MAJULI ISLAND

Year	Number of Swamp/ Water Body	Number of Streams/Drainage Channels
1917	112	49
1972	52	7
2013	21	1

Many of these swamps and wetlands were engulfed by the river. Total number of swamps and wetlands reported to be observed during 1917 was 112 which decreased to 52 by1972. At present, the figure stands at just 21.

Natural drainage channels, like the Tuni, were plugged in a bid to get relief from backwater effects which in turn led to drainage congestion in several parts of the Island. Sluices and outlets provided for draining rain fed discharge became ineffective due to choking by sand deposits in recurring floods. But, congestion becomes worse when there are floods due to breach of flood embankment. Congestion in turn leads to contamination of stagnant water and adversely affects aquatic life as well as environment.

In 1917, the number of named streams draining Majuli was 49 which decreased to only 7 by 1972. At present there is only one drainage channel, the Kakorikata Channel, draining entire mainland Majuli. The historical Tuni Channel, meandering like a serpent, now ceased to flow. It opened several mouths due to erosion of its several segments and ultimately had to be plugged by constructing embankment across the channel.

C. Effects of Flood and Erosion on Geomorphology

There had been several floods of high magnitude occurring in the island in recent past. Floods of 1987, 1988, 1994, 1998, 2000, 2004 and 2008 have ravaged the island inundating nearly entire Island. Government has constructed more than 100 km embankments surrounding the island in an effort to give relief from recurring floods. But breaches in the embankments due to high floods and erosion rendered the situation worse. Fertile lands are eroded and unproductive patches of landmass with sand deposits add to area of the island.

D. Land-use and Land-cover of Majuli Island

Present area of Majuli Island (Main Island) is 522.73 sq-km. "Ref. [9]" Land-uses and land cover of the Island is broadly categorized as below and shown in Fig. 4.

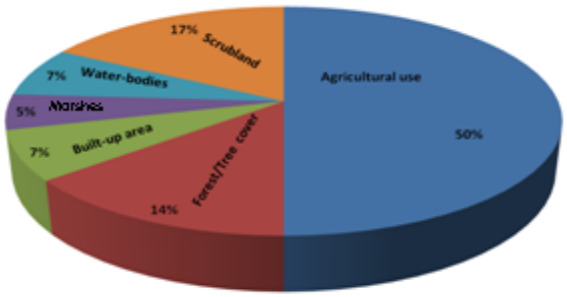

Figure. 4. Land-use of Majuli Island

E. Effect on Biodiversity

Diminishing factors – reduction of land mass and drainage channels due to erosion; and reduction of water bodies due to silt deposition have not only affected but also imparted remarkable imprints on existing rich biodiversity of the island, its flora and fauna, socio-cultural fabric and the demographic pattern. Majuli, a hotspot for flora and fauna, possesses a significant range of animal and plant life. Being an island, it maintained certain distance from large-scale human interventions on its natural habitats. Its existing wetlands alone could sustain a plethora of aquatic life and a wide variety of species. There could well be more than 300 varieties bird species including Siberian Crane, Whistling Swan, etc., and many of them are resident. Among the resident bird species are threatened species like pelicans, greater and lesser adjutant storks and black-necked cranes. During winter, large flocks of migratory birds have also been documented in and around the Island. But, the phenomenon of diminishing water bodies and swamps has become a matter of grave concern as far as the winged visitors to the island are concerned. Resultant effect is disturbance of the eco-system and shrinkage of habitats of migratory birds.

F. Change in Demography

One of the significant effects of recurring river bank erosion in the island is on its demography. Nearly 70% of the inhabitants of the island are ethnic Mishing tribes who traditionally dwell near rivers in their propped-up houses. Nearly 227 sq-km of land mass, which is over 30% of island area and mostly dwelt by this community, had been eroded away over the years since 1914. Consequently, they were compelled to shift to other areas in the island away from the river. Many had to move out of the island seeking other areas conducive to their life style while many others were compelled to change their way of living altogether. Consequently, demography of the island has witnessed sea changes in it.

IV. Discussion and Conclusion

Reversal of the scenario after nine decades of continuous erosion can definitely be attributed to application of pro-silting engineering method of RCC porcupine structures. These 6 member tripod-like structures, which remain a tripod on any of its three faces, when placed across a silt bearing river in series and clusters, work excellently to avert river bank erosion. They essentially contribute in making river bed shallow in desired places as well as in deflecting eroding bank channel away. Embankments constructed for flood prevention, prevented uniform deposit of fertile humus carried by nominal floods. Embankments fragmented island into countryside and river areas with distinct land pattern.

A. Problem Management Approaches

As a problem management approach, different causes of landmass degradation are first identified. Different zones are marked out depending on magnitude of flood and erosion and consequent effects as well as importance of the area economically, socially and culturally. Zones are tagged as (i) most critical, (ii) moderately critical and (iii) marginally critical.

Kamalabari, Bengenaati-Dakhinpat and Salmara areas of the Island are identified as most critical needing highest priority of attention. Bhakat Chapari, Molual and Kandulimari areas are marked as moderately critical while Garmur, the administrative hub of the island, Jengrai and Upper Majuli areas are zoned as marginally critical. Problem management agencies and beneficiaries are identified. Stakeholders identified for problem management are agencies dealing with Flood and Erosion management, Public Development Works, Forest and Environment, Social Welfare, Agriculture and primarily local Civil Administration. The livelihood option created by stakeholder agencies should be a holistic one that links the micro with the macro. Aspects that change livelihood scenario should have positive impact on one's life socially, economically and culturally, both directly and indirectly.

B. Flood-proofing and Erosion Protection Measures Taken

The State Government has been carrying out the flood proofing and erosion control works in Majuli Island since 1953 after the island had been severely hit by the fury of flood in the aftermath of Great Earthquake of 1950. Since then, nearly 100 km of embankment, 42 km of retirement embankment, dowel bunds, impermeable spurs and other conventional anti-erosion measures were constructed in an effort to contain flood and erosion in a span of nearly 50 years. However, these efforts gave results far less than expected. With adoption of R.C.C. porcupine, the pro-silting anti-erosion measures, from 2004 in the erosion prone reaches of the island, intensity and extent of bank erosion reduced significantly. The present pro-silting measures have been giving satisfactory result in stabilizing the river course. Even after continuing erosion in patches, a good chunk of land mass got reclaimed in the island. In a bid to contain flood and erosion in long term perspective, Government agencies have taken up construction of rock armoured solid deflecting spurs/ groynes at locations selected through river model studies.

C. Other Approaches for Restoration of Degraded Is-Land

Remedial measures for flood and erosion control to counter the diminishing phenomenon in the island and conservation of its natural resources including waterbodies is utmost urgent. The anti-erosion structures need to be executed judiciously and if required, they need to be modified, rebuilt and efficiently maintained. Agencies have been successful in containing erosion in critical reaches in the Island. Yet, they provide protection to only a reasonable degree and some future version is required for achieving sustainable bank stabilization. Unconventional and approach like plantation of Vetiver grass as anti-erosion and bank stabilization measure may be a good environment friendly proposition. Reclaimed land mass in the island should be brought under green cover through social forestry.

Environmentalists have a good deal of scope to exert their sensitivity to ecosystem. For conservation and restoration of the degraded island, sensitization of common people and their participation in restoration process is very essential. Depending on exposure to different problems, delineated critical areas need to be attended after assigning priority in different problem sectors. Coordination among different stakeholders is very vital. Local administration has a major role to play in this regard.

For wetland conservation and restoration, flood proofing is essential. Water-bodies should be made weed-free and de-silting of degraded bodies to be taken up. People of Majuli, individually as well as through NGOs, are actively engaged in safeguarding the faunas in the Island. Government agencies should come forward with infrastructure development and funding for this and other conservation causes. Anthropologists have a great scope to work on restoration of its unique demography. Majuli, a river island having extreme historical and cultural importance, and also a biodiversity hot-spot, warrants immediate exposure to the world scientific community and needs to be declared an eco-sensitive zone to safeguard its unique identity.

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