Safeguarding the threatened hydrogeo-cultural heritage of Majuli Island in Assam, India: A case study

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Abstract. Water is the basic need for life, and it has a vital role on any riverine island and its diverse culture and heritage. Majuli, the riverine island in Assam is distinctive for its origin, characteristic water resources, hydrogeological manifestations as well as cultural heritage. River Brahmaputra, the lifeline of Assam, transverses through Assam's valley, resulting in the deposition of alluvial sediments and forming one of India's most potential aquifer systems. Every year, the state is prone to frequent natural disasters like massive floods and riverbank erosion in the valley during the monsoon months. Majuli Island is the cultural heritage site of Assam, which is often highlighted as the ‘Cultural Capital’ of the state. It is termed as the largest river island of India and one of the largest inhabited riverine islands in the world. In combination with cultural aspects, the island holds typical hydrogeological heritage, consisting of encircled fresh surface water bodies, wetlands, beels, various sub-surface aquifer systems, and water quality issues. However, the existence of the hydrogeo-cultural heritage in the island is under acute threat due to frequent floods, land erosion by the Brahmaputra and its tributaries, surface water, and groundwater quality deterioration. Hence, the present study has emphasized the changing hydrogeological scenario of Majuli over the last decades and the correlation of diverse cultural perspectives followed by the establishment of mutual interrelationships between hydrogeology and cultures, which have not been addressed so far. The paper also aims at understanding the demographic status, landscape pattern, hydro-geomorphological characteristics, biodiversity, and ethnic diversity perspectives, which would facilitate to adopt the effective measures for the protection of the island from further environmental degradation and thereby to recommend a sustainable management strategy to uphold the multidimensional cultural heritage perspectives of the island.

Keywords: Majuli, Communities, Hydrogeo-cultural heritage, Conservation, Management

1. Introduction

Rivers are considered as resources with multiple cultural, economic, environmental, and social values worldwide. Rivers and the adjacent island are the heritage for humanity, reservoirs of biodiversity, and places of cultural convergence. In any area, hydrogeo-cultural heritage forms a significant part of the hydrogeological diversities. Water plays a vital role in the phenomenon, which
can be manifested in different forms, those in terms of scientific issues, ecological perspectives, educational aspects, socio-cultural understanding, and aesthetics [1]. The reminiscence of water heritage and river heritage is found to be preserved in different parts of India. The well-planned rainwater harvesting in the Indus Valley Civilization; fascinating step-wells are reportedly available in Hampi in Karnataka; Jhalaras in the city of Jodhpur, Bawaris, Kund, Baolis and Ahaneri in the Rajasthan and Bundelkhand. The structures linked with the water are of different kinds as documented like ‘ghats’ at Benaras, Srrinagapatam, and designed step structures on the bank of River Narmada. The beauty of water has been portrayed by storing in the ponds at temples located at the Thiruvananthapuram, Madurai, and Melkote. The aesthetics of water has charmingly displayed in the channels and fountains at the Hampi and also at the tomb of the king Humayun [2]. Hence, water plays a central role in developing cultural heritage in an area/islands depending upon area-specific significance.

Similarly, the largest river island, Majuli has established its significance as the cultural capital of Assam state since five centuries ago. The island was formed by the River Brahmaputra on account of its course changes and its tributaries, especially the Lohit. The major attraction of Majuli was the fresh surface water resources, which influenced the Neo-Vaishnavism culture in the 16th century. Then period, a monolithic form of Hinduism was developed in the form of Vaishnavism and that resulted in the formation of monasteries and hermitages in the Majuli, which are called as Satras. Out of 65 Satras, now only 23 are operating. The noteworthy Satras are Bhimpur, Shamaquri, Dakhinpat, Aunniati, Garamur, Kamalabari, Narasingha, and Benegenatai. The aim of the establishment of Satras on the island was to preserve the satriya culture music, dance, and the antique items of cultural significance, like art and craft traditions, potteries, ask-making, weapons, jewelry, handlooms etc. In Majuli, all the satras are considered important organizations with socio-cultural influences [3]. The island hosts a number of Vaishnava monasteries and their gurus, which have elevated it as pilgrimage land and is pronounced as “Vatican of Hinduism” [4]. The island is dominated by the tribal population and has been designated as a district in 2016. The tribal people are preserving the traditional cultural heritage of Majuli and are elevating their importance at the international level. The river island has portrayed superbly the interrelationship of diversified cultural heritage and the influence of surface water and groundwater resources. The mutual promotion of water and culture in Majuli deserves worth mentioning.

Majuli, the world’s largest inhabited riverine island comprised of 243 villages and is configured as a long narrow strip of land. It is situated between two rivers parallel to each other. The island had suffered from natural calamities like frequent earthquakes between 1661 and 1696. In 1750, the land had witnessed the shocking flood that lingered for more than two weeks. This catastrophic flood has been indicated in the historical texts and over time that has been manifested as cultural heritage in the form of folklore. The flood had forced the split of Brahmaputra into two branches, of which one maintains the parallel course of the Brahmaputra itself and another follows the course of the Burhidihing channel. The resultant effect of this split of Brahmaputra gave birth to Majuli Island. Hence, it is evident from the study that the River Brahmaputra and seismological activities have an enormous influence on the hydrogeological, ecological, and biological coordinates of the island. Apart from the reduction of the island area, the island’s biodiversity is also getting adversely affected on account of ongoing hydrogeological and ecological changes. This frequent ecological transformation, adversity of flood, and susceptibility of water to pollution are cumulatively resulting in the migration or extinction of the flora and fauna in the region. Therefore, all these factors are cumulatively affecting the cultural life of the island in a big way. In this paper, the issues on hydro-geological heritage and cultural heritage of Majuli are emphasized from the perspectives of geographical location, climate, cultural and socio-economical contexts, and the intangible heritage. It also focuses on the issues relating to the water resources both in quantitative and qualitative perspectives in relation to the cultural aspects.
1.1. Cultural Heritage of Majuli

Majuli, the land of Vaishnavite culture has established itself as the cultural heritage site of Assam. Frequent floods and continuous erosion by the River Brahmaputra are the responsible factors for this cultural heritage's ongoing destruction process. Considering the picturesque landscape and cultural diversities, the Government of India proposed the riverine island to include in the list of UNESCO World Heritage Site within the category of “Cultural Landscape” [5]. The island is fulfilling the prescribed criteria like Outstanding Universal Value (OUV), which is coming within the purview of UNESCO Operational Guidelines that ought to be accounted as the potential criteria of a site for enlisting as a World Heritage site. However, UNESCO has not yet been considered the island within the list of World Heritage Sites. The enlisting of Majuli in the UNESCO list would be beneficial to enjoy the facilities with better preservation and protection of heritage in terms of sensitization to the local people, civil society groups as well as the government or Non- government organizations (NGO).

Once Majuli is included within the UNESCO list, the avenues will be opened up for handsome financial assistance, multifaceted cooperations, and most importantly advice from the World Heritage Committee experts for the restoration of hydrogeological deterioration, preservation of its unique heritage, and above all upliftment of the social and economic status for local tribal people. In this context, the interlinking of social and cultural perspectives is obvious in demand for consideration.

The hydric soils on floodplains contain shallow groundwater, which is catering to the need of the people of Majuli island through dug wells. Since its formation, the drinking and agricultural demands of the island population are meet up by groundwater. Two aquifer systems are having good groundwater potential and are capable to cater to the drinking and agricultural requirements of the island population. Central Ground Water Board (CGWB) has undertaken the groundwater exploration initiatives to obtain an overview of the disposition of sub-surface aquifer systems and the island's regional groundwater condition. The study reveals that the detailed understanding of two aquifer systems includes the shallow aquifers and deeper aquifers lying within 50 m bgl and within 50 to 200 m bgl.

River flows connect lands, people, and other life forms, inspiring and sustaining diverse cultural heritage properties and hydrogeo-cultural heritage. The Brahmaputra River creates an alluvial plain covering an area of 56000 sq. km maintains a gradient in the direction of NE to SE with a slope 12 cm/km [6]. The typical location of Majuli in the middle of the Brahmaputra River and vast freshwater reserve with biodiversity attracts the researchers to take up multi-dimensional research initiatives in the region. Various research activities have already been conducted and ongoing on this island. The published papers indicate that no research has been carried out in Majuli in the line of addressing hydrogeological heritage issues in conjunction with existing cultural diversities and their interrelationships. As water has a vital role in the preservation of cultural heritage, a thorough understating and in-depth knowledge of the hydrogeological scenario and its interrelationship are prerequisites for any kind of research on the island. This island is a vibrant culture with different ethnic cultures, Vaishnavite Bhakti tradition, and ethnic diversities. Moreover, the island attracts a considerable number of tourists with its riverine beauty, migratory birds in winter and cultural heritage. The island has been declared as the Cultural Heritage of India vide the Majuli Cultural Heritage Act, passed by the State Assembly of Assam in 2006, for its unique tangible and intangible heritage [7].

Majuli Island has huge surface water bodies like wetlands, ponds, beels etc., which are susceptible to bacteriological contamination, especially by fecal coliform and eutrophication effect. Moreover, during different festival seasons, idols' immersion is causing pollution to fresh surface water reservoir/wetlands. The poisonous chemical elements like lead (Pb), Aluminium (Al) and Zinc (Zn) etc. are used for painting those idols that are made in the Satras or elsewhere in Manjuli. These harmful chemicals are responsible for killing flora and fauna inhabiting the surface water, which pollutes the groundwater resources through percolation. The less harmful chemicals, preferably organic chemicals, can be used for idols/ mask-making to avoid water reservoirs' pollution. The island inhabitants are dependent on agriculture for their livelihood, where indiscriminate exploitation of groundwater is
creating severe stress on subsurface aquifer systems. Further, the use of chemical fertilizers/pesticides/herbicides is also a responsible factor for surface water as well as groundwater contamination through irrigation return flow/run-off during monsoon.

The shallow aquifers extended up to 50 m bgl depth are containing arsenic-contaminated groundwater. Hence, the groundwater from the shallow aquifer is not suitable for drinking. Groundwater occurring below 50 m is free from arsenic, but extraction from deeper aquifers is a costly affair. Alternative fresh surface water bodies are affected by plastic pollution also. The surface water for drinking is also not cost-effective, as it needs to be lifted by a centrifugal pump to store in an overhead tank followed by the processes of bacteriological treatment and filtration for supplying through the street taps via pipeline supply. Hence, protection of both surface water and groundwater resources are of priority for the sake of water secured lives of the island people.

1.2. Details of the study Area

The island (Figure.1) is situated in the confluence point of two rivers - Brahmaputra and Lohit and lies within the co-ordinates of 26° 39’ 57.6” and 27° 16’ 19.2” N and 93° 34’ 12” and 94° 42’ 36” E. Majuli maintain the elevation of 84.50 meters above mean sea level (m amsl). The island encompasses the following Survey of India toposheets 83 F/13, I/4, I/8, I/12, J/1, J/5, J/6, and J/9. The three sides of the island are surrounded by the river Brahmaputra and its tributary, the Subansiri River, and the fourth side is bounded by the Kherkutia Suti, a distributary of the Brahmaputra River [8]. Due to its typical position, the island is susceptible to frequent severe natural calamities and environmental hazards.

As part of the Jorhat sub-division, the island does not have road linkage with the remaining part of the Assam state. It is one of the Assam state’s sub-divisions. The Majuli subdivision consists of two blocks - Majuli and Ujoni Majuli. From administrative points of view, each block consists of Gaon Panchayats (GPs) and each GP comprises of few villages. The island covers a total 20 GPs, within which Majuli and Ujoni Majuli block have 12 and 08 GPs respectively. Majuli can be accessed from both the sides of north and south ends that connect to the Jorhat town via National Highway – 37 followed by capital Guwahati and other parts of the country. The island experiences a subtropical climate with high rainfall during monsoon and occasional precipitation in winter. Heavy rainfall receives during summer due to the influence of the south-west monsoon. The island receives annual

![Figure 1. Location Map of Majuli Island (Source: Sharma B.K., 2014)](image-url)
rainfall within the range of 1494 to 2552 mm and last decade annual rainfall has been recorded as 1922 mm.

1.3. Demographic Status
The total population of Majuli Island is 1,53,400 that includes 79,481 males and 73,919 females with their ratio 930:1000 [10]. Around 45722 of the total population (29.81%) constitute the total workforce. This workforce consists 80.85% farmers and another 2.05% are agricultural labour (Census, 2001). The island comprised an area of 487.55 km² and the total population of the island is 1, 67,304 (2011 census) [11]. Analysis of the island's demographical statistics during the period between 1901, 2001, and 2011 is depicted in figure 2.

![Population Graph](image)

**Figure 2.** Demographical status of Island.

2. Research Methodology
The present study has analyzed the hydrogeological scenario and cultural perspectives based on the secondary data sources of Central Ground Water Board and published scientific findings with due acknowledgments and citations. The secondary data sources have been compiled and correlated with justifications in parity with local wisdom.

3. Discussion
3.1 Satra tradition of Majuli
In the North-Eastern part of India, Majuli forms the most distinguished sites of the Neo-Vaishnavite renaissance. The Bhakti movement that emerged during the 15th and 16th centuries in India had a strong linkage with the Neo-Vaisnavite waves. Shankardeva, the neo-Vaishnavite renaissance father, had established Satras or monasteries and preached the monotheistic Vaishnavism (Fig.3). Majuli hosts a vast treasure of extreme historical and cultural importance and is home to Assam's pristine cultural heritage and the ‘Vaisnavite’ shrines, which are called ‘Satras’. Vaishnavite monasteries or *Satras* have integrated the society, culture, and even the economy of the island in a row [14]. The *Satras* (Fig.4) and *Namghars* later have transformed into the centers of several intangible heritages of *Satriya* dance, drama, music, art, and spirituality. The meeting is emblematic because it ushered in an era of more egalitarian, inclusive, and non-violent Vaishnavite Bhakti tradition of Shri Shankardev in the state with a noticeable deviation from the hyper-ritualistic Shakta tradition of Shri Madhavdev. This exclusive cultural tradition is still living on the soil of the island. Further, there are a few civilizational aspects, which raise inquisitiveness. For example, pottery made from beaten clay
and burnt in fired kilns bears extraordinary resemblance with pottery made by people of the ancient Harappan civilization.

![Figure 3. Neo-Vaishnavite Satras](https://majuliriverisland.wordpress.com/2016/10/29/satras-of-majuli-island/)

3.1.1. Shamaguri Satra.

Samaguri is a popular Satra of the island and is considered an important centre of Vaisnavism in the Assam State. The Satra renders service as the famous center of culture, art classical studies and is familiar for attractive mask crafts and artworks. Samaguri Satra (Figure 4) draws keen attraction for its exquisite craftsmanship and also teaches the old art of mask making. The Satra is approachable from Mimati Ghat by ferry service.

![Figure 4. Samaguri Satras in Majuli](http://www.natgeotraveller.in/the-mask-making-traditions-of-assams-majuli-island/)

3.2 Portraying the classical interchange of human quality

The sustenance of humans is based on creativity. The multifaceted cultural diversities of the island have woven nicely the cultural life of Majuli in the various dramatic tradition that includes Rasleela in Garamur Satra and Kamalabari Satra, mask traditions (Mukha shilpa of Shamaguri Satra), songs (Borgeet, which were composed by Shankardev and Madhavdev), festivals and day to day life.
Human values of love, forgiveness, and non-violence form part and parcel of island cultural life. The island's socio-cultural life includes syncretism, peaceful coexistence, and egalitarianism.

3.3 Traditional habitation, land-use, and relation in between culture and human

In an era of intense consumerism and materialism, families inhabiting in the Hatis (area of habitation for followers in Satras) lead a decent peaceful life on the land owned by Satras. One will be surprised to experience that people living peacefully in concrete houses with private gardens in front without campus walls or separate entry gates and sharing common access roads.

3.4 Riverine and Water oriented Cultures

The island's typical location at the heart of the Brahmaputra provides an ambiance to develop a distinct cultural heritage, where tales of the Hindu god, Vishnu, are entangled with local tribal lore. The magnificence of the cultures' orientation is enhanced by the riverine topography, the Chars (strips of sand and silt deposition), and the biodiversity of the island. In the Brahmaputra, the sunsets spell of rain in the green fields and evenings melted in Mishing Chang-ghars offer a visual extravaganza. The dreamlike nights spread across swamps, marshes, and open fields around Dariya-Dubi define supernatural pragmatism's coordinates. The full-moon nights of Raas Purnima with peaceful music from distant Raasleela drama performances have a magnetic appeal for connoisseurs.

The wetland ecosystem has facilitated the developing the cultural heritage. Mājuli wetland is a hotspot for flora and fauna, harboring many rare and dying out avifauna species, including migratory birds that arrive during the winter season. Among the birds seen here are the greater adjutant stork, pelican, Siberian crane, and the whistling teal. The migratory birds arrive from places like Ladakh, Kashmir, Nepal, China, Tibet, and Europe. After dark, wild geese and ducks fly in flocks to far-away destinations. The wetland is being sold in a secret way that may transform the habitat of migratory birds into high-rise buildings in the future. The island is almost free from pollution because of the lack of polluting industries and factories and the sound rainfall. The puja used to perform at Dakshinapat Satra is a prominent example of a water-oriented heritage in Majuli (Figure.5). Groundwater abstraction structures like dug wells and tube wells of shallow depths are lifelines of this island people serving through the ages. Arsenic contamination in groundwater is the highlighted issue to be addressed with utmost priority.

![Figure 5. Pooja at Dakshinapat Satra](https://commons.wikimedia.org/wiki/File:Filial_Piety_Rituals.jpg)

3.5 The interrelation of Ecological and Biological Processes

The fact is well understood that the frequent change in River Brahmaputra courses is one of the reasons for frequent floods in its alluvial plains and is further supported by heavy siltation and
deposition. The flood and erosion data received from the Circle office, Kamalabari in Majuli indicates that out of 210 cadastral villages 67 are affected by erosion (32%), whereas out of 33 Non-cadastral villages 12 (36.36%) are affected by flood and subsequent erosion during the year 1969 to 2011. Sedimentological processes through the shifting of channel course of Brahmaputra are responsible for the formation of Char’s in and around Majuli Island.

3.6 Biodiversity of Majuli

Favorable location helps the Majuli to become a biodiversity hotspot and a prominent tourist destination. The fertile floodplains and highly productive wetlands are the main attraction of around 260 migratory bird species to have the island an ideal habitat [15]. The island of has a unique fluvial landform situated in the Brahmaputra river basin of northeast India and houses 55 Cladocera species of 36 genera. These include ~46.0% and ~79.0% of the freshwater species and genera of the taxon known from India respectively [16].

3.7 Hydrogeo-morphological characteristics

With an aim for sustainable management of wetland resources in the island, Remote sensing and GIS studies were conducted by B. Phaneendra et al. (Source: Tropical Ecology 51(1): 31-40, 2010). The study indicates that total of six geomorphological characters are present over in the Majuli – sand bar, sand bar with grass cover, natural levee, swamps, flood plain (active and old), and channel fills. Area wise coverage of the geomorphological features exhibits that 43% of the area was under sand bars concentrated in the Brahmaputra riverbed, 16% of the area was under active floodplains, and 14% under swamps. The hydric soils on floodplains are characterized by the Inceptisols and Entisols type holding groundwater in the shallow zone of aeration. The soil includes stratified textures and a depleted grey matrix of < 2 chroma. The soil map of the island explains that there are 13 nos. of soil series and 25 nos. mapping units, which signifies that 35% of the area can be suitable for cultivation as against the current practice of 7%. It is advised that the beels should be spared for the migratory birds. The paddy fallows were found worthy for growing cow pea, peas and French bean, whereas swamps were appropriate for paddy-fish integrated farming. The land use pattern of the island designates the human settlement in different geomorphological units. The Chang-ghars (mounted houses) of Mishings and other ethnic communities inhabiting flood-prone areas of the island correspond to the long-established human settlement with local disaster-resistant technology, organic lifestyle, and efficient material use.

3.8 Geological and Hydrogeological set up

Morphologically, the island is characterized by an elongated shape like a spindle trending nearly NE–SW and has plain topography with sufficient low relief. There are innumerable swamps and lowlands of different sizes and shapes, which habitually breaks the boredom of relief. A big number of tiny streams and a few large rivers flow across the Majuli. The island's average altitude is 85.9 m and the gradient is 1:5000 extending from east to west. Majuli houses of alluvium and active flood plain deposits of the recent Age having huge groundwater potential. The stratigraphy of the island is analogous to the stratigraphy of the Brahmaputra Valley on the southern bank of the Brahmaputra as it occupies both Older Alluvium and Newer Alluvium of Recent Age at places like Haldibari, Salmora, Ratnapur, Bongaon, Garmur, Kamalabari, Auniati, Goalgaon, Ahaguri to many others [12]. Alluvial fine loamy soils cover the island originated from recent river deposits.

Hydrogeological diversities characterize the island in various aquifer systems, groundwater contamination, swamp, landscape pattern, bio-diversity, and cultural diversities focusing on water perspectives. Emphasis to be given to sanitation and safe drinking water as almost the entire population drink and use raw groundwater without understanding their water quality problems and any filtration procedure. Brahmaputra River ranks fourth among the world's largest rivers with regard to mean annual discharge [13].
3.9 Riverbank erosion and its impact on cultural heritage in Majuli

The Majuli has been subjected to flood and riverbank erosion since the historical past. However, the intensity of the phenomenon has been increased over recent decades due to the great earthquakes of 1897 and 1950, which had changed the valley’s topography. The island adjacent to the Brahmaputra is one of the world’s greatest rivers, with violent currents. High rainfall is the accountable factor for the long-standing bank erosion difficulty. But the unpredictable rainfalls, as well as the devastating flood pattern over the last few years, have made the problem more intense. The island faced enormous erosion due to the 2017 floods, which were triggered by the influence of the Ranganadi Hydropower Project. The impact could have been minimized if there had been the timely prior transmission of information regarding the release of water from the upstream state of Arunachal Pradesh. The erosion problem is more acute after flood events in most places, the main cause being over-steepening of the bank materials due to the accumulation of high amounts of sediments during the flood [9]. The typical location of the island separates from the mainstream Assam state due to lack of road linkage and insufficient water transport, severe bank erosion issues, and regular floods, besides large segments of tribal illiteracy. On account of the lack of connectivity and frequent floods, the island faces trouble in administrative and developmental activities. The accelerated rate of shrinkage in the island's size has a severe impact on the socio-economic, demographic, and cultural dimensions of the population. The Assam Government (since 1967) has been periodically estimating the loss of life and property due to floods, damage to agricultural land due to deposition of sand, and depletion of the land area due to erosion, all these leading to the displacement of many families from their homes. Therefore, erosion and flood are not only environmental but also socio-economic issues for the Island.

The Majuli has been a principal place of pilgrimage for the last 400 years. But at present it is known for having suffered from two natural hazards - severe bank erosion (Figure.6) and flooding [17] [18] and [19]. The society, culture, and even economy of the island are large to be viewed in the circumstance of its being a land of Vaishnavite monasteries or Satras. The active flood plain zone occupied considerably high population concentration and has suffered from backline shifting and erosion resulting in the eroding of villages on the island. Brahmaputra River is characterized by the braided pattern when enters into the plains of Assam state for high sediment load, steeper gradient, and weak bank materials [20][21]. Sarma and Phukan (2004) say that the island has been reduced to 480 square kilometers in 2001 from the original land of 1246 square kilometers in 1950, which was reduced to 924 square kilometers in 1971 and further reduced to 875 square kilometers in 1997. The families affected by flood and land resources loss in the island are increasing to 9566 and 272615 Bighas respectively in the year range of 1969 to 2011.

![Figure 6. Bank erosion by the River Brahmaputra (Source: CGWB Report)](Source: CGWB Report)

Majuli was severely affected by erosion since the 1950 devastating earthquake, which brought about amazing natural and geographical changes to the island and the River Brahmaputra. The river
bed filled up due to silt and alluvium accumulation, resulting in severe erosion [22]. The island was severe earthquake has been reduced the size of the island from 1250 sq. km to 352 sq. km. in 2014 due to frequent floods and drastic soil erosion [23]. Presently the island is reported to be in the size of about 400 sq. km. The shrinking of the island area over the last 100 years has been shown in figure 7.

The study reveals that erosion is predominant in the southern boundary of Majuli. The rate of erosion is more in the south-western part of the island. The rate of bank erosion is observed to depend on bank stratigraphy and the presence of anabranching channels. The erosion is due more to undermining by water, where the thick sand layer exists beneath the topsoil. In places where cohesive silty-clay beds are present at the base of the banks, erosion is comparatively slower. The Subansiri River has been adding land to Majuli Island due to its channel's northward migration, thereby reducing the net effects of erosion on the island [24].

The Brahmaputra is an international river is draining the countries like China, India, and Bangladesh for 2880 km and drains a basin of 580,000 km². It has a large braided channel in Assam. The mean annual flow of the Brahmaputra at Bechamara in Majuli during the period of 1975–1990 was 8829.5 m³/s (WAPCOS, 1993). The average annual hanging sediment load of the Brahmaputra as measured at Pandu, 240 km downstream of Majuli island, is 402 million metric tons during the period 1955–1979 (Goswami, 1985). The Subansiri is the largest tributary of the Brahmaputra with a total length of 520 km and it drains a basin of 37000 km². The mean annual flow of the Subansiri during 1956–1982 was 1671 m³/s. The Subansiri carries on an average of 35.48 million tons of suspended sediment annually (WAPCOS, 1993). Majuli Island is situated at the mouth of the Subansiri and 850 km upstream of the Brahmaputra's mouth. The island is underlain by unconsolidated alluvial sediments of the Quaternary age, which can be differentiated into Older and Younger alluvium. The Older alluvium occupies the upland areas with sediments of oxidized and relatively compact nature, while the Younger alluvium occurs along the low-lying tracts of the area along with the river courses. The north side's sediments are derived from the young Himalayas, while the sediments on the south side originate from the older Assam plateau. The newer alluvium is generally confined to topographical lows following the stream courses.

In Majuli, the CGWB has not carried out any groundwater exploration due to the problems of approachability. The truck-mounted rig cannot be transported through the water route to Majuli Island. As such, the disposition of granular zones to the depth of about 300 m bgl has been confirmed based on exploratory well data of CGWB [25] constructed in the Jorhat subdivision under similar hydrogeological conditions. Based on groundwater occurrence and movement, the area's regional
groundwater condition has been grouped under two categories- a) a Shallow aquifer group occurring within the depth of 50 m. and b) Deeper aquifer beyond a depth of 50 m and down to 200 m below ground level (b.g.l).

The shallow aquifer occurring within a depth of 50 m from the land surface consists of a mixture of sand, clay, and silt. The thickness of the aquifer is about 20 m and groundwater occurs under unconfined condition. Open wells and shallow tube well groundwater are generally used for domestic as well as irrigation purposes. The water table is shallow and rests within 2-4 m below ground level during the pre-monsoon period. The flow of groundwater follows the general topography of the area and towards River Brahmaputra.

3.10 Hydrogeochemical Scenario

Shallow aquifers depict a high concentration of arsenic in groundwater (>10 ppb). CGWB has conducted a detailed study, Ministry of Jal Shakti, to understand the Spatio-temporal distribution of arsenic and its sporadic nature of the shallow aquifer system (fig.5). The source of arsenic in groundwater is geogenic in origin and the release of arsenic is the result of interaction in between arsenic bearing sediment and groundwater. The reported high concentration of arsenic in groundwater is a strong concern for the people of Majuli. This arsenic toxicity on the island has been confirmed by other prominent organizations like the North-Eastern Regional Institute of Water and Land Management (NERIWALM), based on their study and by a collaborative study in between Public Health Engineering Department (PHED) and UNICEF. However, no physical manifestation of ‘arsenicosis’ has been observed to date among the people residing in the island. Since no deep tube wells are available on the Island, it is difficult to determine the arsenic content in groundwater in the deeper aquifer system of the island. In every year during the pre-monsoon period, CGWB is collecting water samples from the groundwater abstraction structures like dug wells (Open wells), shallow tube wells/hand pumps within the depth range of 50 m bgl to understand the hydrochemical scenario of the Majuli with emphasis on arsenic content (Fig.5). There is no specific source of arsenic identified yet on the island. Arsenic fluxes in groundwater depend on redox processes (anaerobic and aerobic). Arsenite’s behavior (As III) and Arsenate (As V) vary significantly on redox conditions. An anaerobic aquatic environment relatively favors high Arsenic concentration in groundwater in the Island depending on the local geochemical controls. Depth wise variation in the concentration of arsenic in groundwater is depicted in the figure.8.

![Figure 8. Variation in concentration of arsenic with depth in Majuli (Source: CGWB)](source_url)
The aquifers within 50 to 200 m bgI consist of fine to medium-grained sand with clay intercalation. The exploration data revealed the presence of four to five major aquifer zones. Groundwater occurs under confined to semi-confined conditions in these aquifers. The unconfined aquifer consists of a mixture of sand, clay, and silt, wherein the thickness of the aquifer is about 20 m and groundwater occur under unconfined condition. Open wells and shallow tube well groundwater is generally used for domestic as well as irrigation purposes. The water table is shallow and rests within 2-4 m below ground level during the pre-monsoon period. The flow of groundwater follows the area's general topography and towards River Brahmaputra, whereas the confined aquifer consists of fine to medium-grained sand with clay intercalation. The exploration data revealed the presence of four to five major aquifer zones. Groundwater occurs under confined to semi-confined conditions in these aquifers.

3.11 Arsenic in Groundwater in Majuli

In the preliminary arsenic survey by CGWB could identify some hand tube wells having arsenic above 50 μg/L in certain villages of the Majuli block. The villages/G.P. include village- Aalimur gaon, G.P.- Dakhin Kamalabari, Village- Jogi gaon, G.P.-Bongaon, Villages- Potia gaon, Hokanamukh, G.P.- Rawanapar, Village- Meruwabari, Jokaibowa, G.P.- Pokajora, Villages- Samoguri, Cherpaikhua, Baghgaon, Maluwal miri, Bebejia, G.P.- Karatipar, Village- Barun Citdar Chuk, G.P.- Chilakola, Village- Borduar Chapor, G.P.- Sri Luhit, Village- Chayani miri, G.P.- Ahatguri. Out of these villages/G.P., the higher level of arsenic contamination (>50 μg/L) in the hand tube wells have been observed in the Balijan, Borduar Chapor, and Eri chapor villages. Hence, it is evident from the said study that high arsenic contamination (6 - 90 ppb) in groundwater is reported in the confined aquifer system in parts of the island, which is an alarming issue to be addressed with priority. As far as groundwater extraction is concerned, the long-term water table trend indicates that the island is coming under the safe category.

The concentration of arsenic has been found beyond the permissible limit (Permissible limit-10 ppb, WHO) at all locations except the locations of Kamalabari Ghat and Gutiamari. Prolonged consumption of arseniferous groundwater may result in a large-scale health hazard in the concerned region due to arsenicosis symptoms, skin lesions, hyperkeratosis, and melanosis as well as other types of carcinogenic manifestations. However physical manifestation of arsenic effect has not been reported in the Majuli. Arsenic may occur in groundwater because of mineral dissolution and industrial discharges containing Arsenic or by the application of Arsenic based pesticides used for agricultural purposes. In Assam, the arsenic contamination problem is mainly due to geological reasons. Groundwater may contain varying amounts of Arsenic compounds of As (III) or As (V). Therefore, not quantity, but groundwater quality issues are affecting the people residing in said villages/ Gram Panchayats (G.P.) of the island. Hence, it is mandatory to address the hydrogeological perspective with emphasis on mitigative measures of arsenic in shallow confined aquifer systems followed by sustainable management.

4. Conclusions

Majuli, the cradle of Vaishnavite monastery culture and Satra tradition, has been facing several threats like the erosion of riverbank and flood, etc. The existence of the island is in danger. Although many efforts have been made to tackle these issues, the problem of erosion is still looming large. Shri Sankaradeva established the first Sattra in 1522, and originally there were more than 65 Sattras in Majuli [26]. The number has now decreased to 22 which in operation. Satra's unique culture is its liturgical training, which includes dance, drama, music, and poetry. The performing art forms were specifically for the monks to be performed only within the premises of the Sattra, which are now staged and have become the sources of income for many monks. The island has great potential for tourism. Now the challenge is to develop tourism on a large scale without disturbing the cultural and hydrogeological heritage and life of the communities living on the island. The island's cultural and ethnic artifacts may be thoroughly documented, preserved, and displayed in the museums of the island. The various educational programs on the island's cultural and hydrogeological heritage may be
organized to actively raise awareness among the communities to actively preserve their heritage. It is also an urgent need to understand the ecological, hydrological functioning of the River Brahmaputra under the influence of development techniques and conserve the landforms and cultural heritage of the island due to continuous interactions between the communities and their environment.

For addressing the bank erosion issues and to delineate the area of erosional severity, an automated warning and recording system needs to be devised, so that Spatio-temporal gravity of the problematic area can be demarcated and necessary steps can be undertaken to mitigate massive erosion through the flood-affected area development and prediction system [27]. Over the last 100 years, the Majuli has been shrunk to one-third of its total area. Special care is needed to arrest the bank erosion caused by the river to save the *Satras*. The shifting of the inhabitants from one place to another in every year during floods adversely affects the cultural heritage and the hydrogeological scenario of the island. Hence, an earnest endeavor is needed to drain out flood water immediately after the disaster.

The plantation of indigenous flora and other species on the riverbank can be an effective way of arresting the riverbank erosion of Majuli Island [28, 29]. The protection of hydrogeological issues with an emphasis on the conjunctive use of surface water and groundwater resources would help maintain the sustainable availability of the island people's existing water wealth. Integrated Water Resource Management (IWRM) and sustainable maintenance and monitoring of cultural properties are the keys to safeguard the traditional cultural and hydrogeological heritage of the Majuli Island.

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