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A Comprehensive Study on River Bank Dynamics of the Brahmaputra River in Bangladesh

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ABSTRACT: The study investigates the dynamics of the Brahmaputra River in Bangladesh, a braided river characterized by constantly changing channels and shifting alluvial charlands. Using satellite imagery and geospatial analysis, the research reveals substantial landscape alterations over only two years (2020-2022). Charland areas decreased while river coverage expanded, emphasizing the river's dynamic nature. These transformations have socio-economic implications, affecting agriculture, fisheries, and local livelihoods. The findings underscore the significance of comprehending charland shifting in braided river systems and the necessity for comprehensive mitigation strategies addressing environmental sustainability and community well-being.

KEYWORDS: Brahmaputra River, Charland shifting, GIS analysis, Satellite imagery, Socio-economic implications, Environmental sustainability

I. INTRODUCTION

Rivers are the lifeblood of our planet, shaping landscapes, influencing ecosystems, and impacting the lives of people near their banks [1-2]. In some parts of the world, rivers take on unique characteristics, and one such example is the Brahmaputra River in Bangladesh [3]. This river exemplifies the dynamic nature of braided rivers, where multiple interconnected channels and islands create a complex and ever-changing landscape. The shifting of river channels, erosion, sediment deposition, and flooding are all integral components of the river's behavior [4]. These processes have far-reaching consequences, particularly for land use and land cover in the surrounding areas [5].

The braided nature of the Brahmaputra River, with its ever-changing network of channels and islands, serves as a testament to the dynamic character of specific river systems [6-7]. It challenges our understanding of stability and permanence in natural environments. The ongoing shifts in river channels, accompanied by erosion and sediment deposition, contribute to a constantly evolving landscape that poses opportunities and challenges for those who call its banks home [8-11].Of particular interest in our study is the role of alluvial charlands, which play a vital part in the complex web of interactions within the river ecosystem. These charlands are not just inert pieces of land but are intricately linked with the lives and livelihoods of the local population [12-15]. The study's core objective is to unravel the underlying causes of charland shifting, such as changes in river flow and sediment transport, and to examine the consequences of these shifts on the charlands and the communities dependent on them.

In this comprehensive study, we delve into the intricate dynamics of the Brahmaputra River, focusing on the shifting of alluvial charlands. Charlands are not just a critical part of the river ecosystem but also central to the livelihoods of the people living in the region. To gain a more profound and nuanced understanding of this phenomenon, we utilized a combination of satellite imagery, geospatial analysis tools, and field research to examine the spatial and temporal dynamics of the river and its impact on the charlands. This study aims to elucidate the causes and consequences of charland shifting and its implications for the local population.

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Objectives

The objectives of this study are:

i. To determine the Land Use and Land Cover (LULC) changes in the Brahmaputra River area.

ii. To demarcate the spatial and temporal extent of the Charland shifting area in the Brahmaputra River.

II. METHODOLOGY

The methodology employed in this study was a multi-faceted approach that combined geospatial analysis, satellite imagery, and field research to comprehensively understand the dynamics of the Brahmaputra River and its impact on the shifting charlands. This section details the various methods used to achieve the study's objectives.

1. Data Collection:

The primary data source for this study was satellite imagery obtained from reputable sources with a resolution suitable for capturing the intricate landscape dynamics. These images covered two key years, 2020 and 2022, allowing for a temporal assessment of land use and land cover changes.

2. Geospatial Analysis:

Random Forest in Python: Geospatial analysis began with implementing the Random Forest algorithm using Python programming. This tool was adapted to the geographic area of interest within the Google Earth Engine platform. Random Forest, a machine learning algorithm, was employed to classify and analyze the satellite imagery to determine Land Use and Land Cover (LULC) changes. It is a robust method for classification tasks and is particularly suitable for large-scale land cover assessments.

Change Detection Difference Map: To discern specific changes that occurred between 2020 and 2022, the "Change Detection Difference Map" tool in the ENVI platform was used. This technique allows for detailed visualization of alterations in the landscape and provides a clear representation of the differences in land cover and land use over two years.

3. Field Research:

Field research was conducted to validate and ground-truth the findings obtained from satellite imagery and geospatial analysis. This involved on-site visits to charland areas, riverbanks, and adjacent communities. Field researchers collected data on the extent of charland erosion, observed changes in the river course, and engaged with local communities to understand the socio-economic impact of charland shifting.

4. Data Analysis:

The geospatial and field research data were analyzed to identify trends and patterns in charland shifting. Specific focus was given to the temporal and spatial changes observed in the Charland areas along the Brahmaputra River.

5. Socio-Economic Assessment:

In addition to the scientific analysis of land cover changes, the study delved into the socio-economic implications of charland shifting. Data collected from field visits and interviews with local communities were used to assess the impact on agriculture, fishing, livelihoods, and community well-being.

6. Mitigation and Adaptation Strategies:

The study considered potential mitigation and adaptation strategies to address the challenges ofcharland shifting. This involved a review of existing literature and case studies and an assessment of the feasibility of various strategies. The strategies were designed to be holistic, considering environmental sustainability, local communities' well-being, and the river ecosystem's preservation.

III. RESULTS AND DISCUSSION

For determining the LULC change, the “Random Forest in Python” code is used and adapted for this particular area in the Google Earth Engine Platform (figure 1). A similar code is run for two years (2020 and 2022) to see the temporal changes. The results show that the Charland shifts yearly due to the Brahmaputra River's multi-channel flow and braided characteristics. Between these two years, the highest Charland accumulation area was measured as 110 sq km in 2020. The river-covered area was 244 sq km at that time. However, within two years (in 2022), the Char area reduced to 74 sq km, and the river area increased to 286 sq km. This means that in this two-year Charland eroded a lot (about 18sq km per year) and increased the river area (Figure 2). Finally, using the “Change Detection Difference Map” tool in the ENVI platform, changes between these two years have been determined and presented in Figure 3.

The reasons behind this dramatic shift are multifaceted and are closely linked to the Brahmaputra River's unique characteristics. The river exhibits braided features, characterized by multiple interconnected channels and islands,

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which contribute to the high degree of dynamism in the region. Seasonal variations, sediment transport, and shifting river courses all play a role in shaping the landscape.Furthermore, the presence of a braided river in Bangladesh holds significant cultural and ecological importance. The Brahmaputra River supports diverse ecosystems and sustains communities along its banks. The fertile charlands are not just vital for agriculture but are also habitats for various flora and fauna.

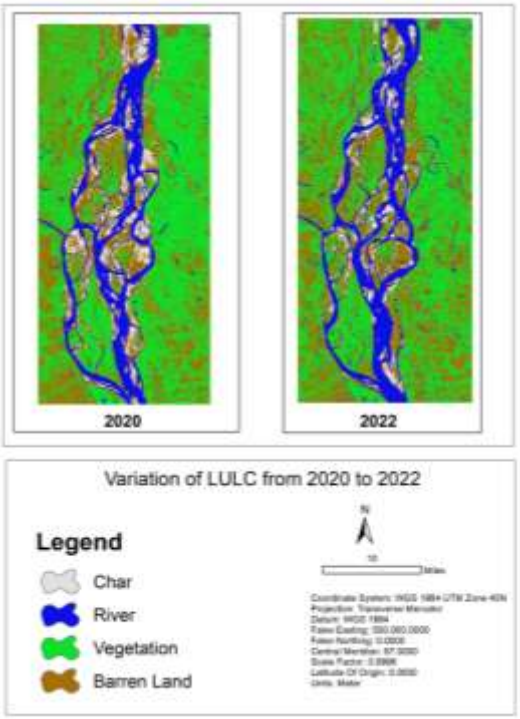

Figure 1: Variation of LULC from 2020 to 2022in the Brahmaputra River area.

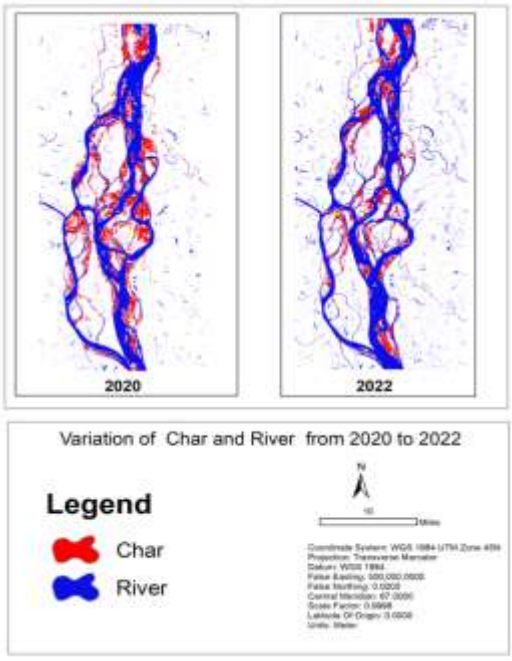

Figure 2: Variation of Char and River area from 2020 to 2022 in the Brahmaputra River area.

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Change Detection and Impact Assessment:

To further analyze and illustrate the specific changes between 2020 and 2022, the "Change Detection Difference Map" tool in the ENVI platform was employed (Figure 3). This tool allowed for a detailed visualization of the alterations in the landscape, providing a clear representation of the changes that occurred in the study area.

The change detection map revealed the intricate dance between the river and the charlands. While the river's expansion signifies erosion and land loss, it also underscores the dynamic nature of the region. This dynamism is both a challenge and an opportunity for the communities living along the riverbanks.

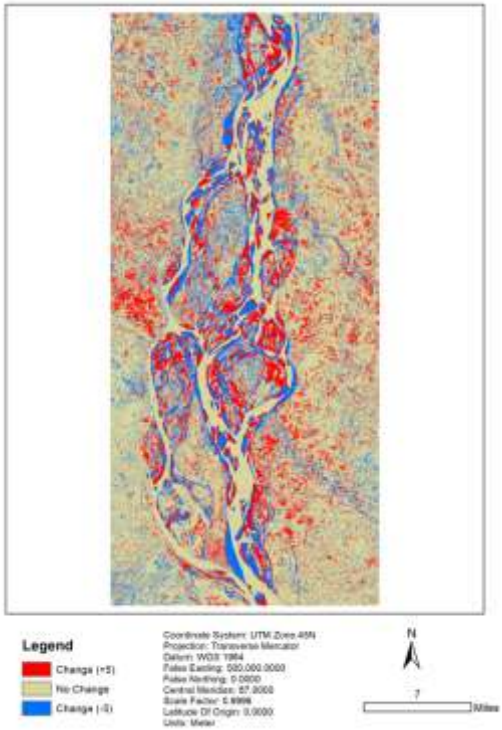

Figure 3: Change detection difference map in the Brahmaputra area.

Implications and Importance:

The findings of this study underscore the critical importance of understanding the phenomenon of charland shifting in braided rivers like the Brahmaputra in Bangladesh. The consequences of charland shifting are significant and have profound implications for the inhabitants of these regions. It can lead to the loss of life, changes in the landmass, population displacement, and a range of socio-economic challenges.Charlands play a vital role in settlement, agriculture, vegetation, and the livelihood development of the local population. As such, preserving and effectively managing these charlands is essential for the sustainable growth and well-being of the communities living along the banks of the Brahmaputra River.

The results of this study are particularly relevant for the development and implementation of land use policies, river management plans, and disaster preparedness strategies. The insights gained from this research can serve as a foundation for informed decision-making and addressing the complex challenges of dynamic river systems. Additionally, the study has the potential to benefit not only the people living along the banks of the Brahmaputra River but also those living near other similar braided river systems around the world.

The importance of this study extends beyond the immediate geographical area of the Brahmaputra River. It contributes to our broader understanding of river dynamics and their effects on the surrounding landscape and communities. It highlights the need for ongoing research and the development of proactive measures to manage and mitigate the challenges posed by braided rivers.

Socio-Economic Implications:

Beyond the scientific and environmental aspects, examining the socio-economic

implications of charland shifting is crucial. The local population in the Brahmaputra River region heavily relies on the charlands for their livelihoods. Agriculture is a dominant occupation, with crops like rice, jute, and vegetables being cultivated on these fertile lands. The changing landscape directly affects their agricultural practices and productivity.

In addition to agriculture, charlands also support fishing and livestock farming. The shifting river dynamics have implications for the availability of fish and the grazing lands for cattle. Moreover, many households are located on the charlands, and the erosion of land can lead to the displacement of entire communities.The consequences of charland shifting are far-reaching. Not only does it disrupt the economic activities of the local population, but it also poses a risk to their lives and properties. People are forced to adapt to these changes by rebuilding homes, relocating, or seeking alternative livelihoods

Ecosystem Consequences:

The river ecosystem itself is greatly impacted by the shifting dynamics. The fertile sediment carried by the Brahmaputra River contributes to the productivity of the charlands. As the river erodes these lands, it can release sediment and pollutants into the water, affecting water quality and aquatic life downstream. This has implications for fisheries and the overall health of the river ecosystem.

Furthermore, the changing landscape can influence the habitats for wildlife and bird species that inhabit the charlands. Conservation efforts are affected by the altered terrain, which can lead to changes in migration patterns and breeding grounds for various species.

Mitigation and Adaptation Strategies:

It is essential to develop mitigation and adaptation strategies to address the complex challenges posed by the shifting charlands. These strategies should be informed by the findings of this study and aim to safeguard the well-being and livelihoods of the local population and the ecological health of the region.One potential strategy is to reinforce the riverbanks and charland areas with appropriate engineering solutions. Dikes, embankments, and levees can be constructed to protect against erosion and reduce the risk of inundation. However, it's important to ensure that such interventions are environmentally sustainable and do not lead to unintended consequences, such as changes in sediment transport or adverse effects on downstream areas.

Another approach is to promote sustainable land use practices. Implementing crop rotation, agroforestry, and soil conservation techniques can help preserve the charland's fertility and minimize the impact of erosion on agriculture. Additionally, communities can diversify their livelihoods to reduce their dependence on charland-based agriculture and explore alternative income sources.

Disaster preparedness and early warning systems are crucial for mitigating the risks associated with river dynamics. Communities should have access to timely information on river conditions and be prepared to respond to changing circumstances, including evacuation plans in the event of severe flooding or rapid erosion.

Furthermore, robust policies and governance mechanisms are needed to regulate land use in the region. Zoning regulations can help prevent construction in high-risk areas, reducing the vulnerability of communities to charland shifting.

IV. CONCLUSION

The study delved into the dynamic intricacies of the Brahmaputra River in Bangladesh, a braided river exhibiting an ever-changing landscape due to its multiple channels and shifting alluvial charlands. Based on satellite imagery and geospatial tools, the analysis uncovered significant environmental modifications between 2020 and 2022. It is evident that charland areas experienced reduction while river expanses grew, further emphasizing the river's dynamic character.

These shifts extend beyond ecological concerns, having palpable socio-economic consequences by affecting local agriculture, fisheries, and livelihoods. As the landscape evolves, there is a growing need for comprehensive mitigation strategies that take into account environmental sustainability and community well-being. This research underscores the critical importance of understanding the phenomenon of charland shifting within the context of braided river systems, advocating for holistic solutions to address the multifaceted challenges at hand.

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