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Transformation of the Shinhati Badland (Ramsagar Area, Bishnupur): Observation-Based Assessment Through Satellite Data and Ground Verification

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Abstract

Shinhati is situated on the left bank of the Birai, a right-bank tributary of the Dwarkeshwar. Now, Shinhati is part of the Ramsagar Fishery Project, operated by the government of West Bengal. Ramsagar has identical climatic conditions and a very high range of fish production. The Shinhati Badland area, characterized by its rugged terrain and intense erosion processes, has undergone significant transformation due to anthropogenic factors that initiated and developed the fish production ponds. This study presents an observation-based assessment of these changes using multi-temporal satellite data complemented by extensive ground verification. High-resolution remote sensing imagery was analyzed to detect variations in landform dynamics, vegetation cover, and hydrological patterns over time. Digital elevation models (DEMs) and spectral indices were employed to quantify geomorphological shifts. Ground-truthing efforts validated the satellite-derived interpretations, ensuring accuracy in identifying landscape alterations. The findings indicate a significant change in landform morphology, characterized by the expansion of existing fishponds and the construction of new ones. This transformation is altering the shape of gully channels, which are areas where erosion and sporadic sediment deposition are actively occurring. Human activities have intensified geomorphic instability in certain regions. This study emphasizes the importance of ongoing monitoring in addressing environmental degradation in badland regions. The insights gained can help policymakers develop sustainable land management strategies that balance ecological conservation with developmental needs.

Keywords: Shinhati Badland, remote sensing, ground verification, geomorphology, erosion, landform transformation.

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1. Introduction

1.1 Background of the Shinhati Badland Formation, factors, and mechanisms

Badlands are intensely eroded landscapes that mainly develop in arid and semi-arid regions. They are characterized by features such as steep slopes, sparse vegetation, and complex gully networks. These landforms form due to the rapid erosion of sedimentary rocks. Typically, low vegetation cover leads to rugged, barren terrain (Goudie, 2004). Shinhati Badlands are situated in the lateritic region near the fringe of the lower Ganga basin. They result from intensive laterite erosion, seasonal rainfall, and sheet flow primarily during the monsoon. The lack of proper vegetation directly affects the soil surface, creating a complex gully network (Sarkar & Pal, 2018). The laterites deposited here were reworked through weathering and redeposited as secondary lateritic deposits during the mid-to-late Pleistocene (Ghosh & Majumdar, 1981). Major rivers, such as Dwarka, Ajoy, Mayurakshi, Damodar, Dwarkeshwar, Shilabati, and Kangashabati, flow through the Rarh region of West Bengal. Shinhati, in the Bankura district, features extensive lateritic Badlands. It is located 4 km northwest of Bishnupur and lies on the left bank of the river Birai, a tributary of the Dwarkeshwar River. A localized badland has developed from the lateritic sediments of the river Birai (Aown & Kar, 2016). In recent times, the Badlands have undergone significant transformation, with numerous fish hatcheries being established to prevent the expansion of gully channels. The laterites primarily deposited here were reworked through weathering and redeposited as secondary lateritic deposits during the mid-to-late Pleistocene (Ghosh & Majumdar, 1981). The Birai River flows near the Shinhati badlands. Its main river and tributaries are the primary sources of fish spawns and eggs supplied to other states such as Jharkhand, Bihar, Odisha, and Uttar Pradesh. The vegetation cover in the badlands has increased significantly over the past 5 to 10 years due to plantation efforts. These methods include contour trenching, planting native drought-resistant species, and using fast-growing grasses to stabilize the soil, which has also improved soil health and enhanced the area's biodiversity.

1.2 Significance of the study

The transformation of Shinhati Badland in the Ramsagar area, Bankura District, is of significant importance for academic, environmental, and socio-economic purposes. Badlands are considered a wasteland due to their rugged topography, fertile soil, and minimal vegetation. However, the transformation of Badlands can be monitored and assessed to uncover vital insights, including environmental, technological, socio-economic, and developmental significance. However, the transformation can try to stabilize the rugged landscape by reducing further land degradation. This study helps to track the changes in vegetation cover over time due to the plantation and development of the watershed. Through ground verification, it ensures that the vegetation recovery and soil quality improvement are possible. Due to the transformation initiatives, the event led to improvements in the rural livelihoods of the surrounding villages. Previously, the area was considered economically unproductive; however, it has now transformed into a representative site that adds significant academic value for researchers. Based on these insights, this case study is selected for its fluvial and erosional processes of the lateritic zone. This study is more significant due to the application of modern technology and traditional field techniques for the transformation of land and biodiversity.

1.3 Literature survey

Badlands are one type of sensitive region that is shaped by intensive erosion, steep formations of gullies, rugged terrain, and sparse vegetation. Numerous studies have been conducted on the vulnerability of specific terrains where both natural processes and anthropogenic interventions are at play (Gallart et al., 2022). The Shinhati Badlands are situated within the Rarh plain of West Bengal, a type of plateau fringe zone, and the western tributaries of the Bhagirathi-Hugli River fan, comprising old alluvium (Bandyopadhyay et al., 2014; Aown & Kar, 2016). Some research has been conducted using remote sensing and GIS, which are reliable techniques that can monitor spatiotemporal landscape dynamics in this region (Agarwal et al., 2002; Sharma & Mahapatra, 2021). Bankura is located in a semi-arid zone, where the Badlands transformation has been influenced by the application of land-use change methods and the implementation of fishery development projects (Singh & Singh, 2017). Some local studies mainly focused on the direct geomorphological impacts of the expansion of fishponds in this Badlands area. Near Ramsagar, Shinhati Badland is a unique case study area where the government is directly involved, having led numerous fishery projects aimed at altering the physical environment and landscape. According to Kirkby et al in 1990, there is a gap in empirical, ground verification research that assesses recent transformations with the use of multi-temporal satellite imagery, DEMs, and spectral indices.

1.4 Formulation of research question

In the Badlands regions, concerns regarding environmental sensitivity and observable evidence of transformation due to anthropogenic interference in the Shinhati area of Bankura have led to the formulation of specific research inquiries: a) In what manner does anthropogenic activity in the Badlands area affect this erosion-prone zone? b) How have the spatial and temporal patterns within the Badlands region undergone geomorphological changes? c) What methods can be employed to modify the gully structure? This study delineates precise and targeted research questions that are essential for guiding any scholarly investigation. Based on these questions, the research aims to elucidate the relationship between developmental activities and the fragile ecosystem of the Badlands, evaluate the effectiveness of Remote Sensing and GIS techniques in environmental monitoring, and propose land degradation management strategies to policymakers and planners to support sustainable economic development.

1.5 Objectives of the Study

First, systematically identify and analyse the human-induced changes that affect the natural geomorphological process of Shinhati Badlands. Nowadays, a massive amount of intervention, mainly in the form of fish hatchery construction and land use modification under the Ramsagar Fishery project, has directly transformed the fragile landscape of Shinhati. This rugged and erosional topography has been altered by anthropogenic interference, including the construction of artificial check dams, the levelling of natural gully channels, and the redirection of water channels. Through the application of satellite imagery and ground verification, the study focuses on measuring the spatial extent and transformation to understand the impact of human activity on the landscape of the Badlands. Second, thoroughly emphasized the temporal dimension of the changes of the Badlands landscape. Here, we utilize multi-temporal satellite data to investigate changes in landform dynamics over time, the rate of vegetation cover increase or decrease, and the modification of the hydrological network due to the construction of fishponds and check dams. Thirdly, a scientific framework was developed to investigate the modification of gully structure and the expansion rate of fishponds using geospatial techniques. The ultimate goal of this study is to establish a framework for environmental planning that incorporates erosion control and sustainable land use policies.

1.6 Limitations of the Study

Several constraints have been noted regarding the study. Researching the Shinhati Badlands is challenging for multiple reasons. Various human activities have transformed the landscape of the Badlands. There are several limitations throughout the Badlands area. It requires multi-temporal satellite imagery to interpret the historical data; however, only data from specific years are available. High-resolution satellite imagery can identify fine-scale geographical changes in the landform, such as the advancement of minor gully heads, sediment deposition within channels, and shifts in vegetation. However, not all of these may be accurately captured from the satellite imagery, which affects the landform classification and erosion analysis. This study mainly focused on the Shinhati Badlands within the Ramsagar area. In the case of in-depth interpretation, there is a limitation to generalizing the environment of the Badlands in the Bankura District. This study aims to examine human activities through the transformation of the terrain and reducing the effects of rainfall erosion and mass wasting. However, it is not very easy to prevent this all-natural process. Geomorphic transformation is the central focus of this paper, where socio-economic conditions are deeply intertwined, including the local livelihoods of the fisheries, ownership and rights to land, and community perceptions of environmental degradation.

2. Study Area

The Shinhati badlands are located 4 km northwest of the Bishnupur town in the Bankura district of West Bengal. The extension of this badland region is 23°05'16" N to 23°05'34" N and 87°16'06" E to 87°16'24" E (Fig. 01). It is located beside the left bank of the river Birai. This region of poor land is part of the Rarh plateau fringe plain, situated at the transition zone between the Chhotanagpur plateau and the Bengal basin (Sen et al., 2004). These types of landforms were originated over the unconsolidated secondary deposits in the Pleistocene and reworked later as weathering and became the low-level lateritic Badlands (Oldham, 1939; Niyogi et al., 1968; Chakraborty, 1970; Bandyopadhyay 1987, 1988; Mukhopadhyay, 1992; Das and Bandyopadhyay 1995, 1996; Sen et al., 2004; Dey et al., 2009; Aown et al., 2016). The overall area of this Badland is composed of ancient lateritic crust, where the fluvial erosion process is very active and the vegetation cover is very low. The red loamy soil cracks up due to hot and dry weather during summer.

The highest temperature in this region during summer reaches up to 40°C-45 °C. However, the temperature ranges between 8°C and 34°C for the rest of the year (Fig. 8a), and the annual rainfall range in this region varies between 1300 mm and 1400 mm, with 75% of precipitation occurring in June and September (Ghosh, 2015). These seasonal rainfalls increase the rate of surface runoff during the monsoon, which is a primary factor in the formation of gullies in this farmland. Various types of soil erosion occur, including rain splash, non-concentrated flow (such as sheet flow or surface runoff), concentrated flow (like rill erosion), and gully formation. As a result, the region experiences intense physical weathering during the summer and intense chemical weathering during the monsoon, due to the disintegration of rocks and soil. Specific geomorphological characteristics, including deep gully channels, steep slopes, lateritic duricrust, and undulating terrain, identify the badlands. However, the terrain has been smoother in recent years than in previous times, mainly due to human interventions. Shinhati Badland is situated on the left bank of the Birai River, and this river plays a significant role in sediment transportation, deposition, and gully formation, providing a perfect example of dynamic landform changes.

The livelihoods of the local communities in this region depend on their agricultural activities. Mainly rainfed paddy, pulses, and vegetation are cultivated in the surrounding areas of the badland. Most individuals have been engaged in pisciculture in the region in recent years. Women are also participating in these activities. In 2006, with the collaboration of the MGNREGA scheme and the West Bengal Department of Fisheries, the Ramsagar Fishery Project was initiated, and the excavation of ponds began under the RSVY scheme. Ponds were dug in the significant deep gullies, reducing the expansion of the gully channels. The people in this region have become more economically stable than before due to the development of fish cultivation activities. Over the past few years, afforestation and plantation programs have been implemented in this arid area, which can help prevent gully expansion. Additionally, programs were helpful in the growth of vegetation cover and restoring the ecological balance. The West Bengal Forest Department and local authorities have initiated social forestry efforts to enhance the ecological status of the badland area.

Figure 01. Shinhati badland (23°05’16’’N to 23°05’34’’N and 87°16’6’’ E to 87° 16’24’’E) is located on the concave left bank of the river Birai, a tributary of the Dwarkeshwar River. It falls under the Ramsagar Gram Panchayat of Shinhati village, located in the northwest part of Bishnupur Town, Bankura district, West Bengal, India.

3. Methodology

To understand the geomorphological characteristics and land transformation of the Shinhati badland area, multiple data sources are used. For multi-temporal analysis of this area, utilize high-resolution satellite images from various platforms, such as Landsat and Google Earth. These datasets provide a significant analysis of the changes in land cover and the decrease in gully expansion over time in this region. A field survey has been conducted to verify the satellite imagery, collect ground truth evidence, and cross-check the transformation of landform characteristics through GPS tracking, visual observation, and photographic documentation. Mapping was conducted using geospatial tools. The satellite image is processed by following radiometric and geometric corrections to get an accurate and high-quality image. Band rationing techniques were employed through time-series analysis of multispectral satellite data, utilizing methods such as NDVI and NDWI analysis to detect changes in land cover (Fig. 8a, b, c). Badland mapping and transformation were manually digitized from high-resolution images (Google Earth Pro) for gully and badland features (Fig. 02). A spatiotemporal framework was established using selective satellite images from different years to understand the transformation pattern of this badland area.

4. Results and Discussion

4.1 Morphological Changes in the Shinhati Badland

Over the past two decades, notable morphological changes have been observed in the Shinhati Badland, located near the Ramsagar area of Bankura District. This land transformation has occurred due to fluvial erosional activity, slope instability, and anthropogenic influences. The laterite soil surface became exposed due to excessive deforestation and physical processes that created a highly gully-erosion-prone zone. These are the primary factors contributing to the formation of dissected and rugged terrain (Sen et al., 2004). Multi-temporal satellite images and ground truth verification are used to understand the expansion of gully numbers and depth. These rills or gullies not only provide an example of the active denudation process but also offer insight into the intensive classification of fluvial processes, especially during the monsoon season when the rate of surface runoff is very high (Bandyopadhyay & Ghosh, 2019). The landscape of this badland region has expanded due to the headward erosion of gullies between 2003 and 2023, creating an undulating, rugged terrain that surrounds the badlands. The high-resolution satellite image and ground truth verification provide information about morphological changes, which assures the accuracy of slope steepness and rapid displacement (Fig. 04). Unsustainable livelihood practices, such as deforestation and unregulated fish farming, increase runoff and soil erosion in this land. This dynamic transformation is the primary factor in badland formation, where natural processes are accelerated by human activity.

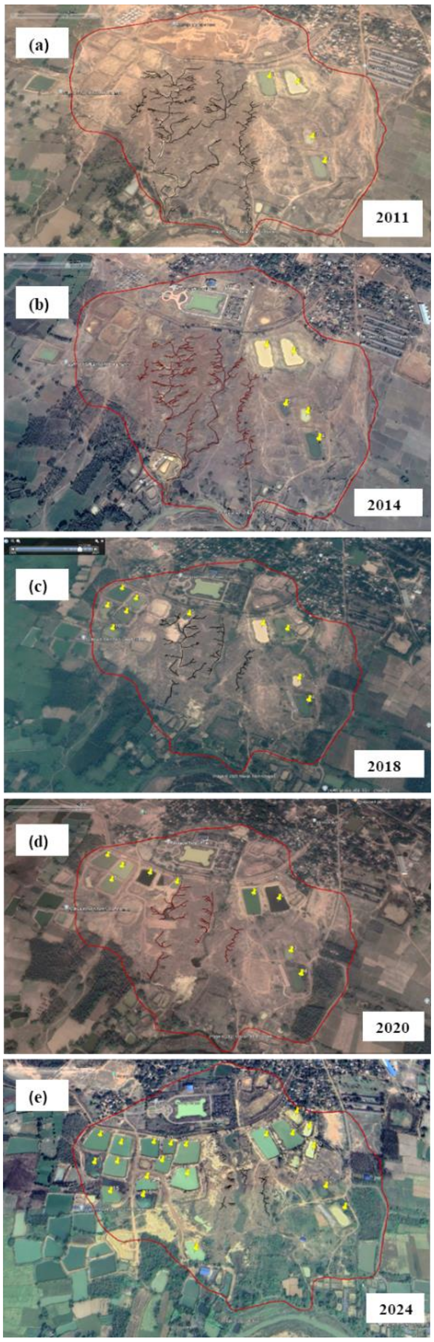

Figure 02. Shinhati Badland landscape from 2011 to 2014. Chronological maps have been collected from the Google Earth historical maps section to represent the transformation in the badland and surrounding area over time

4.2 Mechanism of transformation

Near the Ramsagar area, the transformation of the Shinhati badland is driven by human interference through initiatives involving aquaculture practices, in collaboration with the West Bengal Department of Fisheries and the MGNREGA scheme under the Ramsagar Fishery Project. From the satellite imagery, the terrain modification is evident due to the construction and expansion of fish hatcheries (Fig. 03). This anthropogenic intervention plays a significant role in reshaping the land's geomorphological features. In the primary stage, badland excavating and leveling were performed to accommodate fishponds, resulting in a total alteration of the gully system. Previously, the gully channels were identified due to the concentration of overflow and sediment transport through the fluvial activity of the Birai River. However, in the present day, this structure has undergone significant changes, and the capacity for erosion has decreased due to the redirection of water flow. This micro-terrain landscape illustrates the concept of artificial land surface smoothing. Plantation has been done to prevent the expansion of gully channels. Ground truth verification confirmed that the badland area is changed, and many fishponds have developed, which exhibited high sediment deposition in the downstream area (Fig. 02). Additionally, the head part of gullies is bounded with constructed ponds, check dams, which give a perfect example of slope destabilization (Fig. 07).

Figure 03. This photo shows newly built fishery ponds in Shinhati Badland, part of the Ramsagar Fishery Project. The human-made changes in the landscape are a sign of a significant transformation from a barren area to a productive aquaculture zone. Government efforts to alter the gully channels, slow down surface runoff, and stabilize the landscape have driven this change. The photo highlights the water storage, which helps reduce erosion. While this construction has a positive impact on land reclamation and economic stability, it also creates environmental stress as an adverse side effect.

4.3 Land Cover and Land Use Dynamics

Various satellite images have been observed, and through field visits, it is understood that the region of Shinhati badland, as well as its land cover and land use patterns, have changed. According to the 2011 Google Earth data, only four fishponds and a significant number of gully channels were present. After 3 years, in the 2014 Google Earth image, the number of fishponds had increased by only one. Again, in 2018, the number of fishponds increased significantly, as 10 fisheries were seen in that image. Additionally, it has been observed that the number of gully channels has decreased, while in some areas, there has been an increase in plantation. Nevertheless, in 2020, the picture is reversed. The number of fishponds was reduced, and only eight fishponds were observed that year; additionally, the number of plantations decreased. The gully channels were reduced in 2020. On the other hand, by 2024, the number of fishponds had increased significantly after four years. Nearly 17 ponds were seen, and the gully channels were reduced verily (Fig. 02). The vegetation cover also increased in that region, mainly in the southern part. From the images, it is also evident that the river Birai has shifted. In 2014, the gully channels merged with the river, but the gullies retreated and were reduced by time. Thus, the river Birai also shifts to the right.

Figure 04. The Shinhati Badlands exemplify the quintessential badland topography, characterized by steep gullies and deep vertical rills. These geomorphological features are the result of intensive soil erosion in an area susceptible to lateritic soil development. The photograph shows the exposed soil surface resulting from fluvial activity. The lack of vegetation and the presence of dry, red, loamy soil on the slope highlight the geomorphic instability of this degraded land. Such landscapes are limited in terms of agricultural productivity and are associated with significant sediment loss. This image depicts the pre-transformation condition of the Badlands area prior to human interventions, such as the construction of fishponds and plantations, which aim to mitigate erosional processes near the Ramsagar region.

Figure 05. This photograph explicitly demonstrates geomorphological instability, predominantly in regions susceptible to erosion. It depicts exposed soil strata exhibiting signs of undercutting and surface fissures, all of which are indicative of highly active subsurface erosion. The exposed surface provides evidence of frequent surface runoff and rill formation, which facilitate sediment transportation and landform dissection. Ground verification confirms that this area requires land stabilization due to the high levels of natural erosion activity. In contrast, the surrounding regions have undergone transformation programs through the construction of fish hatcheries.

4.4 Human modification: Causes of Transformation

The Shinhati badland transforms in such a way that improves the economic status of the local people. Many reasons are behind this transformation. Both natural and anthropogenic activities contribute to this, but human activities have had a significant impact on this change. The Ramsagar Fishery Project collaborates with the West Bengal Department of Fisheries and the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) scheme to promote scientific aquaculture practices in erosion-prone areas, transforming barren terrain into productive fishponds. It was initiated to increase fish yield and improve the economic status of the local people in the Onda block of Bankura district. Under the Rashtriya Sam Vikas Yojana (RSVY) scheme, ponds were excavated on the gully channels, and about 81 hectares of pond area were excavated. Initially, the number of ponds was fewer (610-612 hectares) (Fisheries of Bankura), but it has increased in recent times. Over time, many modifications have been made throughout this project. Many new ponds were excavated, and modifications to fishery training were implemented (Fig. 02). Numerous business people have invested in this area, resulting in improved livelihoods for local people. Plantation and afforestation activities have been undertaken in recent years with the assistance of the local administration and the West Bengal Forest Department. The West Bengal Forest Department has also started social forestry. As a result, the vegetation cover of these regions has increased. Initiatives were taken to establish and expand fishponds under the Ramsagar Fishery Project. The ponds were created in deep gully channels, thereby reducing soil erosion in the gullies. To reduce the rate of surface runoff, the expansion of gully channels involves constructing check dams, embankments, and irrigation canals, which alter the flow and sediment transport in that region.

Figure 06. This photograph depicts the transitional geomorphic features, specifically a low marshy depression formed through natural processes and human interventions. The presence of stagnant water in the shallow basin, surrounded by dense, moisture-tolerant vegetation, indicates poor drainage of the micro basin due to sediment deposition and the convergence of surface runoff. These characteristics are crucial in understanding the hydrological dynamics of the area. This temporary water retention zone functions as a depression, promoting soil moisture accumulation. In the surrounding landscape, patches of vegetation and trees suggest partial ecological regeneration, influenced by low erosional activity during early interventions. From a geomorphological perspective, this marshy vegetation zone illustrates the interaction between erosional and depositional activities, as well as the formation of varied micro landforms within this rugged terrain.

4.5 Feedback Mechanism of Birai Subsystem

Shinhati Badland is situated on the left bank of the Birai River, a tributary of the Dwarkeshwar River. Positive feedback indicates that afforestation and soil conservation activities have been implemented in the southern parts of the region's badlands. Thus, the soil stability is improved. Additionally, constructing check dams and embankments in slope regions reduces surface runoff, which helps control the high rate of sheet flow in the badlands. On the other side, the sediment trap of fishponds naturally moved through the gully and fell into the Birai basin. For this reason, the lower part of gullies became more erosive due to a deficiency of sediment-water, which can cause headward gully retreat and bank collapse. The construction of fishponds and check dams is the primary driver of morphological changes in this river subsystem. The feedback mechanism of this river also transformed from natural to human-modified, resulting in a hybrid subsystem of Birai that monitors its. Erosion deposition dynamics

Figure 07. The photograph depicts a semi-constructed pond excavated for fish cultivation within the Shinhati Badland. It exemplifies human-induced geomorphic modification, where predominantly eroded landscapes have been reshaped for fish hatcheries under the Ramsagar Fishery Project. This pond demonstrates partial water retention along the embankments. It is primarily influenced by fluvial erosion, which has expanded the gully channels. The sparse vegetation surrounding the area indicates pathways of surface runoff that may contribute to sediment redistribution into the pond basin during the monsoon season. This image illustrates the dual impact of development activities and the emergence of geomorphological challenges, such as riverbank erosion, sedimentation, and slope instability, within the broader Badlands region.

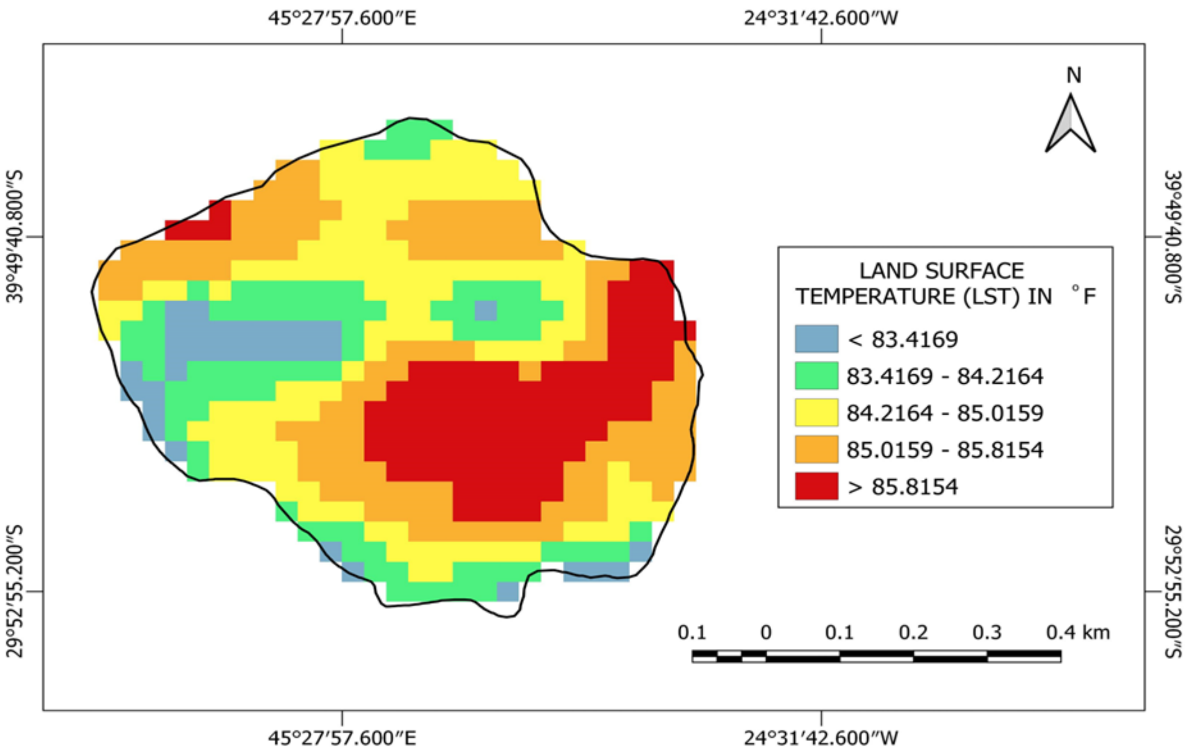

Figure 8(a) This map illustrates the distribution of Land Surface Temperature (LST) in degrees Fahrenheit (°F) across a designated area. It depicts the spatial variation in surface temperature within a specified boundary (a particular region or land parcel). Colour Classification (Legend): The LST is categorized into five temperature intervals: Blue: < 83.4169°F (coolest zones), Green: 83.4169 – 84.2164°F, Yellow: 84.2164 – 85.0159°F, Orange: 85.0159 – 85.8154°F, Red: > 85.8154°F (hottest zones). Key observations from these maps indicate that the central and eastern regions exhibit the highest land surface temperatures (marked in red). Conversely, cooler zones (blue and green) are predominantly situated in the southwestern and western areas. The LST tends to increase toward the center and northeast.

4.6 Impact of Badland Transformation on Soil Erosion, Vegetation, and Water Resources

The transformation of the badlands has a significant impact on soil erosion, vegetation cover, and water resources. The embankment of gullies was created to provide fish breeding grounds. Many fish and fish spawns bred here are supplied to different districts. Thus, this place is a famous fish breeding ground in the Bankura District. The management strategies were adopted gracefully to reduce soil erosion. Fish hatchery ponds were built on the embankment of gullies. During the monsoon season, overland flow and surface runoff are stored here (Fig. 03). These ponds also act as sediment trapping zones (Fig. 07). The fish breeders leave the silted ponds and build new ponds at the end of newly formed gullies in order to manage the gully erosion. As part of a management plan, a fish farm was established in the southern section of the region, near the Birai River, to mitigate soil erosion and prevent soil loss. Small check dams and bunds are constructed on the gully channels to concentrate the rills and gullies. These management activities have reduced soil erosion over the past years. For afforestation, plantation activities were undertaken to increase the vegetation cover in that region. In the southern portion of the badlands, vegetation has increased due to these activities (Fig. 6). During the monsoon season, rainwater is collected, which also aids in pisciculture in this drought-prone area.

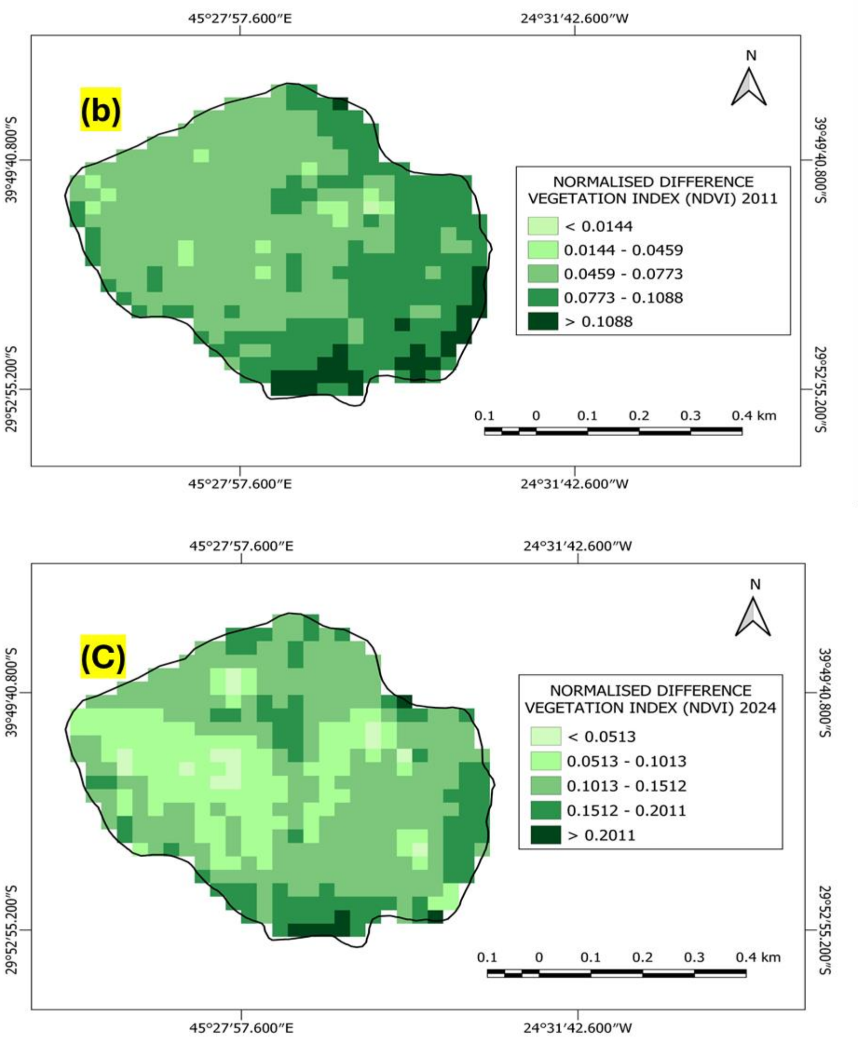

Figure 08 (b), (c) The two maps depict the Normalized Difference Vegetation Index (NDVI) for the Shinhati Badland area in 2011 (Map B) and 2024 (Map C), illustrating the temporal evolution of vegetation cover. NDVI is a widely recognized remote sensing index employed to quantify and monitor plant growth, vegetation coverage, and biomass production. Its values range from -1 to +1, where values close to 0 or below signify bare soil or non-vegetated regions, and values approaching +1 denote dense green vegetation. In Map (b), representing NDVI for 2011, the values vary from less than 0.0144 to greater than 0.1088, with the colour spectrum transitioning from very light green (indicating low NDVI) to dark green (indicating higher NDVI). The majority of the area falls within mid-range classes (0.0459–0.1088), indicative of moderate vegetation coverage. Conversely, map (c) for 2024 shows NDVI values ranging from less than 0.0513 to greater than 0.2011, reflecting a broader and higher range compared to 2011. The predominance of darker green shades suggests an enhancement in vegetation height observation over the intervening years. A higher number of grid cells fall within higher NDVI ranges (>0.1512), indicating improved or regenerated vegetation. Several changes have been made, with average NDVI values increasing from 2011 to 2024. A larger proportion of areas are classified within higher NDVI categories in 2024, signifying improved vegetation density or health. The probable causes include afforestation, conservation initiatives, natural regeneration, or diminished human interference. The maps show a positive change in vegetation over time, from 2011 to 2024, with significant increases in NDVI values, indicating improved ecological health or successful vegetation management within the region.

5. Implications and Challenges

The Fishery Project led the transformation of the Badlands, which also benefited the environment and ecology of this area. The construction of the fishponds disrupted the native geomorphological balances by altering the gully channels and redirecting natural flows. This anthropogenic interference increases erosion in some untreated zones where the vegetation cover has been removed (Fig.8 b,c) due to the construction of fishponds. This deforestation activity is also a contributing factor to biodiversity loss. The ecological balance has also disrupted due to fish feed, fertilizers, antibiotics which also threaten for soil and water quality (Fig. 06). From the socio-economic point of view the changes of badland into productive fish hatcheries under the government project has provide economic opportunities to the local communities which benefited in their employment and livelihood diversification. Previously, some local communities that relied solely on agricultural labour have now found a new income source in pond construction, fish feeding, cultivation, and maintenance. This activity raises their income levels and helps to improve food security in the surrounding villages. The badlands of Shinhati have been transformed suitably. However, there are some challenges in monitoring and managing the degradation of the badlands, including the rapid excavation of fishponds and plantation activities. Additionally, these changes in land use patterns affect the communal grazing area, agricultural land, and access to natural resources. The shift to a water-based economy was introduced alongside increased vulnerability to climate variability. Due to decreased rainfall rates, water scarcity is affecting fishery production, which in turn impacts the environment and the sustainability of local livelihoods.

6. Conclusion and Recommendations

Through the study, it is observed that the Shinhati badlands were once rugged and barren. However, under the Ramsagar Project, the formation of fish hatchery ponds and the development of this region have been done positively. The economic status of the local people has improved. The increase in vegetation cover through plantation and social forestry initiatives by the local administration and the West Bengal Forest Department has a positive impact on the region's ecology and environment. The soil erosion by gully channels has been reduced by making check dams and embankments, and the sheet flow or surface runoff has also been reduced to a lesser number than before. Overall, it is observed that the transformation has a positive impact on the badlands. Although the management works effectively, other policies should also contribute to the sustainable management of the badlands. One is mulching, plantation, and grass cover, which would have been perfect for resisting soil loss in this region. The excavation of new ponds is complete, but fish breeders leave the old ponds as siltation occurs in these ponds, which affects and reduces fish yields. Their agriculture would benefit from the siltation process. The sand mining on the bank of the Birai River needs to be reduced to decrease the rate of riverbank collapse. Planting native vegetation rather than introducing exotic plants would be better. The fish hatchery ponds and afforestation will increase in numbers in the badland in future years. Additionally, land cover and land use patterns will change in response to socio-economic patterns. Thus, further research would be beneficial for this arid region of Shinhati.

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