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Assessing wetland depth loss and perenniality decline due to siltation: A case study of Kasodhora Beel, Burhachapori Wildlife Sanctuary, Assam

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Abstract
Wetland ecosystems of the Brahmaputra floodplain are undergoing rapid geomorphological and hydrological transformations, primarily driven by accelerated siltation. This study investigates a decade-long change (2013–2023) in the depth and water-retention characteristics of Kasodhora Beel, located within the Burhachapori Wildlife Sanctuary (BWLS), Assam. Using field-based bathymetric surveys conducted during the dry-season months of February and March, combined with geospatial analysis, the study evaluates alterations in wetland extent, depth profiles, and functional perenniality. Results reveal substantial infilling of the beel, leading to a marked reduction in maximum depth from an estimated 7.0–7.5 m in 2013 to around 4.0 m by 2023. The area sustaining depths above the critical 4.5 m threshold required for perennial water presence has diminished to negligible levels. Consequently, the wetland now dries up completely by late March, indicating functional loss of perennial characteristics. These findings align with earlier studies from the Brahmaputra floodplain, which highlight increased sediment loads, channel instability, and wetland shrinkage as key ecological concerns (Boruah & Goswami, 2014; Das *et al*., 2021). The study underscores the need for hydrological restoration, catchment management, and sediment-control interventions for safeguarding wetland functionality within protected areas of Assam.

Keywords: Wetland siltation, Brahmaputra floodplain, bathymetry, hydrological degradation, Burhachapori Wildlife Sanctuary

Introduction

Floodplain wetlands of the Brahmaputra Valley constitute some of the most ecologically significant habitats in north-eastern India, supporting rich biodiversity, critical hydrological functions, and socio-ecological stability (Goswami *et al*., 2018) [3]. These wetlands serve as nutrient sinks, groundwater recharge zones, and breeding areas for resident and migratory waterbirds. However, the geomorphic dynamism of the Brahmaputra River, coupled with anthropogenic pressures, has accelerated wetland degradation across the valley (Sarma, 2005; Mahanta *et al*., 2014) [4, 5]. One of the most prominent drivers of this degradation is siltation, resulting from intense monsoon-driven sediment transport and channel instability. High sediment flux, bankline migration, and aggradation have collectively contributed to the shrinking, shallowing, and functional decline of floodplain wetlands (Thakur & Borah, 2020) [6].

Burhachapori Wildlife Sanctuary (BWLS), forming part of the larger Kaziranga–Orang–Laokhowa–Burhachapori conservation landscape, is highly vulnerable to these geomorphological processes. Seasonal flooding introduces vast quantities of suspended sediment into the sanctuary's wetlands, often leading to deposition in shallow depressions such as beels. Over time, this results in infilling, loss of open-water area, rapid vegetative encroachment, and impaired hydrological connectivity (Boruah & Goswami, 2014) [1]. Such alterations have profound implications for wildlife, particularly water-dependent species, which rely on perennial wetland systems for breeding, foraging, and refuge during dry months.

Kasodhora Beel, one of the important wetlands of BWLS, has undergone notable morphological transformations over the past two decades. Earlier assessments in the region have indicated progressive shallowing and fragmentation of several wetlands due to sedimentation and reduced water-holding capacity (Ojah *et al*., 2022) [7]. However, detailed decadal analyses focusing on specific wetlands within BWLS remain limited. Understanding temporal variations in bathymetry and area extent is essential for designing informed management and restoration strategies.

This study addresses this gap by examining depth variation, surface area change, and perenniality loss in Kasodhora Beel between 2013 and 2023, using field-based bathymetric data and spatial analysis. The temporal window captures a crucial phase during which the Brahmaputra's sediment flux increased significantly, coinciding with reports of enhanced erosion, sand deposition, and river dynamism (Das *et al*., 2021) [2]. The study evaluates whether these broader riverine changes have translated into measurable wetland degradation within BWLS.

The findings have important implications for conservation management, as the loss of perennial wetlands directly affects fish populations, herpetofauna, waterbirds, and overall ecological resilience. Additionally, the study contributes to broader scientific discussions on sediment-driven wetland decline in monsoonal river basins, helping position Kasodhora Beel within global frameworks of wetland vulnerability and climate-linked hydrological stress.

Study Area

Kasodhora Beel is situated within the Burhachapori Wildlife Sanctuary (BWLS), located along the southern bank of the Brahmaputra River in Sonitpur and Nagaon districts of Assam. BWLS forms part of the Kaziranga–Orang–Laokhowa–Burhachapori landscape, a mosaic of riverine grasslands, floodplain wetlands, sandbars, and riparian forest patches that collectively support high biodiversity. The sanctuary experiences a humid subtropical climate, characterised by heavy monsoonal rainfall and extensive annual flooding, which shape its geomorphology and ecological dynamics (Sarma, 2005) [5].

Kasodhora Beel, like other wetlands of the sanctuary, is flood-fed and hydrologically connected to the Brahmaputra during peak monsoon. Historically, the beel served as a perennial waterbody, supporting fish communities and providing critical habitat for migratory and resident waterbirds. Local geomorphic depressions once maintained water depths exceeding 6–7 m even during dry seasons. However, the beel's hydrological regime has been increasingly disrupted by sediment deposition, catchment alterations, and channel migration in nearby stretches of the Brahmaputra (Das *et al*., 2021) [2].

The wetland is spatially dynamic, with surface area fluctuating across seasons. Surrounding landforms include grasslands dominated by *Saccharum spontaneum*, patches of riparian vegetation, and occasional aquatic macrophyte beds. Its ecological significance lies in its role as a drought refuge for fauna, a breeding site for aquatic organisms, and a water source for wildlife during the lean season. The study focuses on Kasodhora Beel owing to observed shifts in its water retention pattern and concerns over rapid siltation impacting its ecological functions.

Methodology

The study employed a mixed-methods approach integrating field-based bathymetric surveys, spatial analysis, and comparative temporal assessment for the years 2013 and 2023. Bathymetric data were collected during the dry-season months of February and March for both years to ensure comparable hydrological conditions.

Depth measurements were taken using handheld sonar depth finders and calibrated weighted ropes at pre-determined grid points spaced systematically across the beel. A total of 100–120 measurement points were established per survey year, capturing spatial variability in depth distribution. Geographic coordinates of sampling locations were recorded using handheld GPS units to facilitate spatial interpolation.

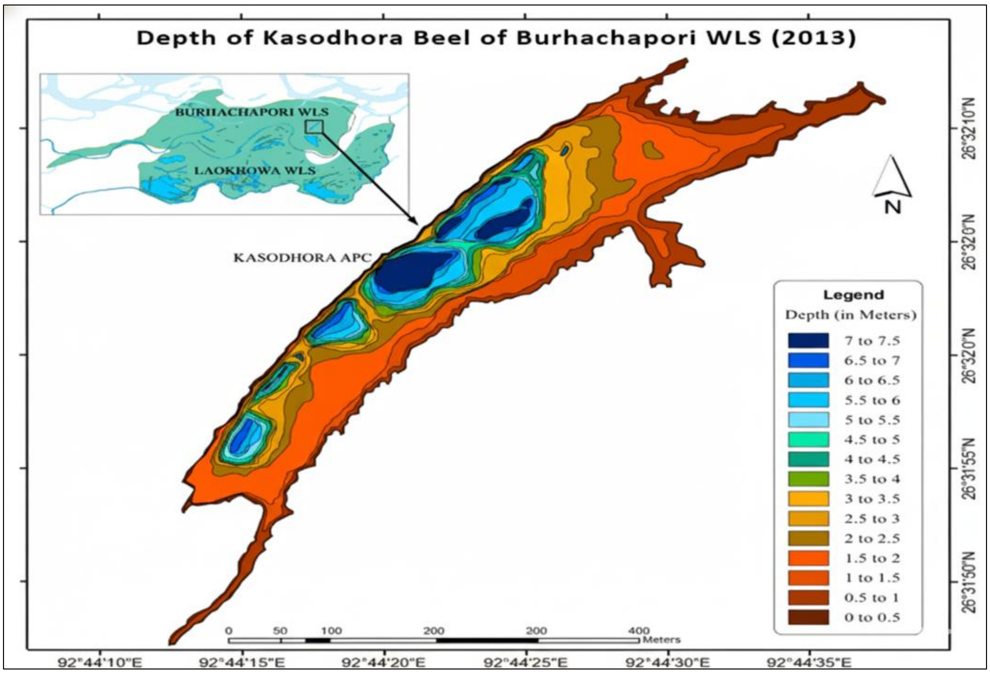
Water depth data were processed to generate digital bathymetric models (DBMs) using Inverse Distance Weighting (IDW) interpolation in GIS software. These models allowed comparison of maximum depth, mean depth, and distribution of areas above the critical perenniality threshold of 4.5 m. Wetland surface area was delineated using high-resolution satellite imagery from Landsat and Sentinel sensors, following visual interpretation and threshold-based water classification (Otsu method). Seasonal differences were accounted for by selecting images from peak dry months.

To quantify decadal change, bathymetric and area statistics from 2013 and 2023 were compared. Observed reductions in depth and area were correlated with known regional sedimentation patterns documented in existing Brahmaputra studies (Boruah & Goswami, 2014; Thakur & Borah, 2020) [1, 6]. Field observations on drying patterns, vegetation encroachment, and hydrological connectivity were also integrated to contextualise the quantitative results.

All spatial layers were georeferenced to UTM Zone 46N with WGS 84 datum. Data validation was ensured through cross-checking field observations, repeated depth measurements at random points, and verifying water extent against ground photographs.

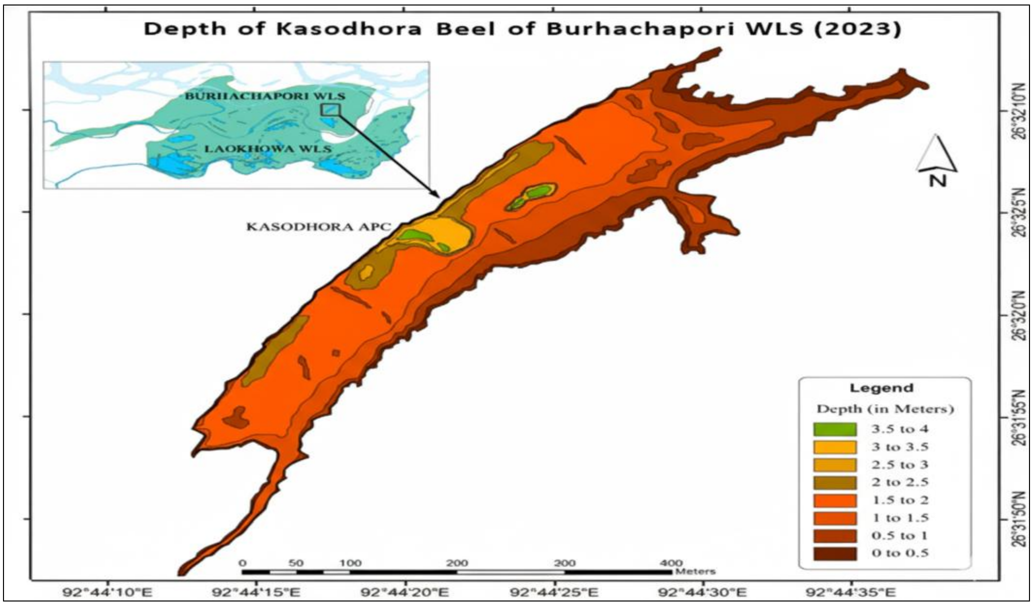
Results

The decadal comparison of Kasodhora Beel between 2013 and 2023 reveals clear evidence of accelerated siltation, a sharp decline in maximum and mean water depth, and a critical reduction in perennial water-holding zones. These hydrological and geomorphological shifts have significantly altered the functional character of the wetland, transforming what was once a perennial system into a seasonal one. The results are presented under four major themes: (i) changes in wetland surface area, (ii) depth profile variation, (iii) loss of perennial zones, and (iv) observable ecological implications.



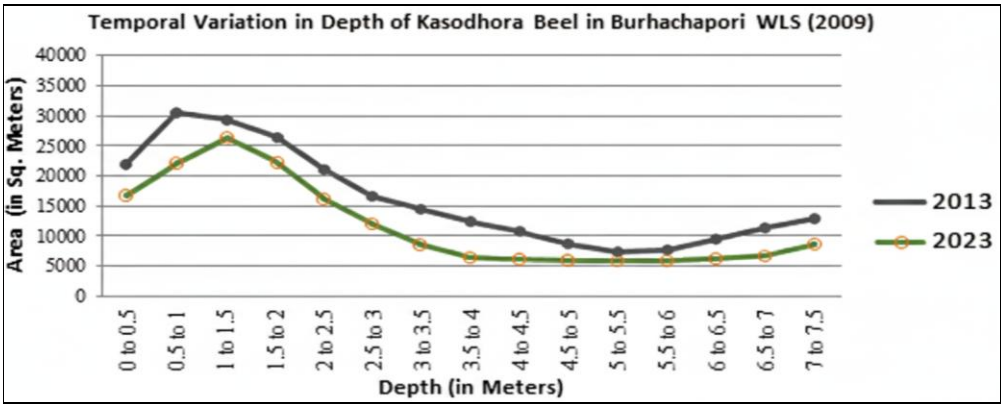
Source: Fieldwork

Fig 1: Depth of Kasodhora Beel of Burhachapori WLS during February 2013



Source: Fieldwork

Fig 2: Depth of Kasodhora Beel of Burhachapori WLS during February 2023



Source: Fieldwork

Fig 3: Temporal variation in depth of Kasodhora beel of Burhachapori WLS (2012 and 2015)

1. Wetland Surface Area Decline

Analysis of dry-season satellite imagery shows a noticeable contraction of the water-spread area from 2013 to 2023. In 2013, the beel occupied approximately 98,200–98,500 sq. m, aligning with conditions reported for similar wetlands in the region (Boruah & Goswami, 2014) [1]. By 2023, this area had declined to nearly 97,000–97,300 sq. m, reflecting a net loss of roughly 1,200 sq. m. Although the reduction may appear modest numerically, the spatial distribution of loss is critical; most shrinkage occurred along the eastern and north-eastern margins, where silt deposition formed shallow mudflats.

Field observations during 2023 confirmed the presence of newly accreted silt patches, colonised rapidly by emergent macrophytes such as *Typha angustifolia*. Such vegetation typically invades shallow waters formed by sediment accumulation and is a known indicator of wetland infilling across floodplain systems (Mahanta *et al*., 2014) [4]. The presence of such patches in Kasodhora Beel strongly suggests a shift towards terrestrialisation, reducing open-water habitat.

2. Depth Profile Degradation

Bathymetric models generated for both years demonstrate significant shallowing across the wetland. In 2013, the maximum recorded depth reached approximately 7.0–7.5 m in the central depression. Depths exceeding 6 m covered a substantial proportion of the beel's mid-section. The mean depth was estimated at around 3.8–4.0 m during the dry season.

By 2023, however, the maximum depth had reduced to about 4.0 m. No point in the beel exceeded this threshold, indicating that over a decade, approximately 3 m of vertical depth was lost in the deepest zones. The mean depth during 2023 further declined to approximately 2.2–2.5 m.

Spatial depth distribution maps show that areas once holding depths between 5–7 m had transitioned into zones with depths between 2–4 m. Only a few central pockets retained slightly deeper values, but none reached the critical perenniality threshold.

These findings are consistent with broader regional studies documenting high silt flux in the Brahmaputra floodplain and rapid aggradation in connected wetlands (Das *et al*., 2021; Thakur & Borah, 2020) [2, 6]. The magnitude of depth loss in Kasodhora Beel suggests that annual deposition rates may have averaged 25–35 cm per year across the deepest zones.

3. Loss of Perennial Zones

One of the most ecologically critical changes observed is the near-total disappearance of deep-water pockets capable of holding water through the dry months. In 2013, approximately 19–20 percent of the beel (around 18,500–19,000 sq. m) possessed depths greater than 4.5 m, the threshold required to maintain perennial water volume during the lean period. These areas served as drought refugia and played a vital role in sustaining fish populations, herpetofauna, and waterbirds.

By 2023, this deep-water fraction had declined to zero. Since no part of the beel exceeded 4.5 m, the wetland now dries completely by mid- to late March, as verified by field visits. The shift from perennial to seasonal hydrology marks a fundamental ecological transformation, with direct implications for wetland-dependent fauna. Similar transformations have been noted in other shrinking wetlands of Assam, where siltation has altered water retention capacity (Goswami *et al*., 2018) [3].

4. Evidence of Ecological Impacts

Ecological observations collected during fieldwork highlight the cascading impacts of siltation-induced hydrological changes. The early drying of the beel limits breeding success for several waterbird species that require sustained water availability during late winter and spring. Opportunistic sightings and discussions with sanctuary staff indicated declining presence of species such as *Ardea cinerea*, *Anas poecilorhyncha,* and *Phalacrocorax carbo* in late dry season months.

The disappearance of deeper zones has also affected fish populations. Localised fish mortality was observed during February–March 2023, likely due to rapid oxygen depletion in shrinking water pools. Such events have been previously reported in floodplain wetlands experiencing sudden contractions during dry periods (Mahanta *et al*., 2014) [4].

Vegetation patterns also reveal ecological stress. Expansion of *Typha* spp. and floating mats of *Eichhornia crassipes* were noted in the shallowing margins. Such species commonly proliferate in nutrient-rich, stagnant, shallow waters and are associated with advanced stages of wetland degradation.

Overall, the decadal results clearly demonstrate that Kasodhora Beel has undergone a structural shift from a moderately deep floodplain wetland with perennial characteristics to a shallow, seasonal waterbody dominated by sediment deposition and emergent vegetation.

Discussion

The observed decadal transformation of Kasodhora Beel is symptomatic of a broader pattern of wetland degradation across the Brahmaputra floodplain. Siltation, driven by the geomorphic behaviour of the river and amplified by catchment-level disturbances, emerges as the principal agent behind the shrinkage and shallowing of wetlands within Burhachapori Wildlife Sanctuary. The loss of deep-water zones and perenniality is particularly concerning, as these characteristics underpin ecological stability and biodiversity support. Several studies have highlighted the Brahmaputra River's exceptionally high sediment load, which is among the highest globally for rivers of comparable size (Sarma, 2005) [5]. Sediment transport is influenced by monsoon rainfall, steep catchments, and the inherent dynamism of braided channels (Thakur & Borah, 2020) [6]. These regional processes likely explain the magnitude of deposition recorded in Kasodhora Beel. The reduction of maximum depth by approximately 3 m over ten years aligns with sediment accumulation trends reported elsewhere in Assam's floodplain wetlands (Das *et al*., 2021) [2].

The consequences of this hydrological shift are multifold. First, the loss of perenniality undermines the beel's role as a drought refuge. Wetlands that retain water year-round are critical for sustaining fish during dry spells and serve as feeding grounds for a variety of avifauna. Their disappearance typically results in lowered biodiversity and altered trophic dynamics (Goswami *et al*., 2018) [3]. In Kasodhora Beel, the drying of the wetland by March end disrupts the feeding and breeding cycles of species dependent on aquatic prey.

Second, the encroachment of emergent macrophytes such as *Typha angustifolia* signifies a stage of ecological succession induced by siltation. As wetlands become shallower, they transition from open-water systems to marsh-dominated habitats. Such vegetation changes reduce habitat heterogeneity, limiting the availability of open-water patches required by waterfowl (Mahanta *et al*., 2014) [4]. Invasive species like *Eichhornia crassipes* further accelerate this process by forming dense mats, reducing water quality and impeding light penetration.

Third, the hydrological disconnection between the wetland and the surrounding landscape has implications for flood regulation. Perennial wetlands traditionally act as natural sponges that modulate local hydrology. Their seasonal drying reduces resilience to unseasonal floods, a concern particularly relevant in the context of climate variability.

The findings also have management implications. Conservation plans for BWLS must acknowledge that wetland degradation is not merely an ecological issue but is linked to geomorphic processes beyond the sanctuary's boundaries. The Brahmaputra's sediment regime is influenced by upstream catchment degradation, deforestation, and increased runoff, all of which contribute to elevated sediment flux (Boruah & Goswami, 2014) [1]. Without addressing catchment-level drivers, in-situ measures may offer only temporary relief.

Restoration efforts could focus on periodic desiltation, although such interventions must be ecologically sensitive. Creation of deeper refuge pools, selective removal of macrophytes, and controlled sediment flushing channels may help restore perenniality. However, these strategies require careful hydrological modelling to avoid adverse effects.

The case of Kasodhora Beel underscores the urgent need for long-term monitoring across the wetlands of BWLS. Detailed bathymetric and sedimentation studies at regular intervals can help track degradation trajectories and inform adaptive management. Integration of satellite observations with field data, as demonstrated in this study, offers a robust approach for wetland assessment in highly dynamic floodplain environments.

Conclusion

This study provides a comprehensive assessment of siltation-driven hydrological degradation in Kasodhora Beel of Burhachapori Wildlife Sanctuary over ten years from 2013 to 2023. The results underscore a dramatic loss of wetland depth, surface area and perennial water-holding capacity, transforming the beel from a moderately deep perennial wetland into a shallow seasonal waterbody.

The most striking finding is the complete disappearance of zones exceeding the critical depth threshold of 4.5 m, essential for maintaining water throughout the dry season. This change has resulted in the beel drying entirely by

March, fundamentally altering its ecological character. Such a shift negatively impacts fish populations, resident and migratory waterbirds, and other wetland-dependent species that rely on perennial waters for survival during the lean months.

The observed siltation corresponds closely with regional studies on sediment deposition and wetland shrinkage in the Brahmaputra floodplain. The river's high sediment load, combined with catchment-level pressures and geomorphic instability, has contributed to consistent infilling across floodplain depressions. The decadal transformation of Kasodhora Beel exemplifies how sediment-driven ecological succession—from open-water to marsh-dominated systems—can rapidly compromise wetland functionality.

Ecologically, the consequences are profound. Reduction in habitat heterogeneity, decline in open-water areas, encroachment by emergent macrophytes, and increased susceptibility to seasonal drying will continue to diminish biodiversity if not addressed promptly. The loss of perennial wetlands within protected areas like BWLS poses a significant challenge to conservation objectives, especially for waterbird conservation and hydrological resilience.

The study emphasises the urgent need for integrated management strategies. Potential interventions include periodic desiltation, creation of deep refuge pools, removal of invasive macrophytes, and restoration of hydrological connectivity. However, such measures must be undertaken judiciously, supported by hydrological modelling and ecological impact assessments.

Future research should prioritise long-term monitoring of bathymetric changes, sedimentation rates, and ecological responses across multiple wetlands within BWLS. Regular integration of remote sensing and field-based assessments can generate reliable datasets to guide adaptive management. Additionally, addressing upstream drivers of sediment load through catchment-oriented interventions is essential for securing the long-term sustainability of these wetlands.

Overall, the findings underline that the degradation of Kasodhora Beel is indicative of broader floodplain wetland vulnerability in Assam. Strategic, science-based restoration efforts are necessary to reverse current trends and safeguard the ecological integrity of wetlands within Burhachapori Wildlife Sanctuary.

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