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Assessment of Flood Affected Areas using GEE and SAR Imagery: A Spatio Temporal Analysis of Morigaon District

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Abstract:

Flooding is a recurrent and severe environmental hazard in Morigaon district, Assam, driven by the hydrodynamics of the Brahmaputra River and its tributaries. The study assesses the spatial extent of flood-affected areas and examines their interaction with land use and land cover (LULC) patterns using multi-temporal geospatial techniques. Sentinel 1 Synthetic Aperture Radar (SAR) imagery for 2015 and 2025 was processed on the Google Earth Engine (GEE) platform to delineate flood inundation, employing VV and VH polarization in Interferometric Wide Swath (IW) mode. A refined Lee filter and image mosaicking were applied in SNAP to enhance data quality. Additionally, a LULC map for the years 2015 and 2025 were generated using Sentinel 2 imagery and visual interpretation techniques, classifying the district into six major land use categories. Results reveal that Morigaon district is predominantly agricultural, with cropland covering over 55% of its total geographical area in both years. Temporal flood analysis indicates a substantial decline in inundation from 25,748.67 ha in 2015 to 13,706.35 ha in 2025, although cropland consistently remained the most affected category. The reduction in flood extent over time may be linked to improved flood mitigation infrastructure, hydrological variations, rainfall intensity and pattern, and changes in sediment dynamics. Despite this decline, the district continues to exhibit considerable ecological and socio-economic vulnerability due to its agrarian dependence and exposure to riverine processes. The study highlights the value of integrating SAR and optical data for reliable flood assessment and underscores the need for sustainable floodplain management and adaptation strategies to enhance resilience in Morigaon district.

Keywords: Flood inundation, GEE, Satellite Imagery, LULC, SAR

Introduction:

Floods are among the most frequent and devastating natural hazards worldwide, causing significant loss of life, damage to infrastructure, and disruption of socio-economic systems(Kumar et al., 2022a). In India, the Brahmaputra Valley faces particularly severe flood risks due to its distinctive physiography, hydrology, and climate, with the braided nature of the river, high sediment load, and bank erosion exacerbating inundation. Assam, especially districts like Morigaon on the Brahmaputra's south bank, endures recurrent monsoon flooding

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from heavy rainfall (often exceeding 2000 mm monthly in upper catchments), river overflow, snowmelt, and poor drainage (Kumar et al., 2022; Deori & Boro, 2025). Morigaon experiences annual erosion and flooding from May to August, shifting riverbanks southward at rates up to 79.6 meters/year, eroding ~182 km² and 94 villages between 1996–2021(Nath & Medhi, 2021). Recurrent floods in Assam's Brahmaputra Valley diminish agricultural productivity, disrupt livelihoods, and drive long-term environmental degradation, including wetland loss, siltation, and erosion (Bhat, 2024; Kumar et al., 2022a).

Traditional methods of flood mapping and assessment are often constrained by limited accessibility, time consumption, and lack of real-time data, particularly during extreme weather events(Bentivoglio et al., 2022). In this context, remote sensing and geospatial technologies have emerged as effective tools for flood monitoring and damage assessment. Among these, Synthetic Aperture Radar (SAR) imagery has gained prominence due to its ability to penetrate cloud cover and provide reliable data regardless of weather conditions or time of day(Mudi et al., 2022). This makes SAR particularly suitable for flood mapping in regions like Assam, where persistent cloud cover during monsoon seasons limits the use of optical satellite imagery(Bentivoglio et al., 2022; NRSC, 2022). The advent of cloud-based geospatial platforms such as Google Earth Engine (GEE) has revolutionized large-scale environmental monitoring by enabling efficient processing and analysis of massive satellite datasets(Gorelick et al., 2017; Lal et al., 2020). GEE provides access to multi-temporal satellite imagery and powerful computational capabilities, allowing researchers to conduct near real-time flood assessments and spatio-temporal analysis with greater accuracy and efficiency. The integration of SAR data within GEE further enhances the capability to delineate flood-affected areas and monitor their temporal dynamics(Lal et al., 2020; Pandey et al., 2022).

Morigaon district, located in the central part of Assam within the Brahmaputra floodplain, is highly vulnerable to annual flooding due to its low-lying topography, proximity to major rivers, and high rainfall intensity. Despite its vulnerability, there remains a need for comprehensive spatio-temporal flood assessment using advanced geospatial techniques. Previous studies in the study region focuses on the crop loss assessment due to flood(Rasid et al., 2019), land use land cover change(Bora & Bora, 2024), dynamics and severity of flood using Landsat images(Singh & Bhattacharjee, 2023) leaving a gap to study spatio temporal impacts of flood, particularly in the various land classes of the district.

Therefore, this study aims to assess flood-affected areas in Morigaon district using SAR imagery processed through GEE, with a focus on spatio-temporal dynamics. By leveraging multi-temporal datasets, the research seeks to identify flood extent, analyze patterns of inundation over time, and contribute to improved flood management and mitigation strategies in the region. The outcomes of this study are expected to support policymakers, planners, and disaster management authorities in making informed decisions for reducing flood risk and enhancing resilience.

Aims and Objectives:

The main aim and objective of the study is to execute the flood inundation with analysis and social-economic consequences of Morigaon district of Assam. The objective are:

i) To produce land use land cover map of the study area for the years 2015 and 2025.
ii) Delineating the flood affected areas in the study area.
iii) Assessing spatial distribution and quantifying the magnitude of flood impacts across different land use and land cover categories.

Study Area:

Morigaon is an agrarian district of Assam. It lies at 26.06º N to 26.50º N latitude and 91.96º E to 92.56º E longitude. It is situated on the south bank of the river Brahmaputra. Nagaon district is situated on its East, River Brahmaputra and Darrang district on the North, Kamrup Metro on the West, West Karbi Anglong on its South(Goswami & Kalita, 2019). Covering an area of about 149417.06 hectares, the district has natural beauty, a rich cultural heritage and wildlife sanctuaries. The district comprises 5 revenue circles, 7 blocks, 85 Panchayats, 632 villages, 1 statutory town, 3 urban areas and 5 census town with total 9,57,853 population of different communities according to the 2011 census(Singh & Bhattacharjee, 2023).

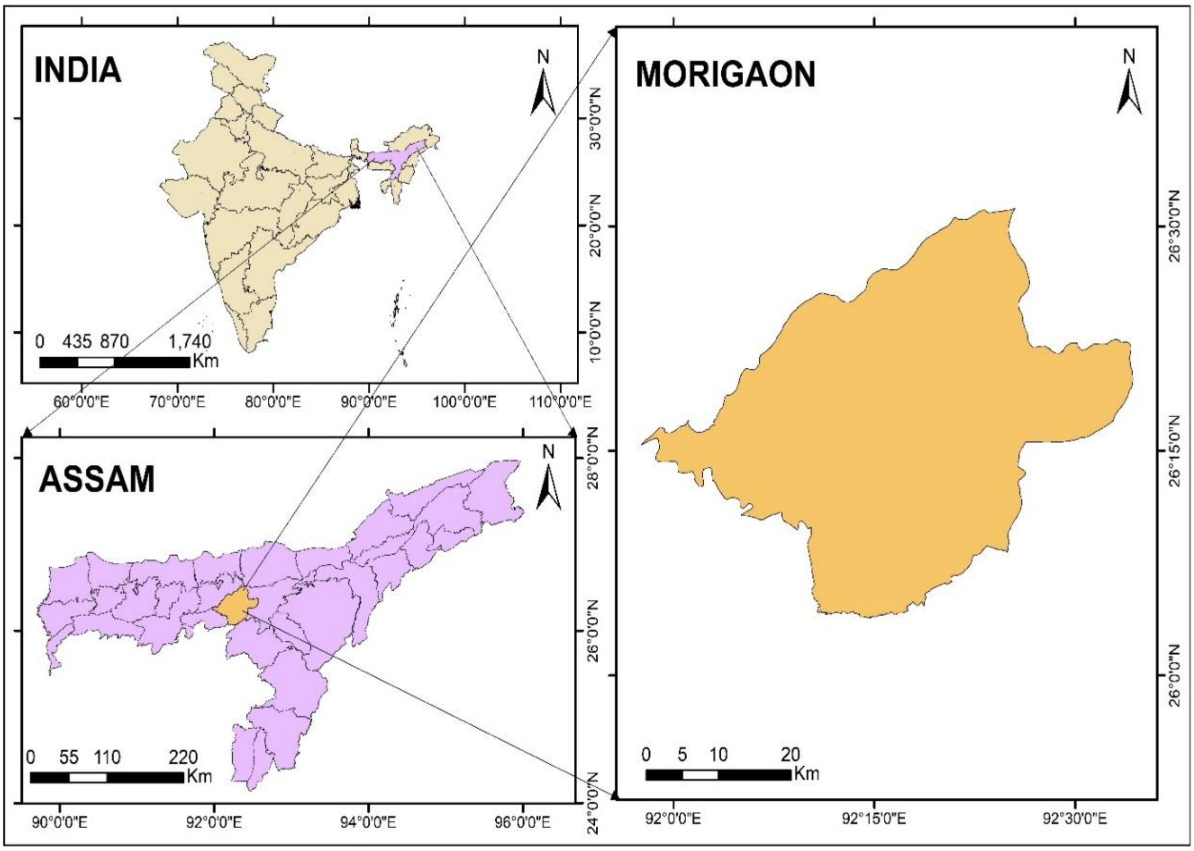

Figure 1: Map of study area

However, the district frequently floods almost every year due to its location in the floodplains of the Brahmaputra and its tributaries, such as the Kolong and Kopili rivers. The monsoon rainfall and river overflow lead to flood inundation. The low-lying terrain and siltation in river channels further aggravate the situation, resulting in recurring floods that disrupt livelihoods, displace communities, and pose long-term socio-economic challenges for the region.

Material and Method:

This study adopts an integrated geospatial approach combining optical and microwave remote sensing data to assess flood-affected areas and their impact on land use and land cover (LULC) in Morigaon district, Assam. Multi-temporal satellite datasets were processed using Google Earth Engine (GEE) and ArcGIS 10.8 to achieve the stated objectives(Gorelick et al., 2017).

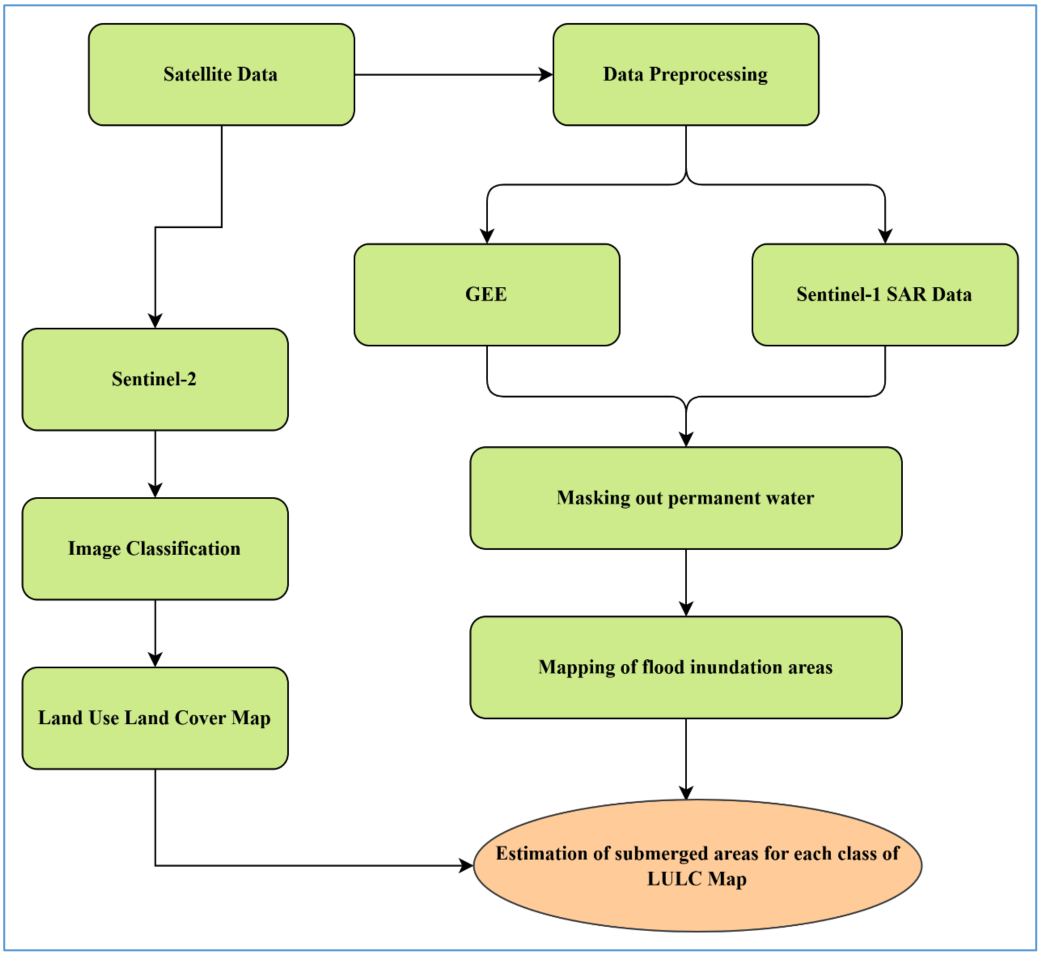

Figure 2: Flow chart for delineation of flood inundation areas

To fulfil the first objective, LULC maps for the years 2015 and 2025 were generated using Sentinel-2 imagery having spatial resolution of 10 m(Drusch et al., 2012; ESA, 2015). Cloud-free images corresponding to similar seasonal periods were selected to ensure temporal consistency(Wulder et al., 2018). The satellite data were pre-processed, including atmospheric correction and cloud masking in Erdas Imagine, before being imported into ArcGIS 10.8 for classification. A visual image interpretation technique, supported by spectral, spatial, and contextual characteristics was adopted to classify the topography into six major land classes: crop land, built-up area, forest, grassland, sandbar and water body(Lillesand et al., 2015).

For the delineation of flood-affected areas (Objective ii), Sentinel-1 Synthetic Aperture Radar (SAR) data were utilized owing to their capability to penetrate cloud cover and acquire data under all-weather conditions(Torres et al., 2012). The SAR images for pre-flood and flood periods of 2015 and 2025 were processed within the GEE platform(Gorelick et al., 2017). Preprocessing steps included radiometric calibration, speckle noise filtering, and terrain correction using a digital elevation model(Kiran et al., 2019). Flood inundation was identified based on the characteristic low backscatter values of water surfaces in SAR imagery(Tassew et al., 2025). A thresholding technique was applied to distinguish flooded areas from non-flooded regions by comparing pre- and during-flood backscatter values(Travert et al., 2025).

To achieve the third objective, the spatial distribution and magnitude of flood impacts were assessed by integrating the LULC maps with the flood inundation layers. Overlay analysis was performed in ArcGIS 10.8 to quantify the extent of flooding within each LULC category(Narasayya, 2024). The area affected under each land use class was calculated in hectares and expressed as a percentage of the total class area. Comparative analysis between 2015 and 2025 was conducted to examine changes in flood extent and its impact on different land cover types. This spatio-temporal assessment enabled the identification of the most vulnerable land use categories and provided insights into changing flood dynamics in the study area(Shrestha, 2019).

Result and Discussion:

The LULC analysis of Morigaon district for the years 2015 and 2025 reveals a predominantly agricultural landscape characterized by significant spatial heterogeneity shaped by both natural and anthropogenic influences *(Figure 3 & 4)*. The total geographical area of the district is approximately 149,417.06 hectares, of which cropland constitutes the largest share, 83438.16 ha (55.84%) in 2015 decreased to 82542.32 ha (55.24%) in 2025(*Table 1*), indicating the district's strong dependence on agriculture as the principal livelihood source(Rasid et al., 2019). Built-up areas, occupying merely 2676.63 ha (1.79%) in 2015*(Figure 3)*, increased to 3902.76 ha (2.61%) in 2025*(Figure 4),* this increasing trend of built-up areas is mainly due to infrastructure development and population growth of the study region. Forest areas account for 35885.09 ha (24.02%) and 35316.85 ha (23.64%) in the years 2015 and 2025 respectively, playing a vital role in maintaining ecological stability and biodiversity.

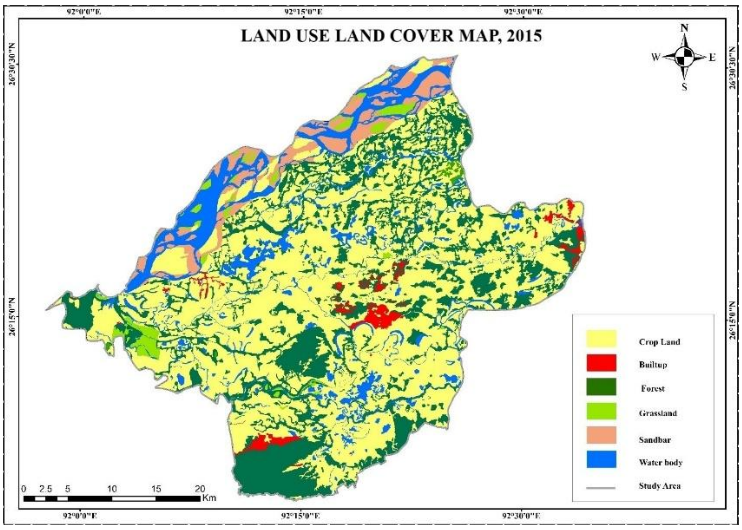

Figure 3: LULC map of Morigaon 2015

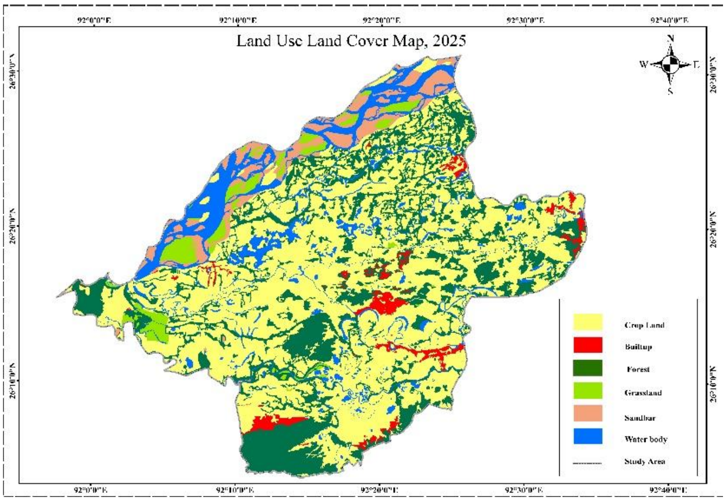

Figure 4. LULC map of Morigaon 2025

Table 1: Area of different classes in LULC (2015 & 2025)

LULC Class	2015		2025	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Crop Land	83438.16	55.84	82542.32	55.24
Built-up	2676.63	1.79	3902.76	2.61
Forest	35885.09	24.02	35316.85	23.64
Grassland	2875.07	1.92	4407.62	2.95
Water body	17199.4	11.51	15755.01	10.54
Sandbar	7342.71	4.91	7492.53	5.01
Total	149417.06	100	149417.09	100.00

Water bodies, including rivers, lakes, and wetlands, constitute 11.51% (17,199.40 ha) in the year 2015 and 10.54% (15755.01 ha) in the year 2025 as represented in a bar diagram *(Figure 5)* are crucial for irrigation, fisheries, and sustaining the hydrological balance of the Brahmaputra valley as well as for Morigaon district. Sandbars, occupying 7342.71 ha (4.91%) and 7492.53 ha (5.01%) for the year 2015 and 2025 respectively, reflect the dynamic fluvial processes of the Brahmaputra River system, where continuous sediment deposition and erosion shape landform stability and influence agricultural practices(Das, 2022; Talukdar et al., 2022). Grasslands cover 2,875.07 ha (1.92%) in the year 2015 and 4407.62 ha (2.95%) in the year 2025, serving as transitional zones between cultivated land and riverine tracts, and provide important grazing resources while supporting local biodiversity(Talukdar et al., 2022) of the district, highlight its predominantly rural character with limited urban expansion concentrated mainly around Morigaon town and Jagiroad (Borah et al., 2016).

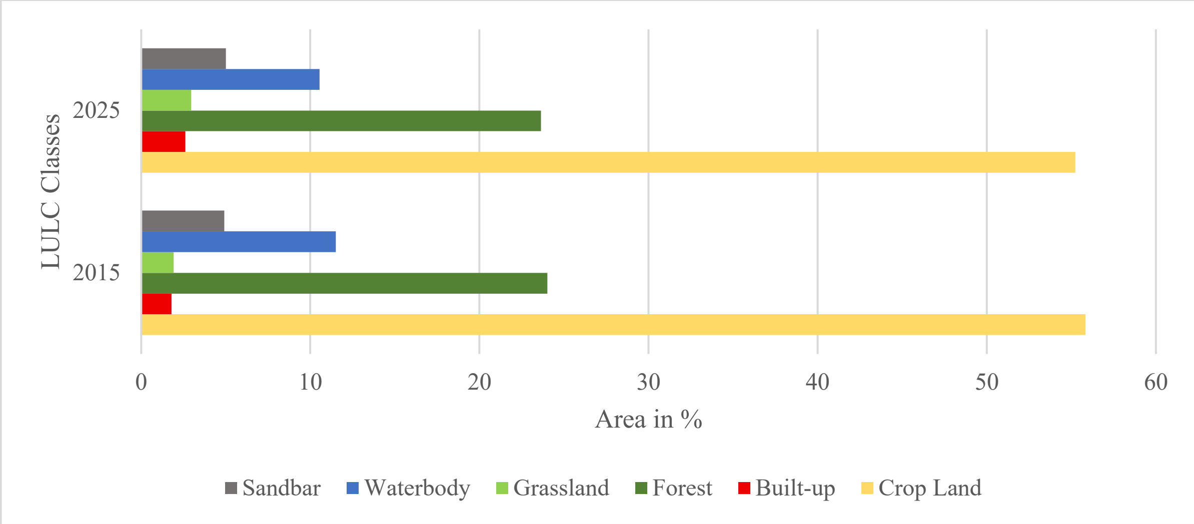

Figure 5: Bar diagram showing percentage shares of LULC categories for the year 2015 & 2025.

The problem of flood in the Morigaon district is arguably the most severe and unique because it differs significantly from that of other states in terms of the magnitude and duration of floods as well as the volume of erosion. Morigaon has faced major flood event throughout its history, with some of the most significant years being 1993, 1994, 1995, 1997, 1998, 2000, 2002, 2003, 2004, 2014, 2015 and 2016 and even recent time. Morigaon has consistently been among one of the most severely affected district of Assam. In 2004 around 39421 hectares and 17,800 hectares of the cropped area were affected and population of 418,000 was affected covering 319 villages(*India*: Situation report, 2004).

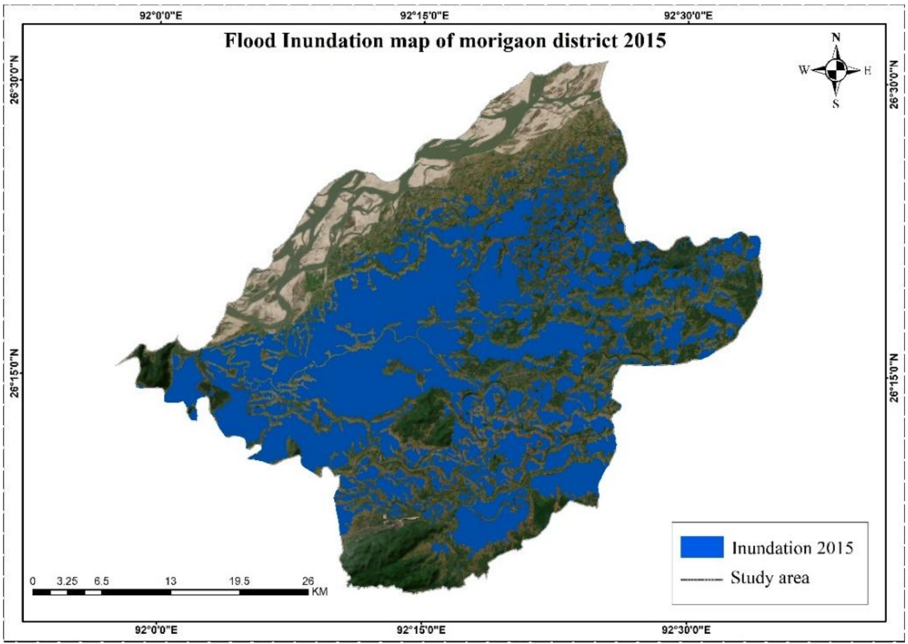

Figure 6: Flood map of Morigaon in 2015

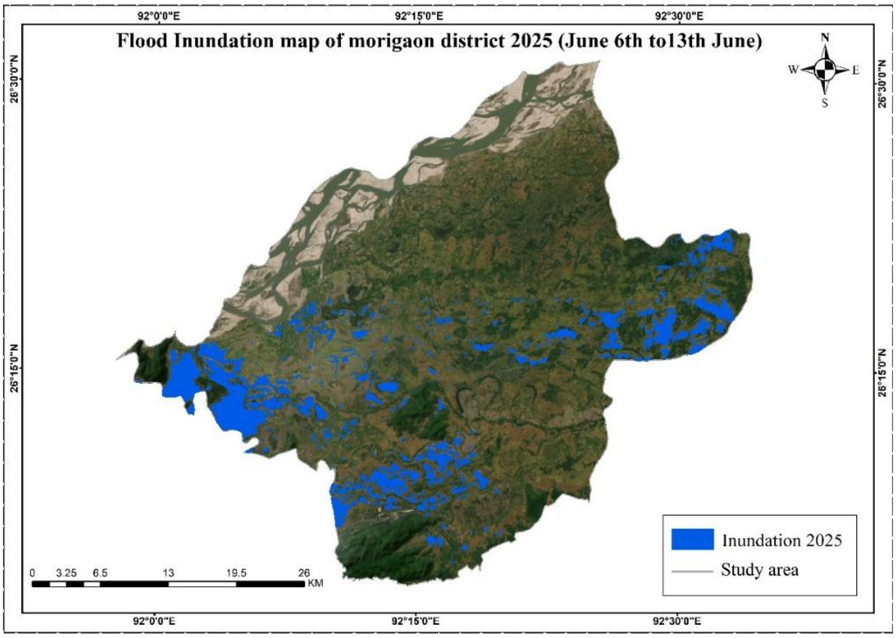

Figure 7: Flood map of Morigaon in 2025

The temporal assessment of flood inundation across different Land Use and Land Cover (LULC) categories in Morigaon district for the years 2015 and 2025 *(Table 2 & Figure 8)* reveals that in the year 2015 *(Figure 6)* the district was worst affected in flood with a total flood inundation of 25748.67 ha of which 18270.46 ha was croplands the dominant land feature of the study area indicating high vulnerability of agriculture in the region. Built-up areas, forests, grasslands, and sandbars accounted for 233.43 ha, 3532.91 ha, 2572.32 ha, and 1139.55 ha of inundation, respectively. During the same year, twelve fatalities were registered due to flooding. According to the District Disaster Management Department of Morigaon's departmental records for the year 2014, 262 villages and 18,900 hectares of agricultural land were affected(Singh & Bhattacharjee, 2023). The District Disaster Management Department in Morigaon produced the Flood Contingency Report (2022–2023), the villages under Mayong revenue circle were the worst affected by flooding.

Table 2: Flood Inundation over various land classes (2015 & 2025)

District	**Land Use Land Cover**	**Year**		**Year**	
		2015		**2025**	
		Area under Inundation (ha)	**Total Area under Inundation (ha)**	**Area under Inundation (ha)**	**Total Area under Inundation (ha)**
Morigaon	Crop land	18270.46	25748.67	9535.81	13706.35
	Built-Up	233.43		197.23	

	Forest	3532.91		1372	
	Grassland	2572.32		1643	
	Sandbar	1139.55		958.31	

A marked reduction occurred in 2025 *(Figure 7),* when total inundation dropped to 13706.35 ha, including 9535.81 ha of cropland, 197.23 ha of built-up area, 1372 ha of forest, 1643 ha of grassland, and 958.31 ha of sandbar *(Table 2)*. This progressive decline in flood extent over the period may be linked to factors such as reduced rainfall intensity, improved embankment systems, and changes in sediment deposition along the Brahmaputra River and its tributaries (Hazarika, as cited in The Assam Tribune, 2025; Water Resources Department, Assam, 2026). The flood of 2017 resulted in the unfortunate loss of 31 human lives within the affected community, marking the highest number of fatalities reported between 2015 and 2020(Singh & Bhattacharjee, 2023).

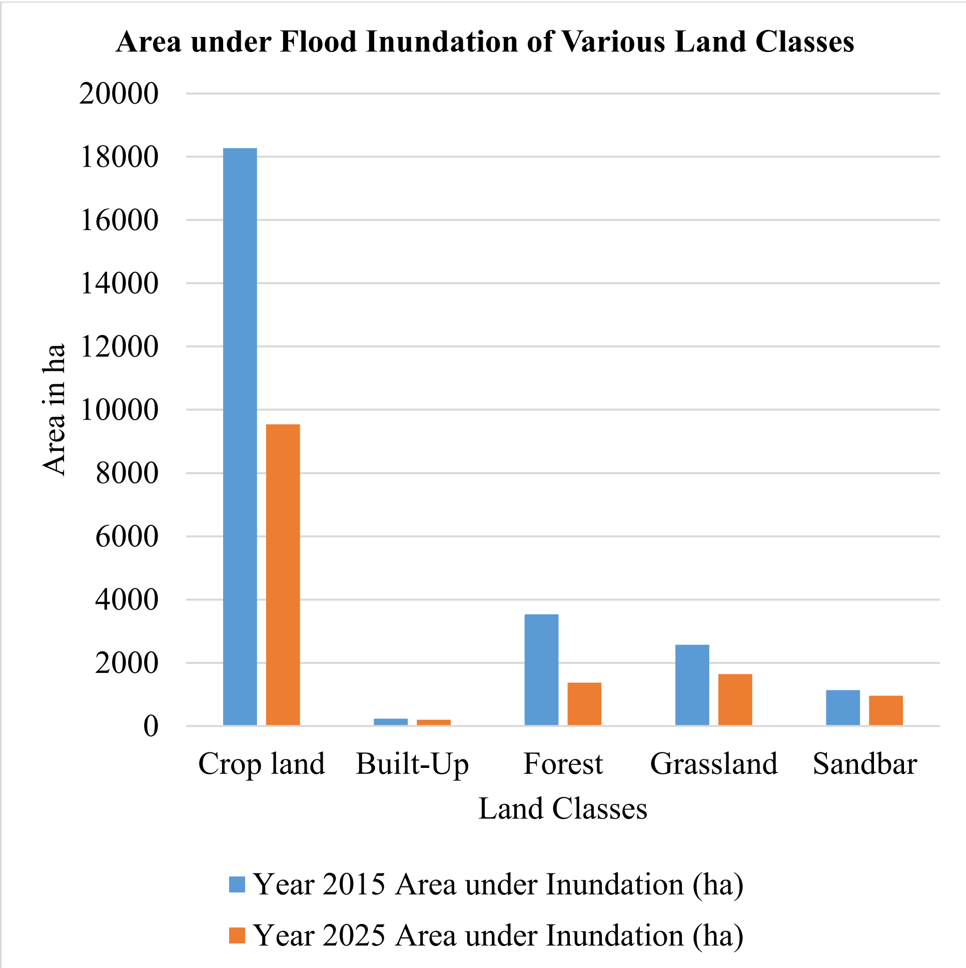

Figure 8: Column diagram showing area under inundation of land classes (2015 & 2025)

Despite the overall decrease, cropland remains the most flood-prone category, underscoring the persistent exposure of the agricultural sector to flood hazards. Therefore, promoting adaptive land management practices, such as flood-resilient cropping and sustainable floodplain utilization, is essential(Kumar et al., 2022b). Overall, the findings suggest that while flood intensity and spatial coverage have diminished considerably between 2015 and 2025, Morigaon district continues to exhibit ecological and socio-economic vulnerability, necessitating continuous monitoring and integrated floodplain management for long-term resilience.

Conclusion:

The study highlights that combining Sentinel-1 SAR and Sentinel-2 datasets within the Google Earth Engine platform offers a robust approach for mapping flood affected areas and examining their relationship with various land use and land cover classes in Morigaon district, Assam. Using multiyear datasets for the year 2015 and 2025, the study accurately outlined the spatial spread of flooding and measured each effect on key land feature types. Analysis of the 2015 and 2025 LULC conditions showed that agriculture dominates the district landscape, with crop land constituting more than half of the total district's geographical area, alongside significant forested regions and riverine systems that influence the geomorphology of Morigaon district. The comparison of flood extends over time indicated a marked decline between 2015 and 2025, potentially resulting from enhanced flood management infrastructure, shifts in hydrological processes, and variation in rainfall patterns.

Despite the overall reduction in flooding, agricultural areas continued to be the most impacted, reflecting the high exposure and sensitivity of agricultural land to flood events. These findings suggest that even with decreasing inundation levels, Morigaon remain socio-economically at risk due to repeated flooding and its reliance on climate-dependent economic activities. The results highlight the necessity of implementing flood-tolerant farming methods, improving embankment and drainage infrastructure, and fostering sustainable approaches to floodplain utilization. Additionally, the spatial information derived from this work offers crucial, data-driven guidance to policymakers, planners, and disaster response bodies for designing more effective mitigation measures. Continuous monitoring using SAR based flood maps, along with periodic LULC evaluation, will be essential for tracking future flood dynamics under changing climate and geomorphological conditions. Overall, this study reinforces the significance of modern geospatial tools in strengthening flood preparedness, enabling informed risk-based planning and contribution to long term resilience in Morigaon district.

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