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# Nature and Trend of Floods in Assam, India

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*geospatial technologies.*

***Abstract***

*Assam is one of the most impoverished and flood-affected regions in India for various reasons. The state of Assam qualifies as one of the disaster vulnerable states in India because it is situated in the floodplains of river systems of Brahmaputra and Barak that receive heavy rainfall during the monsoon season. These problems get worse due to the violent and silt-laden geography of the Brahmaputra River which causing siltation leading to loss of river retention. All these activities have the same effects as the detention of floods causing activities such as deforestation, encroment on the river bank and poor development structures. The primary causes of buyout floods are the increasing climate change and the resultant environmental transformation and the result of the hi-imalayan frosta melt. The flood prone area of flood flood prone area is only about 10.2%in the whole country but in Assam it is upto 39.58%. After the independence of the country, major floods in Assam occurred in 1954, 1962 and 1972 and consecutive years like that of 1988 and 1998, followed land between 2004 and 2012.This is an indication of Assam having to tackle flood bordering which is fourfold more than the national benchmark being flooded. The devastation that follows Assam, in the form of loss of agricultural output and extensive damage to infrastructure instead is compensated with human displacement*

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*entirely and recurring health crises. Flood forecasting, construction of embankments and dams, afforestation projects etc. are measures being taken for the management as well as mitigation of floods with disaster response mechanisms becoming fairly efficient now in our country. At the same time, sustainable and holistic solutions are required to deal with this complex blend of natural as well as human elements behind flooding in Assam. Study aims to identify the nature and trend of floods using geospatial technologies in Assam.*

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## Main Discussion

### 1.1.**Inroduction**

In simple terms, a flood is an overflow of water that submerges normally dry ground. It is frequently brought on by heavy rains, overflowing rivers, storm surges along the shore, or the melting of ice and snow quickly. Floods can be categorized into several types, including flash floods, riverine floods, and coastal floods, depending on their cause and impact (Smith, 2013). Floods can result in significant damage to infrastructure, ecosystems, and human lives, making them one of the most destructive natural disasters globally (Parker, 2000). A flood is described by Blaikie et al. (1994) as a natural event characterized by the rising and spreading of water over normally dry land, which can result from various hydrological and climatic factors. According to Kundzewicz and Takeuchi (1999), a flood occurs when water builds up on land quickly or gradually and exceeds the ability of natural or artificial mechanisms to control it. This frequently results in property damage and fatalities. According to the U.S. National Weather Service (2019), a flood is an inundation of land caused by heavy rainfall or the overflowing of rivers, streams, or coastal waters that disrupts human activities and infrastructure. Northeastern Indian state of Assam has long been known for its particularly vulnerable position to flooding. The short-course channels of the Brahmaputra and Barak river systems, which undergo significant erosion and course changes during the monsoon season, crisscross the area. It has a vast basin and numerous slowly winding tributaries lent by the Brahmaputra one of the world's widest rivers increasingly make it vulnerable to floods (Goswami, 2019). As a result of the region's

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exceptionally high rainfall during the monsoon season, which runs from June to September, Assam frequently experiences floods. It is especially vulnerable to flooding because of the plains and uneven terrain. The flood situation is further complicated by the topography of Assam, which sees water rushing downstream into low-lying areas (Barua 2020). Floods in Assam: A Threat to Both Human & Nature Every year agriculture lands are submerged into water for a long time which results in loss of crop, damage to infrastructure and displacement (Das, 2018). These floods have caused enormous financial damageA total of 5.5 million people were affected by the floods 2020 which even damaged 1.3 million hectares of agricultural land (ASDMA, 2020). The floods have longer-term impacts, too, on areas critical to public health and food security. The main reason of Assamese floods is heavy monsoon rains.The state receives 2,500 mm of rainfall on average each year. Situations where rainfall exceed normal conditions causes water in rivers to increase further than regular and cause them spill out over their banks, flooding the areas on its perimeter. The erosion of riverbanks, mostly from the Brahmaputra River one more factor that adds up to increased risk for flooding areas. The Brahmaputra has lost more than 7,500 square kilometres of land in the past century due to erosion (Hussain, 2017). And we have to understand when it goes through these cycles, the river is getting eroded continuously and that raises its bed levels further so even if the same quantum of water comes in after a few decades or maybe every 100 years then due to this erosion upstream has reduced capacity of storage. The flow happens with more force as well because there are less such sand banks which can redistribute energy right and now downstream will see more flooding happening, both on counts from flood coming down and also local rains about drainage needs some help too. This has led to floods in the Brahmaputra basin, especially Assam but more significantly it was merely symptomatic of rising trend. Despite all these facts there's a bigger picture that appears and its here deforestation leads huge amount of water retention capability lost. There is a greater risk of flash floods occurring due to increased surface runoff compared with vegetation that possibly can soak up rainwater (Singh, 2019). Meanwhile, the poor drainage infrastructure and ill-planned urbanisation has made matters worse by preventing natural water flow. The floods in Assam are an annual

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affair and despite the government constructing embankments to tame them, they still ravage with full fury. It appears that a combined strategy covering better land management, afforestation and more effective drainage will be needed to manage the incidence of floods in Assam (Goswami 2019).

1.2. **Review of the Literature**

Studies to understand the types and course of floods in Assam highlight a hydraulic war between Mother Nature and human beings that pushes more flood water into our homes now than it would over 100 years. Parker (2000) has identified the natural vulnerability of Assam landscape cradled in between Brahmaputra and Barak river systems, which brings seasonal floods. A study conducted by Goswami (2019) finds riverbank erosion and siltation to be principal factors responsible for the floods occurring in Brahmaputra. Channel degradation has been accompanied with a reduction in channel cross-sectional area hence creating an imbalance between floodwaters flow and restricting river sediments (Hussain, 2017). According to Das (2018), floods have become a regular phenomenon in India and the severity of these monsoon-related floods is further aggravated by climate change that has resulted in erratic rainfall patterns and other extreme weather events. The Brahmaputra is braided in its morphology (Bora and Goswami, 2015) which leads to frequent migration of active course shifting frequently from one belt to another rendering new set of area flooded every year. In a similar context, Barua (2020) too observed and stated that due to sediment deposition with deforestation in the upstream area has decreased further carrying capacity of River. In one of the highest-profile studies, Deforestation and forest degradation have consequently amplified surface runoff in the upper catchment areas that increase flood risk on a wide scale over much of Brahmaputra basin (Singh 2019) Due to low vegetation cover meant for water absorption, floodwater now flows rapidly down stream resulting in flooding downward in the available catchment (Bharali and Hussain, 2017). Gupta (2010) maintains that the flood situation in Assam has been compounded by inadequate and old maintenance infrastructure which include embankments. Embankments protect areas from flooding on design lines but due to lack of their upkeep they often become redundant and there is wide spread flood in these area during heavy rains, Gupta

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said. Hussain (2017) similarly reports increasing frequency of embankment breaches leading to intensified flood impact. Barua et al. (2019) highlight the necessity of improved river management that once in a while request to dredge rivers so as not to get too filled with silt and start flooding. Human activities have also exacerbated flooding in Assam, which can happen due to environmental factors that are out of human control. Uncontrolled development of cities has further deteriorated the condition, with improper design for drainage unable to contain water flows during monsoon (Das 2018). Baruah (2019) reported urban flooding as an aftermath of floodplain encroachment and illegal construction which hindered natural water-passing channels. Jha et al. Sarma et al. (2012) also note the issue of urbanisation in escalating flood hazard, particularly for a city like Guwahati where urban sprawl has exceeded drainage infrastructure outcomes. Unlike other natural disasters, the long-term trend of floods in Assam reveals that they have become much more frequent and intense over recent decades. Milly et al. (2002) attribute this rise to increasing global climate change with more erratic weather patterns and increased rainfall. Cl€usler and Kundzewicz (1999) have also claimed that extreme flood events are likely to become more common in regions especially vulnerable such as Assam, because of climate change. Singh et al. (2010) report that the extent of flood-affected areas has been rising between 1954 and 2006 in Assam, which is a clear sign for an intensification and distributional shift towards more widespread flooding. Singh and Bora (2021) alerted that flood pattern has become erratic in Assam with higher frequency of flash floods due to the abrupt heavy rainfall events. More often than not, these flash floods come uninvited causing great loss of life and property (Borah & Nath, 2019). According to Tariq and van de Giesen (2012), an approach of Integrated Flood Management combining traditional embankment structures with modern flood forecasting systems, taking appropriate community-based preparedness measures is required. For example, Barua (2014) recommends ecosystem-based strategies including afforestation and fine tuning wetland systems for natural flood mitigation of the altered landscape in Assam.

The study indicates that floods in Assam are a complex phenomenon which occur due to different causes related environmental (climate change and geological), climatic and

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human induced factors. In Assam, the changing morphology of the Brahmaputra coupled with rampant erosion and sedimentation substantially determine flood dynamics in this region with deforestation and poor urban planning adding to it. The trend also indicates an increased risk of flooding on the background of climate change and anthropogenic pressures, requiring holistic approaches to flood management by means of modern technology supported governance systems and active participation from communities so that sustainable landuse practices are ingrained.

**1.3.Rationale for the study**

The northeast Indian state of Assam has unique location on river Brahmaputra and its tributaries that prone to widespread floods almost every year, the severity of which is severe. Such floods ruin a lot of land which is detrimental to livelihood, infrastructure and agriculture. They are a significant threat not only to the economy of the state. With the increased intensity and frequency of floods owing to climate change and erratic monsoon patterns, there lies an imperative need for an exhaustive appreciation of flood trends and dynamics. Geospatial techniques provide detailed and accurate information about the scale, nature, and pattern of floods in Assam through satellite imagery and GIS tools.This study intends to examine these floods. A thorough evaluation of flood-hazard mapping, their spatial distribution, and trend of flood patterns over many years. The findings will give types and trend of flood disaster that will help management officials and policymakers as useful information that enhance long-term planning, early warning systems, and flood mitigation techniques.

**1.4.Materials and Methods**

To examine the type and pattern of floods in Assam, the study combines hydrological data, geographic information system (GIS) methods, and remote sensing data. Reaourcesat-1 LISSIII sensor, IRS WiFS, IRS P6 AWiFS (56m), and radarsat ScanSAR Wide & Narrow (100m & 50m) over 1998-2007 produced multispectral satellite data of 2005-2006 (NRSC, Hyderabad).

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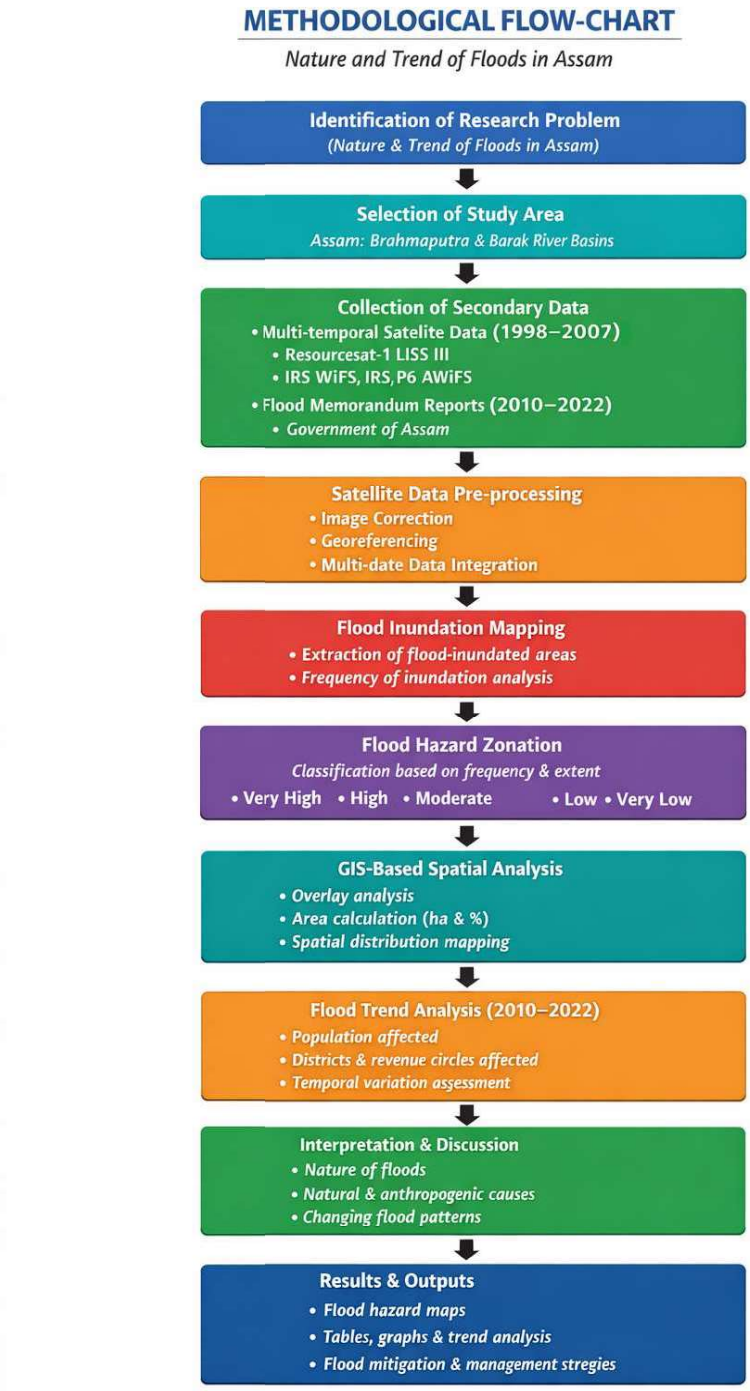


**Figure 1** Methodological flow chart

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Flood is the result of the combination of any of the reaffirms. The decision support center as a first step has generated the Flood Hazard Zonation maps for Assam State based on the flood inundation derived from 10 years of multi-temporal satellite data 1998-2007. The classes of flood hazard is categorized as Very High, High, Moderate, Low and Very Low based on the frequency and extent of the inundation. Recent trend of flood hazard from 2010 to 2022 has been identified based on the Assam flood memorandum report of Government of India shown in the figure 1.

## 1.5.Results and Discussions

### 1.5.1. Nature of Flood in Assam

One of the deadliest history every year are simply flooded in Assam flood waters overflow from their banks due to recurrent inundations make up shaped on account hotspot stream Brahmaputra and monsoon rains. Assam, witnesses annual floods which inflict heavy damage to property and life as well. The Brahmaputra River and its many tributaries-especiallly from advance deforestation of the grasslands in their vast catchment plain over time, leaving huge mountains-snows areas also devoid of natural vegetation and embankments have been major causes for increasing flood problems.

1.5.1.1.Geographical & Climate Insight

The Unique physiography of the Assam state exposes it to frequent floods, The climate is also important factor which intensifies this catastrophes. The state lies deep in the Brahmaputra river valley, along and around both sides of the long low lying floodplains with alluvial flanks together to a length 200 miles (320 km) from east-west direction. High rainfall during the monsoons (June to September) causes rivers discharge, and an extensive over flooding is a common phenomenon in this region (Goswami, 1985). Because of its enormous amounts of sediment and this frequent shifting, the Brahmaputra is prone to large-scale soil erosion on its banks with major loss in property every year (Bhattacharyya, 2001).

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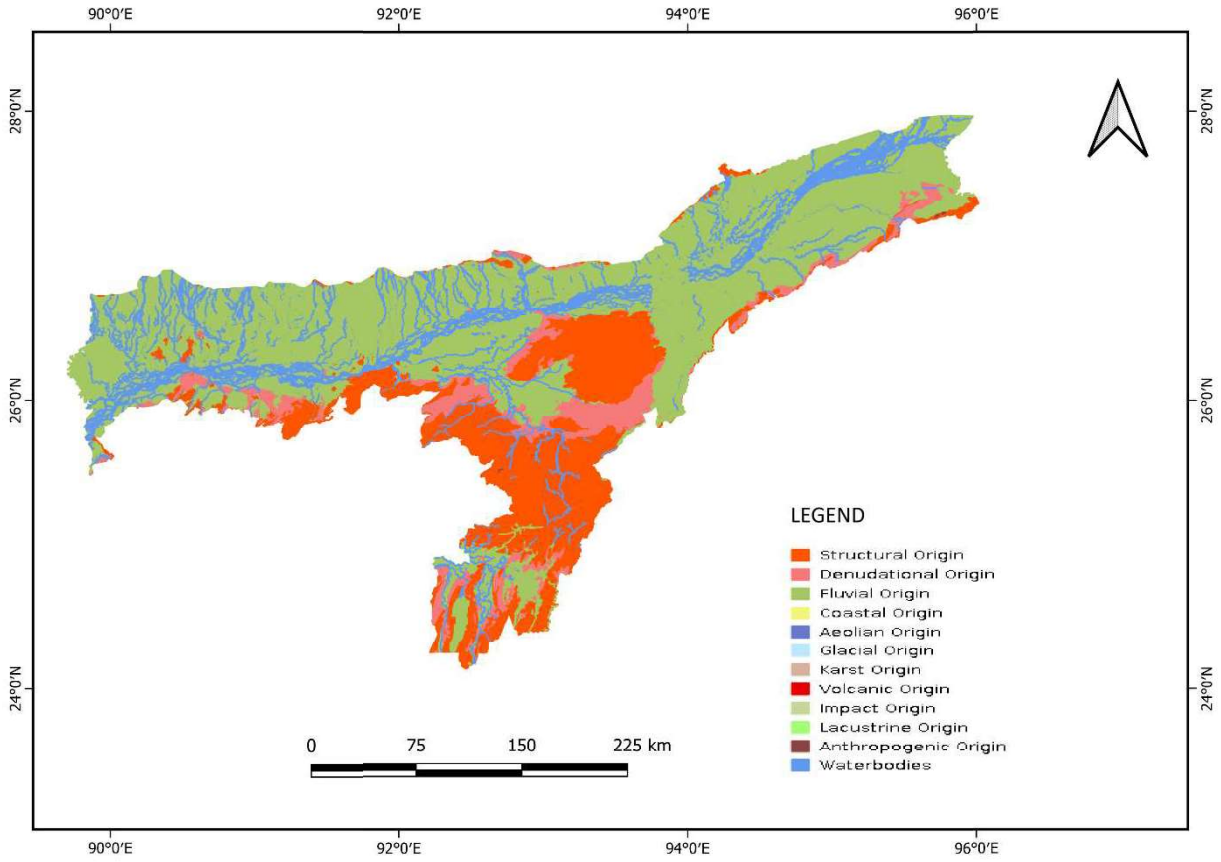


**Figure 2** Geomorphology of Assam

The geomorphological map of Assam (figure 2) highlights the complex landscape of the state, which significantly influences flood patterns. The extensive fluvial origin areas dominate Assam's central and northern regions, which coincide with the Brahmaputra River Basin. These low-lying floodplains, combined with intense monsoon rainfall, create high susceptibility to seasonal flooding. Structural and denudational origins cover southern Assam, particularly in hilly areas. These regions experience high runoff due to steep slopes, contributing to riverine flooding downstream. Sediment deposition from these areas raises riverbeds, reducing water-carrying capacity and worsening floods in the plains. Waterbodies and anthropogenic origins further illustrate the region's vulnerability to flooding. Human interventions like embankments, which disrupt natural drainage,

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exacerbate flood impacts. The interaction of these geomorphological features leads to Assam's frequent and severe flood events, affecting livelihoods and the environment.

1.5.1.2.Types of Floods in Assam

a. Riverine Floods: The most common flood in Assam is riverine floods. The same floods occur when the Brahmaputra River and its tributaries clear their riverbeds because of heavy monsoonal rainfall or due to the melting of the snow in the Himalaya. During such floods, vast expanses of the floodplains are inundated, and this land is submerged in the water along with the agricultural land, villages, and all of the infrastructure that is built on the land. Riverine floods can last for many weeks and can also have a long-term damaging impact on the state's economy and agriculture (Choudhury & Sarma, 1999).
b. Flash Floods: Flash floods occur in Assam's hilly regions, specifically, in the Karbi Anglong, and the North Cachar Hills. The floods are caused by sudden heavy rainfall and quick drainage from the hills to the plains. The floods are mostly localized, but they are also harmful (Sharma, 2012).
c. Embankment-Related Floods: There are many different kinds of flooding. In the world today, we experience too many devastating floods in different kinds. In Assam, there is an extensive network of embankments along the Brahmaputra and its tributaries. These are designed to minimize flooding. However, these embankments fail due to the poor maintenance and high pressure of the water during the flood (Goswami, 2001). Most of the flooded rivers are generally breached under water pressure occasionally in two or three places, depending on the flow of water and the action of the sediments. Just as anything related to flooding, the uncontrollable movement of water spreads to the adjacent areas within a short period and causes devastating destruction.

1.5.1.3.Natural Causes of Flooding in Assam

a. Heavy Rainfall and Monsoon: The monsoon is the major cause of flooding in Assam. The state experiences a heavy rainfall season from the months of June to September emanating from the south-west monsoons which normally results in the

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rivers overflowing above their normal levels. There is also rainfall in the upper catchment areas of the rivers resulting from rain-bearing clouds of Tibet and Arunachal Pradesh. These factors are to blame for flooding in Assam.

b. Dynamism of Rivers and Sedimentation: The Brahmaputra River is an example of a highly dynamic river with a significant impetus to overflow. This river is extremely sediment-filled resulting in more of the riverbeds being raised. Raised riverbeds pose great risks of spillages of the floodwaters. The floods also cause the river flow to shift, thus causing erosion and displacement of encroached communities and agricultural lands. The sediment also causes clogging of the river which impacts negations free flow of water contributing to flooding.

c. Snow and Glacial Melting: The monsoon may not be adequate enough to cause the flooding; however, the currents and water flows in Assam are contributed by the melting of snow and glaciers in the Himalayas during the summer season. The frequent water flows to the plains result in flooding. The snows and glaciers provide an alternative cause of periodically flooding to Assam in areas where there are no monsoons.

1.5.1.4.Human Enhancements to Floods

a. Deforestation: Deforestation in the foothill areas of Assam and the included northern states have resulted in the cutting down of trees and forest cover. Land is no longer capable of absorbing water causing the water to flow on the surface directly to rivers. The river receives the volume at a faster rate causing an element of spilling of the water. Assam's urban expansions have also increased rates of flooding. Buildings have been erected without concern for their proximity to riverbanks (Sharma, 2012).

b. Embankments System: Enhancements such as embankments have been constructed to help in the prevention of floods in Assam. However, they have, instead, resulted in areas where flooding is more intense and difficult to control. The embankments inhibit the flow of floodwaters to the floodplains causing an added impetus on the river bank causing dilapidation (Choudhury & Sarma, 1999).

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c. Climate Change: The rising global temperature is a result of an increase in the greenhouse effect. Tremendous amounts of water vapor are obtained from the added temperature, which flows to the catchment areas to form clouds and subsequently rain. The river accretion in such instances causes flooding (Hirabayashi et al., 2013).

### 1.5.2. Trend of Flood in Assam

a. Flood: 1950: Assam witnessed one of its most catastrophic floods in the year 1950. The flood was triggered by the 1950 Assam-Tibet earthquake which stood at a magnitude of 8.6. This flood changed the course of the river creating a new basin and causing a lot of damage. Siltation raised the river's bed hence increased its susceptibility to future flooding (Bhattacharyya, 2001). The flood affected considerably large areas of Assam, especially the many districts lying on the banks of the Brahmaputra displacing thousands of people and destroying plantations and infrastucture.

b. Flood:1988: Another flood that caused a lot of damage across the entire Assam state was experienced in the year 1988. The floods were as result of excessive rainfall recorded from the month of June to September during that year. The Brahmaputra River and all its tributaries were reported to be full to the brim and were thus overflowing. Many villages were completely submerged in the water and the state agricultural produce dropped by a big margin. The floods revealed that enough developmental measures like construction of dykes and other structures to control flooding and enhance drainage were not present in the region (Goswami, 2001).

c. Flood:1998: The 1998 flood is one of the numerous disasters in Assam's history. A great amount of rainfall has led to the swelling of the Brahmaputra River, which was not able to stay within its banks, covering a record area. The situation below the river was even worse as more 300,000 hectares of agricultural land were destroyed. The number of people who suffered from the flood reached about three million. The event further facilitated the erosion and shifting processes along the river banks, creating new lands and threatening people's safety (Choudhury & Sarma, 1999). Even despite the fact that this event negatively influenced the economy of the country, the relief team arrived only one month after the catastrophe. Thousands of people died, and hundreds

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of people were forced to leave their homes and find safe shelters. It was after the flood that the government made the first important steps to establish the system, which could control the current situation on the river.

d. Flood: 2004: In 2004, the world observed Assam's one of the worst floods for the last decades. It was caused by the constant raining and the swelling of four Brahmaputra and Barak rivers. As a result, about ten million people in 27 districts suffered from the disaster, which made it one of the most disastrous events in the region's history. Hundreds of people died, the roads, and bridges were destroyed, and the Kaziranga National Park became the place of a new tragedy as thousands of its habitants were killed or drowned. The event just inspired the authorities to develop new plans of how to control the disastrous situation.

e. Flood: 2012: The 2012 flood in Assam affected nearly 2 million people and damaged infrastructure and wildlife. Kaziranga National Park was again covered with water, and many animals, including endangered populations, such as the one-horned rhinoceros, were washed out. This accident has evidenced the inefficiency of the flood protection measures realized by the state, such as embankments and flood forecasting system.

f. Floods of 2020: The 2020 disaster was especially detrimental to Assam, and about 5.7 million people were affected by the flood in this state. The floods of that year were provoked by the unceasing rains of the monsoon season whereas the Brahmaputra and other rivers overflowed their banks. The territory adjacent to these rivers remained under water for many weeks, which resulted in the mass evacuation of the population and the destruction of housing, crops, and infrastructure. The 2020 floods took the lives of more than 100 people, and Kaziranga National Park was under water again. This disaster has evidenced once again the urgency of climate-resilient infrastructure in Assam.

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g. Floods of 2022: Assam experienced catastrophic floods in 2022, which were among the worst in recent history. Over 190 people lost their lives, and millions were displaced across several districts. Entire villages were submerged, roads were washed away, and critical infrastructure was severely damaged. The state's agriculture sector suffered a heavy blow, with rice paddies and other crops destroyed by the floodwaters (Borah, 2022). The 2022 flood raised concerns about the increasing frequency and intensity of floods in the region, exacerbated by climate change. The figure 3 depicts the percentage of the population in Assam affected by floods from 2010 to 2022. A clear trend of increasing flood impact is visible over time, with significant variability between years. Notable observations include:

i. **2010-2013:** The population affected fluctuated, peaking at 29.14% in 2012, followed by a sharp decline to 8.48% in 2013.

ii. **2014-2018:** After a significant low in 2014 (4.04%), the affected population rose sharply, reaching a peak of 73.55% in 2018. This suggests that flood severity and spread increased dramatically during this period.

iii. **2019-2021:** There is a significant drop in 2019 (13.22%), but it rebounded in 2020 with 57.89%. The year 2021 saw a notable decline (9.1%).

iv. **2022:** The highest percentage of the population affected is recorded in 2022, with 88.51%, indicating a particularly severe flood event.

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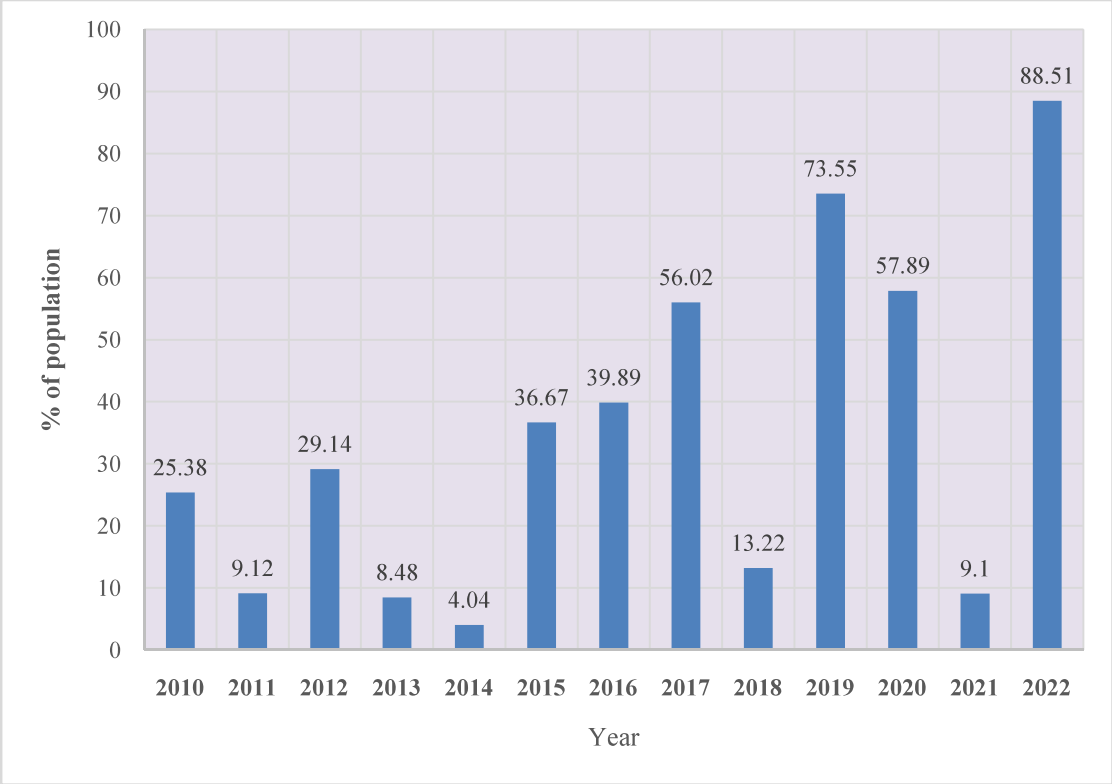


Source: Assam Floods, 2022, Flood Memorandum to the Government of India

**Figure 3** Percetage of population affected by flood in Assam (2010 to 2022)

This data reflects the increasing flood vulnerability in Assam, likely linked to geomorphological factors, climate change, and intensifying monsoon patterns. The table 1 provides data on the number of districts affected and the number of revenue circles affected for the years 2010 to 2022.

1. **General Trend:** The number of districts affected mostly fluctuates between 2 and 3, with the lowest being 1 district (in 2011) and no values greater than 3. The revenue circles affected show more variation, ranging from 37 (in 2011) to 156 (in 2022).

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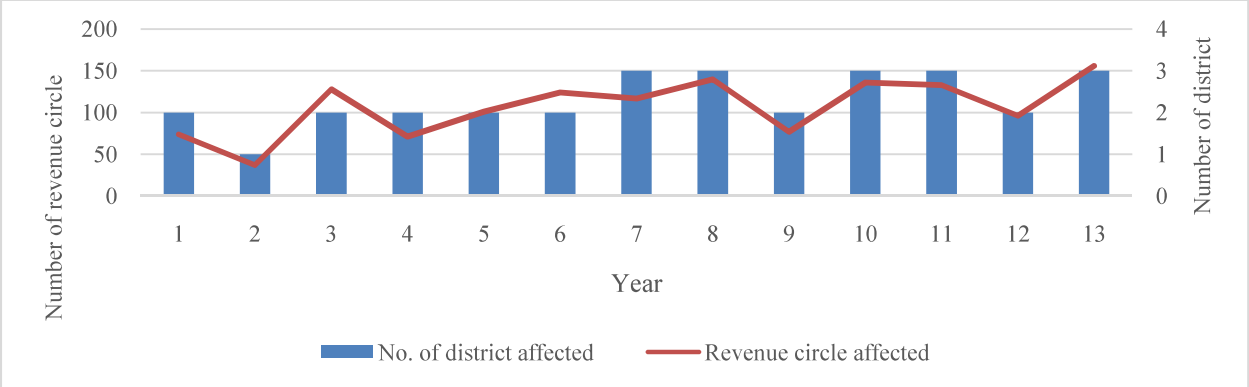
**Table 1 Number of districts affected and revenue circle affected**

| Year | No. of district affected | Revenue circle affected |
|---|---|---|
| 2010 | 2 | 74 |
| 2011 | 1 | 37 |
| 2012 | 2 | 128 |
| 2013 | 2 | 71 |
| 2014 | 2 | 101 |
| 2015 | 2 | 124 |
| 2016 | 3 | 117 |
| 2017 | 3 | 140 |
| 2018 | 2 | 77 |
| 2019 | 3 | 136 |
| 2020 | 3 | 133 |
| 2021 | 2 | 96 |
| 2022 | 3 | 156 |

Source: Assam Floods, 2022, Flood Memorandum to the Government of India




Source: Assam Floods, 2022, Flood Memorandum to the Government of India

**Figure 4** Number of District and Revenue Cirle Affected by the Flood (2010-2022)

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2. **Notable Years:** 2011 stands out with only 1 district affected and the lowest number of revenue circles affected (37). This suggests a relatively low impact during that year. 2022 records the highest number of revenue circles affected (156), with 3 districts affected, marking it as a year with significant impact. 2012, 2017, 2019, and 2020 also show high numbers of revenue circles affected, ranging from 128 to 140, despite some of those years affecting fewer districts.
3. **Increasing Impact:** Over the years, there seems to be a general increase in the number of revenue circles affected, especially from 2016 onward, with most years reporting figures well over 100.
4. **Years with Lower Impact:** Apart from 2011, the years 2013, 2018, and 2021 show relatively lower numbers of revenue circles affected, with values below 100, despite the districts affected remaining at 2 or 3.

The figure 4 suggests a fluctuating but generally increasing trend in the number of revenue circles affected over time, especially from 2016 to 2022. The number of districts affected generally ranges between 2 and 3, indicating a stable geographic spread, while the severity in terms of revenue circles affected tends to increase over the years.

### 4.5.3 Flood Hazard mapping

The flood hazard map (figure 5) of Assam visually represents the flood-prone areas categorized into various levels of risk, including **Very High, High, Moderate, Low,** and **Very Low** flood hazards. This map provides essential insights into the geographical distribution of flood risk in the region, mainly driven by the Brahmaputra River and its tributaries. This hazard zonation mapping was done by NRSC, Hyderabad, India based on flood inundations in Assam derived from ten years of multi-spectral satellite data 1998-2007.

The **Brahmaputra River**, depicted as normal river and water bodies, dominates the floodplain areas of Assam. Most regions adjacent to the river and its tributaries face a **very high flood hazard** .These regions, primarily along the central Assam plain, are frequently inundated during monsoons, affecting both urban and rural settlements.

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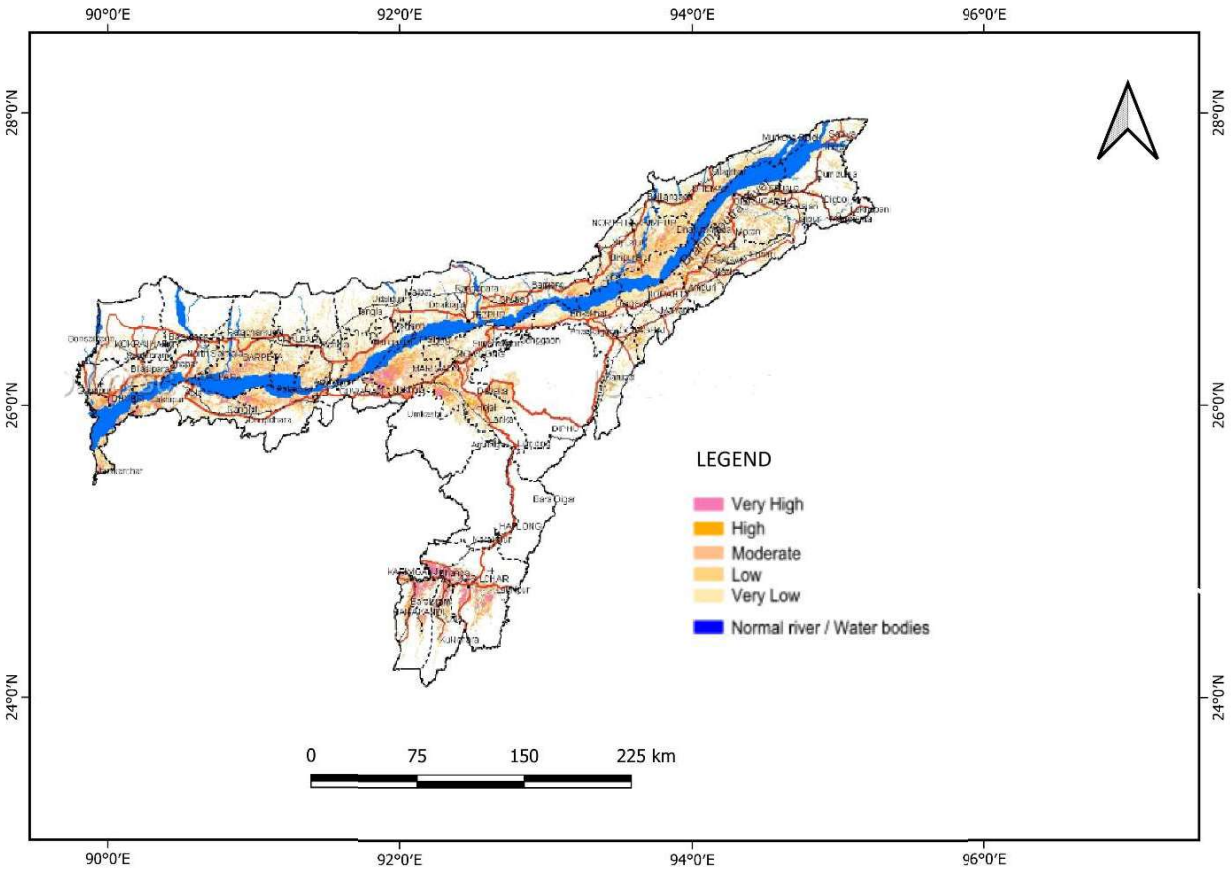
The **high-risk zones** spread outwards from the very high-risk regions and include districts that remain vulnerable to seasonal floods. The **moderate-risk zones** surround the high-risk zones, acting as a transitional buffer toward less flood-prone areas. **Low** and **very low-risk zones** indicate regions farther from the riverbanks, generally located on elevated terrains or hilly areas, which experience minimal to no flooding. Flooding in Assam is primarily attributed to heavy monsoonal rains, the swelling of the Brahmaputra River, and the state's topography. The flat floodplains with rivers that carry immense silt loads lead to frequent breaches of embankments and inundation of large tracts of land .




Source: NRSC, Bhuvan Geoportal, Hyderabad

**Figure 5** Flood hazrd mapping of Assam

**Table 2** Distribution of flood hazard area in Assam

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| Hazard Severity | Flood Hazard Area (ha) | % of Flood hazard (wrt State Geographic Area) | % Flood Hazard (wrt Total Flood Hazard Area) |
|---|---|---|---|
| Very High | 1,28,687 | 1.64 | 5.79 |
| High | 2,24,629 | 2.86 | 10.11 |
| Moderate | 3,51,667 | 4.48 | 15.83 |
| Low | 4,91,761 | 6.27 | 22.14 |
| Very Low | 10,24,584 | 13.06 | 46.13 |
| **Total** | **22,21,328** | **28.31** | **100** |

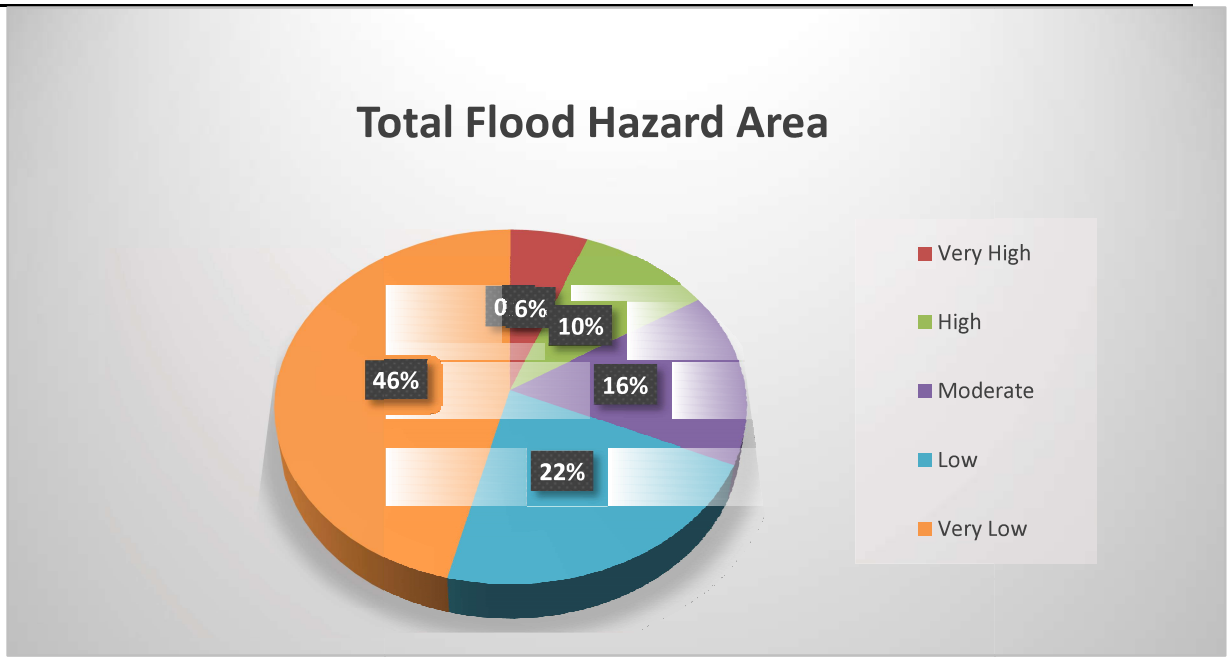


**Figure 6** Flood hazard Area

The table 2 presents the distribution of flood hazard areas in Assam based on hazard severity. About **28.31%** of Assam's geographic area (22,21,328 ha) is flood-prone. Of this, the **very low hazard** category covers the largest area, accounting for **46.13%** of the total flood hazard area, while the **very high hazard** areas make up only **5.79%.** Moderate and low hazard areas account for **15.83%** and **22.14%** respectively, while high hazard zones

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represent **10.11%** of the total flood hazard area (figure 6). Overall, flood risk is distributed unevenly, with most areas falling under low to very low hazard, but a significant portion remains at higher risk.

## 1.6.Recommendations

1.6.1. **Adopt Integrated Flood Management (IFM) instead of embankment-only solutions:**

The article emphasizes that reliance on embankments alone has proven inadequate due to frequent breaches and poor maintenance. A holistic flood management approach combining structural measures (selective embankments, river training) with non-structural measures such as flood forecasting, land-use regulation, and community preparedness is strongly recommended.

1.6.2. **Promote afforestation and ecosystem-based flood mitigation**

Deforestation in upper catchments has significantly increased surface runoff and sediment load in rivers. The study recommends large-scale afforestation, wetland restoration, and protection of natural floodplains to enhance water retention capacity and reduce flood intensity naturally.

1.6.3. **Strengthen use of GIS and Remote Sensing for flood forecasting and planning:**

The article highlights the effectiveness of GIS and Remote Sensing technologies in flood hazard zonation, real-time monitoring, early warning systems, and damage assessment. Expanding these technologies can support scientific planning, timely evacuation, and long-term mitigation strategies in flood-prone areas of Assam.

1.6.4. **Ensure climate-resilient infrastructure and regulated urban development:**

Unplanned urbanisation and poor drainage systems have aggravated flooding, especially in cities like Guwahati. The study recommends climate-resilient infrastructure, improved drainage networks, and strict control over floodplain encroachment to reduce future flood losses.

## 1.7.Conclusions

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The floods in Assam have become more frequent and severe in the past years. They are caused by the state's geographical, climatic, and human factors. The Brahmaputra and Barak river systems, which have heavy monsoonal rainfall and erode substantial amounts of alluvial soil from the Himalayas and other structures and silt in their path, make the state's climatic conditions highly susceptible to floods. Moreover, with climate change, the floods have turned into an all year around phenomena due to erratic and never seen before rainfall patterns, where the rain most of the time is unpredictable and comes in sudden and bursts. The river also has more water volume now with the help of faster glacier melting from the Himalayas. The natural drainage basins have been concreted in the process of unplanned urbanization, construction of embankments, and deforestation, and it has deteriorated the situation further, increasing the area of damage from the floods. This results in the state losing billions of rupees each year, displacement of millions of people, submergence of millions of acres of agricultural land, and destruction of infrastructure. Moreover, it increases the risk of soil erosion, decrease in the number of the types of flora and fauna unique to the region, and water-borne diseases. Therefore, the problem of increased frequency and severity of flood needs a broader solution than the construction of embankments or the development of early warning systems, and the authorities and the locals alike need to act in conjunction to improve the situation. The technologies mostly used in flood management in Assam are Geographic Information Systems and Remote Sensing. Thus, these systems are beneficial in mapping the areas party facing floods and the places that are generally flood-prone. Moreover, it is quite effective in conducting the analysis of land use for the planning of suitable measures as well as helps to reduce the destructiveness. It is possible due to the provision of the spatial data including topographical and river system information, while RS can be applied to real-time monitoring of activities and events from space. Further, they allow to re-analyze the data and conduct the forecasting of the same. They also support the process of damage assessment and planning of rescue operations before the beginning of the season.

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