

Role of Natural and Anthropogenic Factors in Causing Frequent Floods in Assam, India: A Scoping Review

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Abstract

Assam is a state in Northeast India facing floods every year which leads to human misery and devastation of nature. The objective of this review is to explore the natural and anthropogenic factors causing flood in Assam over a period of 11 years. The SCOPUS, Science Direct, and Web of Science databases were searched to identify relevant studies in Assam. The outcome of interest was to identify the natural and anthropogenic factors that contributed to the occurrence of floods in Assam from 2010 to 2020. Data were charted and reported in accordance with the "PRISMA guidelines." From 1582 screened citations, 54 articles went under full-text screening, among which 35 studies were eligible for this review. Rainfall events, climate change, urbanization, deforestation, improper drainage and embankment construction contributed most. This review concludes that anthropogenic factors outweigh the natural factors for flood occurrence in Assam.

Keywords: Anthropogenic factors, Assam, catastrophic floods, floods, India, natural disaster, natural factors

INTRODUCTION

Assam, India's largest state in the north-eastern region, is one of the states ravaged by floods. The river Brahmaputra flows through Assam and is called "the sorrow of Assam" due to its tendency to flood, which comes with heavy detriment and destruction. It all commenced with the massive earthquake that devastated Assam in 1950. Along with claiming human lives, it also resulted in changing the course of the Brahmaputra river. The aftermath of the earthquake had an impact on the river; however, over the years, the problem was accentuated by both natural and man-made interferences. According to the Assam State Disaster Management Agency's daily flood update, 5.69 million people have been affected by the monsoon in Assam, flooding 30 of the 33 districts as of August 2020.^[1] Apart from this, the floods have also affected the wildlife, as the Kaziranga National Park was almost entirely submerged. According to the Rashtriya Barh Ayog, around 40% of Assam's total land is flood-prone, and the state accounts for 9.4% of India's total land area vulnerable to floods.^[2]

The problem of flooding in the state has been recurring, and the aftermath of the disaster is only getting worse. This

region is hit by floods every year, and the causes are known to be both natural and anthropogenic. Many studies have identified the causes of flooding as natural and manmade, but the crux of these findings is focused on the impact and management measures that occur due to the event. These concerns are related to human health, infrastructure, affected individuals' socioeconomic well-being, and damage to the health-care system. There is a need to explore each of the factors contributing to the occurrence of floods in the state.

Therefore, the current scoping review was undertaken to explore the contribution of various natural and anthropogenic factors in causing floods in Assam. This will help in the planning of policy or intervention to prevent the damage to

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life and property caused by frequent floods in the state and the optimal allocation of limited resources.

METHODS

The review protocol was developed using a scoping review framework.^[3] The process included the following steps: (1) identifying the research question and purpose; (2) identifying relevant articles; (3) selecting articles for inclusion; (4) extracting data from included articles; and (5) summarizing, analyzing, and reporting results.

Identifying the research question

The question that guided this scoping review was: “What are the factors, natural or anthropogenic, responsible for the yearly occurrence of floods in the state of Assam?”

Identifying relevant studies/search strategy

Three electronic databases were included: SCOPUS, Science Direct, and Web of Science. The literature search was limited from 2010 to 2020 (11 years) using the keywords “flood factors” (“rainfall” OR “cloudburst” OR “watershed” OR “urbanisation” OR “encroachments” OR “deforestation” OR “dams”) AND (“factors” OR “cause” OR “floods”); location (Assam); and time frame (“2010” to “2020”). Additional literature was searched in the references of screened full-text articles.

Inclusion and exclusion criteria

Review articles, case studies, viewpoint papers, cross-sectional studies, case–control studies, cohort studies, literature reviews, narrative reviews, systematic reviews, meta-analyses, and rapid reviews were included in this review. Studies with full-text access and clear statements of association between flood factors and flood occurrence were included. Other criteria included articles in English and any studies published from 2010 to 2020.

Study selection

All the references meeting the inclusion criteria were imported into the EndNote X9 software. A three-stage (title, abstract, and full-text) screening and data extraction were done independently by two authors, with arbitration by a third author. The substance of the eligibility criterion was examined in terms of linkages drawn between the flood factors and the occurrence of floods in the state of Assam. The reviewers discussed the screening results in order to establish a consensus on which items should be included in the final list.

Data extraction

The data were encoded in a single Microsoft Excel 2013 worksheet (Microsoft Corporation, Redmond, WA, USA). The data were organized into a data-charting form to ensure a uniform approach. All the data collected were categorized into emerging themes and key issues within the conceptual framework. Key features of each study included authorship, article title, year of publication, geographical context,

methodological characteristics, and natural and anthropogenic factors.

COLLATING, SUMMARIZING, AND SYNTHESIZING THE RESULTS

Searches of the three electronic databases identified 1582 studies (Science Direct: 1310; Scopus: 224; and Web of Science: 48). Overall, 1150 articles were excluded as duplicates, after which 432 studies were examined. The 432 studies were retrieved, and initially, the titles and abstracts were reviewed. A majority of the 387 articles were omitted since they were not related to the study area. A total of 45 studies passed the abstract screening. Following a review of the full-text, 25 studies were deemed to have no mention or explicit association with flood-causing factors, not limited to the state of Assam, and their findings were not relevant to this study. Fifteen studies were retrieved from references found in the selected articles. Thus, this review included a total of 35 studies for the final data extraction [Figure 1].

RESULTS

General characteristics of the included studies

Among the included studies, 54% ($n = 19$) were published in the last 5 years of this current study (2016–2020), and the remaining were published between 2010 and 2015. In terms of geographic location, 37% ($n = 13$) of the studies included Guwahati city, while the rest included other districts of Assam. About 85% ($n = 30$) of the studies were published articles, 6% ($n = 2$) were reports, 6% ($n = 2$) were conference papers, and 3% ($n = 1$) were a working paper.

Methodological characteristics of the included studies

The studies in this scoping review included 26% ($n = 9$) mixed methods, 20% ($n = 7$) secondary data analysis, 20% ($n = 7$) literature reviews, 14% ($n = 5$) qualitative studies, another 14% ($n = 5$) statistical analysis, and 3% ($n = 1$) a case study and a working paper. Statistical tests like the Mann–Kendall trend test and the Analytical Hierarchy Process, in-depth interviews, semistructured interviews, focus group discussions, surveys, observation questionnaires, remote sensing, and GIS mapping were performed as measurement methods to collect data in the included qualitative and mixed methods studies. Based on the nature of the factors assessed, the characteristics of the included studies are represented in Table 1.

Among all the studies included, 40% ($n = 14$) of the studies identified both natural and anthropogenic factors contributing to floods in Assam, 37% ($n = 13$) of the studies identified only anthropogenic factors, and 22% ($n = 8$) of the studies identified only natural factors as responsible for flood occurrence in the state.

The articles in this review explored or reported on a number of factors that contribute to the occurrence of floods in Assam. Figure 2 represents the reported natural factors and

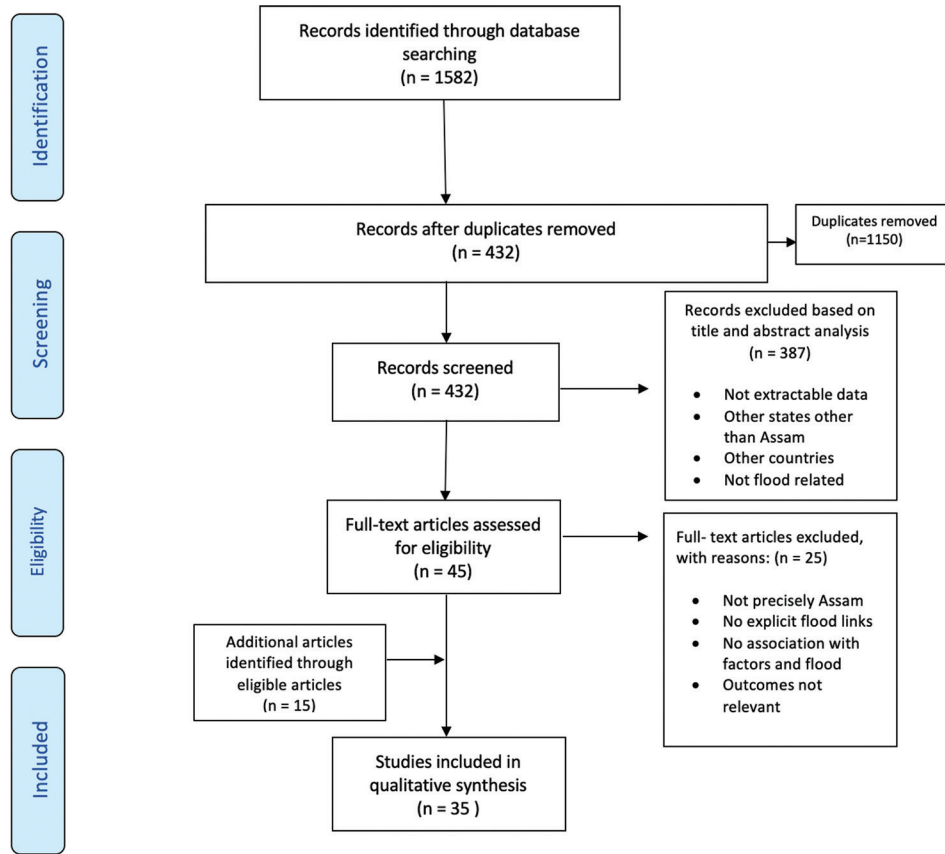


Figure 1: Flowchart illustrating the number of records identified through initial searches, then processed through relevance and eligibility screening

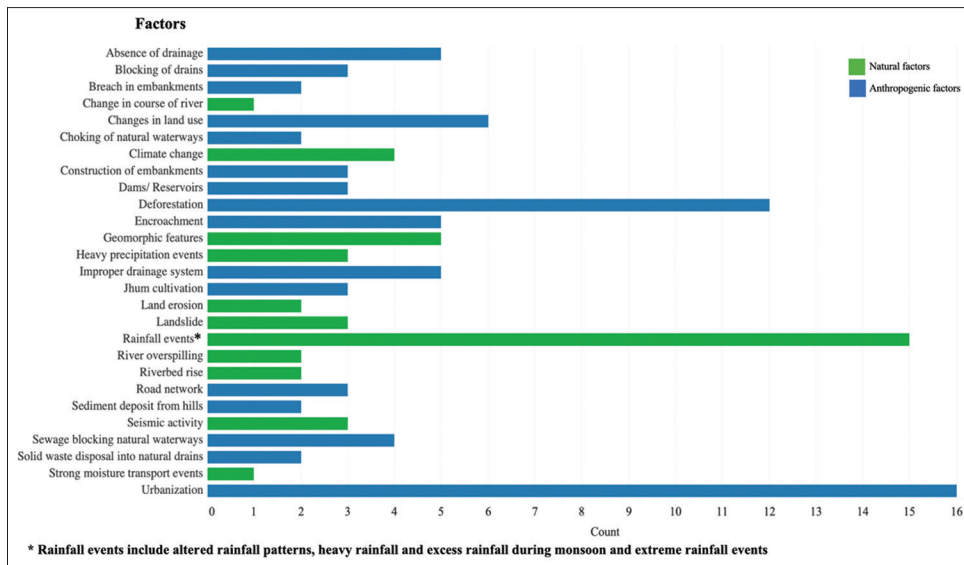


Figure 2: Distribution of factors assessed in the included studies (count)

anthropogenic factors contributing to flood occurrence from the included studies.

It can be seen that urbanization accounts for 45.7% ($n = 16$) of the reported factors, followed by rainfall events at 42.8% ($n = 15$), deforestation at 34.2% ($n = 12$), and changes in land use at 17% ($n = 6$) of all the factors retrieved. Geomorphic

features, an absence of drainage, an inefficient drainage system, and encroachments, each of which accounts for 14.2% ($n = 5$) of the listed factors.

The year-wise distribution of identified factors causing floods in Assam, both natural and anthropogenic, is depicted in Figure 3. The initial years reported only natural factors,

Table 1: Characteristics of factors in the included studies

Nature of factors assessed	n	Reference and study design						
		Mixed-method study	Secondary data analysis	Qualitative	Statistical analysis	Literature review	Working paper	Case study
Natural	8		[4-6]	[7-9]	[10,11]			
Anthropogenic	13	[12,13]	[14,15]	[16]	[17,18]	[19-22]	[23]	[24]
Both natural and anthropogenic	14	[25-30]	[31]	[32]	[33]	[34-36]		

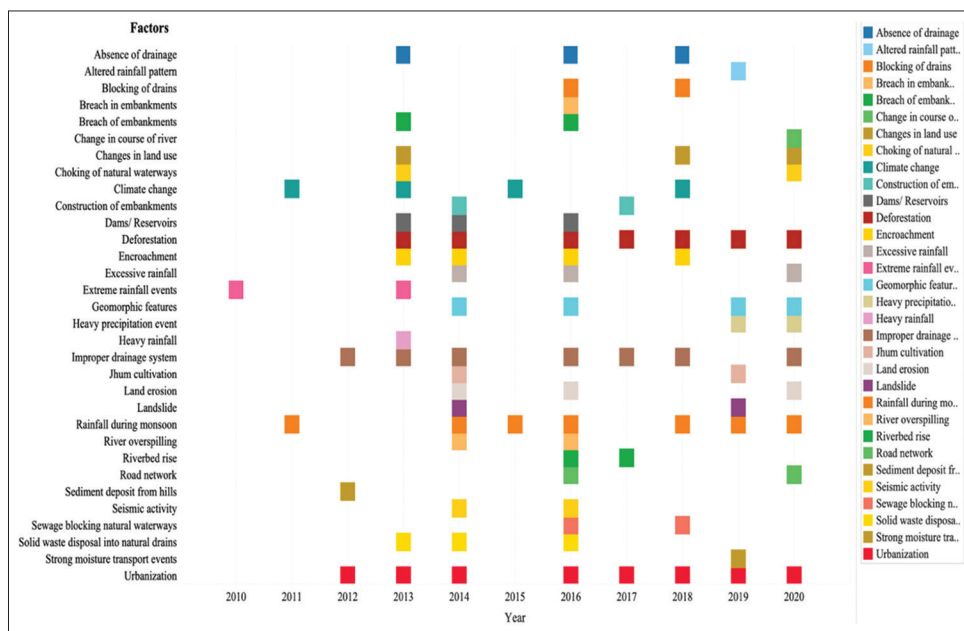


Figure 3: Year-wise distribution of identified factors causing floods in Assam

but many anthropogenic factors were reported over the years.

Natural factors assessed

Figure 4 represents all the natural factors reported in the included studies. The main natural factors reported are:

Climate change and rainfall events

Among the natural factors identified, four studies include climate change and changing weather patterns,^[7,37-39] which resulted in heavy downpours and altered rainfall patterns.^[4,5] Rainfall during the monsoon season,^[6,8,9,38,39] nature being extreme and excessive or heavy rainfall,^[10,11,16,17,19-21,24] and heavy precipitation events^[12,16,22] were discovered to be major factors in the occurrence of floods in the state. It was also discovered that, while overall seasonal rainfall was decreasing, extreme rainfall events were increasing,^[10,21] resulting in more rainfall in a short period of time, which is a contributing factor to urban flooding. One study discussed strong moisture transport in association with heavy precipitation events having a widespread link to floods.^[22]

Geomorphic features and changes in the course of the river

Other factors that contribute to flooding include geology and geomorphology,^[5,9,11,19] the contour and slope of the

region (steep slopes and easily erodible rocks), and changes in river course.^[23] Due to the unique topography of the state, extreme rain events result in flash flooding due to the unique topographic feature of the state.^[10]

Seismic activity, landslides, and erosion

The studies identified that the river bed rises^[13,19] due to landslides,^[9,11,20] and large amounts of sediment and silt deposits flow into the river water, which in turn results in the river overspilling^[18,20] and causing a flood. In addition, it was found that seismic activity,^[11,19,20] which results in landslides^[11] and land erosion,^[19,23] is responsible for pushing the soil and debris into the river, which raises the river bed and causes floods.

Anthropogenic factors assessed

Figure 5 depicts all the anthropogenic factors reported in the included studies, and the important ones are as follows:

Urbanization

Among the identified studies, 16 identified urbanization as the major factor responsible for floods in Assam.^[4,5,7,11,14,15,17,19-21,24,25,33,34,39] Urbanization of flood-prone sites, squatter settlements, and improper construction at the core of the city are responsible for floods.^[17,34] Flood occurrence in the state has been exacerbated by unplanned urbanization, particularly in the hills and lowlands, as well as remarkable

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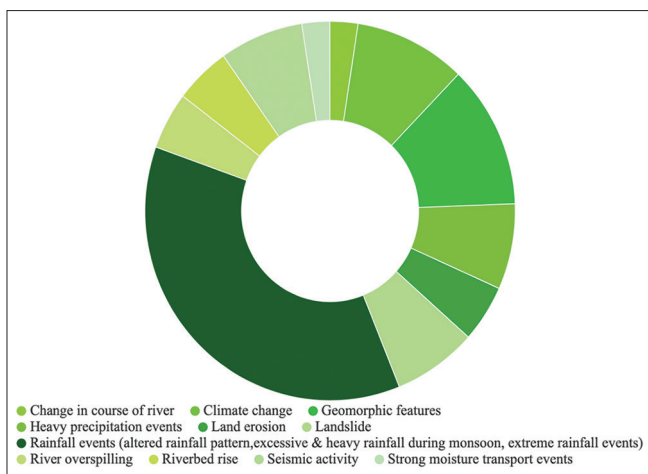


Figure 4: Natural factors assessed in the included studies

population expansion in plain areas and flood-prone belts with densities exceeding 200 people per square kilometer.^[7,11,15,17]

Deforestation

Deforestation was identified as a factor responsible for flood occurrence in 12 of the included studies.^[9,11,16,17,19-21,26-28,31,35] The extent of the negative impacts and the intensity of floods are both significantly influenced by forest cover. The presence of trees acts as a natural flood control measure.^[31] Tree roots absorb water and help keep soil in place (reducing erosion and anchoring topsoil). Massive erosion and destruction of hills has resulted from hill cutting for development and illicit tree felling, resulting in flash floods.^[9,27]

Drainage system

Five studies identified an improper drainage system,^[15,19,20,24,25] and five studies identified the absence of a drainage system as the reason for flooding.^[11,21,26,28,39] The studies identify the inadequate design of the drainage system and blockage of the natural drainage system (NDS) due to human activities like garbage dumping and the construction of roads, bridges, railway tracks, and buildings,^[15,19,25] which result in flooding and improper drainage management.^[24] Flooding is caused by a lack of adequate gradient to drain excessive river discharge, increased silt load due to deforestation, and landslides.^[11,28]

Land use changes, “Jhum cultivation,” and sediment yield

Six studies identified changes in land use and land cover as a factor in flood occurrence caused by external factors and constructions.^[5,11,16,17,24,34] Three studies identified the practice of shifting cultivation to “Jhum” as a factor.^[11,20,29] This shifting of cultivation accelerates soil erosion and accentuates the variability of rainfall, leading to flooding. Another study identified that sediment yield from surrounding hilly areas is a major factor that leads to flooding of the areas located in the plains.^[14,25]

Encroachments and embankments

Among the included studies, five studies identified unplanned developmental activities leading to the

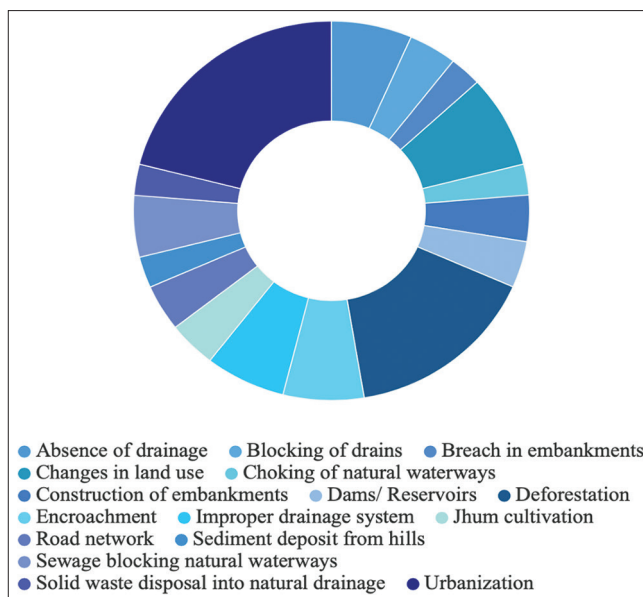


Figure 5: Anthropogenic factors assessed in the included studies

encroachment of natural reservoirs. Flooding was exacerbated by encroachments caused by unplanned land-use practices.^[11,19,21,26,34] Three studies discussed how the construction of embankments raises the river bed further as the silt that was earlier spread out in the flood plain gets deposited inside the river channel, causing floods, and how the construction of sluices has restricted the natural flow of water, forcing it to break the embankments and cause floods.^[13,19,20] Floods caused by a sudden breach of embankments or failure of embankments were discussed in two studies as being far more damaging than normal floods or floods caused by rivers spilling.^[18,28]

Blocking of drains and natural waterways

The studies discovered sewage and other human activities clogging and blocking natural waterways.^[5,7,21,25,26,39] Solid waste disposal into drains and wetlands resulted in the choking of the natural waterways, resulting in flooding.^[21,26] Two studies discussed the blockage of drains with sediments brought down from the inhabited hills that are exacerbating urban floods.^[14,25]

Dams, reservoirs, and the road network

Three studies identified improper and unplanned construction of dams and reservoirs, resulting in dam-induced flooding in the state.^[20,32,36] Unleashing the dam resulted in a problem of artificial flooding and environmental degradation, making the surrounding areas vulnerable.^[36] This release of water for the operation of the project can create dam-induced floods in the downstream areas along with impacts on river flows, leading to extensive flooding.^[32] Three studies identified the improper construction of roads and road networks (arterial, subarterial, collector, and local street network), leading to congestion and inadequate drainage capacity. Drainage congestion accelerated floods.^[5,19,26]

DISCUSSION

Many factors have been identified as contributing to the occurrence of floods in Assam. Studies have identified that natural factors coupled with human activities have accelerated the flood situation, inflicting large-scale devastation on the people and destruction of the environment with little or no mention of all the factors as a whole.^[11] However, in a consolidated manner, this study discussed in detail each of the factors identified as causing floods in the state. Assam has put in place several measures to mitigate the occurrence of floods due to both natural and man-made factors.^[30]

In general, based on the findings of the review, there is a reasonable understanding of what the causes of flooding are. Most studies address rainfall events, geomorphic features, urbanization, deforestation, and inefficient drainage management. Many of the studies have been written after carrying out flood investigations, while others are reviews. There is less certainty in the assessment of the causes where field investigations have not been carried out, but the causes are relatively obvious in many instances.

Apart from heavy rainfall events, especially during the monsoon season, geomorphic features of the state and urbanization are unsurprisingly the most common anthropogenic flooding causes. Improper construction of road networks, drainage systems, and dams is frequently reported as exacerbating the state's flood trend, particularly during heavy rainfall events, and the urban environment naturally contributes to the flood situation.

Deforestation is another major concern. Cutting down trees and destroying wetlands for reasons such as development and “Jhum” cultivation practices is having a negative impact on the flood control mechanism. Forest cover and wetlands conservation are believed to be essential for flood control because trees help keep soil in place, their roots soak up water (reducing erosion and anchoring topsoil), and they operate as a natural flood control technique.

Another factor identified was the construction of embankments, which further raise the river bed due to the silt that was once widely distributed, now gets trapped in the embankments. Furthermore, the failure or breach of embankments is said to be more damaging than floods caused by the river's natural process of overflowing.^[18,28]

Solid waste disposal and sediment deposits result in the blocking of drains, and these blockages of the NDSs can result in flooding in the surrounding areas. Similarly, due to the rapid accretion of debris that occurs due to heavy rainfall, this can result in river bed rise and river overflow, resulting in flooding near the river bed areas. In some catchments, there is limited provision for drainage of the runoff, which leads to many instances of urban flooding. For example, an inadequately sized drainage system causes floodwater to flow into roads from adjacent lands.

Studies also identified flooding due to improper construction and management of dams and reservoirs. Unleashing the dam resulted in problems of artificial flooding and environmental degradation, making the surrounding areas flood-prone. In Assam, dams were built to generate hydroelectric power but not as a measure to control floods, and in recent years, Assam faced dam-induced flooding that caused immense destruction to human lives, property, and wildlife due to the ill-planned engineering of dams and embankments. Local communities now believe that the unreliability of the deteriorating infrastructure is the primary source of their unrelenting flood and drainage problems, as per the Flood and Riverbank Erosion Management report.^[30]

It is identified from the review that anthropogenic factors outweigh the natural factors for flood occurrence in Assam, causing immense loss of life, destroying livelihoods, and affecting wildlife. This makes flooding a public health problem, and it leads to communicable diseases, the loss of lives, damage to health-care infrastructure, transportation, inaccessible health services, hampering the economy, and affecting the mental health of the people. The increase in the intensity of floods is also leading to population displacement in flood-prone areas. Floods were once thought to be a good thing because they enriched the soil and increased biodiversity, but they wreaked havoc over time. We surely cannot control the occurrence of floods, but we can prevent them from becoming disasters by planning better mitigation efforts and strategies.

CONCLUSION

Floods are an annual calamity in the state of Assam, caused by a variety of natural and anthropogenic factors. All the factors responsible are interlinked. The causes of floods vary and might require different control strategies. There is a need for further research to demonstrate the impacts and effects of floods and the factors causing floods on human health-related outcomes and to provide better data for understanding population vulnerability. There is also a need for further research to assess the adaptation of the vulnerable communities to each factor contributing to floods, with added emphasis on the integration of region-specific information.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Prasad E. Floods: The Need for Critical Engagement with Floods in India – Gaon-Connection: Your Connection with Rural India; 2020.

- Available from: <https://en.gaonconnection.com/floods-2020-the-need-for-critical-engagement-with-floods-in-india/>. [Last accessed on 2021 Mar 01].
2. Bhattacharyya R. Assam Devastated by Floods Again. The Diplomat for the Diplomat; 2020. Available from: <https://thediplomat.com/2020/07/assam-devastated-by-floods-again/>. [Last accessed on 2021 Mar 01].
 3. Arksey H, O'Malley L. Scoping studies: Towards a methodological framework. *Int J Soc Res Methodol* 2005;8:19-32.
 4. Paul A, Deka J, Gujre N, Rangan L, Mitra S. Does nature of livelihood regulate the urban community's vulnerability to climate change? Guwahati city, a case study from North East India. *J Environ Manage* 2019;251:109591.
 5. Sarmah T, Das S, Narendra A, Aithal BH. Assessing human vulnerability to urban flood hazard using the analytic hierarchy process and geographic information system. *Int J Disaster Risk Reduct* 2020;50:101659.
 6. Ray MR, Sarma AK. Minimizing diurnal variation of downstream flow in hydroelectric projects to reduce environmental impact. *J Hydro Environ Res* 2011;5:177-85.
 7. Sharma D, Singh R, Singh R. Urban Climate Resilience: A Review of the Methodologies Adopted Under the ACCCRN Initiative in Indian Cities. London, UK: International Institute for Environment and Development; 2013.
 8. Mahanta C, Enmark G, Nordborg D, Sracek O, Nath B, Nickson RT, et al. Hydrogeochemical controls on mobilization of arsenic in groundwater of a part of Brahmaputra river floodplain, India. *J Hydrol* 2015;4:154-71.
 9. Barbhuiya MA. The problem of annual occurrences of floods in Assam, the role of administrative bodies responsible for managing disasters and the quality of risk mitigation and rehabilitation. *Int J Res Appl Sci Eng Technol* 2019;7:737-40.
 10. Goswami BB, Mukhopadhyay P, Mahanta R, Goswami BN. Multiscale interaction with topography and extreme rainfall events in the Northeast Indian region. *J Geophys Res Atmos* 2010;115:D12114.
 11. AIDMI. Review of Studies on Urban Floods in Guwahati-from Flood Knowledge to Urban Action. Guwahati: Assam State Disaster Management Authority (ASDMA); 2014. Available from: <http://sdmassam.nic.in/download/Guwahati%20floods.pdf>. [Last accessed on 2021 Mar 01].
 12. Mandal R. Cropping Pattern Choice and Risk Mitigation in Flood Affected Agriculture: A Study of Assam Plains, India. Silchar, Assam: SHSU Economics & Intl. Business; 2014.
 13. Mahanta R, Das D. Flood induced vulnerability to poverty: Evidence from Brahmaputra Valley, Assam, India. *Int J Disaster Risk Reduct* 2017;24:451-61.
 14. Barman P, Sarma B, Sarma AK. A study on flood hazard mitigation of Guwahati city. *Asia Rev Civ Eng* 2012;1:9-14.
 15. Mili N, Acharjee S. Urbanisation in Dibrugarh district: An important driver of environmental degradation. *Asia J Spat Sci* 2014;2:57-67.
 16. Datta P, Bose S. Assessing the changes in climate extremes over Karbi Anglong district of Assam, North-East India. *Spat Inf Res* 2020;28:547-58.
 17. Gogoi L. Degradation of natural resources and its impact on environment: A study in Guwahati city, Assam, India. *Int J Sci Res Publ* 2013;3:1-7.
 18. Hazarika N, Tayeng T, Das AK. Living in troubled waters: Stakeholders' perception, susceptibility and adaptations to flooding in the upper Brahmaputra plain. *Nat Hazards* 2016;83:1157-76.
 19. Gogoi M. Flood disaster in Assam: Socio-economic vulnerability and control measures. *South Asia J Multidiscip Stud* 2016;3:147-58.
 20. Singh RB, Pandey BW, Prasad AS. Adaptation strategies for flood risk mitigation in lower Brahmaputra river basin, Assam through integrated river basin management. *Transactions* 2014;36:159-70.
 21. TERI. Climate Proofing Guwahati, Assam: City Resilience Strategy and Mainstreaming Plan 70; 2013. Available from: https://www.teriin.org/eventdocs/files/TERI_Guwahati_CityResilienceStrategy.pdf. [Last accessed on 2021 Mar 01].
 22. Lakshmi DD, Satyanarayana AN, Chakraborty A. Assessment of heavy precipitation events associated with floods due to strong moisture transport during summer monsoon over India. *J Atmos Sol Terr Phys* 2019;189:123-40.
 23. Jagnoor J, Bhaumik S, Christou A, Azad AK, Ivers R. Weaved into the fabric of life: A qualitative exploration on impact of water-related disasters in the char community of Assam, India. *Int J Disaster Risk Reduct* 2020;47:101551.
 24. Suntoo Das UM, Bora P. An overview of urban flooding in Dibrugarh town, Assam. *PalArch's J Archaeol Egypt Egyptol* 2020;17:7825-36.
 25. Patowary S, Sarma AK. GIS-based estimation of soil loss from hilly urban area incorporating hill cut factor into RUSLE. *Water Resour Manage* 2018;32:3535-47.
 26. Chakraborty D, Singh M. Development and urban flooding, case-Guwahati. *J Basic Appl Eng Res* 2016;3:1081-6.
 27. Mahadevia D, Desai R, Mishra A. City Profile: Guwahati. Ahmedabad, India: CUE; 2014. Available from: <https://cept.ac.in/UserFiles/File/CUE/Working%20Papers/Revised%20New/Working%20Paper%2024-%20City%20Profile%20Guwahati-N.pdf>. [Last accessed on 2021 Mar 01].
 28. Gogoi C, Goswami DC, Phukan S. Flood risk zone mapping of the Subansiri sub-basin in Assam, India. *Int J Geomat Geosci* 2013;4:75.
 29. Bhuyan R. Review note on shifting cultivation in Northeast India amidst changing perceptions. *Dhaulagiri J Sociol Anthropol* 2019;13:90-5.
 30. ADB. Environmental Assessment Report (Summary Environmental Impact Assessment Project Number: 38412) India: Assam Integrated Flood and Riverbank Erosion Risk Management Investment Program; 2009. Available from: <https://www.adb.org/sites/default/files/project-document/76484/38412-01-ind-seia.pdf>. [Last accessed on 2021 Mar 01].
 31. Bhattacharjee K, Behera B. Forest cover change and flood hazards in India. *Land Use Policy* 2017;67:436-48.
 32. Huber A, Gorostiza S, Kotsila P, Beltrán MJ, Armiero M. Beyond "socially constructed" disasters: Re-politicizing the debate on large dams through a political ecology of risk. *Capitalism Nat Socialism* 2017;28:48-68.
 33. Sahoo SN, Sreeja P. A methodology for determining runoff based on imperviousness in an ungauged peri-urban catchment. *Urban Water J* 2014;11:42-54.
 34. Sahoo SN, Pekkath S. Detention ponds for managing flood risk due to increased imperviousness: Case study in an urbanizing catchment of India. *Nat Hazards Rev* 2018;19:05017008.
 35. Das S, Mukhopadhyay P. Multi-hazard disaster resilient housing with bamboo-based system. *Procedia Eng* 2018;212:937-45.
 36. Hazarika P. Development-induced displacement, deprivation and people's movement in Assam. *Educ India J* 2013;2:80-6.
 37. Chaliha S, Sengupta A, Sharma N, Ravindranath NH. Climate variability and farmer's vulnerability in a flood-prone district of Assam. *Int J Clim Chang Strateg Manage* 2011;4:179-200.
 38. De UK. Farmer's response to changing climate in North East India. *Am Inst Phys Conf Proc* 2015;1643:30-41.
 39. Sarmah T, Das S. Urban flood mitigation planning for Guwahati: A case of Bharalu basin. *J Environ Manage* 2018;206:1155-65.