

Flood Hazard in India and Development of Early Warning Systems: The Role of Indigenous Knowledge

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Abstract

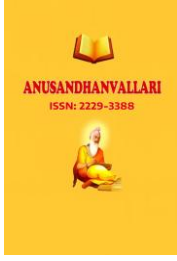
Floods are among the most frequent and most destructive natural calamities occurring in India. The consequences of flood occurrences are not only the loss of lives but also displacement and damage to infrastructure and agriculture. With the changing climate and increasing intensity and irregularity of rainfall due to global warming and climate change, the urgency for better flood control and management is also increasing. This paper aims to highlight the development of flood disaster management in India, including traditional and modern approaches to flood control and the use of indigenous knowledge in conjunction with modern approaches to flood control and management. The paper will conclude by providing some recommendations for better flood control and management in India.

Keywords: conclude, management, climate, recommendations

Introduction

Floods is one such recurring natural calamity in the country, which affects the economy, environment, and human life. Over the years, many flood-prone areas, including the states of Bihar, Assam, and West Bengal, have experienced recurring floods (Parida, 2020). As per the National Disaster Management Authority (NDMA), 12% of the land is prone to floods, which affects millions of people every year (Deshpande, 2022). Climate change is resulting in the intensification of extreme weather conditions, making it even more important to effectively manage floods and issue early warnings.

India is blessed with a rich history of indigenous approaches to effectively manage floods. It is based on indigenous knowledge of environmental factors. But with the advent of modern technology in the fields of meteorology and hydrology, the way flood warnings are issued is completely different (Acharya & Prakash, 2019). This paper will discuss both approaches, including their advantages and disadvantages, and propose a framework to effectively integrate indigenous approaches with the latest techniques to manage floods.



Types of Floods

The floods in India can be broadly classified into the following types:

River Floods- River floods happen due to overflow caused by rainfall or melting of snow. River floods are common in India during the monsoon season in river basins such as the Ganga River and Brahmaputra River basins. (Kale et al., 2010)

Flash Floods- Flash floods happen suddenly in a short time due to rainfall or dam overflow. Flash floods are common in mountainous regions such as the Himalayas. (Kale et al., 2010; Sharma et al., 2021)

Coastal Floods- Floods in coastal areas happen due to storm surges, high tides, or cyclones. States such as Odisha and West Bengal often suffer from coastal floods due to tropical cyclones. (Rahman & Bhattacharya, 2014)

Urban Floods- Due to inadequate drainage in urban areas, urban floods often happen. Cities such as Mumbai, Delhi, and Chennai often suffer from urban floods. (Mukherjee, 2016)

Impacts of Floods

Floods have far-reaching consequences in India, impacting not only the lives of the people but also the environment. Floods result in the loss of many lives every year, especially in vulnerable areas such as low-lying areas. Floods also result in the displacement of millions of people from their homes and agricultural lands (Aldardasawi & Eren, 2021). Floods also result in the destruction of infrastructure such as roads, bridges, buildings, agricultural lands, which are rendered unproductive, further adding to the losses. Floods also result in the erosion of soil, impacting the environment. In the case of coastal areas, the flooding results in the mixing of saltwater with freshwater, which is detrimental to agricultural activities. In light of the devastating effects of flooding, effective flood management and early warning systems (EWS) are the need of the hour to reduce the losses resulting from flood events.

Traditional Flood Management Practices in India

India has a long history of using traditional methods to predict and manage floods, many of which have been passed down through generations. These methods, rooted in indigenous knowledge, reflect a deep understanding of local ecosystems and environmental patterns (European Union et al., 2008).

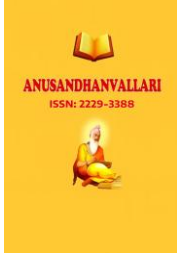
The Vedas are considered the most ancient and original texts of the world. They are regarded as eternal, timeless, and divine as they naturally emerged and illuminated in the hearts of sages for the material and spiritual advancement of humanity (Mallik & Sahoo, 2019; Mishra, 2024).

Indeed, the Vedas are the foundational source of all dimensions of Indian knowledge tradition, and hence are seen as the root of all forms of knowledge and science. As stated,

सर्वज्ञानमयो हि सः (मनुस्मृति- 2/7)

He is indeed the embodiment of all knowledge.

Various texts of the Indian knowledge tradition mention diverse methods for predicting natural disasters through observations of various natural phenomena. Excessive rainfall, which often causes flooding, is frequently discussed in Sanskrit texts. These texts describe the prediction of rainfall through the halos (parivesha) surrounding celestial bodies like the sun and moon. When the rays of the sun or moon reflect off a mountain, forming a circular band with colors and shapes in a slightly cloudy sky, this is known as parivesha. In simple



terms, a circular or other-shaped halo appears around the sun or moon during the rainy season, which can indicate rainfall. If the moon's halo appears silver or dove-colored with up to two rings, continuous rain over seven days may submerge the earth.

Evidence of Vedic Texts as a Primary Source of Indigenous Knowledge in Predicting Flood Events

India is a country where various sages and hermits have meditated for several years for attaining salvation and enlightenment. Buddha, Mahavira and Guru Nanak Dev are some of the eminent examples. These saints were always there for providing relief to humanity. In this regard, natural disasters have always posed significant challenges for the humanity like physical losses, economic losses and mental discomfort. Therefore, these saints provided some shlokas from ancient texts and explained them to common public so that they can be well prepared about these natural disasters. In this paper, the major focus was on flood events and their occurrence as understood through the lens of astronomy and climate patterns like wind directions, cloud formation patterns etc.

त्रयो यत्रावरुद्ध्यन्ते नक्षत्रं चन्द्रमा ग्रहः।

त्र्यहाद् वा जायते वर्षं मासाद् वा जायते भयम्॥ (तत्रैव - 4/38)

When three celestial bodies align,

Rain falls within three days, and danger arises after a month.

In the sixth chapter of Bhadrabahu Samhita, cloud formations are used to predict rain. Clouds that are black, yellow, copper-colored, or white are considered rain-bearing clouds. If a mock sun appears in the sky or if a rainbow appears in the evening, it indicates imminent rain (तत्रैव - 6/4). If the sun's halo is visible in the evening, it suggests heavy rain that may harm humans and animals. As stated,

आदित्यपरिवेषस्तु सन्ध्यायां यदि दृश्यते।

वर्षं महद् विजानीयाद् भयं वाऽथ प्रवर्षणे॥ (तत्रैव - 7/17)

If the sun's halo appears in the evening,

Expect heavy rain or danger.

A sun surrounded by three or five halos in the evening portends the possibility of a major rainfall event.

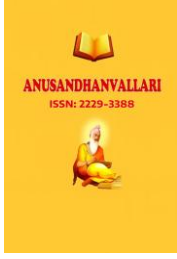
स्निग्धवर्णाश्च ते मेघा स्निग्धाश्च ते यदा।

मन्दगाः सुमूर्त्ताश्च ये ते सर्वत्र जलावहाः॥ (तत्रैव- 8/8)

Gentle clouds that are smooth and auspiciously timed,

Slow-moving, bring abundant rain.

Clouds with shapes resembling animals like lions, jackals, cats, leopards, and vultures predict heavy rainfall. If the first rain occurs in the Uttarabhadrapada constellation, abundant rain follows (तत्रैव- 8/16-17). Additionally, if rain begins in various constellations, it brings different auspicious or inauspicious outcomes as described in the tenth chapter of the Bhadrabahu Samhita (तत्रैव- 10/15-16). The Saptanadi Chakra also helps in forecasting rain, and if there is a risk of excessive rainfall leading to floods, preventive measures for flood management can be implemented (तत्रैव- पृष्ठ सं. 157). In the twelfth chapter of Bhadrabahu Samhita, the gestation and timing of clouds are discussed, which is further elaborated in Brihat Samhita to anticipate excessive rainfall, allowing preparations for possible flooding (बृहत्संहिता- गर्भलक्षणाध्यायः).



The “Brihat Samhita” contains detailed discussions on rain and excessive rainfall in various chapters. Specific planetary alignments can also indicate heavy rainfall, leading to flood-related consequences (बहत्संहिता- गर्भधारणाध्याय, प्रवर्षणाध्याय, सद्योवर्षणाध्याय). For example, during the rainy season, if Mercury and Venus are in the same sign, there is a chance of heavy rain on earth. If the Moon is in a water sign and is ascendant, abundant rainfall is predicted (वनमाला- 1/7).

If the Moon and Mars align with Jupiter in one of the seven nadis (streams), it results in heavy rain. It is clear that the conjunction of Mars and Jupiter is a sign of good rainfall (वनमाला- 1/8).

Indigenous Knowledge and Flood Prediction

Communities in flood-prone areas have historically relied on natural indicators to predict floods, drawing from generations of indigenous knowledge. One of the most notable signs was changes in animal behavior, as animals such as birds, insects, and livestock often acted unusually before floods. For example, birds flying at lower altitudes or the sudden disappearance of insects were seen as early warnings of heavy rain or flooding.

पिपीलिका यदाऽण्डानि गृहीत्वोच्चमग्रयान्ति च।

सर्पा वृक्षं समायान्ति तदा बहुजलप्रदः॥ (मयूरचित्रम्- 15/12)

When ants carry eggs upward, and snakes climb trees,

Prepare for a deluge.

Similarly, if ants are seen carrying their eggs to a higher, safer place, and snakes climb trees, it signals heavy rainfall and possible flooding. There are also rain-forecasting signs in nature: if cows jump or look upwards, rain is likely that day. If, in the morning or evening, clouds resembling the wings of a pheasant appear and birds like teetar, titihiri, and papiha chirp happily, rain may fall day and night (तत्रैव - पृ.सं.- 120-121). When trees bloom abundantly, it suggests heavy rains (तत्रैव - पृ.सं.- 151-155).

The knowledge of astronomy also tells us about the indications of wrath which can be caused by natural disasters. The shift of planets in different months, can cause different cloud formation patterns and thus also causes wind directions to change.

In Sachitra Jyotish Shiksha, if a rainbow appears twice in one day, it indicates excessive rain. The date, constellation, and planetary positions when the sun enters the Ardra constellation are all used to predict rainfall (सचित्र ज्योतिष शिक्षा (संहिता खण्ड)- पृ.सं.-98). At the beginning of each year, positions of the Meghesh, Rasesh, Falesh, Durgesh, Sasyesh, and Dhanyesh planets are determined to anticipate the coming year’s rainfall (तत्रैव - पृ.सं.- 145).

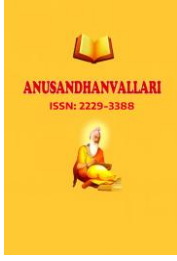
If in the month of Chaitra, on the fourth day of the waxing moon, the wind blows from the south and clouds drift east, rain falls daily in the month of Ashwin. As stated,

चैत्रशुक्लचतुर्थ्यां तु वायुः शमनदिग्भवः।

जलदः प्राङ्मुखं गच्छेदाश्विने वृष्टिरन्वहम्॥ (वनमाला- 6/03)

On Chaitra’s fourth day, if the south wind blows,

Clouds head east, bringing daily rain in Ashwin.



In Mayurachitra, as narrated by Narada, it is mentioned that during the extra month, if Mars and Jupiter move to another sign, excessive rain and flooding cause widespread destruction. As stated,

यदा मलिम्लुचे भौमोऽङ्गिरा राश्यन्तरे ब्रजेत्।

गुरुर्वा महती वृष्टिरथवा लोकसंक्षयः॥ (मयूरचित्रम्- 2/59)

If Mars and Jupiter shift to another sign,

Heavy rain brings devastation

Similarly, indigenous communities learned to interpret cloud formations, identifying specific patterns that indicated impending rainfall. Observing river water levels was another critical practice, with local wisdom guiding when rising water levels posed a danger, allowing communities to take necessary precautions in time.

Traditional Flood Management Techniques

Traditional flood management practices employed both structural and non-structural measures to mitigate the impact of floods, with a strong emphasis on sustainability and community involvement (Shaw et al., 2008; Mercer et al., 2010). Many rural communities built temporary embankments, or dikes, using locally available materials like mud and bamboo to protect homes and agricultural fields from rising floodwaters (Jha et al., 2012). Maintaining riverbank vegetation was another key practice, as trees and shrubs helped reduce soil erosion and served as natural barriers by absorbing the force of floodwaters (FAO, 2007). In hilly regions, terracing techniques were utilized to slow water runoff, decreasing the risk of flash floods, while water harvesting structures, such as ponds and tanks, helped manage excess rainfall (Agarwal & Narain, 1997). Collective community efforts were central to these practices, with villagers working together to construct barriers, repair drainage systems, and evacuate people from vulnerable areas (Shaw et al., 2008). These traditional methods not only minimized flood risks but also relied on local resources and fostered community participation, ensuring long-term resilience (Mercer et al., 2010).

Modern Flood Management and Early Warning Systems

While traditional flood management practices have been effective for centuries, modern technological advancements have significantly transformed the way floods are predicted and managed, with early warning systems (EWS) becoming a cornerstone of contemporary flood disaster management (UNISDR, 2006; WMO, 2011).

The India Meteorological Department (IMD) plays a vital role in flood forecasting by employing advanced meteorological tools and models to predict rainfall patterns (IMD, 2020). Using satellite imagery and radar technology, weather systems are closely monitored, enabling early warnings for potential flood events (WMO, 2011).

Hydrological models further enhance flood predictions by simulating river basin behavior, integrating data on precipitation, soil moisture, and topography (Beven, 2012). The Central Water Commission (CWC) utilizes these models to forecast flood levels in major rivers such as the Ganga, Yamuna, and Brahmaputra, allowing for timely warnings to downstream communities (CWC, 2019). Remote sensing technology, particularly through satellite imagery, provides real-time data on water levels and rainfall, while automated river gauging stations continuously monitor river discharge and catchment areas, triggering alerts when critical water levels are reached (Schumann & Di Baldassarre, 2010).



Geographic Information Systems (GIS) have revolutionized flood risk assessment by offering detailed floodplain maps and risk analyses, helping authorities identify vulnerable areas and plan evacuation routes (De Smith et al., 2018). Additionally, communication systems play a crucial role in disseminating flood warnings. The IMD and CWC use SMS, mobile apps, and social media platforms to deliver timely alerts to affected populations (IMD, 2020). The National Disaster Management Authority's (NDMA) mobile app and state-specific disaster management systems provide real-time updates on flood risks, ensuring communities are well-informed and prepared for evacuation or mitigation (NDMA, 2019).

Comparative Analysis: Traditional vs. Modern Flood Management

Both traditional and modern flood management approaches provide valuable strategies for mitigating flood risks, yet they differ in several key aspects (Jha et al., 2012; UNISDR, 2006). Modern early warning systems, which utilize satellite technology and hydrological models, offer highly accurate and timely predictions, significantly reducing the time available for response (WMO, 2011). Traditional methods, while effective in certain contexts, depend on environmental observations like animal behavior and river water levels, which may not always provide the precision needed in contemporary flood scenarios (Mercer et al., 2010). Community involvement is a cornerstone of traditional flood management, where local populations play active roles in building embankments and maintaining natural barriers (Shaw et al., 2008). In contrast, modern systems tend to be more centralized, with less direct community engagement, although local cooperation remains critical for implementing evacuation plans and disaster mitigation strategies (UNISDR, 2006). Sustainability is another key difference, as traditional methods often emphasize environmental stewardship by incorporating natural features like riverbank vegetation and forests, which help in absorbing floodwaters and preventing soil erosion (FAO, 2007). Modern infrastructure, while effective in flood control, can sometimes disrupt natural ecosystems, contributing to urban runoff and altering water flow patterns (Jha et al., 2012). In terms of cost and accessibility, traditional methods such as levee construction and tree planting are generally low-cost and accessible to rural communities (Agarwal & Narain, 1997). Modern systems, however, require substantial financial investment and technical expertise, which may not be feasible for all regions, particularly in developing areas (UNISDR, 2006).

Technological Innovations in Flood Early Warning Systems

The advancement of technology in recent years has greatly enhanced the accuracy and efficiency of flood early warning systems (WMO, 2011). Artificial Intelligence (AI) and machine learning play a key role in analyzing vast datasets, including weather patterns and historical flood records, to detect trends and provide highly accurate flood forecasts (Mosavi et al., 2018). These AI models are particularly effective in predicting flash floods, which are challenging to anticipate with conventional methods (Mosavi et al., 2018). Drones have also become valuable tools in flood management, offering real-time imagery and data on flood-prone areas (Adams & Friedland, 2011). They are especially beneficial in difficult terrain, where monitoring and delivering aid would otherwise be hindered (Adams & Friedland, 2011). The Internet of Things (IoT) has further revolutionized flood prediction by deploying smart sensors in flood-prone regions to monitor water levels and environmental conditions in real time, allowing for more localized and timely flood warnings (Zanella et al., 2014). Additionally, blockchain technology is being explored to improve data management during flood disasters, creating decentralized, tamper-proof records of flood forecasts and emergency responses (Kouhizadeh & Sarkis, 2018). This improves coordination among disaster management agencies and ensures accurate, secure data sharing, streamlining flood response efforts (Kouhizadeh & Sarkis, 2018).



Challenges in Flood Management and Early Warning Systems

Despite significant technological advancements, flood management in India continues to face several challenges (Jha et al., 2012). One of the primary obstacles is the growing unpredictability of monsoon patterns due to climate change (IPCC, 2021). The increasing intensity and frequency of rainfall events complicate flood predictions, as relying solely on historical data becomes less reliable (IPCC, 2021). Furthermore, infrastructure gaps in many rural and underdeveloped areas hinder the effective implementation of modern early warning systems (EWS) (UNISDR, 2006). Remote sensing technology and hydrological models, essential for accurate flood forecasting, are often inaccessible in regions with limited connectivity and technical expertise (Schumann & Di Baldassarre, 2010). Additionally, public awareness about how to respond to flood warnings remains low in several communities (NDMA, 2019). Even with timely alerts from modern EWS, the lack of adequate flood preparedness and response knowledge among the public undermines the overall efficacy of these systems, emphasizing the need for education and community engagement in flood management efforts (NDMA, 2019).

Integrating Indigenous Knowledge with Modern Technology

The integration of indigenous knowledge with modern flood management systems presents a promising pathway for enhancing resilience and adaptability in flood management efforts (Mercer et al., 2010). By merging local expertise with the precision of contemporary technologies, communities can develop more effective strategies for managing flood risks (Shaw et al., 2008). Non-governmental organizations (NGOs) and community-based organizations (CBOs) play a crucial role in this integration, as they often possess strong local connections that facilitate knowledge exchange between communities and scientists (Mercer et al., 2010). Recognizing the significance of indigenous knowledge in disaster risk reduction, the Indian government has initiated programs such as the Pradhan Mantri Krishi Sinchai Yojana, which promotes traditional water conservation methods to mitigate flood impacts (Government of India, 2015). A hybrid approach that combines modern early warning systems (EWS) with traditional flood management practices offers an effective solution; for instance, while modern technology can provide timely flood alerts, local communities can leverage their knowledge to implement practical mitigation measures, such as levee construction and water diversion techniques (Jha et al., 2012). This collaboration not only enhances flood preparedness but also fosters community empowerment and sustainability in managing flood risks (Shaw et al., 2008).

Conclusion

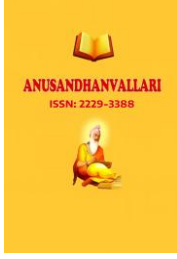
Flood hazard management in India must evolve to meet the challenges posed by climate change and increasing urbanization (IPCC, 2021). While modern technology provides advanced tools for predicting and managing floods, the integration of indigenous knowledge can enhance the resilience of communities and ensure that flood management strategies are sustainable and locally adapted (Mercer et al., 2010). By adopting a hybrid approach that leverages both modern and traditional methods, India can create a more robust and inclusive flood management system, capable of protecting both lives and livelihoods (UNISDR, 2006).

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