FLOOD SUSCEPTIBILITY MAPPING: A REVIEW TO PREPARE RISK MITIGATION FRAMEWORK

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Abstract

Flooding become an environmental threat that challenges vulnerability of ecosystem and communities in the immediate vicinity. Such disasters are expected to increase with the climate change scenarios, growing population pressure and urbanization. To curb the damage caused by flood, it is important to understand role of conditioning factors towards flood occurrence and implementation of management strategies. Flood susceptibility mapping provides a better solution towards curbing the losses.Though the distribution of flood susceptibility will be highly dependent on the terrain conditions, the flood plains is determined by the drainage pattern and run off. Flood susceptibility modelling would enhance the adaptation frame works for the less studied disasters and their dynamics in the climate change scenarios and urbanization.

Keywords: Flood, susceptibility, modeling, mapping, control

Introduction

Flood is a hydrological activity that disrupts the natural cycle and brings devastation to society (Chowdhuri *et al.*, 2020), and has a negative growth effect on economic growth (Das & Gupta, 2021). Flooding results in loss of life (injuries and death of human beings and animals), destruction of property (houses, agricultural land, and crops), and disruption of connectivity (bridges, highways, and railroads) (Patnaik & Narayanan, 2010; Chakrabortty et al., 2021). Flooding affects sustainable development by drawing attention to the relationships among phenomena and development goals that are affected, namely 1-: No poverty; 2: Zero hunger; 3: Good Health and Wellbeing; 4: Quality education; 6: Clean water and Sanitation; 8: Decent work and economic growth; 11: Sustainable cities and communities; 14: Life on water and 15: Life on the land. Recently in many nations, due to climatic change, fast urbanization leading to environmental degradation, and incorrect land use management, these flood-related destructions have escalated (Das & Gupta, 2021). It was estimated that the consequences of flooding result in an annual average loss of about US$ 104 billion, which is about 33% of the total loss in the world (Chowdhuri *et al.*, 2020). According to the United Nations Office for Disaster Risk Reduction (UNDRR), 150,061 flood incidents were globally reported between 1995 and 2015, accounting for 11.1% of all damage (Chakrabortty et al., 2021).

Larger regions (rural and urban) in India are flooded due to extreme rainfall during rainy seasons because short-duration high-intensity rainfall abruptly achieve runoff peak and exceeds absorptive capability of prevailing drainage system. In the country, 12.5% of the land is susceptible to flooding (Usama, 2015). From 1978 to 2006, flood-related fatalities were evenly spread across the nation in terms of geography, with the highest rates occurring in Uttar Pradesh (17%), Maharashtra (13%), Bihar, and Gujarat (10% each) (Singh & Kumar, 2013). Nearly 40 million hectares of flood-prone area is found in India, and each year, floods affect roughly 8 million hectares of land (Das & Gupta, 2021). According to the flood damage statistics report, 2021, presented by the Central Water Commission, India, damage due to floods from 1953 to 2020 is about 492.557 million hectares of land area affected, 2198.788 million population affected, and 113,943 people lost lives. It also indicates an area of 275.773 million hectares of crop damage valuing nearly 131,462.177 crores. Rather than agricultural damages, the destruction of houses and public utilities valued a sum of about 291,167.225 crores.

After a major flooding incident, reconstruction and recovery are costly and might disturb the environment's stability. Flood mitigation strategies can be successful with the prior identification of susceptible zones. The scientific community has differing opinions on how to create a realistic and trustworthy map of susceptibility to environmental disasters. Remote sensing and GIS tools help in susceptibility zonation over the spatial extent and flood management can be implemented (Das & Gupta, 2021). In the future time, many new possibilities are now available when we consider technological advancements for flood control. Modern forecasting and early warning system development are very important for minimizing flood damage and adaptation of control strategies (Plate, 2002; Tingsanchali, 2012).

Flood conditioning factors

Flood susceptibility mapping depends on various flood conditioning factors. Flood conditioning factors mainly includes of topographic parameters like elevation, slope, topographic wetness index (TWI), topographic ruggedness index (TRI), etc. (Das & Gupta, 2021). Elevation is frequently regarded as one of the primary flood-causing elements since low-level altitudes are typically associated with proportionately higher river discharge and flood more quickly from surges of high water (Sahana & Patel, 2019). Infiltration rate and slope angle share an inverse relationship, therefore surface flow rises in high slope areas. However, with an abrupt drop in slope, enormous amounts of water become immobile and cause flooding. Flooding (frequency, extent and magnitude) affects regions adjacent to drainage more than far away sites from river-bank (Chowdhuri et al., 2020). On the other hand, level of separation from water sources is region-specific and varies depending on the hydro-geomorphic response of that region. Drainage density defines spatial extension of risk because it is positively correlated with surface runoff. TWI is a quantifiable representation of washed-out zone and shows impact of landscape on runoff production, ground water depth, flow accumulation capacity in a catchment, soil moisture, and saturation zone. Because runoff rates are higher and ground surfaces are less permeable, urbanization exacerbates floods (Few, 2003). Land-use pattern is cruial parameter in determining occurrence of floods because of the fact that places with densely covered vegetation types are typically less vulnerable to flooding (Wheater & Evans, 2009; Roy *et al.*, 2020). Normalized difference vegetation index (NDVI) is most accurate method for measuring the amount of vegetation or its density (Chowdhuri et al., 2020). TRI can be described as homogeneousness altitudinal distribution, used to determine whether terrain is flat or rugged. In flat terrain conditions TRI value is low showing a significant likelihood of flooding. Curvature duplicates the topography of any surface and determines the degree of distortion of slope surfaces. Positive values of curvature indicate topography that is concave, whereas negative values indicate flat terrain, which increases the likelihood of flooding.

Rainfall is one of the most important factors that might cause a flood, particularly in areas where only 5 months of the year account for 86% of the region's yearly rainfall (June to October). However, because it also depends on a number of other conditions, it is difficult to pin point the precise quantity of rainfall needed to cause an emergency flood situation. Rainfall is major climatic parameter that regulates the frequency and percent of destruction over area and population (Das & Gupta, 2021). Stream Power Index (SPI) is a measure of erosion strength and stream discharge within a specific area; a high value of SPI implies rapid movement of downstream water, reveals lower probability of flood, and vice-versa (Chowdhuri et al., 2020).

Soil texture, geology, geomorphology, and land use pattern are flood conditioning parameters (Das & Gupta, 2021). Fine soil textural composition inhibits infiltration and increases runoff (Chakrabortty et al., 2021), which is consistent with the fact that infiltration is heavily dependent on soil texture. As a result, areas with a lot of fine soil (such as clay and silt) have a greater chance of inundating than those with a lot of coarse soil (e.g. sand). Depending on lithological permeability and porosity parameters, the geological characteristics of a region can directly or incidentally affect runoff and infiltration (Chaturvedi *et al.*, 2015; Rehman *et al.*, 2019). In addition, geology has a big impact on how a drainage pattern develops and how a floodplain forms (Kaur *et al.*, 2017). Low-lying plain areas can undoubtedly be inundated by excess river water; the loose soil in Bad land areas is quickly eroded by accumulated water flow, whilst hilly places are least susceptible to flooding.

Risk Mitigation and management

Strategies for preventing flood disasters include a number of measures that together make up the risk management for the functioning of an existing flood protection system. (Tullos *et al.*, 2016). Its objective is to prevent flood disasters by preparing for them and lessening their effects. It comprises the risk-analysis procedure, which serves as base for long-term management choices for the existing flood protection system. Researchers used remote sensing and GIS techniques to assess flood susceptibility and risk association in order to implement flood management strategies with lower economic loss as well as loss of lives (Tran *et al.*, 2009; Chaturvedi *et al.*, 2015; Lyu *et al.*, 2018; Das & Gupta, 2021). Flood susceptibility and risk prediction assessment modeling approach is used which need prior flood inventory data to understand past events and flood conditioning factors (Chakrabortty *et al.*, 2021). Various modeling approaches like use of frequency ratio (Samanta *et al.*, 2018; Sahana & Patel, 2019), fuzzy logic (Sahana & Patel, 2019), Analytical hierarchy process (AHP) (Das & Gupta, 2021; Vilasan & Kapse, 2022), Partial Least Square Regression-Variable Importance in Projection (PLS-VIP) based AHP optimized

(Das & Gupta, 2021), Evidence Belief Function (EBF) (Chowdhuri et al., 2020), binomial Logistic Regression (LR) (Chowdhuri et al., 2020) and ensemble of EBF and LR (EBF-LR) (Chowdhuri et al., 2020), artificial neural network (ANN), deep-learning neural network (DLNN), and particle swam optimization (PSO) (Chakrabortty et al., 2021), Support Vector Machine (SVM), Random Forest (RF) and Biogeography Based Optimization (BBO) (Roy *et al.*, 2020) were used to understand flood risk within the spatial extent and presenting relationship with conditioning factors.

Over the past two decades, a wide range of engineering applications have benefited from the increased efficiency and accuracy of machine learning methodologies, particularly for challenges involving prediction, estimation, and information processing (Chakrabortty et al., 2021). Understanding a region's flooding mechanism is made simpler by having a record of previous flood locations, which geoscientists generally believe is one of the key instruments for predicting floods and vetting the accuracy of flood models (Das & Gupta, 2021).

Future Scope

Researchers work to understand flood-water mechanisms and create a precise flood susceptibility map that could aid in the development of flood mitigation strategies by administrative authorities. In order to continuously enhance the system, it is necessary to reevaluate the risks that are now present and assess the risks based on the most recent information: new data, new theoretical breakthroughs, or new boundary circumstances, such as those caused by a change in land use. Modern flood control solutions are dependent on three varying aspects, including the available technology, the availability of funding, and the sense of urgency of the need for protection, which is ingrained in a society's value system. As these factors evolve through time, so do the choices that must be made, and new paradigms of thought may call for novel approaches to age-old issues. The potential of remote sensing is now coming to light, and numerous areas are investigating technology for turning forecasts from mathematical models of climatological weather conditions into warning systems. Government researchers and planners are attempting to develop a flood control system that includes pre-flood preparations, flood predictions, and post-flood preparations.

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