RECENT TRENDS IN FLOOD MAPPING TECHNIQUES USING REMOTE SENSING AND GIS: A REVIEW

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ABSTRACT
Remote sensing (RS) and Geographic Information System (GIS) are used to evaluate the flood risk zone. This paper is based on understanding of various recent trends techniques used in flood mapping to know the flood risk and vulnerability. In this regard, studied the various literature articles where in some of them proposes, multi-criteria, hydrodynamic, and various AI models and its techniques and frequency models. With these models we are able to evaluate the expected flood risk zone. Flood maps and digital elevation models (DEM) can be derived with satellite data which is helpful for decision making. The effective use of suitable technique and implementation of flood management strategies resulting in reduced flood impact. Remote sensing and GIS is a mechanism for finding flood risk mitigation plans.
Keywords – DEM, Flood, GIS, Maps, Remote sensing

Introduction

Flood is a most common natural disaster in universe. In India, flood occurs because of continued heavy rainfall, climate change, urbanization, deforestation, melting of glacier and inadequate drainage network. This causes loss of lives, socio-economic activities, property damage. Due to irregularity in the flood, it is very crucial work to consider some hydraulic factors such as discharge of water and depth of water. Throughout the flood period acquiring geographical information from traditional sources is a tough work. Flood management planning plays key role which benefits to relief the flood impacted community to relieve the issue of flood and make the decisions (Bera, Pal & Bandyopadhyay,2012). In such a disastrous situation, remote sensing tool offers near real-time information for flood zone analysis (Agnihotri & Ohri, 2019; Shen, 2019). It is of major help to gauge flood disaster evaluation and resource allotment to find the region of flood zone speedily and exactly. To get proper information of flood disaster and its effect is required to take speedy decisions by authorities. (Bhatt, C. M.., 2017).The unexpected patterns of rainfall are also usual which consist of the flood in Mumbai on July 2005, flood in Bihar on 2019, in 2013 Kedarnath flood and Rajasthan flood (Khan, 2022).To improve awareness of the flood occurrences specifically for observation, mitigation and rescue purposes. Effective adaptation strategies are needed which include architectural measures and nonstructural measures (Mel, Viero, Carniello & D'Alpaos, 2020). Remote sensing is the excellent tool in the mapping of the spatial distribution of disaster related data (Bera, Pal, & Bandyopadhyay, 2012). Flood inundation areas have been mapped with the help of remote sensing and geographical information system.

Role of Remote sensing and GIS in flood mapping

In recent years, the development of computer technology and space borne technology has made significant changes and that will help for mapping the natural disaster. GIS and remote sensing technology is a powerful tool that will be helpful to monitor natural disasters on a near real time basis. Various satellites provide the images with very high resolution with good qualities and quantities that are easily available. Remote sensing and GIS techniques are useful for identifying and gauging the flood vulnerability zones and to prepare the flood risk map on a near real time basis. Optical remote sensing images can also be adopted for mapping floods because of their ability to collect spectral information and high resolution. Remote sensing sensors, SAR (Synthetic Aperture Radar) can have the ability to penetrate cloud and provides the clear images (Syifa, Park, Achmad, Lee & Eom, 2019). To get the accuracy of flood depth estimation is very hard in flat terrain and can mainly depend on the resolutions Digital Elevation Model Data (DEM). It is considered to determine the flood depth from hydrological data or remotely sensed data.

Related Work

To understand the flood extent, flood frequency and changes that occur due to flooding in a particular floodplain is essential because it helps better planning and emergency restoration and mitigation purposes. To get the regular and up to date information about flooding which makes proper decision and management. This information should include spatial and non-spatial information.

Syifa, (2019) discussed the benefit of remote sensing and artificial intelligence algorithm such as Artificial Neural Network (ANN) and Support Vector Machine (SVM).It involves using satellites that capture images of Earth's surface which can then be analyzed for various purposes such as mapping floods. ANNs are computer algorithms modeled after biological neural networks they learn by example rather than being explicitly programmed with instructions on how to solve problems. SVM is another type of machine learning algorithm designed to classify data into different categories based on certain features it has been trained on previously. Both these AI techniques were employed here along with before flood and after flood imagery from the satellite system Landsat 8 and Sentinel 2, allowing researchers to map out the dimensions of the flood area accurately so that future damage could potentially be prevented or mitigated more effectively if similar events occur again.

Waghwala & Agnihotri (2019) studied remote Sensing and GIS (Geographic Information System) tools to analyze the effects of urbanization on flood hazard. Remote Sensing is a technique used to observe and measure the physical characteristics of an area or region from a distance. GIS is a computer-based tool which is used to capture, store, evaluate and to represent geographic data. For each element of flood risk, flood risk index is computed by vulnerability index and hazard index.

Panhalkar & Jarag (2017) discussed multi criteria decision analysis technique which is used to evaluate the potential flood risk area. It is based on the analysis of various factors such as layer of flood, land use, land cover, infrastructure, and elevation. The analysis involves assigning weights to each factor and combining them to generate a flood risk map. RADARSAT SAR data is a satellite imagery data which is applied to segment inundated areas from non-flooded areas. It is used to identify the region affected by floods and to consider the potential of a flood risk region.

Chawan (2020) discussed the flood detection system. There are four steps which are preprocessing, classification, extraction of elements and contiguous deep convolutional neural Network (CDCNN). Flood mapping is the process for monitoring of flood for which images of before flood and after flood are compared to find the inundated area. He used the process as a Gaussian filter and image enhancement for pre-processing. Region wise segmentation is processed by threshold technology which can identify the flooded region by analyzing the color images. The contiguous deep convolutional Neural Network (CDCNN) method is used to analyze the model. This paper has elaborated the implementation of CDCNN method is used to know the flood area by making use of remote sensing images.

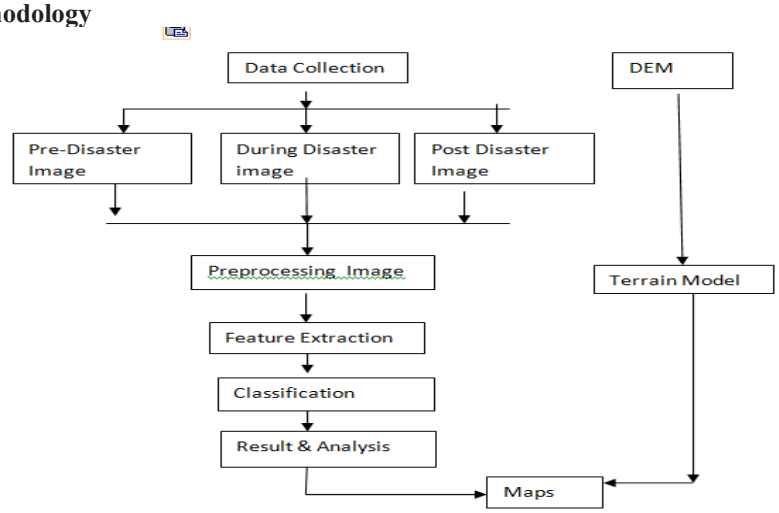
Anusha & Bharathi, (2020) used thresholding and unsupervised classification. Thresholding is a technique used to separate an image in two parts, which depends on the intensity of each pixel. It involves setting a certain value as the cutoff point for determining which pixels should be included or excluded from further analysis. Unsupervised Classification is another method that can be used to identify different features within an image without any prior knowledge about them. This paper used Synthetic Aperture Radar (SAR) images are efficiently identify flood area monitoring and mapping. The conclusion of this research will help to reduce the effect of floods, as well as aid in improving flexibility when it comes to managing them.

Samanta, (2018) discussed the frequency ratio model. Remote sensing is the use of satellites or aircrafts to collect data about Earth's surface. This data can be used for various purposes like mapping land cover types, monitoring changes over time, measuring water quality parameters etc. GIS helps us visualize patterns on maps that would otherwise not be visible with just raw numbers alone. Frequency ratio model was used in this study where weighted-based bivariate probability values were calculated based on input variables related to flood susceptibility zones so as to generate plausible flood risk maps using historical inventory databases. This paper has contributed to the understanding of flood vulnerability by using a Frequency Ratio model. It demonstrated how remote sensing, GIS and FR can be used together for mapping areas vulnerable to floods.

Elkhrachy (2019) discussed the impact of flash flood assessment and management. The Hydrologic Engineering Centers River Analysis software suite is used to model flash floods occurrence, calculate water discharge across the length of a canal, and create digital elevation models for study areas. GPS methods were also employed to collect elevation points which can be used to identify flood inundation maps.

From a related literature review, we can conclude that multi criteria based AHP (Analytical Hierarchy Process) method is used for flood inundation mapping. This is helpful for making proper decisions.

Methodology



Data Collection

Radar remote sensing sensors such as SAR (synthetic aperture radar) can provide clear images due to their ability to penetrate clouds. Optical remote sensing images can be utilized to acquire spectral information. Pre and post flood images which are available with various web-based cloud platform by USGS (United State Geological survey) and Bhuvan (Syifa, Park, Achmad, Lee & Eom, 2019). Acquisition of terrain surface information is from SRTM (Shuttle Radar Topographic Mission) DEM (Digital Elevation Model). ArcGIS software used to process DEM (Das, S., & Gupta, A. ,2021).

Preprocessing:

Image preprocessing includes radiometric correction, geometric rectification, atmospheric and topographic correction (Salah, M. ,2017).

1) Feature Extraction :
   Different variables are available for feature extraction process which includes spectrum signature, textual images, surface roughness, transformed images, multi-temporal images, multisensory images, ancillary data and shape and size of objects (Salah, M. ,2017)
2) Classification

Various classification methods used to manage the floods and other evaluation based on large scale areas of disaster (Syifa, M., Park, S. J., Achmad, A. R., Lee, C., & Eom, J. 2019). For example image refinement, thresholding methods can be used to identify water body, classification of data using supervised and unsupervised methods such as maximum likelihood, PCA(principal component analysis (Elkhrachy, I. ,2019).

Various Indices used to extract water bodies:

Normalized difference vegetation index (NDVI): The normalized difference vegetation index is the standard metric which is used for vegetation index. The formula for calculating NDVI is as

$$NDVI = NIR - Red / NIR + Red \quad \text{Eq(1)}$$

where NIR(Near infrared) and Red are the bands which give the spectral reflectance measurements. Similarly, the MNDWI(Modified Normalized Difference water Index) can be used in identifying water body in the remotely sensed data is calculated as:

$$MNDWI = Green - SWIR / Green + SWIR \quad \text{Eq(2)}$$

where SWIR(Short Wave Infrared) and Green are the spectral reflection of the short wave infrared band and green band respectively (Devi, N. B., & Kavida, A. C., 2021).

Flood Mapping Techniques

Flood maps can help to recognize the flood risk areas and it also helps to take the decision for urban planning, domestic and land use system of a catchment area. It also gives detailed information about flood protection, mitigation and flood management systems to minimize the loss of lives and property damage (Al Faisal, A., Al Kafy, A., & Roy, S. ,2018).

Flood mapping parameters

For mapping of flood, it is required to consider some parameters such as rainfall, land use, elevation, soil texture, distance between inundation area from river, slope, drainage network, wetness index of topographic

area, geomorphology, curvature, and ruggedness index of topographic region. The following are some methods for mapping of floods.

AHP(Analytical Hierarchy Process)
This method was developed by Satty (1980), and it is one of the systematic mathematical processes that permit solving complicated decision problems. The advantage of this method is to assign the allocation of user stated weights into hierarchical structure. This technique is multi criteria-based decision support (Khan, A..,2022; Das, S., & Gupta, A. ,2021).

The Analytical Hierarchy Process is deciding which is used to assess and prioritize alternative options. The process includes pairwise comparisons to allocate weights to criteria and then uses those weights to calculate the optimal alternative. It involves breaking down the decision-making process into hierarchical levels, which are then evaluated according to criteria that are assigned weights. The weights are then used to calculate the overall rank of each alternative. AHP is often used in areas such as engineering, operations research, and management, and has been found to be particularly useful for flood risk analysis (Panhalkar, S. S., & Jarag, A. P. ,2017).

FR(Frequency ratio) Model
Frequency ratio model is a statistical technique. This technique proposes a quantitative relationship between different attributes and flood frequency. This model is used to calculate the ratio of probabilities of the flooded to non flooded region (Samanta, Pal & Palsamanta, 2018).

ANN (Artificial neural Network
ANN is the mathematical model. It is the pixel-based technique which can identify large scale disaster areas. The process of this method is to train particular tasks across several factors.It is ability to transfer input data into output data (Syifa, Park, Achmad, Lee & Eom, 2019).

SVM(Support Vector Machine)
It is an efficient method for solving nonlinear classification. It has the capability to work on high dimensional data. The kernel function is important to transform the data (Syifa, M., Park, S. J., Achmad, Lee & Eom, 2019).

Thresholding
Specifically, this method works for smooth surface area. This is the very simple method to classify flooded areas from non-flooded areas. The process of this method is to consider the pixel value which is compare with its threshold value (Chandrakant, Kakade & Jadhav, 2020; Anusha & Bharathi, 2020).
CDCNN (Contiguous Deep Convolutional Neural Network)

This method contains multilevel architecture, and each step has multiple layers. Every step contains a convolution layer, a nonlinear and a group layer. The starting point and ending point of every step is a collection of patterns known as feature maps. The ending step is defined by the features extraction process from all the entry point positions (Chandrakant & Jadhav, 2020).

Conclusion
Remote sensing and GIS are the technology for mapping of flood inundation area and also helpful for extent of flood by analyzing before flood, during flood and after flood images. Various flood mapping methods are AHP which is allowed to allocate user specified weight to hierarchical structure of criteria. Frequency ratio model measures frequency of flood with various conditioning parameters. The advanced methods such ANN, SVM, CDCNN etc are also applied for flood mapping.

References
Agnihotri, & Ohri, . (2019). Flood inundation mapping and monitoring using SAR data and its impact on Ramganga River in Ganga basin. Environ Monit Assess (2019) 191:760

Al Faisal, , Al Kafy, & Roy, (2018). Integration of Remote Sensing and GIS Techniques for Flood Monitoring and Damage Assessment: A Case Study of Naogaon District, Bangladesh. Journal of Remote Sensing & GIS, 07(02).

Anusha, & Bharathi, (2020). The Egyptian Journal of Remote Sensing and Space Sciences Flood detection and flood mapping using multi-temporal synthetic aperture radar and optical data. The Egyptian Journal of Remote Sensing and Space Sciences, 23(2), 207–219.

Bera, Pal, . & Bandyopadhyay, (2012). Application Of RS & GIS In Flood Management: A Case Study Of Mongalkote Blocks, Burdwan, West Bengal, India. International Journal of Scientific and Research ublications, 2(11), 1–9.

Bhatt, ., Rao, , Farooq, , Manjusree, ., Shukla, , Sharma, Kulkarni, S. S., Begum, ., Bhanumurthy, , Diwakar, P. G., & Dadhwal, V. K. (2017). Satellite-based assessment of the catastrophic Jhelum floods of September 2014, Jammu & Kashmir, India. Geomatics, Natural Hazards and Risk, 8(2), 309–327.

Chandrakant Chawan, A., K Kakade, V., & K Jadhav, J. (2020). Automatic Detection of Flood Using Remote Sensing Images. Journal of Information Technology and Digital World, 02(01), 11–26.

Das, S., & Gupta, A. (2021). Geoscience Frontiers Multi-criteria decision based geospatial mapping of flood susceptibility and temporal hydro-geomorphic changes in the Subarnarekha basin ,. Geoscience Frontiers, 12(5), 101206.

Devi, N. B., & Kavida, A. C. (2021). Pre-processing on remotely sensed data with unsupervised classification analysis. Journal of Ambient Intelligence and Humanized Computing, 12(6), 6825–6839

Elkhrachy, I. (2019). Assessment and Management Flash Flood in Najran Wady Using GIS and Assessment and Management Flash Flood in Najran Wady Using GIS and Remote Sensing. Journal of the Indian Society of Remote Sensing, 46(2), 297–308.

Joy, J., Kanga, S., & Singh, S. K. (2019). Kerala flood 2018: Flood mapping by participatory GIS approach, Meloor Panchayat. International Journal on Emerging Technologies, 10(1), 197–205

Khan, A., Govil, H., Khan, H. H., Kumar Thakur, P., Yunus, A. P., & Pani, P. (2022). Channel responses to flooding of Ganga River, Bihar India, 2019 using SAR and optical remote sensing. Advances in Space Research, 69(4), 1930–1947.

Mel, R. A., Viero, D. P., Carniello, L., & D'Alpaos, L. (2020). Optimal floodgate operation for river flood management: The case study of Padova (Italy). Journal of Hydrology: Regional Studies, 30(April), 100702

Panhalkar, S. S., & Jarag, A. P. (2017). Flood risk assessment of Panchganga River (Kolhapur district , Maharashtra) using GIS-based multicriteria decision technique.Current Science February 2017.

Salah, M. (2017). A survey of modern classification techniques in remote sensing for improved image classification. Journal of Geomatics, 11(1), 20.

Samanta, S., Pal, D. K., & Palsamanta, B. (2018). Flood susceptibility analysis through remote sensing, GIS and frequency ratio model. Applied Water Science, 8(2), 1–14.

Shahiri Tabarestani, E., & Afzalimehr, H. (2021). Artificial neural network and multi-criteria decision-making models for flood simulation in GIS: Mazandaran Province, Iran. Stochastic Environmental Research and Risk Assessment, 35(12), 2439–2457.

Shen, X., Anagnostou, E. N., Allen, G. H., Brakenridge, G. R., & Kettner, A. J. (2019). Remote Sensing of Environment Near-real-time non-obstructed flood inundation mapping using synthetic aperture radar. Remote Sensing of Environment, 221(November 2018), 302–315.

Syifa, M., Park, S. J., Achmad, A. R., Lee, C., & Eom, J. (2019). Flood Mapping Using Remote Sensing Imagery and Artificial Intelligence Techniques : A Case Study in Brumadinho , Brazil. Journal of Coastal Research-September -2019.

Waghwala, R. K., & Agnihotri, P. G. (2019). Assessing the impact index of urbanization index on urban flood risk. International Journal of Recent Technology and Engineering, 8(2), 509–512.

