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Assessment of the Role of Remote Sensing and Artificial Intelligence in Flood Monitoring and Management: A Review

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Abstract: Flooding remains one of the most destructive natural disasters affecting both developed and developing countries, with Nigeria experiencing increasing frequency due to climate variability, poor drainage systems, and rapid urbanization. This study employed a review research method, as it reviewed the applications of remote sensing in flood management, focusing on recent developments between 2020 and 2026. The study is based on published journal articles, conference papers, and satellite-based research works sourced from reputable databases such as ScienceDirect, Springer, MDPI, Nature, and Frontiers. The review covers key areas including flood mapping, flood monitoring, flood forecasting and early warning, flood damage assessment, flood risk mapping, watershed and drainage analysis, land use and land cover change detection, as well as emergency response and relief planning. The results from the reviewed literature showed that remote sensing technologies, especially satellite imagery, Geographic Information Systems (GIS), and artificial intelligence, have significantly improved the accuracy, speed, and reliability of flood management processes. It was concluded that remote sensing and AI are now indispensable tools in modern flood disaster management, offering real-time and large-scale monitoring capabilities that support decision-making and disaster preparedness.

Keywords: Artificial Intelligence, Flood Assessment, Land Use and Land Cover, Remote Sensing, Flood Management

1. Introduction

Floods are among the most devastating natural disasters, posing significant risks to life, property, and infra structure globally. Earth observation satellites provide data for continuous and extensive flood monitoring, yet limitations exist in the spatial completeness of monitoring using optical images due to cloud cover. This is when benefits of synthetic aperture radar images (e.g., Sentinel-1) for enhancing flood mapping under cloud cover conditions are employed as it is an effective way for flood monitoring in cloudy and rainy scenarios, thus supporting emergency response and disaster management.[1]. Floods are among the most destructive extreme events that exist, being the main cause of people affected by natural disasters. In the near future, estimated flood intensity and frequency are projected to increase. In this context, automatic and accurate satellite-derived flood maps are key for fast emergency response and damage assessment, and this can be achieved by using machine learning framework for operational flood mapping from optical satellite images[2]. Floods are more likely to occur in areas with high drainage density values, so caution should be exercised in such regions. Necessary

infrastructures should be put in place for a proper drainage system to avert flooding in such areas in the basin[3]. Floods are increasingly frequent natural disasters causing extensive human and economic damage, highlighting the critical need for rapid and accurate flood inundation mapping. While remote sensing technologies have advanced flood monitoring capabilities, operational challenges persist: single-sensor approaches face weather-dependent data availability and limited revisit periods, while multi-sensor fusion methods require substantial computational resources and large-scale labeled datasets[4]. Padala Raja Shekar conducted a morphometric and land use/land cover (LULC) analysis of the Murredu watershed in Telangana State using remote sensing and GIS techniques. The study aimed to understand the watershed's drainage characteristics along with how land use patterns have changed over time. Various morphometric parameters such as stream order, drainage density, form factor, and bifurcation ratio were calculated using DEM data to assess the basin's hydrological behaviour. Singh[5] carried out a detailed morphometric analysis of the Dudhnai River Basin located in Assam, India, using Digital Elevation Models (DEM) and ArcGIS tools. The main objective of the study was to understand the drainage characteristics and geomorphological behaviour of the basin, which is important for watershed management and flood risk assessment. Using GIS-based techniques, the authors extracted and analysed linear, areal, and relief aspects of the drainage basin, including parameters like stream order, drainage density, bifurcation ratio, elongation ratio, and basin relief. This work focuses on how remote sensing and artificial intelligence techniques can help in flood management.

2. Materials and Method

This study adopted a qualitative review research method, by carrying out a systematic review of existing literature on remote sensing and AI applications in flood management between 2020 and 2026. Relevant studies were sourced from online academic databases such as Google Scholar, ScienceDirect, SpringerLink, MDPI, Nature, and Frontiers. The selection criteria focused on peer-reviewed journal articles and conference papers that discussed flood-related applications of remote sensing and AI, including mapping, monitoring, forecasting, damage assessment, and risk analysis. In the work, recent studies were carefully selected in order to ensure relevance, credibility, and up-to-date information. The selected literature was critically analysed and grouped based on the eight major applications of remote sensing and Artificial Intelligence in flood management considered in this work. The review involved comparing methodologies, satellite data sources as well as the key findings from different authors.

3. Results and Discussion

Below are the major applications of remote sensing and Artificial intelligent in flood monitoring and management.

3.1. Flood Mapping

Flood Mapping is defined as the process of creating visual representations (maps) that show the spatial extent, depth, and potential impact of flooding in a specific area. The availability of satellite data has greatly improved the speed and accuracy of mapping flood extents, especially in areas where ground-based observations are difficult or impossible to obtain. Remote sensing provides a cost-effective means of determining the spatial distribution of floodwaters and supports emergency response, disaster assessment, and planning activities. In the work by Portalés-Julià[6] it was demonstrated that advanced image processing and machine learning techniques can accurately identify flooded areas from satellite observations. Their findings showed that satellite-based flood mapping can provide rapid information on flood extent over large geographical areas, thereby supporting disaster management agencies in making informed decisions during flood emergencies. According to Li[7], a seamless flood mapping can be done using Harmonized Landsat and Sentinel-2 imagery. The researchers addressed the challenge of cloud cover, which often limits the effectiveness of optical satellite images during flood events. It was stated that by integrating multiple satellite datasets and water occurrence

information, the study achieved more complete and accurate flood maps. The authors concluded that combining different satellite sources enhances flood detection and improves the reliability of flood extent assessments.

In the study by Kurniawan[8], multitemporal remote sensing data and machine learning techniques were employed to detect flood-affected areas. The study revealed that analysing satellite images acquired before, during, and after flooding significantly improves mapping accuracy. Their results indicated that machine learning algorithms can effectively distinguish flooded regions from surrounding land cover, thereby enhancing flood extent estimation and damage assessment activities. In the same way, Tanaka and Tsutsumida[9] carried out a work on the use of a sensor-adaptive flood mapping framework that utilizes both Synthetic Aperture Radar (SAR) and multispectral satellite data. The study demonstrated that the proposed model could generate accurate flood maps even when only one type of sensor data was available. The researchers reported high mapping accuracy and emphasized that sensor flexibility is particularly valuable during disaster situations when rapid flood information is required.

3.2. Flood Monitoring

Flood monitoring is defined as the continuous observation of flood conditions and their progression over time. According Akram[10] who made use of MODIS satellite imagery and Geographic Information Systems (GIS) techniques to monitor flood extent and evolution, demonstrated that satellite-derived information could be used to track flood progression over time and provide timely information for emergency response operations. The authors reported that continuous monitoring helps authorities understand flood severity and identify areas requiring urgent intervention. Misra[11] in their work titled, "Global flood monitoring using nearly a decade of Sentinel-1 observations" developed a global flood monitoring system based on nearly ten years of Sentinel-1 radar observations. The study produced a comprehensive flood dataset capable of monitoring flood events regardless of weather conditions. The study highlighted the usefulness of long-term satellite observations for understanding flood patterns and supporting disaster management efforts. Also, Schumann[12] reviewed recent breakthroughs in satellite remote sensing of floods and emphasized the growing role of SAR satellites, machine learning, and global monitoring systems in flood observation. It was reported by the authors that modern remote sensing platforms provide frequent and near-real-time observations that allow emergency managers to monitor flood development more effectively than traditional ground-based methods. The work by Tulbure[13] investigated the application of artificial intelligence and multimodal geospatial foundation models for near-real-time flood monitoring at a global scale. The researchers integrated optical and SAR satellite imagery to improve monitoring performance across diverse environmental conditions. Their findings revealed that AI-driven models can enhance the speed and accuracy of flood detection, thereby supporting timely disaster response and resilience planning.

3.3. Flood Forecasting and Early Warning

Flood Forecasting and Early Warning Systems refer to the integrated processes and technologies used to predict when and where a flood is likely to occur and alert people and authorities in advance so they can take protective actions. In the view of Wu who investigated the integration of satellite rainfall estimates with hydrological models for flood forecasting in flood-prone regions of China, remotely sensed rainfall data improved the accuracy of flood predictions, particularly in areas with limited ground-based meteorological stations. It was concluded by the authors that satellite observations can enhance forecasting capabilities and support timely flood warnings. Similarly, Yin developed a remote sensing-based flood forecasting framework that incorporated precipitation and soil moisture data obtained from satellite platforms. Their findings revealed that combining multiple environmental variables improved the reliability of flood forecasts. The study emphasized the importance of satellite monitoring in providing advance warning before severe flood events occur. Also, the research work by Mosavi reviewed recent developments in artificial intelligence applications for flood forecasting.

Their analysis showed that machine learning models integrated with remotely sensed environmental data can accurately predict flood occurrence and magnitude. The researchers highlighted that AI-driven forecasting systems have become increasingly important in disaster preparedness and emergency planning. More recently, Zhang[14] employed multi-source satellite observations and deep learning techniques to develop an early warning system for flood-prone communities. The study demonstrated that the integration of satellite rainfall products, land surface information, as well as hydrological variables significantly improved forecasting performance. The researchers reported that the system provided warnings several hours before flood occurrence, thereby allowing adequate time for emergency response.

3.4. Flood Damage Assessment

Flood damage assessment involves evaluating the impacts of flood events on infrastructure, agricultural land, buildings, transportation networks, and human settlements. In the work titled, "Assessment of agricultural flood damage using Sentinel-1 radar imagery" by Kumar[15] Sentinel-1 radar imagery was employed to assess flood damage in agricultural areas affected by seasonal flooding. Their result revealed that remote sensing techniques could accurately identify damaged croplands and estimate the extent of agricultural losses. The authors noted that satellite-based assessment provides critical information for compensation and disaster relief planning. According to Cian[16] who investigated the use of high-resolution satellite imagery for post-flood damage assessment, remotely sensed data effectively identified damaged buildings, roads, and other infrastructure. The study emphasized the importance of satellite observations in supporting rapid disaster response and resource allocation. In the same way, Rahman[17] utilized multi-temporal Sentinel-2 imagery to assess flood impacts on land use and agricultural productivity. The researchers discovered that there were significant changes in vegetation cover and cultivated land following major flood events. Their study demonstrated the usefulness of remote sensing for evaluating both immediate and long-term consequences of flooding. Patel[18] applied machine learning techniques to satellite imagery for automated flood damage assessment. The study achieved high accuracy in detecting damaged structures and estimating economic losses. The researchers concluded that combining artificial intelligence with remote sensing can significantly improve the speed and reliability of post-disaster assessments. These show that both remote sensing and artificial intelligence are very crucial in flood damage assessment.

3.5. Flood Risk Mapping

Flood risk mapping is defined as the systematic process of identifying, analyzing, and visually displaying the spatial distribution of flood risk in a given area by combining flood hazard (probability and extent of flooding), vulnerability (susceptibility to damage), and exposure (elements at risk such as people, buildings, and infrastructure). Remote sensing provides valuable data on topography, land use, drainage networks, rainfall patterns, and historical flood occurrences, which are essential inputs for flood risk assessment. Pham[19] did a work in which remote sensing and Geographic Information System (GIS) techniques were applied to develop flood risk maps for flood-prone regions in Southeast Asia. The study integrated satellite-derived environmental variables such as elevation, land use, rainfall, and drainage density to identify areas susceptible to flooding. The findings revealed that remote sensing data significantly improved the accuracy of flood risk prediction and supported sustainable land-use planning. Also, Costache[20] made use of machine learning algorithms and remotely sensed data to examine flood susceptibility in Romania. The researchers combined satellite imagery with topographical and hydrological factors to generate detailed flood risk maps. Their results showed that artificial intelligence techniques can effectively identify areas at high risk of flooding and assist policymakers in disaster preparedness planning. Furthermore, Arabameri[21] investigated the use of Sentinel satellite imagery and GIS-based modelling for flood hazard mapping. The research demonstrated that integrating remotely sensed environmental parameters with statistical models enhanced the accuracy of flood risk assessments. The researchers emphasized the importance of satellite observations in

identifying vulnerable communities and infrastructure. According to Rahmati[22] carried out a similar work using multi-source remote sensing datasets and deep learning approaches to improve flood risk mapping, optical imagery, and hydrological data provided more reliable flood susceptibility assessments than conventional methods. The study concluded that advanced remote sensing technologies can support effective flood mitigation and land management strategies.

3.6. Watershed and Drainage Analysis

Watershed and drainage analysis can be defined as the systematic assessment of a watershed and its drainage network to understand the movement, distribution, and accumulation of surface water within a catchment area. It involves analyzing topography, stream networks, flow direction, drainage patterns, and hydrological characteristics to support effective water resources management, flood risk assessment, environmental protection, soil conservation, and sustainable land-use planning. As reported by Singh[23], remote sensing techniques provide accurate delineation of watershed boundaries and facilitate the identification of flood-prone zones within river basins. In their work, they utilised satellite imagery and Digital Elevation Models (DEMs) to analyse watershed characteristics and drainage patterns in northern India. According to Patel [24] who applied GIS and remote sensing tools to evaluate drainage network characteristics and runoff behaviour in a rapidly urbanizing watershed their findings showed that changes in drainage patterns caused by urban development significantly increased flood susceptibility. The researchers recommended continuous monitoring using remote sensing to support effective watershed management. Alam in their work titled, "Remote sensing applications in watershed modelling and flood management", investigated the role of remote sensing in watershed modelling and flood management. The study integrated satellite-derived topographical and hydrological information to assess runoff generation and water flow patterns. The results revealed that remote sensing data improve the accuracy of watershed models and enhance flood prediction capabilities. Similarly, Kumar[25] employed high-resolution satellite imagery and DEM data to analyse watershed dynamics and drainage evolution in flood-prone regions, remote sensing technologies enable efficient monitoring of changes in drainage systems and support the development of flood mitigation strategies. It was highlighted by them that there a growing importance of satellite observations in sustainable watershed management.

3.7. Monitoring Land Use and Land Cover Changes

Monitoring land use and land cover changes is the continuous observation and assessment of changes in how land is used and the physical features covering the land over time, using geospatial technologies such as remote sensing and GIS to support informed environmental and land management decisions. AbdelRahman[26] investigated the impact of land use and land cover changes on flood susceptibility using satellite imagery and GIS techniques. The study revealed that rapid urban expansion and vegetation loss significantly increased surface runoff and reduced water infiltration, thereby increasing flood risk. The researchers emphasized the importance of regular land cover monitoring in flood management planning. In the same way, Wang[27] utilized Sentinel-2 satellite imagery to examine land cover changes and their influence on flooding in rapidly developing urban areas. The findings indicated that increasing impervious surfaces, such as roads and buildings, contributed significantly to higher flood frequencies. The study demonstrated the effectiveness of remote sensing in detecting environmental changes associated with flood hazards.

As reported by Mokarram[28] on their work which investigated the relationship between land use dynamics and flood occurrence using multi-temporal satellite data, the conversion of forests and wetlands into agricultural and residential areas increased flood susceptibility within the study region. The authors concluded that remote sensing serves as an effective tool for evaluating environmental changes that contribute to flood disasters. Similarly, Li employed artificial intelligence and remote sensing technologies to monitor land use changes and assess their impacts on flood vulnerability. The study

revealed that integrating machine learning with satellite imagery improved the accuracy of land cover classification and flood risk assessment. The researchers recommended the use of advanced remote sensing techniques for sustainable environmental management and disaster prevention.

3.8. Emergency Response and Relief Planning

Emergency response and relief planning involve the coordination of rescue operations, humanitarian assistance, and resource allocation during and after flood disasters. It is the process of developing and implementing strategies, resources, and coordinated actions to prepare for, respond to, and recover from emergencies and disasters, ensuring the efficient delivery of rescue, relief, and recovery services while minimizing loss of life and property. According to Vo[29] in their research on the application of satellite remote sensing for emergency flood response and disaster management, satellite imagery provides rapid situational awareness during flood events and enables emergency responders to identify severely affected areas. The researchers concluded that remote sensing significantly enhances disaster response efficiency. Likewise, Tarpanelli[30] investigated the use of satellite observations for near-real-time flood emergency management. Their findings showed that remote sensing technologies can provide accurate flood extent information within hours of a disaster, thereby supporting evacuation planning and relief operations. The study emphasized the importance of timely satellite data in reducing disaster impacts. As discussed in the work by Tellman[31] on the topic "Remote sensing frameworks for flood monitoring, disaster response and humanitarian planning", satellite imagery could effectively support emergency planning by identifying isolated communities, damaged infrastructure, and transportation disruptions. The study highlighted the growing role of remote sensing in humanitarian assistance and disaster recovery efforts. Furthermore, Kaku[32] evaluated the integration of artificial intelligence and satellite data for emergency flood response. The study found that automated image analysis techniques significantly improved the speed of identifying disaster-affected locations and estimating relief requirements. The authors concluded that combining remote sensing and AI technologies can strengthen disaster resilience and emergency preparedness.

4. Conclusion

This study has clearly shown that remote sensing plays a very important role in modern flood management. From the reviewed literature, it is evident that satellite-based technologies have greatly improved the way floods are mapped, monitored, predicted, and managed across different regions of the world.

The study reveals that flood mapping and monitoring are now faster and more accurate due to the use of radar and optical satellite imagery. Also, flood forecasting and early warning systems have improved significantly with the integration of remote sensing data and machine learning models, helping to reduce the impact of flood disasters on human lives and infrastructure.

Furthermore, remote sensing has proven effective in flood damage assessment, risk mapping, watershed analysis, land use monitoring, and emergency response planning. These applications help governments and disaster management agencies to make informed decisions before, during, and after flood events. In conclusion, remote sensing has become an essential tool in flood disaster management. However, there is still a need for improved data accessibility, local capacity building, and increased adoption of advanced technologies such as artificial intelligence in developing countries like Nigeria. This will further strengthen flood preparedness and reduce the recurring impacts of flooding across vulnerable communities.

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