URBAN FLOODS ANALYSIS BY USING REMOTE SENSING IMAGERIES IN ASIAN: SYSTEMATIC REVIEW

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Abstract: Floods are not extraordinary natural disasters; in fact, it happens every year in Asian countries. In the future, climate change will increase the likelihood of flooding in most urban areas due to extreme events and rising sea levels. The objective of this article is to provide an overview and systematic literature on the remote sensing approach in order to examine and analyse urban floods in Asian countries. This paper highlights various aspects of remote sensing and its applications in flood studies in Asian countries particularly. For mapping and analysing urban floods, remote sensing data and methods such as high-resolution data from optical and SAR satellites are vital. This technology is able to analyse and display visualizations of a geographical area because the action of identifying and understanding the possibility of flood risk areas accurately is very important to reduce the risk during a disaster. The finding shows that remote sensing technology has been used in Asian countries widely in terms of surveying, identifying, classifying, mapping, and monitoring natural resources, environment, and disasters in the context of flood risk analysis. The majority of Asian nations employ remote sensing imagery from optical and microwave satellite sensors. Remote sensing technology is capable of disaster monitoring, mitigation, damage assessment, security, preventive, training, information exchange, and regional and worldwide collaboration. The right procedures through this technology should be made to mitigate a disaster for achieving the resiliency of cities. Every level of project design, execution, and monitoring should put in a valiant effort to address the existing flood disasters.

Keywords: Urban Floods, remote sensing, GIS, geospatial techniques and Urban Planning

1. Introduction

Floods are one of the most common natural disasters in most countries around the world including in Asian countries. According to the World Meteorological Organization (WMO), floods are the third-worst natural disaster to ever occurred. According to Federal Emergency Management Agency (FEMA), flooding is described as a condition in which dry land is covered with water. Several causes contribute to the formation of water reservoirs, including river overflow, rainwater runoff, and blocked drainage conditions. Flood risk has been linked to climate change in several studies. According to the IPCC assessment (IPCC, 2018), due to severe events and a rising sea level, climate change will increase the likelihood of floods for many urbanised areas in the future (Scott and Strauss, 2019). Increases in impervious surface due to urban and suburban development intensify floods and their impacts (Anderson 1968).

Currently, almost 50% of the world's population lives in urban areas, and this ratio will rise in the future, especially in emerging nations (United Nations, 2018). According to World Urbanization Prospects (United Nations 2014), more people live in urban regions than rural; 54% of the world's population lived in urban areas in 2014, and by 2050, 66% of the population would live in the same. Growth in urban economies is a primary factor in urbanisation in both developed and developing countries. (Cohen 2004). Urban areas are particularly vulnerable to flooding, which can result in fatalities and significant infrastructural damage. One of the most severe natural disasters that affect urban areas is the risk of flooding, which results in the loss of life, destruction of property, depletion of resources, and environmental degradation (Forkou, 2011). Other experts claim that the increasing frequency of floods is caused not only by extreme climate change but also by the ongoing expansion of people and property in flood-risk regions, which increases the potential for damage (Hooijer et al., 2004).It is projected every year, about 200 million people in over 90 countries experience devastating flooding, a number that is anticipated to increase due to climate change, population growth that is ongoing, urbanisation, and other factors (UNESCO 2008). It is estimated that by the end of the twentieth century, floods killed over 100,000 people and impacted another 1.4 billion throughout the world. (Jonkman, S. N. 2005). The trend of flash floods that occur, especially in urban areas, is seen to be on the increase. Incident floods have a huge impact, especially on the social and economic aspects of the people especially in developing areas and having high population densities where it results in loss, destruction of property and even loss life.

High rainfall intensity, dense development areas, poorly maintained drainage systems as well as drain and drainage pollution problems are seen as major contributors to flash floods in urban areas. Increased flood risks and hazards are a result of blocked drainage channels and changes in hydrological and hydro-meteorological processes brought on by fast urbanisation without effective urban planning and the effects of climate change, such as sea-level rise, seasonal floods, and storms (Eccles et al. 2019). Drastic changes in land use patterns have resulted in many –water-impermeable areas that increase the flow rate and discourage the natural absorption of runoff into the soil. Utilizing larger expanses of land as system components provides a more accurate means of quantifying damages and estimating flood risk, as seen by the size of elements in a flooded urban area. (Romali, N.S et al. 2018).

It is challenging to foresee natural disasters like floods. But in order to prepare the community for the scenario in the face of foreseen phenomena, experts are attempting to construct more precise models. Countries need to be able to gather data independently across borders in order to provide appropriate flood warnings. Primarily, an early warning system requires an evaluation of the potential risk of flooding based on geographic location. (Mason et al.2021). Also, gauging stations measure water height, not flood magnitude. These criteria can be filled by data from remote sensors on satellites and aeroplanes. Multitemporal satellite data may monitor urban floods. Several studies demonstrate that GIS and Remote sensing imageries approach which are the most efficient, fast, high -tech as well as relevant tools for the modern world today can solve this problem. The most acceptable strategy for a certain flooding phenomenon is determined by the data type, processing methods, and geographical representation. (Ismail et al.2015).

A systematic literature review (SLR) is an effective technique to gather data, evaluate critically as a whole, integrate, and present the findings from diverse research papers that are relevant to the research questions or areas of interest. Therefore, the objective of this article is to provide an overview and systematic literature on the remote sensing approach in order to examine and analyse urban floods in Asian countries.

2. The phenomena of Urban Flood in Asian Countries

Asian countries have been the victim of the most destructive floods in recent history. Many cities in Asian have been severely impacting due to these extreme climate events, and many more such events are expected in the near future. The majority of Asian nations are vulnerable to disasters. Developing countries usually suffer higher casualties from natural hazards than developed countries. In developing countries, thousands of victims are killed or injured by natural disasters every year (Rodriguez, J et al 2008). They are more susceptible to natural catastrophes and environmental risks due to of their physiography, morphology, and other climatic factors. In Asian countries such as Malaysia, China, Thailand, Indonesia and Vietnam have experienced these flood disasters in the past decade. Extreme rainfall events due to climate change have made floods more frequent and destructive.

In Malaysia, monsoon floods and flash floods are the two main forms of floods that frequently happen. Recently, the trend of flash floods in Malaysia that occur especially in urban areas is seen to show an increase. While flooding happens often in Malaysia during its yearly monsoon season, as in many other Asian countries, the wealthier regions, such as the capital and neighbouring Selangor, often experience such broad disasters. Government authorities classified the recent floods in Malaysia as a "once-in-a-100-years" weather disaster some of which occurred in locations that were formerly thought to be impervious to such destruction and resulted chronic damages. According to the Asian Reduction Disaster Centre 2011, Malaysian floods cause $915 million in damage annually and affect 29,800 km2 and 4.82 million people. In addition to already having a difficult time coping with population increase, fast urbanization, and deteriorating infrastructure, the region's metropolitan areas now face a greater threat from storms brought on by climate change, heat waves, floods, and forest fires.

In China, urban flooding has grown severe and extensive, with social, economic, environmental, and ecological effects. Beijing was hit with some of the worst floods two years in a row in 2011 and 2012. The major causes of floods are insufficient urban drainage networks, the loss of natural water bodies, and the urbanisation of China. (Liu et al 2003). These causes, along with the worst rainfall in Beijing in 60 years, led to widespread flooding. Most Chinese cities' drainage networks have been constructed in previous decades. Hundreds of years ago, urban flooding was less frequent than today (Du and Qian, 2012; Tao et al., 2014; Wang and Zhao, 2014). Citizens were stranded as floodwaters claimed many roads and forced the closure of subway stations. Within one day of the flooding, more than 50,000 people were evacuated and more than 70 perished. Furthermore, these twin flood events resulted in waterlogging.

Furthermore, Jakarta also is considered one of the most susceptible cities to floods worldwide due to its low elevation and land subsidence, and the heavy rain that it experiences. In recent years, the increasing unplanned development of the city has caused many urban problems. For example, the vegetative coverage across Jakarta has become very low because of excessive urbanization. According to International Jakarta River Basin Management, Jakarta is very polluted and freshwater resources are limited. Residents overexploit subsurface water without official authorization, causing Jakarta's surface to sink every year. Jakarta is now particularly susceptible to climate change. Flooding is the most serious climate and disaster risk confronting Jakarta, with severe human and economic consequences. 40% of the city, particularly in the north is below sea level and susceptible to tidal floods, storm surges, and future sea level rises. Total rainfall and rainfall intensity have risen, while global warming and the urban heat island effect have raised average temperatures.

Bangkok also experienced one of the worst floods in recent history. From March to August 2011, heavy and successive rainfall up north joined forces with five tropical storms. The floodwaters ravaged provinces until they reached the city. The year of this severe flood was caused by a failure in the drainage system, which was expanded and upgraded 20 years earlier so that water could be absorbed during the monsoon season with ordinary rainfall, but was not effectively maintained in the year of the disaster happen. The flood affected more than one-third of the country, killed hundreds of people, destroyed millions of hectares of crops, and forced thousands of factories to close. Slums close to natural drainage canals suffered the highest toll. People had to be relocated outside the city.

Vietnam, situated in a tropical monsoon region in the Asia Pacific Region, is particularly affected by urban flooding. Typhoons, tropical storms, floods, landslides, and droughts generated USD $7.9 billion in economic damages from 1980 to 2010. (Vietnam Disaster Statistics). 70% of the country's population is vulnerable to natural hazards, although floods cause the greatest damage to life and property (Central Committee for Flood, and Storm Control) (CCFSC). The central region of Vietnam has a complicated sloping topography and is prone to frequent and destructive floods. Increasing population, fast socioeconomic development, unplanned urbanisation, strains on natural resources, and climate change have increased the Vietnamese population's flood dangers and catastrophe risk.

The number of publications on urban flooding in Asian countries in the Scopus database stated (418) publications involving articles, book chapters, conference papers, reviews, books, etc. The United States stated (52) publications that were mostly produced as research articles, while the least number of countries that published papers was Malaysia, with only (19) publications. Figure 1a shows the total publication on “Urban Flood in Asian Countries” in the Scopus database. For the past 20 years, the number of publications on urban flooding in Asian countries in the Scopus database for year 2002-2022 shows fluctuation trends. The highest publication was recorded on 2021 which is (57) publications while the lowest number of publications was on 2004, 2005, 2007 with only (1) publications by each year. None of the publications was recorded for 2003.Figure 1b shows total publication on “Urban Flood in Asian Countries” for the year 2002-2022 in the Scopus database.

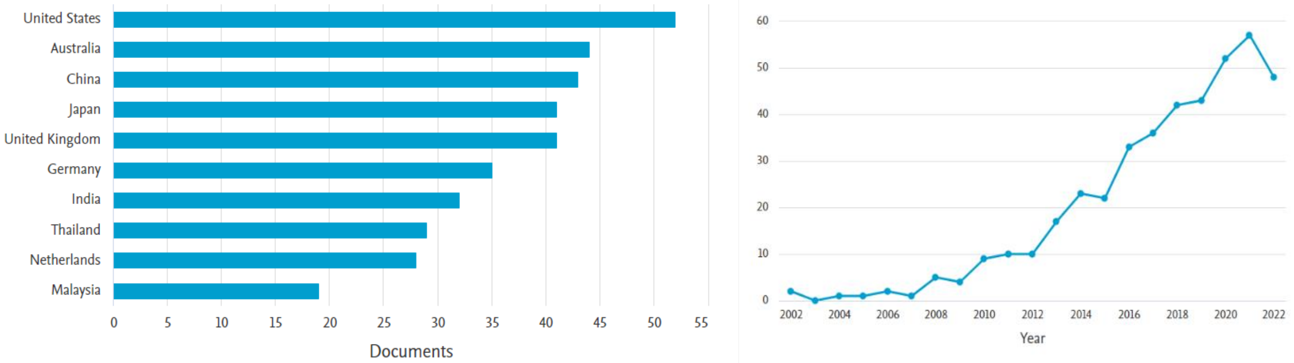

Figure 1a) total publication on “Urban Flood in Asian Countries” in scopus database 1b) total publications on “Urban Flood in Asian Countries” for year 2002-2022

4. Techniques for Urban Flood Analysis

The various studies of digital tool approach on Remote Sensing for urban flood analysis. Various case studies and approaches have been developed to evaluate the scope and effect of floods.

Table 1: The various case studies in Asian Countries of Remote Sensing approaches for flood analysis

Author	**Year**	**Floods Context/urban or non-urban**	**Types of remote sensing data**	**Techniques that have been used for this study**	**Countries**
Hui Zhang et al	2022	Assessment and Improvement of Urban Resilience to Flooding at a Subdistrict Level	Satellite Sentinel-1A (S1A)	Multi-Source Geospatial Data (principal component analysis)	Indonesia
Xu Yuan et al	2021	Flood disaster monitoring	Sentinel-1 satellite images	C-band SAR, Vertical Transmit / Vertical Receive (VV)	China
Dhara et al	2020	Accounting for Uncertainty and Reconstruction of Flooding Patterns	Multi-Satellite Imagery (Landsat, MODIS and Sentinel-2)	Support Vector Machine	Vietnam
Zhen Dong et al	2020	Monitoring the summer flooding in the Poyang Lake area	Sentinel-1 Synthetic Aperture Radar (SAR) imagery (optical imagery)	Multiple Convolutional Neural Networks	China
Littidej, P.; Buasri, N.	2019	Built-Up Growth Impacts on Digital Elevation Model and Flood Risk Susceptibility Prediction	Digital Elevation Model / Cellular Automata (CA)	Geographic Weighted Regression (GWR)	Thailand
Kabir Uddin, Mir A. Matin, Franz J. Meyer	2019	Operational Flood Mapping	Sentinel-1, Landsat-8	Multi-Temporal Sentinel-1 SAR Images (ESA's Sentinel Application Platform)	Bangladesh
Rupal K. Waghwala & P.G. Agnihotri	2019	Impact assessment of urbanization on flood risk and integrated flood management approach	Satellite image Resourcesat-1	Spatial Analyst	India
Nguyen Thanh Son et al	2018	Flood Risk Assessment	Landsat imageries	Linear unmixing model (LUM) Support Vector Machines (SVM)	Cambodia
Aprillia Findayani et al	2018	Food Risk Disaster Mapping	Multispectral Satellite Imagery (Landsat 5 L1T, Landsat 7L1T, ASTER L1A)	Landsat L1T	Indonesia
Xiaohua Tong et al	2017	Flood Monitoring	Multi Satellite Imagery (Landsat 8 optical imagery and COSMO-SkyMed radar imagery)	Fast Line-of-Sight Atmospheric Analysis of Spectral Hypercubes (FLAASH)	China

Gabriele Bitelli, Francesca Franci and Emanuele Mandanici	2014	Remote Sensing analysis for flood risk management in urban sprawl contexts	Multispectral Satellite Imagery (Landsat 5 L1T, Landsat 7 L1T, ASTER L1A)	Landsat L1T	Dhaka, India
Kridsakron Auynirundronkool et al	2011	Flood detection and mapping of the Thailand Central	RADARSAT and MODIS	Multi-source (SOS, WPS under a sensor web environment)	Thailand Central

4.1 Remote Sensing techniques in Flood Analysis

Since the 1990s, remote sensing has dramatically improved flood mapping and risk assessment. Earth observation satellites, also known as remote sensing satellites, are used to observe, map, and monitor environmental occurrences on the earth's surface. This satellite differs from weather satellites in that it is equipped with superior optical equipment capable of producing high-resolution pictures to the metre level. Satellite RS technology could play a vital role in disaster monitoring, mitigation, damage assessment, preparedness, prevention, training, information exchange, regional and international cooperation (M.A.H. Pramanik, et al). It is evident that, remote sensing is a very important part of managing natural hazards since they are complex and have a strong spatial component (Cappock, 1995). Mejia-Navarro et al. (1994) attempted to employ remote sensing imagery for flood analysis initially.

The use of remote sensing to identify river flooding, stage, and discharge is discussed by Smith (1997). In this way, the attention has shifted from flood boundary mapping to risk and disaster monitoring. Therefore, there is a need to analyse the current literature with a holistic approach of applying remote sensing in flood analysis. Islam and Sado (2000, 2002) recommended countermeasures in a flood risk map utilising RS technology to create land use plans and coordinate emergency action. The data gathered in these analyses is a crucial technological resource for determining and mitigating flood risks. In particular, this study will emphasise many features of remote sensing and its applications in Asian flood analyses.

4.2 Analysis of Floods Applying Remote Sensing Technology in Asian Countries

In this evolved and contemporary age, the usage and adaption of technology is viewed to aid and facilitate an application. This has been established and applied in many developed nations where "satellite technology" plays such an important part and influence in dealing with and coping with disaster situations. In particular, floods, which are reportedly common in Asian countries, are a major benefit of remote sensing image for disaster management efforts. It is possible to observe flood-prone areas by combining satellite photos taken before, during, and after floods with topographic data such as hydrology and land use information. As part of the operations for the International Geophysical Year (1957–58), the Russian satellite Sputnik I was launched on October 4, 1957, starting in the space age. Earth resources satellites ERTS / LANDSAT I in 1972 and SPOT in 1986 and the meteorological satellite, which was launched in 1960, have expanded the use of satellite technology globally (M.A.H. Pramanik et.al 1993). In Asian nations, multiband, multidate, and multistage satellite imagery has been widely employed for water resource assessments, monitoring, and management, including flood analysis.

The number of publications on "Flood Analysis using Remote Sensing" in Asian countries in the Scopus database stated (127) publications involving articles, book chapters, conference papers, reviews, books, etc. China stated (16) publications that were mostly produced as research articles, while the least number of countries that published papers was Malaysia, with only (6) publications. Figure 1a shows total publication on "Flood Analysis using Remote Sensing Approach" in Asian countries in Scopus database. For the past 20 years, the number of publications on "Flood Analysis using Remote Sensing" in Asian countries in the Scopus database for year 2002-2022 shows fluctuation trends starting on 2010-2022. The highest publication was recorded on 2021 which is (23) publications while the lowest number of publications was on 2002 with only (1) publication. None of the publications is recorded on 2003 until 2010Figure 1b shows total publication on "Flood Analysis using Remote Sensing" for year 2002-2022 in Scopus database

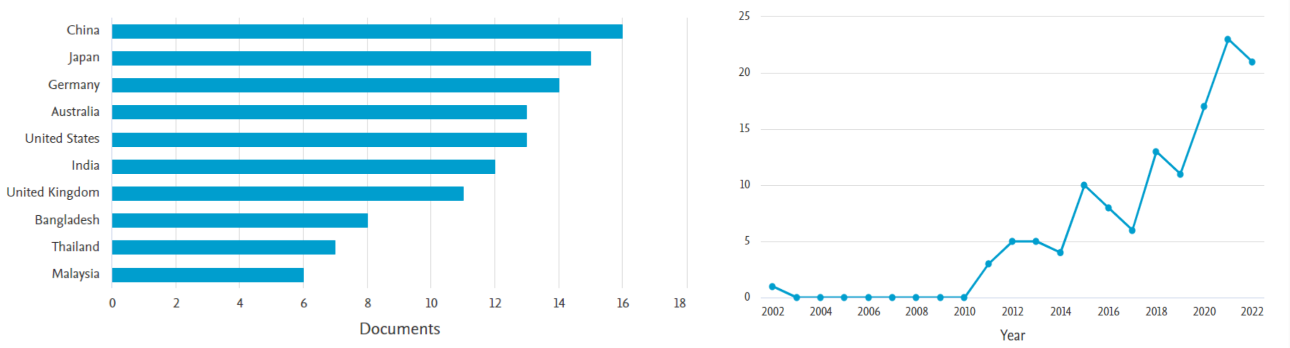

Figure 2a: total publication on "Flood Analysis using Remote Sensing" in Asian countries in Scopus database
2b: total publication on "Flood Analysis using Remote Sensing" for year 2002-2022 in Asian countries in Scopus database

Findings and result

According to the existing literature, the finding indicates that remote sensing technology has been widely employed in Asian countries for surveying, detecting, categorizing, mapping, and monitoring natural resources, the environment, and disasters in the context of urban floods risk analysis. The table shows, the Asian countries which has been applied the remote sensing methods such as high-resolution data from optical and SAR satellites images, in context of analyse urban flood

Table 2: Satellites data that has been applied in Asian countries

Country	Year	Types of satellite images / sources data	Techniques
Bangladesh	1984	Canadian RADARSAT and European ERS-1 and 2	NOAA/ Advanced Very High-Resolution Radiometer (AVHRR), High resolution Picture Transmission (HRPT), Shuttle Imaging Radar (SIR-B)
	1993	ERS-1 SAR Image	High-Resolution Data
	1998	RADARSAT 7	RADARSAT Scan SAR Wide data (SPARRSO, CEGIS)
	2017	LANDSAT 5,7,8, Moderate Resolution Imaging Spectroradiometer (MODIS), Sentinel-1A (optical imageries)	Multi-satellite Precipitation Analysis (TMPA)
	2022	RCM-1 images	Synthetic-Aperture Radar (SAR) Data (High Temporal Resolution)

Malaysia	2010	RadarSat-2	High-resolution SAR C-Band HH-polarized
	2013	Landsat 8 OLI/TRS	Moderate Resolution Imaging Spectroradiometer (MODIS)
	2014	RADAR imagery of SENTINEL-1	SENTINEL application platform (SNAP)
China	1980-1984	NOAA-AVHRR, Landsat	Landsat-5/TM data Multispectral Scanner (MSS) Thematic Mapper (TM) (multi-temporal, multi-source)
	1993-1999	JERS-1 (Japanese Earth Resources Satellite-1), ERS-1/2 (European Remote Sensing Satellites 1, 2), Radarsat, FY-2, airborne SAR, Landsat TM	Synthetic Aperture Radar (SAR) data, Thematic Mapper (TM)
	2009	HJ-1 A/B, TERRA and GF-1, GF-2	MODIS (Moderate Resolution Imaging Spectroradiometer)
	2020	Sentinel-1	Synthetic Aperture Radar (SAR)
India	1980-1990	Radarsat	NOAA Advanced Very High-Resolution Radiometer (AVHRR)
	2014	Landsat 5 L1T, Landsat 7 L1T, ASTER L1A	Landsat Thematic Mapper (TM) imageries
Thailand	1980	Landsat	Landsat Thematic Mapper (TM) imageries
	2011	Radarsat	MODIS
	2021	Sentinel-1	Multi-satellite Precipitation Analysis (TMPA)

The majority of Asian nations employ RS imagery from optical and microwave satellite sensors including Sentinel, Landsat ERS, Radarsat high-resolution data. In the context of flood analysis, this form of remote sensing data is very useful for inventorying and analysing many elements of human relationship with land and water. The meteorological satellite imagery/data (1000m resolution), Landsat / Spot imagery/data (30m & 10m) have wide global applications for flood forecasting, monitoring, damage assessment, construction, rehabilitation. It can map and track flood occurrences as they are happening and in close to real time. The capacity of radar satellite photos to see through clouds makes them more useful for monitoring floods in this condition. Images taken before, during, and after floods may be merged to show changes experienced and calculate property damage. The mapping of the flood damage area has been completed and other socio-economic consequences due to flooding have been described using conventional as well as integrated RS.

There are several studies that have been conducted to reduce the impact in the event of a flood through flood risk management, mapping and flood modelling. The use of RS technologies in research on natural disasters has been increasing in recent years. This can be evidenced by the increase in research studies related to the mapping of flood risk areas using RS in various Asian countries. The presented methodologies and their use in diverse studies indicate how risk assessments provide system, flood event, and outcome data.

Challenge and Way Forward

Nowadays, remote sensing data and techniques provide essential help for mapping and studying urban floods. In the context of urban flood studies, this technique has been extensively employed to solve critical difficulties and challenges in sustainable development. There has been important research on the integration of remotely sensed data with flood modelling, and today there is a widespread agreement among space agencies to increase the assistance that satellite missions can provide. However, the flooding of urban areas remains a big challenge for remote sensing techniques and researchers. One of the main challenges is the absence of more accurate global topography, especially in urban areas where assets are located that are at danger. Another issue is the lack of more open-access model driving precipitation, discharge, and boundary data. Improved integration between data, models, and output products is required for the science of flood hazard and risk to be more accurate and have a greater impact. This involves complex topography, quick changes, and river management action which must be detected and mapped to obtain quality flood analysis to mitigate the impact of floods as well as for resiliency of cities in future

Conclusion

It is clear that, majority of Asian countries use optical and microwave satellite imaging from sensors such as Sentinel, Landsat ERS, and Radarsat high-resolution data. This form of remote sensing data is suitable products for flood inundation mapping and it widely used for inventorying and analysing flood in Asian countries. It has been demonstrated that satellite-based flood maps may be highly useful for analysing and evaluating the spatial extent of flooding occurrences as well as for directing rescue and relief operations. The government may utilise all this information to plan, organise, and anticipate disasters in order to create an efficient disaster control system. To overcome this worldwide issue, it is important to keep helping and developing basic and applied research that allows better targeting of interventions to improve resilience, reduce vulnerability, and speed up recovery, as well as helping decision-makers create more effective risk of flooding policies. A more effective and informative administration must be formed so that all stakeholders may contribute in tackling this issue. The use of current satellite technology to aid disaster management before, during, and after a disaster is an effective initiative. Mapping the extension, the depth and the velocity of flooded water by remote sensing data and techniques should provide contributions to the urban managers, emergency planning managers insurers, and decision-makers. They need the outcomes of this study in order to prepare for more effective science-based urban planning, choices about early warning, and adaptation and mitigation efforts.

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