FLOOD DAMAGE ASSESSMENT USING REMOTE SENSING AND GIS: THE PAST AND PRESENT

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ABSTRACT

A flood is a runoff of water that sinks land that is generally dry. Floods are caused not only by rain but also by human changes to the surface of the earth. Flooding occurs as an overflow of water from water bodies, such as a river, lake, or ocean, in which the water overtops or breaks embankments. It results some of that water escaping its usual boundaries or it may occur due to an increase of rainwater on inundated ground in an areal flood. Deforestation and urbanization increase the runoff from rains thus inundate vast areas today that previously caused no flooding. The careless building in vulnerable areas, poor watershed management and failure to control the flooding create the disaster condition. This paper presents a literature review on flood damage assessment in urban areas and their applications. It also describes the methodologies used for assessing the flood damage.

Keywords: flood, inundation, disaster

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1. INTRODUCTION

1.1. Causes of Flooding

Flooding is an overflowing of water onto land that is normally dry. Floods can happen during heavy rains, when ocean waves come on shore, when snow melts too fast, or when dams or embankments break. Flooding may happen with only a few inches of water, or it may cover a house to the rooftop. They can occur quickly or over a long period and may last days, weeks, or longer.

Different types of flood have different effects in terms of their impact, damage and cost, both economically and to the public who experience them. The different flooding types are Fluvial (River) flooding, Coastal (Surge) Flooding and Pluvial (Surface water) flooding.

Fluvial flooding occurs when rivers burst their banks as a result of sustained or intense rainfall. There are two main types of fluvial flooding:

- Overbank flooding occurs when water rises overflows over the edges of a river or stream.
- Flash flooding is characterized by an intense, high velocity torrent of water that occurs in an existing river channel with little to no notice

There are two types of events that can be the source of a flooding and their combination of the two sources is also possible.

- Precipitation: causing excessive discharge.
- Large water bodies: Wind or earthquake causing temporarily higher water levels in a sea or lake. This is often combined with tidal effects.

Coastal flooding is caused by extreme tidal conditions including high tides, storm flows and tsunamis. Coastal flooding is categorized in three levels:

- Minor: A slight amount of beach erosion will occur but no major damage is expected.
- Moderate: A fair amount of beach erosion will occur as well as damage to some homes and businesses.
- Major: Large-scale beach erosion will occur, numerous roads will be flooded, and many structures will be damaged. Serious threat to life and property. Citizens should review safety precautions and prepare to evacuate if necessary.

Pluvial flooding occurs when an extremely heavy downpour of rain saturates drainage systems and the excess water cannot be absorbed. There are two common types of pluvial flooding:

- Intense rain saturates an urban drainage system. The system becomes overwhelmed and water flows out into streets and nearby structures.
- Run-off or flowing water from rain falling on hillsides that are unable to absorb the water.

The most important physical cause of floods concerns the interaction between precipitation and drainage basin response. Figure 1 shows the physical causes of flood.

Figure 1 Physical causes of Flood

Urban flooding is a significant problem for many cities across the developed and developing cities. Betterment of the floods effect need to formulate a sound flood management policy which is driven by knowledge of the frequency and magnitude of impacts of these floods. Figure 2 shows the causes of urban flood.

Figure 2 Causes of urban Flooding

The size, or magnitude, of a flood is described by a term called recurrence interval. The recurrence interval measures the frequency of a flood of a specific size occurring. The accuracy of the recurrence interval is reliant on the amount of historical data available about previous floods. The large flood has a large recurrence interval and less frequent recurrence interval. A small flood has a smaller and more frequent recurrence interval. The recurrence interval is calculated using the formula given below:

$$T = \frac{n + 1}{m}$$

Where T is the recurrence interval, n is the number of years on record and m is the ranking of the flood relative to all the other floods on record for a specific river.

1.2. Remote Sensing

Remote sensing refers to the activities of recording /observing /perceiving objects or events at far away (remote) places. In remote sensing, the sensors are not in direct contact with the objects or events being observed. The information needs a physical carrier to travel from the objects/events to the sensors through an intervening medium. The electromagnetic radiation is normally used as an information carrier in remote sensing. The output of a remote sensing system is usually an image representing the scene being observed.

The remote sensing data is primarily important to monitor the Earth as an entire system. Remote sensors collect data by detecting the energy that is reflected from Earth. These sensors can be on satellites or mounted on aircraft. Remote sensors can be either passive or active. Passive sensors respond to external stimuli. They record natural energy that is reflected or emitted from the Earth's surface. The most common source of radiation detected by passive sensors is reflected sunlight. In contrast, active sensors use internal stimuli to collect data about Earth. The most common remote sensing methods is by satellite, airplane and drone.

Passive remote sensing is divided into multispectral and hyperspectral. The main difference between multispectral and hyperspectral is based on the number of bands and how narrow the bands are. Multispectral imagery generally refers to 3 to 10 bands with each band acquired using a radiometer. Hyperspectral imagery consists of much narrower bands (10-20 nm). A hyperspectral image has hundreds of thousands of bands using an imaging spectrometer.

Remote sensing image resolution is divided into spatial, spectral and temporal resolution. Spatial resolution is the detail in pixels of an image. While higher spatial resolution means more detail and smaller pixel size, lower spatial resolution means less detail and larger pixel size. Temporal resolution is how often revisit times occur, often for satellite data. The height of the satellite above the Earth surface will determine the time it takes for the orbit to take one complete orbit of the Earth. Orbital period increases with satellite height. Spectral resolution is the amount of spectral detail in a band. While high spectral resolution means bands are narrower such as hyperspectral, low spectral resolution is broader bands covering more of the spectrum. The Light Detection and Ranging (LiDAR) data, satellite data and digital elevation models accurately model the landscape and build the human environment in a sustainable manner.

In Optical Remote Sensing, optical sensors detect solar radiation reflected or scattered from the earth, forming images resembling photographs taken by a camera high up in space. The wavelength region usually extends from the visible and near to the short-wave infrared. The infrared sensors measures the thermal infrared radiation emitted from the earth, from which the land or sea surface temperature is derived.

There are some remote sensing satellites which carry passive or active microwave sensors. The active sensors emit pulses of microwave radiation to illuminate the areas to be imaged. Images of the earth surface are formed by measuring the microwave energy scattered by the ground or sea back to the sensors. These satellites carry their own flashlight emitting microwaves to illuminate their targets. Microwaves have an additional advantage as they can penetrate clouds. Images can be acquired even when there are clouds covering the earth surface.

Remote sensing images are normally in the form of digital images. In order to extract useful information from the images, image processing techniques may be employed to enhance the image to help visual interpretation, and to correct or restore the image if the image has been subjected to geometric distortion, blurring or degradation by other factors.

1.3. Geographic Information System (GIS)

A Geographic Information System is designed to store, retrieve, manage, display, and analyze all types of geographic and spatial data. GIS data represents real objects such as roads, land use, elevation, trees, waterways, etc. with digital data. Real objects are divided into two abstractions: discrete objects and continuous fields. There are two methods used to store data in a GIS for both kinds of abstractions mapping references: raster images and vector. Points, lines, and polygons are the stuff of mapped location attribute references. A new hybrid method of storing data is that of identifying point clouds, which combine three-dimensional

points with RGB information at each point, returning a 3D color image. GIS thematic maps are more realistically visually descriptive of what they set out to show or determine. GIS recognize and analyze the spatial relationships that exist within digitally stored spatial data. GIS and remote sensing are reliable tools and used in the evaluation of geo-environmental catastrophes by providing a sort of synoptic coverage of a very broad area in a cost effective way. In the recent years, development in the areas of GIS and remote sensing has been embedded into the assessment of geoenvironmental catastrophes, which profoundly facilitated advancement of flood susceptibility mapping, flood risk assessment, and flood management.

The purpose of the survey is:

- To spotlight the advancement of GIS and remote sensing as tools used in flood delineation, management and land damage assessment.
- To categorize the different methodologies and satellite images used.

In this paper section 2 describes the Literature review on flood damage assessment using remote sensing and GIS. Section 3 presents conclusion of the survey.

2. REVIEW ON FLOOD DAMAGE ASSESSMENT

Tadaharu Ishikawa et al., [37] used the hydraulic function of the Hyakken-gawa Floodway, which was constructed in the 17th century to reduce the flood risk to Okayama Castle City, by numerical flow simulation method. The alluvial plain topography used for the inundation calculation which was obtained from recent GIS data. The flood risk reduction using was composed of two stages. In the first stage the flow divergence to the Hyakken-gawa channel was induced by premeditated collapse of the first dike made of earth at the floodway head. In the second stage was the inundation of the east side farmland, which was induced by the bank overflow due to the backwater from the third dike.

National Remote Sensing Center (NRSC) and Decision Support Center (DSC) [28] provided the annual flood Inundation for Assam and Bihar. The flood inundation layer was delineated from classification techniques. About 13 years during 1998-2010 of annual flood inundation layers were prepared by integrating different flood waves in a calendar year. The department briefly explains the methodology adopted in the generation of flood inundation layers for Assam state. The satellite data from Indian Remote Sensing Satellites (IRS) and microwave satellite data from Radarsat satellites was acquired during the flood season of 1998-2010.

Kabir Uddin and Basanta Shrestha [18] proposed a common disaster by flood in Nepal the Terai region Sunsari district numerous affected by flood. Landsat 2000 to 2008 images were used to determine the river channel migration, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) 2008 image for base land cover is used to assess the damage and radar images for identification of flood extent area. Object based technique was used for image classification and ArcGIS spatial analysis for necessary statistics calculation. Object base remote sensing technique and GIS were used for river channel mapping and morphological changes, flood extends and land cover classification.

Inzamul Haque MD and Rony Basak [14] evaluated the nature, significance, and rate of wetland change in Tanguar Haor is located in the northeastern part of Bangladesh from 1980 to 2010. Authors have used change detection techniques like Pre-classification method and Post classification method. The analysis found that over anthropogenic influence was the major cause behind the change and it is observed 40% of land cover change was influenced.

Glas et al., [11] chosen Annotto Bay, Jamaica, a case study area to perform a flood damage assessment. Flood damage map was created for the 2001 flood caused by Tropical

Storm Michelle. The map focuses on three types of damage: building, road and crop damage. The comparison of total damage map with actual damage caused by 2001 flood by visualizing the location of high risk areas with high accuracy showed promising results.

Abdullah et al., [1] stated that flood water causes a lot of property damage almost every year in Naogaon District in Bangladesh. Satellite images collected from Landsat 4-5 Thematic Mapper for the year 2004, 2007 and 2012 and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images for the year 2017. In each year images of different times (March and September) of Naogaon district have been analyzed with GIS and ERDAS Imagine software. The authors concluded that the applications of ArcMap are used to calculate the flooded area using LANDSAT Images and also it helped for map the flooded area with an accuracy of 73-81% depending on various indices used.

Sangyal Lama Tamang et al., [33] focused the way to predict the area vulnerable to flood by a 3-D numerical model calibrated with past records of inundation and geographic information available. The study area is located in Shillong the state capital of Meghalaya in the North-eastern part of India. The authors used DEM and hydro metrological data to simulate the flood-impacted area and building. To execute and estimate the extent of floodplain mapping through floodplain simulation and the integration of hydraulic model with GIS was carried out. They also have used IRS P5 CARTOSAT-1 Stereo (acq: 2008 to 2010) with 10,000 scale having a resolution of 2.5m are used for the extraction of the DEM.

Da-wei Zhang [9] used Hydrological method for flash flood simulation - Xiapu River Basin, Xianning City in central China. Kamrul Islam et al., [19] undergone various land use changes from 2005 to 2015 using Landsat TM and Landsat 8 OLI/TIRS images and also authors have used ArcGIS v10.1 and ERDAS Imagine v14 for processing satellite imageries.

Beatriz Revilla-Romero et al., [6] performed a comparative evaluations of several operational global flood forecasting and flood detection systems, using 10 major riverine flood events case study recorded over 2012–2014 in Asia, Africa, and South America.. Furthermore, they compared the Global Flood Detection System (GFDS) flood maps with those from NASA's two Moderate Resolution Imaging Spectroradiometer (MODIS) sensors.

Akhtar Ali Memon et al., [2] referenced accuracy assessment has been performed using spatial statistical techniques and found NDWI (Normalized Difference Water Index), RSWIR (Red and Short Wave Infra-Red) and GSWIR (Green and Short Wave Infra-Red) with kappa coefficient (κ) of 46.66%, 70.80% and 60.61% respectively for Pakistan floods during 2012.

Mattia Amadio et al., [24] proposed SDC (Stage-Damage Curve) flood damage assessment modeling in Italy. The comparison of damage estimates made by SDC models with empirical recorded damage is the key for this task. They have also carried out an analysis takes on both damage to physical assets and losses due to foregone production, this is being measured by spatially distributed gross added value.

Cham, et al., [7] refereed that when the excessive water flows from upstream into the water level of downstream it increases the possibility of flood risk. The purpose of their research is to clarify the flood condition midstream and recommend proper flood management measures. The flood inundation depth is calculated with a GIS in order to understand the temporal, spatial scale and transition and also flood volume is calculated to understand the total flood volume needed to be stored midstream before reaching downstream. Their study area is Chao Phraya River Basin, Thailand and the calculation is based on GIS and RID data. They recommended conducting simulation of flood condition at study area in order to have more accurate estimation for flood volume and inundation depth.

Ismail Elkharchy [15] generated the flash flood map for Najran city, Saudi Arabia, using satellite images and GIS tools. For this SPOT and SRTM DEMs data is used for accuracy

assessment obtained by GPS observations. Analytical Hierarchical Process (AHP) is used to determine relative impact weight of flood causative factors to get a composite flood hazard index (FHI). The areas in high risk flood zones are obtained by overlaying the flood hazard index map with the zone boundaries layer. By using SRTM model, 22% population residing in 13 zones is prone to low flooding risk, 7% population belonging to 20 zones is prone to moderate, 69% population belonging to 30 zones is prone to high and about 2% population belonging 5 zones is prone to very high flood hazard risk.

Eleuterio et al., [10] presented the development of the first version of a GIS tool for evaluating future flood damage potential: Federal Railroad Administration (F.R.A) GIS tool extension, for using with ArcGIS 9.2. (ESRI). The main functionalities includes: input data pre-processing functions; assets flooding potential estimation module; assets damage potential estimation module; expected annual damage calculation module; and results analysis and interpretation functions. The methodology proposed here can be used to guide analysts on the realization or the automation of flood risk analysis using other GIS software.

Nabajit Hazarika et al., [26] documented land-use changes driven by river dynamics along two tributaries in the chronically flood affected Upper Brahmaputra flood plain. Planform changes for a period of 40 years are documented using topographical map and Landsat data associated with hybrid classification of GIS environment. Hybrid classification of Landsat images yielded a higher level of accuracy with land use classification ranged 88.5% and 96.25%. The results generated after analysis shows that most affected land-use class is agriculture. Here land-use for different periods was mapped using hybrid classification which clearly tells us that hybrid classification using Landsat images is an effective tool in studies aimed at land-use analysis.

Mateeul Haq et al., [23] used MODIS Aqua and Terra images of Sindh province in Pakistan which are acquired during the flood events and used as the main input to assess the damages using GIS analysis tools. In this study it is found that processed satellite images which overlaid with population density data and land use/land cover maps for damage estimation and rapid damage assessment. Table 1 shows the Literature review on flood damage assessment using remote sensing and GIS.

Table 1 Review on Flood damage assessment

Ref. No.	Location	Images	Date	Objective	Methodology	Software used	Observation
[23]	Sindh Province, Pakistan The study area is located in southern part of the country stretching about 579 km from north to south and 442 km from east to west with an area of 140915 km ²	MODIS, Aqua and Terra images	Aug 11, 2011-Sep 14, 2011 Sep 15, 2011	Damage Assessment	It was found that this method required processed satellite images which were then overlaid with population density data and land use/land cover maps for damage estimation.	ENVI 4.5 and ArcGIS 9.3	to carry out rapid damage assessment
[11]	Jamaica SIDS (Small Island Developing	Land Use data Flood		To develop a damage map	1. Building damage 2. Road		All three flood damages were assessed.

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Ref. No.	Location	Images	Date	Objective	Methodology	Software used	Observation
	States) Annotto Bay, a coastal town in the north-east of the island	Hazard map Satellite DigitalGlobe			damage 3.Crop damage These above damages were assessed		Overview of damage cost and damaged area per damage type is assessed. This methodology can be used by decision makers as a qualitative tool.
[30]	Northeastern Iran	Digital land use cover maps ETM Satellite data collected using hand held GPS	Maps of 2001 & 2002	To verify the % of changes within Boundaries.	Fuzzy Change map Generation	-	Remote sensing, GPS and GIS in delineating and estimating flooded areas of Golestan province, Iran. Two major floods that happened in two successive years were examined.
[38]	Okayama Castle City located on an alluvial plain in the mid-west part of Japan.	IRS 1D Satellite image. 1:1,00000 Scale Land use /Land Cover Map	Rainfall in 2001 & 2002		Fuzzy Change map Generation	ArcGIS environment	It makes uses of all the change Information that exists in each band of satellite images. Statistics derived from such studies could be useful to agricultural management officials and private insurance companies. Necessary precautions and proper and further management should be followed for the affected areas in this part of the world.
[15]	Najran City, Kingdom of Saudi Arabia (KSA).	SPOT 5 and SRTM DEMs With Ground Control Points(GC Ps)	Rainfall during June 2001 to 2014.		AHP	ArcMap	By using SRTM model, 22% population residing in 13 zones is prone to low flooding risk, 7% population belonging to 20 zones is prone to moderate, 69% population belonging to 30

Ref. No.	Location	Images	Date	Objective	Methodology	Software used	Observation
							zones is prone to high and about 2% population belonging 5 zones is prone to very high flood hazard risk.
[9]	Xiapu River Basin, Xianning City, Southeast Hubei Province, in central China.	-	10 historical flood events from 1994 to 2004.	-	GUH method based on DEM		This study has developed a new conceptual distributed hydrological model for the simulation of flash floods, and the novelty of the new hydrological model is the use of GUHs to model the surface runoff. GUHs are suitable for catchments with limited observed rainfall and runoff data, because they are computed based on catchment hydraulics and geomorphologic al data
[1]	A Case Study of Naogaon District, Bangladesh	Google earth image, Land use map before occurring & land use map during flood occurring. ERDAS and LANDSAT imagine.	March 25, 2004 October 19, 2004	It helps to find out the losses and related relations of flood and thus the importance of water management. The analysis demonstrate the variation of land use changes in before and after flood occurrence month from 2004 to 2017	Combining the outcomes from the first two components through matrix union in ERDAS imagine	ArcMap	an efficient methodology to accurately delineate the flooded areas with the help of remote sensing data and GIS tools That Naogaon District area comes under high risk due to low gradient and slope watershed and surrounded by numerous small and large rivers and here needs proper flood management by accurate flood mapping
[18]	Nepal - Terai Region South East part of the Nepal and name Sunsari	ASTER, Radar Landsat Images	30-10-2000 23-12-2002 02-11-2004 04-07-2006 16-11-2006	Determine the trends of river channel migration to breach the embankment	Normalized Difference Vegetation Index (NDVI),	Object-based image analysis (OBIA)	This study have shown operational users for planning

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Ref. No.	Location	Images	Date	Objective	Methodology	Software used	Observation
	District.		19-03-2008 26-03-2008 31-08-2008 03-09-2008 24-08-2008	object base algorithms to produce detailed land cover maps for flood damage assessing.	Used to develop suitable classification algorithms for individual land cover classes.	Approach using Definiens/eCognition software.	flood-related emergency response measures including river migration to breach the embankment
[39]	1,000 year flood event in the Lower Don Valley region of Sheffield UK	VGE is constructed using Geographic Information System (GIS) data from OS Master Map's Topography Layer, Integrated Transport Network Layer and Address Layer 2	In June 2007 100 mm of rainfall		Revitalised Flood Hydrograph (ReFH) methodology 1D-2D ISIS-TUFLOW hydrodynamic model	Simulation Model is used here.	Research has focused on modelling existing, or typical, behaviours of SMEs in response to flooding and potential, or enhanced, behaviours aimed at improving their response
[32]	Kendrapara district of Orissa State of India was selected. Kendrapara District lies in 20° 20' N–20°37'N Latitude and 86°14'E to 87° 01' E Longitude and situated in central coastal plain zone of the Orissa	RADARSAT SAR images	During flood The date of 18, 20, 22 and 24 September 2008. RADARSAT -1 SAR is a C-band frequency (wavelength of 5.6 cm) with HH polarization and 100 m spatial resolution data. Pre flood To extract the pre-flood surface water, IRS 1C LISS III multi-spectral data with 23.5 m spatial resolution dated 21 January 2006 was used.	To detect the flood water extend and monitor the flood water propagation in the part of Kendrapara of Orissa District, India using multi-Temporal SAR data.	Image overlay	Integrated Land and Water Information System (ILWIS), ERDAS Imagine and ArcGIS image processing and GIS software were used for image processing, analysis and mapping.	The SAR data is of value for water related investigations, particularly, flood water delineation and analysis.
[2]	20 adjacent districts of the	MODIS , TERRA	Sep 2011 and Sep 17 th 2012	Accuracy assessment has	Flood mapping		The comparative analysis of

Ref. No.	Location	Images	Date	Objective	Methodology	Software used	Observation
	Baluchistan, Khyber Pakhtunkhwa, Punjab and Sindh provinces of Pakistan.	satellite Landsat ETM		been performed using spatial statistical techniques and found NDWI, RSWIR and GSWIR with kappa coefficient.			NDWI, RSWIR and GSWIR using spatial statistical techniques and visual interpretation suggests RSWIR to be more efficient for delineating water bodies during floods.
[3]	Islamabad, Pakistan	ERDAS imagine	Landsat 5 and SPOT 5 for the years 1992 and 2012	Classification is being done here	Accuracy assessment and Land use /cover change detection. Kappa	Data collected by using GPS and GIS	Shown a classification In a map.
[36]	Izmir city Turkey Kucuk Menderes & Gediz Basin	Thematic Maps are used	Oct 2013 to Aug 2013 Oct 2013 to June 2014 Heavy Rainfall in these days	To study and predict potential flood –hazard.	Areas using Shuttle Radar Topography Mission – Digital Elevation Model (DEM).	ArcGIS 10.2.1 modules are used.	Potential flood area map is created. GIS based methods to identify flooded areas. DEMs could strengthen the accuracy of regional analysis of flood hazards. Classification and weighting of factors observed.
[31]	Jakarta, the capital city of Indonesia	-	Flood on 17–19 January 2013	Regression analysis is used to develop flood damage functions to know how flood characteristics are related to the damage.	Damage scanner model.	Python programming, (Numpy and GDAL libraries to produce the flood risk maps) CorelPoly GUI add-ons on LibreOffice Calc to plot the exceedance probability.	The damage scanner employs aggregated land-use data instead of individual units.
[24]	Northern Italy	residential and industrial land use map	January 2014	Asset losses Agricultural losses Production losses All above were assessed	Asset damage Production loss.	Most commonly, flood risk R is determined as a function of hazard probability (H),	The comparison of damage estimates made by SDC models with empirical recorded damage. tested two frequently used

Ref. No.	Location	Images	Date	Objective	Methodology	Software used	Observation
						exposure (E) and vulnerability (V): $R = \frac{H}{3} \frac{E}{3} \frac{V}{3}$	SDC models against reported flood damage after a major flood event in Northern Italy.
[5]	Study Case of Romania-Danube is the second longest European river.	MODIS TERRA and AQUA images FORMOSAT 2 and SPOT 4 Topographic maps	No specific dates.	In order to extract the flood-affected areas along the Romanian sector of the Danube has been developed in the framework of NATO SFP Project.	1. Image geo-referencing. 2. Compute the NDVI. 3. Separate the water from other cover classes. 4. Extract the water-mask. 5. Economic damages estimation. 6. Data dissemination	-	MODIS images underestimate the flooded areas over the settlements, tiny agricultural parcels; - MODIS images overestimate the flooded areas over the forest and inland wetlands.

3. CONCLUSION

Remote Sensing data along with Geographic Information System has become a key tool for flood monitoring and assessment in recent years. In this paper the review on flood damage assessment is discussed. Remote Sensing has made significant contribution in flood monitoring and damage assessment. Flood monitoring using satellite data gives an effective method to get quick and precise overview of flooded areas. It leads the disaster management authorities to contribute considerably.

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REFERENCES

- [1] Abdullah - Al Faisal, Abdulla - Al Kafy and Sumita Roy. Integration of Remote Sensing and GIS Techniques for Flood Monitoring and Damage Assessment: A Case Study of Naogaon District, Bangladesh. *J Remote Sensing & GIS, an open access journal* 7(2) 2018, pp.1-5.
- [2] Akhtar Ali Memon, Sher Muhammad, Said Rahman, Mateeul Haq, Flood monitoring and damage assessment using water indices: A case study of Pakistan flood-2012. *The Egyptian Journal of Remote Sensing and Space Sciences*, 18(1) 2015, pp. 99 – 106.
- [3] Amna Butt, Rabia Shabbir, Sheikh Saeed Ahmad and Neelam Aziz Land use change mapping and analysis using Remote Sensing and GIS: A case study of Simly watershed, Islamabad, Pakistan. *The Egyptian Journal of Remote Sensing and Space Science*, 18(2) 2015, pp. 251–25.

- [4] Andrei Urzica, Alin Mihu-Pintilie, Elena Hutanu, Bogdan Vasile Ghindaoanu, Liviu Marian Albu, Using GIS methods for modelling exceptional flood events in Baseu river basin. Ne Romania, *International Scientific Conference GEOBALCANICA*, 2018, pp. 463-471.
- [5] Anisoara. Irimescu, Vasile. Craciunescu, Gheorghe. Stancalie, Argentina. Nertan Remote Sensing and GIS Techniques for Flood Monitoring and Damage Assessment Study Case in Romania, *BALWOIS* 2010 pp. 1-10.
- [6] Beatriz Revilla-Romero, Feyera A. Hirpa, Jutta Thielen-del Pozo, Peter Salamon, Robert Brakenridge, Florian Pappenberger and Tom De Groeve, On the Use of Global Flood Forecasts and Satellite-Derived Inundation Maps for Flood Monitoring in Data-Sparse Regions. *Remote Sens*, 7 2015, pp. 15702-15728.
- [7] Cham, T.C., Mitani Y., Fujii, K. and Ikemi H. Evaluation of flood volume and inundation depth by GIS midstream of Chao Phraya River Basin, Thailand. *Japan Sustainable Development*, 2 2015, pp. 1049 – 1060.
- [8] Dano Umar Lawal, Abdul-Nasir Matori, Ahmad Mustafa Hashim, Imtiaz Ahmed Chandio, Soheil Sabri, Abdul-Lateef Balogun and Haruna Ahmed Abba, Geographic information System and Remote Sensing Applications in Flood Hazards Management: A Review. *Research Journal of Applied Sciences, Engineering and Technology*, 3(9), 2011, pp. 933-947.
- [9] Da-wei Zhang, Jin Quan, Hong-bin Zhang, Fan Wang, Hong Wang, Xiao-yan He, Flash flood hazard mapping: A pilot case study in Xiapu River Basin, China. *Water Science and Engineering*, 8(3) 2015, pp. 195 – 204.
- [10] Eleuterio, J., David Martinez, Rozan, A., Developing a GIS tool to assess potential damage of future floods. *7th International Conference on Computer Simulation of Risk Analysis and Hazard Mitigation* 2010.
- [11] Glas, H., Van Ackere, S., Deruyter, G. and De Maeyer, P. Flood Damage Assessment in a GIS – Case Study for Annotto Bay, Jamaica. *Int. J. of Safety and Security Eng*, 6(3) 2016, pp. 508 – 517.
- [12] Guetchine Gaspard., Flood Loss Estimate Model: Recasting Flood Disaster Assessment and Mitigation for Haiti. The Case of Gonaives – *Thesis*, 2006, pp. 1-64.
- [13] Guy J. P., Schumann Remote Sensing in Flood Monitoring and Management *Remote Sens*, 7 2015, pp. 17013-17015.
- [14] Inzamul Haque M. D., Rony Basak, Land cover change detection using GIS and remote sensing techniques: A spatio-temporal study on Tanguar Haor, Sunamganj, Bangladesh. *The Egyptian Journal of Remote Sensing and Space Sciences*, 20 2017, pp. 251 – 263.
- [15] Ismail Elkharchy. Flash Flood Hazard Mapping Using Satellite Images and GIS Tools: A case study of Najran City, Kingdom of Saudi Arabia (KSA). *National Authority of Remote Sensing and Space Sciences - The Egyptian Journal of Remote Sensing and Space Sciences*, 18 2015, pp. 261-278.
- [16] John T. Reager, Alys C. Thomas, Eric A. Sproles, Matthew Rodell, Hiroko K. Beaudoin, Bailing Li, and James S. Famiglietti, Assimilation of GRACE Terrestrial Water Storage Observations into a Land Surface Model for the Assessment of Regional Flood Potential. *Remote Sens*, 2015 7, pp. 14663-14679.
- [17] Jongman, B., Kreibich, H., Apel, H., Barredo, J. I., Bates, P. D., Feyen, L., Gericke, A., Neal, J., Aerts, J. C. J. H., and Ward, P. J., Comparative flood damage model assessment: towards a European approach, *Nat. Hazards Earth Syst. Sci.*, 12(12) 2012, pp. 3733-3752.
- [18] Kabir Uddin, Basanta Shrestha . Assessing Flood and Flood Damage Using Remote Sensing: A Case Study from Sunsari, Nepal. *Proceedings of the Third International Conference on Water and Flood Management (ICWFM 2011)*. 1, 2011, pp. 293-301.

- [19] Kamrul Islam, Mohammed Jashimuddin, Biswajit Nath , Tapan Kumar Nath, Land use classification and change detection by using multi-temporal remotely sensed imagery: The case of Chunati wildlife sanctuary, Bangladesh. *The Egyptian Journal of Remote Sensing and Space Sciences*, 21 2018, pp 37 – 47.
- [20] Literature Review for the Development of a Socio-Economic Impacts Assessment Procedure to be applied to the flooding of Qianliang Hu Detention Basin, Hunan Province, *China Yangtze River Flood Control and Management Project*, 2013 pp. 1-37.
- [21] Laura Giustarini., Marco Chini., Renaud Hostache., Florian Pappenberger and Patrick Matgen., Flood Hazard Mapping Combining Hydrodynamic Modeling and Multi Annual Remote Sensing data. *Remote Sens*, 7 2015, pp. 14200-14226.
- [22] Marina-Ramona Rujoiu-Mare and Bogdan-Andrei Mihai, Mapping Land Cover Using Remote Sensing Data and GIS Techniques: A Case Study of Prahova Subcarpathians. *Procedia Environmental Sciences*, 2016 32, pp. 244 – 255.
- [23] Mateeul Haq, Memon Akhtar, Sher Muhammad, Siddiqi Paras, Jillani Rahmatullah, Techniques of Remote Sensing and GIS for flood monitoring and damage assessment: A case study of Sindh province Pakistan. *National Authority of Remote Sensing and Space Sciences - The Egyptian Journal of Remote Sensing and Space Sciences*, 15 2012, pp 135 – 141.
- [24] Mattia Amadio, Jaroslav Mysiak, Lorenzo Carrera1, Elco Koks Improving flood damage assessment models in Italy. This article is published with open access at *Springerlink.com*, 2016.
- [25] Michael Hammond Flood Impact Assessment Literature Review *CORFU* Collaborative research on flood resilience in urban areas 2104, pp. 1 – 68.
- [26] Nabajit Hazarika, Apurba Kumar Das, Suranjana Bhaswati Borah, Assessing land-use changes driven by river dynamics in chronically flood affected Upper Brahmaputra plains, India, using RS-GIS techniques. *National Authority of Remote Sensing and Space Sciences - The Egyptian Journal of Remote Sensing and Space Sciences*, 18(1) 2015, pp 107 – 118.
- [27] Noor Suraya Romali, Zulkifli Yusopa, Muhammad Sulaiman and Zulhilmi Ismail Flood Risk Assessment: a review of flood damage estimation model for Malaysia. *Jurnal Teknologi* , 80(3) 2018, pp. 145–153.
- [28] Nambi Harish, Chakradhar Rao .K., Venkateswarlu .K.,Govardhan Reddy .B., Abubakar Siddiq .M., Rajarajeswari .P., KARTHIK SAI .M., Land use Land Cover change mapping using Remote Sensing and GIS: A case study of Gudur Mandal, SPSR Nellore District, Andhra Pradesh. *International Research Journal of Engineering and Technology (IRJET)*, 3 2016, pp. 1575-1578.
- [29] National Remote Sensing Center (NRSC) - RS & GIS AA-DMSG-DMSD-JAN., 2012-TR-374, pp. 1-5.
- [30] Parviz Zeaiean Firouzabadi, Saeed Saroei and Esmat Madaniyan, Flood Damage Assessment using Remote Sensing, GIS and GPS technologies: a Case Study in Golestan Province. Northeastern Iran. *Papers of the Applied Geography Conferences*, 35 2012, pp. 501-508.
- [31] Pini Wijayanti., Xueqin Zhu., Petra Hellegers., Yus Budiyono., Ekko C. van Ierland., Estimation of river flood damages in Jakarta, Indonesia. *Natural Hazards*, 86(3) 2017, pp. 1059 – 1079.
- [32] Rejaur Rahman M. D., Praveen K. Thakur., Detecting, mapping and analysing of flood water propagation using synthetic aperture radar (SAR) satellite data and GIS: A case study from the Kendrapara District of Orissa State of India. *The Egyptian Journal of Remote Sensing and Space Sciences*, 21(1) 2018, pp. 37 - 41.
- [33] Salghuna. N.N., Rama Chandra Prasad. P., Asha Kumari. J., Assessing the impact of land use and land cover changes on the remnant patches of Kondapalli reserve forest of Eastern Ghats,

- Andhra Pradesh, India, *National Authority of Remote Sensing and Space Sciences - The Egyptian Journal of Remote Sensing and Space Sciences*. 18(1) 2015, pp 107 - 118.
- [34] Sangyal Lama Tamang, Victor Saikhom and Zigmi T Bhutia, 3D Flood Simulation System using RS & GIS. *International Journal of Engineering Research & Technology (IJERT)*, 3(5) 2014, pp. 2218-2222.
- [35] Saut Aritua Hasiholan Sagala., Analysis of Flood physical Vulnerability in Residential areas. Case Study: Naga City, the Philippines – *Thesis*, 2006, pp 1-77.
- [36] Sevim Pelin Ozkan and Cigdem Tarhan, Detection of Hazard Areas Using GIS : Izmir case 9th International Conference Interdisciplinarity in Engineering, INTER-ENG 2015., *Procedia Technology*, 22 2016, pp. 373-381.
- [37] Shanlong Lu, Bingfang Wu, Nana Yan, Hao Wang, Water body mapping method with HJ-1A/B satellite imagery. *International Journal of Applied Earth Observation and Geo information*, 13(3) 2011, pp. 428 – 434.
- [38] Tadaharu Ishikawa & Ryosuke Akoh. Estimation of flood risk management in 17th century on Okayama alluvial plain, japan, by numerical flow simulation. *Int. J. of Safety and Security Eng*, 6(3) 2016, pp. 455-465.
- [39] Coates, G., LI, C., Wright, N .G., & Ahilan, S., Investigating the flood responsiveness of small and medium enterprises using Agent based modeling and simulation. *G. Coates, et al., Int. J. of Safety and Security Eng*, 6(3) 2016, pp. 627-635.