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GEOSPATIAL APPROACH FOR URBAN FLOOD ASSESSMENT: A REVIEW

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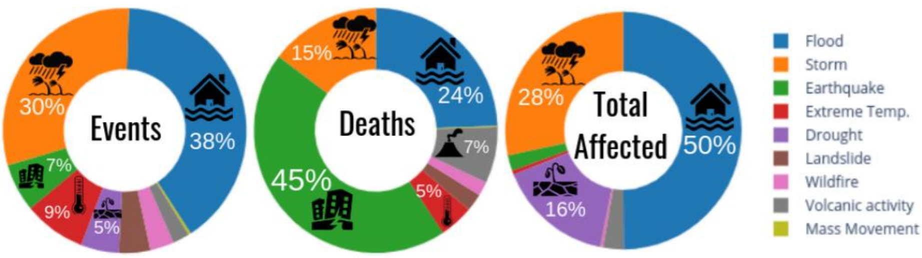
ABSTRACT

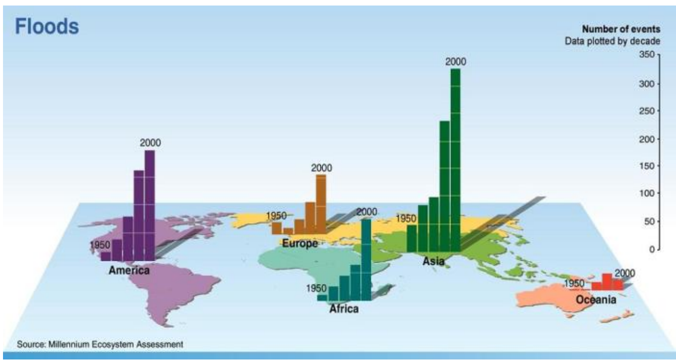
Urban flood is one of the emerging hydro-meteorological disasters which has been causing huge socio-economic losses and disruption to the urbanization process. Land cover and vegetation are stripped away for urbanization to make the way for construction of buildings, roads, parking lots & other impervious structures which has caused floodwaters getting accumulated leading to urban flooding. Urban flooding is natural disaster taking place every year in many parts of the world. Remote sensing and Geographic Information System (GIS) have been considered as efficient and effective tools for the management of land and other form of resources. There are a number of spatially explicit models that have been developed by incorporating the geographic information system (GIS) and remote sensing (RS) to simulate & predict future LULC scenarios efficiently. Hydrologic modelling is used to analyse environmental circumstances such as water excess, scarcity, or dissolved or solid content which is of primary importance. Flood plain maps for different flow conditions are developed to find out estimation of the flood extent & flood depth. The flood plain& depth maps are generated which are used as the main input for generating the flood hazard maps.

INTRODUCTION

Urban Flooding is type of flooding where the infiltrated runoff water gets accumulated on the earth surface caused mainly due to its volume exceeding the capacity of drainage system of the city. In urban periphery, flood effects have increased due to existing paved streets and roads, which cause increase in the speed of flowing water. Impervious surfaces don't allow rainfall infiltrating into the ground, thus causing a higher surface run-off that may be in more than the capacity of local drainage system. Urban flood is one of the emerging hydro-meteorological disasters which has been causing huge socio-economic losses and disruption to the urbanization process. Land cover and vegetation are stripped away for urbanization to make the way for construction of buildings, roads, parking lots & other impervious structures. The natural storage capacity of the land in the area is destroyed. Constructed drainage channels change the existing hydrology and flow regimes which lead to precipitation flowing rapidly across the surface in short, more intense, high-volume rather than sinking into the soil.Meteorological and hydrological factors which include rainfall frequency & intensity, storms, temperature, and Hydrological factors which include existing moisture levels in the soil, groundwater levels, impervious surface, natural channel of water courses, are factors causing urban flooding.

Urban flooding is natural disaster taking place every year in many parts of the world. Cities in developing countries, often have more severe flooding and damages because of larger densities of population, higher intensities of rainfall and lower drainage standards. Urban flood is the natural process which cannot be avoided but the effects of it can be prevented through proper flood mitigation plans. It is necessary to have a accurate estimation of flood extent, the causes, and its consequences for different flow conditions so that proper disaster management plan and flood evacuation plan can be framed accordingly.





All figures presented in the CRED CRUNCH from "EM-DAT: The OFDA/CRED International Disaster Database

The South Asian monsoon usually affects the Indian subcontinent belt, including Bangladesh and Nepal. It can be sub - categorized into the south-west monsoon (SWM) and the north-east monsoon (NEM). The SWM occurs over the Indian subcontinent and neighboring countries, with most of the rainfall concentrated between the months of June and September. The 2017 South Asian monsoon caused an unexpected devastation in the India-Bangladesh-Nepal border region (Solace Global, 2018) despite the predictions of average monsoon. It is stated that almost 2,700 humans lost their lives as a result of the monsoon, with more than 41 million people affected by the disaster between the start of June & October (The Guardian, 2017a; Munich Re, 2018). The 2017 monsoon had the highest number of deaths from natural disaster that year (Munich Re, 2018).

Indian Cities are growing in urban sprawls having Greenfield Construction and development, engulfing several natural features such as forests, water bodies, & agricultural land, transforming it into urban agglomerations. These urban agglomerations have numerous issue and problems which aggravates the vulnerability to urban flooding. Many Indian cities have faced severe floods in recent years which has caused a number of fatalities huge damage to property and ultimately affecting the economic growth of the country. An estimate by the Central Water Commission (CWC) states that 12% of India’s available land surface is prone to floods. The present decadal share of these losses has gone down to 0.1% of the National GDP (CAG, 2013).

REMOTE SENSING AND GIS IN URBAN FLOODING

Rahman et al (2021) mapped flood susceptibility using Bayesian regularization back propagation (BRBP) neural network, classification and regression trees(CART), a statistical model (STM) using the evidence belief function (EBF), and their ensemble models(EMs) in the northeast region of Bangladesh for three time periods (2000, 2014, and 2017).This study has shown the relationships among land cover change (LCC), road density (RD),population growth (PG), and relative change of flooding (RCF) areas.Idowuet al (2021)in his research had detected the link between LULC dynamics & flooding in Lagos State through a multi-year study for over 35 years. This study observed that most changes in LULC has resulted in the conversion of wetland areas into developed areas & unplanned development in very high to moderate flood hazard zones.

Chang et al (2021) observed the importance of using the SETS framework for evaluating flood vulnerability at the census block group scale across six US cities. This study applied an interlinked social-ecological-technological systems (SETS) vulnerability framework by forming an urban flood vulnerability index for six US cities. Zhu et al (2021) had proposed a modelling framework that can be used for urban flood assessments based on its short-record remotely sensed rainfall & hydrologic model in ungauged drainage basins. Rainy Day-based estimates have underestimated the flood characteristics under short duration scenarios or low return period, but it reflects the characteristics with increasing time duration or return period. Authors specified that the calculated design rainfall is transformed into the Chicago rainfall pattern & is placed into the SWMM hydrological model to simulate & analyse runoff processes &flood features under different return periods.

Bufeboet al (2021) used field observation, household survey, key informant interview, & focus group discussion field to determine the drivers & consequences of land use/land cover changes (LULC) using remote sensing data (for the years 1973, 1995, & 2017) in Shenkolla watershed, south central Ethiopia. The main objective of the study was to analyse the land use/land cover changes from 1973 to 2017 and its driving forces and to find out the coherence of community perception tothe changes that are being observed through the interpretation of GIS images in the study watershed area. The major driving forces of the land use/land cover changes were agricultural expansion, policy change & social unrest, shortage of farm land, population pressure& other biophysical factors.

Barros et al (2021) observed the relation between the temporal &spatial dynamics of Land Use/ Land Cover with the hydro-geomorphological processes. Author has specified to characterize the artificialization criteria, its intensity & territorial dispersion, as a result of urban sprawl & peri-urbanization, along with its consequences in exposure to hydro-geomorphological processes. The analysis showed an aggressive increase in the artificial areas & a continuous decrease in the farmland areas. This change of the risk drivers has resulted in increase in frequency & spatial dispersion of hydro-geomorphologic disasters over the study period.

Feng et al (2021) observed that urban flooding is sensitive towards urban land growth and the simulation under different urbanization conditions & different flooding stages are carried out for flood flows. The areas that are influenced by flash flood and floodplain due to increase in urbanization which can be calculated through the spatial distribution of impervious surface coverage. The analysis of both pluvial &fluvial flooding during the precipitation is carried out with two varied hydrologic/hydraulic modelling strategies. Land use with spatial variation may lead to more intense flash flood conditions compared to spatially uniform land use distribution.

Umukiza et al (2021) carried out the research in order to evaluate the impact of Land Use/Land Cover (LU/LC) changes on flow volume &peak discharge in the aforementioned areas. Author investigated the effects of projected Land Use/Land Cover (LU/LC) changes on total runoff and peak flow resulting in the two catchments of Narok town, Kenya. Song et al (2020) observed the effects of urban land-use patterns on flood regimes in a typical urbanized basin in eastern China. Author quantified the effects of TIA magnitude under different TIA levels on flood regimes through simulating the flood process; determined the impacts of urbanization on their relative location on flood flow behaviour; and also quantified the results of impervious area with composite structure onto flooding regimes through investigation of the relationship between flood characteristics and landscape pattern metrics. Comprehensive assessment of urban land use pattern were carried out through three levels which includes hydrologic model calibrated with varied parameters including land use change, configuration of impervious area quantifying the urbanization effects.

DEVELOPMENT OF DIGITAL ELEVATION MODEL:

A Digital Elevation Model (DEM) is a representation of the bare earth topographic surface of the Earth including buildings, trees and any other surface objects present on earth surface. It is a three-dimensional (3D) representation or digital model of a terrain's surface created from elevation data. The vertical datum helps to references raster grids of the Earth’s surface. (Marwaha et al, 2020). DEMs are generated from remotely sensed data collected by planes, drones, and satellites. Dems can be divided into Digital Surface Models (DSMs) and Digital

Terrain Models (DTMs). A DSM captures both natural and human-made features of the environment whereas DTM only retains features of the bare-earth terrain, such as rivers and ridges. Some remote sensing methods for obtaining DEM surfaces are: SAR interferometry, Shuttle Radar Topography Mission (SRTM), Stereo Photogrammetry, LiDAR, etc. (Marwaha et al, 2020)

A Digital Surface Model (DSM) captures a surface including natural &artificial structures using LiDAR (Light Detection and Ranging) technology or stereo photogrammetry. DSM has great importance in urban planning because they represent the bare-Earth with all ground features.3D surface models help to learn complex urban scenarios, especially as built-up areas which changes with time due to urban expansion. (Marwaha et al, 2020)

They are useful across greater spatial scales for the contouring of topographic and relief maps:

- Modelling water flow or mass movements
- Creating physical models
- Rectifying aerial photography or satellite imagery
- Rendering 3D visualizations
- Reducing terrain correction gravity measurements (e.g., gravimetry, physical geodesy)
- Analysing the terrain features in physical geography and geomorphology

In order to find global DEMs, elevation data can be taken from:

- Space Shuttle Radar Topography Mission (SRTM)
- ASTER Global Digital Elevation Model
- JAXA's Global ALOS World 3D
- Light Detection and Ranging (LiDAR)
- UP42 marketplace: Intermap'sNEXTMap& Airbus' WorldDEM

DEMs are files that contain either vector (points) or raster (pixels), with each point or pixel containing an elevation value. File formats of DEMs ranges from .csv and .tifto.flt and .dem .which intended for scientific use and evaluation. Thus, there is a need of Geographic Information System (GIS) software to recognize DEM files which include: ArcGIS, QGIS, gVSIG, GRASS GIS, etc.

DEM analysis includes four important components, namely:

- **Data Acquisition -** capturing terrain featured images or scanning the earth surface area
- **Data Modelling -**interdisciplinary approaches which includes image processing, photogrammetry, interferometric, etc.
- **Data Management -**data structuring, data coding, computer graphics, spatial database technique
- **Application Development -**facility management, urban planning, civil engineering, mine management, resource management, surveying, geomorphology analysis, landscape design, geological engineering, computer games and missile/airplane navigation, hazard identification and monitoring.

ANALYSIS OF LAND COVER CHANGE

Remote sensing and Geographic Information System (GIS) have been considered as efficient and effective tools for the management of land and other form of resources. The studies have been endeavoured explaining the effectiveness of GIS technologies for analysing LULC changes. For analysing, monitoring, and quantifying the Land Use and Land Cover (LULC) changes effectively, a large quantity of data is required. (Mishra et al, 2016). Remote sensing and GIS technologies provide the advantage for rapid data acquisition and analysis to collect LULC information at a lower cost than traditional ground survey techniques. An updated LULC data provided by GIS technologies can be applied to extract &analyse the past and present trends of LULC change as well as to formulate future trends efficiently. Therefore, there is a need to apply spatially explicit models to simulate Land Use and Land Cover (LULC) changes to simulate the future LULC scenarios. (Dadhich et al, 2011)

For preparation of LULC map from satellite imageries, a classification scheme defining the LULC classes was considered. The number of LULC classes are considered based on the requirement of a particular project for a particular application. Major LULC classes are selected for mapping the entire area viz; barren land; agricultural land; built-up land; open forest; dense forest and waterbodies, etc. The land use classes are divided based on their spectral characteristics & are separated by their spectral response. (Kumar et al, 2020)

There are a number of spatially explicit models that have been developed by incorporating the geographic information system (GIS) and remote sensing (RS) to simulate & predict future LULC scenarios efficiently such as Logistic Regression (LR) Model, Markov Chain (MC) Model, Artificial Neural Network (ANN) Model, Modified Cellular Automata-Based SLEUTH Model, Cellular Automata (CA) Model. Conversion of Land Use &its Effects (CLUE) Model, etc. Recently, Al-sharif and Pradhan (2015) proposed a approach based on the integration of different models to simulate, analyse& predict future urban expansions by taking into consideration of various urban deriving factors.

HYDROLOGIC MODELLING:

A hydrologic model is a simplification of a real-world system (e.g., soil water, surface water, wetland, estuary, groundwater) that helps in understanding, predicting & managing water resources. the flow and quality of water are studied using hydrologic models. Hydrologic modelling is used to analyse environmental circumstances such as water excess, scarcity, or dissolved or solid content which is of primary importance. (Burges, 1986).

There is no single best model as it totally depends upon the nature of environmental predictions. The hydrological models have many plausible solutions, depending on purpose & needed complexity. The practice of hydrologic modelling has, in generalized way, included too much of mathematics at the expense of true knowledge, there is always a need for more rigorous evaluation of appropriateness. The practice of hydrologic modelling is greatly disturbed by uncertainties in process & the overwhelming influence of variations & other poorly described natural phenomena. Therefore, a wide variety of different hydrological models exist, which are inadequate & falsifiable in nature. Except in extremely data driven environments, simpler modelling techniques with highly uncertain predictive confidence limits are considered rather than complex approaches with highly uncertain inputs & process descriptions. (Ogden, 2021).

Hydrological modelling using HEC-HMS model has options for base flow, infiltration runoff and river routing. The HEC-HMS model has three major models of simulation which includes basin model, metrological model & control specification. The catchment model containing the area of sub watershed, delineation of sub watershed, longest flow path, stream length, elevation, and slope is developed by using HEC-GeoHMS& the given catchment model is exported to the HEC-HMS model. The SCS curve number method is kindly adopted for infiltration.

The SCS-Unit hydrograph method is majorly used for transformation whereas kinematic wave method is used for flood routing.

RAINFALL-RUNOFF ANALYSIS

Runoff is generated by rainfall and the characteristics of rainfall such as intensity, duration and distribution etc. help in defining the occurrence & quantity of runoff. The important factors which influence the runoff generating process are:

- Rainfall Characteristics
- Variability of Annual Rainfall
- Probability Analysis
- Rainfall-Runoff Relationship
- Runoff Coefficients
- Assessment of Annual or Seasonal Runoff

FLOOD PLAIN AND HAZARD MAPS

The local flooding mainly depends on the factors such as precipitation, land slope, land cover, the effectiveness of drainagefacilitiesand the presence of local depressions and obstructions. Flood maps is formed taking into consideration the three thematic factors: excess rain (surface runoff), slope andelevation.These thematic factors are integrated with weighted contribution of each factor into flooding. To neutralize the effects of influencing factor sand different measurement units, reclassification is considered to unify all of the factors. (Shanableh et al, 2018)

Flood plain maps for different flow conditions are developed to find out estimation of the flood extent & flood depth. The flood plain& depth maps are generated which are used as the main input for generating the flood hazard maps. The various parameters considered for generation of the flood hazard maps which are: slope, generated flood plain map, distance from the river to different locations taken through the DEM and the distance from the coast bank & flood escape. (Shanableh et al, 2018)

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