URBAN FLOOD MANAGEMENT USING GEO-SPATIAL TECHNIQUES – A LITERATURE REVIEW

Pallavi Tomar*

*Centre for Climate Change and Water Research, Suresh Gyan Vihar University, Jaipur

Email id- pallavi.49382@mygyanvihar.com

ABSTRACT

In the recent years Remote sensing technology coupled with geographic information system (GIS) has become the key tool for flood monitoring & management. GIS in flood management helps to map flood hazards of vulnerable areas and delineates flood zones are core attention areas. Advancement in this field has grown from optical to Microwave remote sensing, which has provided flood mapping capability in all weather conditions. In flood hazard mapping and management, most crucial parameter is flood depth and to estimate flood depth from remotely sensed or hydrological data, digital elevation model (DEM) is considered as a most effective means and the accuracy of flood estimation depends on the better resolution of Digital elevation model. This paper highlights the review of remote sensing & GIS techniques, methodologies and models use for urban flood management in various cities. These techniques have provided a scientific approach for city planners and decision makers to manage flood risks more efficiently.

Key Words: Remote Sensing, GIS, Digital elevation Model, urban flood management etc.

Introduction:

Flood is an important part of the ecosystem and is annual phenomenon. Flood is a probably most frequent and widespread hazard in all kind of natural hazard. It has played a vital role in shaping the economy, society and culture of this deltaic country**.** The uneven distribution of rainfall together with the uncontrolled growth of urban areas, lack of proper drainage system, encroachments on storm drains, decreasing of wetlands etc. are the cause of urban flood (Lavanya 2014). Urban flood management is a complex issue & a challenging task for the decision-makers, planners and designers. Proper management of urban flood is to minimize human loss and economic damages, while making use of the natural resources for the benefit and well-being of the people.

In the recent years Remote sensing technology coupled with geographic information system (GIS) has become the key tool for flood monitoring & management. GIS in flood management helps to map flood hazards of vulnerable areas and delineates flood zones are core attention areas. Advancement in this field has grown from optical to Microwave remote sensing, which has provided flood mapping capability in all-weather condition. Using Remote Sensing & GIS for flood management, damage can be reduced. Analysis of satellite remote sensing data is a powerful tool for identification and quantification of water spread area.

Advantages of the information acquired by satellite remote sensing are its synoptic coverage, receptivity, near real time data availability and ease of data collection before, during and after the flood event. To identified and obtaining valuable information regarding flood affected/waterlogged areas various remote sensing satellites at different spatial and spectral resolution can be used. Some of the sensors are LISS - III and PAN sensors can be used to provide the details for the affected area. While WiFS sensor, which has got wide swath of about 810 km and a receptivity of 5 days, proves to be very effective in monitoring flood affected areas at the state level, while With IRS-1D and P6 in orbit, the effective receptivity of WiFS sensor is thrice in five days. However, the non-availability of cloud-free data during monsoon season one of the major disadvantages of the optical sensors. Microwave data from ERS and RADARSAT have got cloud penetration capability and can effectively be used in such cases for flood mapping and management.

GIS approach to explore urban flood risk management:

In rural areas flooding can cause mostly due to high river discharge while in urban areas due to poor drainage system and increase imperviousness. The impact of in imperviousness and different rainfall intensities are two main parameters for urban flooding risk modelling. Both parameters can easily estimate by the various remote sensing & GIS Techniques Sahoo (2013). Under the impact of climate changes and urbanization, the flood risk increases and the flood mitigation become more difficult, complex and long-term. More emphasis should be put on flood forecasting, flood emergency planning and response, and post-flood recovery Chaochao Li et al (2016). A reasonable flood risk analysis is important, which can be utilized for land use planning, for flood control works design, and for emergency response decision making. GIS computation of water balance model for urban surface helps in a quick assessment of a potentially flooding, or critical storage areas within in the catchment J. Diaz-Ni et al (2008). Physical damage can be estimated by the indicators, evaluated by the GIS tool, have helped to define a hierarchy among the various structures and infrastructures ,in order to guarantee victims assistance and rescue activities Raffaele Albano et al (2014). Multi-criteria analysis in GIS Environment incorporating a Flood Hazard Index (FHI) can help to identified hotspots zones for flood risk and allow a comparative analysis between different basins Nerantzis Kazakis et al (2015).

Microwave data from ERS and RADARSAT have got cloud penetration capability and can effectively be used in such cases for flood mapping and management Purba et al (2014). For the flood risk analysis the regression tree based loss model RT3 with the three predictor's water depth, inundation duration and floor space of the building is recommended for building loss estimation Chinh et al (2017). It is observed that the area located on lower side or near the river have higher risk of flooding. With the help of multicriteria spatial analysis or overlay method of several GIS layer like land use information, Flood risk map coupled with rainfall can help to prioritize spatial flood risk area and overall effectiveness of flood management Armenakisa and Procedia (2014). For the estimation about the magnitude of flash flood as well as surface runoff various hydrological model can be used. These hydrological models can construct by integration of landuse landcover information especially alluvial channels and morphometric parameters derived from Digital Elevation Model (DEM) on GIS platform El-Magd et al (2010).Micro level data collection and provision coupled with proper coordination with government and public will be reduce the potential impacts of flood events on particular area Nkwunonwo (2012).Many urban researchers realized that flood risk can't be completely unavoidable but can only be reduce to an acceptable level. That can be done by systematic integration of structural and non-structural events with community level SaiduIdris and Dharmasiri, (2011).

Models for Flood:

Prediction and control of floods is a major challenge, nowadays due to the human intervention in natural environment and effects of global climate change floods are occurring more frequently. Therefore various hydrological models have been applied for the flood prediction. WetSpa hydrologic model is one of the model used to simulate flood generation and propagation in the upper sub-basins. This model worked on simulate flood flows and inundation levels, varying hydrological processes such as rainfall interception, depression storage, evapotranspiration, infiltration, surface runoff routing, soil water percolation, and groundwater drainage. This model proves to predict water level and flood flow accurately Dang and Smedt (2017).

Lianga et al (2016) analyzed in this paper that a number of studies have predicted more frequent and intensive storms as a result of climate change in UK and other parts of the world, which may consequently cause more hazardous flash floods in steep catchments of small to medium. These flash floods are commonly characterized by high-velocity overland flow as a result of rapid catchment response to the intense rainfall. The hydrological processes related to the rapid catchment response are poorly understood and reliable prediction is generally beyond the capability of traditional hydrological models or simplified hydrodynamic models. This work aims to present a shock-capturing hydrodynamic modelling system to simulate the complex rainfall-runoff and the subsequent flash surface flooding process in a rapid-response catchment. The model solves the fully 2D shallow water equations using a finite volume Godunov-type shock-capturing numerical scheme for the rapidly varying overland flow hydrodynamics following intense rainfall. Typically, this type of shock-capturing hydrodynamic models is not able to provide efficient and high-resolution simulations for large-scale flash flood events due to their high computational demand. In order to substantially improve the computational efficiency and enable catchment-scale simulations at very high resolution involving millions of computational nodes, the model is implemented on GPUs for high-performance parallel computing.

Prasad et al (2016) analyzed in this paper that There are many sources of flooding viz. river flooding, coastal flooding, surface water flooding, drain and sewer flooding, groundwater flooding etc. This study envisages identification of various flooding sources, estimation of maximum floods and their routing through drainage system for a proposed industrial site. The digital elevation model (DEM) is developed from DGPS points, 0.5 m interval contour and spot levels and contours extracted from survey of India topographical maps for the surrounding area. The L-moments based rainfall frequency analysis has been performed to estimate 1 day maximum rainfall for various return periods. The synthetic unit hydrographs are derived from catchment characteristics and flood hydrographs for 10, 25, 50 and 100 year return periods are computed. The two major source of flooding are flow in the drain and rainfall induced catchment. It is observed that there is increase in both extent and duration of flooding for higher return period floods. Though there is variation in depths of flooding in upstream and downstream reaches, the duration of flooding are very identical. These computed parameters like flood extent, depth, level, duration and maximum flow velocity are used in designing safe grade levels for the industrial site to safe guard the flood hazard.

Jafari et al (2017) analyzed in this paper that with the increase in urbanization, the surface of earth and its climate are changing. These changes resulted in more frequent flooding and storm inundation in urban areas. The challenges of flooding can be addressed through several computational procedures. Web services have facilitated the integration and interactivity of the web applications. A Web Processing Service (WPS) makes it possible to process spatial data with different formats. The automatic calculation process service of storm inundation was developed on the basis of USISM model. In order to examine the implemented service, a web application was also developed. This system made it possible to measure the inundation of a rainfall event. The output of the system can be used for decision-making and carrying out practical measures in minimum possible time. The storm inundation calculation in the developed service is based on some simplifying assumptions. First, the equipment's related to storm water collecting infrastructure was only regarded in determining hydrological characteristics of the research site. Moreover, in calculating inundation amount, the medium capacity has been utilized that was designed for flood collection infrastructure. Indeed, such simplification sometimes overestimates and sometimes underestimates the drainage capacity. In addition, ignoring the spatial distribution of the drainage process makes errors in the simulation. USISM also simulates the final status of storm event, and thus, the intensity and duration of rainfall enjoy such a great importance with respect to the inundation calculation.

Salvana et al (2016) analyzed in this paper that flash floods are increasingly occurring due to climate change and the dramatic increase of population over areas characterized by aging and undersized drainage systems. Many studies are dealing with the topic of urban pluvial flooding, but few of them thoroughly consider interactions between surface runoff and pipe flow.This study-case enables to investigate on such problematic as a high-resolution (0.2m) photo-interpreted topographic dataset is available. Investigation based on Geographic Information System (GIS) is followed by 1D and 2D modelling. Results are presented by confronting outcomes given by GIS analysis and hydrodynamic modelling. It is shown that high-resolution data should be used carefully while dealing with urban hydrology and hydraulics. The reflection is driven towards a set of guidelines for modellers interested in helping storm water operational management.

This study has presented preliminary results given by a method set in order to improve operational modelling of urban systems regarding flood kinetics throughout detailed urban topography. Indeed, the selection of the level of topography details to include impacts the results to a great extent. Moreover, in this modelling approaches (GIS and Hydrodynamic modelling) surface features are included in the topography and therefore hundred percent impermeable which is not a fully satisfying statement. Furthermore, effects not encompassed here such as clogging effects, surface features which temporally evolve quickly over urban area or which can be destroyed by flood event, etc. are sources of uncertainty affecting drainage path.

Gerl et al (2014) analyzed in this paper that **t**he modeling of flood damage is an important component for risk analyses, which are the basis for risk-oriented flood management, risk mapping, and financial appraisals. An automatic urban structure type mapping approach was applied on a land use/land cover classification generated from multispectral Ikonos data and LiDAR (Light Detection and Ranging) data in order to provide spatially detailed information about the building stock of the case study area of Dresden, Germany.

An urban structure mapping approach was applied based on multispectral remote sensing data and LiDAR data to obtain information about the building stock and their characteristics. The urban structure map achieved a good accuracy of 74% and on this basis modeled flood losses for the case study, the Elbe flood in 2002 in Dresden, are in the same order of magnitude as official damage data. Single-family houses show significantly higher losses than the other three urban structure types, so that information on their specific location derived from remote sensing is very valuable for flood damage modeling.

Davor et al (2017) analyzed in this paper that the potential flood inundation extent can be estimated with flood inundation models, which can differ in the level of physical and numerical modeling complexity included in the solution procedure. In recent years, several studies have highlighted the benefits of shock-capturing flood inundation models, particularly when modeling a high Froude number or supercritical flows, or in areas prone to the occurrence of rapidly varying flood events, such as flash floods.

Nonetheless, decision makers are often reluctant to implement more complex modelling tools into practical flood inundation modeling studies, unless evidence is provided to establish when such refined modeling tools should be used.

El-Magd et al (2010) analyzed in the assessment of flash flood hazards in the Abu Dabbab drainage basin. Remotely sensed data were used to delineate the alluvial active channels, which were integrated with morphometric parameters extracted from digital elevation models (DEM) into geographical information systems (GIS) to construct a hydrological model that provides estimates about the amount of surface runoff as well as the magnitude of flash floods. The peak discharge is randomly varied at different cross-sections along the main channel. The estimation of spatial variability of flow parameters within the catchment at different confluences of the constituting sub-catchments can be considered and used in planning for engineering foundations and linear infrastructures with the least flash flood hazard.

Opolot (2013) analyzed in this paper that the application of Geographical Information Systems (GIS) and Remote Sensing (RS) techniques in all the flood management stages. Case studies of flood management using GIS and RS are summarized. It can also be deduced that RS technique offer cheaper and faster option so facing spatial data about the flood even in the physically in accessible areas .GIS techniques on the other hand facilitate hydrological models in data collection, analysis, querying and presentation of information in a more simplified format. Flood management is a three phase procedure that includes pre-flood, during flood and post-flood activities. These three phases can further be subdivided into flood prediction, flood prevention and mitigation, flood risk identification and mapping and flood damage assessment. The lesson we learn from here is that flood management is very diverse and it requires multidisciplinary involvement. As an example flood prediction, mapping and damage assessment require disciplines of hydrology, soil science and geography

Wang (2015) analyzed in this paper analyzes the necessity and potential on storm water management of this area and then it concludes the alternative strategies of improvement based on the theory of urban resilience. Firstly, the utilization rate of rainwater is low. Secondly, the network of water system is destroyed. Thirdly, the vegetation level on the revetment is too simple. On the premise of meeting the proper function, urban park landscape design could combine with storm water management. Rainwater planting ditch, rainwater filter strips, rainwater planting pools, permeable pavement and other storm water landscape facilities can be designed in the park fringe area, focusing on the surrounding buildings, roads and storm water management in the marginal area. Focusing on the connection of water system, integration of canals and ponds, in order to achieve unity of regulation and storage of rainwater and effective usage. In addition to the connectivity of water system distribution inside the park, the outside edge of the park area and park internal storm water management facilities can communicate with each other, in order to achieve the largest storm water management abilities of the park. The flood problems would never be solved with the original monolithic construction, and seeking for a comprehensive settlement through the entire landscape process of the heritage area is needed. Through establishing the ecological infrastructure, identifying the key point of controlling these processes, building up appropriate landscape security pattern, multiple relationships are coordinated and the security of ecology and heritage.

Conclusion: Floods are a natural phenomenon. The occupation of flood plains continues to increase due to rise in population and economic, industrial and other activities. Consequently, the flood damages also continue to increase. Satellite Remote Sensing and GIS techniques have emerged as a powerful tool to deal with various aspects of flood management in prevention, preparedness and relief management of flood disaster. They have greater role to play as an improvement over the existing methodologies. GIS is ideally suited for various floodplain management activities such as, base mapping, topographic mapping, and post-disaster verification of mapped floodplain extents and depths. Remote sensing and GIS techniques and hydraulic models like WetSpa, HEC-RAS, UFDAM, FHI index can replace, supplement or complement the existing flood management system. Extensive use of these technologies have great prospect in creating long-term database on flood proneness, risk assessment and relief management.

References:

Aronica, G.T.; Brigandí, G.; Morey, N. Flash floods and debris flow in the city area of Messina, north-east part of Sicily, Italy in October 2009: The case of the Giampilieri catchment. Nat. Hazards Earth Syst. 2012, 12, 1295–1309.

Brigandì, G.; Bonaccorso, B.; Aronica, G.T.; Gueli, R.; Basile, G. Flood and Landslide Warning based on rainfall thresholds and soil moisture indexes: The SyS Alert model for Sicily. In Proceedings of the 15th Risks Plinius Conference, Giardini Naxos, Italy, 8–11 June2016.

Büchele, B.; Kreibich, H.; Kron, A.; Thieken, A.; Ihringer, J.; Oberle, P.; Merz, B.; Nestmann, F. Flood-risk mapping: Contributions towards an enhanced assessment of extreme events and associated risks. Nat. Hazards Earth Syst. Sci. 2006, 6, 485–503.

Chen, J.; Hill, A.A.; Urbano, L.D. A GIS-based model for urban flood inundation. J. Hydrol. 2009, 373, 184–192.

Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the Assessment and Management of Flood Risks; Official Journal of the European Union L288 on 6.11.2007; European Union:Brussels, Belgium, 2007; pp. 27–34.

Duan,W.; He, B.; Takara, K.; Luo, P.; Nover, D.; Yamashiki, Y.; Huang,W. Anomalous atmospheric events leading to Kyushu's flash floods, 11–14 July 2012. Nat. Hazards 2014, 73, 1255–1267.

Fernández, D.S.; Lutz, M.A. Urban flood hazard zoning in Tucumán Province, Argentina, using GIS and multicriteria decision analysis. Eng. Geol. 2010, 111, 90–98.

Forkuo, E.K. Flood Hazard Mapping using Aster Image data with GIS. Int. J. Geomat. Geosci. 2011, 1, 19.

Gong, M.; Wang, S.; Liu, W.; Yan, J.; Jiao, L. Evolutionary computation in China: A literature survey. CAAI Trans. Intell. Technol. 2016, 1, 334–354.

Huong, H.T.L.; Pathirana, A. Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam. Hydrol. Earth Syst. Sci. 2013, 17, 379–394.

Jaafari, A.; Najafi, A.; Pourghasemi, H.R.; Rezaeian, J.; Sattarian, A. GIS-based frequency ratio and index of entropy models for landslide susceptibility assessment in the Caspian forest, northern Iran. Int. J. Environ. Sci. Technol. 2014, 11, 909–926.

Joy, Jean Kanga., Shruti and Singh, Suraj Kumar. 2019. Kerala Flood 2018: Flood Mapping by Participatory GIS approach, Meloor Panchayat" International Journal on Emerging Technologies, 10(1): 197-205

Patel, D.P.; Srivastava, P.K. Flood hazards mitigation analysis using remote sensing and GIS: Correspondence with town planning scheme. Water Resour. Manag. 2013, 27, 2353–2368.

Singh, Suraj Kumar. 2017. Delineation of waterlogged areas in Vaishali district (Bihar) using normalized difference water index. SGVU J Clim Change Water, Vol. 4, 2017 pp. 33-37

Singh, Suraj Kumar. 2017. Evaluation of flood and waterlogging dynamics in indo-gangetic plain using geospatial technique: a review, Open Access International Journal of Science and Engineering, 2(3), 1-7.

Singh, Suraj Kumar., & Kanga, Shruti. 2017. Mapping of salt affected and waterlogged areas using geospatial technique, International Journal of Recent and Innovation Trends in Computing and Communication, Volume: 5, Issue: 5, 1298 – 1305

Sohail, Abu, Talha., Singh, Suraj Kumar and Kanga Shruti 2019. A Geospatial Approach for Groundwater Potential Assessment Using Multi Influence Factor (MIF) Technique. International Journal on Emerging Technologies 10(1): 183-196

Sowmya, K.; John, C.M.; Shrivasthava, N.K. Urban flood vulnerability zoning of Cochin City, southwest coast of India, using remote sensing and GIS. Nat. Hazards 2015, 75, 1271–1286.

Strobl, R.O.; Forte, F.; Lonigro, T. Comparison of the feasibility of three flood-risk extent delineation techniques using Geographic Information System: Case study in Tavolieredelle Puglie, Italy. Flood Risk Manag. 2012, 5, 245–257.

Tsakiris, G. Flood risk assessment: Concepts, modelling, applications. Nat. Hazards Earth Syst. 2014, 14, 1361–1369.

Vahidnia, M.H.; Alesheikh, A.A.; Alimohammadi, A.; Hosseinali, F. A GIS-based neurofuzzy procedure for integrating knowledge and data in landslide susceptibility mapping. Comput. Geosci. 2010, 36, 1101–1114.

Wang, Y.; Li, Z.; Tang, Z.; Zeng, G. A GIS-based spatial multi-criteria approach for flood risk assessment in the Dongting Lake Region, Hunan, Central China. Water Resour. Manag. 2011, 25, 3465–3484.

Yahaya, S.; Ahmad, N.; Abdalla, R.F. Multi-criteria analysis for flood vulnerable areas in Hadejia-Jama'are River basin, Nigeria. Eur. J. Sci. Res. 2010, 42, 71–83.

Yang,W.; Sun, X.; Deng,W.; Zhang, C.; Liao, Q. Fourier Locally Linear Soft Constrained MACE for facial landmark localization. CAAI Trans. Intell. Technol. 2016, 1, 241–248.

Zerger, A. Examining GIS decision utility for natural hazard risk modelling. Environ. Model. Softw. 2002, 17, 287–294.