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Flood Prediction and Disaster Risk Analysis using GIS based Wireless Sensor Networks, A Review

Naveed Ahmad[1], Mureed Hussain[2], Naveed Riaz[3], Fazli Subhani[4], Sajjad Haider[5], Khurram. S. Alamgir[6], Fahad Shinwari[7]

[1,2,3,5] Department of Computer Science, SZABIST Institute of science and Technology Islamabad, Pakistan
[4,7] Faculty of IT/Engineering, National University of Modern Languages Islamabad, Pakistan
[6]Center for Advance Studies in Telecommunications, COMSATS Institute of Information Technology Islamabad, Pakistan

ABSTRACT

This paper presents a comprehensive study of the flood analysis and prediction using Geographical Information system (GIS). Different scientists and researchers from all over the world had performed detailed analysis of flood risk assessment specifically for human population and to take precautionary measurements before or after the critical condition of disaster occurs using Remote sensing and satellite images. In this research study, we had performed detailed analysis of Flood Prediction techniques based on GIS using Ad hoc wireless Sensor Network Architecture. We had also proposed a Model for Flood Risk Analysis and prediction, which would be very helpful for us in calculating the impact of Flood damage in disaster hit regions. The GIS domain proves to be very helpful for us in geographical survey and to identify the tsunamis causing vast potential and economical damage. In this research study, we had also used Arc GIS simulation tool to identify pre and post disaster flood risk analysis. Our Research study focuses on various geographical information Systems specifically designed for Flood Disaster management and to analyze necessary input parameters including soil moisture, air pressure, direction of wind, humidity and rain fall. These parameters would be very helpful for us in modelling real life scenarios specifically in case of flood disasters. Our proposed model is also very helpful for us in predicting the upcoming disasters and to take necessary actions by emergency and rescue authorities to save the life of thousands of people before this critical condition occurs.

KEYWORDS: Flood Prediction, Geographical Information System, wireless sensor networks, Disaster Management, Remote Sensing, hydrology.

INTRODUCTION

The Extreme Floods are considered to be one of the worst disasters based on environmental conditions. The Floods create a significant impact on human life due to its destructive effect. Due to the extreme environmental conditions, the human beings living in this area cannot accurately predict the extreme event of Flood Risk [1].For these reason different researchers from all over the world had proposed different hydrological Models for flash flood prediction [2] in critical emergency circumstances. As an important technical method for flood hazard occurrence is mainly due to extreme rain fall which has the largest influence of floods [3].

The Role of GIS in disasters, is typically important in critical life saving measures which, is adopted by modern developed countries round the globe. Different researchers, scientists and engineers from all over the world had proposed diversified models and architectures for disaster management by using GIS and hydraulic sensor based approach in critical emergency circumstances.

The core concept of GIS and it's integration with disaster management arises in floods, tsunamis, fires and earth quakes where there is a significant chance of damage and loss in lives. Therefore, the focus of research is moves towards deployment of GIS in case of floods, where emergency rescue authorities can save the life of thousands of people effected from disasters before or after this critical condition occurs [4]and [5].

The role of Information technology and telecommunications had moves the research trends towards remote sensing, satellite images and mathematical modelling technique where GIS, infrastructure is integrated into the custom build application to trace steams and water basins using topographical maps with in Arc GIS software [6],[7] and [8].Whenever, there will be an earthquake or flood there will be a great chance of public life disturbance and among them the biggest problem is loss of life and also results in damage to assets and communication infrastructure[9],[10] and [11].

Some of the Authors had focused their research using intelligent low power sensors that consists of embedded sensor node interfaced with microcontroller which works as a small processing unit. This node consists of wireless ad hoc network within GIS map to transfer the disaster related information to rescue Authority using available communication based infrastructure [12], [13] and [14].

The implementation of GIS in disaster management is typically applicable in planning stages. The major planning issue consists of identifying potential emergency problems and their likely consequences. The reinforcement agencies in the country can adopt certain building standards. Using Google Maps integrated with ARC GIS simulation tool assists in optimal location of

[*]**Corresponding Author:** Naveed Ahmad, Department of Computer Science, SZABIST Institute of science and Technology Islamabad, Pakistan. project_naveed@yahoo.com,

fire stations and ambulances within in a define area [15],[16] and [17]. The custom build application can provide selection of rescue routes, warning systems for the population, shelter, supply of food and medication for the people.

The next important aspect consists of primitive technique for flood prediction using Ad hoc wireless sensor network Architecture [18].Different types of computational sensor nodes are used to sense water discharge from dams, occurrence of rainfall due to climatic conditions such as humidity and temperature. The computational nodes posses' very powerful processing unit which is responsible for sending prediction results to neighbouring sensor nodes. In order to make the prediction result more accurate, the input parameters for example rainfall temperature, air pressure and wind speed should be carefully observed. So we can possibly calculate the upcoming rainfall which also results in water discharge from dam.

The core issue for this investigation entirely depends upon development of a real time GIS system specifically designed for mission critical applications [19], [20] and [21]. The GIS system can also be successfully integrated with Flood detection (prediction) systems [22] and [23] consists of variety of sensors that are responsible to monitor air humidity level, soil moisture, wind speed and intensity of rainfall [24] and [13]. These parameters will be very helpful for disaster rescue authority to predict the occurrence of floods. In this case the disaster relief operations can be adopted with in minimum span of time [26].

The proposed architecture can save the lives of hundred or millions of people in dangerous conditions specifically the rescue of people before the critical condition of Flood occurs.

The paper is organized into the following sections. The Section 1 provides in deep detail about the existing Techniques for Flood prediction using GIS and wireless sensor Networks, section 2 provides the critical evaluation of conclusions and limitations of GIS and WSN in Flood Disaster Risk Management. Section 3 provides the proposed model for Flood Risk Analysis and prediction. Finally, section 4 provides the simulation results using ARC GIS simulation tool.

1. Existing Techniques for Flood prediction using GIS and wireless sensor networks

Literature review is an important part of the research process. The review is generally based on geographical Information system for flood Risk analysis and prediction specifically in case of Disaster circumstances.

Cloke et al. [1], had performed comprehensive review on numerical weather prediction alternatively known as ensemble prediction Systems (EPS). The Authors had performed operational and pre operational flood forecasting system. The strengths of the research work are based on detailed analysis of catchment area and the event period of disaster when the flood hits the targeted region. The Hydrological Models ensembles precipitation, runoff based on deterministic prediction in case of extreme event of flood. The key challenges in the research study depend on quantitative and evidence based case studies for false alarms and uncertainty of future rainfalls.

Alfieri et al. [2], had raised the attention of Researchers towards distributed hydrological modelling for weather forecasting. The hydrological simulation for flash flood prediction and ensemble discharge had been performed at verzasca, Lavertezzo for the period of 4-day lead time. The Relative Operating characteristic curve (ROC) has been used to measure the flood forecast based on probabilistic information. The Strengths of the research work is based on the deployment of last 30 years old metrological data set named as COSMO to predict peak discharge climatology in case of flash flood event.

Rozalis et al. [3], had used an un calibrated hydrological model to simulate flash flood events in Mediterranean watersheds in Israel. The rain fall data has been obtained from C-band non doppler radar system installed at 80km area of study catchment. The intensity of the daily rainfall and its depth can be calculated by using rain gauge bias adjustment method. The proposed Model was applied over 20 selected events, specially the occurrence of floods in case of storms. The peak flow discharge and runoff depth is numerically compared with the help of hydrographs. The core issue for the investigation of research depends on rainfall temporal and spatial resolution from radar satellite images in predicting runoff process in specified zone.

Biondi et al. [4], evaluates the performance of Bayesian Flood forecasting System (BFS) for evaluating uncertainty in Real Time Flood forecasting. The Authors had proposed stochastic and distributed Model in events of Flood disasters. The precipitation uncertainty processor (PUP) had been used for numerical mapping in case of model river discharge. The Hydrologic uncertainty processor (HUP) is used to evaluate precipitation forecast period in specific event time. The strengths of the research work is based on best calibration for predictive distribution (PD) based on TD (total periodic distribution) scheme.

Raha et al. [5], introduces a statistical Model to predict floods using Ad hoc wireless Sensor Networks (WSN).The Multivariable regression technique has been used in order to calculate the extreme flow of flood across the border line. The Authors had proposed the distributed frame work Architecture in which the cluster head is responsible for computation and predictions in case of critical flood events. The strengths of the research work is based on plotting uniform sampling instances of water level in case of two parameters- rainfall data and water discharge form dam. The Authors had proposed the wireless sensor network deployment scheme which is responsible for collecting the input parameters such as rainfall and temperature for prediction purpose. The aim of the Research work is based on using Polynomial fit and Roust fit function in design of the Mathematical Model. The simulation results are performed in Mat Lab which plots the graph of predicted values related to instantaneous water levels at different events of time with respect to flood line.

Dawod et al. [6], had focused his research on occurrence of Flash floods in Makah city. The Authors had proposed the mathematical model for flood series frequency due to heavy rain intensity of the 1969 storm in Makah city. The Authors had designed the GIS Geographical Information system based Model for flood assessment using Soil conservation service formulas, based on hydrologic methods used for flood estimation. The Authors had also study the flood spatial variation in Makah city which includes the flood volume of last 50 years. The conclusions of the research work include CN curve number flood estimation methodology which is more precise then flood estimation methods. The GIS based flood estimation had also many advantages it incorporates and process many data sets which includes metrological, geological, soil parameters and land use. The Digital Elevation method model had been used by King Abdul Aziz University of science and technology Saudi Arabia for Flood forecasting. The development method is also based on integrating various data sets for GIS used for flood modelling scenario.

Samarasinghe et al. [7], had critically analyzed the remote sensing and GIS for flood risk analysis at kalu ganga river srilinka. The authors had focused their study on vulnerability of frequent floods that cause damage to forests, residential areas,

agriculture crop land and many more affected areas. The methodology of the research work consists of specimen data collection including data from geo database. Then they had performed hazard analysis and vulnerability analysis on the hydro metrological and satellite data to perform risk analysis for possible threat to disaster effected region. The strong points of the research are based on Hydraulic analysis to obtain flood extent and depth. For this purpose the authors had designed HEC-RAS Model (Hydrologic Engineering Centres River Analysis stream).The mathematical model for Flood Hazard Mapping provides Flood Risk Map for 100 year period based on Flood simulation study using ALOS/PALSAR HH polarization to detect Flood period extent.

Saud et al. [8], investigates the occurrence of Flood hazards on national and regional levels in Jeddah Saudi Arabia. For this purpose the researchers had used IKONOS satellite images for location map to study the disaster affected areas. The researchers had used Arc GIS 9.3 software to observe geographical distribution of flooded regions and to identify the delineation of drainage system. The topographic maps had also been used to trace streams and water basins with the help of Digital Elevation Model. The Authors had also identify the water shed maps of Jeddah city which clearly depicts the schematic figure of Rock basins and Mountain chains in wadia Fatima located in Jeddah city. The strengths of the research work are based on hydrologic and geomorphologic description of existing basins in the disaster affected area. The authors had also identified the lack of accurate engineering practices with five damage categories in this spatial area. The minor limitations of the research work are based on non availability of mathematical model in this critical real life scenario.

Hailian et al. [9], had identified the assessment of flood risk in Hubei Province China. Flood Risk assessment had typically based on topographical factors including rainfalls, floods, and typhoons. The gradient calculation method using GIS software which indicates the smaller value of standard deviation factor results in intense flood risk in case of disaster effected region. The spatial distribution of floods effected region clearly depicts the frequency of historical floods that occur in the specified region influences the degree of water flood risk assessment in GRID map of Hubei Providence China. The research study results in great improvement of GIS technology for flood risk assessment and decision making. The other parameters also include soil and hydraulic engineering had also been considered in flood risk assessment. The proposed research study lacks the proposed Model scenario using GIS for flood risk assessment.

Zhang et al. [10], had performed, the analysis and frequency of natural flood disasters and its risk assessment in Peral River Basin and Luan River basin China. The Authors had focused their research on ARcGIS based system specifically designed for water resource applications. The major objective of this research study is to use the comprehensive features of Arc Hydro Tools which are embedded inside Arc GIS to obtain watershed features for the flood disaster management. The strengths of the research work are based on implementing Geo data base which is used in spatial data management using Arc Hydro Model. The research study provides in detailed information about post-flood disaster assessment in critical circumstances. The limitations of the research work are based on unavailability of mathematical Model deployed in real life scenarios.

Chen et al. [11], had proposed a conceptual model for urban floods potential in disaster affected areas. The research study provides in deep detail about GIS based urban flood inundation Model (GUFIM) developed at University of Memphis. The input parameter for the research study depends upon rainfall-infiltration and runoff analysis for 2-h long and 100 year storm, historical data. The strengths of the research work are based on Strom-run off Model which depends upon input parameters such as storm intensity and its duration, soil parameters, initial status of soil moisture and sewer system conveyance rate. The output of storm-Runoff Model serves as input for Inundation Model which results in Inundation depth and flooding area in disaster circumstance. The adaptive water fall Model will be very helpful for us in urban planning and emergency preparation in real world scenario specifically for sewer systems which plays a vital role in dynamics of drainage system.

Liu et al [12] had critically analyzed the losses and impacts of flood Disaster loss in Sindh and Punjab Province. The Remote Sensing (RS) and Geographic information System (GIS) plays a vital role in flood monitoring in real time scenarios along with submerged condition about different types of areas under disaster influence. The technical flow chart as designed by Authors provides in deep detail about Flood Extraction Method using decision tree and supervised classification Method. The major focus of The Research work is based on detailed analysis of statistical data using satellite remote sensing images for affected population suffered from floods in cultivated land area of Muzaffargarh and Dera Ghazi Khan.

Liu et al. [13], had performed detailed analysis of flooding risk in the coastal areas of Jiangsu, Shahghai, Zhejing, Taiwan and Guangdong. The Authors had also identified the flood risk and frequency rate which results in great economical and life loss. The ArcGIS geospatial analytical tool serves to be a strong platform in disaster risk analysis towards costal lowlands of china. The results may be very helpful for the disaster rescue Authority to take necessary precautionary measurements where vulnerability of flood disaster is high. The research study also provides in deep detail about the economical and life threat in China due to major population exposure along with the coastal areas.

Zhuowei et al. [14], describes a framework for integrative application system for Flood disaster response and decision making in critical emergency situations. The decision support system for flood scenario is totally based on remote sensing and geographical information system technology using software based methodology. The core element of the research work is based on OHE (Object hazard effect).The OHE Module is directly influenced by the driving factors such as Hazard analysis and vulnerability of flood risk analysis. These factors would be very helpful for researchers in Decision making support analysis. The mathematical Model proposed by the Authors entirely depends on Realization and Encapsulation methodologies. The Authors had also construct software structure for prototype system using powerful application development tools like visual C++ and Python.

Akar et al. [15], had analyzed the effects of human activities on hydro graphic structure that causes the main reason about the floods. Pixel based classification method and IKONOS satellite images are most commonly used for land structure analysis. HEC-RAS 4.0 (Hydrologic Engineering Centres Analysis System) custom designed software application had also been used for flood risk studies and flood flow rate. The required results obtained from the software systems are used for hydraulic modelling. The strong points of the research work are based on identification of flash floods in Yeniciftlik basin near to Istanbul Turkey. The geomorphologic characteristics plays a vital role in land hydrology analysis to reduce the impact of flood disasters parameters

such as slope, aspect drainage etc. The Authors had also suggested using HEC-RAS hydraulic software for determining land surface parameters to reduce the risk of flood in upcoming years.

According to Sulaiman et al. [16], the aims and objectives of this research study is to explore and identify flood risk assessment for Bandar segment using remote sensing and GIS (geographical Information Systems).For this reason in year 2008 a Real Time three dimensional simulation Model for Flood Hazards and risk assessment has been designed by Nizam Ghazali and Amiruddin kamsin et al. [9], at University Malaya, kuala Lumpur, Malaysia. The research methodology of Authors entirely depends upon LiDAR and ASTER satellite images and topography map of Bandar segment which serves as an input for Geometric and quantum GIS simulation tool which is used for generating simulation results. These results and parameters would very helpful for the Authors to design flood risk model and explain each process of research study using flow chart. The key features of the research study focuses on integration of GIS and RS technology with appropriate tools without the need of great knowledge, experience and cost effective features required for this research study.

Dawod et al. [17], had graphically represents the GIS based Unit Hydrographs within Makah metropolitan area, southwest Saudi Arabia. The NRCS (National Resources conservative Service) had performed detailed analysis of water sheds with in Makah city and compared peak discharge ratio with in different intervals of time. The authors had also designed a mathematical Model for peak discharge ratio (m^3/s) which depends on drainage area (km^2) and depth of runoff (mm).The strengths of the research work are based on time interval for peak discharge which is approximately 1.15 hours to 4.47 hours. Along with this the discharge quantity is measured in range of 10.14 to 16.74 m^3/s. Therefore it is highly recommended by emergency concerned authorities that flood protection disaster precautions can be adopted within the limited time span.

Zhang et al. [18], has conducted the flood disaster survey analysis by using powerful spatial analytic tool of GIS. The emphasis of the research work is based on gathering topographical data which is used for calculating serious damages and recoverability after the disaster circumstances, which many cause adverse effects on population and GDP density. According to the statically point of view precipitation is the major factor for the calculation of flood disaster risk assessment. The topography standard deviation method has also being deployed for flood redistribution and drainage system. The strengths of the research work are based on Mathematical Model for Flood Disaster Risk Assessment which entirely depends on influence of flood disaster on population and GDP rate. The limitations of the research work are based on unavailability of any standard for the classification of disaster circumstances especially in case of floods in disaster affected region.

Retna Raj et al. [9], had proposed the Architecture for Disaster management system primarily based on three major GIS web services which are Police, Fire and Hospital. The web application has also being deployed using AJAX (Asynchronous Java script and XML) approach which can be successfully integrated into Google maps for spatial data insertion. The Authors had also proposed three tier Architecture which consists of XML Http request and response infrastructure in between client browser and web server. The GIS data base has also integrated with web server for SQL query processing for analysis purpose only. The strong points of the research work depend on fuzzy sets for GIS web service ranking for quality GIS web service. The proposed system is also successfully integrated into the mobile phone which can provide 3 above emergency services at the point of need selected on the map displayed on Mobile Phone. The small limitation depends on the capability of Mobile phones to support AJAX application and its integration into web supported map.

Chan et al. [20], had realized that using Google earth software application for geographical information system using 3D analysis and digital elevation Model proves to be important feature for flood disaster management system. A web based application has been developed that can easily integrate Google earth Pro v.5 and KML files are useful for monitoring disaster effected region and generating results based on necessary parameters. The success factors for this research work is based on advancement of ArcGIS hydrological tool that can shape files to monitor real time scenario readings related to the movement of rivers causing floods and related file can also be downloadable for future reference purpose use.

Feng et al. [21], had performed fuzzy risk analysis by means of probability distribution method. The Author had performed detailed mathematical derivations using fuzzy sets mathematics theory which proves to be significant and powerful technique in flood risk assessment. The fuzzy cut set of probability distribution method as mentioned in Figure is a triangular function referred to as possible level of probability. The strength of the research work is based on maximum probability of risk value α that falls in different category such as low, high and acceptable risk area in a specific geographical region.

Hachmann et al. [22], has focused its research towards structural Health monitoring (SHM) system to detect and localize damages using wireless sensor networks. The author has proposed a decentralized computing architecture named as Damage location Assurance criterion (DLAC).On the basis of this architecture and strong literature review moves his research towards Damage location algorithm based on Fast Fourier Transform (FFT) and power spectrum analysis for raw vibration readings. The graphical results based on low power sensors represent correlation of damage among multiple discrete locations. The authors had performed structural configuration using steel truss structure and highlighted the elements which were the cause of damage in case of healthy and damage truss. The strong points of the research focuses on limited power management and reduce latency. A short factor of limitation of DLAC is that it cannot localize small damages and symmetric structure.

Almedar et al. [23], describes an overview of Wireless sensor networks scenario especially for health care applications. The authors design considerations mainly depends on Body area Network subsystem. The BAN System consists of RFID Tags embedded on children and elderly people in case of emergency situations. The authors had also designed a modular representation of future scenario for pervasive health care monitoring system. The System is responsible for monitoring daily life activities, fall and movement detection, Location tracking, Medical intake and medical status monitoring. The strong points of the research depend on low cost and energy efficient architecture. The major challenges faced to the authors are security, privacy, ease of deployment and scalability for ad hoc WSN architecture.

Johansson et al. [24], presents Sole Integrated Gait Sensors (SIGS) architecture. The proposed system is a low power and low cost WBAN (wireless body area Network) systems, uses radio frequency based network technology specially designed for patients, elderly people and people affected from disaster circumstances. The Personal server ANT based experimental device is

capable to receive feedback from wireless for pressure sensors to help doctors to analyze the treatment of walking problem and fall prevention. The conclusions of the research work supports high transmission rate using GSM/Wi-Fi and blue tooth based communication infrastructure. For improved channel utilization and power efficiency GFSK and TDMA modulation schemes. The limitations are based on expensive wireless network architecture which is difficult to implement in real life scenarios.

Chen et al. [25], had focused on past health care efforts including self configuration and real time health care instruments used by care givers and doctors for improved quality of health care. The research work had been under taken at Jonkoping University Sweden especially for elderly health care. The proposed system is based on (data decision system DDS) consists of wireless sensor nodes connected with smart gate way data base. The authors had also implemented Ethernet module to communicate with remote server at Health care centre and GSM/GPRS module is used to send emergency messages to Hospital for medical need. The major focus of this research moves towards low power and low cost real time embedded systems and faster response in case of critical situation. The challenges faced by the researchers are secure data transmission and communication. The hidden markov Model can also be used in the future to upgrade the Data decision System.

Chen et al. [26], focused his research on wireless Body sensor Network devices for the treatment of human digestive systems and endoscopic image monitoring. The wireless body sensor network comprises of ZIGBEE and SC-UWB channel to support high speed data communication. The ZIGBEE module is used for device discovery and navigational purposes. The authors had also successfully designed an AMP system to automatically select high speed and low speed data transmission. They had also successfully merged ZIGBEE and SC-WBB for data transmission among multiple sensor nodes. The bottleneck arises at the point where system complexity and power consumption overhead remains a critical issue.

Y.zatout et al. [27], had implemented three tier wireless sensor network Architecture. The authors had proposed wireless Sensor Network solution for health care monitoring. The low density heterogeneous sensor nodes are evenly placed at multiple locations within the house. The Body sensor Network architecture consists of Medical Nodes (MN) which are responsible for transferring the information to coordinator Node (CN).The coordinator nodes transmits the information to video nodes (VN) for event detection. The Video nodes periodically send the relevant information to sink Node. The Medical Nodes are responsible for monitoring the patient's health status including shocks, body temperature, Electrocardiogram (ECG) and pulse rate. The success factors of the research are based on mobility aware and energy efficient protocol. The short comes of the research is based on integrating three tier Network Architecture with secure and reliable data transmission.

Gadallah et al. [28], adapted the techniques used in MANETS (Mobile Adhoc Networks) specifically deployed in event of disasters at numerous buildings, possible fire places and gas leakage. The core concept behind this research studies depends upon need of rescue authority to locate and search the earthquake affected people under collapsed buildings, falling light posts and trees. The Authors had proposed Network participant nodes including service provider nodes, service requester nodes and command center communicating nodes to communicate with each other using wireless infrastructure. The practical work of the authors relies on extended version of Dis SERV simulator for wireless sensor network simulation. The proposed algorithm is also well suitable for service discovery and service provider reservation. The shortcomings of the research focus on expensive architecture to implement in real world scenario.

Aziz et al. [29], have gathered evidences about occurrence of disasters due to climatic reasons with a high level of floods, landslides and heat waves to occur. In Malaysia the most common natural disasters occurs due to heavy rain falls, floods and landslide brings threat for the life of millions of people in the disaster zone. There are multiple issues to consider for the deployment of wireless sensor nodes in pre deterministic and random manner. The blanket coverage, barrier coverage and sweep coverage plays a vital role in maintaining connectivity with remote sever or base station. The controlled and uncontrolled mobility depends upon the movement of sensors in narrow or small spaces. The success factors for the research work is early warning flood detection systems for landside monitoring, WSN Air pollution monitoring system, WSN for volcanic eruption monitoring, WSN for Earthquake Disaster Mitigation in urban areas, WSN for Robot Emergency search and rescue System (RESRS). The short comings of the research focuses on the lack of graphical representation for the research Model used in real life scenarios.

Chenji et al. [30], proposed a motivating and state of Art scenario for surveying the disaster area under critical circumstances. The authors had proposed Anon Architecture for monitoring and sensing disaster effected people using vibration sensors. The vibration sensors are typically seismic nodes which transmits the information to vehicle nodes. The vehicle Nodes transmits the disaster related information to Btag Nodes (Sensors) which are connected to Smart Phones. The proposed Architecture is typically 802.11 Fixed Mesh Network deployed in geographical region. The Delay Tolerant networking (DTN) routers ate typically Vehicle, Btag and seismic nodes that transmits the information to Base station or mobile computing devices. The quality of the research work focuses on the design Delay tolerant Network consists of Body sensor Nodes. The minimized energy consumption factor using mathematical model is a strong factor in real life scenarios. Although it's a complicated architecture but can possibly be integrated with other wireless Networks.

E.A.Basha et al. [31], had proposed the Model based scenario for early warning Flood detection system. The Authors had proposed the statistical hydrological Model for flood prediction using linear regression. The core issue for the research entirely focuses on predictive environmental sensor network for large geographical region. The Ad hoc wireless sensor network architecture consists of sensing nodes, computation nodes and community interface nodes. The authors had used the pressure box sensor to calculate the real time input parameters and interface it with sensor node to calculate the water pressure under sea and air pressure to calculate the external environmental parameters. Along with this the rainfall sensor nodes are deployed on photovoltaic board that has the capability to calculate the rain fall intensity. The strengths of the research work depend upon installation of water level prototype by using computation nodes and antenna (for communication purpose) to calculate the water level runoff in critical emergency circumstance.

3. Critical Evaluation

The following section describes in depth detail about the critical evaluation of research study which, we have discussed in above mentioned literature review.

Table 1 describes about the role of GIS and WSN in Flood prediction technique along with their pros and cons. Cloke et al. [1], had performed Flood prediction in case of hydrological Modelling. Wireless sensor networks had also been used in case of Flash Flood prediction [5],[23] and [30]. GIS technique had also been frequently adopted by scientists and engineers for calculating Flood series frequency. The probability based mathematical model for Flood Risk is designed on the basis of fuzzy logic [21]. Chen et al. [11], simulated the data set for previous 100 year period for calculating the dynamics of drainage system. There are also lot of uncertainties in Flood prediction but biondi et al [4] had evaluates the performance of Bayesian Flood Forecast by using predictive distribution scheme. Related to Disaster Management Hackman et al. [22], had proposed damage localization modelling using wireless sensor networks. The Radar Satellite images and hydrographs also provide an adequate technique for estimating flood series frequency [6]. Now a day's hydrological models had also being used to simulate Flash flood events. The temporal and spatial resolution had also been used to calculate the peak water flow discharge level and the runoff process [3]. Some of the Authors had focused their research towards Distributed Modelling for weather forecasting. The metrological data set such as COSMO had also being used to calculate the peak discharge ratio [2].

Table 1: Tabular representation of GIS, WSN and Flood Prediction Technique used along with Pros and Cons

Authors	GIS,WSN and Flood Prediction Technique used	Modeling Technique used	Conclusions	Limitations
Cloke et al. [1]	Ensemble prediction Systems (EPS)	Hydrological Modeling Technique (deterministic prediction)	Performed comprehensive review on numerical weather prediction	False alarms and un certainty in future rainfalls
Alfieri et al. [2]	Flood forecast is based on probabilistic information.	Distributed Modeling for weather forecasting has been used.	Metrological data set (COSMO) has been used to calculate peak discharge ratio	Relatively short duration test period 17 months
Rozalis et al. [3]	The Peak flow discharge and runoff depth is numerically calculated	Un calibrated hydrological model has been used to simulate flash flood events	Rainfall Temporal and spatial resolution has been used in calculating runoff process	Complex Architecture
Biondi et al. [4]	Evaluates the performance of Bayesian Flood Forecasting systems(BFS)	Proposed a *stochastic and distributed Model in events of Flood disasters.*	Best calibration for predictive distribution scheme	Uncertainty in Flood Forecast
Raha et al. [5]	Flood Prediction technique is based on WSN	Introduces a statistical Model to predict Flood	Graph results are generated related to instantaneous water levels	Complex sensor Node deployment scheme
Dawood et al. [6]	GIS Model for flood assessment has been designed	Proposed the mathematical Model for Flood series frequency	Curve number flood estimation methodology has been used	Environmental parameters are not considered for Flood Prediction.
Chen et al. [11]	Sewer System simulation designed for dynamics of drianage system	Conceptual Model for urban Flood Inundation	Runoff Analysis for 100 year storm	Mathematical Model has not been designed
Feng et al. [21]	Fuzzy logic Flood Prediction scheme has been used	Probability Model for Flood Risk has been designed	Maximum probability for Flood Risk in specific geographical region	Complex inner outer mathematical Model
Hackman et al. [22]	Structural Health monitoring (SHM) system to detect and localize damages using WSN	Damage localization modeling is based on FFT	Damage location algorithm and power spectrum analysis for raw vibration readings	cannot localize small damages
Almedar et al. [23], chenji et al. [30]	WSN for body area Network	Energy Efficient Architecture	RFID Tags are Used in case of emergency situations	Major challanges are security and privancy in case of WSN

3. Proposed Solution

This section provides a brief picture of solution(s) being discussed. The geographical information system as described in Figure 1 provides in deep detail about the role of hydrology based flood prediction sensors [22] and [29] specifically designed for critical disaster situations due to heavy rain falls. The Proposed network Architecture for Flood risk Analysis can further be classified into three sub types elaborated as Wireless sensor network field, GIS based Emergency Response Data Base server and remote sensing and satellite based infrastructure.

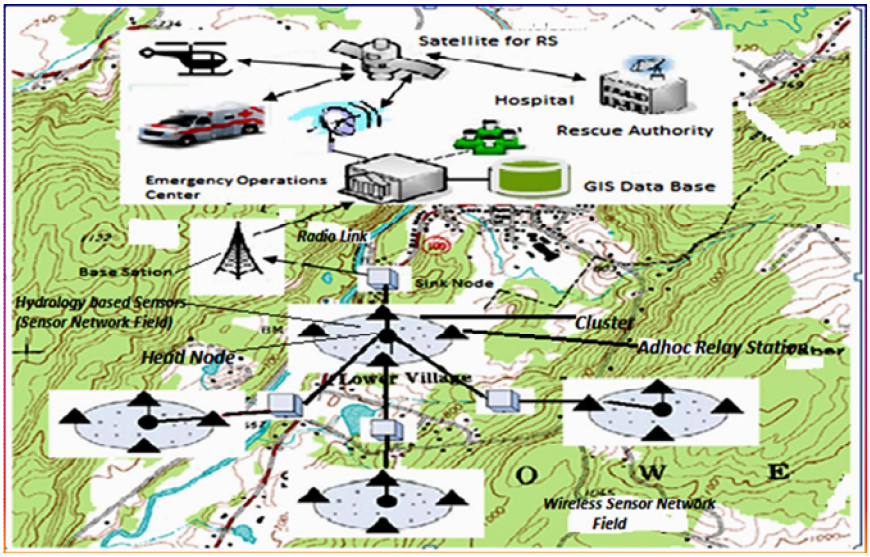

Figure 1: Proposed Solution, N.Ahmad et al [32]

- *Wireless sensor network field*

The sensor field comprises of hydrology based sensor nodes. The sensor nodes within each cluster are capable to sense input environmental parameters, among these the most important climatic parameters are humidity level, air pressure and wind speed. These parameters will be very helpful for us in predicting the intensity of upcoming rainfall. The hydrology based sensor nodes are wirelessly interconnected with head node. The head node is responsible to send the climatic input parameters to sink node via Ad hoc relay station. The Ad hoc relay station installed within the boundary of each cluster is responsible for boosting the input information coming from head nodes and redirects the output information to sink node. The Sink node broadcast the disaster related information to Base station via radio link. The Base station forwards the climatic input parameters to emergency operations center which stores the real rime GIS data base. The Ad hoc wireless sensor Network is also capable to deploy on surface water gauges to predict the runoff process and overflow rate in water basins in critical emergency circumstances.

- *GIS based Emergency Response Data base Server*

The GIS data base will be very helpful for emergency rescue authorities to predict the pre disaster conditions and to prepare themselves for the rescue and life saving arrangements in minimum span of time. The GIS data base is continuously connected via a satellite link. The GIS data base server forwards the extreme climatic information based on input parameters to rescue authorities via satellite link.

- *Remote Sensing and Satellite based Infrastructure*

There are two functionalities of satellite, first is remote sensing and weather forecasting and forwards this information to GIS data base server, second is to transmit the extreme input climatic parameters received from GIS data base server to rescue and medical authorities to prepare themselves for life saving procedures [27] and [28].

3.1 Proposed Model for Flood Forecast Risk Analysis and Prediction

In this Research study we had proposed the Model for Flood Risk Analysis and Prediction as mentioned in Figure 2. In the following mentioned Figure 2 the GIS data base stores the numeric value information that is related to rain fall and Floods. These rain fall and floods imparts a potential impact of damage to residential, Agricultural and Industrial Assets.

The GIS data base would be very helpful for us in Hydrological Modeling. In Hydrological Modeling we calculate the Flood Depth and velocity; along with this we can also calculate Flood submerging and ground elevation factors. This strategy would be helpful for us in calculating the impact of flood in disaster hit regions. The Hydrological Modeling for disaster hit regions provides a strong platform for us in flood modeling using satellite images. These satellite images would be up uploaded in ARC GIS simulation tool from where we can generate the topographical maps. The topographical maps are used to calculate the damage assessment in the disaster hit region. The damage assessment calculation is used to predict inundation ratio for the disaster effected area along with the population suffered from the Flood. The inundation ratio is also used in flood risk analysis and prediction. From this prediction we can take necessary precautionary measurements in Flood Relief prevention. We can also implement flood Control Decision Support System from above results along with Flood Relief and Prevention.

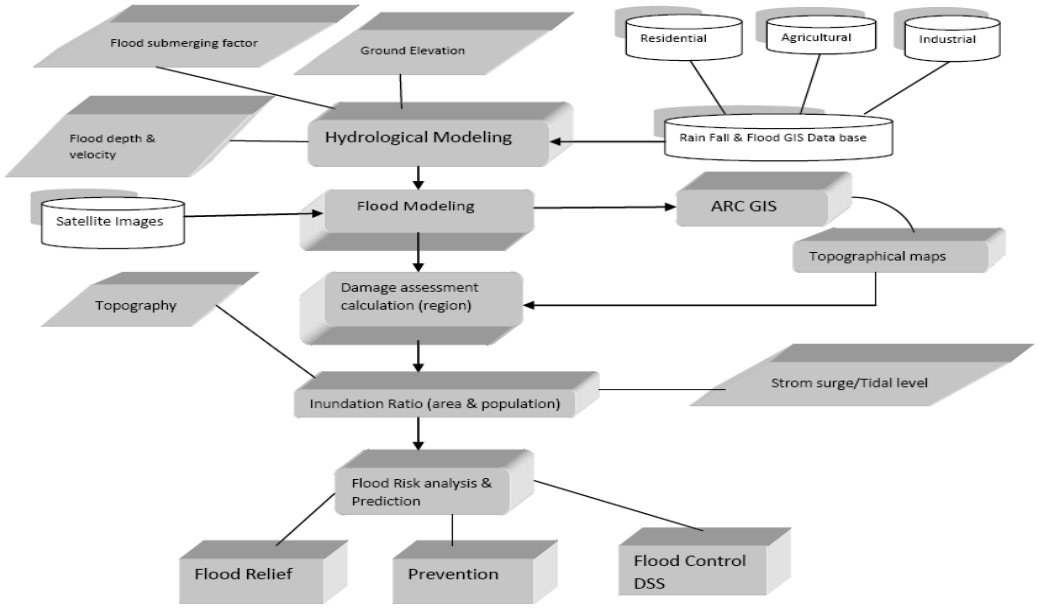

Figure 2: Flood Relief Analysis and Prediction

3.2 Mathematical Model for Flood Analysis and Prediction

We had also designed the Mathematical Model for Flood Analysis and prediction based on the following mentioned input parameters.

Input Parameters

T=Air Temperature, TH=High Air Temperature, TL=Low Air Temperature
H=Humidity Level, HH= High Humidity level, HL=Low Humidity Level
P=Air Pressure, PH=High Air Pressure, PL=Low Air Pressure
W=Wind Speed, WH=High Wind Speed, WL=Low Wind Speed
S=Snow Melt, SH=High Intensity Snow Melt, SL=Low Intensity Snow Melt
R=Rain Fall, RH=High Intensity Rain Fall, RL=Low Intensity Rain Fall
Ro=Run off Process, RoH=High Intensity Run off Process, RoL=Low Intensity Run off Process
t=time scale,
y=Flood Prediction factor

The following mentioned partial derivative equation no (1) scheme has been adopted by using ordinary differential equations. The Flood Prediction factor can be calculated by taking sum of all the above mentioned input parameters and their partial rate of change with respect to time depending upon their real time values.

$$\frac{\partial T}{\partial t}+\frac{\partial H}{\partial t}+\frac{\partial P}{\partial t}+\frac{\partial W}{\partial t}+\frac{\partial S}{\partial t}+\frac{\partial R}{\partial t}+\frac{\partial RO}{\partial t}=y \qquad (1)$$

The equation no (2) describes about the rate of change in steady state values depending upon the difference between high and low input values.

$$\frac{\partial(TH-TL)}{\partial t}+\frac{\partial(HH-HL)}{\partial t}+\frac{\partial(PH-PL)}{\partial t}+\frac{\partial(WH-WL)}{\partial t}+\frac{\partial(SH-SL)}{\partial t}+\frac{\partial(RH-RL)}{\partial t}+\frac{\partial(ROH-ROL)}{\partial t}=y \qquad (2)$$

The ao, a1, a2, a3, a4, a5, a6 are the constant values multiplied by equation no (1). The constant value is substituted by a numerical value which tells us about the impact of Flood Disaster. If the constant value is high the impact of Flood Disaster is also high and if the constant value is low the impact of Flood Disaster is also low.

$$ao\frac{\partial T}{\partial t}+a1\frac{\partial H}{\partial t}+a2\frac{\partial P}{\partial t}+a3\frac{\partial W}{\partial t}+a4\frac{\partial S}{\partial t}+a5\frac{\partial R}{\partial t}+a6\frac{\partial RO}{\partial t}=y \qquad (3)$$

$$y=a_{k=0,1,\dots n}\int_{t=0}^{t=n}(T,H,P,W,S,R,Ro)dt \qquad (4)$$

The resultant equation provides the detail about flood prediction factor which depends on sum of all the input parameters and their rate of change with respect to time multiply by the constant factor value.

4. Flooding impact and Heaviest Spell of Monsoon Rains during 2011 in Sindh Pakistan

According to the data collected from Internet (Pakistan Metrological Department) [33] during the months of August and September 2011 due to heavy rain fall spell in the regions of Sindh Province Pakistan. The data related to heaviest spell of Monsoon Rainfall is mentioned in Table 2 described as follows.

Table 2: Rain fall data collected by Pakistan Metrological department during 2011 in Sindh Pakistan

City	Rainfall (mm)	Rainfall (in)	Rain Fall Months
Mirpur Khas	603	23.7	September 2011
Nawabshah	353.2	13.9	September 2011
Dadu	348.1	13.7	September 2011
Badin	302.1	11.8	September 2011
Hyderabad	244.2	9.6	September 2011
Karachi	212.2	8.3	September 2011
Mithi	760	30	September 2011

From the above mentioned data in the table, the heavy rainfall affected area is Mithi Capital of Tharparker District Sindh Pakistan. The designated area falls under the impact of Floods due to heavy rainfall as recorded in year 2011.Following are the detailed assessment of Floods as calculated by Pakistan Disaster Management Authority Islamabad [34]. The Table 3 provides in deep detail about the impact of Floods in different districts of Sindh which causes heavy damages including causalities, economic and assets damages according to PDMAs data recoded by the official authorities.

Table 3: Flood impact and its damages during 2011 in Sindh province, Pakistan

S.No	District	Persons Affected	Persons in Relief Camp	Houses Damaged Partially	Houses Damaged Fully
01	Badin	1,021,301	77,363	172,155	210,407
02	Khairpur	927,953	----------	7,138	4,291
03	Mirpur khas	705,151	57,269	30,627	87,483
04	Sangher	477,523	145,629	78,118	44.585
05	S.Benazirabad (Nawab Shah)	900,000	55,839	----------	----------
06	Tando Allah yar	253,982	35,294	24,096	3,601
07	Tando Muhammad Khan	267,368	7,029	24,200	26,600
08	Tharparkar	127,454	17,443	10,821	4,367
09	Thatta	178,151	1,640	11,325	----------
10	Umerkot	323,448	58,246	94,172	96,543
Total		5,182,331	455,752	452,652	478,147

4.1 Proposed Scenario Simulation using Arc GIS Simulation tool

We had used Arc GIS simulation tool software for Geographical Flood Risk Analysis. The Simulation tool is open source used for educational purpose. The layers in the simulation tool describes in detail information about geographical analysis. The Base map in the simulation tool consists of Nat Geo world Map. The Online Module of Natural Hazards Support system (NHSS) weather watches and warnings provides in deep detail about recently updated Floods ,earthquakes and Thunder storm warnings within the continent as displayed on the Map. The base Map consists of Boundaries and places with in the continents along which shaded region specially highlighted in case of flood risk identification.

The ARC GIS Simulation Tool is used in our research scenario is to predict the Flood damage Report from Sindh Province Pakistan due to heavy rain falls. The input parameters had been used as described in the previous Table 2.

Most of the cities affected from flood disasters are semi rural areas where the land is used mainly for agriculture purposes. The industrial and commercial activates are limited within these areas. The persons directly affected from these disasters are mainly farmers and their families. The Figure 3 provides in deep detail about the regions of Sindh that are directly affected from disaster as described in Arc Map simulation. The red shadow areas provides in complete detail information of high probability of inundation and occurrence of Flood disasters. The Orange and yellow shaded regions provides moderate (medium) effects of inundation and flood risk lower than the above. The light and dark green shaded area provides the slight effects of flood disasters in the existing geographical region.

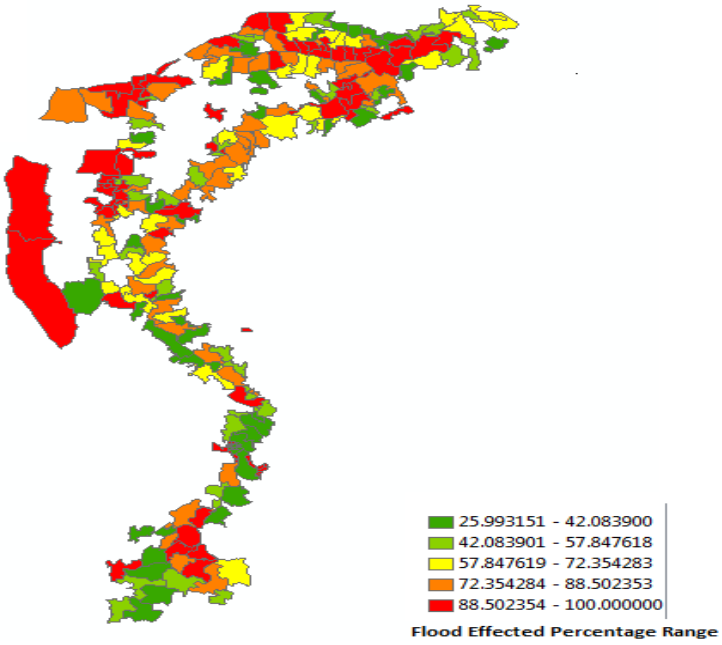

Figure 3: Graphical Representation of Flood Affected Percentage Range

The blue water sheds within the topographical map as described in Figure 4 was typically designed to analyze the areas mentioned in bold dots having high risk of flooding due to having depressed areas. The medium dots represent the regions moderately affected from floods and the small dots represent the regions slightly suffered from the Flood disaster. The direction of water flow depends upon the loss of soil. This parameter is used to calculate the land sediment and slope in disaster hit region. In rural areas of Pakistan due to having limited resources, the water drainage system is a critical issue for flood control measurements. The Tidal affects of rivers near the area of Sind is considered to be the region suffered from high potential risk of floods [29]. The Digital terrain Model (DTM) is used with GIS Software to calculate the steeps and slope of the land.

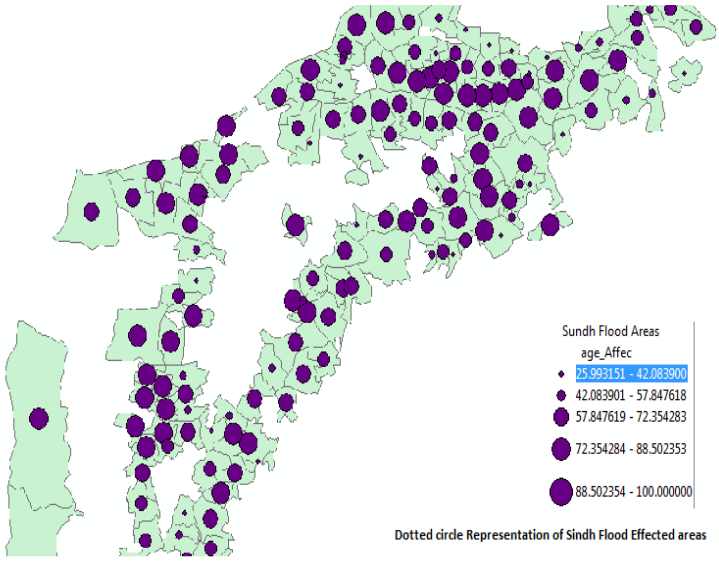

Figure 4: Dotted circle Representation of Sind flood Effected areas

Conclusions and Future Recommendations

The outcomes of the research study focuses on the integration of GIS with wireless sensor Networks in Flood Analysis and Prediction. Along with the deep Literature review we had also proposed a frame work Model for Flood Risk Analysis. We had also performed the simulation for flood forecasting in different regions of Sind Province using ARC GIS simulation tool. The flood forecasting map provides in deep detail about the areas which are suffered from heavy rainfall during the last two years. Finally we conclude that pre and post disaster risk analysis mechanism can save the life of thousands of people before this critical condition of Flood disaster occurs. The integration of underwater wireless sensor Networks [37] also provides a challenging opportunity for researchers to calculate the potential of Floods in disaster hit region whenever there will be an earthquake inside

the bed level of sea. The wireless Sensor Network Protocol can also be independently designed specifically for Flood Risk Analysis and Prediction [35] and [36].

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