

# **WEB BASED SPATIAL DECISION SUPPORT SYSTEM FOR FLOOD DISASTER MITIGATION**

**Ph.D. THESIS**

*by*

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# **WEB BASED SPATIAL DECISION SUPPORT SYSTEM FOR FLOOD DISASTER MITIGATION**

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*Submitted in partial fulfilment of the  
requirements for the award of the degree*

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*by*

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## CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **WEB BASED SPATIAL DECISION SUPPORT SYSTEM FOR FLOOD DISASTER MITIGATION** in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy and submitted in the Centre of Excellence in Disaster Mitigation and Management (CoEDMM) of the Indian Institute of Technology Roorkee is an authentic record of my own work carried out during a period from July, 2011 to September, 2015 under the supervision of Dr. R. D. Garg, Associate Professor, Department of Civil Engineering, Dr. D. S. Arya, Professor & Head, Department of Hydrology, Indian Institute of Technology Roorkee, Roorkee and Dr. S. P. Aggarwal, Scientist/Engineer SF & Head, Department of Water Resources, Indian Institute of Remote Sensing, Dehradun.

The matter presented in the thesis has not been submitted by me for the award of any other degree of this or any other Institute.

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## **ABSTRACT**

Water is a necessity of life. It provides support to life of plants and living being. It is a fact that moderate amount of water provides support to life but a large amount of it can leads a huge disaster and this disaster named as Flood. Generally floods occur due to the river overflows from its banks. This flood water enters the agricultural land and settlements to cause disaster in the region. A large number of people affected and economic losses resulting from flood are on rise at an alarming rate globally.

The main research objective of present study is to develop a web based spatial decision support system (SDSS) for flood disaster mitigation. This research work has been divided in three sub-parts, which includes flood inundation mapping and damage assessment, developing a web-based spatial DSS for flood disaster mitigation and the third is to identify the safe and shortest route for evacuation during flood disaster.

According to the Government of India-UNDP Disaster Risk Management (DRM) programme (2002-2007), Kendrapara, Jagatsinghpur, Cuttack, Jajpur and Bhadrak Districts of Orissa state are the most flood hazard prone districts. The delta region formed by the Nuna and Chitrapala rivers of lower Mahanadi region is taken as the study area for this research. It is located between East Longitude  $86^{\circ}16'30''$  to  $86^{\circ}30'05''$  and North Latitude  $20^{\circ}22'30''$  to  $20^{\circ}31'30''$ . A lot of data and information has been gathered for this study. It includes: Geospatial data as DEM (Digital Elevation Model), temporal satellite images before, during and after flood, Radarsat SAR, IRS P6 LISS-III / LISS-IV, Landsat ETM+, Google Images, Bhuvan data, Toposheets from Survey of India; Socio-economic data; spatial analysis softwares as ArcGIS, ERDAS Imagine; Open source tools used for web GIS application. A field visit was performed during July 2012 for collecting various data and information.

This study uses the Radarsat-1 images of 04-September 2003 and 11-September 2003 for flood inundation mapping. It shows the comparison between different flood duration images. IRS P6 LISS-III image, dated 21 January, 2006 has been used for creating land use map with the help of ERDAS Imagine software. The supervised image classification technique has been used to find ten different classes. These classes are based on field visit,

Google imagery, Government organization data and various remote sensing data. On the basis of the Land Use Land Cover map the main elements at risk have been identified as Built Up, Agricultural Land- Kharif Crop, Agricultural Land- Rabi Crop, Agricultural Land- Double-crop area and Plantation. Flood damage assessment is done by overlaying land use map with flood map. The output map divides the classes into water and land area. It shows the area of different classes in water and land. As most of the study area is rural area, therefore the agriculture land is the prime concern for vulnerability. The crop land and built up are more susceptible to the flood water. The height of the flood and the duration of flood are important factors for the damage assessment. The duration of flood is also a very vital issue related to the crop vulnerability. So as seen in the comparison of different Radarsat data, it is observed that there is a very high damage occurrence. In terms of money it is calculated that more than INR 100 Billion loss of agriculture and INR 17 Billion loss of build-up and roads occur due to the flood.

The delineation of optimal route has been carried out using three different methods and then compared to find the most suitable one. It uses five parameters for finding the priority of route using AHP, Fuzzy and ANFIS methods. The three approaches are knowledge base, data base and learning base approaches. All these three approaches are implemented and compared for the optimal path extraction. An intelligent fuzzy based decision support system has been constructed on the basis of the comparison of these three approaches. ANFIS based DSS for safe route delineation has been implemented and different flood scenarios have been explained. The elevation data plays an important role to find the optimal path in this work.

The three approaches applied in this work for implementing fuzzy inference system (FIS) are: knowledge base, data base and learning base methods. In knowledge base modeling approach, FIS is implemented using expertise knowledge. FIS has been implemented in MATLAB using fuzzy logic toolbox. This modeling requires very deep understanding of input output relationship in each and every scenario. In data base modeling, FIS is modeled directly from data therefore this modeling is known as data base modeling. Clustering of numerical data forms is the basis of many classification algorithms. In this work, since it is quite difficult to calculate the number of clusters in data set, therefore Subtractive clustering method has been applied. Then fuzzy logic has been applied to extract the broad

categories of the clusters. This method is applied for the route evacuation problem, output of the fuzzy system matches to expected value to a degree of 91% to 97%. Thus it can be seen that though clustering and fuzzy logic are effective techniques for data modeling and analysis but still optimization of result is required. For this, fine tuning of membership functions is required which can be done through learning base modeling.

In the learning base modeling, the FIS needs to go through training and learning process. Adaptive learning techniques allow the fuzzy system to learn and extract information from the data they are modeling. Throughout the training, parameters associated with membership function (MF) change and finally adapt the shape and parameter values that best allow the FIS to respond in the approved manner. In this work, FIS is first implemented via all the above mentioned different approaches, then results or decision of each approach has been compared and at last most appropriate decision has been projected out.

The hybrid learning method has been selected for FIS training in this study. FIS model output is to be tested against all the three data sets one by one. The average testing error for the training data set is  $4.7 \times 10^{-4}$ . And the average testing error for checking data set is  $15.4 \times 10^{-4}$  and for testing data set is  $8.2 \times 10^{-4}$ . The checking data has a very near values compared to the FIS values, it is found that the resultant values are accurate up to 99%. Therefore it is observed that the system is working very near to the required result. There are some limitations with the accuracy of the input data, so the result cannot be 100% accurate. But under the practical concern the error up to 6 feet can be considered with these data sets.

The flood extent map is based on the DEM of area. In flood risk zone map the high elevation area is considered as low flood risk zone. The road network map of the area has been constructed on the basis of Google map, field visit, satellite imagery and open source map. The shelter zone map has shelter points on the basis of its Elevation, proximity to safe zone, capacity and convenience. These may be school buildings, commercial complexes, Government constructed shelter zones, or a shelters developed by other public organizations.

Apache Tomcat and GeoServer has been used for constructing a web GIS based DSS for flood disaster mitigation. The GeoServer is like an application server which holds spatial data by using PostGIS for spatial database management and it retrieves data to display it with the application. It stores various GIS layers such as LULC layer, road network layer, soil layer and Google Earth layers. This web GIS can perform a number of functions on these layers. The PostgreSQL is used for information extraction from the layers. Length and area measurements, route display with names of the path are some of the key features of this web GIS. The user friendly interface is developed in JavaScript. It provides an easy way to query. This web GIS is based on open source software, therefore it also has capability to access the resources available on the Internet based on open source. This GIS is developed to support the flood disaster mitigation.

The rescue operation requires shortest and safe path with detail, and this research work provides a very efficient path finder. So this web GIS can play a vital role during flood disaster. This web GIS provides some functionality to length and area measurements, route display with names and visualization of the path are some of the key features of this web GIS. This web GIS is using open source software, therefore the limitations of a freely available spatial geo processing tool is also the limitations of this web GIS. If very high resolution satellite images will use than the accuracy of damage assessment will become better compared to the LISS III images and Radarsat data. An Android based application can be developed for the flood disaster mitigation. It may integrate Google API with android application for further development of flood disaster mitigation app.

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## **List of Abbreviations**

ADPC	Asian Disaster Preparedness Center
AHP	Analytic Hierarchy Process
ANFIS	Adaptive Neuro Fuzzy Inference System
BMTPC	Building Materials and Technology Promotion Council
CWC	Central Water Commission
DEM	Digital Elevation Model
DRM	Disaster Risk Management
DSS	Decision Support System
EFAS	European Flood Awareness System
FCC	False Color Composites
FIS	Fuzzy Inference System
FOSS	Free and Open Source Software
FOSS4G	Free and Open Source Software for GIS
GCP	Ground Control Point
GDP	Gross Domestic Product
GIS	Geographical Information System
GPS	Global Positioning System
HTTP	Hyper Text Transfer Protocol
IFSAR	Interferometric Synthetic Aperture Radar
IRS	Indian Remote Sensing
ISRO	Indian Space Research Organization
LISS	Linear Imaging Self Scanning Sensor
LULC	Land Use Land Cover
MCDSS	Multi-Criteria Decision Support Systems
MF	Membership function
NASA	National Aeronautics and Space Administration
NDMA	National Disaster Management Authority
NDVI	Normalized Difference Vegetation Index

NDWI	Normalized Difference Water Index
NGO	Non Government Organization
OGC	Open Geospatial Consortium
OSDMA	Odisha State Disaster Management Authority
RDBMS	Relational Database Management System
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SDSS	Spatial Decision Support System
SOS	Sensor Observation Service
SRTM	Shuttle Radar Topographic Mission
UNDP	United Nations Development Program
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service
WSN	Wireless Sensor Networks
XML	EXtensible Markup Language

# **CHAPTER -1**

## **INTRODUCTION**

### **1.1 PREAMBLE**

Water is a necessity of life. It provides support to life of plants and living being. It is fact that moderate amount of water provides support to life but a large amount of it can leads a huge disaster and this disaster named as Flood. Floods have the greatest damage potential among all natural disasters and affect the maximum number of people. The number of people affected and economic losses resulting from flood are on rise at an alarming rate globally. Floods are causing extensive damage to the agriculture fields, built up, natural environment and shattering to human settlements. Economic losses due to the affect of destructive floods have increased extensively around the world. The Asian region experiences frequent flood disasters of high magnitude and the number of affected populations and economic losses have increased significantly (ADPC, 2005).

Comprehensive assessments of risks from natural hazards are needed. To obtain a sustainable solution, it is required to involve the community at risk, in the decision making process. Their participation in planning and implementation process can help to disaster managers. These solutions should reflect the human dimension. Changing land use on flooding, erosion, and landslides will help to prepare against these disasters. Integrated water management practices must be embraced. It is essential that these solutions must be suitable for the community at risk, only then it can be sustainable over the long term. During last 10-15 years a lot of work has been done to understand the flood and other natural disasters. Different countries use different policies and methods for minimizing vulnerabilities and adverse impacts of hazards to facilitate sustainable development (Bello and Aina, 2014). To obtain a sustainable solution, it is required to involve the local community for planning, decision making and implementation of process. Conservation and restoration of mangroves can provide a sustainable adaptation against cyclones (Bahinipati and Sahu, 2011). So the system must consider the overall environment and the impacts of changing land use on flooding, erosion, and landslides.

## **1.2 SITUATION OF FLOOD MANAGEMENT IN INDIA**

India is losing about 2% of the GDP on an average due to these natural disasters. Almost every part of the country falls in at least one natural hazard zone or other and the socio-economic vulnerabilities in these areas make it difficult for the people to cope with the impact of these incidents without external support (Disaster Management in India, 2011).

India has been vulnerable to all natural disasters due to its unique geo-climatic conditions. It is highly vulnerable to floods, cyclones, droughts, earthquakes, avalanches, forest fires and landslides. It is observed that out of 35 states and union territories in the country, 27 of them are disaster prone. Cyclones, earthquakes, Floods, droughts and landslides have been recurrent phenomena in India. Over 40 million hectares (12 per cent of land) are prone to floods and river erosion; about 60% of the landmass is prone to earthquakes of various intensities; 7,516 km long coastline, close to 5,700 km (about 8% of the total area) is prone to cyclones and tsunamis; 68% of the cultivable area is susceptible to drought and hilly areas are at risk from landslides and avalanches. In the decade 1990-2000, an average of about 4344 people lost their lives and about 30 million people were affected by disasters every year (Disaster Management in India, 2004). Various natural and human induced factors including adverse geo climatic conditions, environmental degradation, topographic features, industrialization, population growth, rapid urbanisation, non scientific development practices etc. are responsible for the high frequency of natural disasters in India. These factors are accelerating the intensity and frequencies of disasters and are responsible for heavy toll of human lives and disrupting the whole natural and environmental system in the country.

The loss in terms of community, public and private assets has been exorbitant. At the global level, there has been great anxiety over natural disasters. The number of people affected and economic damages resulting from flooding are on the rise at an alarming rate globally. There is substantial growth in technical and material progress, even then the human toll and economic losses have not decrease but rises. Plans and efforts must be undertaken to move from post-disaster response to disaster mitigation preparedness. There is the need for decision makers to adopt holistic approaches for flood disaster mitigation and management (Vojinovic and Tutulic, 2009).

The establishment of a unit for flood forecasting for the river Yamuna at the Central Water Commission (CWC) New Delhi is the beginning of flood forecasting and flood warning in India in the year 1958. This has now grown to cover most of the flood prone interstate river basins. The CWC is currently accountable for issuing flood forecasts at 173 stations, of which 145 are for river stage forecast and 28 for inflow forecast. On average, about 6000 flood forecasts are issued every year with a maximum of 7943 forecasts in 1998. The forecasts issued by the CWC have been consistent with about 96 per cent accuracy as per the present norms of the CWC. A forecast is considered to be reasonably accurate if the difference between forecast and corresponding observed level of the river lies within  $\pm 15$  cm. as a result of which the flood forecasting and warning services have rendered immense benefit to those in flood risk prone areas (CWC, 2014).

Floods always brought miseries to numerous people, particularly in rural areas. The after affects of floods are more dangerous. Flood results in the outbreak of serious epidemics, specially malaria and cholera. At the same time, scarcity of water is also arises. It has a drastic effect on agricultural produce/crops. Many times, water remains logged over large area and for a long span of time which hamper the Rabi crops. As it is discussed that the floods are extremely hazardous for the growth of agriculture crops, social and economical life of people, some sustainable implementation is extremely required for mitigating the affect of flood disasters. It is observed that the north, east and near coastal regions of India are more prone to floods. The flood hazard map of India is shown in Figure 1.1.

The unplanned urbanization and development within high-risk zones, climate change and environmental degradation, epidemics and pandemics, geological hazards are further increases the disaster risks in India. Clearly, all these contribute to a situation where disasters are seriously threaten to India's economy, its citizens, society and sustainable growth.

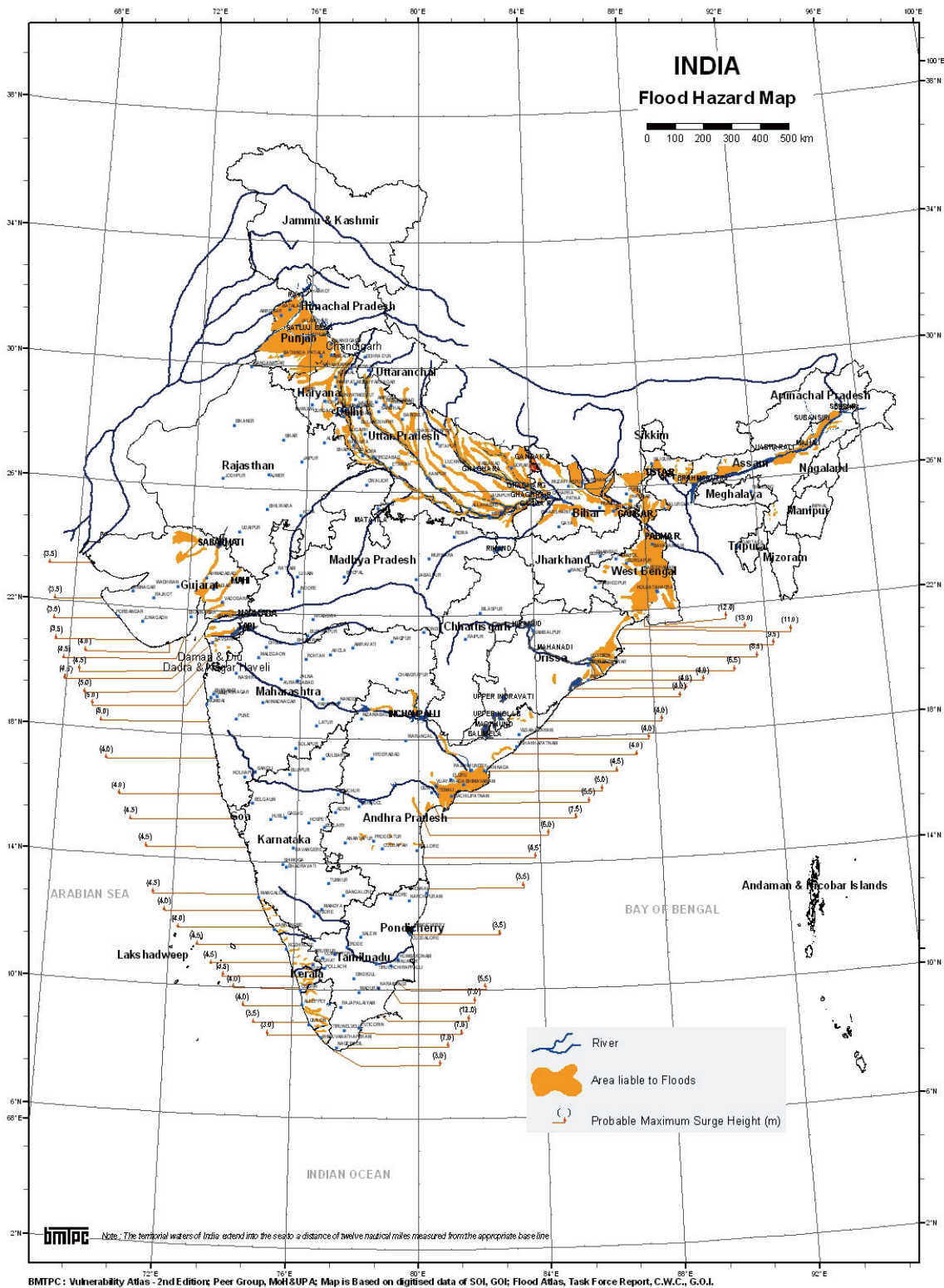


Figure 1.1 Flood hazard map of India

(Source: Building Materials and Technology Promotion Council (BMTPC) Govt. of India)

The main causes of floods in India are heavy rainfall, inadequate capacity of rivers to carry the high flood discharge, inadequate drainage to carry away the rainwater quickly to streams/ rivers, typhoons and cyclones are also cause floods. Vulnerability to flood disaster is caused by the high population density, illiteracy, widespread poverty, enormous pressure on rural land, and economic dependency on agriculture. During floods women and children are particularly vulnerable. Eighty five percent of the deaths during disasters are of women and children (CRED, 2000).

Presently there is an inadequate level of protection in the country against floods. Currently there is greater emphasis on non-structural measures for flood management, rather than on structural measures. These measures include flood-inundation mapping, flood plain zoning and flood forecasting. Remote sensing has emerged as an essential tool in the study of floods, enabling preparation of maps of inundated areas and assessment of damages. Geographical Information System (GIS) is also extensively used in several studies to delineate the flood-hazard areas by incorporating land use maps, topographical information, meteorological data, demographical data, etc. with an aim to achieve a reduction in the loss of life and damages caused by floods (Sanyal and Lu, 2005).

The non-structural measures can only provides some preparedness to floods and reduces some losses, but to reduce the extent of physical damage caused by floods, there is necessity of structural measures. (Disaster Management in India, 2011)

After a critical analysis it can be concluded that a highly integrated system is required for forecasting the floods. It should integrate geo-morphological, hydrological, meteorological, and socioeconomic aspects to provide more accurate and effective results for decision making. It requires coordination across many agencies at national to community levels for the system to work (Goel et al. 2005). Therefore it is clear that efficient disaster mitigation system is rigorously required to minimize the social and financial loss. In current scenario various new technologies and equipments are used to forecast and mitigate the disaster effects.

### **1.3 SITUATION OF FLOOD IN ORISSA**

The 482 km long of coastline of Orissa exposes the state to flood, cyclones and storm surges. Heavy rainfall during monsoon season causes floods. Flow of river water from neighbouring states of Chattisgarh and Jharkhand are also contributes to flooding. High degree of slitting in the rivers, soil erosion, flat coastal belts with poor drainage, breaching of embankments and spilling of floodwaters over them are the main cause of severe floods in the river basin and delta areas. In Orissa, rivers such as the Mahanadi, Rushikulya Subarnarekha, Vansadhara, Brahmani and Baitarani and their many tributaries and branches flowing through the State expose vast areas to floods (OSDMA).

According the OSDMA, in Orissa, damages are caused due to floods mainly in the Mahanadi, the Brahmani, and the Baitarani. These rivers have a common delta where flood waters intermingle, and when in spate simultaneously, cause considerable havoc. This danger becomes even more severe when floods coincide with high tide. The water level rises due to the deposition of silt on the river-bed. Rivers often overflow their banks or water rushes through the new channels which causing heavy damages.

In year 2006, during flood, 245 Blocks, 3574 GPs, 18912 Villages, 67.39 lakh population and 4.90 lakh hectare crop areas of the State was affected. 105 persons lost their lives due to flood/heavy rain. 28,327 hectares of crop area were under sand cast due to the floods. Due to occurrence of series of depressions over Bay of Bengal, heavy to very heavy rainfall was experienced over all catchments of all river systems during July & August 2006. As a result, floods occurred in all major rivers causing damages to life & properties in 27 districts. Figure 1.2 shows the flood zones of Orissa.

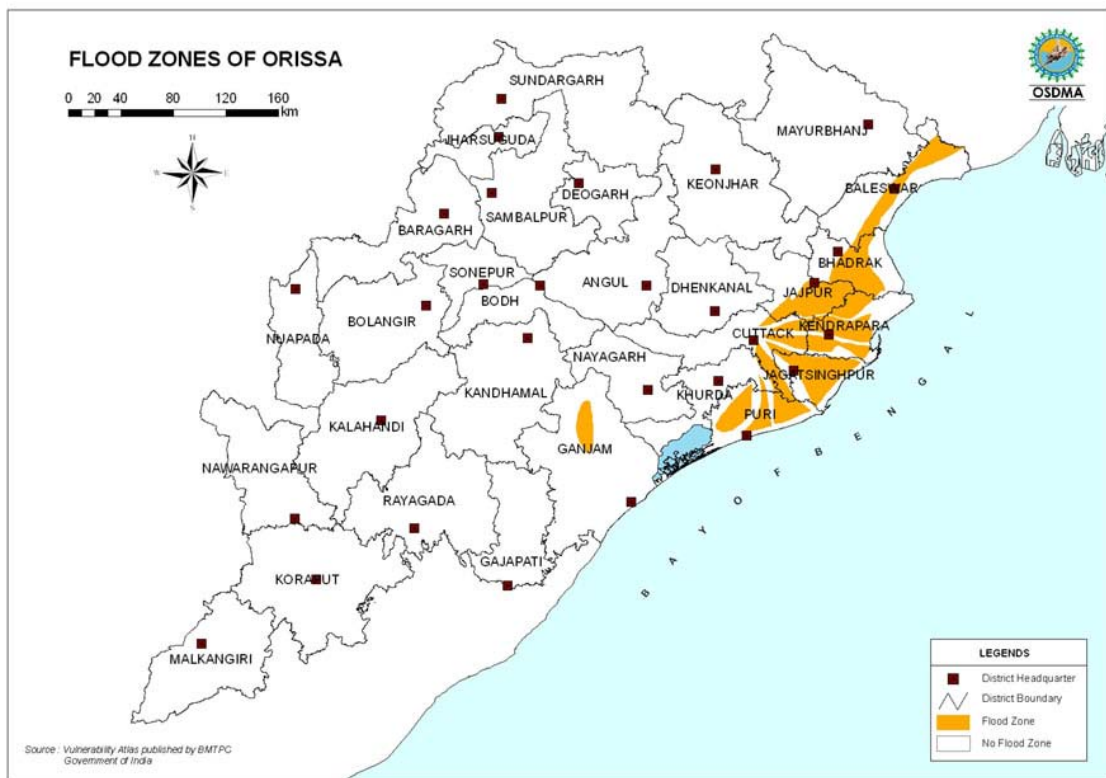


Figure 1.2 Flood Zones of Orissa

(Source: OSDMA)

#### 1.4 REMOTE SENSING AND GIS IN DISASTER MANAGEMENT

Remote sensing (RS) and Geographic Information System (GIS) plays a vital role in the area of disaster management. Through remote sensing the images of pre-disaster, post-disaster and during the disaster can be taken and after analysis important information can be gathered. It is very useful for study of natural hazards like landslides, floods, earthquakes, tsunamis, forest fires, cyclones, volcanic eruptions, etc. and also for manmade disasters like industrial chemical accident, nuclear accident, bomb explosions, destructions, etc. The GIS is incredibly useful for the rescue operations during disasters. It helps to find out exact locations of people in danger. The mapping of disaster area helps to emergency services and disaster management personals to take decisions and actions. It assists to monitor the situation and advise appropriate emergency plans by using advanced prediction models. Remote sensing is also used for effective and quick assessment of the severity and impact of damage. All these processes required a huge spatial database and to manage these databases various softwares are available with different functionality. During the disaster preparedness phase, it is required to rescue people from the disaster area.

Therefore it requires a tool for planning evacuation routes and plan emergency centres for emergency operations. GIS in combination with Global Positioning System (GPS) plays an extremely important role in searching and rescue operations specially those areas which have been devastated and where the conditions are dreadful. During last two decades there has been tremendous development in the area of RS and GIS. The applications of RS and GIS have become well developed and it proves as successful tools in disaster mitigation and management. Location observations, hazard monitoring, disaster mitigation planning and management are some areas where RS and GIS is an essential part of any analysis. Landslide hazard maps, seismic zone maps, flood zone maps, industrial risk zone maps, forest fire risk maps, urban infrastructure development map, etc. are required for the disaster management analysis and also for insurance analysis purpose.

Advanced technologies like satellite imagery and GIS help to identify areas that are disaster prone, it helps to zoning them according to risk magnitudes, inventory populations and assets at risk. It is also very useful for providing simulating damage scenarios. These tools provide instant access to vital information which is essential for management decisions, particularly in search and rescue operations. RS and GIS based information is helpful for providing warnings before the disaster, which is very useful to reduce the impact of disaster. So it can be concluded that the RS and GIS is the essential component of disaster mitigation and management system.

### **Use of Optical Data and Microwave Data in Disaster Mitigation**

RS data is very useful for all stages of monitoring: before flooding, during flooding and after flooding. Before flooding; it can be used for identifying hazard areas, the flood dynamics can be predicted, risk zone mapping, long term trends, ecological unstable areas, landscape morphology, permanent water body, etc can be extracted. During flood it (satellite data) can be used for identifying flooded area in minimal time, accident area, highly affected area, flood zone mapping, immediate attention required area, rescue operation plan mapping, etc. After flooding; the satellite data is used for damage assessment, identifying sequence of disaster, volume of damage, duration of flooding and its effect to risk elements, preparation for restoration, etc.

Usually optical RS data is used to provide environmental information which is beneficial for hydrological applications. The restricted penetration of optical wavelength in vegetative canopy, soil, opaque/dense objects, etc., limits the amount of information which is required for hydrological analysis. In that case the microwave data plays an important role for the flood and hydrological analysis, because SAR (and Radarsat) is an active microwave system and it is capable of providing day and night imaging. The low frequencies allows for data acquisition in fog and also in cloudy conditions. Radarsat has been proven very useful for flood inundation area mapping, due to their active RS capability. So the microwave data is an essential requirement for the flood analysis during flood. Therefore in this study, optical satellite data (LISS-III) from IRS-P6 satellite and microwave (SAR) data from Radarsat satellites is being used for flood inundation mapping.

### **1.5 SHORTEST PATH FOR EVACUATION PLANNING DURING DISASTER**

During flood situation one of the most essential demands is to rescue people stuck into the flood. Therefore it can be said that no flood disaster mitigation and management system is complete without the inclusion of an effective evacuation plan. Different country made their disaster management systems according to their needs and requirements. Such systems require a large data handling systems, RS and GIS data processing techniques, various evacuation parameters based algorithms, decision support systems, managing coordination between different departments and authorities, etc. In the era of advanced technologies, highly technical and accurate systems are required to implement for these purpose. Several evacuation models and optimization techniques have been developed and implemented for various types of emergencies including fire, cyclone, flood, earthquake, and other manmade emergencies/disaster. Based on the idea of Dijkstra's shortest path algorithm which promises for minimizing total evacuation time, various approaches have been realized. These approaches are mainly for urban areas where there is high traffic problem, or for rescue from a building in a case of fire, or for rescue in case of cyclone, etc. An integrated analysis of heterogeneous spatial datasets is required for evacuation planning which includes population, road network, and various other parameters. A spatial analysis system should provide toolkits for spatial data acquisition, processing, analysis and visualisation. During flood the traditional transportation network may not always help people to make a right decision for evacuation due to damages to roads and bridges in the

flooded area. There is a need to understand the situation correctly and promptly to provide a critical instruction in the event of disaster. The disaster situations may create various scenarios in front of the disaster managers. An evacuation management system also requires an easy configuration for use by managers. Therefore it is a complex and challenging task to delineate evacuation circumstances and make practical connections among the datasets for finding the correct evacuation route which is based on various parameters. So in this study finding of evacuation route during flood disaster is a prime concern. It is based on various road parameters and environmental conditions. It also uses three approaches and compare to find the most suitable path on the basis of various parameters. The digital elevation map and the conditions of rural area are also very much considered for the delineation path. The system is trained for different scenarios. Therefore it provides highly satisfactory results.

#### **1.6 SPATIAL DECISION SUPPORT SYSTEM AND WEB GIS**

To support the business, groups, teams and organizational decision-making activities some specific class of computerized information systems are used, which are generally called as Decision Support Systems (DSS). The spatial or geographic component plays a vital role to take decision in a spatial decision support system (SDSS). The SDSS provides computerized support for decision making in a location based system (Wu and Lin 2009, Asghar et al. 2010). Spatial applications represent an area of Information Technology which significantly recognizes the GIS as a computer system that facilitate the display and storage of spatial data; it also relates and integrates the spatial data with non-spatial (attribute) data. A GIS has an advanced data manager that performs queries based on spatial location (Asghar et al. 2010, Levy 2007). An interactive user interface allows the user to interact with this spatial database. It provides functionality like add, update, modify and delete of a spatial data. There is a wide range of interests for spatial data in government and business activities. It includes the area of forestry, agriculture, urbanization, industry, mining and various developmental analyses.

Web GIS is a type of distributed information system, comprising at least a server and a client, where the server is a GIS server and the client is a web browser, desktop application, or mobile application. Web GIS can be defined as any GIS that uses web technology to communicate between a server and a client. Web GIS originates from a

combination of web technology and the GIS, which is a recognized technology that is mainly composed of data handling tools for storage, recovery, management and analysis of spatial data. Web GIS is a kind of distributed information system. WebGIS will make it possible to add GIS functionality to a wide range of network-based applications in business, government, and education. Many of these applications will be run on intranets within businesses and government agencies as a means of distributing and using geospatial data. Internet users will be able to access GIS applications from their browsers without purchasing proprietary GIS software.

### **OGC and Scope of Open Source Software**

As stated in OGC website- The Open Geospatial Consortium (OGC) is an international industry consortium of 518 companies, government agencies and universities participating in a consensus process to develop publicly available interface standards. The OGC Standards support interoperable solutions that geo-enable the Web, wireless and location-based services and mainstream IT. These standards empower technology developers to make complex spatial tools, softwares, information and services accessible to users and it is useful with all kinds of applications.

Open source refers to both the concept and program source code are openly available for public use and modification. It is a practice that the user should refer the original author for using of his code. Open source have some qualities like, unrestricted distribution of software, entire source code can be distributed, it also can be easily modifiable, no restriction on use of application i.e. any number of applications can use them, the license must not be product specific, it should also be technology neutral for use. As the cost of license of GIS based application products and softwares are too high, therefore in this study the open source softwares are used for the development of web based spatial decision support system for flood disaster mitigation. The Apache Tomcat, GeoServer, PostgreSQL, PostGIS, Bhuvan data, and other freely and openly available resources are used in this study.

### **1.7 NEED OF THE STUDY**

From the above discussion, it can be observed that many tools and applications have been used in emergency evacuation planning including GIS as the most.

- Limited research exists using the elevation data in flood disaster situation due to unavailability of high accuracy elevation data at reasonable cost.
- For flood disaster situation, artificial intelligence, data mining, fuzzy system, multispectral images, real-time systems, highly robust and efficient system are not common in use in most of the countries.
- Use of advanced methods, algorithms, techniques in addition to GIS and other existing tools may provide a more effective and robust flood management and evacuation plan to avoid casualties and financial damage.
- Effective decision making system requires an efficient linking and integration of Geo-spatial data with complex flood analysis tools.
- Focus of most of the researches towards urban and build up area, but less priority is given to rural area.
- Non availability of web GIS for flood disaster for rural and agriculture area with rescue plans.

## **1.8 RESEARCH OBJECTIVES**

**Main Research Objective:** To develop a Web Based Spatial Decision Support System for Flood Disaster Mitigation.

### **Specific Research Objectives**

1. Flood inundation mapping and vulnerability assessment using remote sensing data.
2. Identification of safe and shortest route for evacuation using advanced multiple criteria decision making.
3. Development of web-based spatial decision support system for flood disaster mitigation.

## 1.9 THESIS STRUCTURE

The structure of this thesis has been divided into eight main chapters. Brief glimpses of all the chapters are stated below.

**Chapter 1 Introduction:** This chapter gives an introduction to flood disaster and its situation in India, flood hazard zone map, losses due to flood event, use of remote sensing in damage assessment, concepts of flood disaster management.

**Chapter 2 Literature Review:** This is a review of past work done in the field of flood disaster mitigation. Various methods, techniques, tools, softwares etc. were used for flood disaster management. A large number of research papers had been studied and reviewed for acquiring knowledge about flood disaster mitigation and management, role of remote sensing and GIS in the field of disaster management. Explore the requirement and role of web GIS and decision support system for pre, during and post disaster management.

**Chapter 3 Study Area and Data Used:** Details of study area are explained, data and software used and their specifications, local information, data from govt. and from Internet (freely available data) or from other organizations are collected for analysis. Geo- spatial, socioeconomic data, remote sensing and GIS data and data collected form field visit and survey are explained.

**Chapter 4 Flood Inundation Mapping and Vulnerability Assessment:** The monthly discharge data analysis, Microwave data analysis and Flood inundation area delineation has been done in this chapter. Radarsat data has been used for classification of flooded area. Elements at risk and vulnerability are discussed in this chapter.

**Chapter 5 Extraction of LULC and Flood Damage Assessment:** Extraction of LULC using LISS III data has been done. LULC has been classified into 10 classes (Built Up, Agricultural Land- *Kharif Crop*, Agricultural Land- *Rabi Crop*, Agricultural Land- Two crop area, Fallow, Plantation, Scrub, River/Stream-Perennial, River/Stream-Dry, Lakes/Ponds). Damage assessment has been done by using remote sensing data. Seasonal crop and their values are calculated. Vulnerability and damage assessment of elements at risk has been discussed in this chapter.

**Chapter 6 Delineation of Optimal Route during Flood Disaster:** This chapter explain the methodology for delineation of optimal route during flood disaster. It uses five parameters for finding the priority of route using AHP, Fuzzy and ANFIS methods. This chapter introduces three approaches: knowledge base, data base and learning base approach. All these three approaches are implemented and compared for the optimal path extraction. An intelligent fuzzy based decision support system has been constructed on the basis of the comparison of these three approaches. The elevation data plays an important role to find the optimal path in this work. ANFIS based DSS for safe route delineation has been implemented and different flood scenarios are explained.

**Chapter 7 Dissemination of Information using Web GIS:** Apache Tomcat and GeoServer with PostGIS and PostgreSQL have been implemented to disseminate the flood information. Architecture of web GIS has been explained and implemented. To show the path and other information on the web, this web GIS has also been linked to other (Bhuvan) open source websites for spatial data. It also shows Google Earth open source data. Since this web GIS is based on open source platform so it can share data and information to other open source web GIS.

**Chapter 8 Conclusion, Limitation and Scope of Future Study:** It contains the conclusion remarks and the limitations of the research work. The whole work includes remote sensing, GIS, open source software, disaster mitigation approaches, web GIS, decision support system, flood inundation modelling, vulnerability analysis, damage assessment, spatial database and the most important a noble cause to save the lives of people. This chapter concludes by discussing the future scope of this work.

## **CHAPTER - 2**

### **LITERATURE REVIEW**

Flood disaster management concept has very large boundaries; it includes hydro-meteorological data, remote sensing data, rain fall runoff data, river catchment analysis, hydrological analysis, mathematical tools, geographical information, various modelling techniques, different analysis methods, number of advanced software packages, high end tools and many more. But it is very difficult to analyse each tool, as each has its own pros and cons. Different tools are suitable for different scenarios. A different country implements their methods according to their needs and specific requirements. Here it is an honest effort to explain, discuss and identify the various methods and tools described in available literature. There is large literature available related to the flood, however the literature related to the disaster mitigation, web GIS, spatial decision support system are also examined carefully.

#### **2.1 ROLE OF REMOTE SENSING AND GIS IN DISASTER MITIGATION**

The technology which has enormous capacity to impact the disaster management is remote sensing. In the past 10-20 years, remote sensing and GIS technology has been used extensively to describe the vast impact caused by tsunami, earthquakes, floods, hurricanes, landslides, forest fire etc. The high resolution satellite imagery, SAR and LIDAR remote sensing technologies provide very significant and accurate information for disaster management (Eguchi et al. 2008). These technologies have demonstrated significant potential and have resulted in quantifying the post-disaster damage assessment, monitoring the pre and post disaster situations, in recovery and reconstruction process and also in urban infrastructure development. In earlier time these images were available to mainly government agencies (mostly military) and research work, but in recent times these are readily accessible in the public domain. The commercial availability of high resolution satellite imagery sparks the rapid development of various applications which are based on remote sensing and GIS. And the disaster management is one of the most important areas of this development. Kerle and Oppenheimer (2002) investigated the utility of several optical and radar sensors for the volcanic disaster management. The volcanic mudflows are

the outcome of volcanic eruption and these often cover large areas. These can be highly destructive; therefore these are a challenge for disaster management.

Doswell et al. (1996) developed an approach to forecast the potential for flash flood using the notion of basic ingredients. Montoya (2003) explored the use of combination of remote sensing, GPS, digital video and GIS as a tool for low-cost and rapid data collection. He used these for the development of a building inventory which was utilised for display and analysis of a disaster event. Zhang et al. (2002) developed the national integrated system using remote sensing, GIS, GPS, and other technologies which was used for monitoring and evaluating flood disasters at China's National Flood Control Headquarters. Gao (2002) discussed the integration of GPS with remote sensing and GIS. Tralli et al. (2005) addressed the operational requirements of DSS used by policy makers, emergency managers and responders during disaster events. Improved and integrated measurements along with numerical modeling are highly recommended for a greater understanding about a particular hazard event and their socioeconomic impact. Dewan et al. (2007) discussed the flood hazard using Synthetic Aperture Radar (SAR) data with GIS data.

Yamazaki (2001) explored the vulnerability and damage assessment due to natural disasters. Remotely sensed imagery data from satellites have become important tools to assess of damage using pre- and post-event images. He reviewed the applications of remote sensing and GIS from the viewpoint of risk assessment and post-event disaster management. Zerger and Smith (2003) examined and evaluated the application of GIS for cyclone disaster risk management. It has one of the largest and most accurate spatial databases for natural hazard disaster management in Australia. The other spatial dataset included road networks and can be used for decision support for evacuation planning. The main concern of this study was to evaluate the accessibility and management of GIS data to determine the risk, vulnerability, feasibility of evacuation routes and access to shelter zone. The limitations of this application include the scale of spatial data and its suitability for regional-scale decision making. The findings have shown that the use of GIS for urban disaster risk management can readily be unsuccessful due to poor implementation, inefficient user access and knowledge impediments, in addition to the lack of availability of spatial data and models.

Alexey and Vitaliy (1999) developed a very effective experimental system for flood mapping based on Russian Earth observation satellites data. Lindell and Prater (2003) discussed the way in which hazard mitigation and emergency preparedness practices can limit the physical and social impacts on the societies. Dutta et al. (2003) presented an integrated model for estimation of flood loss, which is a combination of a physically based distributed hydrologic model and a distributed flood loss estimation model. Joyce et al. (2009) worked on a number of data types and image processing techniques, which were used for earthquake mapping and monitoring. These techniques and data were also used to analyse the damages associated with volcanic activity, flooding, landslides, and wildfire. According to Kumar et al. (2010) the coastal areas of Orissa State in the north-eastern part of India are potentially threatened by severe coastal erosion and recurring storm flood events. Ahmad and Simonovic (2013) discussed about urban flood risk assessment. The fuzzy set theory approach was used to assess spatial and temporal variability of urban flood damage. Doocy and Gorokhovich (2008) described an integrated approach to disaster assessment for decision making in the post-disaster context. Alparslan et al. (2008) developed a GIS model for earthquake disaster mitigation purposes.

## **2.2 INFORMATION EXTRACTION IN FLOOD DISASTER EVENT USING DIFFERENT TECHNOLOGIES**

The satellite imagery is a very helpful for detailed mapping of hazard assessment and various types of hydrological models used in flood disaster management. It is used for identifying areas at greater risk, immediate assistance, disaster monitoring, land use land cover changes and extent of impervious area in particular. Generally flood prone areas can be identified using remotely sensed imagery as flood mapping (Priestnall et al, 2000; Jeyaseelan 2003; Jain et al, 2005) using images of pre flood, peak flood and post-flood and the other is flood forecasting, mainly based on clouds patterns (Lanza and Conti 1995; Doswell 2006; Qi and Altinakar 2011). The pre-flood scene and peak flood image are compared to delineate the inundated area and based on the land use land cover classification/mapping, the damages assessment can be extracted in terms of money or damage area. Remote sensing data (Landsat, SPOT) would be useful only under cloud-free situations. SAR data (Radarsat) can provide images all the time i.e. day or night, despite any presence of clouds, rain, haze or snow. Therefore, it is most suitable tool for flood inundation mapping and monitoring.

Hristidis et al. (2010) surveyed the recent knowledge and data used in disaster management and analysis. This study presented the challenges in the area of information extraction, data integration, information filtering, data mining, information retrieval and decision support. Demeritt et al. (2010) emphasis that most of the available systems are technically based on rainfall-runoff model for predicting future flooding, therefore less attention was given to the effective ways of communication to non-experts. It indicates at political and institutional challenges, such as false alarms and to responsibility for management of blame in the event of poor or mistaken forecasts.

The German Remote Sensing Data Centre had set up a dedicated Center for Satellite Based Crisis Information for acquisition, analysis and provision of satellite based information products on natural disasters (Voigt et al. 2005). Besides response and assessment activities, it also focuses for medium term rehabilitation, reconstruction and prevention activities. This study shows the quick response to decision makers by using rapid processing of satellite imagery. Space technology is very complex and requires sophisticated processing techniques; it is not possible to be handled (whole process) by an individual organization. Therefore an efficient cooperation networks have to be established among different organizations with full data acquisition, analysis and decision making capabilities in order to set up a significant and acceptable solutions for the disaster mitigation. In the event of any disaster it is a critical problem to efficiently discover, collect, organize, analyse and disseminate information in real-time disaster information system. Zheng et al. (2010) presented a web based prototype of a Business Continuity Information Network (BCIN) system utilizing the advanced data mining technologies to create Internet-based user-friendly information-rich service for company's business process. Here it is observed that the data mining technologies plays an important role in the field of disaster mitigation.

### **2.3 REVIEW OF PRIOR WORKS USING REMOTE SENSING AND GIS FOR FLOOD DISASTER IN INDIA**

Navalgund et al. (2007) described the Indian Earth Observation (EO) programme. From Bhaskara to Cartosat, India's EO capability has increased manifold. Improvements are not only in spatial, spectral, temporal and radiometric resolutions, but also in their coverage and value-added products. Remote sensing data are used in the field of agriculture,

forestry, land use, urban infrastructure development, water resources, snow and glacier, geology, coastal zone, environment, marine resources, , disaster monitoring and mitigation, etc. The inadequate spatial resolution of AWiFS and temporal revisit of LISS-III are some limitations for crop monitoring and crop assessment. Due to the limited availability of optical data during monsoon period, there is an urgent need for space-borne SAR. Non-availability of hyperspectral data is a limitation for many applications including flood disaster management, crop estimation, infrastructure development, land use land cover, etc.

Jain et al. (2000) discussed flood estimation using GIS supported GIUH Approach. This study applied GIS supported Geo-morphological Instantaneous Unit Hydrograph (GIUH) approach for the estimation of flood. However due to non availability of data for velocity estimation and historical rainfall-runoff records, the methodology could not be validated for the observed events. Galy and Sanders (2000) discussed an application for the insurance industry and explained a flood risk assessment model for River Thames. It was based on SAR data and uses GIS and image processing tools. Brivio et al. (2002) uses satellite radar images and ancillary information to detect flooded areas. Two ERS-1 SAR images of pre and post flood event were processed to estimate the flooded area. This study performs the mapping of flooded areas but it is not performing the damage assessment of the area. Laben (2002) GIS technology provides the ability to capture, manipulate, display, organize and analyze the complex geospatial data. It also provides help to emergency managers for disaster management.

According to Zerger and Wealands (2004) flood models can play an important role in natural hazard risk reduction. It provides a structured and flexible framework that of different hazard scenarios. To show a framework of model, a commercial relational database management system was linked with a GIS-based decision support system. Sanyal and Lu (2005) studied the flood vulnerability assessment of human settlements based on remote sensing and GIS. This study seeks to identify the rural settlements that are vulnerable to floods, instead of the conventional approach of flooded area delineation and overall damage assessment. This study considers two main factors for vulnerability assessment. The one is the depth of flood water in and around the settlement and the other is its proximity to an elevated temporary shelter area. This study was an effort to build a flood hazard database that can be analysed from a spatial dimension. The lack of high-

resolution DEM and unavailability of updated maps leads difficulty to attain high accuracy results. Therefore it is observed that the study is limited to find the vulnerable area and to assess the vulnerability of rural settlements.

Jain et al. (2005) mapped the flood-affected areas in Koa catchment using remote sensing satellite data. Various image processing techniques used (density slicing, Tasseled Cap Transformation and water-specific index, NDWI). It was found that NDWI-based approach produced best results for mapping of flood-inundated areas. Data availability during flood in presence of cloud cover and quality of DEM are certain limitations of this study. Adams and Huyck (2006) described the various roles and significance of remote sensing in different disaster like earthquake, floods, landslides, terrorist attacks, tsunami, etc. Different insurances companies required to estimate the damage assessment due to the various disasters. Therefore the demand of the remote sensing technology and its application rises tremendously.

Schumann et al. (2007) also suggested the 3D model for flood disaster management based on the regression analysis and called it as REFIX model. On comparison with a simulated hydraulic flood model, it shows that REFIX model approximates reliably. According to Eguchi et al. (2008), there is a requirement to integrate the damage assessment methodologies using remote sensing and GIS with the internet-based GUI platforms, such as Google Earth. Singh and Sharma (2009) discussed the Tapi catchment flood disaster. They prepared flood hazard maps using remote sensing, GIS, and GPS. This study was based on statistical probabilities of flood frequency, maximum carrying capacity at discharge cross-section of river, mapping of inhabited areas based on high-resolution images, and terrain mapping using global position system. It was a good effort to estimate the flood disaster.

Pradhan (2010) considered that millions of dollars of property and many lives lost due to the floods every year. He presented a flood susceptibility mapping within a watershed using a statistical model and GIS. Spatial database was constructed from topographical map, hydrological map, GPS data, LULC and DEM data. Logistic regression model was used for mapping. Taubenböck et al. (2011) studied the capabilities of multi-source remote sensing data to support decision-making pre, during and post flood event. The urbanized

areas are the main concern for calculating vulnerability and risk mapping. Damage assessment was also analysed for building stability and affected people. Handling of large spatial database is also very difficult for a disaster management system.

Maruyama et al. (2012) performed damage assessment of Chile earthquake using the remote sensing technologies and showed the usefulness of the DEM comparing with the field survey results. Patel and Srivastava (2013) used remote sensing and GIS datasets to prepare the flood zone mapping. This study identified the flood vulnerable area using high resolution remote sensing images, DEM and hydraulic analysis. This hydrological information may be beneficial for policy makers for controlling flood hazards. This study was limited to the flood hazard mapping and it was not extended to damage assessment.

#### **2.4 ONLINE AVAILABILITY OF INFORMATION**

According to Zhang (2002) the major challenge in current humanitarian assistance/disaster relief (HA/DR) efforts is that diverse information and knowledge are widely distributed and owned by different organizations. Therefore resources are not efficiently organized and utilized. A framework was presented to integrate multiple information technologies and to collect, analyze and manage these information for providing support to decision making during disaster.

Voigt et al. (2005) described that the German Remote Sensing Data Center has set up a dedicated interface for linking the remote sensing and analysis capacities with national and international civil protection, humanitarian relief and political decision makers. The complexity of information exchange between different sophisticated processing techniques had been addressed and the requirements of near-real-time mapping are discussed.

According to Tanev et al. (2008) the Joint Research Centre of the European Commission had developed a real-time news event extraction system. It is capable of extracting disaster events from online news with a good efficiency. It also presents the architecture, automatic pattern learning and information aggregation. It requires improvement of the event classification as natural and man-made disasters. It was text based so complex algorithms are required. Soergel (2010) reviewed the remote sensing and Synthetic Aperture Radar (SAR) in context to urban areas.

## **2.5 REQUIREMENT OF WEB GIS AND DECISION SUPPORT SYSTEM**

The rapid growth of information technology also needs a very high speed network to transfer large data. The GIS uses spatial data and it needs spatial database to store the high volume of data. Remote sensing, GIS and web technology are used to mitigate the affect of various types of disasters also. It is observed that a large number of people are affected by the flood disaster. It causes high economic and social loss. So there is a need to develop an effective and efficient system which can mitigate the disaster affect. The web GIS and decision support system can play a vital role in the field of disaster mitigation. There is a need to rapidly gather the vital data and information for disaster management. Various innovations and technologies are growing to help the disaster management system. Rapid monitoring is required for mitigating the affect of a disaster. Highly efficient and robust systems can give a critical response in real time. Information broadcasting and recovery operation needs new communication technologies.

## **2.6 REVIEW OF PAST WORKS USING OPEN GIS AND DECISION SUPPORT SYSTEM**

Todini (1999) described the development of an integrated tool for planning and management of flood disaster. High performance computer systems, meteorological data and real-time analysis were used to forecast floods. Xu et al. (2002) explored the GIS approach to flood disaster control and reduction on small basin. They also studied about the river channel flood routing model and the rainfall-runoff calculation model. DEM was used to evaluate flood submerged area and damage assessment. This provides valuable information for flood prevention and reduction in the small and medium basin. This research also indicates that remote sensing and GIS technologies are powerful tools for flood disaster mitigation. Shim et al. (2002) presented a prototype for spatial decision support system for flood control in a multipurpose reservoir system. It integrates GIS with DBMS and hydrological data monitoring system. The basin wise discharge was used as input to dynamic module for optimal gate control strategy. This SDSS was used to flood control in Han river basin.

Simonovic (2002) discussed two concepts, a flood management virtual database for a complex domain such as floodplain management and a flood management decision support system for improvement in the flood management and decision-making process. Zahra and

Mansor (2003) studied literature review to propose a decision support system (DSS) for combating oil spills, according to the coastal area sensitivity. In this way it can assist the users and managers to choose the most suitable method for disaster mitigation. GIS-based modeling and DSS planning were reviewed for handling and analysing coastal zone data sets.

According to Hsu et al. (2005) a disaster management system should integrate the GIS tools, internet technology, dynamic hazard models and GUI. It should also cover the four different phases of disaster management which include mitigation, preparedness, response, and recovery. A framework for decision support system for emergency response (DSSER) was developed by the Information Division of the National Science and Technology Center for Disaster Reduction of Taiwan. Levy et al. (2005) proposed flood decision support system architecture based on remote sensing, GIS, hydrologic models and decision theory to improve flood risk management.

Levy et al. (2007) proposed the Multi-Criteria Decision Support Systems (MCDSS) to manage complex and flexible structured decision framework. It involves flood management shared resources and broad constituencies. The proposed MCDSS provide enhanced communication and improved emergency management resource allocation. Therefore it reduces flood management cost and it increases decision-making effectiveness. Laituri and Kodrich (2008) advised that integration of key geospatial technologies (remote sensing, GIS, and GPS) and Internet; with the on-line disaster response communities have eventually grown. It was observed that the contribution from the public via the Internet has changed significantly. The on-line disaster response community includes several key characteristics: donate money, creates blogs, uploads pictures, and disseminates information. They consider people as sensors - networks of government, private companies, NGOs and the public - to build rapid response databases of the disaster area.

According to Karnatak et al. (2012), the realization of Web 2.0, new knowledge and services are created by combining information and services from different sources which are known as 'mashups'. They developed a geo-web application which is based on the web and central server system and comprise open source GIS, mobile applications, web

services, Geo-RDBMS and XML to produce spatial information during flood disaster. Han et al. (2012) described the CropScope, a land-cover system which offers the online functionalities of interactive map operations, data customization, downloading, crop acreage statistics, charting and graphing, and multi-temporal change analysis. It also provides Web geo-processing services and on-demand crop statistics.

Sui (2014) suggested that the emerging open GIS should serve as a guiding concept. The opportunities offered by open GIS are explained as technology-driven, application based, curiosity-inspired people based and education-focused opportunities for realizing the vision of a spatial university. Fang et al. (2014) presented an IIS that combines Internet of Things (IoT), Cloud Computing, Geoinformatics: remote sensing, GIS, GPS and e-Science for environmental monitoring and management. Multi-sensors were used to collect data and information. The functions to store, organize, process and to share data and information was provided by this application. It may be useful in the field of environmental monitoring and management.

Pappenberger et al. (2015) explored the monetary benefits of early flood warning system for Europe. These systems were developed in order to save lives and property and reduce the overall impact of severe events. The large scale flood forecasting system can perform effectively for national level authorities to make decisions for upcoming floods. The potential monetary benefit was estimated based on the forecasts by European Flood Awareness System (EFAS) using existing flood damage cost information. It is suggested that there should be an alternative source of information which can provide 'added value' to this national level system. It may be helpful to prevent incorrect action. Swain et al. (2015) discussed the open source softwares for water resources based web applications. A review was addressed for existing Free and Open Source Software (FOSS) for GIS (FOSS4G). It was an effort to understand the web of FOSS, features and capabilities used to develop water resources web applications published in the peer-reviewed literature in the last decade.

According to Horita et al. (2015) it is essential to provide accurate and updated information to the flood risk management system, to ensure the correct and reliable decisions. It is suggested that the Wireless Sensor Networks (WSN) which is used to collecting updated

information about rivers and also cost effective, can provide vital information. They attempt to investigate a Spatial Decision Support System (SDSS) named AGORA-DS, which may be able to make flood risk management more effective. This approach was a conceptual model that combines the Open Geospatial Consortium e.g. Sensor Observation Service (SOS) and Web Feature Service (WFS) and present unified information in a web-based decision support tool. It is also observed that for constructing an efficient and accurate decision support system, it requires tremendous data, which include remote sensing data, GIS data, GPS data, spatial data, hydrological data, meteorological data, climate data, weather data etc. which will be provided by different government and public organizations. It concludes that diverse information and knowledge are widely scattered and owned by different organizations. Therefore vital resources are not efficiently organized and utilized. So it is essential to integrate multiple information technologies. Than the data must be collected in a proper format, analyse efficiently and accurately. After that it will be able to process into a decision support system for decision making during disaster.

## **2.7 STATE OF THE ART FOR OPEN GIS AND FLOOD DISASTER MITIGATION STUDIES**

GIS is the one of most important tool used for emergency evacuation planning. It provides a range of techniques to access the data, and give functionality to overlay graphical location-based information for better interpretation. It is observed that GIS based research provide enormous opportunity to deal with emergency situation and helps for evacuation planning. De-Silva and Eglese (2000) proposed a prototype for spatial decision support system (SDSS) designed for emergency evacuation planning with the capability of spatial data handling, display information and simulation techniques using GIS. ARC/INFO has been used for topographical support and analysis with a simulation model. Sanders and Tabuchi (2000) examined the development of a decision support system for flood plain risk assessment and its applications. This application focuses on the insurance industry. He described the use of airborne Interferometric Synthetic Aperture Radar (IFSAR) map products data in the development of a large-scale flood risk assessment system.

Gupta (2004) discusses the role of GIS in decision support system. Tang and Wannemacher (2005) modeled the spatial patterns of vehicle population during an emergency evacuation

situation. It first finds the accumulation hot-spots or vulnerable places on a street network and then create evacuation scheme according to requirement. According to Ahern et al. (2005), floods impact most on health which varies between populations, their vulnerability and type of flood event. It is predicted that climate change, alteration in precipitation patterns and rise in sea level will increased the frequency and intensity of floods in diverse area of the world.

Kumar et al. (2007) uses fuzzy methods for land cover mapping which is also useful in risk and damage assessment during flood. Jiang et al. (2009) applied fuzzy comprehensive assessment (FCA), simple fuzzy classification (SFC), and the fuzzy similarity method (FSM) to assess flood disaster risk in Kelantan, Malaysia. Flooded area, residential area, urban area, paddy area and refuges were overlaid to validate and analyze the correctness of flood risk. Perumal and Sahoo (2009) and Vojinovic (2010) discussed flood routing and how it supports in flood disaster management. Wagesho et al. (2013) and Kumar et al. (2013) discussed the affect of rainfall variability and the urban growth dynamics.

According to Kim et al. (2011), existing approaches do not perform well due to intensive computation needs to produce the routing plans and schedules of evacuees. He presented a heuristics scalable approach to very large transportation network. The Intelligent Load Reduction heuristic accelerates the routing computation. Tomaszewski (2011) and Agola and Awange (2014) supported the disaster event situation awareness in humans via open source information analysis and visualization. A case study of humanitarian disaster management was used to demonstrate the abilities of the Context Discovery Application and Google Earth to support situation awareness.

## **2.8 COMPREHENSIVE STUDY FOR FLOOD MANAGEMENT APPLICATION IN INDIA**

Sanyal and Lu (2006) addressed the need of an efficient and cost-effective methodology for preparing flood hazard maps. Flood frequency, population density, transportation networks, maximum risk zones and availability of high ground were mapped by using GIS and DEM. A DEM was used to calculate elevated areas suitable for temporary shelter during a flood. Kumar et al. (2010) discusses the optimal reservoir operation policies for flood control of Hirakud Reservoir in Mahanadi basin, India. It was observed that the

combination of 57 thousand cumecs of inflow into reservoir and 14 thousand cumecs for d/s catchment contribution is the most critical among the critical combinations of flow series. Bhatt et al. (2013) discussed the information on the flood disaster provided by the satellite images, which is essential to calculate the disaster impact and to take care of flood mitigation activities. This article discussed the support of multi-temporal satellite images for extracting the maximum spatial extent affected due to the flood. Sanyal et al. (2014) expresses that the data unavailability is the main reason for very limited applications developed for flood management and hydrodynamic models in the developing world.

A lot of work has been done for flood disaster management in India and in the whole world. In consideration of Indian context, these works are more related to the hydrology stream and less related to the GIS field. The structural mitigation methods was more in trends whereas in current scenario the non-structural measures and disaster preparedness and disaster response are more focused compared to the earlier study. Therefore it can be concluded that in practical level there are no such specific flood disaster management agency which can take decisions on the basis of any spatial decision support system in India. Most of the warnings are given by the Central Water Commission and from Meteorological department. The Indian Space Research Organization (ISRO) is very actively participating in providing disaster management information through its Bhuvan portal.



## **CHAPTER - 3**

### **STUDY AREA AND DATA USED**

#### **3.1 STUDY AREA**

According to the Government of India-UNDP Disaster Risk Management (DRM) programme (2002-2007), Kendrapara, Jagatsinghpur, Cuttack, Jajpur and Bhadrak Districts of Orissa state are the most hazard prone districts. The delta region formed by the Nuna and Chitrapala rivers of lower Mahanadi region is considered as the study area for this research (Figure 3.1). It is located in between East Longitude 86°16'30" to 86°30'05" and North Latitude 20°22'30" to 20°31'30". It is surrounded by the Kendrapara district in its north and Jagatsinghpur district in its south.

The geographical area of the Kendrapara district is 2644 sq.km. It constitutes 1.7% of the total area of the state and ranks 26th in respect of area. Flood is frequently and almost yearly occurring phenomenon in the area. The study area is surrounded by the Nuna and Chitrapala rivers; these rivers are the branches of river Mahanadi and are located in the eastern delta region of the state. Mahanadi is most important river in Orissa. The research area lies in the most severe flood zone and according to the Vulnerability Atlas of India (2006), it is referred to as the very high damage risk zone.

The study area is a part of Marsaghai block and Garadpur block of Kendrapara district. It is surrounded by National Highway No. 5A along the north part to eastern area. The coastal area of Orissa is nearly 35 Km. away from this delta region. The coastal region is frequently affected by the devastating cyclones and this affects the whole coastal area including this delta region.

Generally the floods occur due to the river overflows from its banks. Breaching of the embankments is another reason for flood. This flood water enters the agricultural land and settlements to cause disaster in the region. Flood disaster is hard to predict but the flow path of flood water can be assessed. To reduce the severity of disaster and to reduce the loss due to flood, it is essential to determine the way it inundates the region.

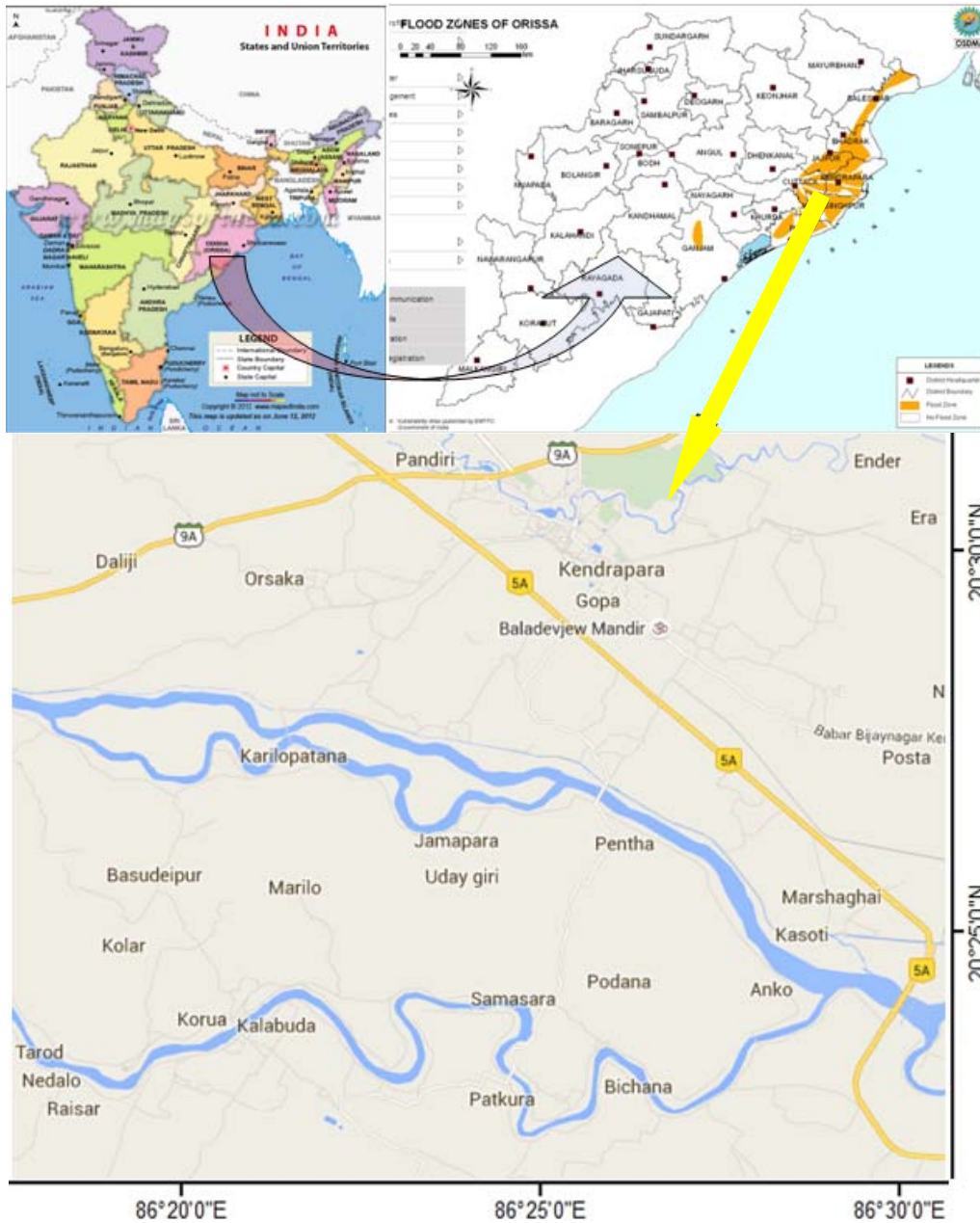


Figure 3.1 Location of Study Area (small delta part of lower Mahanadi region)

The essential information about the research area has been gathered through the various sources including office of district collector, irrigation office, barrage office, state disaster mitigation office, block offices, and websites etc. The basic information about the study area is given below (District Portal Kendrapara, Govt. of Orissa).

**Administrative:** In the present scenario of administrative set up, there are 9 Blocks, 9 Tahsils, 1 Sub-division (Kendrapara) in the District. Kendrapara District has a moderate climate.

**Economic Condition:** The economy of the district is mainly dependent upon agriculture. 68% of workers in the District are engaged in agricultural sector. The economy of the District is primarily rural and based on agriculture and allied activities. More than 75 percent of the total population earns a livelihood from the primary sector.

**Population:** The district of Kendrapara has a population of 14.4 lakh of which 49.84% are males and 50.16% females.

**Literacy:** This District is relatively developed Districts in the field of education. Literacy rate of the population is 85.93 percent, with 92.45 percent male population and total 79.51 percent female population in the District.

**Socio-economic Condition:** Socio economic condition of the people is very alarming in the study area. About two third of the population has income below poverty line. Most of the population (Approx. 90%) living in disaster prone areas. The houses are more vulnerable to the flood due to their construction material which is mainly made by mud, straw of paddy and bamboo. According to the Panchayati Raj Department, Government of Orissa, 66.37% of the rural families living below the poverty line in 1997. Besides structural poverty, this region also faces the conjectural poverty due to frequent cyclone, and floods which intensify the poverty of people lacking either money or material to survive. In terms of the living condition of people, Orissa is far below the national average.

**Agriculture:** Most of the people of Orissa have agriculture as the main occupation. More than 70 percent of people are dependent on agriculture for their livelihood. Rice, black gram, green gram, jute and groundnut are the main crops grown in the District. Frequent occurrence of natural calamities has destroyed the economic condition of the people. It is very hard to survive under these conditions. During rabi season people go for cultivation to staple their food crop rice. Jute is the main cash crop of the area. Groundnut is an important oil seed crop of the District. Coconut is the important horticulture crop in District.

**Soil:** The district comprises two distinct tracts of land. The first being marshy and swampy strips along the coast covered with wild growth of reeds. The second is the deltaic plain. The plain is very fertile and is subjected to frequent floods by the large rivers and their branches. The soil type here is sandy loam to Alluvial in nature. The costal part of this district comprises of saline soils.

**Weather:** The temperature in the region can go up to 34° C in summer while in winter the temperature can drop to 13° C. The normal annual rainfall measured in the district is 15101.3 mm.

### **3.2 DATA USED**

A lot of data and information has been gathered for this study. The main data which are used in this study are depicted below.

#### **A. Geospatial Data**

- i. DEM derived from elevation data of Google maps
- ii. Temporal Satellite Images before, during and after flood
- iii. Radarsat SAR, IRS P6 LISSIII / LISS IV, Landsat ETM+
- iv. Satellite images from Google Earth
- v. Satellite images and geo-spatial data from Bhuvan website
- vi. Survey of India Toposheet, 1:50000 scale; 73 L/3, L/7, L/11

#### **B. Socio-economic Data**

- i. Flood Information
- ii. Population
- iii. Agriculture map
- iv. Element at Risk

#### **C. Software required**

- i. ArcGIS
- ii. ERDAS Imagine

#### **D. Open source tools used for web GIS application**

- i. GeoServer
- ii. PostgreSQL with PostGIS
- iii. Apache Tomcat

- iv. Java Script
- v. CSS (Cascade Style Sheet)

**Field survey:** A field visit was carried out during July 7-16, 2012 for collecting various data and information.

1. Field visits for ground survey and collection of hydro-meteorological data.
2. Collection of GCPs. (using Hand-held Trimble-Juno-S)
3. Vulnerability analysis: social and economic, settlements, road characteristics, population characteristics, agricultural characteristics.

NOTE: The digital elevation data provided by NASA Shuttle Radar Topographic Mission (SRTM) has coverage over 80% of the globe. At present this data is distributed free of cost by USGS and it is available for download from the USGS ftp site or from the National Map Seamless Data Distribution System. This SRTM data is available as 3 arc second (approx. 90 m resolution) DEM. A 1 arc second data product was also produced, but is not available for all countries (including this study area of India). The vertical error of the DEM's is reported to be less than 16m. The data currently being distributed by NASA/USGS (finished product) contains no-data holes where water or heavy shadow prevented the quantification of elevation. These are generally small holes, which nevertheless render the data less useful, especially in fields of hydrological modeling. (Source: <http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v4-1>). The freely available SRTM data for the study area has only 90 m horizontal resolution (<http://geology.er.usgs.gov/eespteam/terrainmodeling/Pete's%20publications/urisa2004.pdf>) with a vertical accuracy of 16-25 m of (RMSE). It means 53-83 feet error in vertical data. On the other side the Google Earth data has vertical data accuracy in 5-8 feet (<http://www.ijmse.org/Volume4/Issue6/paper2.pdf>) ([http://airccse.com/civej/papers/1114\\_civej02.pdf](http://airccse.com/civej/papers/1114_civej02.pdf)) with better spatial resolution. During the field study of the area, 12 GCPs are collected from different locations and then compared to the Google Earth data. These results are found accurate with error of 1 to 6 feet. Therefore the Google Earth elevation data is more useful and accurate as well as it is freely available. Thus the Google Earth data has been used here for this flood study.



## **CHAPTER - 4**

### **FLOOD INUNDATION MAPPING AND VULNERABILITY ASSESSMENT**

#### **4.1 INTRODUCTION**

Remote sensing and GIS technologies are playing key role for pre-disaster preventative measures, during the disaster and for mitigating the effect of disaster. Flood disaster is one of the most destructive natural disasters according to the vulnerability profile of India, given by National Disaster Management Authority of India. This chapter studies the flood inundation mapping and vulnerability assessment of delta region formed between Nuna and Chitrotpala river of lower Mahanadi basin in Orissa using Radarsat data. The delta region of lower Mahanadi basin is one of the most vulnerable regions for flood disaster according to the flood map of India. For any urban development plan, it is required to identify the risk of any disaster or natural hazard. The risk of flooding and the vulnerability assessment of the area are required for any development policy. It is also important to identify those factors that are relevant to current and future flood risks. One of the key issues for managers is to mitigate or minimise the after effects of flood. This study uses the Radarsat-1 images of 04-September 2003 and 11-September 2003 for flood inundation studies. It shows the comparison between different flood duration images. IRS P6 LISS-III image, dated 21 January, 2006 is used for creating land use map with the help of ERDAS Imagine. The LULC map is divided into 10 classes according to the seasonal crop, lake, river, build-up area, plantation, etc. Flood damage assessment is done by overlaying land use map with flood map (in next chapter). The output map divides the classes into water and land area. It shows the area of different classes in water and land.

#### **4.2 DATA AND METHODOLOGY**

The river discharge data are collected from the office of the District Collector and different Irrigation Divisions offices. After analysis of the discharge data of all the months from year 1991-2009, graphs are prepared as shown in the Figure 4.1. It is found that the highest peaks occur during the months of July, August and September, which are considered as rainy seasons. From the month of October the value of discharge is decreasing. The graphs are plotted for the comparisons of data of different months as shown in the Figure 4.2. It is

observed that the year 2001, 2003 and 2006 has very high peaks. The highest peak is observed in August 2006, so it can be concluded that the year 2006 data is more appropriate for flood studies.

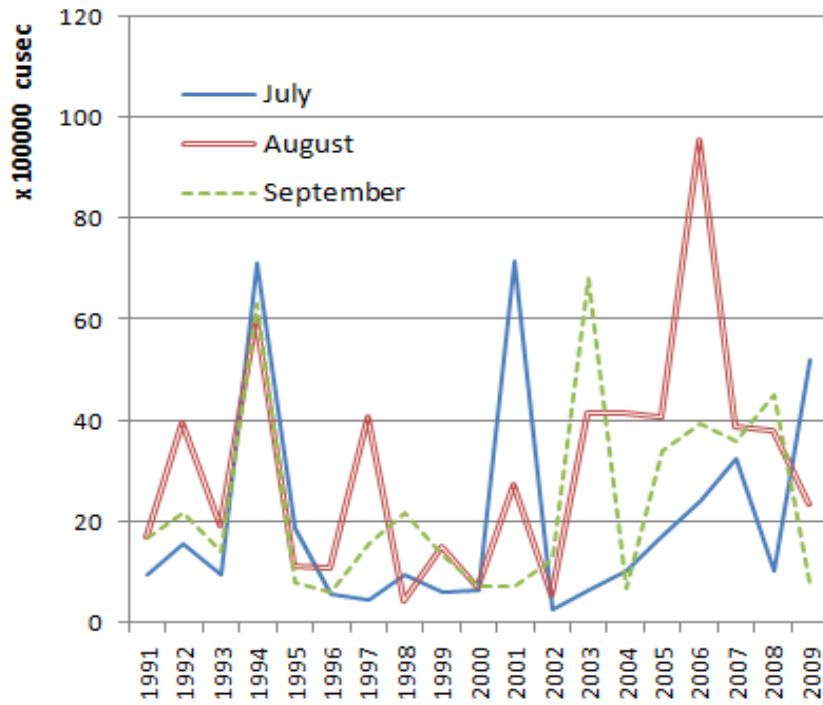


Figure 4.1 Monthly Discharge Data during year 1991-2009 (Jul-Aug-Sep)

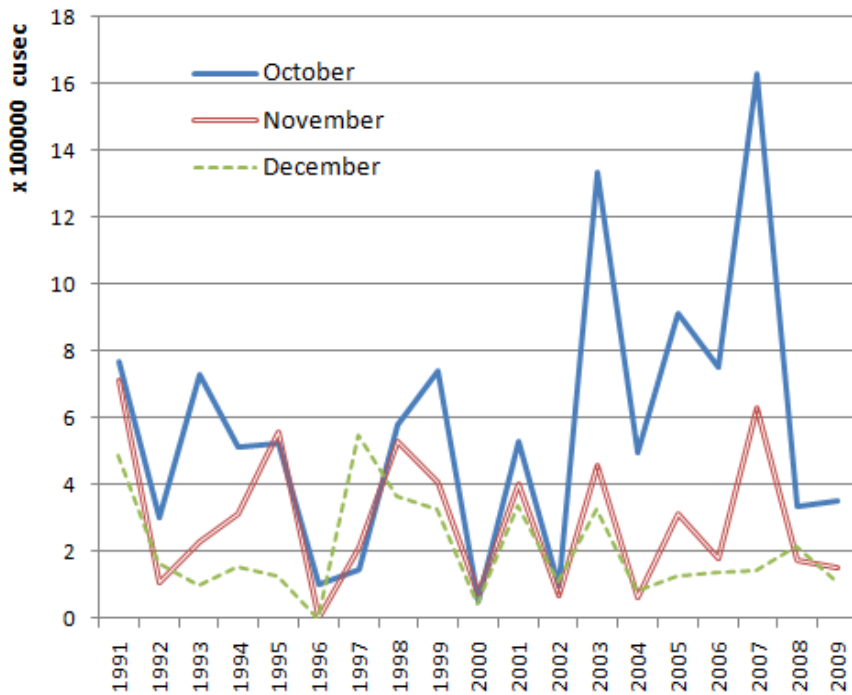


Figure 4.2 Monthly Discharge Data during year 1991-2009 (Oct-Nov-Dec)

The month of August is most hazardous for the area due to high flood risk. According to data it can be seen from November to June, there is normal discharge of river water, but during July to October there is the peak of flood in different years. The high peaks at Mundali gauging station and at Mahanadi and Birupa rivers are shown in the Figure 4.3. These rivers have high peaks in 2001, 2003, 2006 and 2008.

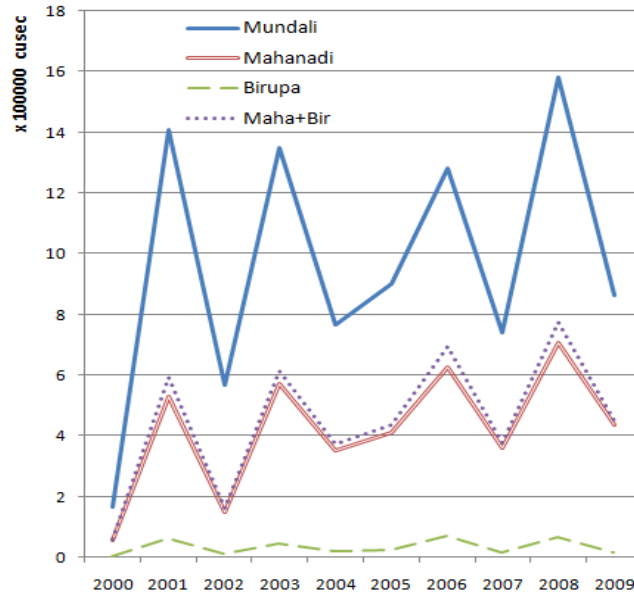


Figure 4.3 Yearly High Flood Data during year 2000-2009

The Mahanadi river has high frequency of flood which shows that the delta region is highly vulnerable to the flood disaster. The vulnerability assessment of the study area has been carried out on the 10 base classes.

### 4.3 FLOOD INUNDATION MAPPING

The inundation or the submerged area characterize that the area is low elevation area and the elements in that area are vulnerable to flood. The standard methodology for extraction of flooded area is to extract the water pixel from the satellite data. Radarsat-1 data of study area is used for extraction of water feature during flood. The Radarsat data is shown in Figure 4.4. It is used to distinguish the water and non water body. Through the use of ILWIS 3.6 software the digital numbers at different location within the flood inundated area has been identified. The water area has lower DN or backscatter values due to specular reflection from water surface.

The density slicing method is used here for extracting the flooded and non-flooded area. To develop a flood thematic map, it is required to slicing of all areas with water as one class and other areas as land. The upper bound 60 is considered as the max value DN of water body. The other with upper limit as 255 is land area. The output of this slicing is a slice map which differentiates the water and non-water pixel. In this map there are two classes one as flood area and the other as non-flood area as in Figure 4.5.

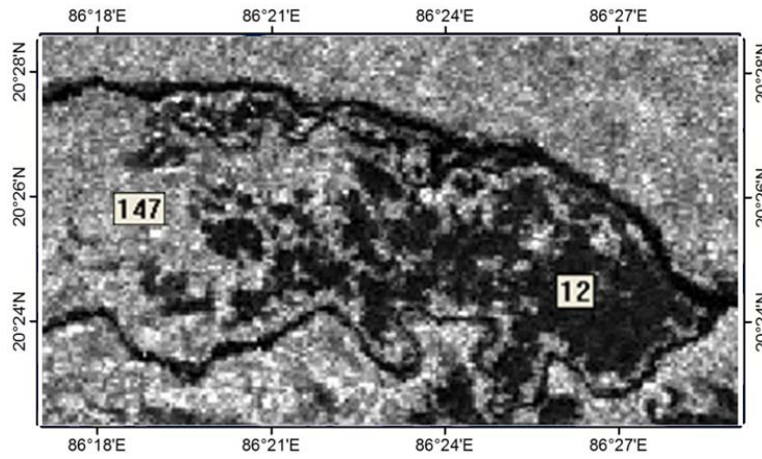


Figure 4.4 Lower DN values showing water and higher DN values are non water content

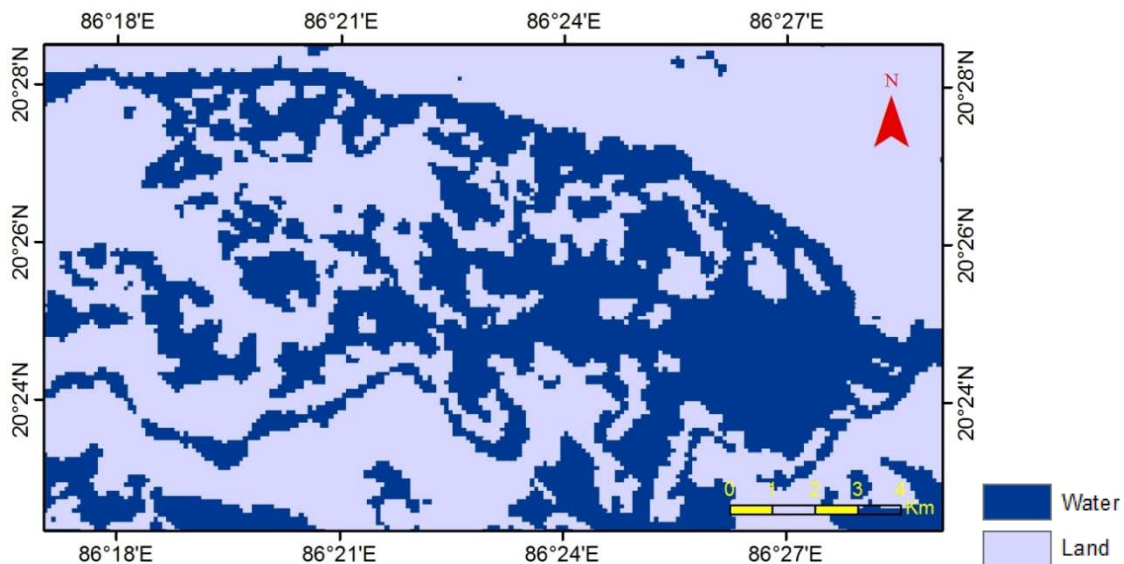


Figure 4.5 Classified image of Radarsat -1 dated 04-Sep-2003

The classified image of Radarsat data of 04 September 2003 is shown in Figure 4.5. The dark blue colour represents the water inundated area and the light colour represents the land area.

The threshold value of a pixel for water may be in between 45 to 60. The clear water has a high scatter value and moist soil has low scatter value. It can be seen in Figure 4.5 and Figure 4.6, that most of the delta region is flooded and both the Garadpur and the Marsaghai blocks are highly vulnerable areas. The agriculture area, built-up area and plantation area are damaged due to the flood water. On comparing of Figure 4.5 and Figure 4.6, it can be seen that the flood duration for the area is more than 7 days. It is definite that seven days duration of flood will caused a very high damage probability to all types of vulnerable things that is vegetation, built-up area, etc. Here the elements of risk are mainly agriculture land, houses, roads etc. in rural areas.

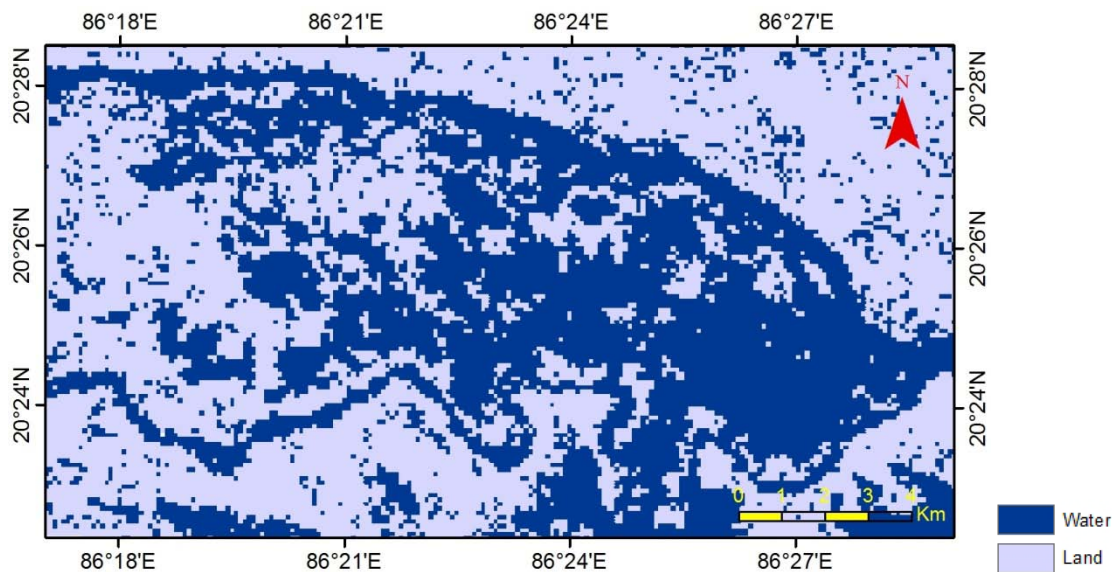


Figure 4.6 Classified image of Radarsat -1 dated 11-Sep-2003

#### 4.4 VULNERABILITY ASSESSMENT

Vulnerability, in general, refers to the resilience of a particular group, people, property and the environment, and their ability to respond to a hazardous condition (Kumar et al. 2010, Saini et al. 2012, Pandey et al. 2014). Aghataher et al. (2008) have stated that the most vulnerable groups are those who cannot be able to reconstruct their livelihood after a

disaster. It seems that, well prepared communities are less affected by these disasters due to their strong social structure compared to those unprepared or ill equipped communities which face severe affect of these disasters (Ouma et al. 2014). According to Sanyal (2005), Human vulnerability is a function of the costs and benefits of inhabiting areas at risk from natural disaster. Tang et al. (2005) compared risk with vulnerability as risk is static and hypothetical (though re-assessable from period to period of time) but vulnerability is accretive, morphological and has a reality applicable to any hazard. Yerramilli (2012) had given flood vulnerability and preparedness model approach using HEC-RAS model to mitigate the risk for local communities. As most of the study area is rural area, therefore the agriculture land is the prime concern of vulnerability. The crop land and built up are more susceptible to the flood water. The duration of flood is also a very vital issue related to the crop vulnerability. Long duration of flood water cause full damage to the crop, and even short duration of flood may cause high damage due to the highly contaminated water.

### **Agriculture in Orissa**

The economy of Orissa is highly dependent on agriculture. It employs around 70% of its total population in farming who contribute around 30% to the Net State Domestic Product. Around 40% of the total land area that turn to roughly around 87.46 lakh hectares is brought to cultivation every year and about 18.79 lakh hectare of this cropped area is irrigated. Thus it is observed that a major portion of the agriculture land depends on rain water to nourish the crop. The area under agriculture is comparatively more in the coastal districts of Orissa i.e. Bhadrak, Balasore, Jagatasinghpur, Ganjam, Jajpur, Kendrapara, Nayagarh, Khurda, Puri etc. Incidentally these are also the regions of the state which are better in the literacy rate compared to other regions. The major crops are rice, oil seeds, pulses, coconut, jute, and turmeric. The crops like cotton, tea, rubber and groundnut are of immense economic importance in other parts of state. One tenth of the total rice produced in the country has been contributed by Orissa. Other important food grains include pulses like arhar, gram and Oilseeds like mustard, groundnut and castor oil.

Apart from food grains various cash crops are also cultivated in the state. These include sugarcane, Jute, mesta, rubber, tobacco, tea, coffee and turmeric. These crops are cultivated in diverse geographical areas of the state. After West Bengal, Bihar and Assam; the state of Orissa stands fourth in the production of jute in the country. Jute and Rice,

compete with each other as they require almost similar soil and climatic conditions. Cultivation of jute is primarily confined to the coastal plains of Balasore, Baleshwar and Puri districts. Table 4.1 shows the regions where different crops are produced in Orissa.

Table 4.1 Different crops produced in Orissa.

<b>Food-grains</b>	<b>Names of Area</b>
Rice	Baleshwar, Cuttack, Koraput, Sambalpur, Puri, Ganjam, Kalahandi and Kendujhar.
Pulses (Gram, Arhar)	Cuttack, Koraput, Puri, Kalahandi, Balangir, Dhenkanal and Sambalpur.
Oilseed(Sesameum, groundnut, mustard, castor and linseed)	Koraput, Cuttack, Sambalpur, Kalahandi, Bolangir, Ganjam and Dhenkanal.
<b>Cash Crops</b>	
Jute	Plains of Balasore, Cuttack, Baleshwar and Puri districts.
Mesta	Balangir, Cuttack, Koraput and Ganjam.
Sugarcane	Sambalpur ,Cuttack, Balangir, Puri and Kalahandi districts.
Tobacco	Koraput.
Cashew	Cuttack, Ganjam & Puri District.
Rubber Plantations	Slopes of Eastern Ghats, Keonjar, Mayurbhanj and Baleshwar. Inland hill areas of Cuttack, Ganjam, Puri and Dhenkanal.
Cotton	Balangir, Koraput and Kalahandi.
Tea	Eastern Ghats, mountainous region of Phulbani and Koraput.
Coffee	Forest lands of Eastern Ghats, Koraput, Malkangiri, Kalhandi, G.Udayagiri, Rayagada and Balliguda areas of Kandhamal district.

In India the agricultural cropping season can be classified as follows:

- (i) Kharif crop and
- (ii) Rabi crop based on the monsoon.

**(i) Kharif crops**

The Kharif cropping season is from July –October. The Kharif crop is also known as the summer crop or monsoon crop. Kharif crops are usually sown with the beginning of first rains in July, at the time of south-west monsoon season. Major Kharif crops of India include Paddy (Rice), Millets (Bajra, Jowar), Pulses (Moong, arhar), Maize, Cotton, Red Chillies, Groundnut, Soya bean, Turmeric, Sugarcane etc.

## **(ii) Rabi Crops**

Rabi cropping season is from October-March (winter). The Rabi crop is a winter or spring harvest crop in India. It is sown in second half of October and harvested in March-April every year. Major Rabi crops in India include Wheat, oats (cereals), Barley, chickpea/gram (pulses), Mustard (oilseeds), linseed, Sesame, and Peas etc.

The terms 'kharif' and 'rabi' originate from Arabic language where Kharif means autumn and Rabi means spring. The crops grown between March and June are summer crops.

It is observed that approximately 77.7% of total area is covered by Paddy, 10.9% of area is covered by Pulses, Oil seeds cover 4.9% and fibre crop covers 1.3%. The other cash crops are harvested in only 2.1% of total agriculture land of the district (OSDMA). In terms of area the food crops is harvested in 289.66 thousand ha and vegetables are in 621.98 thousand ha. Total production is calculated as 7604.36 MT, in which rice (2002-2003) 32.44 lakh MT, oil seeds (2002-2003) 1.15 lakh MT, pulses 2.05 lakh MT and total cereal (2002-2003) 33.50 lakh MT. It is also observed that the total area of degraded land is 61.21 lakh ha.

As it is discussed above that the main concern for vulnerability assessment in this study area is agriculture crops and there is a need to create LULC map of the area to identify the elements at risk in the area. The next chapter discussed the creation of LULC map and damage assessment. The built-up area, plantation and shrubs are also highly vulnerable to the flood. Those areas which are constant and not changed much during last 10 years (2003, 2006, and 2012) are taken in to consideration. The crop pattern has not changed much during these years. As per the discussion with the local villagers, the crop pattern has not being changed much by them. The agriculture fields, buildings and roads are taken into consideration for the damage assessment, therefore the separate classes are not considered for accuracy assessment. During the field work, the local information is collected from the concerned Government offices as well as through interaction with the local people. The information provided by the local offices and various resources are assumed to be correct. So practically the accuracy of damage assessment is based on the accuracy of available resources and it is also one of the limitations of this study.

## **CHAPTER - 5**

### **EXTRACTION OF LULC AND FLOOD DAMAGE ASSESSMENT**

#### **5.1 INTRODUCTION**

Remote sensing and GIS technologies are playing key role for pre-disaster preventative measures, during the disaster and for mitigating the effect of disaster. Flood disaster is one of the most destructive natural disasters according to the vulnerability profile of India, given by National Disaster Management Authority of India. This chapter studies the flood inundation mapping and damage assessment of delta region formed between Nuna and Chitrotpala River of Lower Mahanadi Basin in Orissa using Radarsat data. The delta region of lower Mahanadi basin is one of the most vulnerable regions for flood disaster according to the flood map of India. This study uses the Radarsat-1 images of 04-September 2003 and 11-September 2003 for flood inundation studies. It shows the comparison between different flood duration images. IRS P6 LISS III image, dated 21 January, 2006 is used for creating land use map with the help of ERDAS IMAGINE. The land use land cover (LULC) map is divided into 10 classes according to the seasonal crop, lake, river, build-up area, plantation, etc. Flood damage assessment is done by overlaying the land use map with the flood map. The output map divides the classes into water and land area. It shows the area of different classes in water and land. A flow chart for damage assessment was also discussed to illustrate the process. At the end of this chapter the results are discussed as the evaluation of damage to the elements due to the flood. The land area, build-up area, crop and vegetation area are discussed for the damage assessment.

#### **5.2 EXTRACTION OF LAND USE AND LAND COVER**

Land Use and Land Cover (LULC) data represents the land use information and the land cover area with the classification. It distinguishes the land area by its pixel information or pixel colour. It is basically the manual interpretation of the area. In this raster or grid data structure, each cell has a value which corresponds to a particular colour and it depicts that definite classification. This grid structure of the image provides an opportunity to create summary tables and it also provides support to perform suitable analyses on the basis of pixel value of these grid data. Pixels on raw RS data only have row and column

coordinates; that is, they do not have geographic coordinates such as latitude-longitude. All RS images exhibit varying degrees of geometric distortion. Georeferencing is the process of assigning geographic coordinates to a remote sensing image and 'Rectification' is the process of shifting pixel location to eliminate spatial distortion. It can be said that the process of rectification includes Georeferencing, because one can both shift the pixels to remove distortion and assign coordinates to those pixels at the same time. This process normally has following steps:

- i. Creating ground control points (GCP) from clearly identifiable features.
- ii. Error checking of these GCPs.
- iii. Rectifying and Resampling the image to the GCPs.

It is recommended that there will at least twice as many GCPs as the minimum required for the correction algorithm; and these ground control points will be clearly demarcated on the image and must have precisely known coordinates. Resampling is the process by which values are reassigned to the rectified pixels. The Nearest Neighbour Resampling is a technique where the new pixel receives the value of the pixel centroid that is closest to it after being shifted. Following are the main steps and processes which involved in this study for creating the land use and land cover maps:

- A. Satellite data selection
- B. Pre-processing of data
- C. Classification
- D. Satellite data interpretation
- E. LULC classification
- F. Field verification
- G. Composition of final LULC map

**A. Satellite data selection:** Satellite data should be selected on the basis of the flood or rainy season. The crop calendar is also considered for the main crops at the same time. The purpose of the selection of data is to find the LULC of the study area at the time of flood. The selection of data is also important, because when calculating the damage assessment of the crop and other elements, the LULC at the time of flood will be considered. In India the kharif cropping season is from July –October. The Kharif crop is also known as the summer crop or monsoon crop. As a result images acquired in August to October were preferred for this study. To improve the data interpretation, it is also

recommended to compare those data which are acquired in contiguous months. Therefore some other sources data are also used to improve the LULC.

**B. Pre-processing of data:** In this phase, standard operations of geometric correction and registration have been applied on the satellite image and it is converted to follow the Geographic coordinate system WGS-84 Zone N45. There are twelve ground control points on the satellite image and on the topographic map were identified and linear geometric correction function was applied. False colour composites (FCCs) were prepared for the selection of elements on the image (Figure 5.1 to Figure 5.3).

Point #	Point ID	Color	X Input	Y Input	X Ref.	Y Ref.	Type	X Residual	Y Residual	RMS Error	Co
1	GCP #1		1357.592	-1112.553	77.750	30.000	Control	-0.000	-0.000	0.000	
2	GCP #2		8938.643	-1228.288	78.000	30.000	Control	0.000	0.000	0.000	
3	GCP #3		8875.587	-10110.361	78.000	29.750	Control	0.000	0.000	0.000	
4	GCP #4		1296.514	-10156.581	77.750	29.745	Control	-0.000	-0.000	0.000	
5	GCP #5						Control				

Figure 5.1 GCP for Correcting the Toposheet

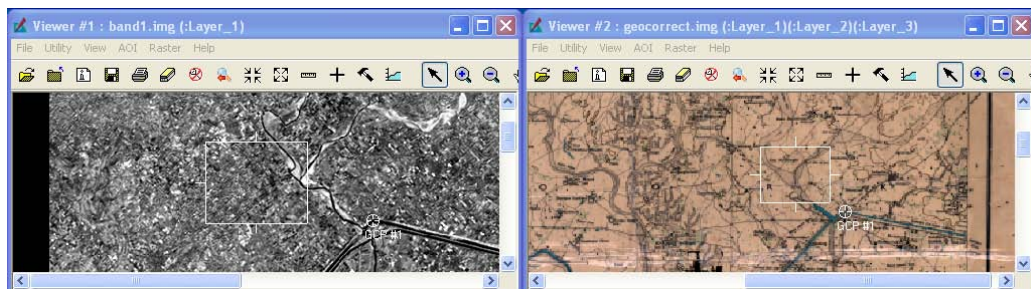


Figure 5.2 Geo-referencing of Image

Point #	Color	X Input	Y Input	Color	X Ref.	Y Ref.	Type	X Residual	Y Residual	RMS Error	Contrib.	Match
1		-189204.399	840409.880		77.956	29.942	Control	0.011	-0.003	0.011	0.235	
2		-194716.173	834179.606		77.889	29.874	Control	-0.070	0.020	0.072	1.511	
3		-195592.152	833087.094		77.884	29.867	Control	0.059	-0.017	0.062	1.289	
4		-181185.377	838549.656		78.707	30.410	Control	-0.001	0.000	0.001	0.012	0.000

Figure 5.3 GCP for Geo-referencing the image from the topographic Sheet

**C. Classification:** The maximum likelihood classification was preferred for supervised classification. Specific procedures and detailed information from topographic maps have been used to identify and categorize the sample areas for supervised classification. Field visit data and information has been incorporated together with the thematic maps and expert knowledge of the terrain.

**D. Satellite data interpretation:** Enhanced false colour composites RGB (red, green, blue) were used for the interpretation of the land cover classes. Different combinations of the various collected data sets are used for identification of elements. Google Earth data, LISS-III data, Landsat 7 data, national repository data and data from Orissa disaster management authority are compared and tried to made most accurate land use map for this study. It is also considered that their year of acquisition should not be too different but there is possibility of slight difference in their pattern of land use. Utmost care has taken for the preparation of land use map, but there is always various limitations and constraints which cannot be removed due to non-availability of high accuracy data, high cost of data, pre and post disaster data, compatibility of data etc.

**E. LULC classification:** Land-use maps are the universal and effective way of representing the land-based data. Different colours have been used to depict different elements visualized on land. Roads, built-up area, agriculture area, forest, public infrastructure, community facilities, etc can be effectively illustrates graphically by using land-use concepts. Different organizations may use different colour scheme to represent the land-use map but there are certain International standards also which the planning agencies have been using since the 1950's and that became a de-facto standard.

Descriptions of land use and land cover classes; LULC classification scheme and brief description of classes are given in table 5.1.

Table 5.1 LULC classification Scheme

Sl.	Class	Sub-class	Classes of LULC
1	Built-up	Urban	Residential, Public/Semi Public, Commercial, Reclaimed land, Recreational, Industrial
		Rural	Rural
2	Agriculture	Crop land	Rabi, Kharif, Two or more crops
		Plantation	Plantation -Agricultural, Horticultural
		Fallow	Fallow, Current fallow
3	Plantation	Evergreen/Semi evergreen	Dense/Closed and Open category of Evergreen / Semi evergreen
		Deciduous	Dense/Closed Deciduous
		Forest Plantation	Forest Plantation
4	Scrub	Scrub Forest	Scrub Forest, Forest Blank, Current & Abandoned Shifting Cultivation
		Swamp / Mangroves	Dense / Closed & Open Mangrove
		Grass/ Grazing	Grassland: Alpine / Sub-Alpine, Temperate / Sub Tropical, Tropical / Deserted
5	Barren/Waste lands	Salt Affected Land	Slight, Moderate & Strong Salt Affected Land
		Sandy area	Desertic, Coastal, Riverine sandy area
6	Wetlands / Water Bodies	River / Stream / canals	Perennial & Dry River/stream and line & unlined canal/drain
		Coastal Wetland	Coastal Natural and Coastal Manmade wetland
		Water bodies	Perennial, Dry, Kharif, Rabi & Zaid extent of lake/pond and reservoir and tanks

The land cover classification system is a standardized, comprehensive and a priori (knowledge based) classification system, which is used for creating maps. The LULC classification is independent of the scale or method used to map. It provides a method to distinguish various elements very clearly to each other. Simultaneously the classification has some reasons to indicate the element with a particular colour scheme.

Classification is the process of sorting pixels into a finite number of individual classes, or categories, of data based on their data file values, (Bahadur 2009). If a pixel satisfies a definite set of criteria, then the pixel is assigned to the class that corresponds to that criterion. There are two ways to classify pixels into different categories:

- a) unsupervised
- b) supervised

#### **a) Unsupervised Classification**

Pixels are grouped on the basis of their reflectance properties. These grouping are known as clusters. The first thing is to identify the number of clusters to generate because it defines the number of class. The combination of band used is also important because it helps to differentiate between elements. This information is required to classification software to generate clusters. There are different image clustering algorithms such as K-means and Isodata. Here in this study each cluster has been identified manually with land cover classes. The unsupervised image classification technique has been used to find ten different classes. These classes are based on field visit, Google imagery, Government organization data and various remote sensing data.

#### **b) Supervised Classification**

In supervised classification, spectral signatures have been developed from specified locations in the image. In this process, samples of each land cover class have been selected to represent that element in the digital image. These samples of land cover classes are termed as training sites. These training sites are used to identify the land cover classes in the entire image by the image classification software. This classification of LULC is based on spectral signature defined in this work as the training set. On the basis of resemblance of each pixel to a specific class in training set, the digital image classification software determines the classes for whole image (Figure 5.4). Maximum likelihood and minimum-distance classification algorithms have been used for this supervised classification.

The supervised classification in ERDAS can be performed by establishing the signatures of classes using the AOI, then evaluate the training data with the help of statistics, histograms and profiles. Establish classes, using maximum likelihood classification and signature file. A priori (already known) information is required to make supervised training data, such as: What types of classes need to be extracted? What classes are most likely to be present in the area or data? Field verification is also required.

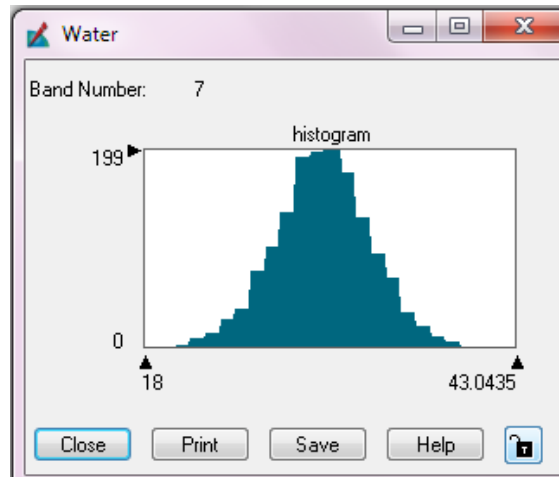


Figure 5.4 Histogram for verification

In supervised training, some pattern recognition skills for identification of the class are required and also priori knowledge of the data is required to determine the statistical criteria (signatures) for data classification. The location of a specific characteristic, such as a land cover type (crop area, river area), was also acquired through ground truthing. Ground truth data are considered to be the most accurate (true) data available about the area of study, because this data was collected through the field visit of the area, personal experience or visual verification of the land area. The field visit data should be collected at the same time as the remotely sensed data. But in this study the field visit has been done in year 2012 although in the same rainy season or Kharif season in July. The interview of personal and the farmers have been taken for collecting more information about the area. However, some ground truth data may not be very accurate due to a number of errors, inaccuracies, and human shortcomings. Global positioning system receivers are useful tools to conduct ground truth studies and collect training sets. In this study the position of GPS was taken by Trimble Juno tool and the data was compared with the Google maps. The results are found correct and appropriate for the flood study.

Some steps are discussed here for the extraction of LULC. The first step is to select the area for classification by using AOI Tools. Classifier/signature editor is used to specify the particular class in the classifier. The signature file created in the signature editor is the specification of LULC. Histograms plot is used for testing the correctness of the signature file. The colour of the histogram reflects the colour of the corresponding signature. Supervised Classification uses this signature file as the classifier to create the LULC. Here

the Maximum Likelihood algorithm is selected as the Parametric Rule for this classification.

**F. Field verification:** A field visit was carried out during July 2012 for collecting GCPs, runoff data, hydro-meteorological data, socio-economic data and ground study of the study area. Field visits were carried out in most of the area come under the study area to collect terrain information. Various key points are considered during field visit for the image interpretation. A GPS has been used to precisely locate the ground points.

**G. Composition of final LULC map:** For creating LULC Map, the IRS P6 LISS III image, dated 21 January 2006 has been used for the purpose. Figure 5.5 shows the FCC image of the area. The corresponding LULC map of study area is shown in Figure 5.6. This map will be used to find flood damage assessment.

The ERDAS Imagine software is used for the supervised classification of the study area. For verification of the ground data with the satellite data, a field visit of study area was performed during July 2012. The ground control points (GCP) are collected throughout the area at 12 different locations. These GCPs are then compared to the Toposheet and the satellite data; they are found correct and accurate with the image. The collected GCPs are also compared with the Google earth data and found accurate. For LULC verification the data from national repository and Google data are also compared to the constructed LULC data. Although the LULC data cannot be perfectly accurate, but here in this study it is tried hard to make it correct, as the damage assessment depends on the accuracy of the LULC.

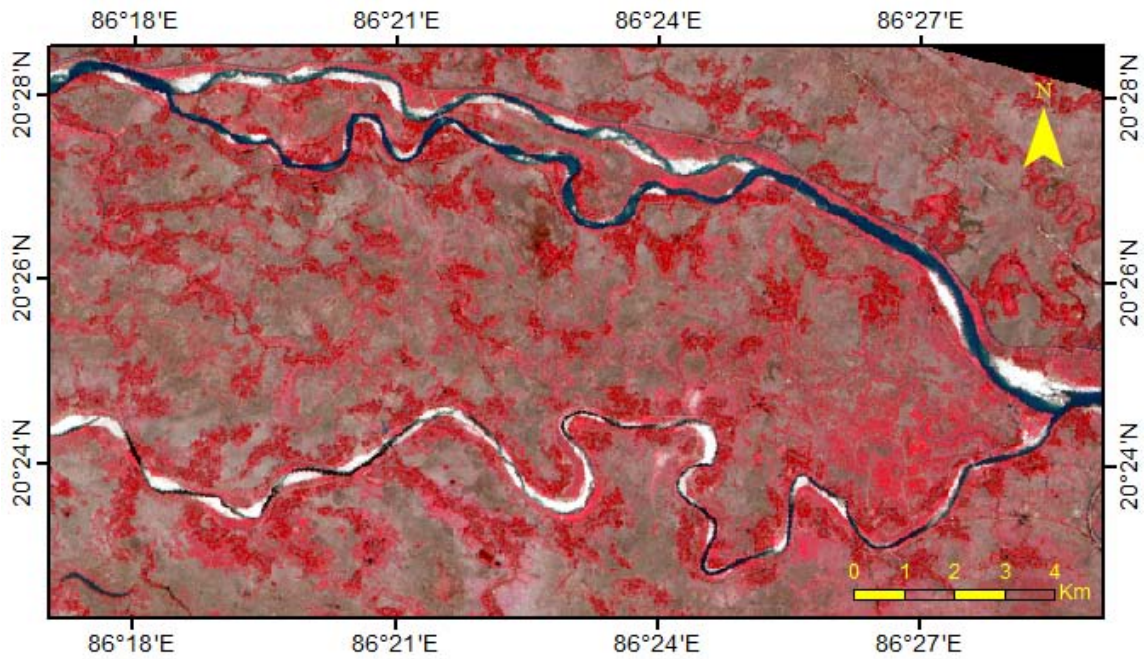


Figure 5.5 IRS P6 LISS-III FCC image of study area, dated 21 January 2006

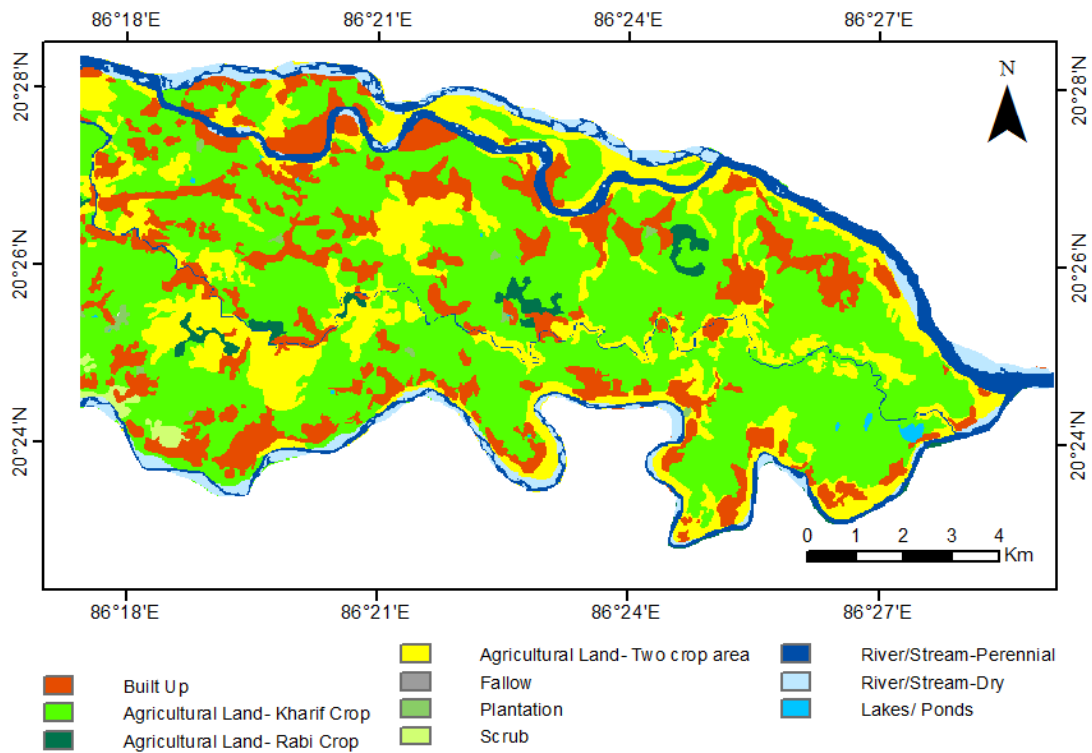


Figure 5.6 LULC map of study area

On the basis of the LULC map the area is divided into 10 classes as shown in Figure 5.7. As this is a rural area the main element at risk is agriculture field. The main elements at

risk are considered as the built up area, agricultural land- Kharif crop, Rabi crop, two or more crop area, fallow land, plantation area and scrub area. The 10 classes are as follows:

**Class Name**

- Built Up
- Agricultural Land- Kharif Crop
- Agricultural Land- Rabi Crop
- Agricultural Land- Two crop area
- Fallow
- Plantation
- Scrub
- River/Stream-Perennial
- River/Stream-Dry
- Lakes/ Ponds

According to the International Federation of Red Cross Societies: Vulnerability can be defined as the diminished capacity of an individual or group to anticipate, cope with, resist and recover from the impact of a natural or man-made hazard. This concept is relative and dynamic: Vulnerability is most often associated with poverty, but it can also arise when people are isolated, insecure and defenceless in the face of risk, shock or stress. Lack of preparedness may result in a slower response to a disaster, leading to greater loss of life or prolonged suffering. Human activities are always affect hydrological cycle in nature. These activities changed the environmental conditions significantly, which leads to change in the stability of natural process in long duration. The vulnerability of a community and its environment depends on their exposure to flood, susceptibility or openness to flood, ability to response the flood event and also the intensity and magnitude of flood.

**5.3 FLOOD DAMAGE ASSESSMENT**

After the flood inundation mapping and identification of elements at risk and creation of LULC, the next step is to estimate the damages due to the flood water. The flood damage assessment process is shown as in Figure 5.7. ERDAS Imagine, ArcGIS and ILWIS software are used in processing the remote sensing data.

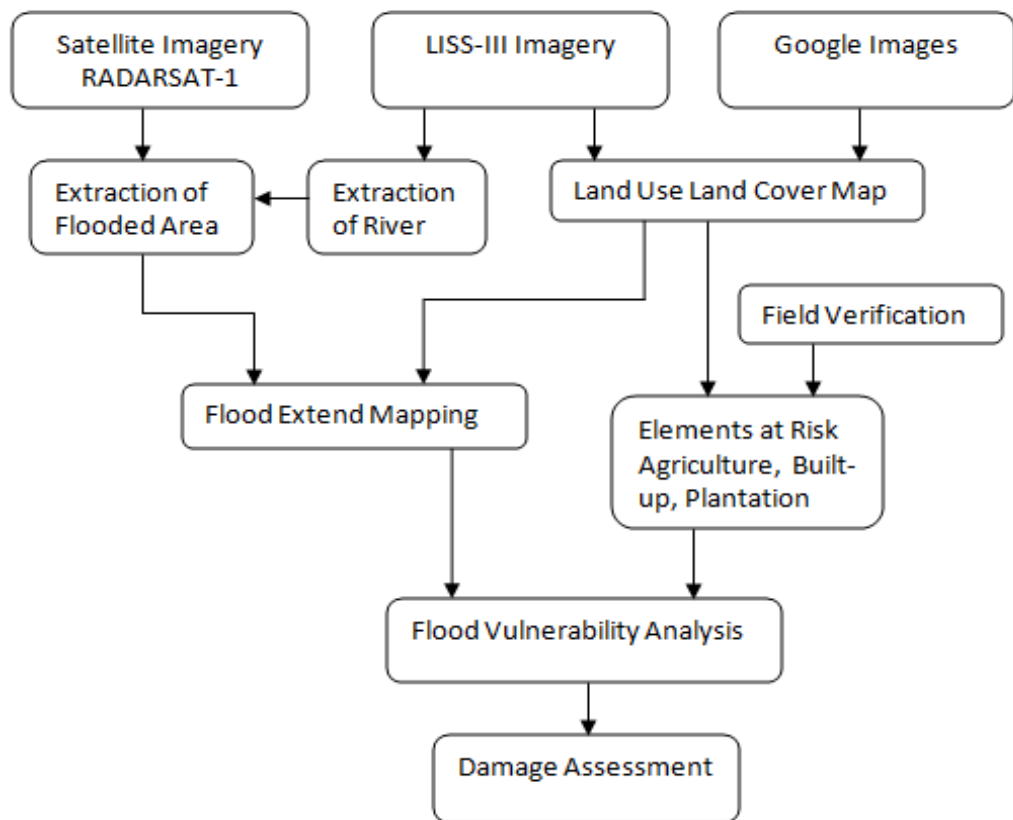


Figure 5.7 Flow Chart for Flood Damage Assessment

The extraction of the flooded area and the construction of LULC map have been done by using the Radarsat-1 data and LISS-III data. The field work of study area and Google images are also used to verify the accuracy of the LULC map. LULC map and extracted flooded area is used for creating the flood extended map. By the process of overlay of the LULC map with the flood extended map, the inundation of different types of classes can be delineated. It is used to find elements at risk with the help of field verification and Google images.

#### 5.4 RESULTS AND DISCUSSION

The LISS-III is a multi-spectral camera operating in four spectral bands, which provides data with a spatial resolution of 23.5 m. The crosses of LULC and flood map showing the area under water and land in Table 5.2. The outputs of cross table specify the number of pixels, so the total area can be identify by simple mathematical calculation. The flooded area and the damage due to the water are calculated. Elements which are inundated due the heavy flood are shown in Figure 5.8. It shows the various elements which are considered

for this study. The Build\_up/F represents the build-up area which is in flooded condition and the Build\_up/NF represents the build-up area which comes under non-flooded area. Therefore all the classes have flooded and non-flooded area and represents in different colours. The calculated area which is damaged due the flood is listed in the Table 5.2 and it also shows the features under risk. By observing different maps the statistics of each land use inundated can be calculated.

Table 5.2: Crosses of LULC and Flood map showing the area under water and land

Class Name	Flooded	Non-Flooded
	Area (Hectare)	Area (Hectare)
Built Up	1299	936
Agricultural Land- Kharif Crop	4468	2072
Agricultural Land- Rabi Crop	720	57
Agricultural Land- Two crop area	1522	879
Fallow	13	02
Plantation	37	21
Scrub	42	32
River/Stream-Perennial	709	269
River/Stream-Dry	329	180
Lakes/ Ponds	23	04

The height of the flood and the duration of flood are important factors for the damage assessment. Strong objects/features can face 7 days of flood water but agriculture and mud houses are very susceptible to flood and there may be full damage to these things. So as seen in the comparison of different Radarsat data, it is observed that there is a very high damage occur. Approx 67% (91.53 sq.km) area is flooded and 33% (44.67 sq.km) area is non flooded according to this map. In terms of money it is calculated that more than INR 100 Billion loss of agriculture and INR 17 Billion loss of build-up and roads occur due to the flood.

According to the Census of India 2001, Panchayati Raj Department, Government of Orissa, the Kendrapara District has 2644 sq.km area, with a population of 1301856, was severely affected by the flood. As compared to the study area 65.48% of the total area was flooded, which can say that approx 8.5 M people are severely affected by this flood.

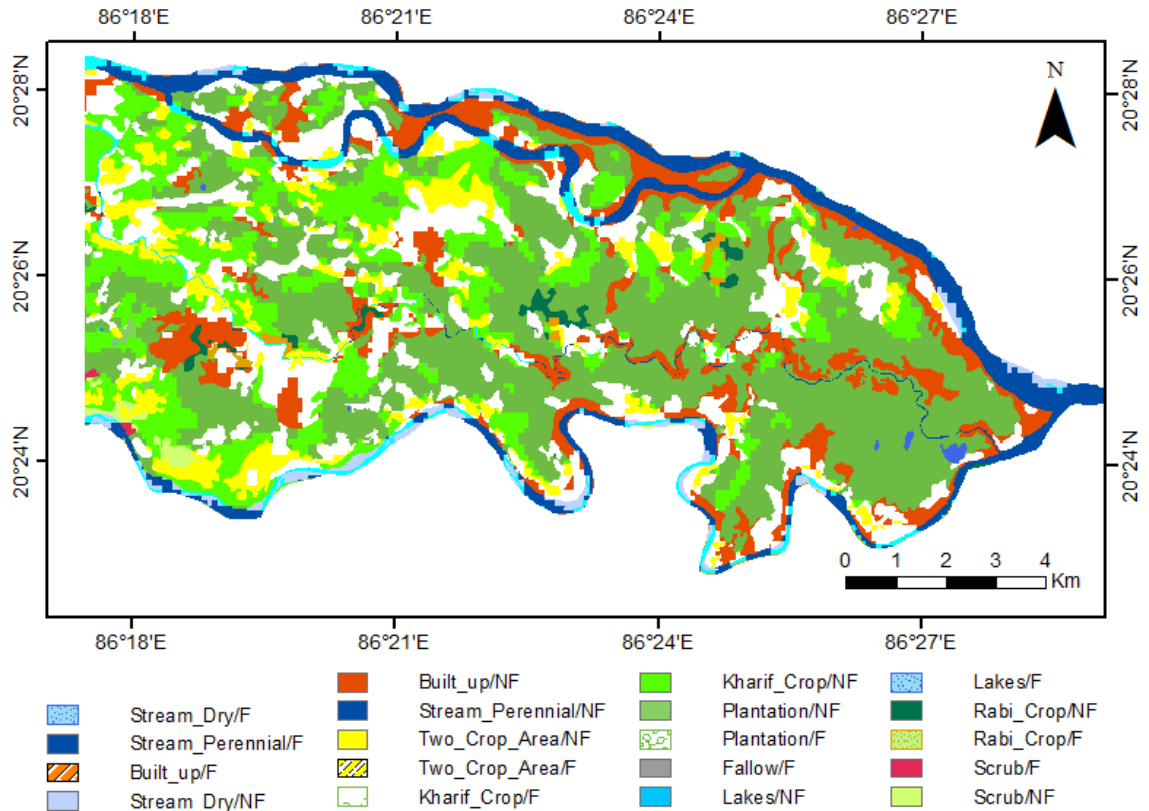


Figure 5.8 Vulnerable elements due to flood

Risk can be calculated as qualitative or quantitative. It may be in terms of cost or money. In this study the vulnerability analysis has been done mainly on agriculture, plantation and built up area, which can be measured as in terms of amount of money. The lakes and ponds are normally dry or very less water for the major part of the year. The damage to the elements is measured on the basis of flood duration and flood depth. The damage to agriculture crop has been calculated by using the formula for Risk=Probability of occurrence\*Vulnerability\*cost. Near the location of agriculture land to the river, more it is vulnerable to flood. As the flood duration affect differently on paddy, rice, sugarcane and mature crop, it is considered that the loss in terms of money in INR/ acre as 8000 for paddy, 18000 for rice and sugarcane and 27000 for mature crop. The built up area can be structural (RCC) or partially muddy type. The cemented house may damage cost between INR 2000-15000 and the partially muddy type house may damage cost between INR 1000-4000. These statements are based on the conditions and rates at the time of flood (data taken from Orissa Government websites). The damage assessment is based on the area calculated as flooded, and by using the LULC map it is classified for the elements of risk.

The agriculture and built up area are considered for calculation of damage in terms of money.

## **5.5 CONCLUSION**

This chapter discussed the flood inundation mapping and damage assessment of delta region formed between Nuna and Chitrapala river of lower Mahanadi basin in Orissa. Flood damage assessment is done by overlaying land use map with flood map. The output map divides the classes into water and land area. It shows the area of different classes in water and land. The result shows that 65.48% of total land area is submerged in water. 66.73% of crop and vegetation area is damaged due to flood. 58.13% of the build-up area is come under the flooded land area. If socio-economic data is integrated with more accurate land use map the amount of loss due to damage and damage to life can be calculated accurately.

To mitigate the effect of the flood some measures should be considered. In India main focus for flood protection is taken as structural measures like embankments to prevent the flood water from reaching potential damage centres. Drainage improvements, diversion of flood water and channel modifications are some effective methods for preventing the susceptible to flood damage. Embankments are the most common, quick and effective way of protection with locally available material and labour. To control the flood, Water reservoirs have also great potential to prevent the loss. Flood plain zoning, flood forecasting and warning systems are gaining increased attention of planners and disaster managers. Flood fighting and flood insurance are demand of the current scenario. The CWC has established the flood forecasting system and continues to update and modernize forecasting services more accurate, effective and timely. The automated data collection and transmission forecast through the use of satellite-based communication systems has improved the flood mitigation and management. Development of a real-time decision-support system for flood forecasting and inundation forecast for the Mahanadi basin is highly required.

# **CHAPTER -6**

## **DELINEATION OF OPTIMAL ROUTE DURING FLOOD DISASTER**

### **6.1 INTRODUCTION**

This chapter presents a safe route delineation process during flood disaster. It first constructs a weighted parameter model by considering road quality and environmental factors. Cost of road quality factor is based on road length and road width. Cost of environmental factor consists of traversal speed, traffic volume and safe zones. These parameters are given as input to the AHP for building the weighted model based on the minimum time consumption with safety. In a flood scenario the shortest path is not always the best path for rescue operation. The water depth and the availability of high altitude building or area are the most important factors for immediate rescue. Path around the outskirts of urban areas can have low vehicle flow rate, compared to highways. So the optimal path is not necessarily the shortest path. This method finds the lowest impedance on path based on various factors which are important during flood. This method is applied on the roads of Kendrapara district of Orissa. The results are found according to the criteria involved and it offers the optimal evacuation path during the flood. People, who live in flood plains, can locate the areas at higher altitude which are less vulnerable to the flood water. The main objective is to find the optimal evacuation route during flood.

### **6.2 METHODOLOGY**

The data and images used to achieve the objective are shown in a flowchart in Figure 6.1. Google imagery is used to extract the elevation points. In this study, a 60×60 grid is considered for applying the method. Landsat-7 images are compared with Google Earth images for verification of land and river area. This land-use has also been compared with the LISS-III imagery land-use which was discussed in chapter 5 for damage assessment. The area is calculated through visual interpretation and field calculator. This has been done because to find the paths through the agriculture fields and built-up area. The Google Earth imagery was very useful for extracting the vital information. DEM is created by using the Google Earth elevation points. It is further used for the extraction of flood extent map and flood depth map. These maps constructed on the basis of elevation. So these are further

classified as the low, medium and high elevation zone and as flood zone map (explained in section 6.6). The LULC map is used for the classification of vulnerable items and to find the damage assessment (as discussed in chapter 5). The shelter map is also based on some parameters like higher elevation, capacity of shelter, distance or proximity to the user location, safety of shelter zone and ease to reach or connectivity to shelter point. The road map is developed as shape file. Roads are considered as highways (NH-5 State Highway) district roads, village roads and narrow roads on the basis of their width and utility. The flood extent is very large so a large area has been considered for route delineation for this study and it has been carried out extensively. It is important to consider the dense urban area of the district and the delta region of lower Mahanadi delta region which has low density population and considered as rural area. The urban area has good population density but the delta region which is prone to flood has mostly agriculture land. For finding the optimal safe route AHP and fuzzy logic concepts has been implemented with some modifications, which is discussed in subsequent sections.

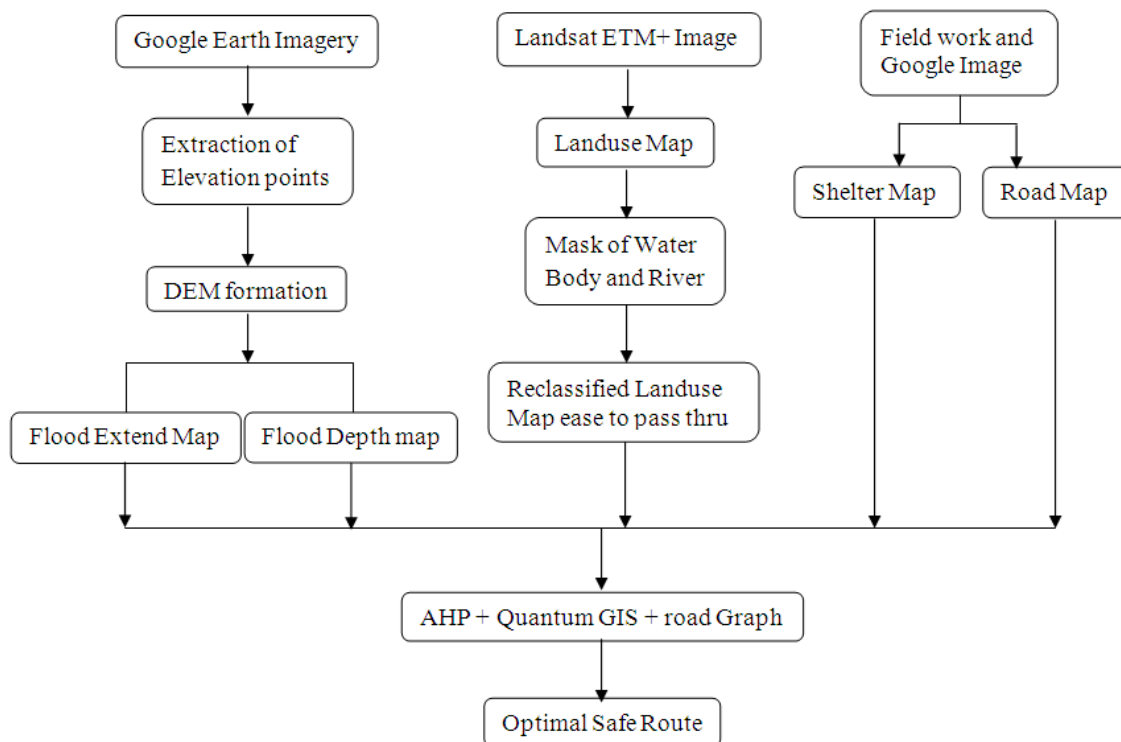


Figure 6.1 Safe route delineation

### **Analytical Hierarchical Process**

The concept of AHP was developed by Thomas L. Saaty in the year 1970 which has been extensively studied and refined during the decades. The AHP is a well structured technique for dealing with complex decision making processes. Rather than providing a particular definite decision or solution, the AHP helps the managers to find solution that best suits their requirements and their understanding of the problem (Saaty, 2008).

**Determination of Weights Using AHP:** In AHP, first process is to divide the problem into a hierarchy model of objects. These hierarchical orders or model helps to simplify the problem to understand and finding out a bottom up method to solve it more easily (Rahman and Saha 2008, Ouma et al. 2014). The weights of the elements are calculated at each hierarchical level. By considering the weights of criteria and available alternatives, the final goal can be achieved. Based on the AHP analysis, the parameter weights can be calculated for further processing. The procedure for using the AHP can be summarized as (Yang 2010): Model the problem as a hierarchy form which holds the decision goal. The criterion is used to evaluate the alternatives and the alternatives are used for reaching to the goal (Stefanidis and Stathis, 2013). Then by making a series of judgments which is based on pairwise comparisons of the elements, the priorities among the elements of hierarchy structure has been established.

To generate a set of overall priorities for the whole hierarchy, it is required to analyse these judgments and then assign them priority (Pawattana and Tripathi, 2008). Then the consistency of the judgments has been validated (later in this section). Based on the results of this process, the priority of all the parameters has been achieved. In this method, a weighted parameter model is constructed by considering road quality (length and width) and environmental factors (traversal speed, traffic volume and shelter zone). The parameters considered are: road length, road width, traversal speed, traffic volume and safe zone (higher altitude). These five parameters are selected for further analysis in AHP. The weights are taken as impedance, i.e. lower the impedance, more suitable are the option. AHP processing starts with modelling the problem as hierarchy in which overall goal of processing is considered as root and criterion are modeled as branches from that root (Aghataher et al. 2008, Siddayao et al. 2014). Similarly, all parameters towards obtaining

minimum travel time are considered here in the form of criteria and hierarchy is created as shown in the Figure 6.2.

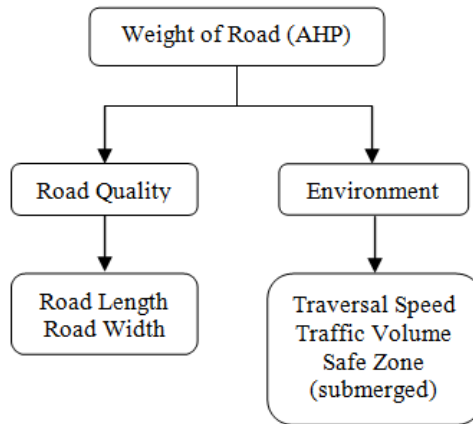


Figure 6.2 Hierarchy of weight factor

In AHP method, for obtaining priority vector of all criteria, pair-wise comparison is performed. Pair-wise comparison is done in order to compare the importance of one criterion on another. In Table 6.1, scales are defined to quantitatively evaluate the importance of one criterion over another (Saaty, 2008).

Table 6.1 Scales in pair-wise comparisons

Intensity of Importance	Definition
1	Equally Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance

The relative importance among these elements can be determined as shown in Table 6.2.

Table 6.2 Pair-wise importance of parameters

Parameter	Road Length	Traversal Speed	Safe Zone	Traffic Volume	Road Width
Road Length	1	3	4	5	6
Traversal Speed	1/3	1	3	4	5
Safe Zone	1/4	1/3	1	3	4
Traffic Volume	1/5	1/4	1/3	1	3
Road Width	1/6	1/5	1/4	1/3	1

Priorities of each factor are calculated by geometric mean method. The  $n^{\text{th}}$  root of the product of the values in each row is computed. Priority vector is the  $n^{\text{th}}$  root divided by the sum of the  $n^{\text{th}}$  root values. The consistency index and ratio can be calculated as equation (1) and (2) respectively.

$$\text{Consistency Index (CI)} = \frac{(\lambda_{\max} - n)}{(n - 1)} \quad (1)$$

$$\text{Consistency Ratio (CR)} = \frac{CI}{RI} \quad (2)$$

Where  $\lambda_{\max}$  is the maximum Eigen value of comparison matrix,  $n$  is number of criterion and R.I. is Random Index (Table 6.3). If C.R. < 0.1, then consistency is acceptable otherwise comparison matrix should be modified again until it reaches consistency criterion.

Table 6.3 Random Index for  $n=1,2,3,4,5$

n	1	2	3	4	5
R.I.	0	0	0.58	0.90	1.12

Priority vector of  $n$  criterion indicates the priority of each criterion toward final goal that is obtaining enhanced routing. Greater priority value indicated that a particular criterion is having greater contribution in achieving final goal. The integration of AHP with Dijkstra's algorithm has been done by combining priority value of road length factor with its real value to give modified distances in between two nodes.

Here AHP is using for finding the priority or the importance of these factors, which is further used for calculating the optimal path in next section. For safest route delineation during flood disaster, a fuzzy based system is developed which uses the AHP based weighted parameter model for finding the route. The web GIS can give the information on the basis of data input to the system. If high quality data is provided to the system then it will give a high quality results.

### **6.3 DECISION SUPPORT SYSTEM**

To support the business, groups, teams and organizational decision-making activities some specific class of computerized information systems are used, which are generally called as Decision Support Systems (DSS). A properly designed and implemented DSS should be an interactive system, which is used to assist decision makers/managers to compile useful information from raw data, documents, personal knowledge, business models or any other source to identify and solve the problems by providing a suitable decision making options (Alter, 1980, Levy 2005). Therefore a DSS can be expressed as an interactive computer based system that utilizes data and models to solve problems with varying degrees of structure and it supports decision makers by providing focuses on effectiveness of solutions in decision processes to make decisions more efficient (Asghar et al. 2010).

The spatial or geographic component plays a vital role to take decision in a spatial decision support system (SDSS). The SDSS provides computerized support for decision making in a location based system (Wu and Lin 2009, Asghar et al. 2010). Computer and software support for partial applications are provided by the systems based on GIS. Spatial applications represent an area of Information Technology which significantly recognizes the GIS as a computer system that facilitate the display and storage of spatial data; it also relates and integrates the spatial data with non-spatial (attribute) data. A GIS has an advanced data manager that performs queries based on spatial location (Asghar et al. 2010, Levy 2007). An interactive user interface allows the user to interact with this spatial database. It provides functionality like add, update, modify and delete of a spatial data. It also provides simple query like comparison of two data or searching a particular data, to a complex spatial data query like performing an operation on spatial data. A GIS can be distinguished with the SDSS from a simple map display program that lacks these query features.

The decision-making ability of these SDSS systems based on the spatial data sets, which was characterised and defined by GIS (Levy 2005, Binghu et al. 2010, Cheong 2012). There is a wide range of interests for spatial data in government and business activities. It includes the area of forestry, agriculture, urbanization, industry, mining and various developmental analyses. The other important area of GIS application is transportation (Ahmad and Simonovic 2006). It includes the design of transport infrastructure and in the

routing of vehicles that uses this infrastructure. GIS continues to grow in importance in various locations based fields and playing a central role in the emerging field of new services such as mobile information systems. There is tremendous potential in environment information systems with the GIS and spatial decision-making systems. It provides information for disaster mitigation and management.

Flood forecast has no value if the forecast information does not reach to the people at risk on time. It is extremely essential to convey this vital information to the disaster managers to take appropriate action on time. Flood forecast information must be acknowledged timely so that suitable decision can be made and the actions can be taken to reduce the impact of the impending event (Castellet et al. 2006). At the beginning of an event of flood disaster, the disaster managers ought to decide what should be the most appropriate response: food supply, evacuation of the population, health facility, rehabilitation, reinforcement of dykes, etc. A DSS should provide flood management and forecast information in an efficient, flexible and easily understandable manner to users and decision makers (Levy 2005, Bayraktar and Bayram 2009). Real-time flood forecasting systems, which links weather forecasts, river discharges and water levels, the state of the river catchment, can be integrated to respond to floods as they occur and it will help to reduce the loss of lives, property, livestock, agriculture and infrastructure (Taslina and Slobodan 2005, Asghar et al. 2010).

With the growth of technology in the area of Artificial Intelligence (AI), computer systems are more capable of demonstrating their capacity to support humans in area of creative and analytical thinking (Levy 2005, Chen et al. 2011). As the AI is becoming more complex; it provides highly efficient solutions to real world problems. AI is used in various areas to support the decision making process (Corani and Guariso 2005). In disaster management it plays a vital role for predicting the natural disaster (Ahmad and Simonovic 2011). Flood forecasting, heavy rain, high wind and cyclone/storm forecasting helps the disaster managers to prepare for the response. Integrating human knowledge with modeling tools, an intelligent fuzzy based decision support system is developed to assist decision makers to find short and safe route for evacuation during flood (DeSilva and Eglese 2000, Dou et al. 2012). Fuzzy logic is an effective method to handle vagueness. It takes imprecise observations as inputs and arrives at precise and crisp values for outputs (Kumat et al.

2007, Jiang et al. 2009). Also, the FIS involves a logical and simple way to build systems without using difficult and complex equations (Akter and Simonovic 2005, Sahoo et al. 2006). It formulates the mapping from a given input to an output using fuzzy logic by applying membership functions, fuzzy logic operators, if-then rules, aggregation and at last defuzzification.

**Weighted parameters:** In this study Road Length, Road Width, Traversal Speed, Traffic Volume and Safe Zone (Higher Altitude) are given as input to the Fuzzy Decision Support System for building the path model based on the minimum time consumption with safety. The output of the system is the shortest and the safe path.

#### **6.4 INTELLIGENT FUZZY BASED DECISION SUPPORT SYSTEM**

This Fuzzy Inference System (FIS) is developed in Matlab using Fuzzy Logic Toolbox. The fuzzy logic toolbox provides two types of FIS, that can be implemented as the: *Mamdani-type* and *Sugeno-type*. These two types of FIS vary in the way, they produce their outputs. Mamdani-type inference, expects the output membership functions to be fuzzy sets. Whereas, Sugeno-type systems are used to model any inference system in which the output membership functions are either linear or constant. Further, there are three different approaches applied here in this work for implementing FIS:

**1) Approach 1: Knowledge Base Modeling:** In this approach, FIS is implemented using expertise Knowledge. This modeling requires very deep understanding of input output relationship in each and every scenario. The knowledge base modeling allows the user to design its own membership functions MF's which includes: deciding number of MF's in each input variables, their shapes and also ranges of each membership function. User has freedom to build up their own if-then rules which decide the input output relationships. User can also decide the fuzzy logic operators such as [*min*, *max*] and select its own *implication*, *aggregation* and *de-fuzzification* methods. This type of modelling is applied to those systems whose rule structure is essentially predetermined by the user's explanation of the characteristics of each variable in the model. In overall, knowledge base modeling allows the user to customize the fuzzy inference process according to their application.

**2) Approach 2: Data Base Modeling:** Though knowledge base modeling provide freedom to the user to customize their own fuzzy inference process, still user faces many problems in deciding what parameters should be suitable for their application. But if the user is able to collect the previous data of their application then there is no more need to choose the parameters associated with a given MF arbitrarily. By applying various data modeling techniques, it can generate membership functions and rules automatically. Since FIS is modeled directly from data therefore this modeling is known as Data Base Modeling.

**3) Approach 3: Learning Base Modeling:** In some modeling scenarios, FIS generated from above two approaches gives insufficient or imprecise response due to slight variations in either expertise knowledge or in data values. Therefore to overcome these types of variations in the data values, FIS needs to undergo through training and learning process. Adaptive learning techniques, allows the fuzzy system to learn and extract information from the data they are modeling. Throughout the training, parameters associated with membership function changes and finally adapt the shape and parameter values that best allows the FIS to response in the approved manner.

In this work, Fuzzy Inference System is first implemented via all above mention different approaches, then results or decision of each approach has been compared and at last most appropriate decision has been projected out.

#### **6.4.1 Approach 1-Implementation of FIS Using Knowledge Base Modeling**

In this section; knowledge base modelling of FIS has been implemented in Matlab using fuzzy logic toolbox. The fuzzy logic toolbox is a collection of functions which is built on the Matlab computing environment and provides a variety of functionality. It provides an easy way to construct and modify the FIS. Thus, the user has the freedom to design and customize the system according to their requirements.

Figure 6.3 shows the five basic GUI tools for building, editing, and observing FIS using the fuzzy logic toolbox: the FIS Editor, the MF Editor, the Rule Editor, the Rule Viewer, and the Surface Viewer. All these GUIs are dynamically linked to each other, so that

changes made in one part of FIS, will affect the whole FIS system and reflects simultaneously.

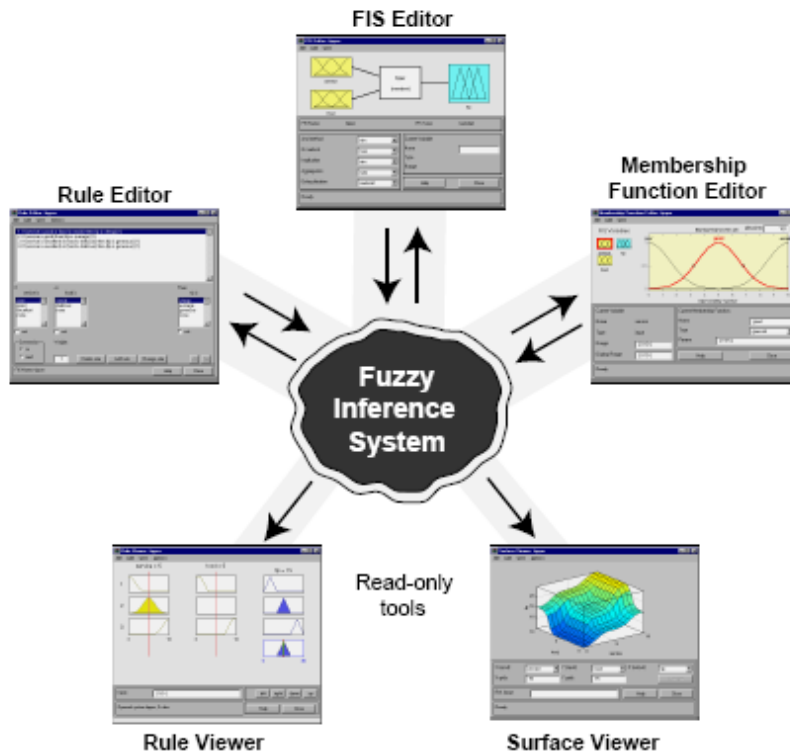


Figure 6.3 Fuzzy Inference Systems (FIS)

**FIS Editor:** In fuzzy logic toolbox, the FIS Editor has been used to construct the fuzzy inference systems. The FIS Editor handles the high-level issues such as the number of input and output variables, fuzzy implication, fuzzy inference, defuzzification method and displays explicit information about input-output to the system. GUI of FIS Editor shown in Figure 6.4 can be opened using the *Fuzzy* command in the Matlab command window. The FIS can be defined by two methods or it can be said as two types of FIS as the default, Mamdani-type inference system, and the other is Sugeno-Type fuzzy inference system. In this study the Mamdani type FIS has been selected, as the output of this system will not be a fixed value. To define the number of inputs and output variables, the Add Variables or remove selected variables in the Edit menu allows to add or remove the input and output variables. There are total five input variables are defined in this study. This model has

selected 5 input variables: *Road Length*, *Road Width*, *Traversal Speed*, *Traffic Volume* and *Safe Zone* and 1 output variable: named as '*Weight*' that refers to load or hindrance or obstruction (in the shortest route).

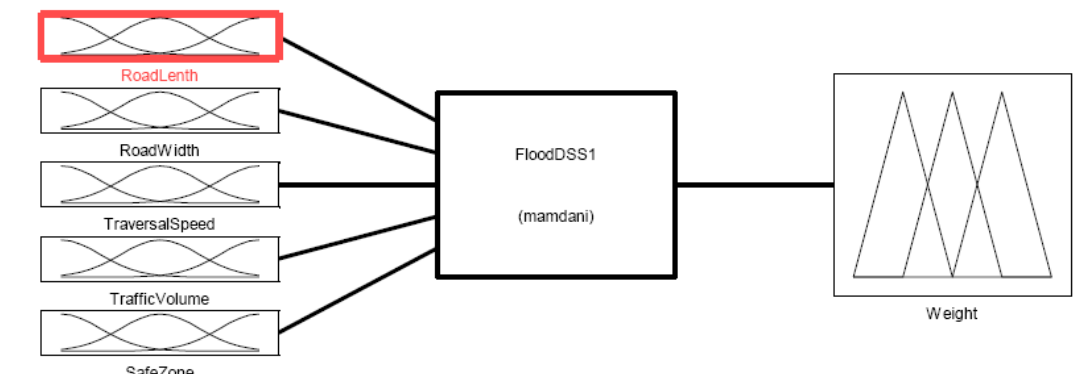


Figure 6.4 Input –Output of Fuzzy Inference System

Next, the FIS is required to define the Fuzzy operators, implication, aggregation and defuzzification methods. In this FIS AND operator is used with min value and OR operator is used with max value. The MIN function is selected for Rule implication, MAX function is selected for aggregation and the centroid method is applied for defuzzification. Then the membership function for each variable has been defined in MF Editor GUI.

**Membership Function Editor:** The MF Editor is a tool that display and define the shapes of all the MFs associated with all of the inputs and output variables for the entire FIS. From the Edit menu list in the FIS editor, the Membership Functions can be selected as shown in Figure 6.5. It is used to define the shape and range of each MF associated with each input/output variable. Properties of membership functions can edit by using this editor. Also it provides to add as many as MF's to each input by clicking on 'Add MF' from the edit pull down menu.

Figure 6.5 shows the MF's plots for output variable Weight. As it is clearly seen in the plot, that variables are divided into three ranges defined by linguistic variables: Low, Medium and High. Further, Z-shaped MF is selected for Low, Trapezoidal- shaped for Medium and for High range S-shaped MF is selected for FIS. In the same manner MF's for

other input variables are set with the three types of ranges. After defining the MF's, the composite rules for the system are defined with the help of Rule Editor.

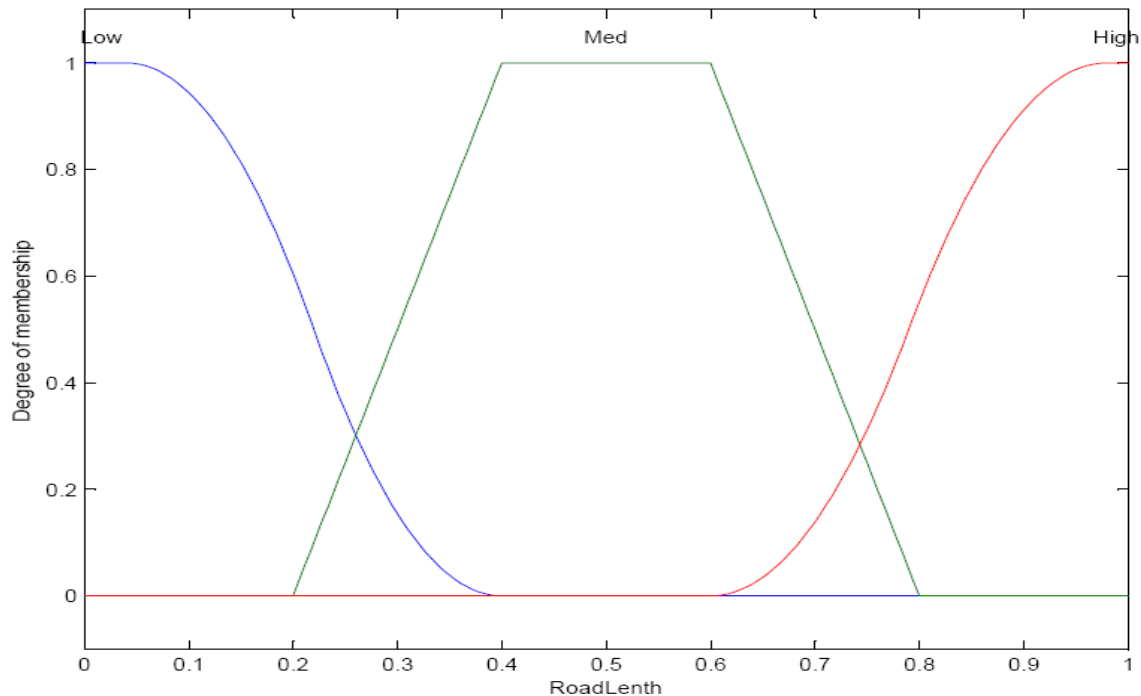


Figure 6.5 Membership Function Editor for Input Variable Road Length

**Rule Editor:** The list of rules can be edited by using this Rule Editor, which defines the behaviour of the system (Figure 6.6). This Rule Editor provides GUI to construct If-then statements. The ‘if-part’ of the rule is called the antecedent or premise, while the ‘then-part’ of the rule is called the consequent or conclusion.

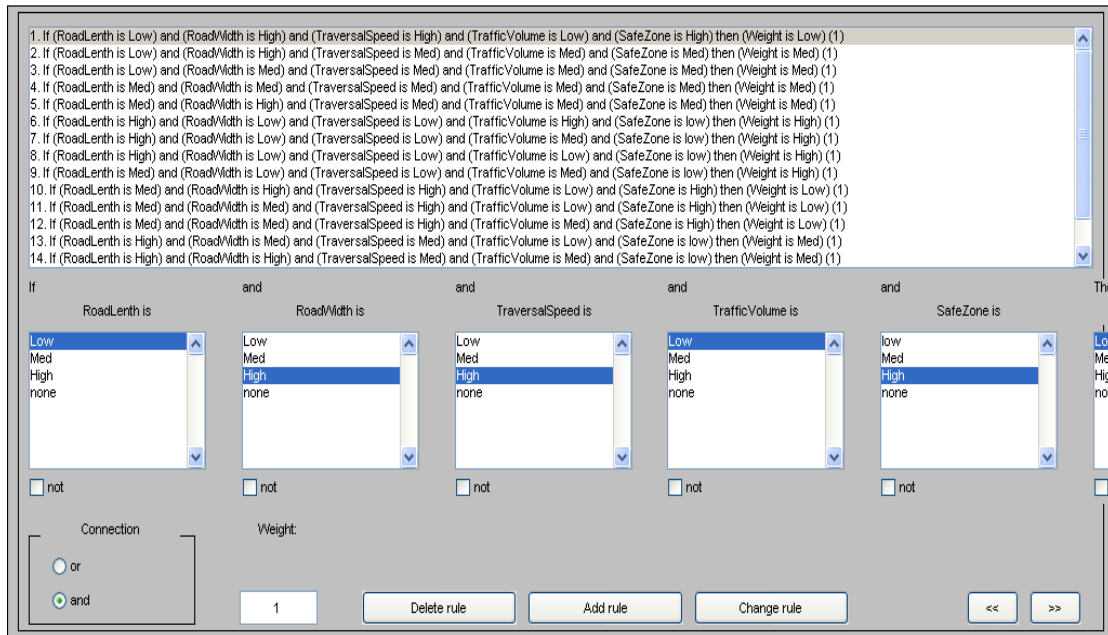


Figure 6.6 Rule Editor GUI

Antecedent of the rule has fuzzy logic operator to combine all input variables to a single number between 0 and 1 (for Normalized form). This is the degree of support for the rule and is known as rule composition. The consequent specifies a fuzzy set to be assigned to the output and is known as rule implication. The implication function modifies that fuzzy set, to the degree specified by the antecedent. An example of such a rule is:

If (RoadLenth is Low) and (RoadWldth is High) and (TraversalSpeed is High) and (TrafficVolume is Low) and (SafeZone is High) then (Weight is Low)

There are 243 rules have been constructed to covering all possible combinations of MF's of each input variable. Some rules are shown in Figure 6.7. The last column of rule viewer represents weight, which signifies the degree of hindrance or impedance to follow the criteria. It means higher the weight (impedance), lower the priority. These weights signify the importance of that rule while calculating the output. Weights can be specified by assigning a desired number between zero and one under the Weight setting. All values are in normalized form. Rules with lesser weights will count for less in the final output. If the weights are not specified at the rule editor then the weights are assumed to be unity (1).

As the above mention method completely defines the FIS, with variables, MFs, and the rules that are necessary to calculate safe route. Now, to verify the FIS that everything is behaving the way as it was specified or intend to response; there is a tool called ‘View Rules’, which shows the behaviour of the FIS.

**Rule Viewer:** The Rule Viewer is perfect tool to display the FIS. It is also used as a diagnostic tool, because it can show which rules are active, or how individual MF characters are influence the results. This is strictly a read-only tool. The Rule Viewer displays all the information in one screen, i.e. all parts of the fuzzy inference process from inputs to output are depicted all together as in Figure 6.7.

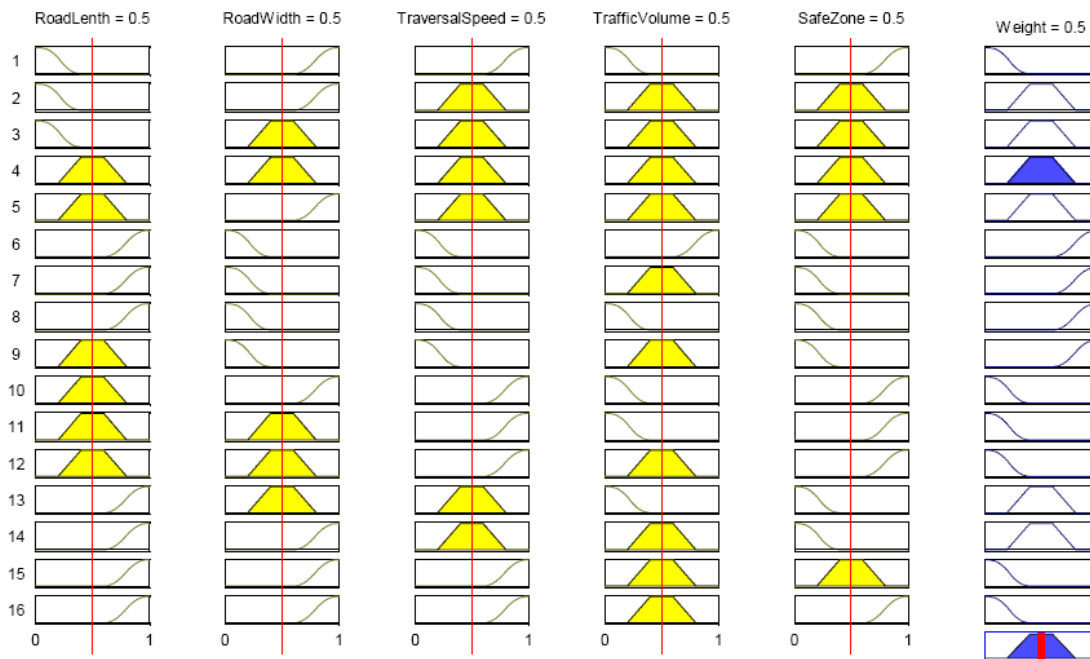


Figure 6.7 Rule Viewer that simulates the entire fuzzy inference process

Each row of plots in Figure 6.7 corresponds to one rule, and each column (first five columns) corresponds to membership function plots of each input variables referenced by the antecedent, or the if-part of each rule. The last column represents the output variable MF referenced by the consequent, or the then-part of each rule. The yellow colour under the membership function curves determines the degree to which the rule is activated and it is used to construct the fuzzy membership function visually apparent. This is known as input fuzzification. The blue colour in the last column represents the rule implication. The aggregation of all the input variables occurs at the last column as an output variable, and

the resultant aggregate plot of whole process is shown as the single plot in the lower right corner of the last column or plot field. The defuzzified output value is shown by the thick red line passing through the aggregate (blue colour) fuzzy set.

The red index line in the middle of each (of first five) column, indicates the input value of that variable given to the system. The systems output for any input combinations can be checked by sliding this red index line. Also on the top of each column selected input value of that particular variable is displayed. For ex: In this screen shot it can be seen that: Road Length = 0.5, Road Width = 0.5, Travel Speed = 0.5, Travel Volume=0.5 and Safe Zone=0.5. It can be easily seen in the Figure 6.7 that output comes out for this input variable is Weight = 0.5.

Entire fuzzy inference process can be interpreted at once by the help of Rule Viewer tool. The results of a FIS are highly dependent on the shape of a membership function. How the shape of a certain MF influences the overall result; it can be understand through the rule viewer,. The Rule Viewer shows one calculation at a time with proper detail. It can be said that it represents a sort of micro view of the whole FIS process.

**Surface Viewer:** The output of the FIS to the inputs can be plotted against the inputs as a surface by using surface viewer tool. It helps to understand the behaviour of the FIS. Surface viewer is a read-only editor. The Surface Viewer can generate a three-dimensional output surface, where any two of the inputs can vary. But in this research work, there are five input variables, so it is not possible to show here the surface viewer for the five inputs parameters. As the five main contents of a FIS have been discussed above, this concludes the brief description of fuzzy system involved in this work.

#### **6.4.2 Approach 2-Implementation of FIS using Data Base Modeling**

The implementation of Data Base modeling using fuzzy clustering is discussed in this section. Clustering of numerical data forms is the basis of many classification system algorithms. Clustering can be a very effective technique to identify natural groupings of data from a large data set to produce a crisp representation of a system's behaviour. Clustering and fuzzy logic together provide a simple yet powerful way to model the

evacuation route problem during flood. The Fuzzy Logic Toolbox has some tools that allow user to find clusters in input-output training data. This cluster information is used to generate a Sugeno-type FIS that best models the behaviour of data, using minimum number of rules. The fuzzy character associated with each of the data cluster helps to define the partition characteristics of each cluster. Further, clustering can be of two types:

a) **Fuzzy c-means (FCM)** is a data clustering method in which each data point belongs to a cluster to some extent which is specified by a membership grade. It is a technique that shows how to group the data points that occupy same multidimensional space into a specific number of different clusters.

b) **Subtractive clustering** is a one-pass algorithm to assess the number of clusters and their cluster centres in a data set. It is applied when there is no clear idea about how many clusters there should be for a given set of data. The number of clusters obtained from the subtractive clustering method has been used further to initialize the iterative optimization-based clustering methods (FCM) and to use with model identification methods (ANFIS).

In this work, since it is quite difficult to calculate the number of clusters in data set, therefore Subtractive clustering method has been applied here which estimates number of clusters in the data set. Then fuzzy logic has been employed to capture the broad categories identified during clustering into FIS. Then the FIS will act as a model that will reflect the relationship between all the input parameters and output parameter i.e. safe route. Here weighted parameters: *Road Length, Road Width, Traversal Speed, Traffic Volume and Safe Zone (Higher Altitude)* are given as input to FIS for building the path model based on the minimum time consumption with safety. The output of the system is expected to be the shortest and the safe path denoted by variable '*Weight*' it reflects the degree of hindrance in that route. Higher the weight or impedance, lower the preference.

Various steps involved in this implementation are as under:

### **Step 1. Loading Data**

Load the input and output variables (*datin* and *datout* respectively) into the workspace. Variable *datin* has 5 columns representing the 5 input variables (*Road Length, Road Width, Traversal Speed, Traffic Volume and Safe Zone*) and *datout* has 1 column representing the

1 output variable (Weight or impedance). The data sets have been prepared based on the experiences and general logics by assuming the various ranges to different parameters: Road Length to be in range [34 994] (meter), Road Width [2 19] (feet), Traversal Speed [1 4] (m/s), Traffic Volume [19 978] (no. of vehicle in road length), Safe Zone [54 94] (weight based on distance, capacity, elevation and facility) and Impedance [31 94] (normalized value). All the data is normalized between [0 1]. Few samples of normalized data are as shown in Table 6.4 below:

Table 6.4 Sample of Data Set

<i>datin</i>					<i>datout</i>
<i>Road Length</i>	<i>Road Width</i>	<i>Traversal Speed</i>	<i>Traffic Volume</i>	<i>Safe Zone</i>	<i>Impedance</i>
0.804	0.15	0.4	0.309	0.268	0.65
0.699	0.08	0.1	0.787	0.728	0.91
0.994	0.14	0.4	0.794	0.892	0.94
0.585	0.19	0.3	0.557	0.509	0.54
0.67	0.14	0.2	0.161	0.553	0.48
0.403	0.03	0.3	0.058	0.88	0.73
0.094	0.06	0.4	0.3	0.456	0.48
0.068	0.15	0.3	0.047	0.099	0.31
0.393	0.07	0.3	0.908	0.482	0.67
0.233	0.15	0.2	0.287	0.112	0.42

The various inputs are given to the system and the corresponding output of the system that is the impedance occur in that route is shown as the graph as in the Figure 6.8.

The x-axis shows the number of rows or the particular event i.e. a specific road. All the five parameters corresponding to that road is depicted simultaneously as input variables. The Blue, Green, Red, Cyan and Purple colour represents the five parameters i.e. Road Length, Road Width, Traversal Speed, Traffic Volume and Safe Zone respectively. The y-axis represents the Normalized value corresponding to each parameter and for each event (road). All the parameters are calculated in a normalized value form. The output variable i.e Impedance (weight) is shown in Dark Blue colour. It shows the output of corresponding five input parameters. A column in input constitutes a set of observed values of the 5 input variables (*Road Length, Road Width, Traversal Speed, Traffic Volume and Safe Zone*) and the corresponding column in output plot represents the observed value for the *Impedance* generated by the observations made from the input variables.

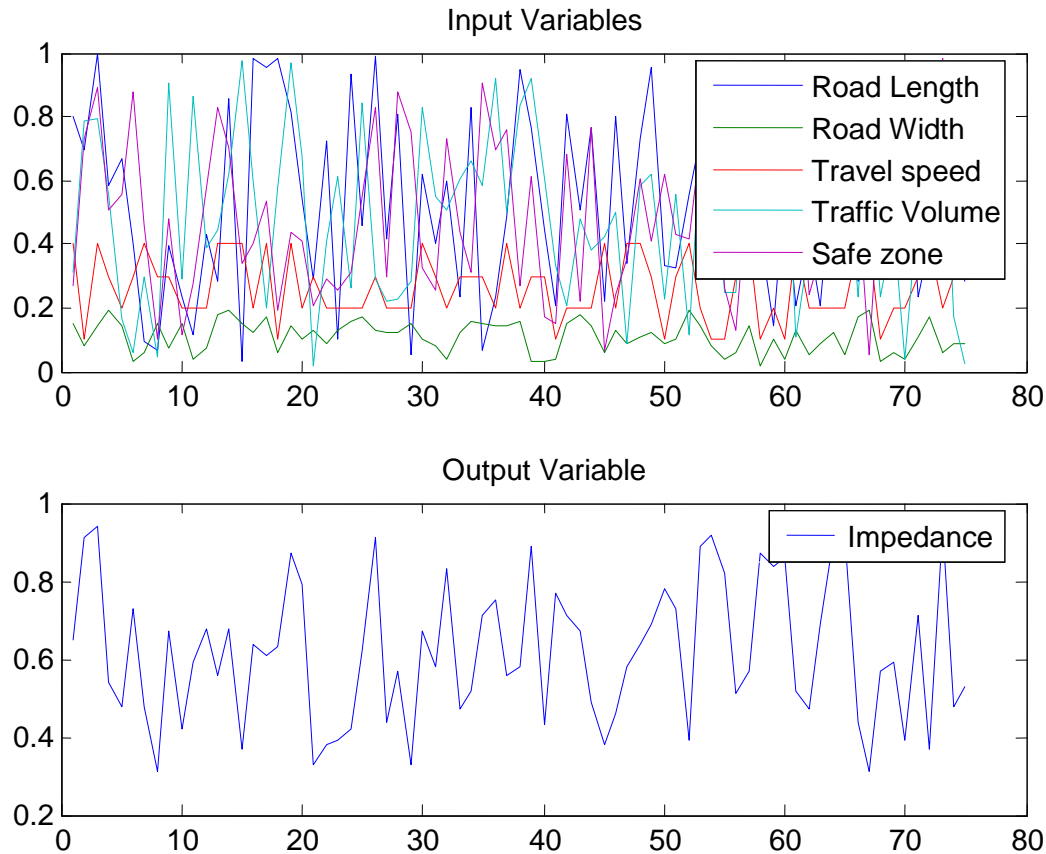


Figure 6.8 Graph of Output data corresponding to the Input Data Sets

Now the subtractive clustering has been applied on the data to find cluster centers and to model the relationship between the input and the output variables. The cluster centers will be used as a base to define FIS, which will further be used to explore and understand the route evacuation problem.

### Step 2. Clustering the Data

Subtractive clustering (SC method) of the data has been done using Matlab inbuilt function ‘*Subclust*’. It is used to estimate the cluster centres created in a data-set by applying the subtractive clustering method. The SC method assumes each data point as a potential cluster center. It determines the likelihood of each data point to become cluster centre on the basis of density of surrounding data points. There is an algorithm to define this process:

- First it selects the data point with the highest potential to be the first cluster center.
- Then it removes all the data points in the vicinity of first cluster center (as determined by radii), in order to determine the next data cluster and its center location.

- Iterates the above two steps of this process until all of the data comes under radii of a cluster center.

This function drive to find an optimal data point as a cluster center which is based on the density of nearby data points. All those data points enclosed within the distance of the radii of this center point are removed. To find the next data cluster and its center, this process is repeated until all of the data is processed.

The Matlab command used for clustering the data is

$$[C, S] = \text{subclust}([datin\ datout], \text{Radii});$$

The first argument in the command is the data to be clustered and the second argument to the function is the radii, which specifies the size of the cluster in each of the data dimensions in the input space. Radii has a value between 0 and 1 assuming the data falls within a unit hyperbox (range [0 1]).

The variable C holds all the centres of the clusters which have been identified by function *Subclust*. This function returns cluster centers in the form of matrix C; where each row of C contains the position of a cluster center. The resultant Matrix C is of size (61-by-6). It indicates that 61 clusters are formed for each of the 6 data set dimensions (5 input points and 1 output) when radii is set to value 0.5.

The other variable S holds sigma values that specify the range of influence of a cluster center in each of the data dimensions. Since all cluster centers share the same set of sigma values, so Matrix S is of size (1-by-6).

Graphical visualization of the formation of clusters in any selected input data and the output dimension can be represented as in Figure 6.9 shows: how the clusters have been identified in the 'Road Width' and 'Weight' (Impedance) dimensions of the data space.

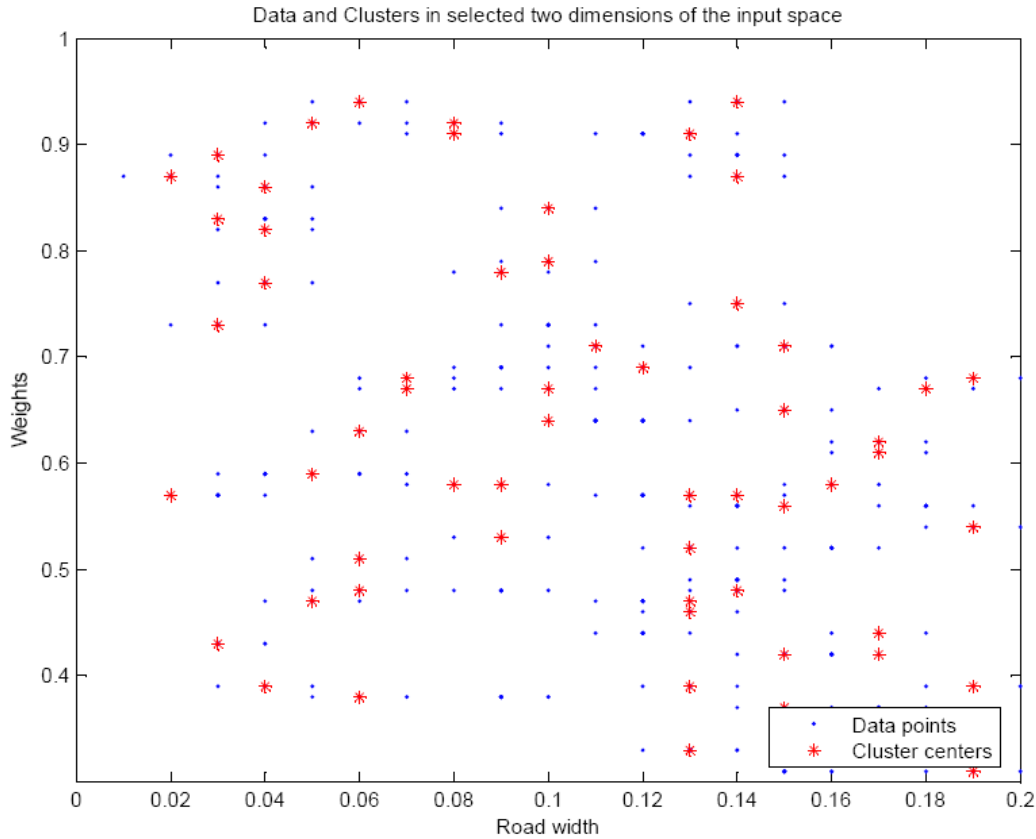


Figure 6.9 Cluster centers in the 'Road Width' and 'Weight' dimensions of the data space.

### Step 3. Generating the Fuzzy Inference System (FIS)

With the help of cluster centers and their range of influence obtained during subtractive clustering in step 2, another inbuilt function 'genfis2' generates a Sugeno-type FIS automatically. The function 'genfis2' performs the extraction of set of rules that models the data behaviour. The 'Subclust' function is used to determine the number of rules and antecedent MF. It then uses the linear least squares method to determine each rule's consequent equations. The outcome FIS is then used to explore and understand the route model. The Matlab command used for generating FIS is:

```
myfis =genfis2(datin,datout,radii)
```

'genfis2' is a rapid, one-pass method that does not perform any iterative optimization. The first argument is the input variables matrix, the second argument is the output variables matrix and the third argument is the radii that should be same as was used while using sub-clustering. The matrices 'datin' and 'datout' have one column per FIS input and output,

respectively. Radii define the range of cluster center. Smaller radius yields large number of clusters with smaller size of data and hence generates more rules. The generated FIS is stored and named as 'sug51' and the variable as 'myfis'.

#### **Step 4 Analysis of generated FIS**

As it is already discussed in previous section that the FIS is composed of three main things: inputs, outputs and rules. Each input and output variable may be able to have any number of MFs. The rules define the behaviour of the fuzzy system based on inputs, outputs and MFs. The function 'genfis2' attempts to constructs the FIS based on the cluster method.

Since the dataset has five input variables and one output variable, the function *genfis2* constructs a FIS with five inputs and one output. Each input and output has as many MFs as the number of clusters identified by sub-clustering. Also, number of clusters depends on the radii of the cluster. Lesser the radii selected more number of clusters will formed. Further, the number of rules is equals to the number of clusters.

To understand, how the clusters got converted internally into membership functions and rules, sug51.fis generated in step 3, can be explored and analyzed by calling each FIS GUI Tool through following commands:

fuzzy(myfis);	for FIS editor
mfedit(myfis);	for MF editor
ruleedit(myfis);	for Rule editor
surfview(myfis);	for Surface viewer
ruleview(myfis);	for Rule viewer

There are 61 rules generated through clustering approach. Each rule, attempts to map a cluster in the input space, to a cluster in the output space. Some of the rules are shown below:

1. If (Road Length is in1mf1) and (Road Width is in2mf1) and (Traversal speed is in3mf1) and (Traffic Volume is in4mf1) and (safe zone is in5mf1) then (Weight is out1mf1) (1)

2. If (Road Length is in1mf2) and (Road Width is in2mf2) and (Traversal speed is in3mf2) and (Traffic Volume is in4mf2) and (safe zone is in5mf2) then (Weight is out1mf2) (1)

3. If (Road Length is in1mf3) and (Road Width is in2mf3) and (Traversal speed is in3mf3) and (Traffic Volume is in4mf3) and (safe zone is in5mf3) then (Weight is out1mf3) (1)

4. If (Road Length is in1mf4) and (Road Width is in2mf4) and (Traversal speed is in3mf4) and (Traffic Volume is in4mf4) and (safe zone is in5mf4) then (Weight is out1mf4) (1)

5. If (Road Length is in1mf5) and (Road Width is in2mf5) and (Traversal speed is in3mf5) and (Traffic Volume is in4mf5) and (safe zone is in5mf5) then (Weight is out1mf5) (1)

The first rule can be explained as: If the inputs to the FIS: *Road Length, Road Width, Traversal Speed, Traffic Volume and Safe Zone*, strongly belong to their respective cluster-1 MFs then the output, *Weight (Impedance)*, must strongly belong to its cluster-1 MF. The (1) at the end of the rule is to indicate that the rule has a weight or an importance of the degree of '1'. The significance of the rule is that it maps cluster 1 in the input space to cluster 1 in the output space. Similarly second and third rule maps cluster 2 and cluster 3 in the input space to cluster 2 and cluster 3 in the output space respectively. If a data point having strong membership to the first cluster or in other words, closer to the first cluster, is fed as input to myfis then rule 1 will fire with more firing strength than the other rules. In the same way, an input with strong membership to the third cluster will fire the third rule with more firing strength than the other rules.

The outputs of the rules (based on firing strengths) are then used to generate the final output of the FIS through the output MFs. The output of the FIS, *Weight (Impedance)*, has 61 linear MFs representing the 61 clusters identified by sub clustering. Those coefficients of the linear MFs that are not taken directly from the cluster centers are estimated from the dataset using least squares estimation technique.

Due to the fact that the distance from the safe zone is a key factor for the rescue operation, the weight is more dependent on the road length and less dependent on the road width. The weight is influenced by the road width upto a limited extent, because for walking purpose the value for road width parameter is not very high.

The `genfis2` can be used as a stand-alone and it is a fast method for generating a fuzzy model from data. The clustering method provides more customized rules set to the input data than without clustering. This process reduces the problem of combinatorial explosion of rules when the input data has a high dimension.

This method applied for the route evacuation problem, output of the fuzzy system matches to expected value to a degree of 91% to 97%. Thus it can be seen that though clustering and fuzzy logic are effective techniques for data modeling and analysis but still optimization of result is required. For this, fine tuning of membership functions is required which can be done through learning base modeling.

### **6.4.3 Approach 3-Implementation of FIS using Learning Base Modeling**

In this section, Adaptive Neuro-Fuzzy Inference System (ANFIS) is discussed and implemented. To compute the best suited MF parameters for the associated FIS the ANFIS provides a method for the fuzzy modeling procedure to learn information about a data set. In this study, ANFIS constructs a FIS by using the input/output data set whose MF parameters are tuned by using either a back propagation algorithm alone or in combination with a least square type of method. The modeling approach performed by the ANFIS is: it first, needs to relate inputs to MFs, MFs to rules, rules to outputs, outputs to MFs, and so on. Next to collect input/output data in a form that can be utilizable by ANFIS for training. At last ANFIS is used to train the FIS model to emulate the training data presented to it. The MF parameters can modify according to a chosen error criterion, as in this study it is chosen as zero error (minimum). The performance of FIS with its data can be measure by using a gradient vector. This gradient vector is used to optimize the FIS modeling parameters. By obtaining the gradient vector, any of several optimization routines could be applied optimally in order to adjust the parameters and to reduce error measure which is as the sum of the squared difference between actual and desired outputs. Here ANFIS uses the combination of both least squares estimation and back propagation for MF parameter estimation. This whole approach involves various steps as discussed below:

### **Step 1. Collection of Data Sets**

A Decision Support System for various activities, is required to integrate with the web GIS to accomplish the task. The web GIS can give the information on the basis of data input to the system. If high quality data is provided to the system then it will give a high quality results. It is found that ANFIS is for very large data and uses neural network and fuzzy for producing the result. So if a large and accurate data is available than the ANFIS is working well for the requirement. Thus collecting a finer data set is vital.

After collecting the data it is first divided into three different data sets: training, testing and checking.

#### **a) Training Data**

As ANFIS is an adaptive process it requires the training data (trnData) as an argument. Each row of trnData is a desired input/output pair to the FIS modeling of the system. Every row starts with an input vector and is followed by an output value. Therefore the number of rows of trnData is equal to the number of training data pairs. Consequently the number of columns of trnData is equal to the number of inputs plus one as there is only one output. The training data contains 500 different structures. Some assumptions are also considered for the proper execution of system and to obtain the required output results. The whole system depends on the training data. The accuracy and correctness of the results depends on training data.

#### **b) Checking Data**

The checking data set (chkData) helps with model over fitting during the training. Over fitting has been countered checked by testing the FIS against the checking data. And if there are errors that indicate model over fitting then the minimum checking error has been chosen for the MF parameters. The checking data has same format as of training data. The checking data is important for learning tasks for which the input number is large, and/or the data itself is noisy. This data set is used to cross validate the fuzzy inference model.

#### **c) Testing Data**

Through the testing data set the data can check the capability of the resulting FIS. Testing data set has also the same format as that of training data set but the combination of values

of all input variable must be distinct from those of the training data. This data set is optional for the system.

All the collected data sets are required to be stored separately into workspace in .dat file format.

## Step 2. Loading Data

In this step, all the three stored data sets (.dat files) are to be loaded into the ANFIS Editor GUI from the workspace (Figure 6.10). The ANFIS Editor has been used by the ‘anfisedit’ command. This GUI provides facilities for loading data and generating FIS as shown in Figure 6.10:

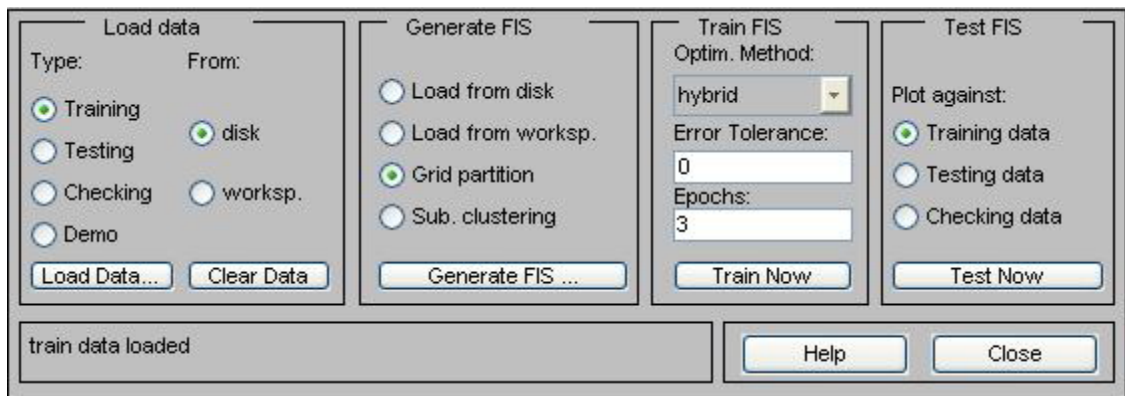


Figure: 6.10 ANFIS GUI Window

The training data appears as a set of circles (ooo) in blue colour in the GUI plot as shown in Figure 6.11. It can be seen that training data has very wide distribution and the centre of cluster points are very random so it can be concluded that the system is able to perform on a wide range of parameters values. The x-axis shows the different pattern and structure of data sets i.e. the roads resultant impedance (weight) in normalized form and the y-axis shows the normalized values of these variables between 0-1.

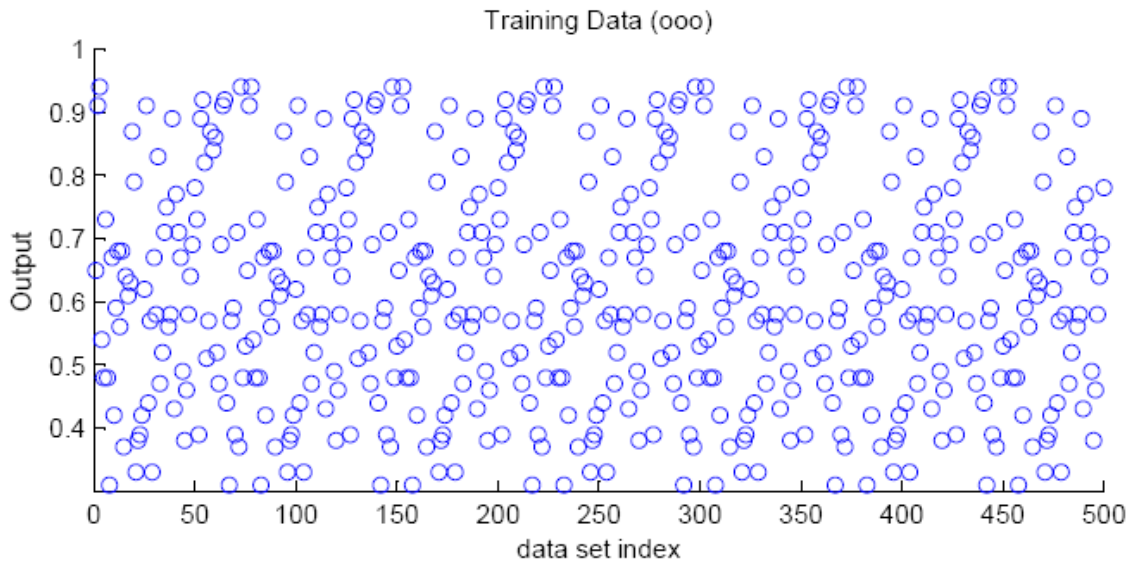


Figure 6.11 Training Data Set

In the same manner the Checking data set has been also test by the ANFIS GUI tool. Checking check box of the Load data portion provide the functionality to test the Checking data set. The chkdata loaded from workspace appeared as pluses (+++) in the GUI plot and it is superimposed on the training data (Figure 6.12). There are 75 different data-sets have been used for this purpose. It is observed that most of the pluses (+++) are near the testing data-sets. So it can be said that the system performs well for checking data-sets.

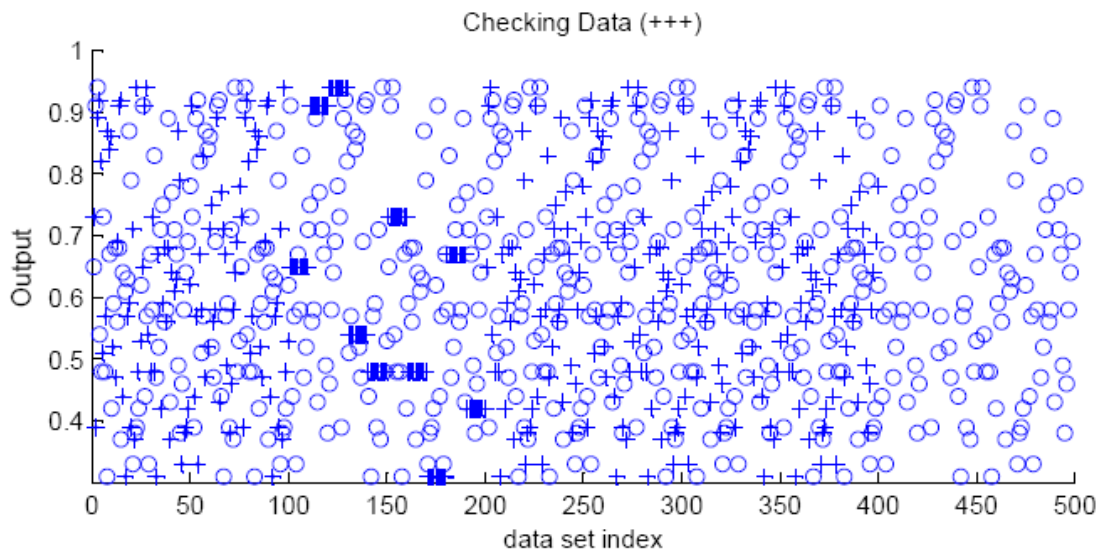


Figure 6.12 Training Data Set Vs Checking Data Set

Loading of testing data is optional. To test the system, load the testing data also by selecting the testing checkbox (Figure 6.13). The testing data-sets are represented by dots (...) in blue colour. It is observed that most of the testing data is very near to the training data-sets. So the system can give required results on the basis of training data-sets.

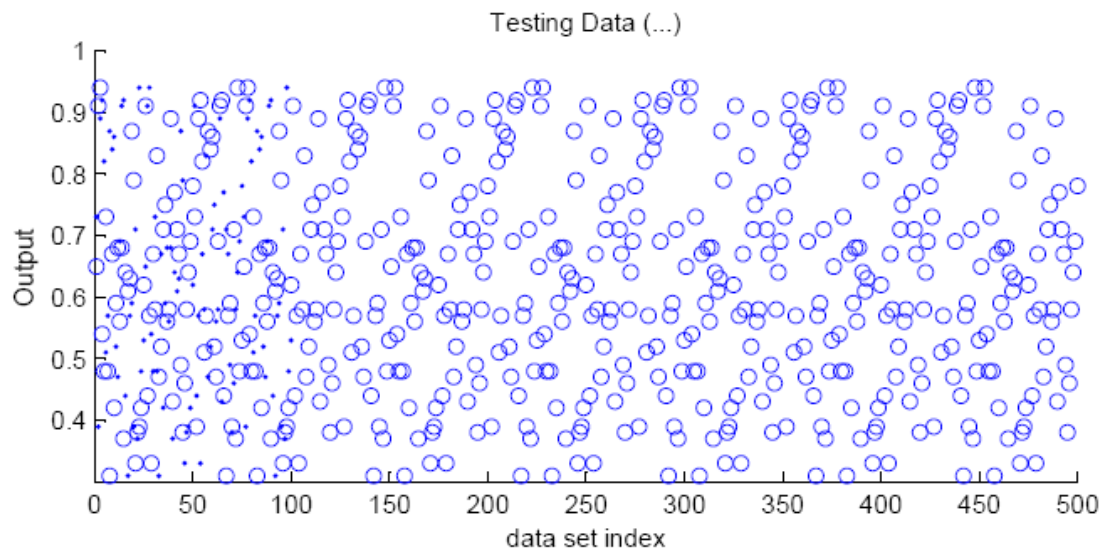


Figure 6.13 Training Data Set Vs Testing Data Set

### Step 3. Generating Initial FIS

Before we start the ANFIS training, we have to specify initial FIS parameters. To initialize the FIS parameters, we can either load the initial FIS file from the disk or workspace or the initial FIS can be generated using grid partition or sub clustering methods. As already discussed in previous section, for fine tuning of Membership Functions of FIS developed in approach 2, we have to initialize our ANFIS with this FIS only.

### Step 4. Viewing FIS Structure

After generating the initial FIS, the model structure can be viewed by clicking the Structure button. Structure of the Sugeno model is designed in such a way that the input data is mapped to input MF, then this input MF is mapped to rule, then the rule is mapped to the output MF and at last this output MF is mapped to the output. Thus the system takes five layers. Each node in the first layer generates a membership grade. Each node in the second layer calculates the firing strength of the rule. Each node in the third layer calculates the ratio of the  $i^{\text{th}}$  rule's firing strength to the total of all firing strength. Each node in the fourth layer is an adaptive node which maps to the output MF. The overall

output has been given by the node in the fifth layer. This configuration is shown in Figure 6.14

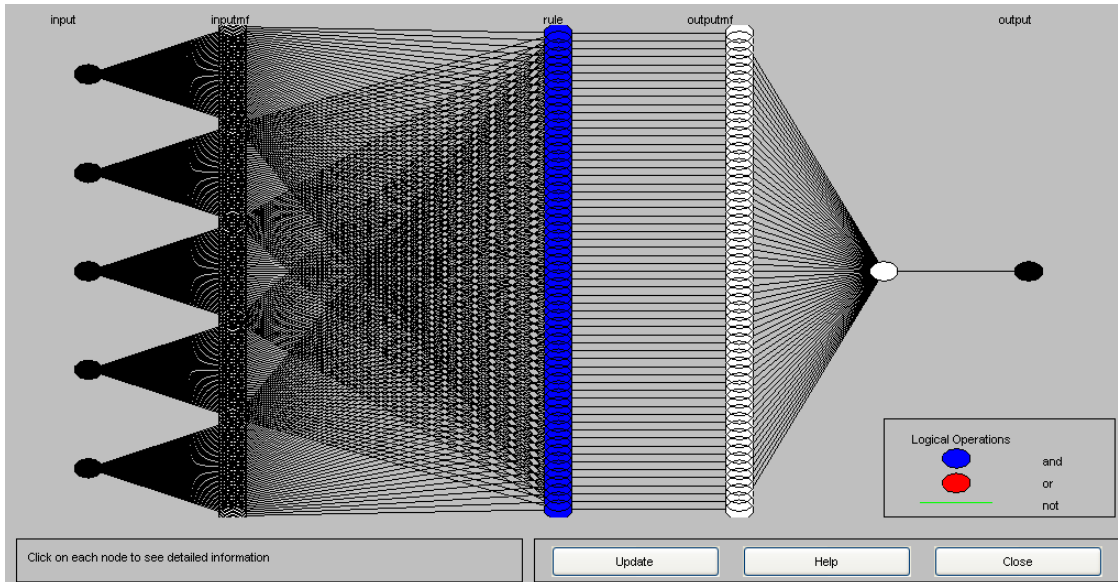


Figure 6.14 ANFIS Model Structure

### Step 5. Training the ANFIS

Training of ANFIS is the most important step in this approach. It is a learning process of a developed model. The model is trained till the results are obtained with minimum error. To design an ANFIS system for real world problems, it is essential to select the parameters for the training process. It is essential to have proper training and testing data sets. If the datasets are not selected properly, then the testing data set will not validate the model. If the testing data set is completely different from the training dataset, then the model cannot capture any of the features of the testing data. Then, the minimum testing error can be achieved in the first epoch. For the proper data set, the testing error decreases with the training proceeding until a jump point. Over fitting occurs when the training passes that point. The optimization methods are used to learn about the training data. During the learning process, the parameters of the MFs are updated.

#### a) Selecting optimization method:

For FIS training, there are two ANFIS parameter optimization methods. The first one is hybrid learning and the other is back propagation method. The hybrid learning method have been selected for this study.

**Hybrid learning:** The hybrid optimization method is a combination of least-squares and back propagation gradient descent method. There are two steps in Hybrid learning algorithm. Forward pass and the Backward pass. In the forward pass, premise parameters are fixed and least square method is used to update the consequent parameters. Similar way in the backward pass, consequent parameters are fixed and back propagation gradient descent method is used to update the premise parameters. By repeating the forward and backward passes, the premise and consequent parameters are identified for the FIS system. In the training part, hybrid optimization method is faster and has closest results than the back propagation gradient descent optimization method.

**b) Setting Error Tolerance:**

The Error Tolerance is used to create a stopping criterion for training process. It is related to the acceptable size of error. This is the criteria to stop the training after the training data error remains within this tolerance or within the limits of permissible error. Here it is set to 0 as it is unknown how to training error is going to behave.

**c) Setting No. of Epochs:**

It is the frequency to train the model. The number of training epochs is set to 40.

Training of ANFIS system with the training data set is shown in the Figure 6.15. This training adjusts the MF parameters and plots the training (and/or checking data) error plot(s) in the plot region. The training process stops whenever the maximum epoch number is reached or the training error goal is achieved. It is shown in Figure 6.15 that the error in training data is reached to  $4.8 \times 10^{-4}$  because the error tolerance was set to zero for this data set. The training-error is the difference between the training data output value and the output of the FIS corresponding to the same training data input value. The training error records the root mean squared error (RMSE) of the training data set at each epoch.

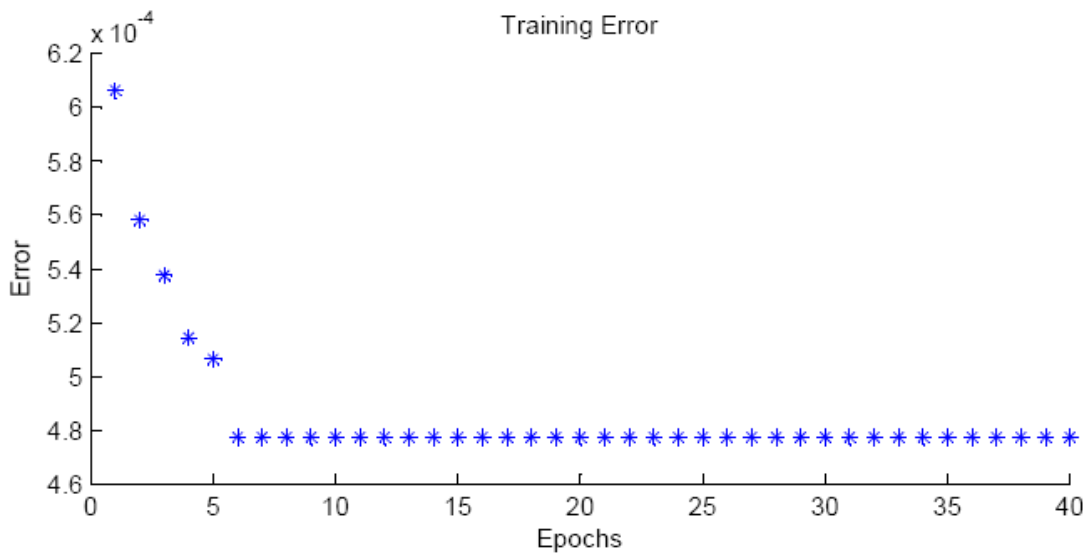


Figure 6.15: The training error versus epochs curve

**Step 6. Testing Trained FIS against Data / Validating the Trained ANFIS:**

In general, it is expected that the data collected for training data set must represent full features for the intended MF parameters to establish correct model. But it is not always certain that the data collected is free of noise or any error, therefore it requires model validation to achieve the perfection.

For model validation process, the input vectors from input/output data sets, certainly those data sets, on which this FIS was not trained, are presented to the trained FIS model. It is the way to understand the behaviour of FIS model to the new data set and than to analyse the corresponding output values.

FIS model output is to be tested against all the three data sets one by one. For example: To test trained FIS against the training data, select the training data check box in the Test FIS portion of the GUI shown in figure 6.10, and click Test Now. This action plots the training data against the FIS output in the plot region as shown below in Figure 6.16.

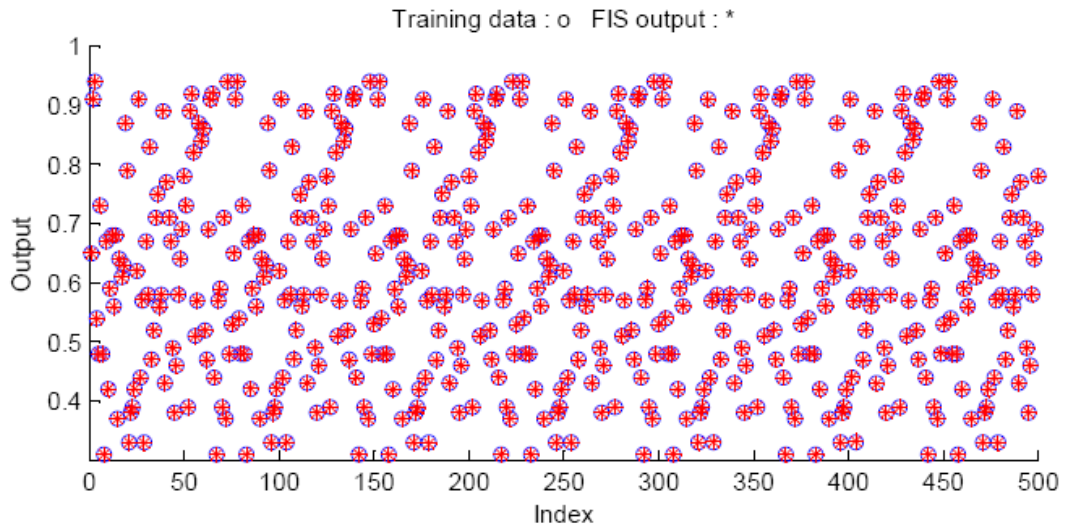


Figure 6.16: Testing the Training Data Set

The average testing error for the training data set is 0.00047746. Similarly, plots shown in Figure 6.17 and 6.18 are the plots of checking and testing data against the FIS output. And the average testing error for checking data set is 0.0015408 and for testing data set is 0.00082825. The checking data has a very near values compared to the FIS values, it is found that the resultant values are accurate up to 99%. Therefore it is observed that the system is working very near to the required result. There are some limitations with the accuracy of the input data; it may be due to the resolution of the satellite data and the systematic error in elevation data, so the result cannot be 100% accurate. But under the practical concern the error up to 6 feet can be considered with these data sets.

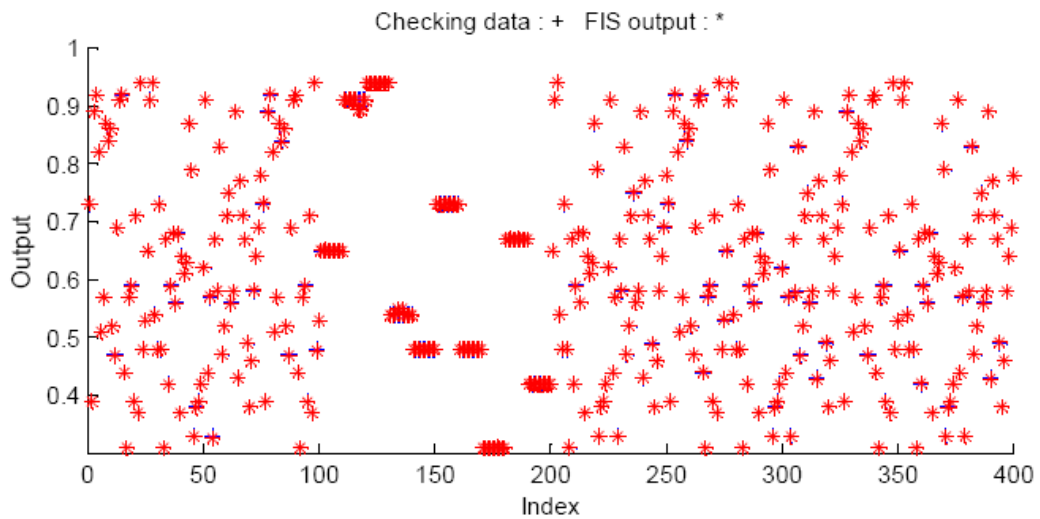


Figure 6.17: Testing the Checking Data Set

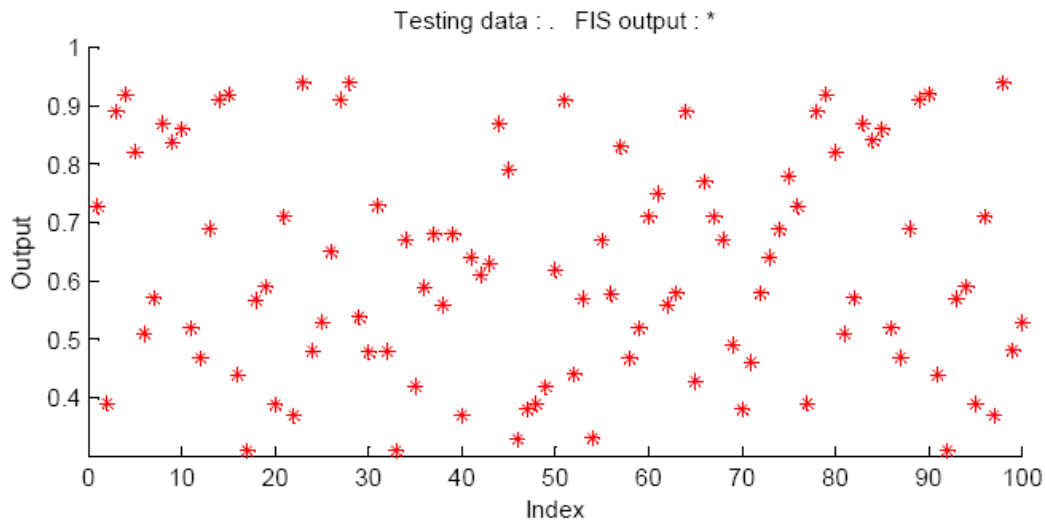


Figure 6.18: Testing the Testing Data Set

### Constraints of ANFIS

The ANFIS is much more complex among all the approaches discussed. Specifically, ANFIS only supports *Sugeno-type* systems. Further ANFIS must have the following properties:

- It should be of first or zeroth order Sugeno-type system.
- The system must have a single output, which obtained by using weighted average defuzzification.
- There must not be sharing of rules. Same output cannot be shared by two different rules. The number of output MFs must be equal to the number of rules.
- Each rule must have the unity weight.

An error will occur if the FIS structure does not comply with these constraints. Moreover, ANFIS cannot accept all the customization options that basic fuzzy inference allows.

## 6.5 COMPARISON OF APPROACHES

All the three FIS are called and tested for the same set of input combinations and a comparison plot is developed as shown below:

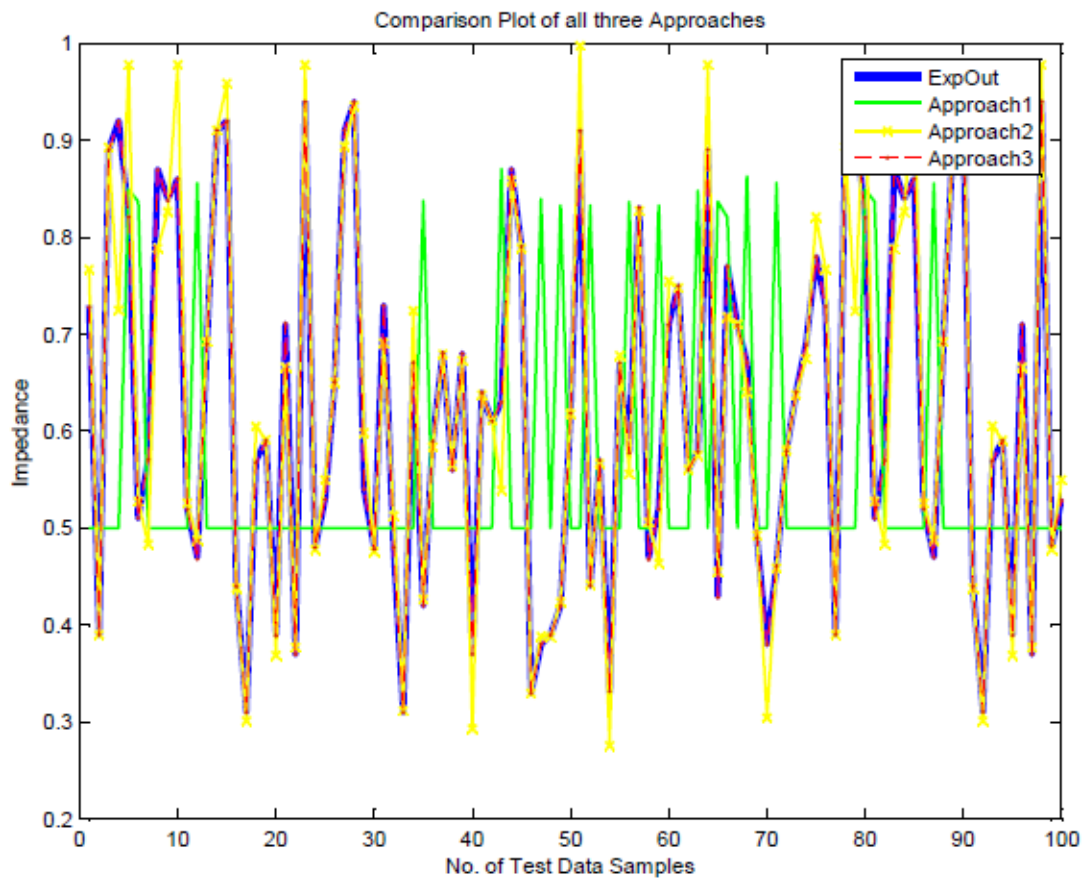


Figure 6.19 Comparison of all the three approaches with Expected output

Figure 6.19 shows the comparison of all the three approaches which are discussed earlier in this section. The x-axis represents the no. of test data samples and the y-axis represents the output impedance (weight) of the particular path. In this graph the approach 1, which is knowledge based, depicted by bright green colour. The approach 2 is based on the clustering of data and is represented by yellow colour on the graph. The approach 3 is based on the ANFIS model, which is learning based and it is represented with red dashed line. The dark blue line depicts the expected output as 'ExpOut'. As it is seen that the approach 3 red dashed line is nearly over the blue ExpOut line, it can be concluded that the approach 3 is the most suitable for path extraction. On focusing of the dark blue line of graph, it is found that the red dashed line is also overlapping on this dark blue line. The approach 3 is nearly overlapping the expected output on the graph. The AHP with modified fuzzy approach is found suitable for the safe and shortest route delineation. Therefore the approach 3 has been used for route delineation during the event of flood. It also enclosed the five parameters which are essential to consider during flood disaster. The

comparison of all the three approaches provides a comprehensive study on the route delineation concept.

## **6.6 RESULTS AND DISCUSSION**

Three types of fuzzy systems are compared and tried to make the most appropriate decision for the required path. Finally it is observed that the learning based approach is most suitable for the optimal path extraction. The DEM plays key role for finding the most suitable evacuation route. Shelter zones and evacuation routes are one of the most important factors for rescue operation managers. Flood map, digital elevation map, flood hazard/risk zone map, shelter map, all are essentially based on the elevation data, so the accuracy of DEM induce high impacts on the results. The DEM used in this study is based on Google data and the permissible error of DEM in this study is 6 feet. So it can be concluded that the results of this study are remarkably satisfactory and highly accurate compared to the ASTER/SRTM based study which has 16m to 25m error in elevation data.

There is a need of web GIS for flood hazard mitigation and management. A web based system provides accessibility and dissemination of timely and accurate information. In the present work, initially ArcGIS software has been used for creation of GIS layers. But after observing the requirement of commercial software ArcIMS (Arc Internet Map Server) to host the GIS data over the web, the subsequent GIS data creation work was carried out using Quantum GIS (QGIS), which is open-source software. All the functions are made to work in an open source environment. So the whole approach is different from earlier theories. This work uses Apache Tomcat as web server and GeoServer as application server. The PostgreSQL and PostGIS have been incorporated for the spatial database. All layers are stored in spatial database and the web GIS has the capability to access, update, delete and create features with these layers. There is no need of GIS Software at client side. Initial training is also not required for the end users. So it provides an online web based spatial DSS for flood disaster mitigation.

### **6.6.1 Flood Extent Map**

The Figure 6.20 shows the flood extent map of the area. In this map the lowest elevation area is depicted by the Red colour and the highest elevation area is represented by the light Blue colour. According to the scheme the very low flood area is shown by red colour, than

low flood area is shown by the green colour, yellow colour represents the medium elevated area, than violet colour represents the high flood area and at last the light blue colour represents highest elevation area or the very high flood area i. e. when there is a very high flood in the study area than only there is a flood in area shown by light blue colour. The author considered low elevation area as the high flood risk zone (in red colour). Similarly the high elevation area is considered as low flood risk zone (in light blue colour).

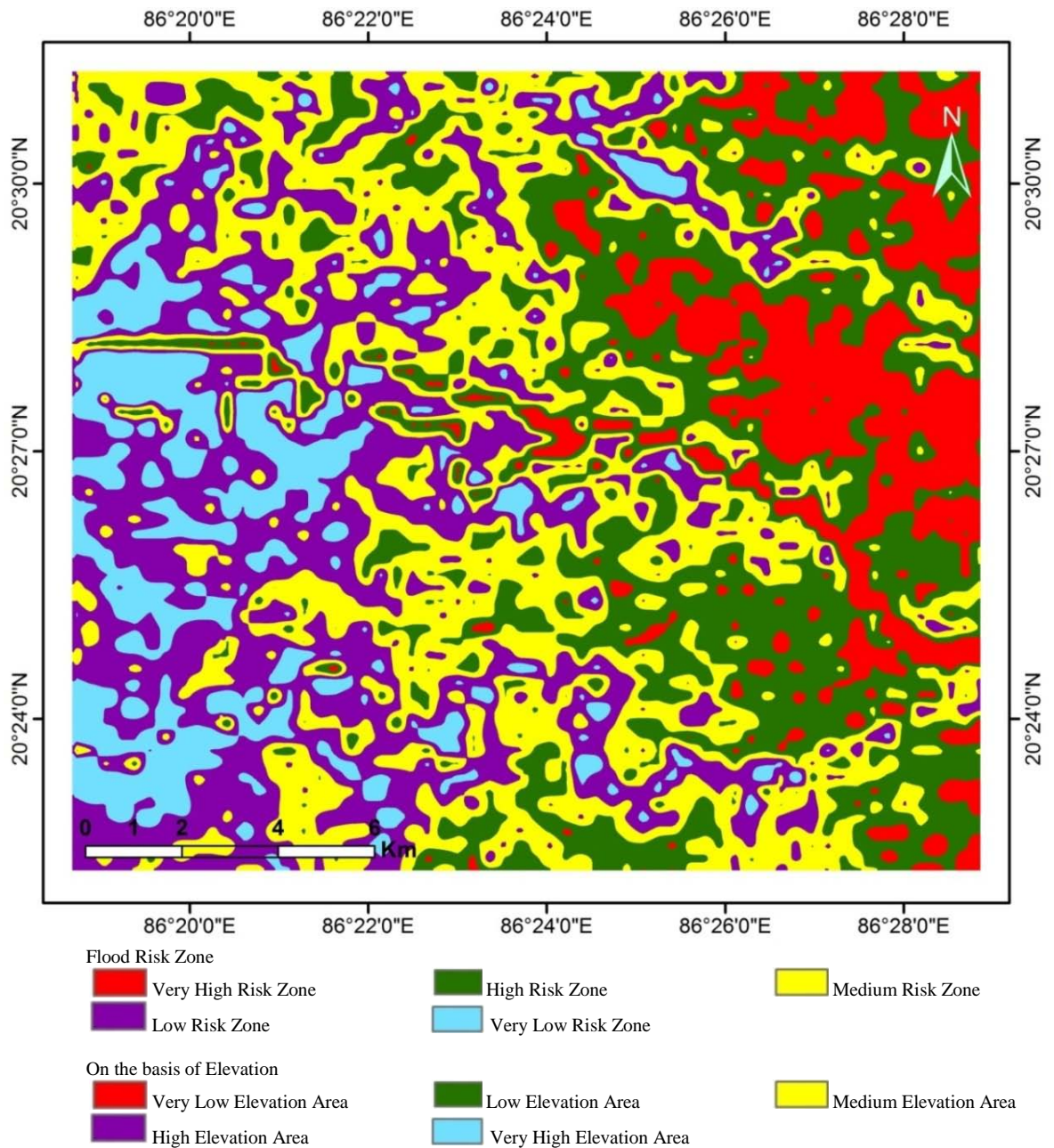


Figure 6.20 Flood Extent Map (based on elevation)

### 6.6.2 Road Networks Map

The Figure 6.21 shows the road network map of the area. In this map there is a straight national highway NH-5A. The urban area has dense network of roads while the delta region has lesser number of roads. The map shows an area slightly more than 20 km x 20 km area that is 400 km<sup>2</sup>. As the eastern part of the area is nearer to the sea, approx 35 km, and it is also surrounded by the delta, so the eastern part of the study is highly vulnerable to the floods. The north-west and the west part have a higher elevation area so it comes under low risk flood zone.

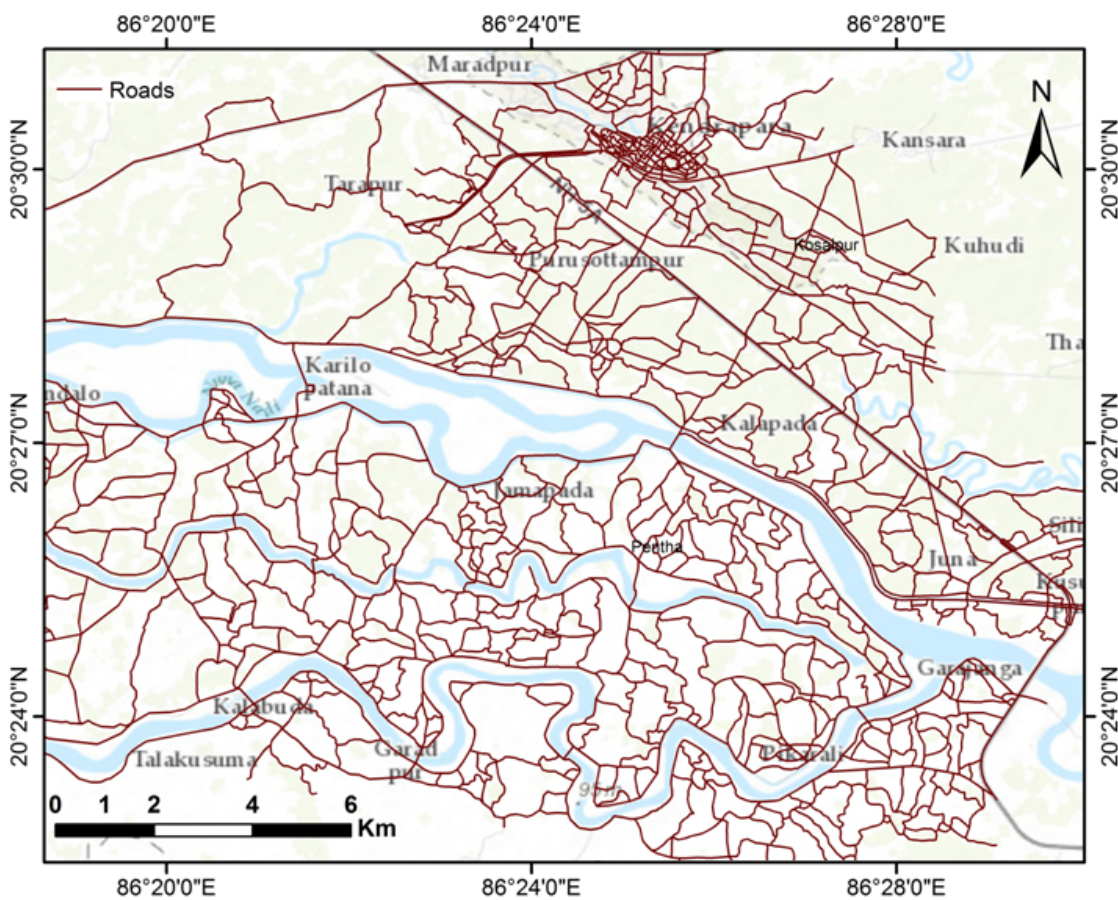


Figure 6.21 Road Networks Map

### 6.6.3 Shelter Zone Map

The Figure 6.22 shows the shelter zone map of the area. This map shows the shelter points. The shelter points may be school building, commercial complex, Government constructed shelter zone, or a shelter developed by other public organizations. The selection of Shelter Zones is on the basis of its Elevation, proximity to safe zone, capacity and convenience.

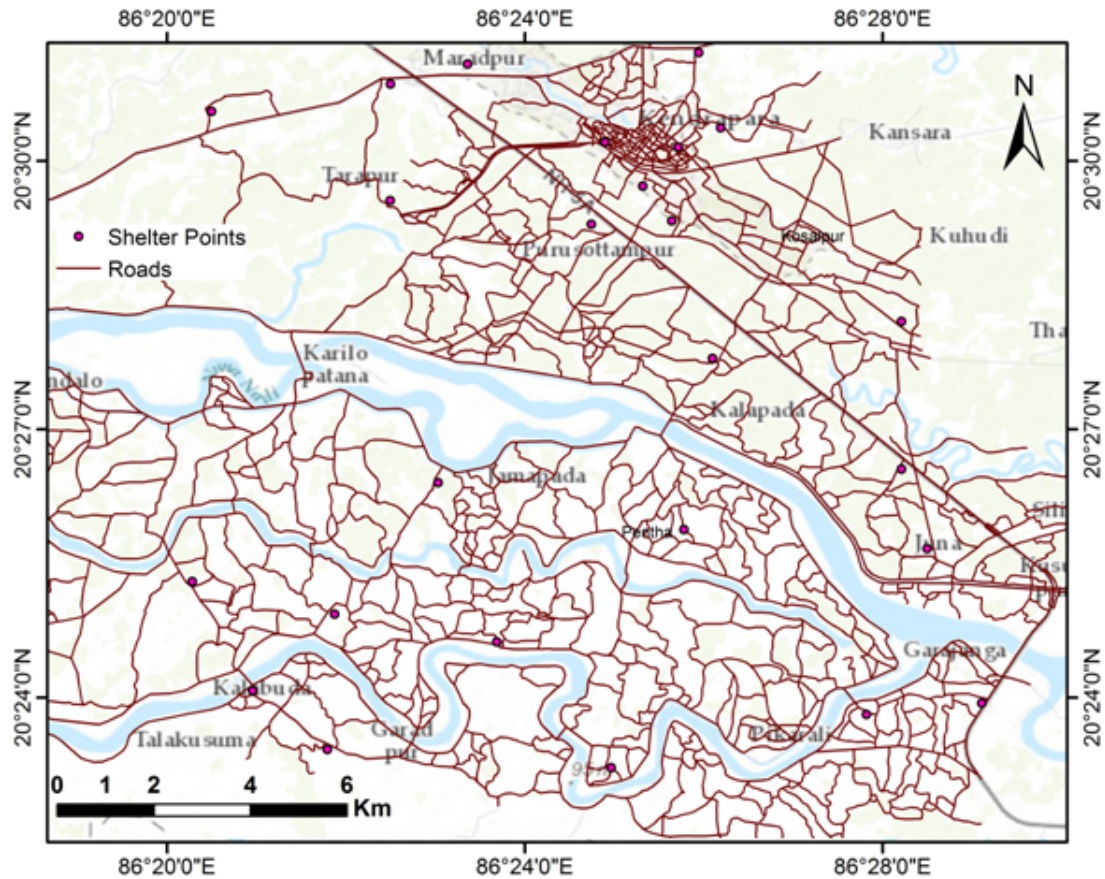


Figure 6.22 Shelter points maps

The shelter map shown in Figure 6.23 is based on the elevation data. The shelter points have been chosen on the basis of some criteria as below:

**Elevation:** Shelter point must be the high elevation area compare to the surroundings. Again it is classified as low, medium and high elevation shelter points. Therefore if there is a medium flood then the high elevation shelter zone is very safe for the rescue.

**Capacity:** It can be a High School building or any two or more storey building. It should have high capacity to keeps people and other basic necessary things. It is again classified as low, medium and high capacity shelter points.

**Connectivity to main road:** The shelter points must have good connectivity with main roads or the highways. So that food and other necessary items can be supplied here without difficulty. Proximity to safe zone is also a prime objective.

**Distribution of shelter points:** The shelter points are located in the area such that any location should not be very far (>3 Km.) away from its nearest shelter point as shown in the Figure 6.24.

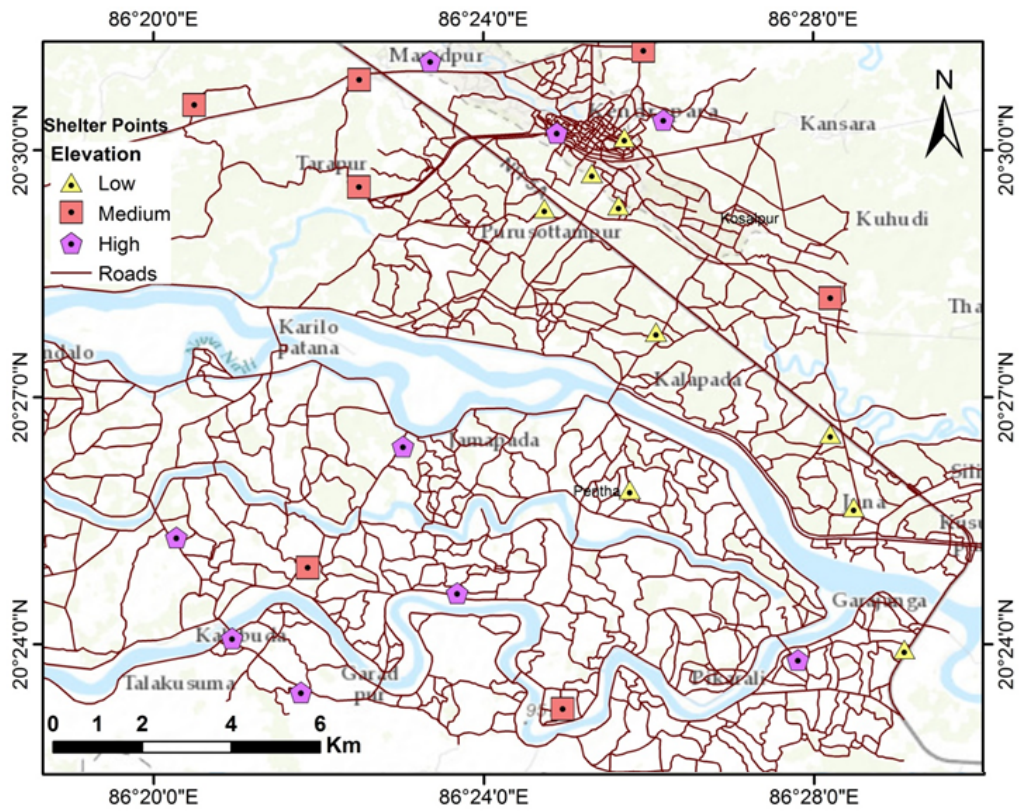


Figure 6.23 Shelter Zones on the basis of Elevation

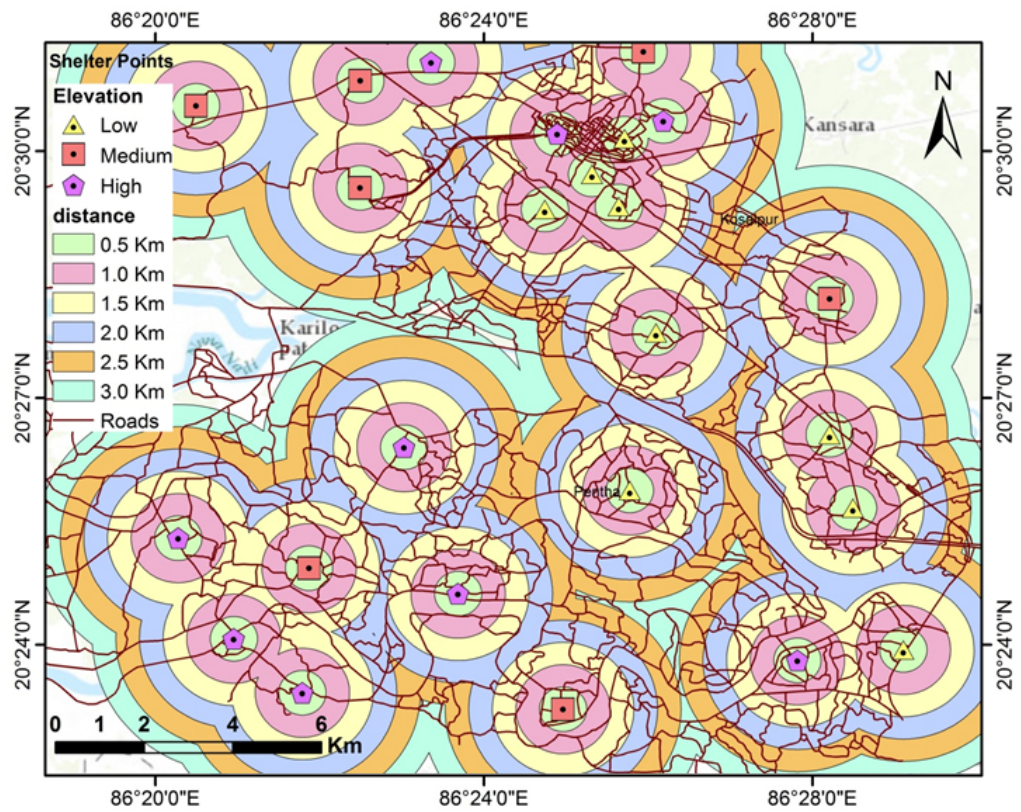


Figure 6.24 Shelter Zones on the basis of Distance, capacity and convenience

It is considered that the location of shelter points should be distributed evenly. The distance of a shelter location can be from 500 meter to 3000 meters from any location in the study area. It is also considered that the number of shelter zones may be higher in a highly populated area. The Figure 6.23 shows the shelter points on the basis of the elevation and capacity. The triangle shows the low elevation area shelter location, the square shows the medium range of shelter and the pentagon shaped icon depicts the shelter zone in located in a high elevation area and have higher capacity to accommodate people.

In Figure 6.24 the different circles shows the distances (proximity) from the shelter zones. It clearly shows that the most of the region have the shelter zone in the range of 2 Km. distance. The whole area can be reached to a nearest shelter zone in the range of 500-3000 meters distance. So it can be said that all the shelter zones are located at an approaching range. The distribution of shelter zones are evenly. Most of the high schools are considered as a primary source for shelter locations because they have large constructed area with some basic facilities and communication systems. Commercial building, post office, and cyclone shelters are also very helpful shelter zones during flood.

#### **6.6.4 Optimal Route Extraction**

The method for extracting the optimal route has been discussed in previous sections. It is based on analytical hierarchy process, learning based adaptive neuro-fuzzy inference system and used digital elevation data, satellite data, demography data, socio-economic data, census data, hydro-meteorological data and open source data and softwares for implementing the system. Some route delineation scenarios are discussed and implemented here with different low, medium and high flood situations.

##### **Scenario 1**

Figure 6.25 shows the Path1 from 'Kendrapara' to 'Kalabuda' as in no flood situation. This route is also suitable even in the medium flood situation as shown in Figure 6.26 (Here in this study Path 1 is generally represents at the no flood situation). But, if a high flood occur in the region then the Path 1 is not suitable for consideration because few part of the roads are submerged under the water as shown in the Figure 6.27. The Path 1 shown in Figure 6.27 is indicated for demonstration that the Path 1 is not suitable in the High flood situation. Therefore an alternate Path 2 is required which is safe and suitable during the

high flood as shown in the Figure 6.28. Again this Path 2 is checked for the very high flood situation in Figure 6.29 and found that this path is submerged and no other alternate route is available for this scenario. In this study 'Path 2' represents the alternate path when the previous path (Path 1), is not suitable for the rescue due to the low-flood, medium-flood or high-flood situation. The path is shown in map as a red line and the road network is shown as brown line.

Here in this section there are five different scenarios will be discussed. It is based on the elevation data of the area, the flood situation, five parameters of road conditions and the resultant weight or impedance of the path. The flood situations are considered as very-low, low, medium, high and very-high. The parameters and methods discussed in previous chapters are implemented and the results are discussed here in the subsequent sections and scenarios.

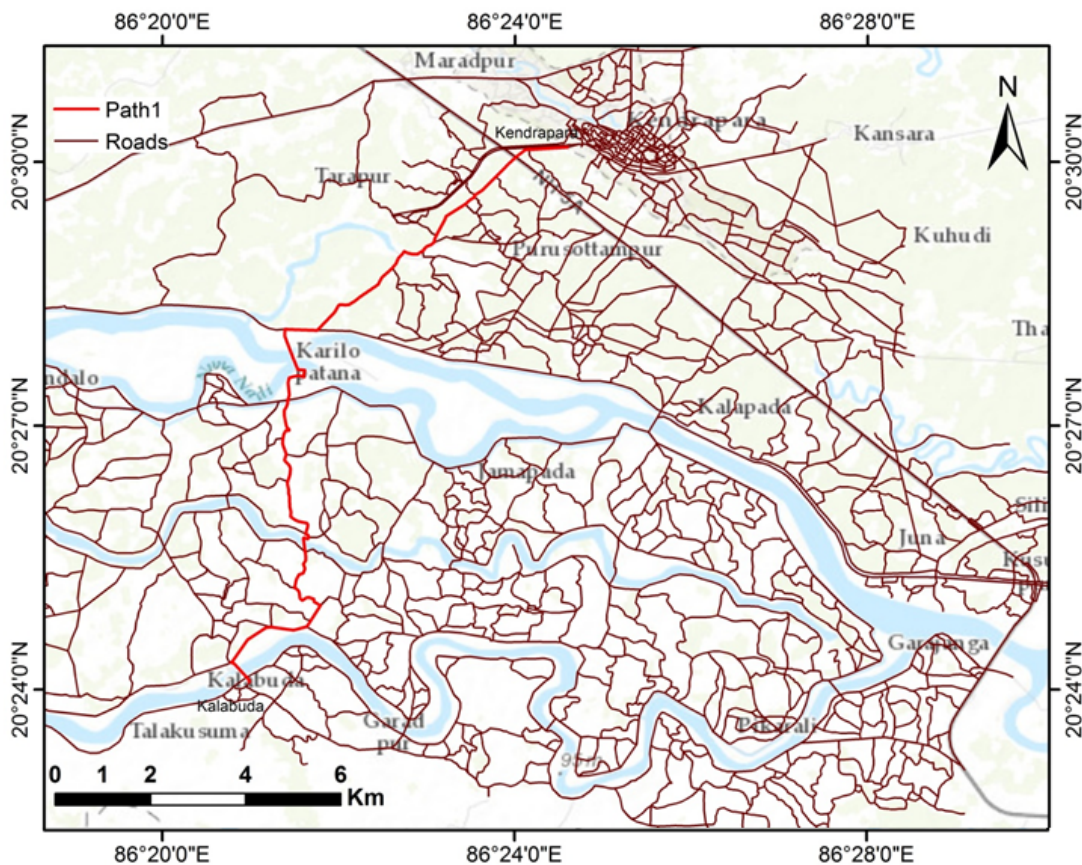


Figure 6.25 Scenario 1 Path 1 at no flood situation

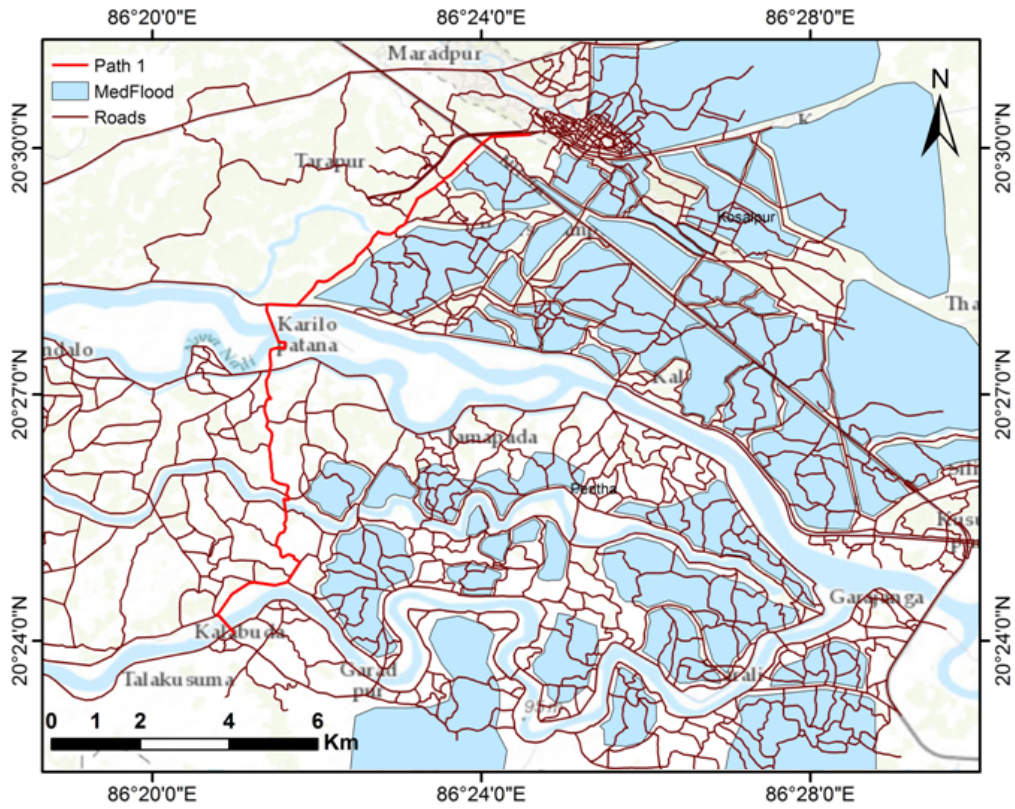


Figure 6.26 Scenario 1 Path1 at Medium flood Situation

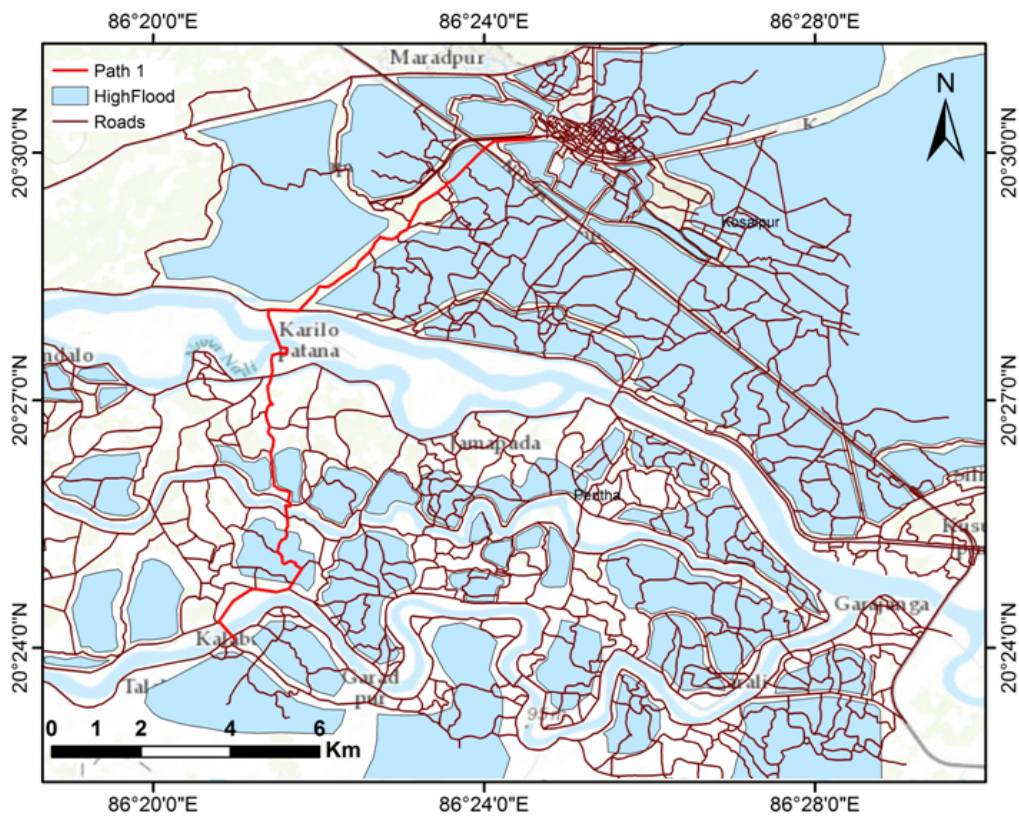


Figure 6.27 Scenario 1 Path 1 at High flood situation

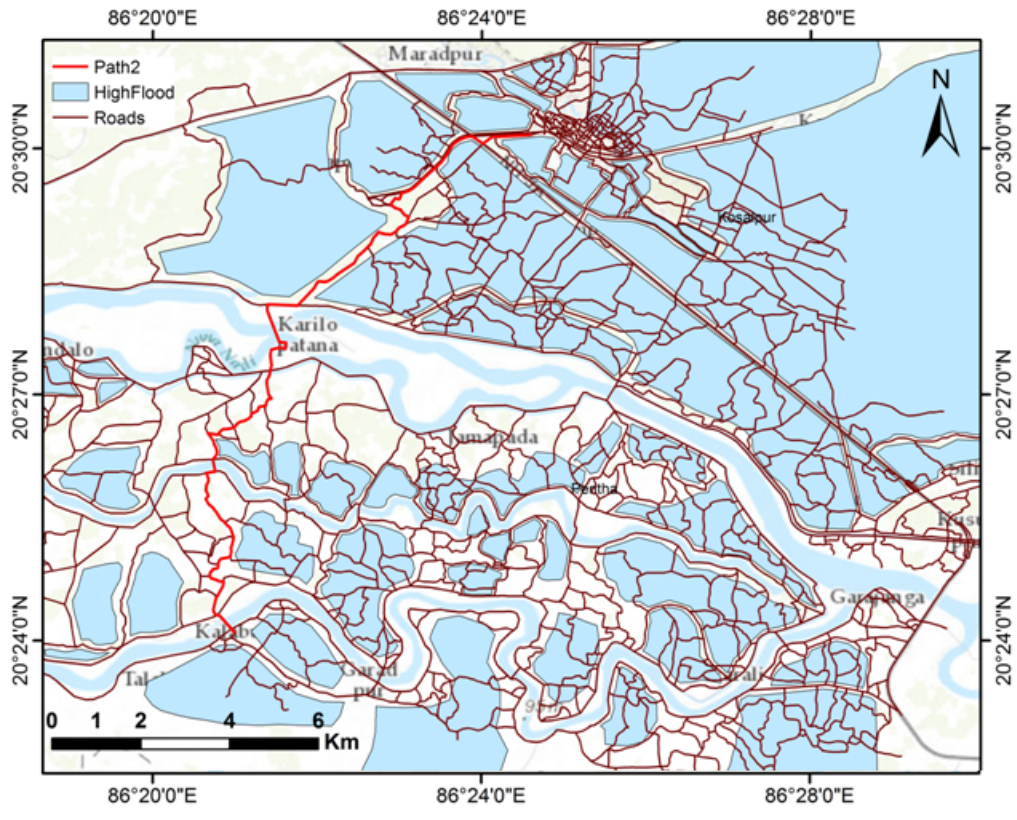


Figure 6.28 Scenario 1 Path 2 at High flood situation

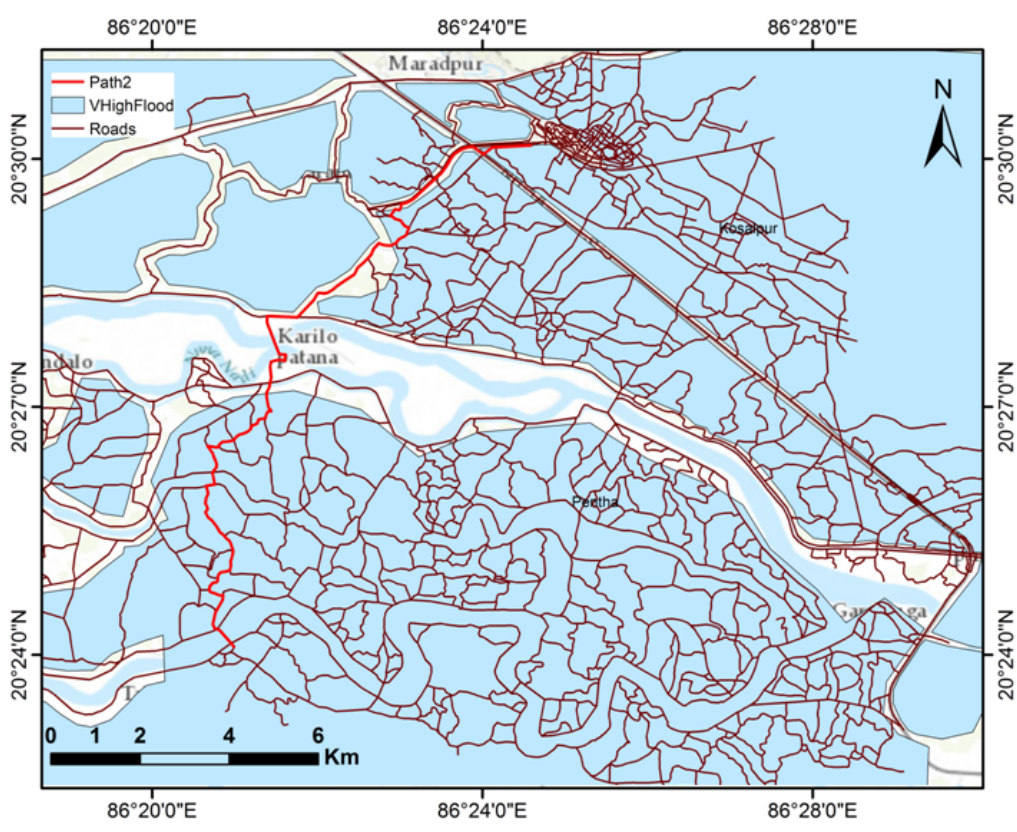


Figure 6.29 Scenario 1 Path 2 at Very High flood situation

## Scenario 2

Scenario 2 is depicted by Figure 6.30, in which the source is considered as the 'Dalanta' and the destination point is refers to the 'Bajraban' area. The above figure shows the route as there is no flood situation in the region. This is a zoomed map of central area of delta region which is mostly agriculture land. The roads are not so good. It may be constructed by concrete or of bricks or interlocked tiles. The various parameters are defined on the basis of data collected through various sources. It is considered that most of the roads are constructed at a higher elevation compared to the adjacent area.

The Figure 6.31 shows that the Path 1 comes under the flood situation if there is a medium level of flood happens. So the alternate route is required which is safe and suitable for the current scenario. In this situation an alternate route is extracted in next step.

The Figure 6.32 shows the Path 2 as the alternate route for the 'Dalanta' to 'Bjraban' at the medium flood situation. It shows that it choose the embankment road which has high elevation road along the river and still safe even in the medium flood condition. So the Path 2 is suitable for the required situation.

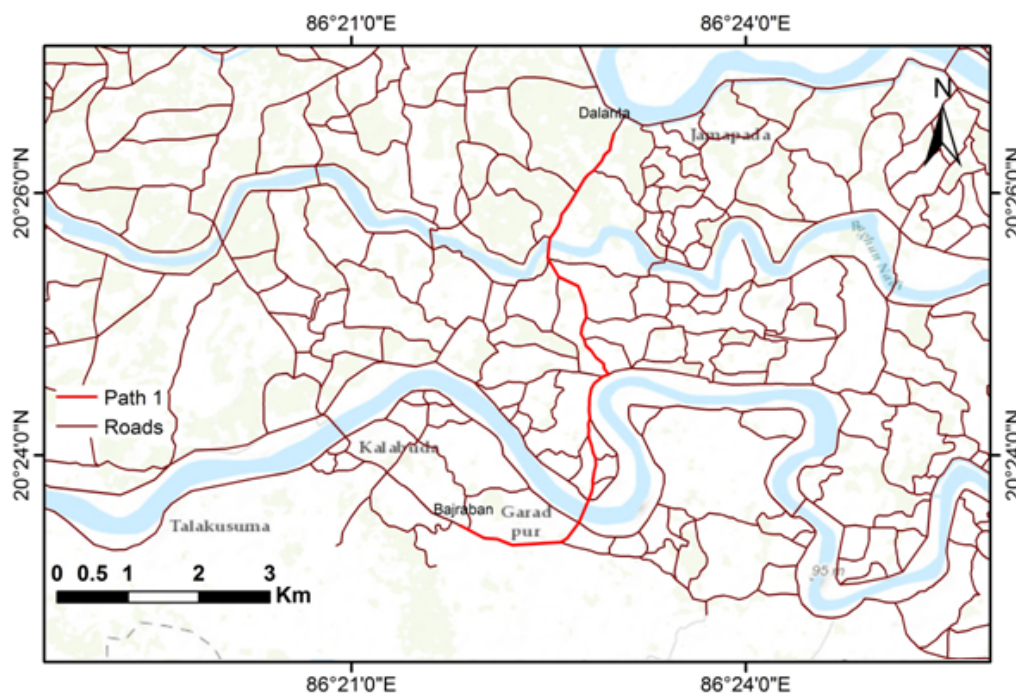


Figure 6.30 Scenario 2 Path 1 at no flood situation

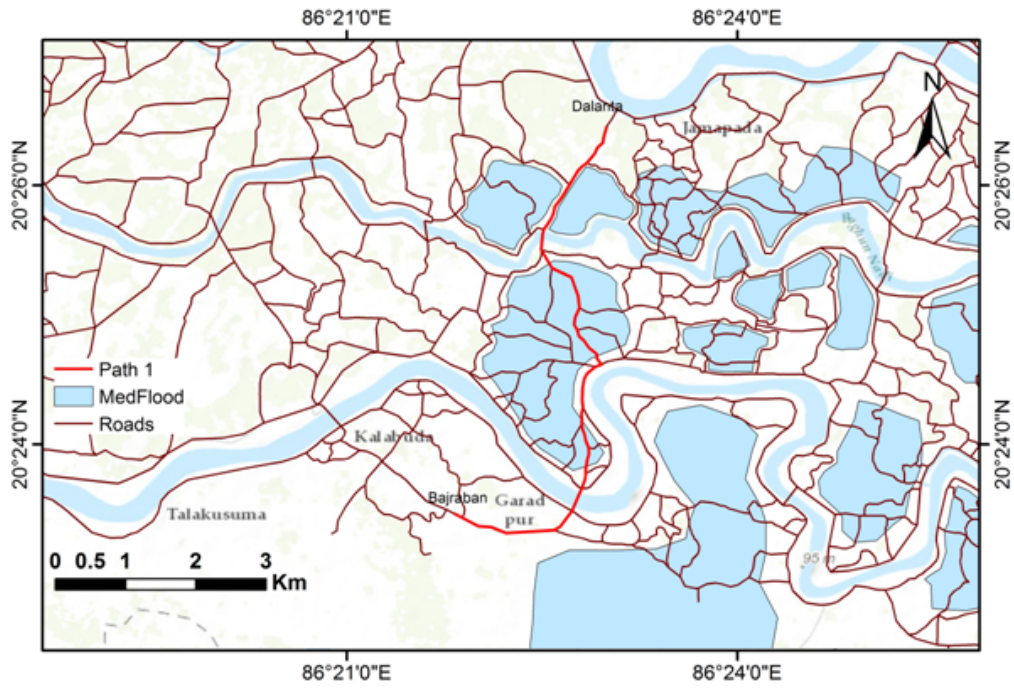


Figure 6.31 Scenario 2 Path 1 at Medium flood situation

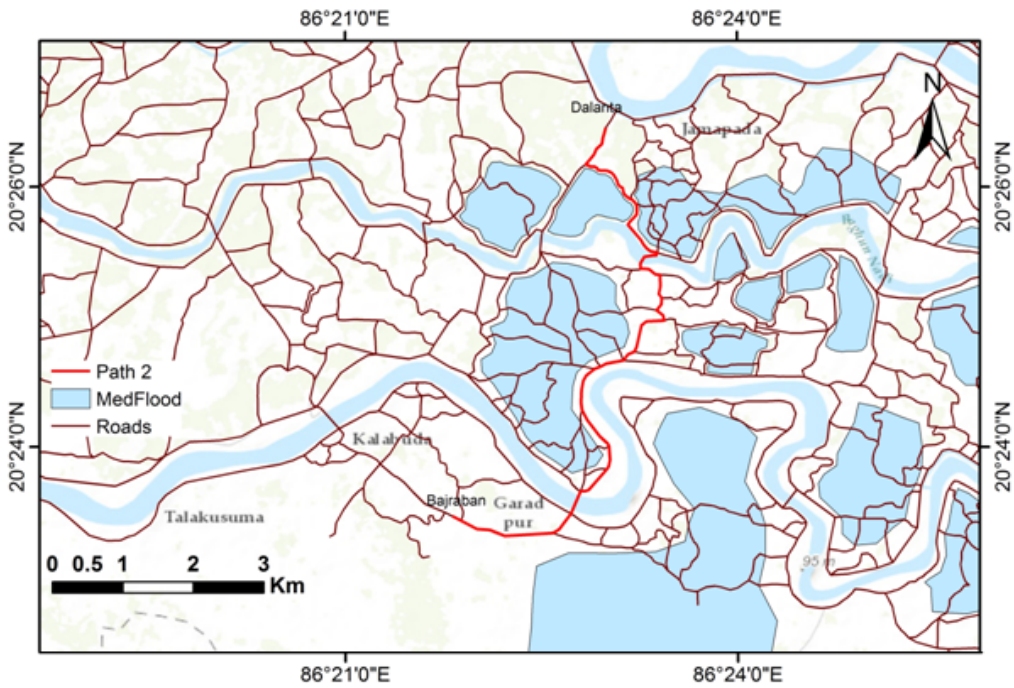


Figure 6.32 Scenario 2 Path 2 at Medium flood situation

This Path 2 is also suitable in the high flood situation as shown the Figure 6.33. But in very high flood situation the source and destination with the roads are submerged, so there is a

flood situation in the whole area as shown in the Figure 6.34. Therefore no path will be available for the rescue. The red line in Figure 6.34 is shown for the depiction purpose.

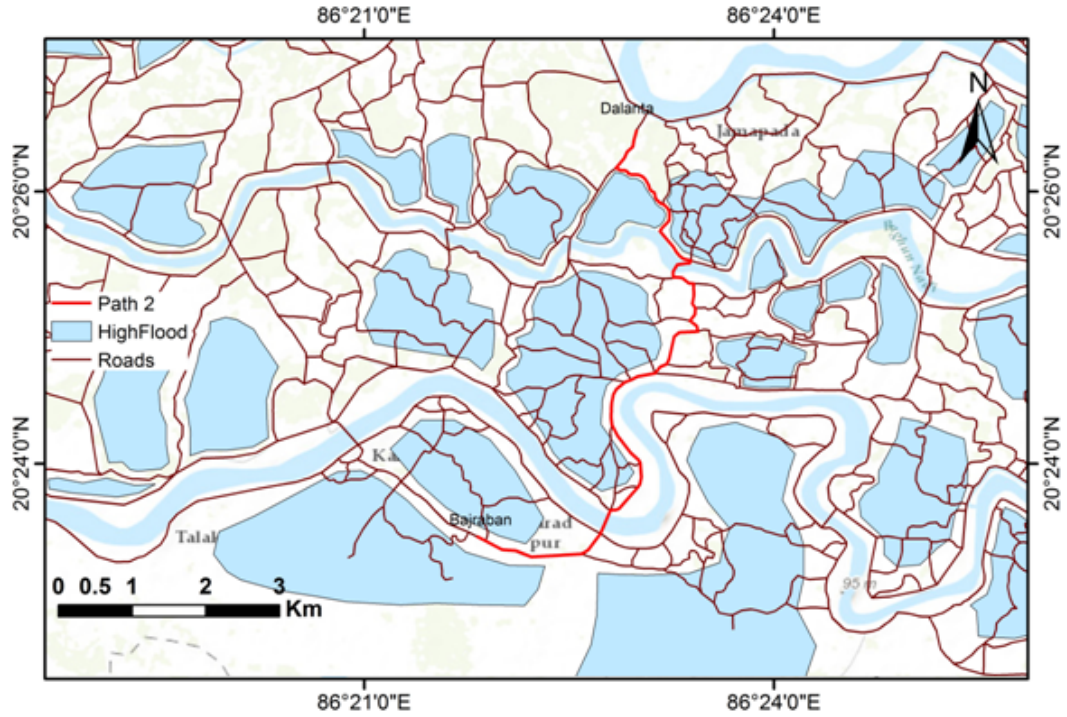


Figure 6.33 Scenario 2 Path 2 at High flood situation

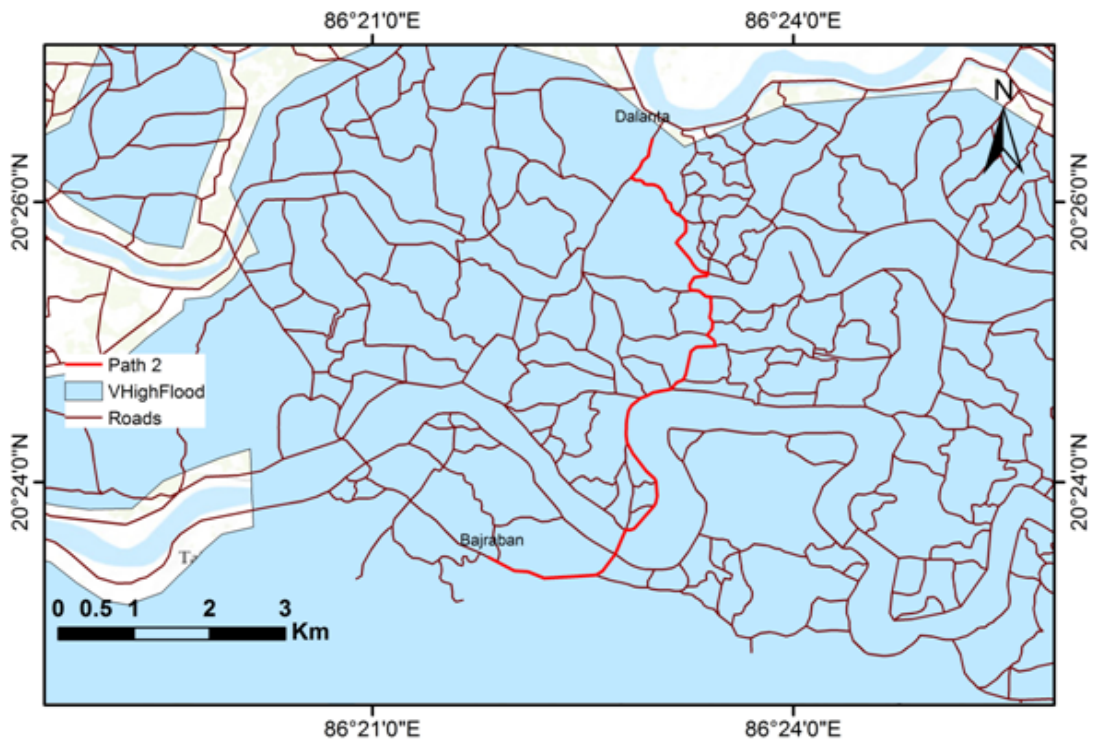


Figure 6.34 Scenario 2 Path 2 at Very High flood situation

### Scenario 3

Figure 6.35 shows the Path 1 from 'Kapaleswar' to 'Kehsapur' in the urban region of Kendrapara block. This region is highly populated and come under the high elevation zone. It has schools, banks, post-office, commercial area and good facilities for transport, disaster management and other essential requirements. The Figure 6.36 shows the Path1 is also suitable even in the low flood situation. As the urban area is situated at a higher elevation compared to the nearby areas, it is safer against the high flood also.

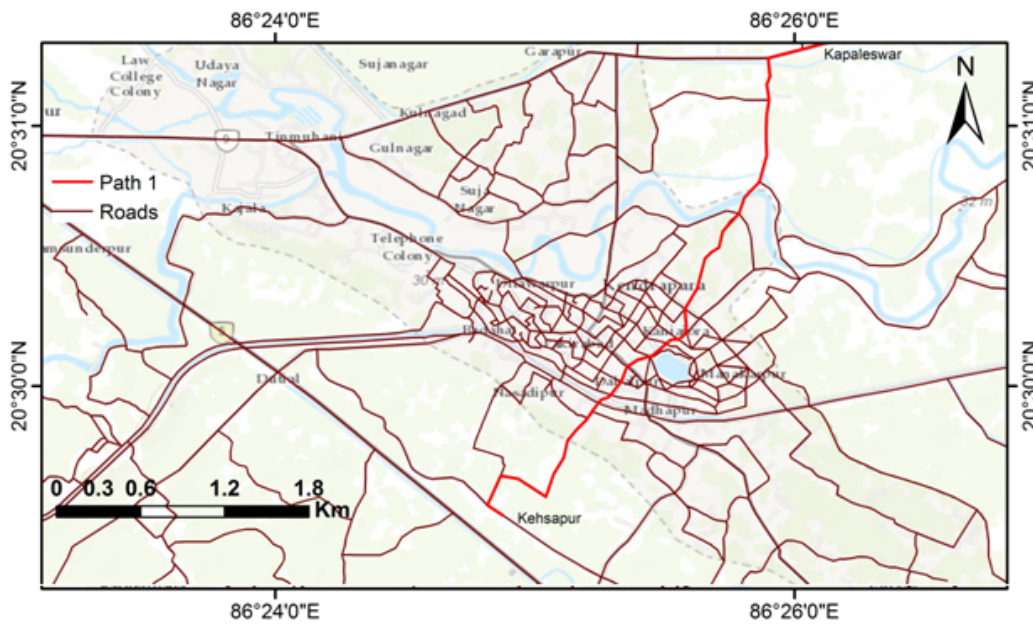


Figure 6.35 Scenario 3 Path 1 at no flood situation



Figure 6.36 Scenario 3 Path 1 at Low flood situation

Figure 6.37 shows a medium flood situation in which some part of the Path 1 come under the flood threat. So an alternative Path 2 is determined by the system as a safe and reliable route as shown in the Figure 6.38. The urban area is at the north region of the study area. The national highway NH-5A is passing through the south of urban area of the district. It is observed that the highly populated area will remain intact even in the high flood condition.

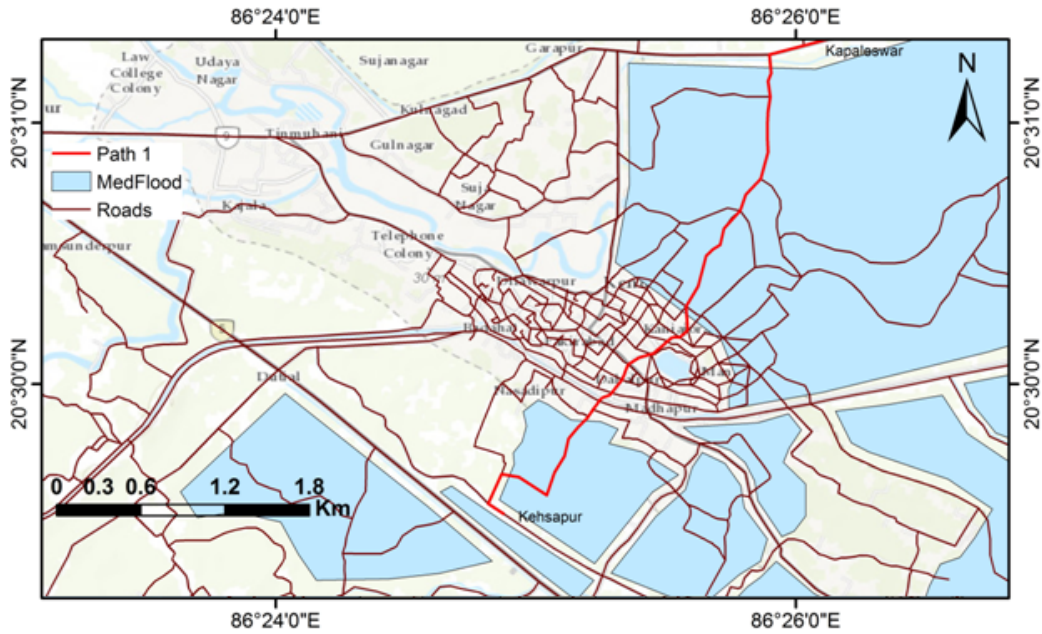


Figure 6.37 Scenario 3 Path 1 at Medium flood situation

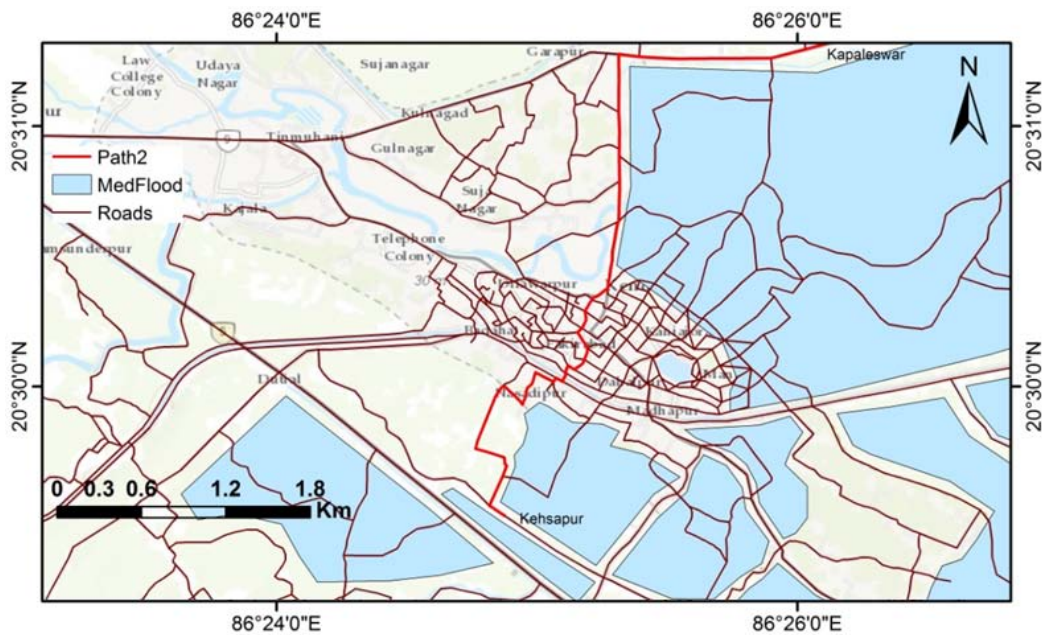


Figure 6.38 Scenario 3 Path 2 at Medium flood situation

This path 2 is also suitable in the high flood situation as seen in the Figure 6.39. But again when the very high flood situation comes, this Path 2 is also submerged and there is no other alternative path for this scenario as shown in Figure 6.40. Therefore the extraction of the optimal path shows the route according to the flood level and the values of parameters defined by the system.



Figure 6.39 Scenario 3 Path 2 at High flood situation

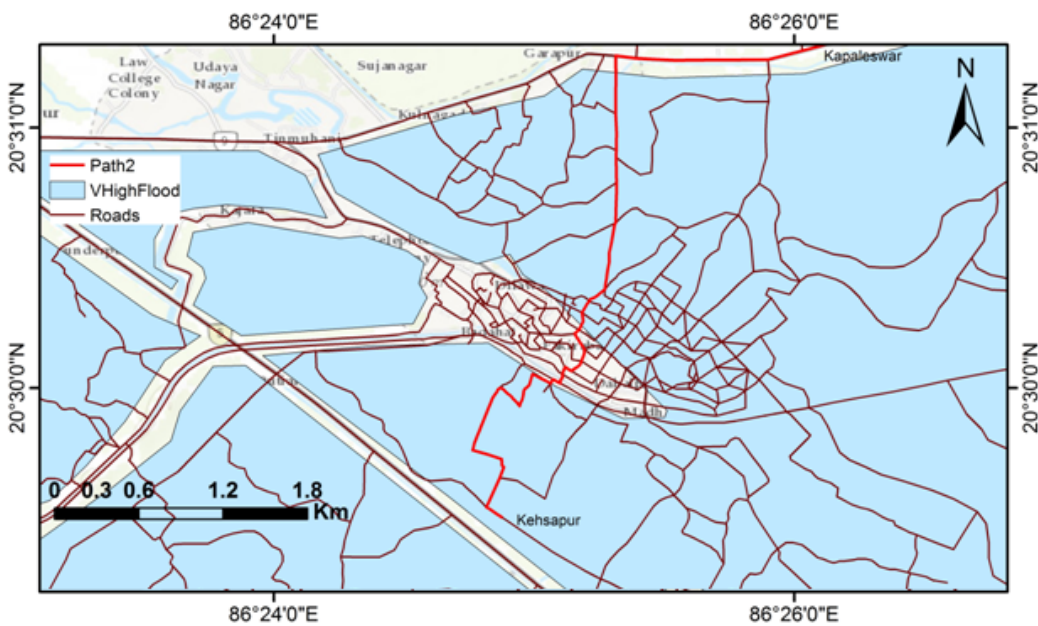


Figure 6.40 Scenario 3 Path 2 at Very High flood situation

#### Scenario 4

The road network is shown in the Figure 6.41 and it also shows that there is no flood situation in the delta and the urban region. It shows the route from 'Khadigang' to 'Manitiri'. The shortest path is shown as red line which is started from the Khadigang area and reach to the Manitiri area through various roads and also through NH-5A. This is the normal route when there is no flood situation.



Figure 6.41 Scenario 4 Path 1 at no flood situation

In Figure 6.42, there is a very low flood situation and it is shown that few part of Path1 is submerged so this route is not suitable for consideration. As this area is situated at the eastern part of the district and is very nearer (35Km.) to the sea, it is highly vulnerable to the floods. This area is also adjacent to the delta region, so a very low flood can be hazardous for it. So an alternate route has been extracted as Path 2 shown in the Figure 6.43. This Path 2 is slightly changed near the NH-5 highway due to the very low flood area. So it is observed here that a more suitable path can be identified during flood.

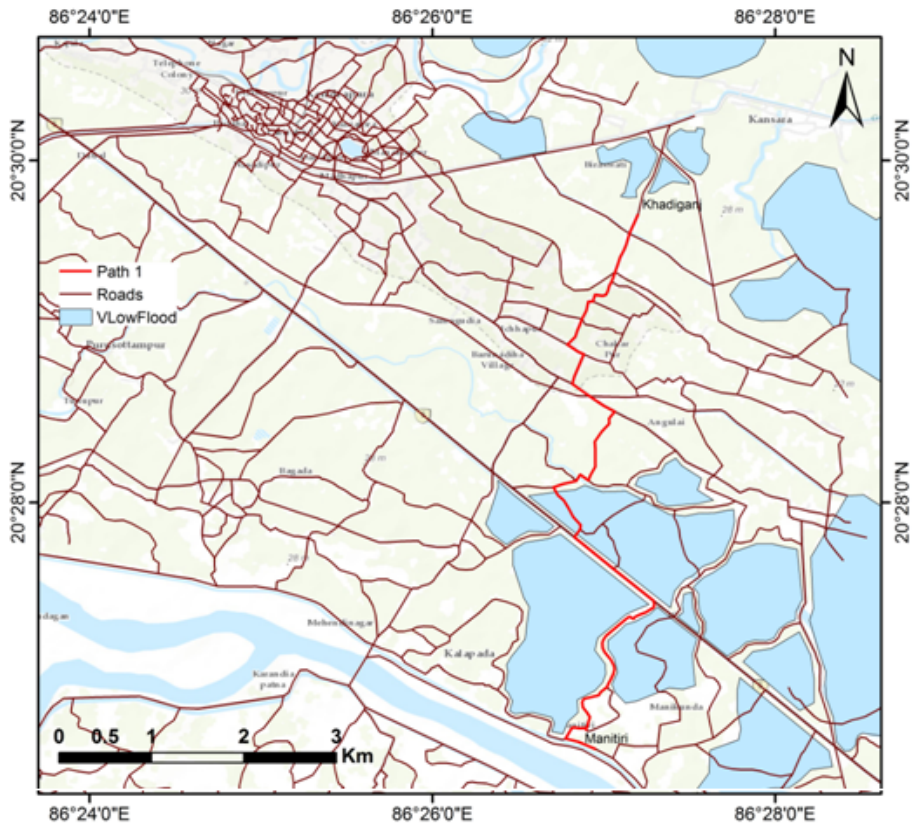


Figure 6.42 Scenario 4 Path 1 at Very Low flood situation



Figure 6.43 Scenario 4 Path 2 at very low flood situation

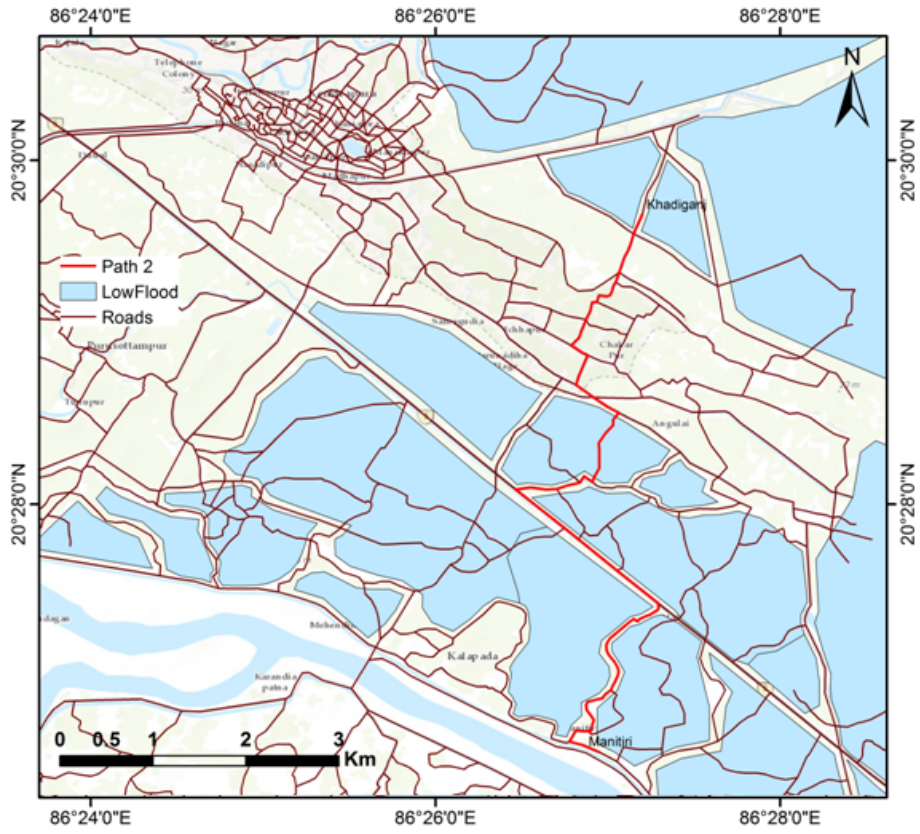


Figure 6.44 Scenario 4 Path 2 at Low flood situation

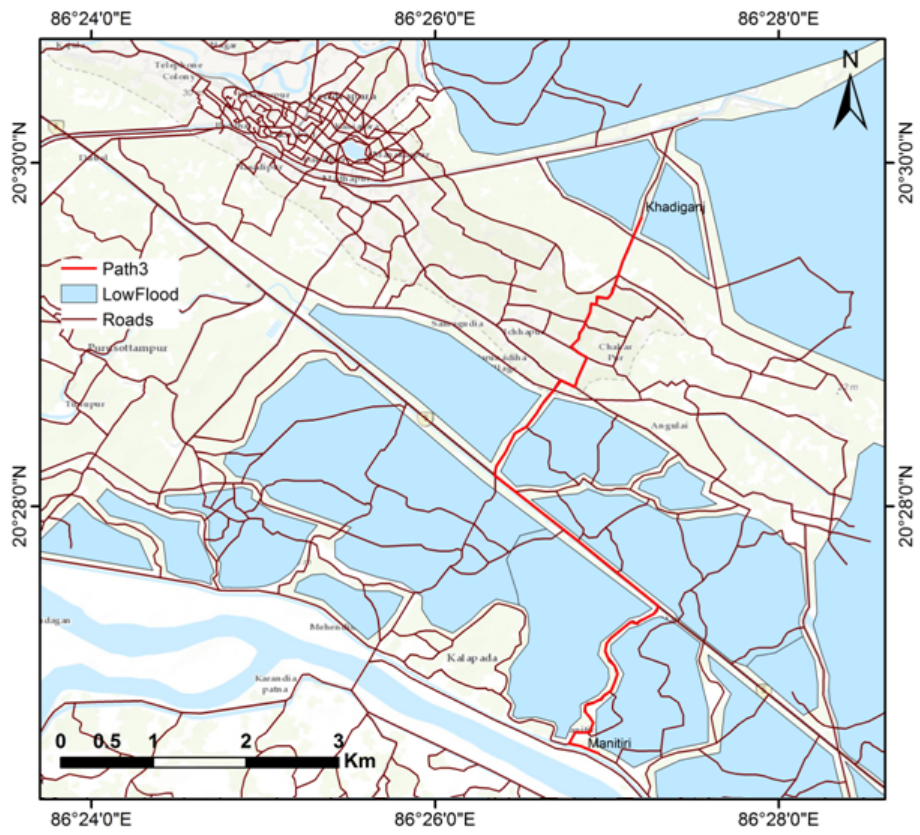


Figure 6.45 Scenario 4 Path 3 at Low flood situation

Again in Figure 6.44 the Path 2 is not suitable for the low flood situation, so another route may be extracted for this source and destination.

In scenario 4, if there is low flood situation in the area than the path 3 will be followed by the user as the route according to the Figure 6.45. It is observed that the source is also surrounded by the flood water, but the road is not submerged, due to its higher elevation state. So the Path 3 is suitable for the scenario.

The Figure 6.46 shows that the Path3 is submerged in the Medium flood situation. Again if there is a high flood situation then the source and destination are also submerged, so it will not provide any route for this situation.

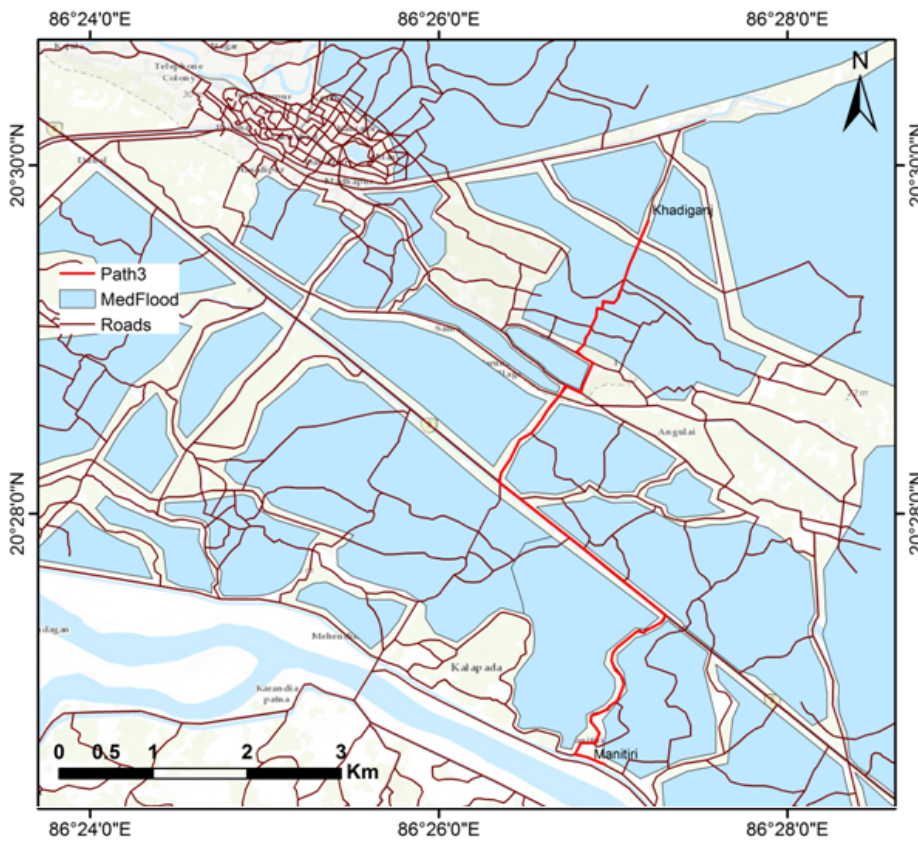


Figure 6.46 Scenario 4 Path 3 at Medium flood situation

### Scenario 5

The scenario 5 represents a path from source name 'Chakarpur' to destination named as 'Pentha'. It is a straight path crossing the NH-5 and the Nuna River through the bridge. The Figure 6.47 shows the path as Path 1 at no flood situation.



Figure 6.47 Scenario 5 Path 1 at no flood situation

Figure 6.48 shows the Path1 in the low flood situation. The figure shows that the path1 is submerged due to the low flood situation, so it is required that there must be an alternate route for this situation. Figure 6.49 shows the alternate path 2 for the Low flood situation. The roads are at a higher level compare to the flood level so the path is safe and fine for the travel. The path adjacent to the Nuna river is also shown in the route, because the road is at higher level on the embankment. In Figure 6.50 shows that the path2 is also feasible in the Medium flood situation. The high flood situation is very difficult for this path and it is found that the source point is also submerged at this level so the route is not found for high flood levels.

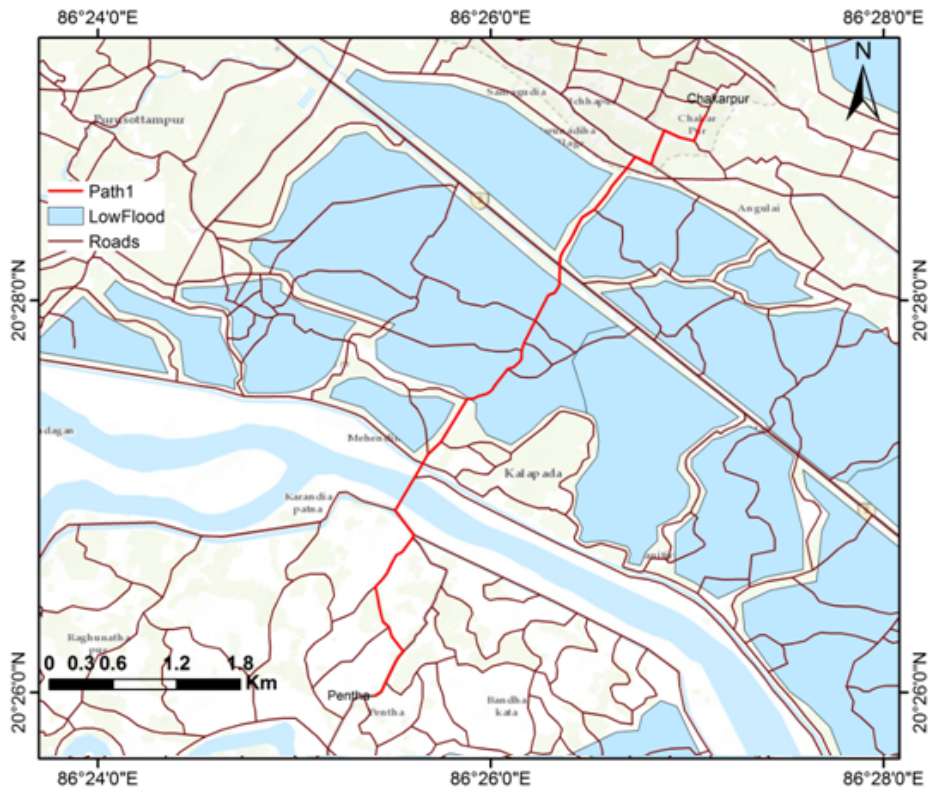


Figure 6.48 Scenario 5 Path 1 at Low flood situation

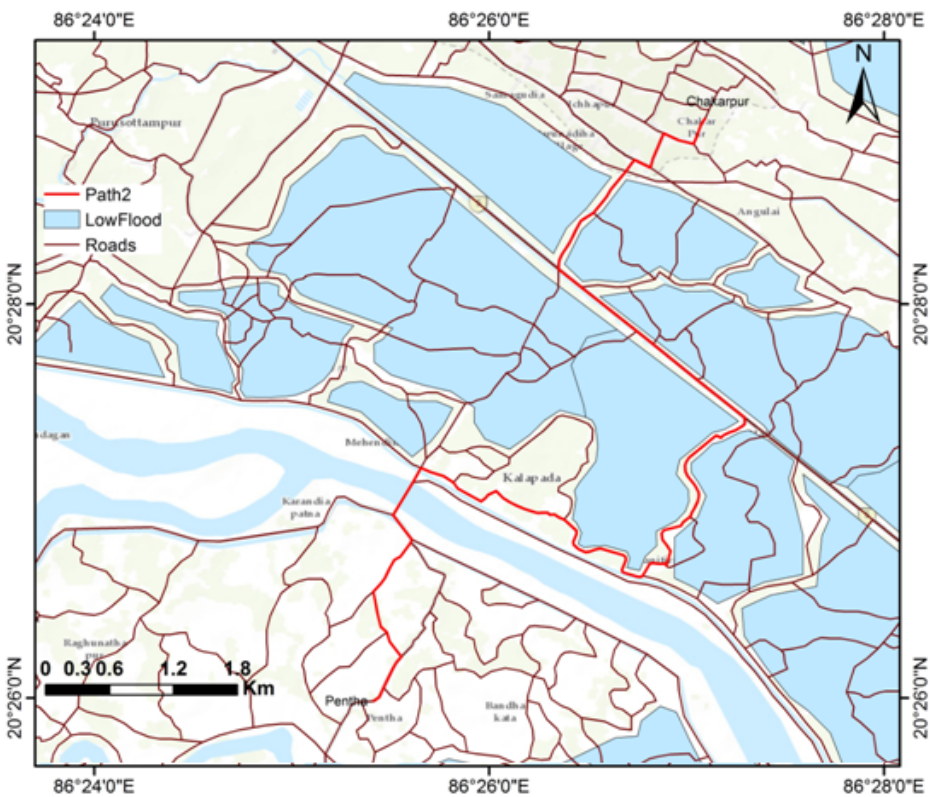


Figure 6.49 Scenario 5 Path 2 at Low flood situation

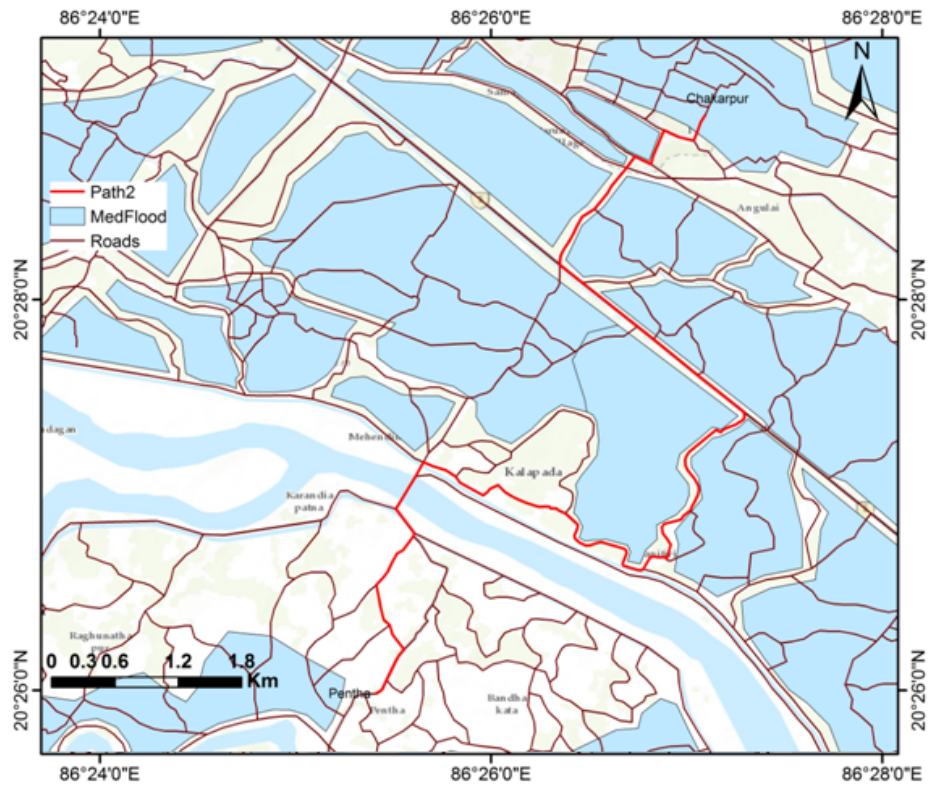


Figure 6.50 Scenario 5 Path 2 at Medium flood situation

The web GIS for flood hazard mitigation is working well and gives required and expected results as discussed in above section. It is the characteristic of a web based spatial decision support system that it should provide basic functionality of add, update, delete, modify and perform some query on the basis of criteria specified in the query. Accessibility and dissemination of timely and accurate information are the key elements to success any disaster mitigation system. In the present work, the ERDAS Imagine 2011, ArcGIS 10.2, Quantum GIS 2.6, ILWIS 3.6, softwares have been used to create GIS layers. The web GIS implemented in this work is based on the OGC standards, therefore the other OGC based systems can share and access its data and resources if the permission is granted and vice-versa. Therefore this flood web GIS is also able to access the Bhuvan open data and other Google data which are based on same standards. Therefore it is observed that this web GIS is also working well with other web sites (Bhuvan, Google, Bing, etc.) and the objective of optimal path delineation is also achieved with an online web based spatial DSS for flood disaster mitigation.



**DISSEMINATION OF INFORMATION USING WEB GIS****7.1 INTRODUCTION**

This chapter discusses the architecture of web GIS based decision support system for flood disaster mitigation and management. Apache Tomcat and GeoServer are used for constructing a web GIS. These tools are open source and freely available through Internet. It is observed that the use of open source software or freely available data is more suitable for large web GIS projects in near future. Google Earth data is also freely available data so it is used here for acquiring satellite images and data. The GeoServer is like an application server which holds spatial data by using PostGIS for spatial database management and it retrieves data to display it with the application. It stores various GIS layers such as LULC layer, road network layer, soil layer and Google Earth layers (base map, road networks, etc.). This web GIS can perform a number of functions on these layers. The PostgreSQL is used for information extraction from the layers. Length and area measurements, route display with names the path are some of the key features of this web GIS. The user friendly interface is developed in JavaScript. It provides an easy way to query. The architecture of this web GIS system is also discussed in detail in this chapter. The user friendly interface is developed in open source software. It provides an easy way to query, such that a person without any technical background of GIS can also view and explore its maps and results, and can understand it in detail. The timely and easy to understand information will help flood managers and emergency services to take appropriate decision at right time.

**7.2 ARCHITECTURE OF WEB GIS**

To view and search the information like length, area, optimal path, route visualization etc., there is a need for web GIS, which can provide different functionalities to the end user. To develop a web GIS for flood disaster mitigation and management, this study uses Apache Tomcat as web server and GeoServer as application server. These tools are open source and freely available through Internet. Apache Tomcat is an open-source web server, which provides a pure Java HTTP (Hyper Text Transfer Protocol) web server environment for Java code to run in. Apache Tomcat is the world's most widely used web application server, with over one million downloads per month and over 70% penetration in the enterprise data centre (<http://www.mulesoft.com/tcat/understanding-apache-tomcat>).

Apache Tomcat is used to power everything from simple one server sites to large enterprise networks. The GeoServer uses PostGIS for spatial database management. It stores GIS layers for LULC, road network, soil and satellite data layer from Google Earth. PostGIS is an open source, freely available spatial database extender for the PostgreSQL Database Management System. It allows GIS objects to be stored in the database and adds spatial functions such as distance, area, union, intersection and spatially geometry data types to the database. PostGIS is used with GeoServer, which is a Java-based software server that allows users to view, share and edit geospatial data. GeoServer provides great flexibility in map creation and data sharing. GeoServer is OGC compliant implementation of a number of open standards such as Web Feature Service (WFS), Web Map Service (WMS), and Web Coverage Service (WCS). Designed for interoperability; it publishes data from any major spatial data source using open standards. Apart from it, Apache Tomcat server is used to host the data. It provides various functionalities of a web server. Use of all these softwares is a requirement of open-source web GIS. This web GIS can perform area extraction and distance measurement on GIS layers. This web GIS can also display the shortest route during flood disaster situation. The architecture for the web based spatial flood disaster mitigation system is shown in Figure 7.1. It has mainly three layers: spatial database layer, application server layer and user interface layer. The brief description of components is as given.

- **Database Layer:** PostGIS spatial database is used to manage the read/write data store. A spatial database system supports spatial data types: i.e. point, line and polygon. It store, retrieves, edits and deletes spatial data in a database. Different functions can be performed on the spatial data, geographic properties and location based data sets. GIS layers and maps can be stored in this layer. The PostgreSQL is used to retrieve the information from the spatial database. It is a query tool to the web GIS.
- **Application Server:** The GeoServer is used as application server. The processed data needs to be accessed using web services. GeoServer is deployed over Apache Tomcat Server. A web server is any machine that receives requests from a client machine and is able to turn around process the requests and send back a response. HTTP is the protocol that is used to send and receive data/information from the server. Apache web server understands and uses protocol to send information back to the client machine.

- **User interface framework:** GeoExplorer is used to develop a user-friendly user interface. GeoExplorer is a browser-based interface for composing and publishing web-mapping applications. Layers can be added, removed and saved by GeoExplorer.
- **User interface map component:** Google Maps API (Application Programming Interface) and OpenLayers are used for map component. PostgreSQL is used for query to the database.

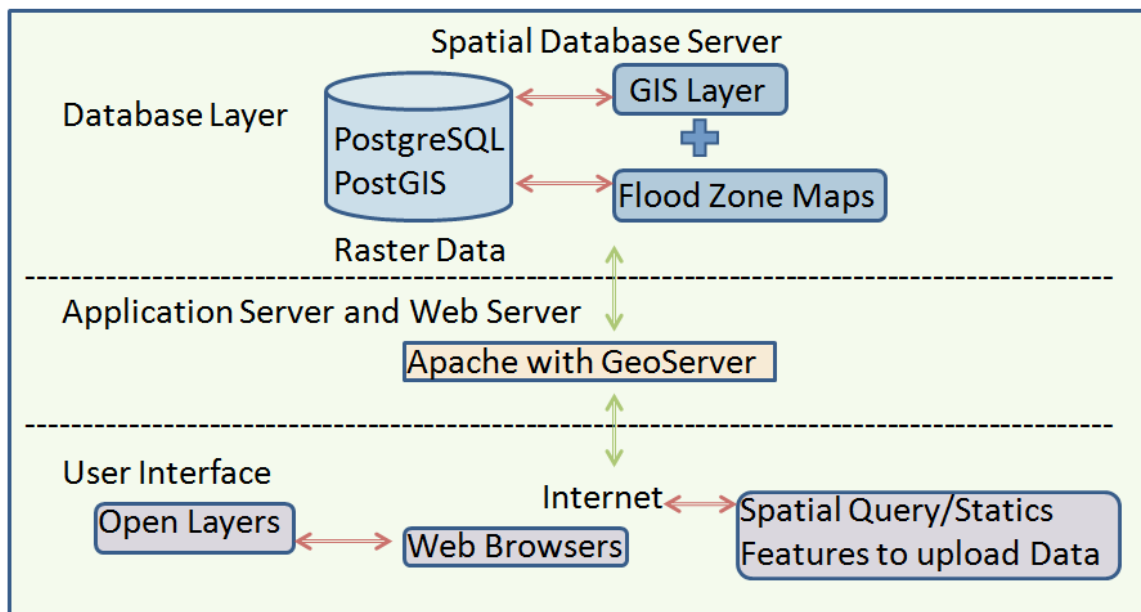


Figure 7.1 Architecture of Web based flood mitigation system

This geospatial architecture provides a spatial database, data manipulation, Internet publishing and client-server architecture which integrate a portal with some end user applications that are able to communicate with other application servers. This architecture is designed for spatial data management with specific functionality to publish maps, data, and metadata on the web. Also it provides a functionality to create maps, develop web pages that communicate with the maps, and administer a web mapping site. In this web GIS the functionality for modification of map is also available. The simple functions for this architecture are implemented since it works as an application but not as software. It is scalable as the demand for maps increases and also distributed across a network. There are several components in each tier of the system as it is discussed earlier and some will be discussed in subsequent sections.

**Functionality in Web GIS:** There are several basic and advanced functionality incorporated in this flood disaster mitigation web GIS. This web GIS is tested at localhost port 8080 and found working perfectly. The description and working are explain below for all the functionality. The basic functionality like add layers, remove layers, zoom-in and zoom-out are the integral part of any web GIS system. This web GIS is based on open source software, therefore it also has capability to access the resources available on the Internet based on open source. This GIS is developed to support the flood disaster mitigation. The main components of the web GIS are discussed in the architecture. The user interface is based on the GeoExplorer. It is the platform on which the user interacts with the GIS layers. The GeoExplorer is based on GeoExt framework and it acts as a web application for composing and publishing maps. With GeoExplorer, the user is able to assemble maps easily from GeoServer or any OGC Web Mapping Server (WMS). It also integrates with hosted maps such as Google Maps and OpenStreetMap. GeoExt is a JavaScript toolkit for creating rich web mapping applications. GeoExt is built using OpenLayers and ExtJS. ExtJS is a pure JavaScript application framework which is used for building interactive web applications. It has interoperability with JQuery. This section provides a brief description of the ‘Flood GIS for Spatial DSS’ web application (Figure 7.2), which is based on GeoExplorer and PostGIS database. It can be launched at localhost as <http://localhost:8080/geoexplorer/composer/>.

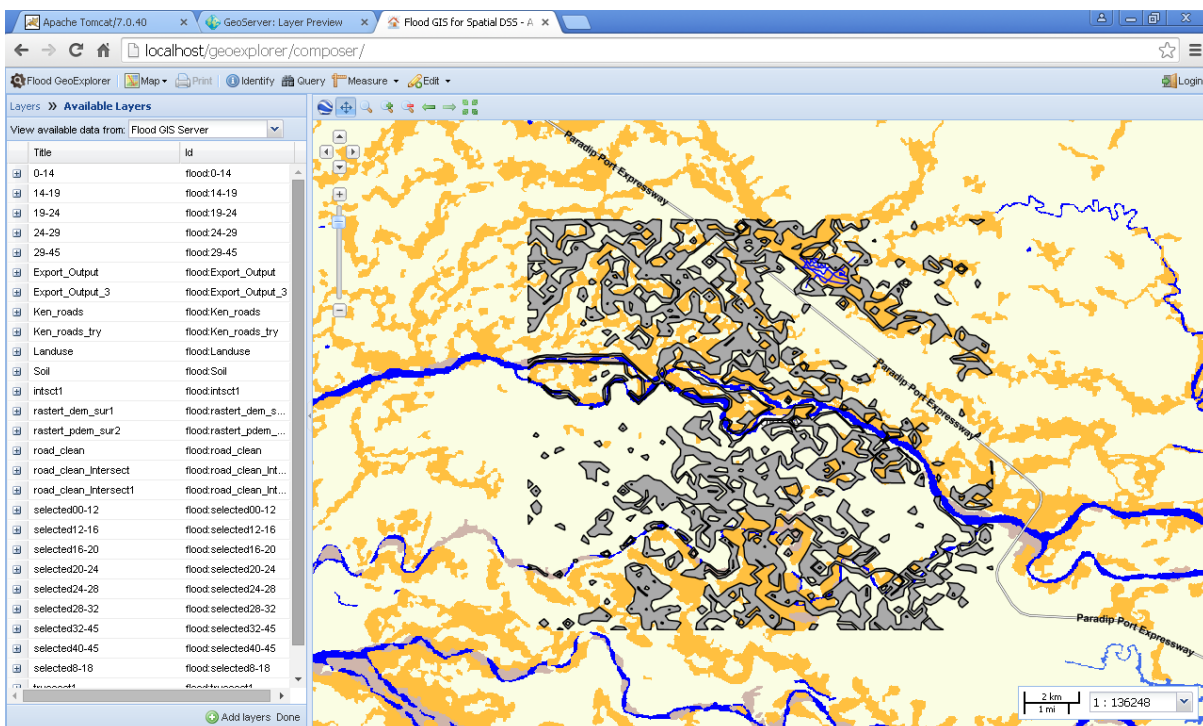


Figure 7.2 Map Window of Web GIS for Flood Disaster

### 7.3 FLOOD GIS

The 'Flood GIS for Spatial DSS' (Figure 7.3) has seven main tabs: Flood GeoExplorer shows the about feature of this GIS. User can find the information about the flood web GIS by using the tab 'Flood GeoExplorer'. This will provide information about Flood Map info and Flood GIS and spatial DSS; the second tab has Map feature which provide Publish Map and Save Map feature to the user (Figure 7.4-a). The Measure tab provides Length and Area calculation on the map (Figure 7.4-b). The Edit feature provides capability to create and modify the data and properties of the map (Figure 7.4-c).

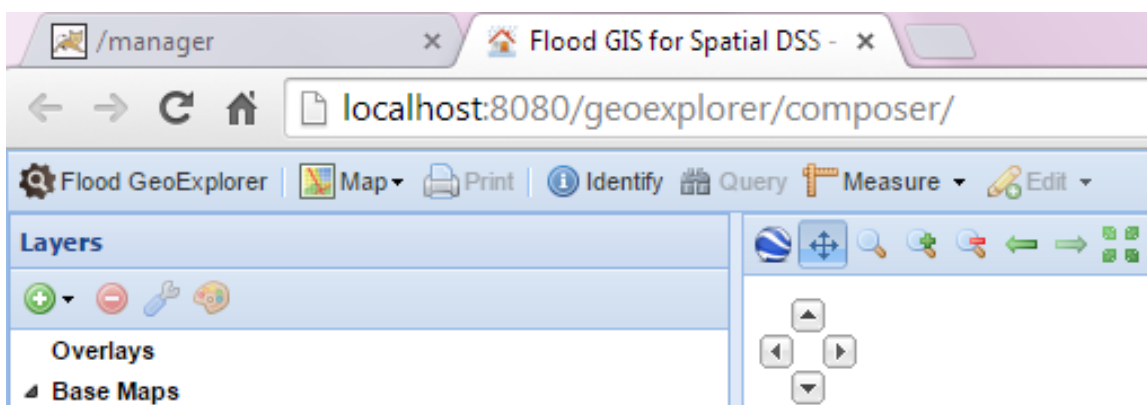


Figure 7.3 Flood GIS for Spatial DSS

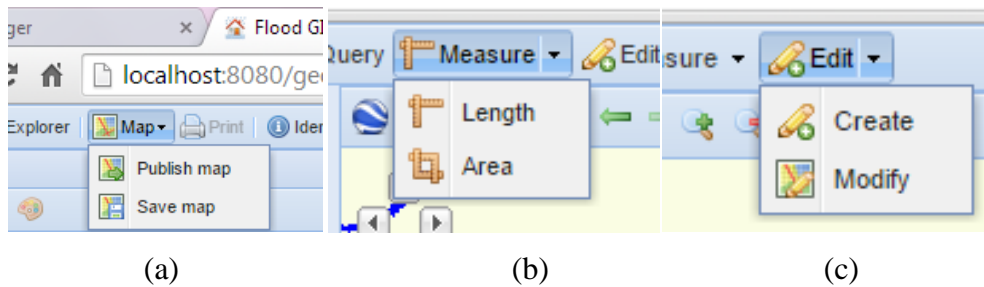


Figure 7.4 Map Feature

To add a new layer or some existing layer, it offers a view to the available data from connected resources (Figure 7.5). The user can access any of the layer, which will be shown by the server.

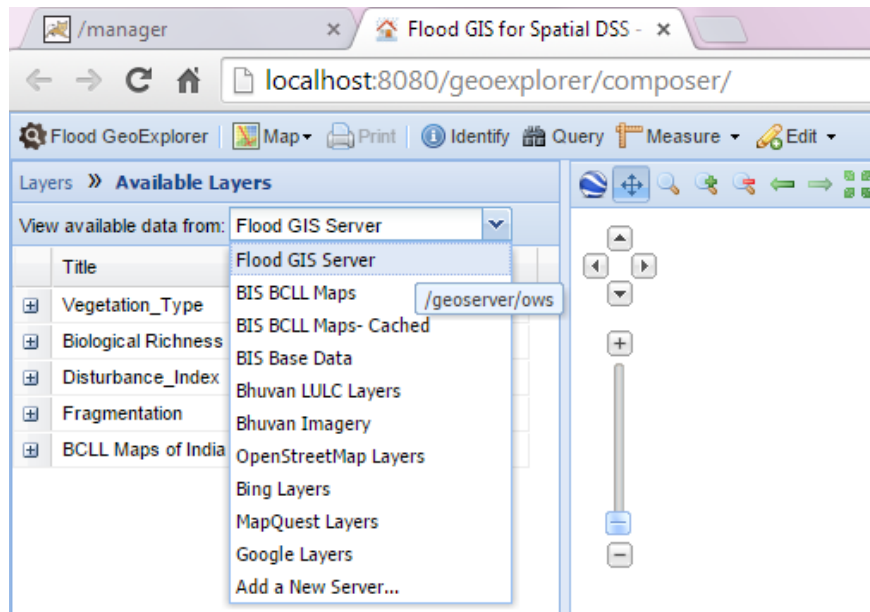



Figure 7.5 View of Available Data and Map Servers

This web GIS has various functions. A new layer can be added to the 'Map Window' by using the Add-Layers button  on the Layers panel toolbar. To open the Available Layers panel, click Add layers (Figure 7.6).

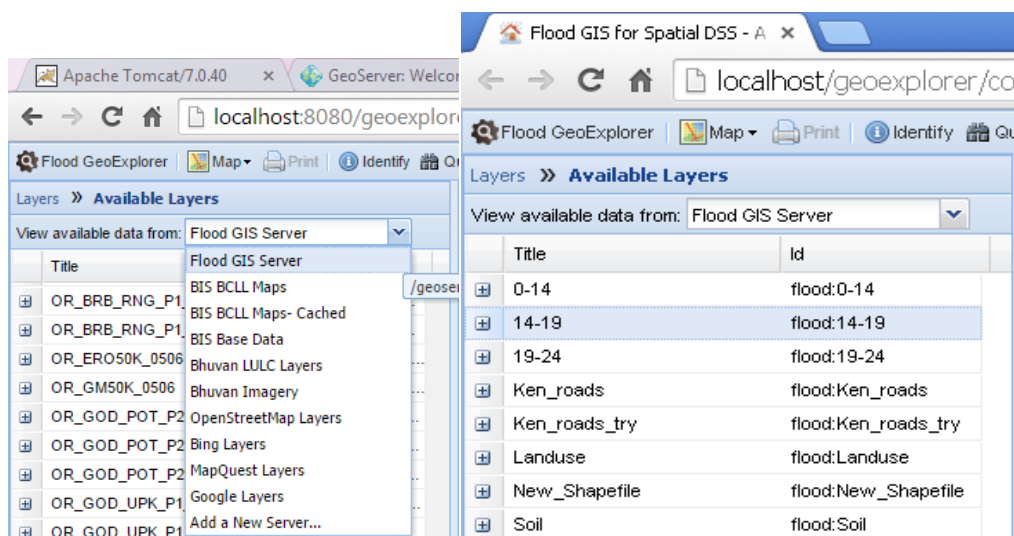


Figure 7.6 Add Layers and Available Layers in the Flood Web-GIS

In the 'Available Layers panel', the user can click the desired layer to add it to the map by using the Add-layers button. Multiple layers can also be added simultaneously by holding down Ctrl-key while selecting all the layers needs to be added.

Web Map Services (WMS) is a standard protocol for serving geo-referenced map images over the Internet that is generated by a server (GeoServer) using data from a GIS database (PostGIS). Flood GIS also provides functionality to add a WMS server which has valid URL. A new WMS server can be added by using the ‘View available data from’ list (Figure 7.7).

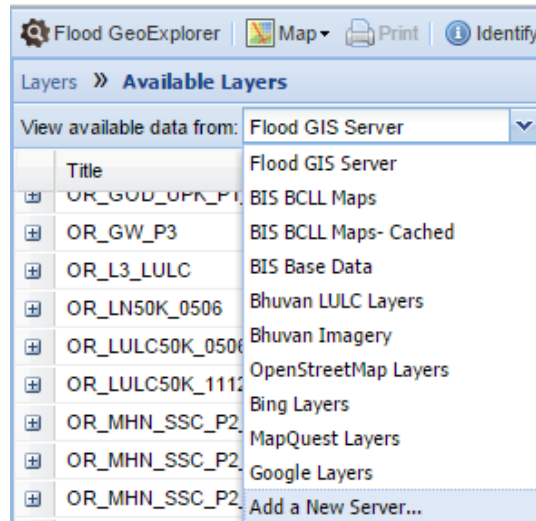


Figure 7.7 Add a new (WMS) server

Layers on the ‘Layers panel’ can also be rearranged by clicking and dragging a layer up or down to the required position as shown in Figure 7.8.

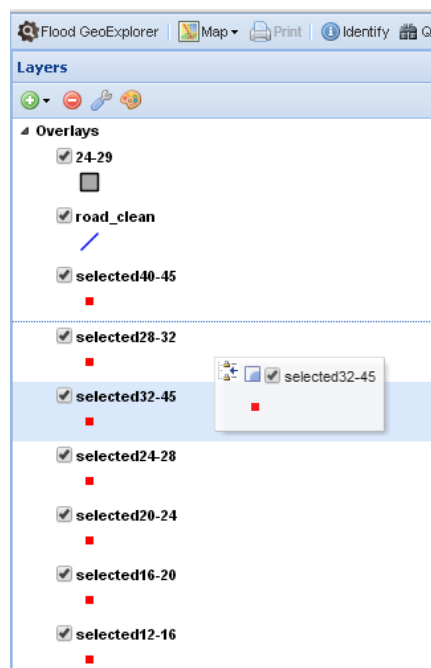


Figure 7.8 Ordering layers

This web GIS also provides a service to generate a map application and the HTML code to embed it into a web page which is based on the layers active in Map-Window. On the GeoExplorer toolbar, click Map tab and then click Publish map button to open the Publish map dialog box (Figure 7.9). The *Publish map* dialog box provides some tools to select and add to the toolbar in the map application, which will be included in the published map application (Figure 7.10).

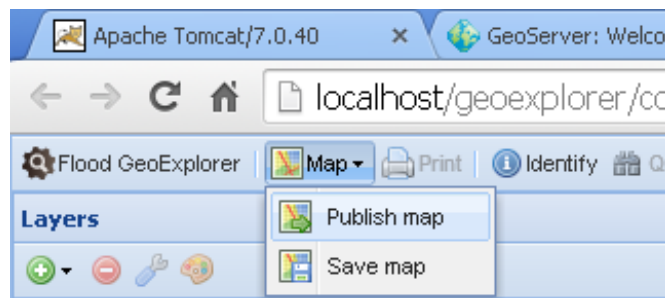


Figure 7.9 Publish map tool

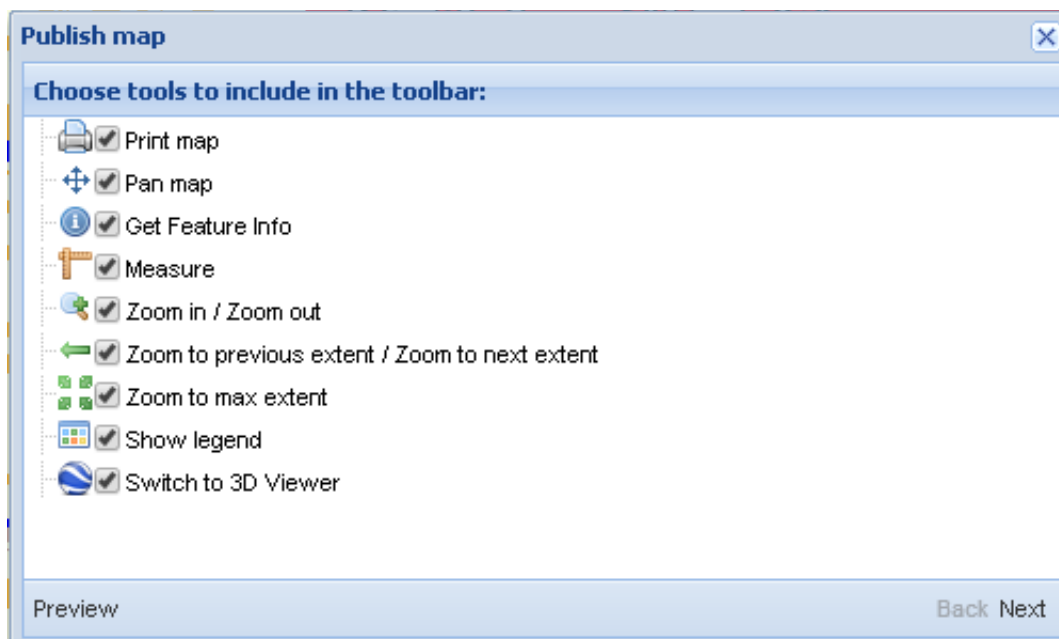


Figure 7.10 Selecting tools for publish map

The *Preview* button gives a preview of map application as in the Figure 7.11.

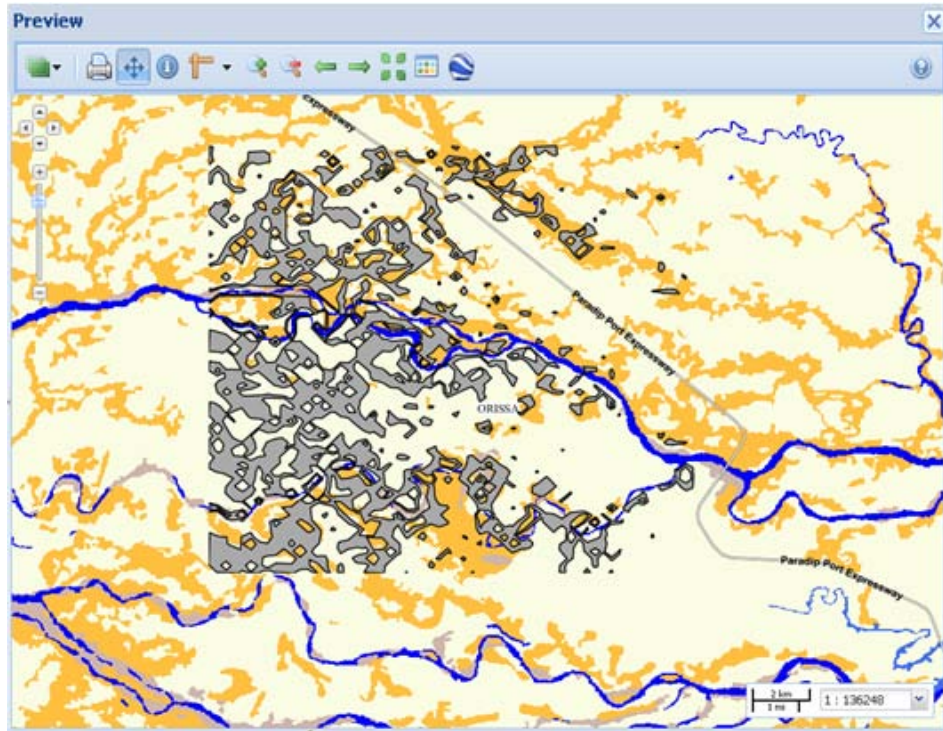


Figure 7.11 Preview of a map

The Publish Map tool also provides a HTML code which can be included in any web page for displaying map. HTML code can be generated by Clicking *Next* tab available in the Publish map window (Figure 7.12).

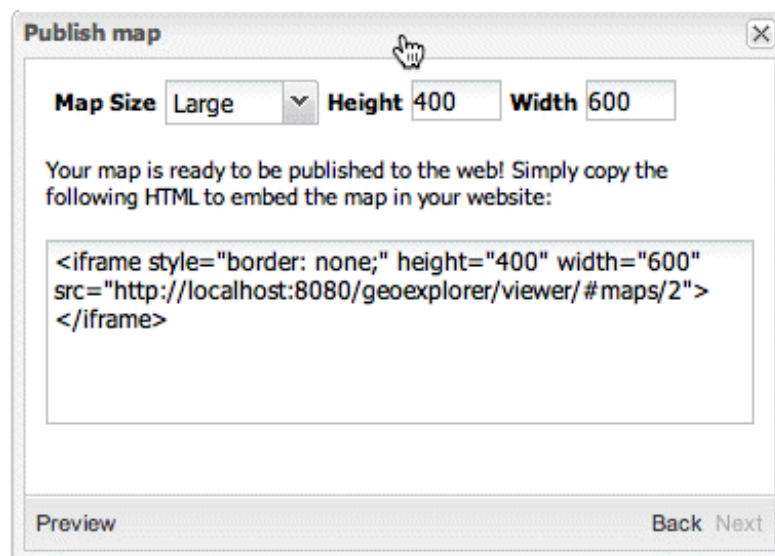


Figure 7.12 Generating HTML code

The map can also be viewed by using GeoServer Layer preview as shown in Figure 7.13.

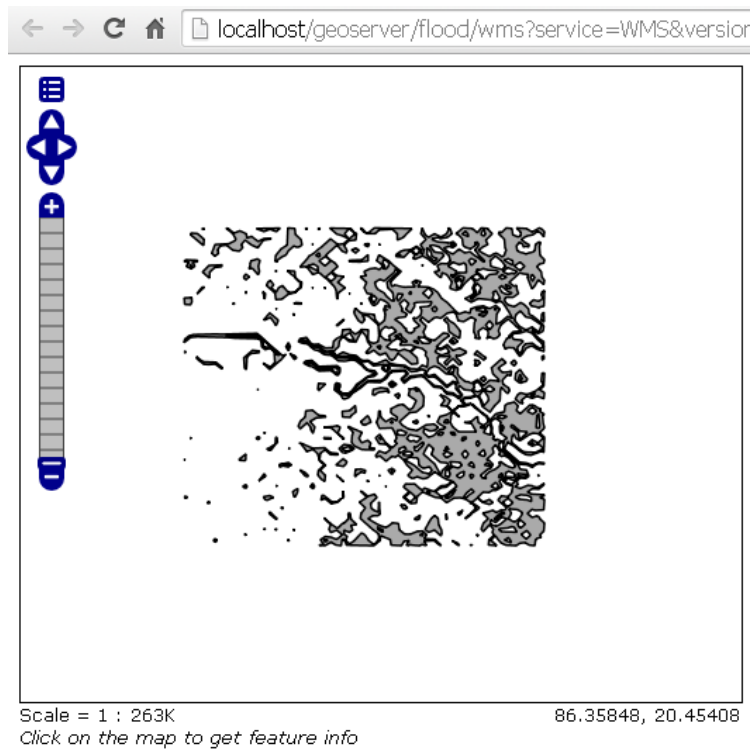


Figure 7.13 Open Map Layer

### The Flood GIS workspace

The Flood GIS workspace can be divided as the following three main areas:

- *Map Window:* This is the right pane of screen and also the largest area of the window, as it displays the map.
- *GeoExplorer toolbar:* This is the GIS application toolbar which provides various basic and few advanced functionality to the user.
- *Layers panel:* It contains the list of map layers. It provides access to the different layers and their properties.

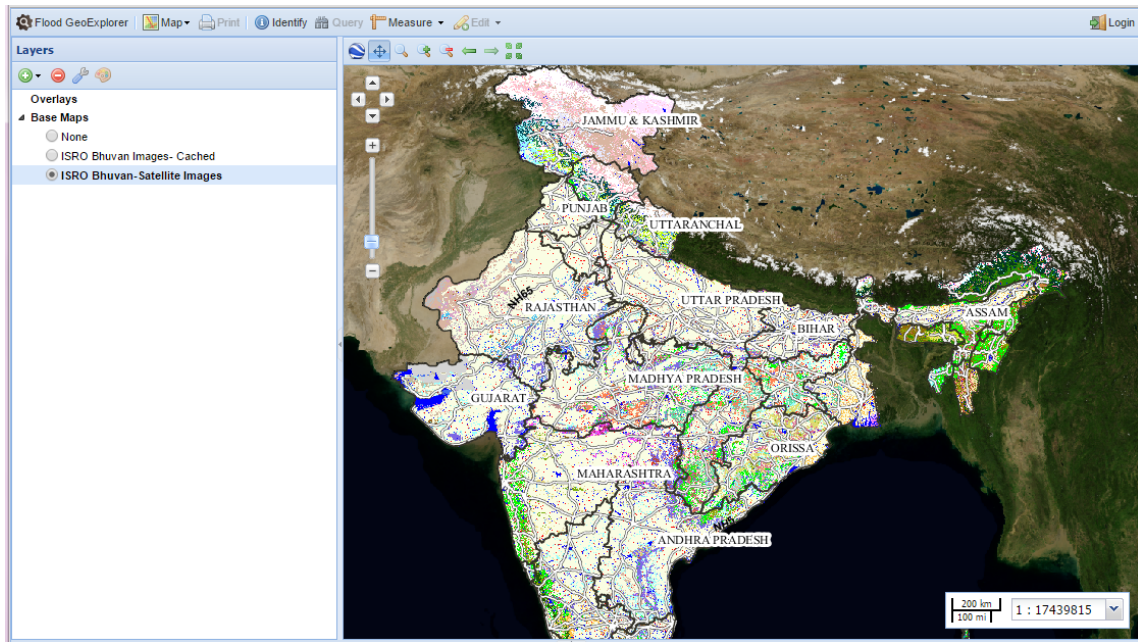


Figure 7.14 Flood GIS workspace

**Map Window:** It is the main display area for any added layers to Flood GIS (Figure 7.14). The contents of the Map-Window are configured via the *Layers panel*. The ‘Map Window toolbar’ offers some tools for navigation as for zooming, panning, etc.

**Map Window toolbar:** The *Map Window* toolbar shown in Figure7.15, it offers access to the following tools:

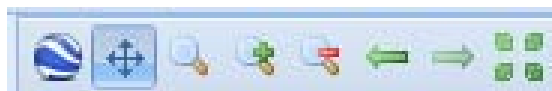


Figure 7.15 Map Window toolbar

The map window toolbar has eight tools for performing simple operations like zoom-in or zoom-out for the map. It provides functionality for Pan Map, Zooming in and out, Zoom to previous and next extent and Switch to 3D view.



Figure 7.16 Flood Geo-Explorer toolbar

The Flood *GeoExplorer* toolbar provides access to the following tools (Figure 7.16):

- Flood GeoExplorer
- Publish map
- Save map
- Print
- Identify
- Measure
- Query
- Create
- Modify
- Logi

The descriptions of these tools are as follows:

The Flood GeoExplorer tool gives the information of this application. The ‘Publish map’ tool offers to publish the current map by providing the HTML code which can embed in any web page. The ‘Save map’ tool saves the map display in map window by generating a URL of present configuration of map. Print tool offers the map in a PDF form for printing. ‘Query’ tool provides simple query by attributes of the table. It can search on the basis of the attribute of an object. The LULC map provides the area, land use of the area, similar crop production area, etc. The Measure tool measures the length (distance) in Km. and Miles and the Area in Km<sup>2</sup> and mi<sup>2</sup> as specified by the user. The Create tool provides a functionality to create a new feature for the current map in the window. Modify tool offers the functionality to edit the existing feature available in the current map. The Create and Modify tools requires the Login to Server for their functioning, so the Login tool provides the access to the authorized functions available with this server.

*Layers panel:* The *Layers* panel contains a list of available layers (which was included to the map). These layers are stored and managed by two folders as – *Overlays* and *Base Maps*. The base map is the background layer which displays first when the application starts and the *Overlay maps* layer is visible according the configuration settings as specified by the user (Figure 7.17). The base map and the overlay layers can be changed as required. The visibility of layers can be changed by using the checkbox to set it as visible or invisible.

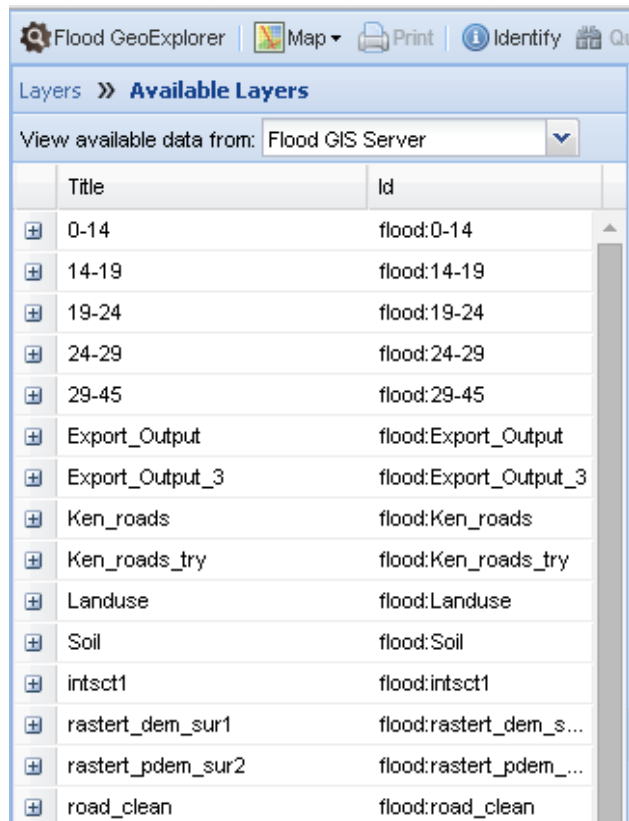



Figure 7.17 Available Layers panel

At the starting of Flood-GeoExplorer, the *Overlays* folder is initially empty. Add-layer button  which is available on the *Layers panel toolbar* provides feature to add new layers to the map window (Figure 7.18).

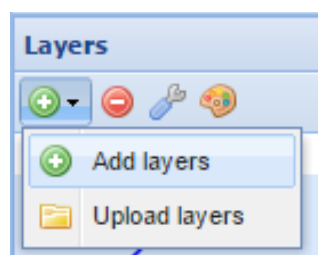


Figure 7.18 Add Layers Button

The new layer can be added as base or overlay. Google maps, Bhuvan maps, and OpenStreetMap and other open source maps can be added base or background map. Multiple base layers can be accessed in the list but only one base layer can be active at any time. The default base layer is Bhuvan Satellite Image of India (open access image). There is a black screen display at the time when no base layer was selected.



Figure 7.19 Layers Panel Toolbar

The *Layers* panel toolbar provides access to some tools. This panel has tools for adding a new layer in the display window, remove layer from the layers panel list (Figure 7.19). It also has tool to display the layer properties for viewing, editing the later properties. The layer styles tool provides access to editing the styling rules of a layer which also requires Login. The Layer Properties panel offers display and style setting properties of current layer (Figure 7.20).

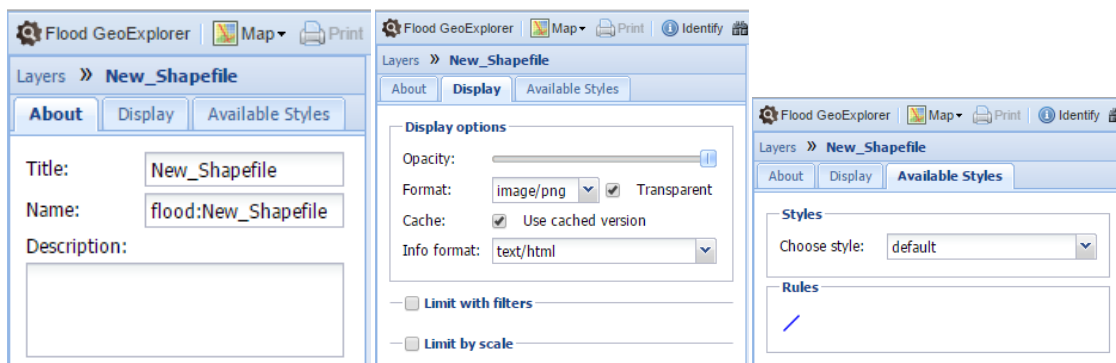


Figure 7.20 Layer Properties: About, Display and Available Styles.

Flood GIS can connect to many different types of data sources which is based on open source system with read-only access. Flood GIS is connected with the GeoServer which is used to display the layers which is stored in PostGIS. GeoServer provides the functionality to Edit, Modify and Delete any layer which is stored in the PostGIS and have full read/write access through the administrator authority. This means Flood GeoExplorer provides the functionality to *Create and delete features*, *Edit existing features* and *Edit map layer styling*. To facilitate the security motive to this Flood GeoServer, before read/write access is enabled, users must be authenticated by the Flood-GeoServer. The Login button is at top-right as shown in Figure 7.21. This provide access to the *Login popup* (Figure 7.21-a). It ask for user name and password as shown in (Figure 7.21-b). Then for exit the user can *Logout as in* Figure 7.21-c.

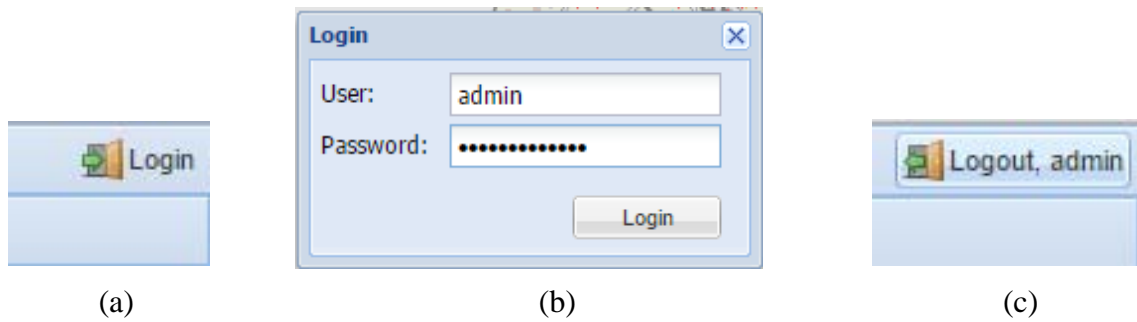


Figure 7.21 Authentication in Web GIS

**Available Layers from Different Servers:** The Flood-GeoExplorer grants access to those servers which have open source accessibility. Currently it includes few servers as follows:

- Flood GIS Server
- BIS BCLL Maps
- BIS Base Data
- Bhuvan LULC Layers
- Bhuvan Imagery
- OpenStreetMap Layers
- Bing Layers
- MapQuest Layers
- Google Layers

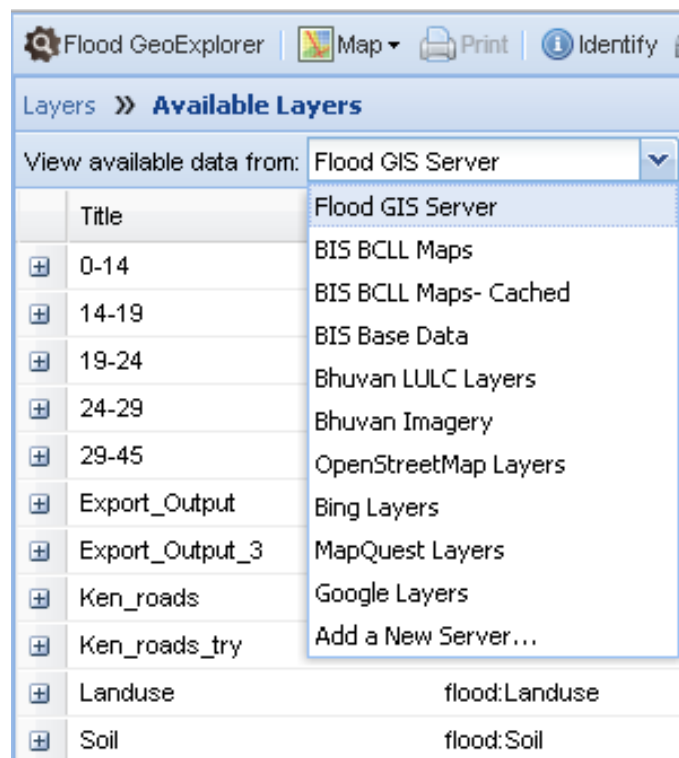


Figure 7.22 Available Servers on Web GIS

**Flood GIS Server:** Flood Height Layers, Road Layers, Landuse Layers, Soil Layers, Road intersection Layers, Shelter Layers etc (Figure 7.22).

**BIS BCLL Maps:** Vegetation Type Layer, Biological Richness Layers, BCLL Maps Layers, India State Layers, Rail, Road, River, Irrigation, Soil, Forest Layers, etc.

**BIS Base Data:** Vegetation, DEM, District, Satellite Layers, etc.

**Bhuvan LULC Layers:** A large numbers of different LULC and various other features layers of India.

**Bhuvan Imagery:** AWIFS Layers and Bhuvan OGC web services.

**OpenStreetMap Layers:** Mapnik Layers.

**Bing Layers:** Bing Roads, Bing Aerials, Aerial with labels Layers.

**MapQuest Layers:** Open Street Map and Imagery Layers.

**Google Layers:** RoadMap, Satellite, Hybrid and Terrain Layers.

The layers available with these servers can also added in this Flood web GIS. Any valid *WMS* can be added by adding that server and the layers accessible through the open source system. The 'Flood-GeoExplorer' also allow to upload the geospatial data, shapefiles (compressed into an archive file) or GeoTIFF files directly into this local web GIS server. Here in Flood GIS the different layers are stored in the robust PostGIS database and accessed through the GeoServer (Figure 7.25). The Flood GeoExplorer displays the different layers through the GeoServer. The PostgreSQL is used for the spatial query which can be performed by using the Query tool, available at the Flood GeoExplorer toolbar.

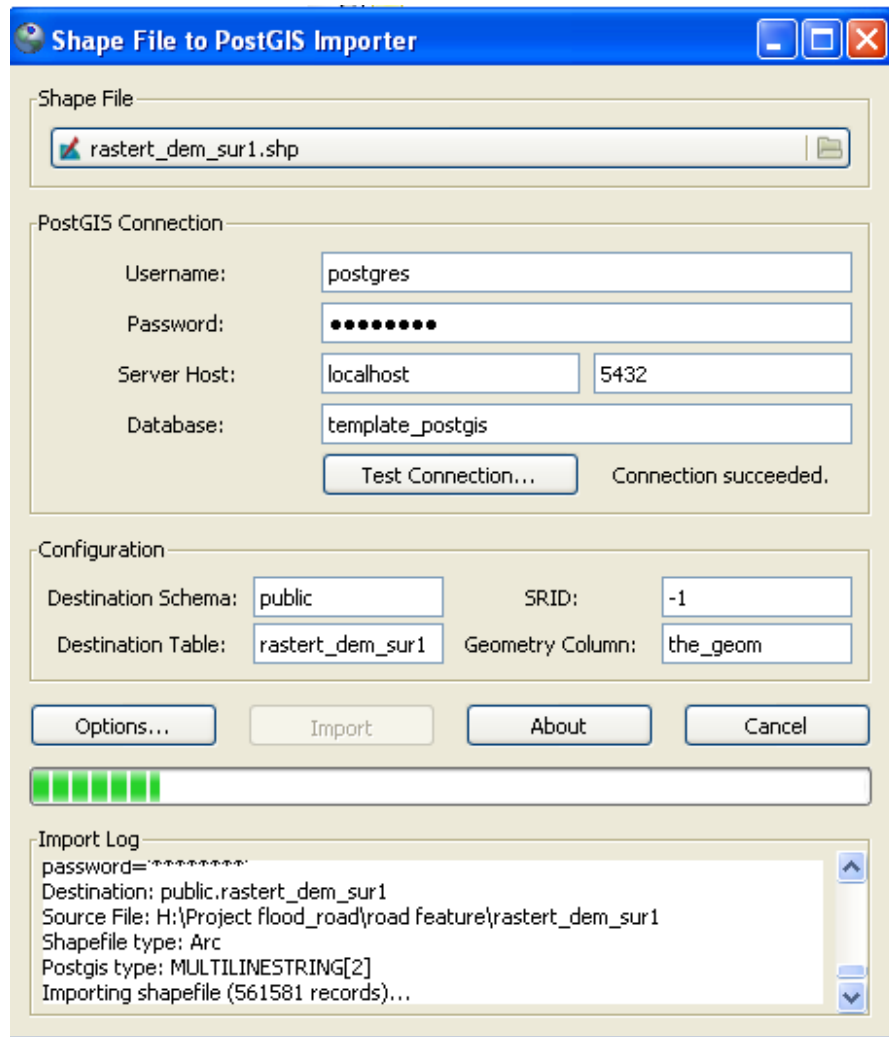


Figure 7.23 Importing Shapefile to the PostGIS Database

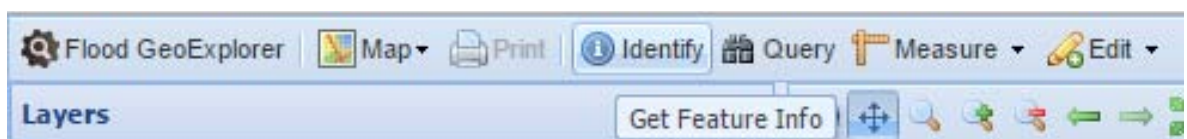


Figure 7.24 Identify tool (Get Feature Info)

**Identify:** The Identify tool provides the attribute information of the current layer (Figure 7.23). The Identity tab is used for display the information of a particular area (Figure 7.24). The user can click on Identify tab to activate the tab and then click on that area to retrieve the information about the particular area. It provides the feature of that location which it activated by this tool. As shown in the Figure 7.25, Get Feature Info tab gives the related information of the layer using the Identify Tool and shows the Feature Info of that particular point area on the layer. The Built-up area feature info also gives description of

Urban and rural area. In the map, the red colour represents the Built-up Urban area and the brown colour represents the Built-up Rural area. So the user can get the information instantly by using the Identity feature.

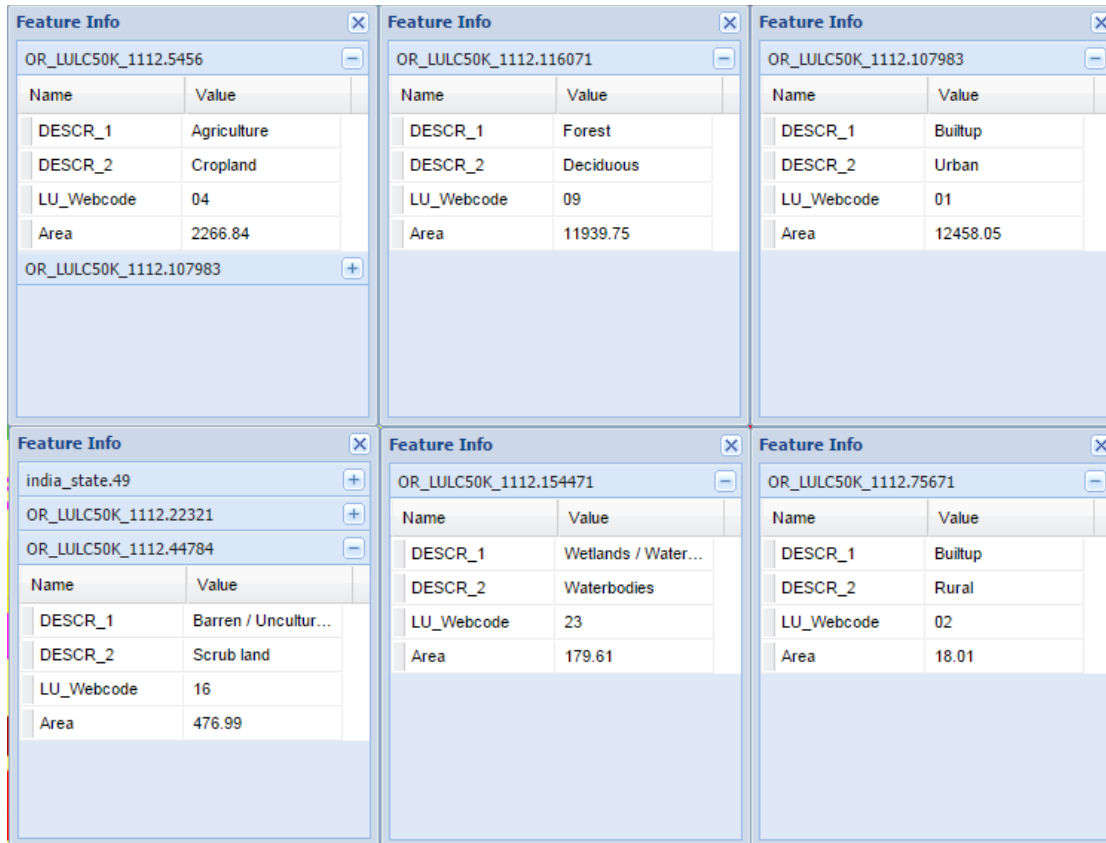


Figure 7.25 Feature Info using Identify Tool

The illustration of Agriculture Land, Wet Land, Barren Land and Forest Land has been shown in the Feature Info description. Some more interesting features are discussed in the consecutive section.

*There is a tool which permits to edit the existing feature of active map window: the Edit button. The Edit Button provides the feature for editing and modifying of the layer data or attributes (Figure 7.26).*

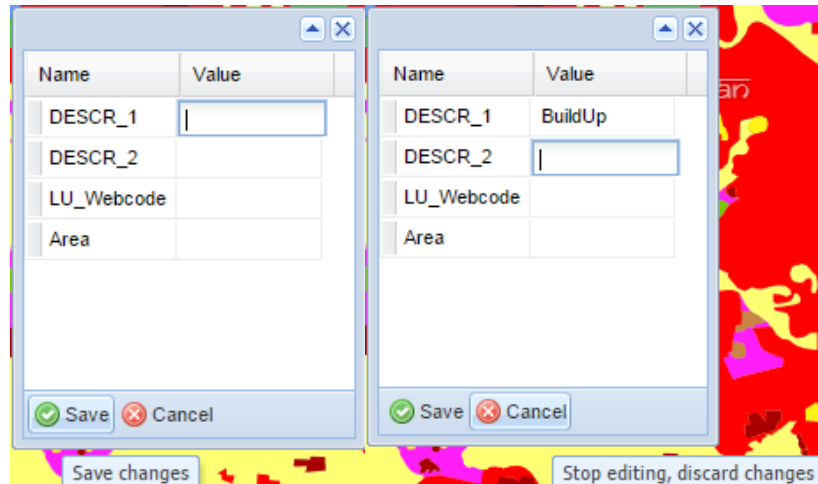


Figure 7.26 Editing and modify tool

The attribute values can be edited, changed and then save by this tool. It will update the layer immediately. The current map can be saved in Flood Web GIS. The other way Edit, Save, Update and Delete feature is that for the map opened in the map window. To Edit a map feature, simply click the Edit tab and then click Create button for Add some Feature or click Modify button for modify the existing feature in the map (Figure 7.27).

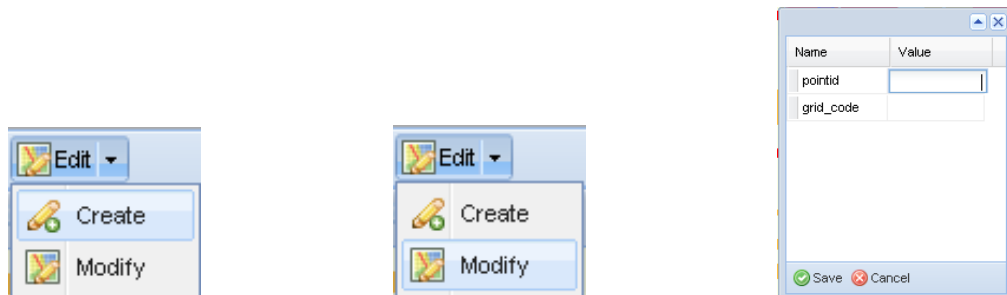


Figure 7.27 Create and modify Feature

As the Create feature provides the facility to add some attributes to the map, the Modify feature provides the capability to Edit or Delete the feature in the map (Figure 7.28).

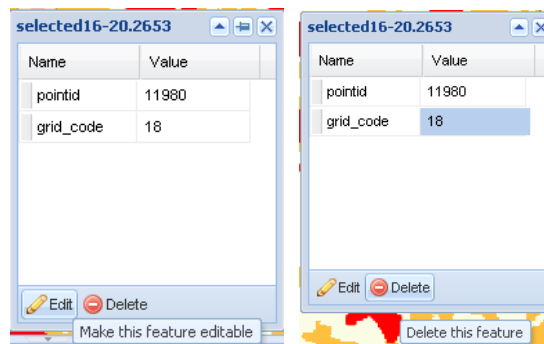


Figure 7.28 Edit and Delete Feature for existing map attributes

The existing map shows the attributes values to the user by different ways. One can show all the attributes by right clicking Layer on the Layer panel or the other way is for viewing the attribute at any specific point location, by simply clicking at that point as in Figure 7.29. This Feature also provides to view and make changes to the data.

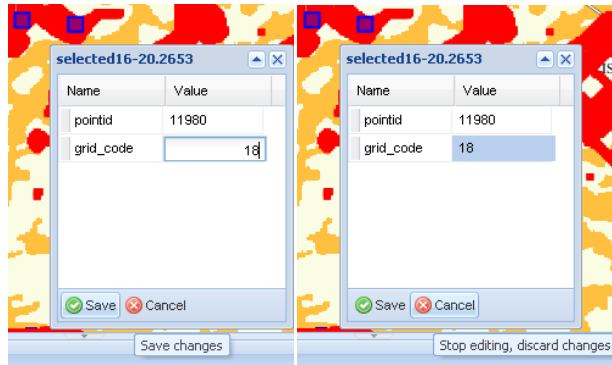


Figure 7.29 Save and Discard Feature for Map

**Query Tab:** The Query tab is available in the Flood GeoExplorer tool bar. This Query tool provides a query builder based on the attributes of the current map in the map window. Figure 7.30 shows the query to find all the points whose value of grid\_code is equal to the 18. The right panel shows the result of the query.

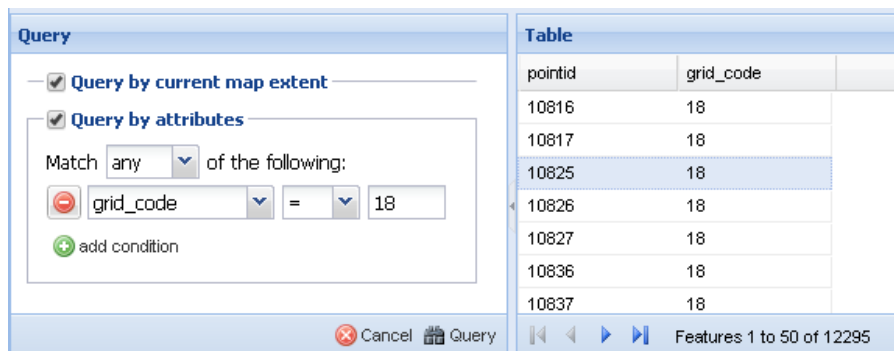


Figure 7.30 Query on Map by Attributes

By this way it is found all the points whose height is 18 feet. The layer is based on the values of elevation of each point. So it shows the points having similar elevation.

The integration of GIS and open source software can provide enormous opportunity to develop new application. The Google earth is the main source for raw data in this web GIS. Here it uses the Google API for the depiction of the shortest route during flood disaster.

This web GIS has taken 130 places as the safe zones for evacuation on the basis of the availability of the resources. The user friendly interface helps to identify the exact path with the route description. Route delineation of study area is shown in the Figure 7.31 with the information of directions, using Google API. The user can find distance and the path between any two places using start and end tabs (Figure 7.32).

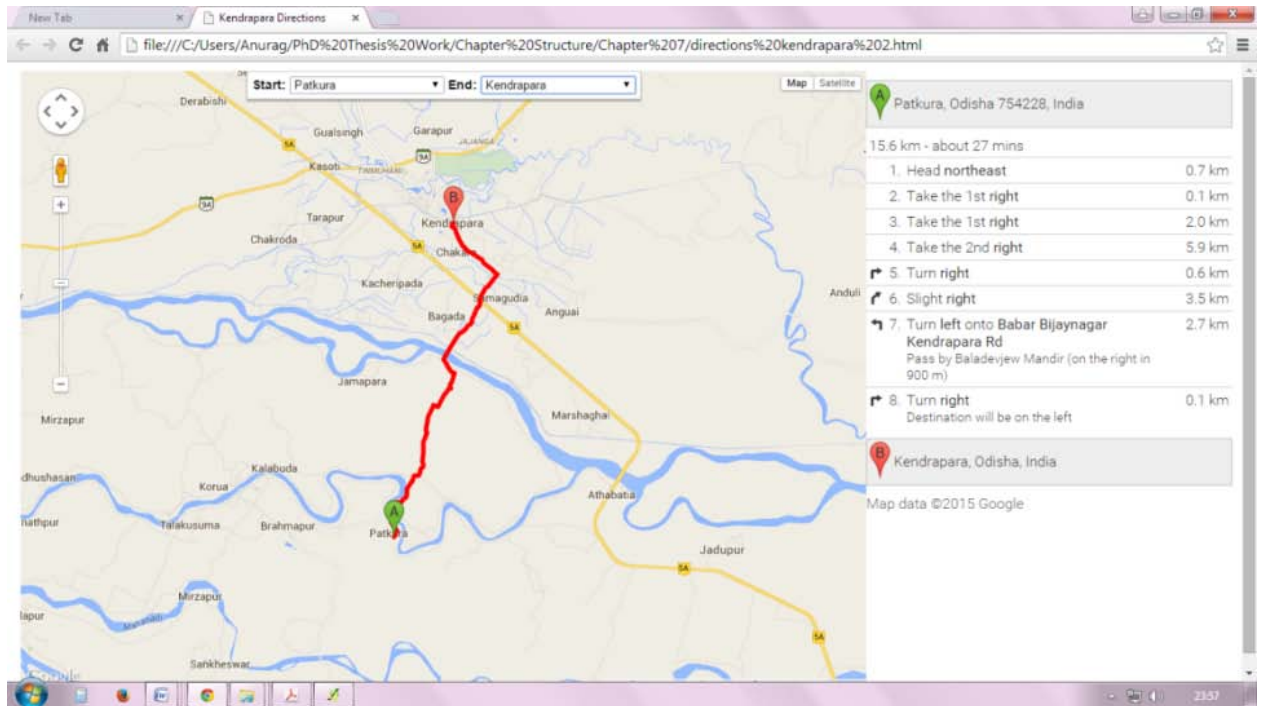


Figure 7.31 Route delineation using Google API

The Figure 7.31 shows that the path between 'Patkura' and 'Kendrapara' has a distance of 15.6 km. and it may take about 27 minutes by car. The path shows to the user explains that the route steps by steps i.e. heads towards northeast (.7km) then take the first right (.1km) then again take first right (2km) then take the second right (5.9km) then turn right (0.6km) then again slight right (3.5km) then turn left (2.7km) then turn right (.1km) to reach Kendrapara. Similarly Figure 7.32 explores the route from 'Badahat' to 'Kendrapara' with a distance measured as 1.9 km. This feature of web GIS gives a very good idea of route and distance. It may be very helpful in the event of emergency situation. The user can get the information about the various options available in the list of places to find the most suitable one. It also provides the information about the minimum time required to complete the route. This may help the user to calculate the time during the emergency situation.

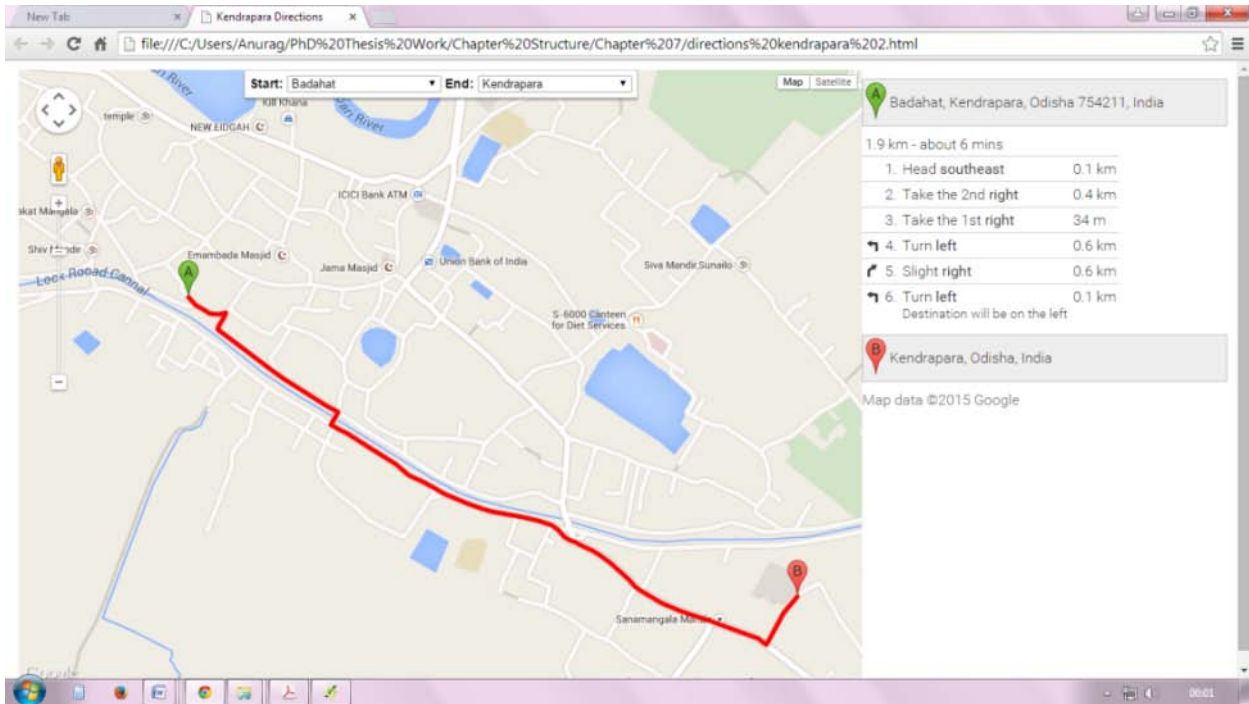


Figure 7.32 Route with directions shown in Urban Area

Names of the places which can be reached by using this web GIS tool are given in Appendix. These are considered as the shelter zones because these places have some kind of constructed area, like primary school, Panchayat School, high school etc. There are total 418 schools in Kendrapara, but only those places which are near to the study area are given in Appendix A.

This method provides a development process for on-line flood disaster mitigation and management system, integrating information retrieval and analysis for information sharing and decision-making support. The users can use this web GIS with a web browser. The personnel evacuation plan would be implemented by the integrated system to improve the ability of flood disaster pre-warning and monitoring system. To improve the disaster mitigation and management system it needs water depth changing process, 3D displaying, real time water management system, Real time satellite data processing, flood inundation damage evaluation and other applications are required to make a full functional perfect system.

## **CHAPTER - 8**

### **CONCLUSION, LIMITATION AND SCOPE OF FUTURE STUDY**

#### **8.1 CONCLUSION**

Presently there is an inadequate level of protection in the country against floods. The main causes of floods in India are heavy rainfall, inadequate capacity of rivers to carry the high flood discharge and cyclones are also cause floods. Vulnerability to flood disaster is caused by the high population density, illiteracy, widespread poverty, enormous pressure on rural land, and economic dependency on agriculture. During floods women and children are particularly vulnerable. Eighty five percent of the deaths during disasters are of women and children (CRED, 2000). According to the Government of India, Kendrapara, Jagatsinghpur, Cuttack, Jajpur and Bhadrak Districts of Orissa state are the most flood hazard prone districts. The Delta region formed by the Nuna and Chitrapala rivers of lower Mahanadi region is considered as the study area for this research. It is located in between East Longitude  $86^{\circ}16'30''$  to  $86^{\circ}30'05''$  and North Latitude  $20^{\circ}22'30''$  to  $20^{\circ}31'30''$ . It is surrounded by the Kendrapara district in its north and Jagatsinghpur district in its south.

This research work focuses on the web based spatial decision support system for flood disaster mitigation. The first objective of this work was to perform the flood inundation mapping which was performed by using Radarsat data. The monthly discharge data analysis, Microwave data analysis and Flood inundation area delineation has been done. It is observed that the year 2001, 2003 and 2006 has very high peaks. This study uses the Radarsat-1 images of 04-September 2003 and 11-September 2003 for flood inundation studies. It shows the comparison between different flood duration images. IRS P6 LISS-III image, dated 21 January, 2006 is used for creating land use map with the help of ERDAS Imagine. The LULC map is divided into 10 classes according to the seasonal crop, lake, river, build-up area, plantation, etc. Flood damage assessment is done by overlaying land use map with flood map. The output map divides the classes into water and land area. It shows the area of different classes in water and land. The result shows that 65.48% of total land area is submerged in water. 66.73% of crop and vegetation area is damaged due to flood. 58.13% of the build-up area is come under the flooded land area. As seen in the

comparison of different Radarsat data, it is observed that there is a very high damage occur. In terms of money it is calculated that more than INR 100 Billion loss of agriculture and INR 17 Billion loss of build-up and roads occur due to the flood.

The second objective of this work was to identify the safe and shortest route for evacuation i.e. optimal path identification using ANFIS. It first constructed a weighted parameter model by considering road quality and environmental factors. Cost of road quality factor is based on road length and road width. Cost of environmental factor consists of traversal speed, traffic volume and safe zones. These parameters are given as input to the AHP for building the weighted model based on the minimum time consumption with safety. In a flood scenario the shortest path is not always the best path for rescue operation. The water depth and the availability of high altitude building or area are the most important factors for immediate rescue. Path around the outskirts of urban areas can have low vehicle flow rate, compared to highways. So the optimal path is not necessarily the shortest path. This method finds the lowest impedance on path based on various factors which are important during flood. This method is applied on the rural and urban area roads of Kendrapara district of Orissa.

It uses five parameters for finding the priority of route using AHP, Fuzzy and ANFIS methods. The AHP was used to find the priority of path. Three different approaches have been implemented to find the shortest and correct path. These three approaches are: knowledge base, data base and learning base approach. All these three approaches are implemented and compared for the optimal path extraction.

In Knowledge Base Modeling approach, FIS is implemented using expertise Knowledge. This modeling requires very deep understanding of input output relationship in each and every scenario. The knowledge base modeling allows the user to design its own membership functions (MFs) which includes: deciding number of MFs in each input variables, their shapes and also ranges of each membership function. This type of modeling is applied to those systems whose rule structure is essentially predetermined by the user's explanation of the characteristics of each variable in the model.

Though knowledge base modeling provide freedom to the user to customize their own fuzzy inference process, still user faces many problems in deciding what parameters should be suitable for their application. But if the user is able to collect the previous data of their application then there is no more need to choose the parameters associated with a given MF arbitrarily. By applying various data modeling techniques, it can generate membership functions and rules automatically. Since FIS is modeled directly from data therefore this modeling is known as Data Base Modeling. Clustering of numerical data forms is the basis of many classification algorithms. In this work, since it is quite difficult to calculate the number of clusters in data set, therefore Subtractive clustering method has been applied. Then fuzzy logic has been applied to extract the broad categories of the clusters. This method is applied for the route evacuation problem, output of the fuzzy system matches to expected value to a degree of 91% to 97%. Thus it can be seen that though clustering and fuzzy logic are effective techniques for data modeling and analysis but still optimization of result is required. For this, fine tuning of membership functions is required which can be done through learning base modeling.

In some modeling scenarios, FIS generated from above two approaches gives insufficient or imprecise response due to slight variations in either expertise knowledge or in data values. Therefore to overcome these types of variations in the data values, FIS needs to undergo through training and learning process. Adaptive learning techniques, allows the fuzzy system to learn and extract information from the data they are modeling. Throughout the training, parameters associated with membership function changes and finally adapt the shape and parameter values that best allows the FIS to response in the approved manner. In this work, FIS is first implemented via all above mention different approaches, then results or decision of each approach has been compared and at last most appropriate decision has been projected out.

The learning based approach which was based on ANFIS was found suitable and perfect for the identification of optimal path. An intelligent fuzzy based decision support system has been constructed on the basis of the comparison of these three approaches. The elevation data plays an important role to find the optimal path in this work. ANFIS based DSS for safe route delineation has been implemented and different flood scenarios are explained. Different flood scenario has been found correct for low, medium and high flood.

The results are found according to the criteria involved and it offers the optimal evacuation path during the flood. People, who live in flood plains, can locate the areas at higher altitude which are less vulnerable to the flood water. The shelter points have been identified on the basis of its capacity, elevation and proximity to safe zone. The hybrid learning method has been selected for FIS training in this study. FIS model output is to be tested against all the three data sets one by one. The average testing error for the training data set is  $4.7 \times 10^{-4}$ . And the average testing error for checking data set is  $15.4 \times 10^{-4}$  and for testing data set is  $8.2 \times 10^{-4}$ . The checking data has a very near values compared to the FIS values, it is found that the resultant values are accurate up to 99%. Therefore it is observed that the system is working very near to the required result. There are some limitations with the accuracy of the input data, so the result cannot be 100% accurate. But under the practical concern the error up to 6 feet can be considered with these data sets.

The last objective of this work was to develop a web-based spatial decision support system for flood disaster mitigation. The web based open sources GIS has been implemented using Apache Tomcat web server and GeoServer as the application server. The PostgreSQL and PostGIS has been used for the spatial database management tools. It stored spatial data and perform spatial query based on the attributes. Length and area measurements, route display with names of the path are some of the key features of this web GIS. The user friendly interface is developed in JavaScript. It provides an easy way to query. The web GIS implemented in this work is based on the OGC standards, therefore the other OGC based systems can share and access its data and resources if the permission is granted and vice-versa. Therefore this flood web GIS is also able to access the Bhuvan open data and other Google data which are based on same standards. Therefore it is observed that this web GIS is also working well with other web sites (Bhuvan, Google, Bing, etc.) and the objective of optimal path delineation is also achieved with an online web based spatial DSS for flood disaster mitigation. Therefore this web GIS fulfilled the requirement of a spatial database which can store, update and retrieve data and also perform basic spatial query. The dissemination of information using web GIS have been discussed and thus the development of web based spatial DSS for flood disaster mitigation is implemented successfully.

The whole work includes remote sensing, GIS, open source software, disaster mitigation approaches, web GIS, decision support system, flood inundation modelling, vulnerability analysis, damage assessment, spatial database and the most important a noble cause to save the lives of people.

Intensity and duration of flood and the inundation during low, medium and high flood situation are essential information for any local person or the disaster manager. The pre-disaster vulnerability assessment of various elements and the post-disaster damage assessment of these elements are also required for disaster managers and insurance managers. The remote sensing and GIS provides very effective and efficient methods for this situation.

This work uses Google Earth data which have high accuracy. Various required information must be reached to the end-user in real time to get the benefit. For this purpose a web GIS has been successfully implemented through this research work. This web GIS is based on the open source environment. It provides on-line flood disaster mitigation and management system, integrating information retrieval and analysis for information sharing and decision-making support. Users only require a web browser to access data and perform model analysis without the requirements of installing high cost GIS software and processing software packages.

The rescue operation required shortest and safe path with detail and this research work provides a very efficient path finder. The evacuation path is based on elevation and ANFIS. So this web GIS will play a vital role in flood disaster. This web GIS provides some functionality to length and area measurements, route display with names and visualisation of the path are some of the key features of this web GIS.

## **8.2 LIMITATION**

This web GIS is using open source software, therefore the limitations of a freely available spatial geo processing tool is also the limitations of this web GIS. It includes the various operations which involve the digital image processing, hydrological modelling and other geo spatial methods (which can be performed by ArcGIS) cannot be performed, because it has very limited functions like finding vulnerability and optimal path, etc. If very high

resolution satellite images will be used than the accuracy of damage assessment will become better compared to the LISS III image and Radarsat data.

This web GIS uses pre defined stored spatial data and the requirement of real time analysis cannot be performed. Due to the high cost of various satellite data, this web GIS is not a real time system. It requires the integration of various government organizations and departments to work for a real time system.

The application of flood management model is a very vast area for research. It requires efficient management of huge spatial and temporal datasets, which involves data acquisition, its storage and complex processing, as well as manipulation, reporting and display results. The complexity of flood management model makes it difficult for individual organization to deal effectively with decision-making process. Difficulty in acquiring data, linking data sets, analysis tools and models across organizations make is difficult for implementation. These are some barriers to be overcome to develop an integrated flood disaster management system.

### **8.3 SCOPE OF FUTURE STUDY**

An Android based application can be developed for the flood disaster mitigation. It may integrate Google API with android application for further development of flood disaster mitigation app. It may use Google maps for safe route identification.

Display of 3D visualisation for the route can also be achieved by using Google API, if the 3D images of that area are available through the Google images and maps. It can also show the tremendous potential of Google Maps to explore the new ideas and methods.

Future work will focus on more realistic and practical factors. It should base on real time disaster conditions to achieve more accurate and high quality results; which will be more effective in emergency situations. This study may lead to near real time decision making during and post disaster. A web based spatial flood management system could integrate cellular phone with digital camera and standard GPS system. So the people can upload and share the images of disaster area. It will be helpful for disaster mitigation.

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9. Anurag Aeron, R.D. Garg, D.S. Arya and S.P. Aggarwal (ACCEPTED Paper ID-7881) *Flood Inundation Mapping and Vulnerability Assessment of a Small Part of Lower Mahanadi Delta Region*. IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2015) will be held from July 26-31, 2015 in Milan, Italy.



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## APPENDIX-A

Names of the places which can be reached by using this web GIS tool and these are considered as the shelter zones because these places have some kind of constructed area.

- |                    |                   |                      |
|--------------------|-------------------|----------------------|
| 1. Aitpur          | 27. Bichana       | 55. HDFC Bank        |
| 2. Alifa           | 28. Birijanga     | ATM Kendrapara       |
| 3. Andhalo         | 29. Biswanathpur  | 56. Head Post Office |
| 4. Anguai          | 30. Brahmapur     | Kendrapara           |
| 5. Asureswar       | 31. Canal Rd      | 57. ICICI Bank ATM   |
| 6. Athabatia       | 32. CDMO Office   | Kendrapara           |
| 7. Attabuha        | 33. Chakara       | 58. Jajanga          |
| 8. Axis Bank       | 34. Chakroda      | 59. Jamapara         |
| Kendrapara         | 35. Chandapur     | 60. Jamara           |
| 9. Babujang        | 36. Dahalpur      | 61. Jamunabad        |
| 10. Badahat        | 37. Dalaanta      | 62. Jenasahi         |
| 11. Badanaipur     | 38. Daluani       | 63. Kacheripada      |
| 12. Bagada         | 39. Dara Bachha   | 64. Kalabuda         |
| 13. Baladevjew     | 40. Derabishi     | 65. Kapaleswar       |
| Mandir             | 41. Dhasnapari    | 66. Kasoti           |
| 14. Balisahi       | 42. District Drug | 67. Kendrapara       |
| 15. Balisua        | Warehouse         | 68. Kerilo           |
| 16. Balyakula      | 43. Dutial        | 69. Keutkandia       |
| 17. Bangalpur      | 44. Erakana       | 70. Khairabad        |
| 18. Bangari Rd     | 45. Fakirabad     | 71. Khamagan         |
| 19. Bantala        | 46. Garadpur      | 72. Kharja Brajabana |
| 20. Bantala School | 47. Garapur       | 73. Kinilo           |
| Rd                 | 48. Garuala       | 74. Korua            |
| 21. Bedari         | 49. Gaudagan      | 75. Korua BSNL       |
| 22. Behula         | 50. Gotrabil      | 76. Krushnanandapur  |
| 23. Beruhan        | 51. Gualsingh     | 77. Kulatuthi        |
| 24. Bhagabanpur    | 52. Haladia       | 78. Kusida           |
| 25. Bharatpur      | 53. Haridaspur    | 79. Kusumandal       |
| 26. Bhusaranga     | 54. Hat Badi      | 80. Madhushasan      |

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|--------------------------|---------------------|--|
| 81. Mahamuda             | 99. Parakula        | 118. Talasanga                         |
| 82. Mahanga              | 100. Patana Rd      | 119. Tarapur                           |
| 83. Mandia               | 101. Patkura        | 120. Taratasasan                       |
| 84. Manikipur            | 102. Pithapura      | 121. Tata Docomo<br>Store Kendrapara   |
| 85. Manikunda            | 103. Purusottampur  | 122. Tentol                            |
| 86. Maradpur             | 104. Ramachandrapur | 123. Tikanpur                          |
| 87. Marsaghai<br>Collage | 105. Ramnagarpatana | 124. Tinmuhani                         |
| 88. Marshaghai           | 106. Rasilabad      | 125. Tulasi Women's<br>College         |
| 89. Marshaghai Road      | 107. Samagudia      | 126. Tulasipur                         |
| 90. Mirapatana           | 108. Santol         | 127. Tunupur                           |
| 91. Mirzapur             | 109. Saranga        | 128. UCO Bank<br>Kendrapara            |
| 92. Nadia Barai          | 110. Sekhapatana    | 129. Uday giri                         |
| 93. Naiguan              | 111. Shyamsunderpur | 130. Union Bank of<br>India Kendrapara |
| 94. Narendrapur          | 112. Sikol          |  |
| 95. Nasadipur            | 113. Silipur        |  |
| 96. Naupara              | 114. Sobanpur       |  |
| 97. Pahenta              | 115. Solapat        |  |
| 98. Pandia               | 116. Sujanagar      |  |
|                          | 117. Talakusuma     |  |