RURAL RISK ASSESSMENT IN WESTERN GEORGIA WITH EMPHASIS IN FLOOD RISK

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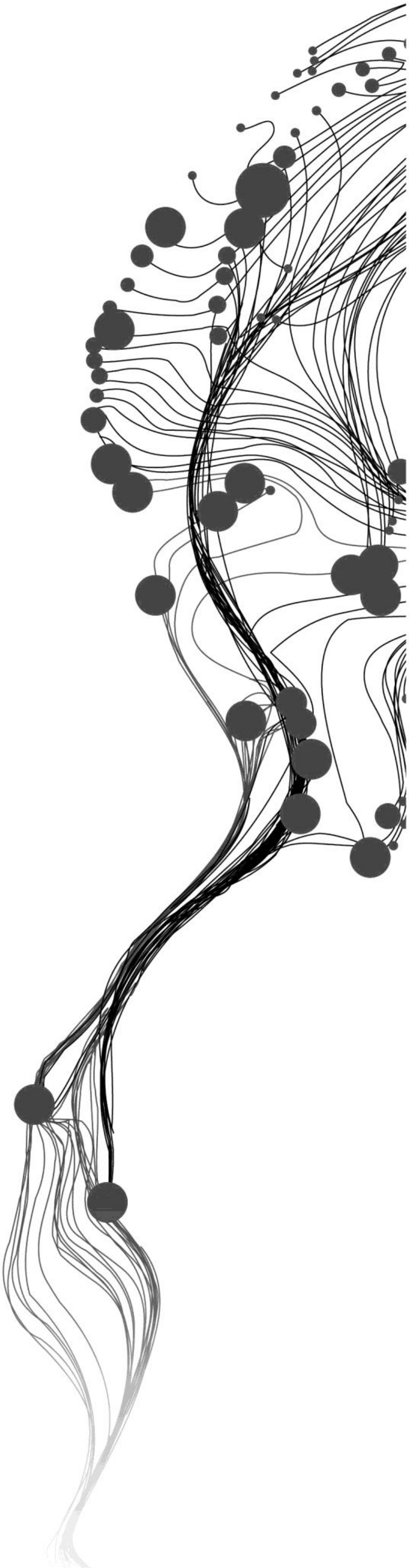

RURAL RISK ASSESSMENT IN WESTERN GEORGIA WITH EMPHASIS IN FLOOD RISK

SAMJANA GHIMIRE
Enschede, The Netherlands, April, 2011

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Applied Earth Sciences (Geo-Hazards)

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ABSTRACT

Flooding is the serious problem in Western Georgia. The study area lies in the flood plain of the Rioni River. The flooding is frequently and almost yearly occurring hazards in this area. In 1987 catastrophic floods had destroyed around two thousands houses, 1300 km of highways and about 16.5 km of railway in this area. In order to reduce the flood risk and vulnerability the coping capacity of the community have to be increased by raising the public awareness and also strengthening the level of capacity. Therefore the local knowledge is very important to minimize the impacts of floods. So the main aim of this research is to identify and categorize the elements at risk and vulnerability assessment of elements at risk. Also the perception of the local people towards the flood and the coping mechanisms employed by the local people in different stage of floods were assessed. To achieve the objective of the research, primary as well as secondary data was collected. 121 households were interviewed and analyzed for the vulnerability, risk perception and coping mechanisms. The impact of annual flood in the physical, economical and societal elements at risk was identified. Under the physical elements at risk the identified elements are roads, railways and houses.

The elements at risk were classified into four major types of house, two types of roads and three basic agricultural crops. It has been observed that the house types 3 and 4 are more vulnerable to floods. The construction materials used for these types of houses are tin roof, wood, stone, mud, tin, ply etc wall and wood, mud and stone floor. The percentage of paved road is less than the unpaved road in this area and the unpaved roads are more vulnerable to floods. The main factor that makes the house vulnerable was floor and the wall materials.

Economic elements at risk are agricultural lands, livestock and crops such as corn, watermelon and beans. For the field crops damage assessment was made for each crop stage e.g. sowing, growth, maturity and harvesting. The vulnerability was assessed for physical and economical elements at risk by generating the vulnerability curves on basis of flood damage information collected from the questionnaire survey. In the area field crops such as beans and watermelon are more vulnerable than corns. The majority of crops in this area were corn. The damage increases with increase in water level and duration. The damage value of the crops was expressed in Georgian currency (GEL). The crop calendar was used to extract the information about the different stages of crops. With regards to farm animals chicken, turkey and ducks are more vulnerable than large sized animals such as cows, pigs, etc. but people can carry the smaller animals during evacuation.

Societal vulnerability was assessed based on age, household size, income level and occupation of people. All the elements at risk were identified and assessed by using the flood parameter like depth, duration. The social economic characteristics were used as a key parameter to analyze the vulnerability of the local people. This area is characterized by high social vulnerability because of the combination of low income, occupation, large household size and so on. The flood annual depth and duration map was generated from the information as perceived by the local people. The local people stated that certain depth and duration is acceptable but when the water starts to cross the limit then it becomes a disaster. The result shows that the ability of people to cope with the flooding is related with the capacity of people. The coping capacity of people to flooding is also based on the socio economic characteristics. Such as the lower income people suffer more than the higher income people as they can't afford the cost of the repair, reconstruction of their houses after the floods. But if the higher income groups experience the higher degree of damage because of their higher value property. There are several coping mechanisms employed by the local government and the local people. But the coping mechanisms are not enough to cope with the flooding in this area.

The research results have comparable results obtained by the modelling result using SOBEK (Tamar). The main reason for this is that the modelling result is entirely based on local elevation data (DEM) and does not consider the water channels present in the various study regions and also other water discharge sources. The second approach is in identifying the elements at risk. Mainly in the literature it shows that the crops and their different stages were not considered as elements at risk. But this study attempts for the granular level of study approach to identify different stages of crops as new added elements at risk for the rural risk assessment in agricultural crops. Also the vulnerability of crops in each crop stages was determined in this study.

Keywords: Elements at Risk, Physical vulnerability, Social vulnerability, Economic vulnerability, Risk perception, coping mechanisms

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Samjana Ghimire

Enschede, The Netherlands

April, 2011

Dedicated to my Parents, my Love Rajiv, Brother, my Sisters and my love Sansreet, Shreyan, Jeenat

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LIST OF ACRONYMS

ADPC	Asian Disaster Preparedness Centre
ASTER	Advanced Space borne Thermal Emission and Reflection Radiometer
CENN	Caucasus Environmental NGO Network
CEOS	Committee on Earth Observation Satellites
CRED	Centre for Research on the Epidemiology of Disasters
DEM	Digital Elevation Model
EM-DAT	Emergency Events Database
ERDAS	Earth Resources Data Analysis System
FEMA	Federal Emergency Management Agency
GEL	Georgian Lari
GIS	Geographical Information System
GPS	Global Positioning System
IFRC	International Federation of Red Cross and Red Crescent Societies
ILWIS	Integrated Land and Water Information System
IPCC	International Governmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
NEA	National Environmental Agency
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
UN	United Nation
UNDP	United Nations Development Programme
USAID	United States Agency for International Development

1. INTRODUCTION

1.1. Background

1.1.1. Disaster in Global Context

Natural hazard refers to all atmospheric, hydrologic, geologic (especially seismic and volcanic), and wildfire phenomena that, because of their location, severity, and frequency, have the potential to affect humans, their structures, or their activities adversely (Burton *et al.*, 1978). Natural hazards are unpredictable and can occur anywhere, anytime in every part of the world. It is the natural phenomena that may cause the loss of life, injury, damage to the property, social and economic disruption or environmental degradation (ISDR, 2009). Also hazards are mainly characterized by the intensity or magnitude, frequency, speed of onset, duration and the area of the extent.

In terms of global frequency of occurrence, EM-DAT: The OFDA/CRED International Disaster Database from the year (1991-2005), shows that flood covers 30.7 percent, windstorm covers 26.8 percent, epidemic 11.2 percent, earthquake 8.9 percent, drought 7.8 percent, landslide 5.1 percent and others combined 9.6 percent as shown in Figure 1.1. In figure 1.2 it shows the trends of occurrence of hydro-meteorological disaster in global context from the year 1991-2005.

According to the International Strategy for Disaster Reduction (ISDR, 2009), among all the common potentially hazardous natural disasters like: earthquake, volcano, landslide, flooding, tsunami and hurricane; flooding is one of the most common and frequently occurring natural disasters in almost every part of the world. Floods are defined as the overflow of areas that are not normally submerged or a stream that has broken its normal confines or has accumulated due to lack of drainage and exceed its carrying capacity (Malilay, 1997).

Any kind of disaster risk arises when the hazards interact with the physical, social, economical and environmental vulnerabilities (UN, 2005). The main causes of river flooding are usually prolonged heavy rains or melting snow, dam failure, human construction, vegetation cover, soil moisture conditions and so on (Nelson, 2008). Flooding can cause damages to the agricultural lands and the infrastructures such as houses, roads, bridges, irrigation infrastructures, dams, etc. It can also cause the loss of human lives. Flood disasters have a wide range of negative effects (will discussed more in Literature Review) especially the people who live near the flood plains are the most vulnerable group.

Disaster does not differentiate between poor and rich. But mainly in the developing nations most of the people's main source of income is agriculture and the people are mostly settled near the flood plains. When there is flood it causes not only damage to agricultural land and rural infrastructure but it also causes loss of human lives.

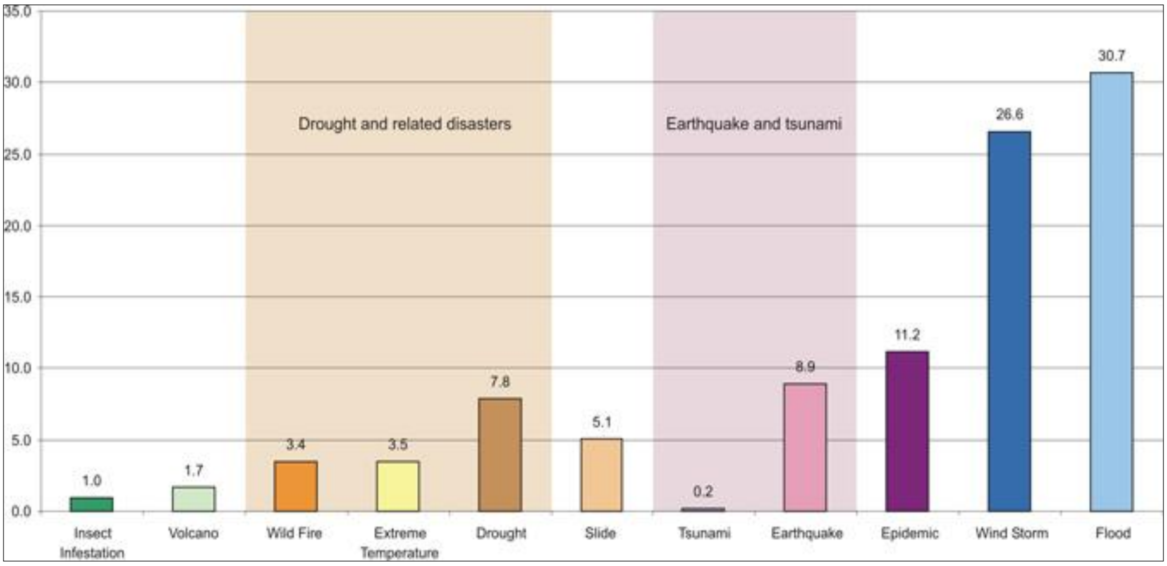


Figure 1.1: Distribution of Percentage of Natural Hazards from the year 1991-2005 by Types (Source:(EM-DAT, 1991-2005)

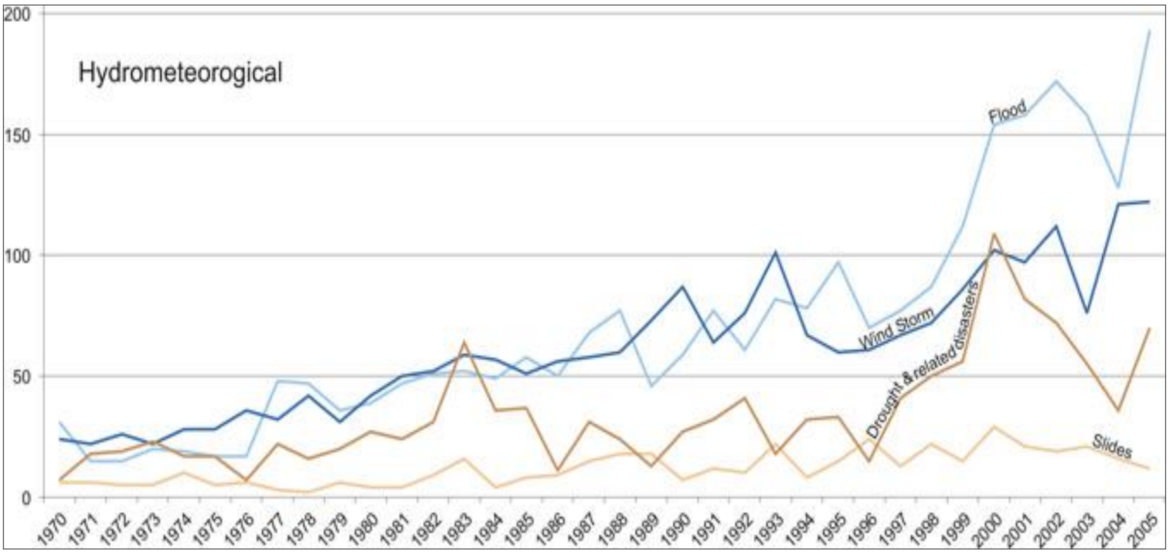


Figure 1.2: Distribution of Natural Hazards from the Year 1991-2005 (Source: (EM-DAT, 1991-2005))

The term "rural areas" applies to the areas that are usually characterized by agricultural, open space and very low density residential development. The geographical and the cultural contexts of rural area are tremendously diverse (Talani, 2003). In the rural areas the most common natural hazards are drought, floods, landslides, earthquakes etc and the risks become one of the parts of everyday life. In both Rural and urban areas flooding is one the biggest issues.

1.1.2. Flooding in Georgia

Georgia is a country prone to wide variety of natural and human induced hazards and disasters. The common phenomena are floods, landslides, earthquakes, drought and avalanches. Because of the country's fragile profile, unsystematic urbanization, huge technological infrastructure makes the country more vulnerable to several disasters. For an example most of the western region of Georgia suffered from the floods in 2005 because of weeklong heavy rains and the snow melting in the mountains OCHA (2005). Also mentioned by OCHA in year 2005, 50 houses were completely flooded in Kutaisi and Tskaltubo cities after the water came out from the banks of Rioni River. Figure 1.3 shows the distribution of common disaster in Georgia. It shows that the percentage of occurrence of hydro-meteorological hazards is higher than any other disasters. Likewise the second commonly occurring hazards are Earthquake.

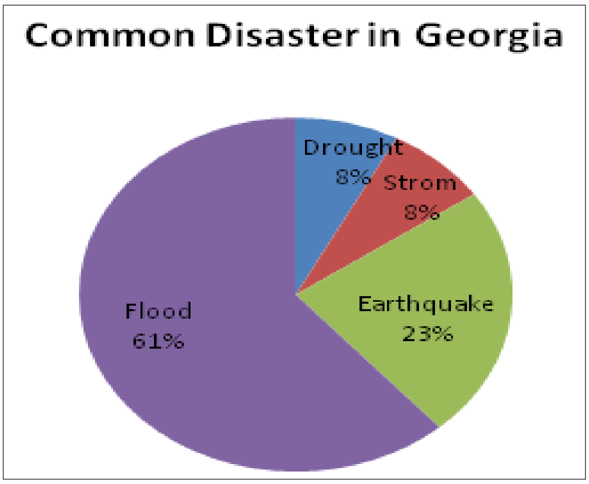


Figure 1.3: Common Disaster in Georgia

(Source: (EM-DAT, 1991-2005))

1.1.3. Rioni River Basin

The Rioni River is the second largest river of Georgia having the total length of 327 km. The major disaster in the area near the Rioni River is due to flooding. Floods have caused wide spread of damage. In addition, the area also suffers the problem of drought. Floods occur annually but there were also catastrophic floods which occurred during the year 1811-1812, 1839, which caused the decrease of the settlements to 30-35 percent in the Imereti region.

Historical data also shows that in the year 1911 the water level in the river was up to 9.6 m, in 1922 it reached 2-3 m and the discharge was 2420 m^3/sec. In 1982 the river discharge was 5220 m^3/sec and the river height reached 7.7m. In 1982 the flood covers the territory of 130 km^2 and the damage was estimated to be approximately 12 million US dollars. The causes of all these devastating floods were due to snow melting or also the outbursts of dammed lakes in the Nival-glacial zones (Tatashidze *et al.*, 2006).

The 1987 flood was one of the well known catastrophic floods in the western Georgia. The water discharge was estimated at 3640 m^3/s. The flood inundated around 200 km^2 of the whole territory. About 2000 houses and 650 public constructions works were completely destroyed. It also destroyed 1500 hydro-technical structures, 16.5 km railway tracks, 1300 km of highways, 1100 km of power transmission lines and 700 km of communication lines were damaged. More than 16000people had to be evacuated. The total damage of 300 million US dollars was estimated due to this disaster (Tatashidze*, et al.*, 2006). Figure 1.3 shows the flood risks from very high to insignificant in the rivers of Georgia. The figure shows that the western Georgia is highly vulnerable to floods by the rivers.

It already mentioned that the occurrence of flooding in western Georgia is very common. In 17th of October, 2010 this area was again hit by the flood. The water level of Rioni was increased and the periphery was full of water. Around 100 houses were affected by the flood in the Patara Poti and the level of water was up to 1 meter inside the house. Almost 90 families were affected and the winter food storage was completely destroyed by the flood. The main cause of this flooding was due to the breakage of the dike (MediaNews, 2010).

1.2. Research Problem

In general, different types of natural hazards such as landslides, avalanches, floods, wildfire, lahars etc. occur in both rural and urban areas. Since Georgia is rich in water resources-it consists of more than

26,060 rivers with the total length of 59,000 km and around 800 lakes the hydro-meteorological hazards are very common in this country (Tsiklauri, 2004).

For the assessment of risks, lots of approaches exist to quantify the elements at risk such as building types, building age, number of household, populations etc. in the urban areas (Guarin, 2008). Most of the research works in risk assessments have so far been carried out in the urban areas since the urban areas have high population densities and there is concentration of higher expensive infrastructure, buildings and so on (Watson *et al.*, 2006). Also mentioned by World Meteorological Organization, (W.M.O., 2008) the damages in the rural areas due to floods are mostly direct in mostly direct in terms of loss of agricultural production but in urban area the damage is very complex. It also mentioned that the impacts of urban floods are almost exclusively adverse; but it state that the rural areas often have positive ecological. So in general the priority is given to the urban risk rather than rural risk. So the priority must be given to the urban risk rather than rural risk. But in case of Rural areas hardly any research has been carried out or methods for assessing the risks in the rural context exist. In the rural context the major elements at risk are agricultural lands, field crops, farm machineries, livestock natural conservation areas, national park, etc. It is thus necessary to develop methodology for assessing risks in the rural context.

This study adds to the work that is already carried out in flood risk assessment by identifying and quantifying the elements at risks in the Rioni river basin in Georgia. Further analysis from this research will more focus on the agricultural land, crops fields, populations and houses as the element at risk and their vulnerability analysis.

1.3. Research Objectives

1.3.1. Main Objective

To develop an approach for identifying, categorizing and quantifying elements at risk in rural areas and their vulnerabilities to floods. Also to analyse the local people's and government perception towards the flood risk as well as the coping strategy employed by them.

1.3.2. Specific Objectives

- To identify the elements at risk in the rural area of Georgia (Rioni River Basin).
- To determine the vulnerability of elements at risk and of people living in the flood plain area due to flood.
- To analyse people's perception about flood risk.
- To identify the coping strategies employed by the local people and the local government.

1.3.3. Research Questions

- What are the elements at risk in the rural context based on the high and low frequency flood?
- What is the level of vulnerability of the elements at risk according to the local knowledge?
- What are the people's perceptions about the flood risk in the area?
- What are the coping capacities of the society in case of high frequency floods (which can occur once in 1-2 years) to low frequency floods (which has long recurrence period)?
    - What are the factors that is responsible in influence the coping mechanism employed by the local people and the local authorities and what measures needed to add in the current coping mechanisms to make it more sustainable?

2. LITERATURE REVIEW

2.1. Hazard and Disaster

Hazards are defined by many peoples and organizations. Hazards are any phenomenon or events that may cause harm or loss to the existing natural and artificial phenomena. According to Twigg, (2004) "hazards are the potential threat or loss to the humans and their welfare like loss of life or injury, social and economic damage etc". Each hazard has its own characteristic, strength, frequency, location and probability of occurrence. The most common definition of hazards by ISDR, 2009 is: "the potentially damaging physical event, phenomena or human activity that may cause the loss of life or injury, property damage, social and economic disruption or the environmental degradation".

The International Red Cross (IFRC, 2005) recognizes two main types of hazards as follows:

- **Natural Hazards:** Such hazards occur naturally and cause negative effect on people or environment. For example the natural hazards are geophysical (earthquakes, landslides, tsunamis, volcanic), hydrological (floods, avalanches), climatological (drought, wildfires) or biological (epidemics, plagues). Many natural hazards are interrelated such as earthquakes can cause tsunamis, drought cause famine etc.

- **Technological or Man-made Hazards:** This category of hazards includes the hazards induced by human or caused by human interferences for example: famine, industrial and transport accidents, war, pollution, environmental degradation etc.

According to the definition given by International Strategy for Disaster Reduction(ISDR, 2009), disaster refers to the serious disruption of the functioning of the community or a society that involves in widespread human, material, economic or environmental losses and impacts. As a result, it exceeds the ability of the affected community or society to cope using its own resources. Natural disaster is impossible to prevent but it is possible to reduce the impact by strengthening the preparedness on all levels. The World Conference on Natural Disaster Reduction in 1994 in Yokohama messaged that the impact of natural disasters in terms of human and economic losses had risen in recent years.

The society becomes more vulnerable by the natural and other disasters. The most vulnerable are the poor and socially disadvantaged and marginalized groups in developing countries because they are least equipped to cope with the disaster, (Enarson, 2000).

According to Blaikie, (2003) disaster occurrence is the product of interaction between the hazards and vulnerability. Disasters are also the complex mixture of natural hazards and human action. Disaster occurs anywhere anytime and does not differentiate between the developing and developed countries. But from the economy point of view the effect of disasters is comparatively higher in the developing countries than the developed ones. Andjelkovic, (2001) mentioned that "an extreme natural event only becomes a disaster when it has an impact on human settlements and activities".

2.2. Flood Hazard

Floods in general term is defined as the overflow of areas that are not normally submerged or a stream that has broken its normal confines or has accumulated due to lack of drainage and exceed its carrying capacity(Malilay, 1997). There is general belief that extreme flood occurs more frequently due to the climate change and land use (Reynard *et al.*, 2001). Flood hazards are the occurrence of flood event with the defined exceedance probability (Buchele *et al.*, 2006). Annually the floods claim over 20,000 lives and adversely affect approximately 20 million people around the world (Smith K *et al.*, 2008). Flood accounts for approximately forty percent of natural disaster in the world and it has become more severe due to the frequent global warming (Reacher *et al.*, 2004).

Floods are the natural hazards that create lots of problems and affect the human from the time immemorial. From the past decades flooding is one of the major disasters and its major causes are deforestation, heavy rainfall, expanding the agricultural land, bad land drainage, and urbanization (Malilay, 1997). Amongst the major natural hazards floods are regarded as the most devastating natural disaster in the world, claiming the largest amount of lives and property damage (CEOS, 2003). All varieties and classes of harm caused by flooding is referred to as the flood damage (Schanze *et al.*, 2006).

The impacts of floods can be environmental, social and economic Petersen, (2001). The environmental impact includes the damages incur to the natural resources, damage to habitats, food chains, destruction to flora and fauna etc. A social impact includes loss of life, human injury, displacement of people, health hazards etc, whereas the economic impacts includes infrastructure and residential losses; governmental and public facility losses; and the agricultural losses includes crop loss, livestock, farm machineries and so on.

According to Petersen, (2001) the impacts of floods are also classified into direct and indirect. Direct damage includes the losses due to the exposure of property to floodwater, the income loss resulting from the crop damage etc. While indirect damage includes the value of losses of the business and services and so on.

Furthermore added by Kliesen, (1994) direct loss are those that results from the buildings, lifelines, infrastructures damages, loss of lives, crop destroyed, forests destroyed etc. Similarly indirect losses are those that come from the physical damages, revenues, reduced tourisms etc. Also the author states that the direct losses are easier to estimate. But the indirect loss is more difficult to calculate than the direct loss.

Flooding can be characterized into many types. The location, terrain characteristics and climate are key components which decide to what degree an area is susceptible for floods and what type of flooding (van Westen *et al.*, 2009). According to ADPC, (2005), there are two types of floods.

- **Riverine floods:** Riverine floods (also referred as monsoon floods in Asia) are characterized by overflow of major rivers and their side channels causing extensive inundation. The level of rivers rise in slow manner and with slow recession may remain high for several weeks. Flood peaks may occur concurrently on many interconnected rivers that particularly can cause extensive flooding. Mainly there are two types of riverine flooding: slow-onset and rapid-onset or flash floods.

  Slow-onset floods: This type of flood occurs slowly and can last weeks or even months. The causes of this type of floods are excessive melt of snow or continuous steady rainfall. The rise of flood levels can be forecasted that provides people the opportunity to evacuate the areas that are at risk. This kind of floods causes extensive damages and losses.

  Rapid onset / flash floods: This type of floods occurs after the periods of heavy and intense rainfall mainly in steep rivers with small and steep mountainous catchments. This type of floods is characterized by a rapid rise and fall in water levels. This type of flood causes intense damages due to sudden onrush of water from mountains at high velocity that sweeps agricultural crops and causes intense damages to property and direct loss of life than slow-onset floods.

- **Localised and urban floods**: This type of floods occurs due to intense local rainfall in areas with inadequate drainage, improper storm water management and unmanaged flood evacuation systems. In this flood type, floodwater gets accumulated in particular areas and may remain for a long duration of time.

Also based on the occurrence, Federal Emergency Management Agency (FEMA, 1997) categorize floods into six different types Riverine flood, alluvial fan floods, ice jam floods, dam break floods, local drainage and high ground water level and fluctuating lake level.

The magnitude of a flood is expressed as the discharge, and is related to the return period in years. In case of flooding the magnitude and frequency follows the inverse relations. High magnitude floods have a longer return period and a lower frequency have less return periods (Straatsma *et al.*, 2010).

The higher is the magnitude the smaller is the frequency. The magnitude frequency relationship is a relationship where events with a smaller magnitude happen more often than events with the larger magnitudes(van Westen*, et al.*, 2009). The objective of frequency analysis of hydrologic data is to relate the magnitude of extreme events to their frequency of occurrence through the use of probability distributions. But for some hazards the occurrence of low magnitudes e.g. if there is no rainfall then it will leads a catastrophe droughts but the occurrence of high magnitudes lead to the flooding.

There are several methods to show the magnitude and frequency relationship of the flood such as gamma, log-normal and Gumbel. The Gumbel's method is the most widely used probability distribution function for extreme values in hydrologic and meteorological studies for prediction of flood peaks and maximum rainfalls (Subramanya, 2008). Thus, for this research the Gumbel methods was used to find the magnitude and frequency relationship. Gumbel's method has been simplified to obtain the magnitude (amount of discharge) of a given return period flood without recourse to use lookup table and computing the value of coefficient of variation of the given data (Al-Mashidani *et al.*, 1978).

In practice, to find the frequencies of the flood the annual maximum of the variable is selected as the largest instantaneous peak flows during the year. The main purpose of selecting the annual maximum is that the successive observations of this variable from year to year will be independent. Ideally there should be more than 20 years records to make the method more reliable and accurate (Wilson, 1990).

2.3. Digital Image Processing

The digital image processing is a computer based process in which images are interpreted by using a series of algorithms (Lillesand *et al.*, 2000). This process includes three levels (Bakx, 1995):

- Pre-processing
- Processing
- Post-processing

Pre-processing operations correct distorted images. This includes - data conversion in which the data are converted to a format easy for user and; the geometric, atmospheric and radiometric correction. In the Processing phase - image enhancement, and feature extraction are done. In the feature extraction, additional data namely old maps or object models can be applied to extract information in more accurate way. The final results of the feature extraction will later be exported into a suitable format in order to be usable for other users in post-processing.

2.3.1. Image Classification

Image classification is based on the principle that each pixel is assigned to a class depending on its feature vector by comparing with the predefined clusters in the feature space. Thus classified image is obtained by doing the same for all the pixels in the image. The purpose of the image classification is to categorize all pixels in a digital image into several classes or themes of land cover (Lillesand *et.al*, 1994). This categorized data can then further be used to produce thematic maps of the land cover present in an image. Usually multispectral data are used for the classification and the numerical basis of spectral pattern present within the data for each pixel is used for categorization (Lillesand *et.al*, 1994). The main objective of image classification is to identify and categorize the features present in an image as a unique gray level or color in an image in terms of land cover types present in the earth's surface. Two main image classification methods are supervised classification and unsupervised classification.

- **Unsupervised image classification**

The unsupervised image classification is a computer based process by which natural bodies are classified into groups according to their inherent spectral characteristics rather than training samples. If there is no much knowledge of study area, the unsupervised classification is preferred to be applied (Bakker *et.al.*, (2009).

There are several methods of the unsupervised classification, all of which use algorithms to partition feature space into clustered groups in each of which the spectral attributes are similar. The user should define the maximum number of clusters. Then each cell is assigned to a cluster by its minimal distance to the cluster's centroid. When all cells are attributed to corresponding clusters, the clusters recalculation is done and this process continues until reaching the final clusters center. At this point the iteration stops Bakker *et al.*, (2009).

Also Tso *et al.,* (2009) mentioned that, in the unsupervised methods the users don't need to select the training data. Instead the user defines number of classifiers automatically and constructs the clusters by minimizing predefined error function.

- **Supervised Image Classification**

Supervised image classification is an alternate to the unsupervised image classification. With supervised classification, different information classes (i.e. land cover types) are identified. As mentioned by Campbell, (2007), supervised image classification can be defined as the process of classifying pixels of unknown identity by using the samples of known identity i.e. with the help of already assigned information classes of pixels. That means in supervised classification, from specified location in the image the spectral signatures are developed. These specified locations are given generic name by the user, these are named 'training sites'. The training sites are used to develop the spectral signatures for the outline areas.

Bakker *et.al.*, (2009), stated that the main step in image classification is the partitioning of the feature space. Normally, the vector layer is digitized over the raster scene and that vector layer contains numerous polygons overlaying the different land use types. Supervised image classification requires the user to be familiar with the area of interests. Also the user needs to know where to find the classes of interest in scene which can be derived from the general knowledge of the scene through the direct field observations (Mather, 1987).

According to Short, (2009), supervised classification is much more accurate for mapping classes; however it is entirely dependent on the cognition and skills of the image specialist or the user. The strategy is straight forward: the user (image specialist) recognizes real and familiar conventional classes or meaningful (but somewhat artificial) classes in a scene from previous knowledge, which may be on-scene personal experiences or by experience with thematic maps, or by on-site field visits (Gibson *et al.*, 2000). Once the training samples have been selected the classification of the image needs to be done using one of the classification algorithms such as box classifier, minimum distance and maximum likelihood classifier.

In this study the maximum likelihood classification algorithm is performed. It is the most common supervised classification method used in remote sensing image data. Beside the clusters center; the shape, size and orientation of the cluster are also taken into consideration in the maximum likelihood classifiers Bakker, *et.al* (2009). The maximum likelihood procedure calculates probability of a pixel belonging to each of the predefined set of classes and the pixel is then assigned to the class for which the probability is the highest (Tso *et al.,* 2009).

As mentioned by Campbell, (2007) this method use the training data in estimating the mean and the variances of the classes and later used to estimate the probabilities for membership in each class. This method of classification not only considers the average values in assigning classification, but also the variations of brightness values in each class.

- **Advantages and Disadvantages of Supervised and Unsupervised Classification**

Advantages and Disadvantages of Supervised and Unsupervised Classification as mentioned by (Gibson*, et al.*, 2000) are as following:

Advantage and Disadvantage of Unsupervised Image Classification:
Advantages:

- The main advantage of this classification is no need of prior knowledge of the image;
- The set up time is shorter for unsupervised classification which also requires less input from operator;

Disadvantage:

- Though the classification does not require any knowledge of area, but it is inevitable to have some independent information of the area so that the classes are assigned to right attributes.

Advantage and Disadvantage of Supervised Image Classification:
Advantage:

- This classification needs the knowledge of the area and training data
- The set up time is longer than unsupervised and more time consuming
- The result is much more accurate than the unsupervised image classification.

Disadvantage:

- The training data should be introduced correctly because poor introduction results in low accuracy

2.3.2. Accuracy Assessment

Unless accuracy is not assessed image classification is not complete. Accuracy assessment attempts to quantify how good the classifier has done the job. The accuracy assessment of the image classification is carried out by comparing the resultant classes to some reference data that is believed to accurately reflect the true class of land-cover (Drury, 1993). Reference data sources may include among other things ground work, maps based on interpretation of aerial photo and higher resolution satellite images. Thus accuracy assessment entirely reflects the differences between the classified images to identify various land covers and the reference data by carrying out its comparison (Linderholm *et al.*, 2004). The apparent reasons of errors might be due to the variation in time between the satellite images taken and the collected reference data due to the fact that landscape might change along the time.

The results of the accuracy assessment are usually summarized by using error matrix. The error matrix is defined as a matrix of numbers that represent the number of pixels assigned to a specific class or category relative to the actual category as verified on the ground(ITC, 2010) .

Two widely used measures of class accuracy are user and producer accuracy (Short, 2009). The producer accuracy refers to the probability that a reference sample (land-cover of an area on the ground) is correctly mapped and measures the error of omission. In contrast, user's accuracy relates to the probability that a pixel labelled as a certain class of land cover in the map is really the same class (ITC, 2010).

As mentioned by Linderholm, *et al.,* (2004) producers, users and overall accuracy are given as follows:
Producer's accuracy: The total number of correct pixels in a category divided by the total number of pixels of that category gives the producer's accuracy or Omission Error.

$$\text{Producer's Accuracy} = \sum \text{Correct Pixels per Category} / \sum \text{Reference Pixels}$$

User's accuracy: The total number of correct pixels in a category divided by the total number of classified pixels in that category gives user's accuracy or Commission Error.

$$\text{User's Accuracy} = \sum \text{Correct Pixels per Category} / \sum \text{Classified Pixels}$$

Overall accuracy: The overall accuracy is then obtained by dividing the total number of correct pixels of each class by the total number of pixels in the error matrix.

$$\text{Overall Accuracy} = \sum \text{Correct Pixels} / \sum \text{Pixels in the Error Matrix}$$

2.4. Elements at Risk

The element at risk is defined as the objects, populations, activities and processes that may be differently affected by hazardous phenomena, in a particular area, either directly or indirectly(van Westen*, et al.*, 2009). The more vulnerable the elements at risk, the more it is exposed to the hazards and more is susceptible to the forces and its impacts (Dhillon, 2008). The elements at risk can be defined as the level of exposure with reference to buildings, infrastructures, population, economic activities, public service and utilities that can be affected by the hazards (Nott, 2006). The elements at risk have spatial and non spatial characteristics.

The elements at risk categorized by (ADPC *et al.*, 2005) are as follows:

Physical Elements at risk

- Infrastructures: Such as roads, railways, bridges, harbour, airports etc
- Critical Facilities: Emergency shelters, schools, hospitals, nursing homes, fire brigades, police etc
- Utilities: Power supply, water supply, services, transport, communications etc
- Government service: All levels national, provincial and local
- Machinery and equipment
- Historical structures and artefacts

Economic Elements at risk

- Business and trade activities
- Access to work
- Agricultural land
- Impact on work force
- Productivity and opportunity cost etc

Societal Elements at risk
- Vulnerable age group categories
- Low income group people
- Landless/homeless
- Disabled
- Gender
- Single parent households etc

Environmental Elements at risk
- Environmental resources such as air, water, fauna, flora etc
- Biodiversity
- Landscape

Further United States Agency for International Development, (USAID, 2010) classified the elements at risk into tangible and intangible depends on whether they can be quantified or not.

- **Tangible elements** at risk are the things that can be identified, localised, mapped and quantified. For example: peoples, buildings, equipments, infrastructures and some of the economic elements such as income and savings.
- **Intangible elements** are the elements that are very difficult to quantify or map because of absence of particular dimensions. For example: social elements like cultural heritage, social ties, well being of communities, psychological conditions etc. It also mentioned that if we quantify the tangible element's vulnerability and capacity then we can use the data to estimate the damage, loss and deaths that may occurs from an event.

  The elements at risk mapping can be carried out in various scale levels and also depends upon the requirements of the study. The scale levels rages from small scale to the detailed scale. This research mainly uses the small scale to map the elements at risk. Table 2.1 shows the elements at risk mapping versus the scale, adopted from (van Westen, *et al.*, 2009).

Table 2.1: Elements at Risk Mapping in Different Scale

Elements at risk	**Scale of analysis**			
	Small (<1:100000	**Medium (25-50000)**	**Large (10000)**	**Detailed (>1:10000)**
Buildings	By municipality - Number of Buildings	Mapping units - Predominant types e.g. Residential, commercial, industrial - Number of buildings	Building footprint - Generalized use - Height - Building types	Building footprints - Detailed use - Height - Building types - Construction type - Quality/ age - Foundation
Transportation Networks	General location of transportation networks	Roads and railway network with general traffic density information	All transportation networks with detailed classification including viaducts, and	All transportation networks with detailed engineering works and detailed dynamic

			traffic dates etc.	traffic data
Population data	By municipality - Population density - Gender - Age	By ward - Population density - Gender - Age	By mapping units - Population density - Daytime, night-time - Gender - Age	Population per buildings - Daytime/Night time - Gender - Age - Education
Agricultural data	By municipality - Crops types - Yield information	By homogenous - Crops types - Yield information	By cadastral parcel - Crop types - Crop rotation - Yield information - Agricultural buildings	By cadastral parcel, for a given period of the year - Crop types - Crop rotation and time - Yield information
Ecological data	Natural protected area with international approval	Natural protected area with national relevance	General flora and fauna data per scale cadastral parcel	Detailed flora and fauna data per cadastral parcel

2.5. Vulnerability

According to United Nations Development Programme (UNDP, 1994), Vulnerability depends upon the degree of loss to a given elements at risk at a certain severity level. Generally, it is expressed as the percentage of loss (the value between 0: No damage to 1: Total damage) for the given hazards. Vulnerability is the degree to which the system is and unable to cope with, adverse effects of climate change, including climate variability and extremes. It is the function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC, 2007). As stated by International Strategy for Disaster Reduction (ISDR, 2004), Vulnerability is a set of conditions and process resulting from physical, social, environmental and economic factors that increase the susceptibility of a community towards the impacts of hazards.

Vulnerability is the combination of various factors. Vulnerability can increase or decrease based on the position of the community or individual due to the effects of various factors which leads to change over time(ADPC, 2005). ADPC, 2005 provide the example of some of the factors that cause vulnerability to flooding are

- Unplanned and unmanaged development with poor drainage and lack of sanitation,
- Poor housing and poverty,
- Construction of squatter settlements in the marginal land like embankments, river banks etc

Vulnerability is not static but a dynamic process that depends upon the social, economic and political contexts which changes over the time which as a result affects the probability of loss (M. H. N. Bakker, 2006). So it can be reduced by increasing the resilience or coping capacity of the communities. A community disaster risk can disclose by demonstrating the vulnerability of existing social, environmental and development practices (Alomatu, 2009). A community is vulnerable or at risk when they exposed to the disaster and likely to be affected by their impacts. Vulnerability and hazards both are the outcome of disaster (Dixit, 2003).

There are four different types of vulnerability as stated by van Westen (2009) , and they are

- Physical Vulnerability: Structural types such as building age, constructions, materials, infrastructures, lifelines etc.
- Social Vulnerability: Risk perception and the way of their life related with culture, religion, ethnic, social interaction, age, gender etc.
- Economic Vulnerability: Business interruption, income, investments etc.
- Environmental Vulnerability: Air, water, land, flora, fauna etc.

As stated by Chambers, (2006), vulnerability is difficult to cope with the community experiences as it is exposure to contingencies and stress. So the vulnerability has two sides i.e.

- External side: is related to the shock and stresses exposure to the individual or households.

- Internal side: is related to the defencelessness which means the incapability to cope without damaging losses. Losses makes physically weaker, economically poor, psychologically harmed, social dependent.

Bohle, (2001) expanded the concept of vulnerability of Chambers. As seen in Chambers, (2006) the vulnerability is having the two sided: External and Internal sides. Figure 2.1: shows that the external side is related to the exposure and shocks and is influenced by the political economic approaches, human ecology perspectives and the entitlement theory. While the internal side is the theory is related to the coping and is influenced by crisis and conflict theory, action theory approaches and models of access to assets.

According to Dwyer, (2004), the vulnerability cannot be determined by one factor but the combination of various factors which influence people prone to more vulnerable due to the certain hazards. Also they justified their saying by one example "the elderly people has high vulnerability not because of their age but also the accompanying condition - if he or she lives alone, being disabled and also low income, but if they live with another person may has some health insurance, has some savings etc then it decrease their vulnerability".

Some of the factors that are considered in vulnerability quantification are water depth, flow velocity, flow duration, wave height, time of onset etc.

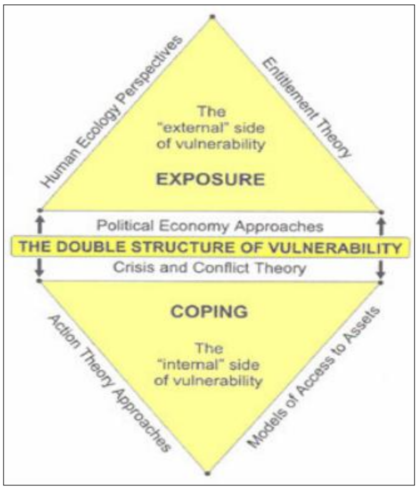


Figure 2.1: Bohle's Conceptual framework for Vulnerability Analysis

The vulnerability is also influenced by social, economic and political factors. So to get the better understanding of vulnerability it is necessary to identify the social, economic, and political dimensions of risk assessment that contributes to vulnerability. There are numerous tools to assess the vulnerability. Polsky *et.al.,* (2003) proposed the eight step methods for the vulnerability assessment and they are:

- Define study area in tandem with stakeholders
- Get to know places over time
- Hypothesize who is vulnerable to what
- Develop a causal model of vulnerability

- Find indicators for the components of vulnerability
- Weight and combine the indicators
- Project future vulnerability
- Communicate vulnerability creatively

2.6. Coping Mechanisms

Coping means the capacity and ability of the people to act within the limits of existing resources. As asserted by Browitt, (1993) for the mitigation of harmful effects of natural hazards, three categories of actions need to by employed – reduction of physical vulnerability, reduction of economic vulnerability and empowering the social structure of the community so that coping mechanism help to assimilate the shock of the disaster and rapid recovery i.e. increase the resilience.

The definition given by ISDR, (2009) is the ability of people, organization and systems to face and manage the adverse conditions, emergencies or disasters using the available skills resources. To raise the coping capacity of each community during the crisis or in disastrous conditions requires continuous awareness, resources and good management in time. The coping capacities contribute to the reduction of disasters. The coping strategies is the result of process of experiments and innovation form which the people build up their skills, knowledge and self confidence which is necessary to shape and react to their environment which provides the sense of safety to them (Heijmans, 2004).

Likewise the coping mechanism provides the insight that how people cope from the different hazards. The perception and the coping mechanisms applied by the local people help the local government and stakeholders in planning to cope from the hazards. The coping mechanisms differ by its region, household, community, age, gender and time. (ADPC, 2004) mentioned that different people have different concept about the hazards so do the coping mechanism. For example, if man and woman have different view and understanding about the risk then the coping mechanism will also differ which as a result have different views to reduce the risks.

Coping mechanisms or strategies is the use of indigenous knowledge in dealing with the hazards and other threats (Twigg, 2004). Twigg purposed four categories of the coping mechanisms implied by the community and they are

- **Economic/material:** The main economic elements are the economic diversification. The important component of economic coping strategies is having more than one source of income. During the time the large family are also seen as the part of coping strategies because it gives the additional labour, saving and credit schemes.

- **Technological:** It includes the building constructions and the material is adapted to the frequent flooding. Such as building houses in stilts so that the water can pass by underneath, building them on plinths or platforms of mud or concrete etc. Some of the common adaptations for the poor families whose major source is agriculture are management of land for food productions such as mixed cropping, kitchen gardens, intercropping etc. Land use strategies that are mainly used by the people who lived in the disaster prone area. For example the villagers in Nepal they convert the hillsides into level of terraces, create some outlets to manage the water overflow from one terrace to another. Also preserve the rainwater runoff and use it for the dry seasons.

- **Social/ Organisational:** It includes the kinship networks, mutual and social contact within the communities. The family is the principle social mechanism for reducing the risk. During the time of stress and disaster relatives who are staying outside the community are important.

- **Cultural:** It includes the risk perception and the religious views that are frequently connected.

Rossi *et.al,* (1994), approach four alternatives that can be used by societies in coping strategies. Such as

- Do nothing either structurally or administratively
- Implement only the non-structural measures for alleviating the flood impacts
- Implement structural flood control measures i.e. intensive and extensive physical measures.
- Combination of Structural and non-structural measures.

2.7. Risk Assessment

Risk is defined in many ways in different literatures. Risk is the product of probability and expected losses. According to Coburn *et.al.,* (1994) the way elements at risk is defined the risk may be measured in terms of expected economic loss or in terms of number of lives lost or the extent of physical damage to the property. It is expressed as the expected number of lives lost, injured, damage to the property due to the hazards over a specified period of time in a specific area

As defined by Ranyard *et.al.,* (1997) risk is the situation where we cannot control the negative or adverse consequences like losses, accidents, health injuries or deaths. Even it is not known that they will happen or not as well as we cannot guarantee that they will not. What we can do is just to suppose.

Risk assessment is the process to determine on whether the existing level of risks are tolerable and current existing risk control measures are adequate for coping with risks and if not whether alternative risk control measures are justified or will be implemented (FEMA, 2003). Risk assessment is an essential step to adopt the adequate and successful disaster reduction policies and measures.

The risk assessment consists of two components i.e. risk analysis and risk evaluation. As mentioned by van Westen(2009) risk analysis is the use of available information to estimate the risk that are caused by the hazards to the people , property or environment from the hazards. The risk analysis contains the definition of scope, danger, identification, estimation of probability of occurrence to estimate hazard, evaluation of the vulnerability of the elements at risk, consequences identification and risk estimation. Risk analysis includes a source assessment, an exposure assessment as well as an effect assessment and is concluded by an integrative risk characterization (Murshed *et al.*, 2007). The risk analysis will enable the community and the local authorities to understand the potential impact of various hazard events. To evaluate the risk by certain disaster and also the vulnerability it requires the people's knowledge and their perception.

Whereas, risk evaluation is the stage at which the values and judgement enter the decision process, explicitly or implicitly by including consideration of the importance of the estimated risks and the associated social, environmental and economic consequences. The purpose of risk evaluation is to make decisions about what strategies should be followed for the reduction of various disaster risks.

- **Qualitative Methods:** This method categorizes the risk in terms of high, moderate, low. This method is commonly used when the hazards and their vulnerability cannot express in quantitative terms.

  Risk= Hazard * Vulnerability * Amount of Elements at Risk

- **Semi-Quantitative Methods:** It is expressed in terms of risk indices. The numerical value often ranges between 0-1, but this don not have a direct meaning of expected losses but just the indications of risk.

- **Quantitative Methods:** Expressed the risk in quantitative terms either as probabilities or expected losses. It can be deterministic or probabilistic scenarios.

Risk=Hazard * Vulnerability /Capacity

The United Nations International Strategy for Disaster Reduction, (UNISDR, 2004) define risk assessment as the process of systematic use of the available information to determine the possibility of occurrence of certain events and their magnitude. The process includes the

- Identifying the nature, location, intensity and probability of a threat
- Determining the existence and degree of vulnerabilities and exposure to those threats
- Identifying the capacities and resources available to address or manage threats
- Determining the acceptable levels of risk

As mentioned by Talani, (2003) the geographical and cultural context of rural area are extremely diverse. So the planning in the rural area needs specific approaches because the rural population lives in extremely unstable environments. The rural people mostly depend upon the local farming systems so the rapid changes in the rules of trade, technology usually increase the risk in the rural households (Anderson, 2001). Anderson also state that rural areas are always subjected to the occurrence of unpredictable and dangerous events in their natural, social and economic environments.

2.8. Flood Risk Perception

According to Plapp, (2006) risk perception is everyday subjective estimation process that rely on experience and on available information without referring to reliable data, series and complex models. Individual, subjective risk judgements are called intuitive to emphasize that major parts of the underlying processes pass unconsciously. In more sociological terms, risk perception is a construction process that is rooted and determined by society and culture. Risk judgements therefore imply value judgements.

People's perception about the risk can be one of the important parameters to extract the information about the floods. In most of the cases the local knowledge helps the local authorities in managing and planning the flood risk. For example, we can gather the information like what they do before, during and after the floods and also how they deal with it. It helps, together with the collaboration between local people and authority, to prepare the action plan for flood risk management (Febrianti, 2010). It is also based on the experience of the local people from their past disaster events like what they think about it and whether they are influenced by some hazards

Perception of the local people is important because it helps in analysing the social state of the community. According to (Alomatu, 2009), the perception is defined in two ways and they are the revealed preferences approach and expressed preferences approach. The revealed preferences approach is based on how people behave and take this as a reflection of public perception. By assuming through trial and error, society has arrived at an acceptable balance between the risk and benefits associated with any activity. The expressed preferences approaches are conducted by the questionnaire survey where a set of questionnaire is prepared and ask to the people. This method has some drawbacks, as this is based on the people to express them verbally but the respondents may not act the same way the surveyor suppose. But in many researches, the expressed preferences approaches were used and the result was also good. For example Peters Guarin, 2003, Alomatu, 2009, Marchiavelli, 2008 etc. use expressed preferences approach.

However the perception is influenced by several interconnected factors such as past experiences, presents attitudes, personality, and value together with the future expectations. The direct experience of the people plays a major role in disaster mitigations. The people who have the experienced knowledge about the past hazards will have the more accurate vision regarding the probability of occurrence in future. But the lay people perceive the hazards differently than the technical experts although in the same geographical location.

2.9. Participatory and Community Based Approaches for Disaster Risk Management

Participatory approaches are very useful tools for the generation of information in the local level. The local knowledge are often critical in understanding about the vulnerabilities and capacities of an area but they are rarely available on maps and even less and also in format that can be entered into a GIS. According to Heijmans, (2004) the integral part of building effective disaster risk reduction is the participation of the people at risk. She states that local people have knowledge about the history of local disasters and knowledge about their locality. Thus, according to her, participatory and community based approach is not just the process of giving information regarding assessment, consultation and implementation but also the empowerment process for the joint assessment of capacities and vulnerabilities building awareness.

As mentioned by Minang, (2006) there are some significant characteristics of local knowledge and also some weakness of the local indigenous knowledge. The significant characteristics of the local knowledge are

- It is a (spatial) information system which came from the close relationship between local people and sources of resources
- Members of the community are expert repositories for different categories of data, according to their experience and social status
- Originally, the local community 'owns' the knowledge,
- It is a 'scientific' system in that it consists of classification structures and employs particular methodologies
- It is holistic because it is used for decision-making in overlapping areas, such as agriculture, food, healthcare etc.

Some of the relevant weaknesses are the difficulties for the communities to predict what will happen when conditions are new or changed. Likewise also due to the lack of ways that information is stored and communicated; only quantified information is used for the analysis.

According to Twigg, (2004), the community participation means the active involvement of people in decision making in implantation of process which cause harm to them.

As listed by Kelly, (2009)The local knowledge consists of many components such as

- Knowledge of historical disaster events and the damaged they have caused.
- Knowledge on the elements at risk
- Knowledge on the factors that contributing to vulnerability
- Knowledge of their coping strategies and capacities
- Knowledge about the community patterns

2.10. Studies in Rural Flood Risk

The previous studies done by Tamar Tsamalashvili (2010) in Flood Risk Assessment shows that the study area is highly prone to the flood. The type of flooding considered in her study was solely alluvial. The 1-D and 2-D flood modelling was used to assess the flood hazard of this region. The result predicted that the probability of discharge of 10 year return period flood was 2951 m3/s. While for 25 years the predicted discharge is 3500m3/s, for 50 year 3907 m3/s, for 100 year 4311 m3/s and 4714 m3/s for 200 year return periods. The discharge of 1987 flood was 3640 m3/s. So this result predicted that the return period of 1987 year flood was once in 25 years based on its discharge.

Also the study that was done by (Alomatu, 2009) in the rural area of Thailand (Nam Chun) shows that the flood that occurs annually doesn't affect the houses, agricultural land, crops and livestock. But the floods with increase return period increase the possibility of high damage.

3. STUDY AREA

3.1. General Information and Location

Georgia is a sovereign state in the Caucasus region which is situated between Eastern Europe and western Asia. The Black sea is boundary to the west, Russia to the north, turkey in the south and Azerbaijan to the east. The projected study area lies in Samegrelo region. The study area covers three municipalities i.e. Poti, Khobi and Senaki. Under the Khobi municipality there are three areas that are located near the Rioni river and they are Sagvichio, Chaladidi and Patara Poti. While under the Senaki municipality, there are Upper Chaladidi, Teklati and Akhalsopeli. The study area only includes the areas that are close to the Rioni river. The study area is located between latitudes 42°03’49” to 42°15’40” North to Longitudes 41°40’18” to 42°05’25” East.

The Rioni River is one of major and largest river of this area. The Kolkheti National Park is also situated in the study area. This area is 320 km from the capital city, Tbilisi. The Kolkheti national park consists of large number of natural wetland ecosystems and is also listed on the RAMSAR list in the year 1996 is also located in this study area. Figure 3.1 shows the study area inside the country. The study area is in the flood plain of the Rioni River. The projected study area is 30km inlands from the Kolkheti national park. The area was selected based on the study area of Tamar, where she did the flood risk assessment. The shape and dimension was also based on that.

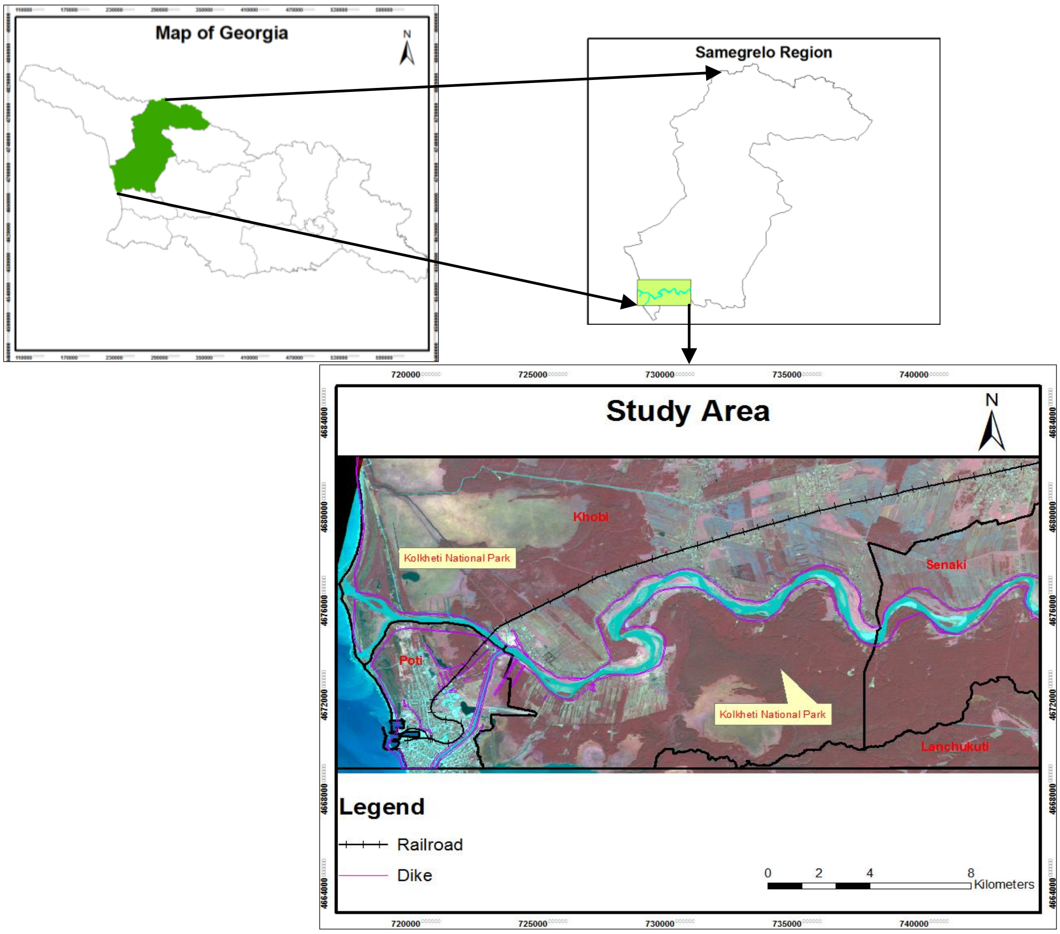


Figure 3.1: Map Showing the Study Area

3.2. Hydrology

The Rioni river is one of the major river of western Georgia. This river drains around 20 percent of the country's total land area (i.e. 40 percent of western Georgia). The river starts from the Caucasus Mountains where 51 percent of the total drainage is located and ends in Black sea. It covers the regions of Racha and flows towards the western part and finally enters to the Black sea. The total length of the river is approximately 327 kilometres.

The area of the entire catchments amounts to 13,400 kilometres. The average annual discharge of Rioni river is 430m^3/s. In the upstream the river flows in a narrow rift. When it reaches to downstream it flows through the widely spread swampy lowland and changes the river course in a meander channel. Which as a result there is formation of small and big numerous islands. Figure 3.2 shows the discharge from the year 1939 till 1990. This figure shows that the discharge is high in the year 1987 i.e. 3640 m^3/s. The table of Discharge is shown in Appendix 2.

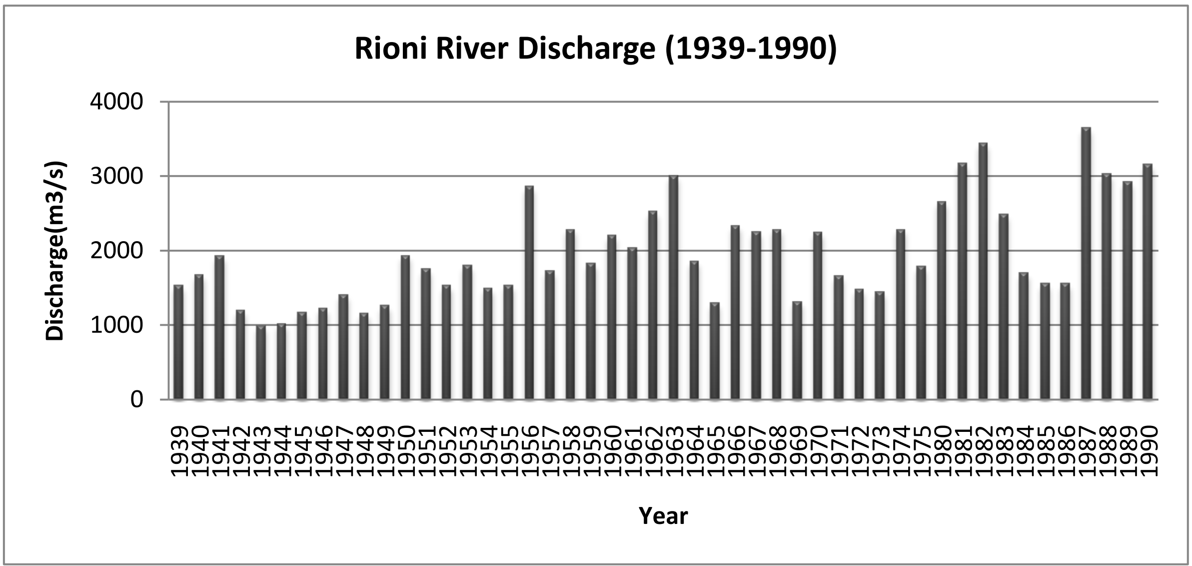


Figure 3.2: Discharge from 1939-1990
Source: National Environmental Agency (NEA)

3.3. Climate

The study area is distinguished by warm and humid climate and also characterized by heavy relative humidity and heavy periodical winds. The climate in this area is determined by the Black Sea to the west, mountain ranges of the Great Caucasus, the Likhi and the Meskheti; and the surrounding Kolkheti wetland. The total annual precipitation in this area varies between 2,531 mm in the south and 1,458 mm in the north of Kolkheti lowland de Klerk *et.al.,* (2009).The precipitation tends to be uniformly distributed throughout the year, although the rainfall can be particularly heavy during the autumn months. Consequently, annual air humidity is high with values between 70% and 83% (Poti station). This part of Georgia is the warmest region in winter (Abramia *et al.*, 2009). In winter the temperature reaches up to 5º in January and in summer it ranges from 22.4-22.6º in July.

3.3.1. Rainfall

The rainfall is heavy throughout the year i.e. 1000 to 2500 millimetres and keeps on increasing in autumn and in winter. The rainy season starts from May and occurs till the end of October. Figure 3.3 shows the annual trend of rainfall in the study area. The graph shows that from starting from June till October the rainfall amount is high and the rest of other month the area experience the drought.

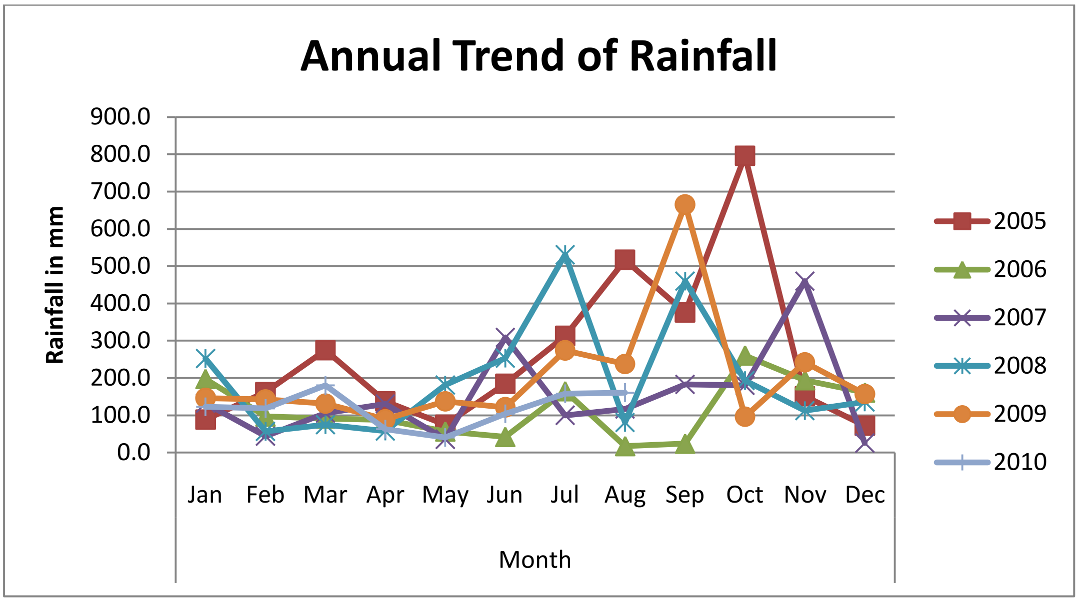


Figure 3.3: Annual Trend of Rainfall in Study Area
Source: National Environmental Agency (NEA)

3.4. Landuse and Economy

In the study area, the majority of population depends on agriculture for livelihood. The major occupation of people in this area is farming and cultivation. Agriculture is the major source of this region's economy (Kan *et al.*, 2006). Corn is the main crops in the study area and it is grown in almost all parts of western Georgia. The other source of economy in this area is the sea port at Poti. The land use and land cover map of study area is shown in Section 5.1 Earlier in the Soviet period the major crops in these areas were tea, citrus plantation and horticultures, tobacco etc. cultivations. The eastern and western part of the country is connected by the railway line which plays an essential role for the transport of goods and supplies across these parts of the country. After the soviet period, currently most of the lands are pastures land, forest, and the main crops in this area is only corn. There is no crop rotation also. There are other crops like beans, nuts and water melon but in very less amount.

3.5. Settlements

The study area covers three municipalities i.e. Poti, Khobi and Senaki. The total population of this Samegrelo region is around 4, 74,100. Out of this total population, Table 3.1 shows the population that are covered by three municipalities in 2010. The main village that are along the Rioni river are Sagvichio, upper Chaladidi, Patara Poti from Khobi municipality, Lower Chaladidi and Akhalsopeli from Senaki and Poti from Poti.

Table 3.1: Distribution of population in Urban and Rural of the Study Area

Municipality		Total	Male	Female
Poti	Urban	183133	84862	98271
	Rural	282967	134956	148011
Senaki	Urban	28082	12742	15340
	Rural	24030	11474	12556
Khobi	Urban	5604	2607	2997
	Rural	35636	17061	18575

Source: Statistical Department of Georgia

The figure 3.4 shows that the distribution of population in these villages and also the gender distribution in these areas. Out of the total population upper Chaladidi have the highest population numbers with compared to others. Patara Poti is having the second highest population i.e. 28 percent of total population.

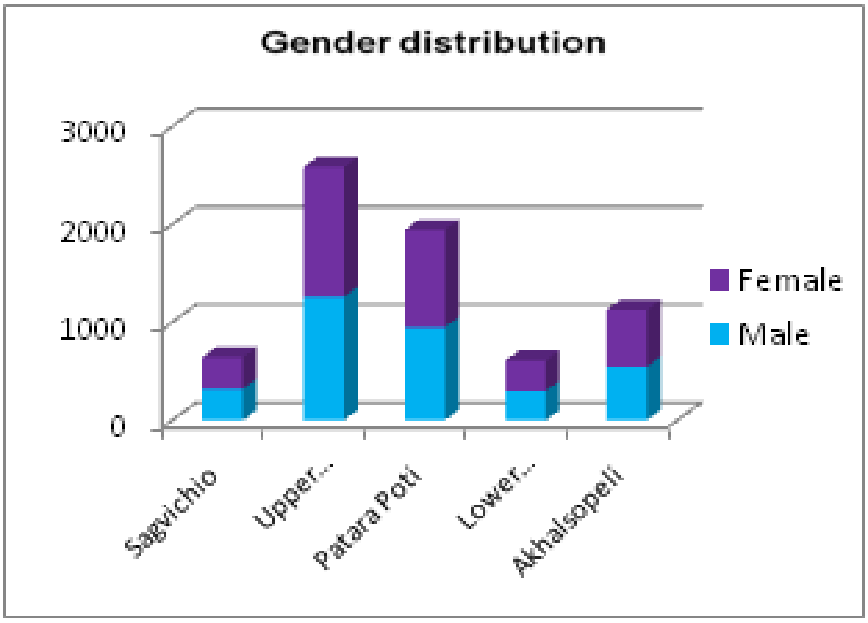


Figure 3.4: Gender Distribution of the Study Area
Source: Statistical Department of Georgia

4. RESEARCH METHODOLOGY

The objectives of this research are to identify elements at risk, assess vulnerability of each element at risk, study local people's and governments perception and coping mechanisms employed by them on flooding in the study area. To achieve the objectives of the research, the methodology for this study primarily includes Data preparation, Data collection and Data analysis.

Data preparation incorporates different steps such as deriving preliminary land cover/land use types map and questionnaires preparation for Field. For data collection, the first step was sampling for the interview in the study area, and then the questionnaire survey was conducted with the local respondents and the local government. Along the field work land cover types were identified by direct observation and the GPS sample points were recorded for land cover map verification. Also the secondary data such as topography map, rainfall data, and population statistics were collected during the phase of data collection.

The primary and secondary data collected from the fieldwork were processed in the Data analysis stage. The elements at risk were identified and further classified (physical, economical and societal) based on the land cover map and the questionnaires output. The vulnerability assessment of each element at risk was done based on the questionnaire output and secondary data. Also, damage assessments in terms of monetary value were done for the agricultural crops based on the vulnerability assessment of each crops and their cost. By using the questionnaire output data, the perception of local people and local government regarding the cause, depth, duration and frequency of floods were studied and evaluated. Also, the coping mechanisms employed by the local people and local governments were studied to prevent flood risks were studied based on the questionnaire output data.

The overview of research methodology could be seen from the framework of research methodology as shown below in Figure 4.1.

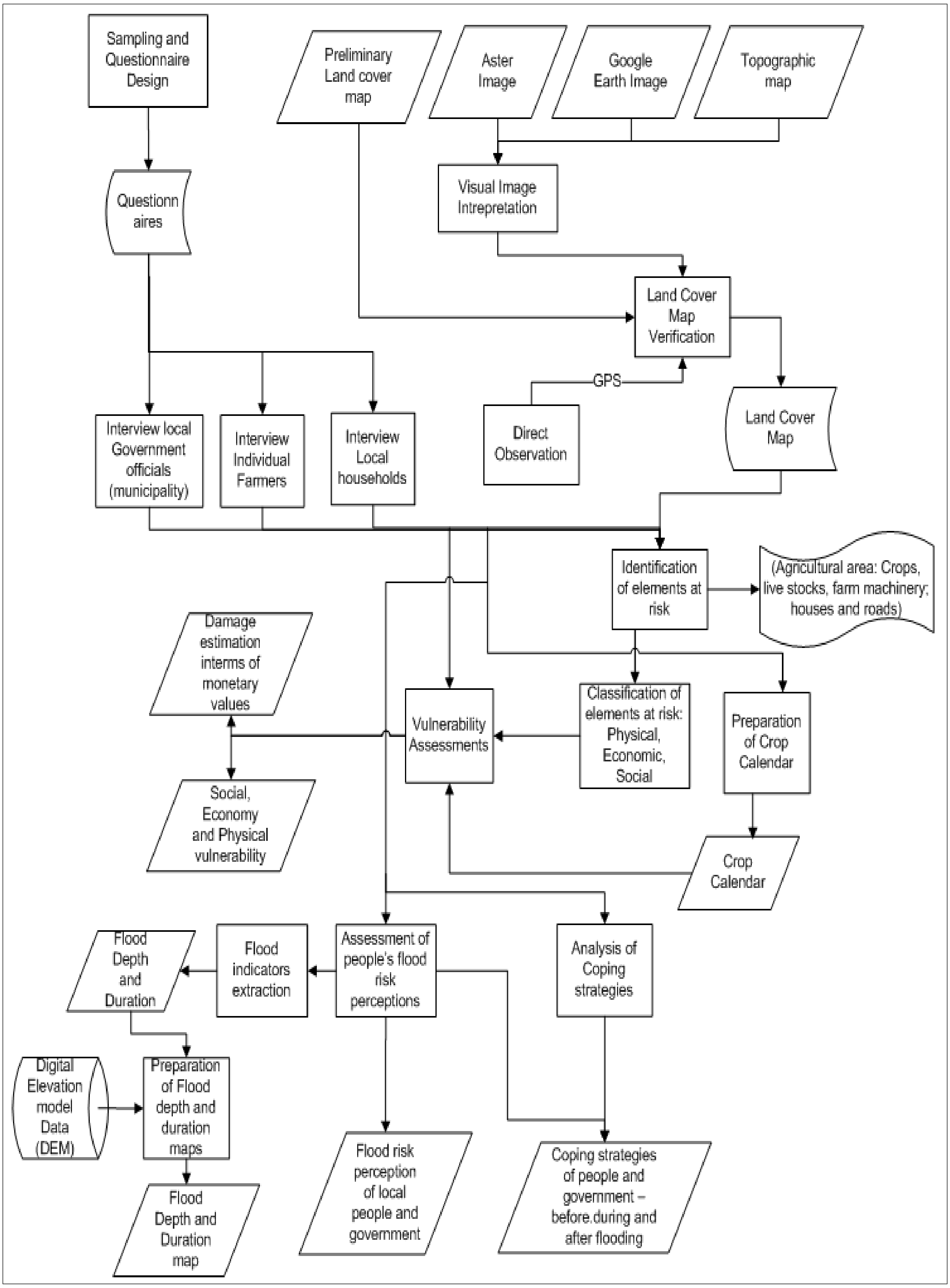


Figure 4.1: Research Framework

4.1. Available data and software used

The required information for this research is mainly based on data collected during the field survey. The available data sets that were available and collected from the secondary source used in the research are listed in Table 4.1.

Table 4.1: Data Availability

Type of Data	Data Format	Data Source /Date
Google earth map	Digital map	Quick bird image from Google Earth with 4 m resolution of / 2006
Topo-maps (1:50000)	Scanned, Geo-referenced maps	CENN/1983
Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Image	Digital image (15m spatial resolution)	ITC/7 Aug, 2010
Rainfall data	Statistical data	NEA / 1980-1990
Population data	Statistical data	Statistical dept. of Georgia /2002
DEM (Digital Elevation Models)		Tamar Tsamalashvili's DEM data
Settlement map, boundary map, road map and agriculture map	Cadastral data	CENN / 1999-2001

Used software's to accomplish this research are:

- ArcGIS 9.3
- ILWIS 3.3 academic
- ERDAS 9.3
- MS Excel 2007

4.2. Pre-Field Work

This stage incorporates checking the availability of existing maps and data's, studying them in context to the research objectives, and preparing the questionnaires for carrying out the interviews. Thus, for the fieldwork preparation proper questionnaires were prepared focussed on different target groups – household, local farmers and local government in order to extract required information's to meet the research objectives. The land cover map and land use types is very crucial for the fieldwork, which was available from the previous works from Tamar Tsamalashvili's. This available land cover map is used as the base map for the fieldwork.

4.2.1. Questionnaires preparation for Field

Three different set of questionnaires were prepared based on respondents - local residents, farmers and local government (municipality authorities and concerned employees). For the local people and local farmers the questionnaires were targeted for the individual interview. The primary focuses of this questionnaire were to obtain socio-economic profile, flood characteristics (depth and duration), flood vulnerability and damages, house types, crop calendar, agricultural crops, flood risk perception and coping strategy. Similarly, for the local government and local stakeholders the questionnaires were targeted for the group interview. The primary focuses were on statistics available about flood characteristics, flood damages, different coping mechanisms employed by the local government (see Appendix: 1).

The questionnaires were divided into five sections to collect information from local community to fulfil all research objectives:

- General profile of the respondent - the general information about the population characteristics such as age, gender, occupation and sources of income.
- Information about element at risk - the information about the elements at risk such as livestock, agricultural field, crops, houses, roads etc
- Information required for vulnerability and damage assessment such as flood causes, flood depth, flood duration, and damage caused by the floods in terms of monetary values. For the flood depth analysis, the scaling was based on the human body scale like ankle, knee, hip, breast and so on.
- Crop calendar- the crop calendar was used to collect the information about the different types of crops and their different stages, starting from sowing to the harvesting. Also the damage of each crops were calculated in terms of monetary value.
- Information about people's perception and coping strategies employed by local people and local government to counteract and mitigate the effects of flood at various flood stages- before flooding, during flooding and after flooding

4.3. Data Collection

This step is the field work in which the primary data and secondary data were collected. The field work was conducted from 18th Sept till 10th of October, 2010. The primary data were collected from the individual interviews, group interviews with the local people/farmers and the government, and direct field observation. The secondary data such as rainfall data, cadastral data set, population statistics and discharge data were also collected. In total 121 households were interviewed and 4 group-interviews, two with local municipality and two with commercial farmers were conducted which covered the three municipality of the Samegrelo region. The primary in-focus study areas were agricultural land, livestock's and different crops. And the secondary focus areas were houses, roads and railways.

4.3.1. Sampling

Stratified random sampling methods were employed to interview the respondents in the study area. The strata were prepared depending on socio-economic characteristics of local people/farmers, agricultural land and house types based on the real-time observation on different study regions (villages) of the study-area. Then, among the groups (strata) prepared, random respondents were chosen which is also driven by their availability. According to Nichols (1991), stratified random sampling has two main advantages: selection is easier and fair than simple random sampling and it is more likely to represent all sub-stratums (sub-groups) because the rearrangement could be done in section or classes. Total of 121 respondents were selected and were distributed randomly along the river according to their geographic location and socio-economic characteristics. The sampling were mainly taken along the river because the victims of annual flooding were along the river basin because this research mainly focus in annual flooding; and also many other areas were swampy area and was inaccessible. In this research, stratified random sampling was the most suitable sampling method.

4.3.2. Questionnaire Survey

For the identification of element at risk and their further analysis, interviews were taken with: local residents, farmers in the study area and local government (municipality authorities and concerned employees). As it was found during the field survey that most of the local residents were farmers; so the questionnaire targeted for two categories of respondent- local people and farmers were often overlapped. Thus following interview methods were applied for the data collection.

- Conducted individual interviews with local residents
- Conduct group interview with local government - municipality authorities and concerned employees
- Conduct individual interview with farmers (small holders or large commercial farmers)

The questionnaires were mainly focussed to identify the elements at risk, to assess vulnerability, damages and flood hazards. And also the data's to assess flood risk perceptions and coping strategies employed by the local people and the government at various stages of flood occurrence – before, during and after flooding were obtained from the questionnaire output.

The information about the elements at risk such as different types of crops, houses, socio economic characteristics of the people, livestock and the agricultural fields were obtained from the household surveys of local people. The characteristics of the flood such as depth, duration, cause, damage were also collected. The respondent provided the information of flood depth in the study area by using the human scale - ankle, knee, hip and breast and higher which was later converted into actual range of scale in meters. There have been annual flooding problems in this area and almost everyone was able to answer it properly based on their past experiences. Some of the old people shared the flood history and the catastrophic affects of the most destructive floods on that area based on their experiences.

Also the secondary in-focus elements at risk like houses and their wall, roof and the floor materials were collected through household surveys and direct observations. The information required for the crop calendar such as different types of crops, their stages such as sowing, growth, maturity and harvesting etc and the money they normally invest on each stages were obtained from the interview with the local farmers. This information of crop calendar was used as a basis for the damage calculation of various crop investments in terms of monetary cost at various flood stages. Similarly, the information on different flood risk perception, coping mechanism applied by the local government to minimise the impacts of frequent flooding were collected from the group interview with the local government.

4.3.3. Direct Field Observation

The land cover interpretation is also one of the important parts of this research. So from the direct field observation around 126 different GPS points of various houses of respondents, roads, dikes and agriculture land were taken. After which the points were divided in two sections i.e. 86 points for the accuracy assessment of the land cover map and 40 points for image interpretation. The main objective of the point overlaying is to make sure whether the land cover types are valid or not. Also from the direct observation the data regarding obstruction to prepare the hazards map were also collected. The main obstruction that were found in this area were dike, water channels, railway track, the local elevation of the area and other associated rivers - Tshivi river and Khobi river. This all information were later used to makes the compartment in generating the flood hazard map of year 1987 and also annual flood.

4.3.4. Secondary Data Collection

Secondary data was also collected during the field work from the local municipalities of Khobi and Senaki that lie inside the study area. The rainfall data of the study area was collected from the National Environmental Agency (NEA). The population information was collected from the statistical department of Georgia. The agricultural field damage was collected from each municipality. Livestock's and the crop details information were also collected from the individual surveys and municipality.

4.4. Data Analysis

The first activity of the data analysis was the organization of the data collected in the field. All the field observation points with GPS coordinates collected from the field was transferred into Arc GIS format by using the Gartrip (which is the shareware program to manage waypoints, routes and maps). The information from the interview that is in the hardcopy format (questionnaires) was converted into digital format in MS Excel. The data's collected during field preparation and field work were analyzed in six portions- Land cover map, extraction of flood indicator and preparation of annual depth and duration map and also for 1987 flood, identification and classification of elements at risk, preparation of crop calendar, vulnerability assessments of each elements at risks and flood risk perceptions and coping strategies.

4.4.1. Land Cover Map

First of all the image was displayed on the computer screen using proper band combination to generate a false colour composite. Aster image of 15 m resolution (2005) with its entire 14 spectral band were used in this study. Number of classes that can be classified from the image is visualized by displaying the false colour composite image on the computer screen. These classes are selected in way that variation within the class is less than variation between the classes. Using field data, training samples were taken and a signature file for each of the classes is generated. The data that were collected in the field was categorized into two parts i.e. a set of field data was used for the land cover classification (40) and the separate set of data was kept for the accuracy assessment (86). The main purpose of this step was not to make the classification bias. Also at the same time the knowledge of field works (i.e. direct observation) and also using the image visualization/interpretation methods additional points were added for classification as well as for accuracy assessment.

The maximum likelihood algorithm was used to generate land cover map. The maximum likelihood classification assumes that spectral values of training pixels are statistically distributed according to the multi-variant normal probability density functions. Accuracy was assessed empirically by checking the classification result against the class determined from the reference data (collected during the fieldwork). The error matrix/confusion matrix/contingency table is used to compute the accuracy of the classification result. In this land cover classification results were compared to ground truth information. The accuracy of an estimator refers to how far way the particular value of estimate is, on average, from the true value of the parameter being measured.

4.4.2. Return Period of Flood Calculation by using the Gumbel's Method

Gumbel method was used to predict the return period of flooding from the discharge data. Attention should perhaps be called to the fact that any statistical estimate based on the short records is untrustworthy while a long record will probably include the old records less accurate than the more recent ones.

The Gumbel method steps to calculate the return periods are given below. To calculate the return period the Gumbel Variate (Y) is first determined as follows:

$$Y= -\ln(-\ln PL) \ldots\ldots \text{ Equation (1)}$$

Where, PL= Left sided probability

- To calculate the left sided probabilities the equation is

$$PL= R/(N+1) \ldots\ldots \text{ Equation (2)}$$

Where, R= rank and N= Number of observations

- To calculate the return periods for each observation is

$$T= 1/PR \ldots\ldots \text{ Equation (3)}$$

Where PR = = Right sided probability

- To calculate the right sided probabilities the equation is

$$PR =1/(1- PL)$$

Steps followed to compute **return period** of floods in the study area are as follows:

- The discharge data is first sorted in ascending order i.e. from lowest to highest.
- A rank value R is assigned to the records, starting from the value 1 for the lowest up to value n (n= number of records) for the highest one.
- The probability of not being exceeded i.e. left sided probability is calculated with the formula $P_L = R/(N+1)$ and the return periods with $T = 1/P_R$. Now the Gumbel Variate (Y) is determined from the formula given in Equation (1) and it is plotted against discharge. From the observed nature of the scattered points, the correlation between Gumbel Variate and discharge is obtained. If found to have higher correlation the line of best fit is constructed to obtain the trend line.
- Now, for any return periods the Gumbel Variate could be calculated using Equation (3), (2) and (1). Thus, for arbitrary return periods (between 1-200 years) the Gumbel Variate is determined. For each return period, now Discharge is estimated using the relation of corresponding Gumbel Variate and Discharge from the best-fit trend line obtained from step (4).

4.4.3. Extraction of Flood Indicator and Preparation of Annual Flood Depth and Duration Map

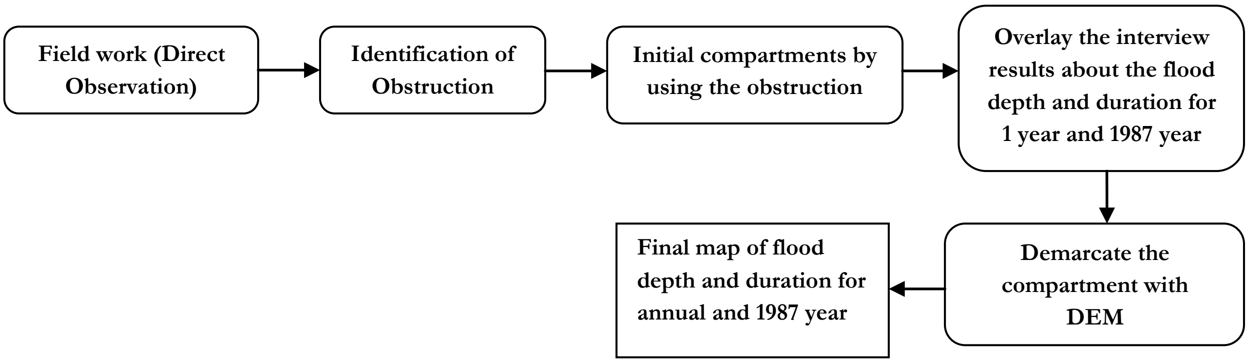


Figure 4.2: Flow Chart to Generate the Flood Hazard Maps

The flood depth and duration information that were obtained from the interview with the local people during the field work was used to generate the flood depth and duration map for annual and 1987 flood as shown in figure 4.2. As it is important to critically analyze the variations in depth and duration of flood water along the study area so for this reason various obstructions needed to be identified. These obstructions play an important role in ceasing the water flow and helps in water accumulation thereby increasing the water depth and duration. The obstructions that were identified by direct field observations in the study area were dikes, railways and as well as the weak point in the dike.

The identified obstructions were delineated and the initial compartments were generated. To generate the flood depth and duration map the compartments is needed because in the study area the water level is not same for whole area. Therefore in order to know which area receives how much of water and how long the water stays in the area the compartments were delineated. As a result, after the delineation of the obstructions the study area were divided into three compartments i.e. the southern part of the Rioni river and the northern part which were further divided into two compartments i.e. the northern part of the railway which is up to the dike and the southern part of the railway track. The flood depth and duration information collected from 121 sample points during the field survey by interviewing with the local people were overlaid in the compartments map. Thus, based on the flood depth and duration from the interviews, the compartments were delineated and further divided into sub-compartments.

The digital elevation model (DEM) was also used to make the overall final compartments. Also due to inaccessibility to the some part of the study area the compartments were demarcated based on the digital elevation model (DEM). In this way the flood depth and duration maps were obtained based on the local interview for both flooding scenarios i.e. annual and 1987 floods.

- **Flood Vulnerability Map**

The flood vulnerability of the study area was generated by combining the annual flood depth and duration map. The high vulnerability is the area where both the depth and duration is high (i.e. flood depth of 1-1.5m and duration greater than 3 days; or duration greater than 5 days) while the moderate vulnerability (i.e. flood depth of 1-1.5m and duration 1-3 days; or flood depth of 0.5-1m and duration 1-3 days) refers to the area where it have high depth but low duration and finally the low vulnerability (i.e. flood depth of 0-0.5m and duration 1-3 days) means the area that have low risk of flood, normal as perceived by the local people.

4.4.4. Identification and Classification of Elements at Risk

Based on land cover map (land cover types) of the study area and the questionnaires output, the elements at risk were identified. The identified elements at risk were house, road, people, agricultural land, crops, crop stages and livestock's. After the identification they were categorized into different classifications – physical, social, economical and environmental. The details about each classification type have been explained in literature review (section 2.4). These classifications were required in order to assess vulnerability depending on different aspects such as physical, social, economic and environmental vulnerability. Out of this the population under social vulnerability was one of most difficult element to be assessed because each individual person has different ability to cope with the floods and any other types of hazards.

After the identification of element at risk and their classification, based on observation and careful study of its characteristics and structures they were analysed separately since the level of vulnerability were different. This helped in the comparison regarding the level of vulnerability later in the phase of vulnerability assessment. Three levels of elements were separated as follows:

- **Physical Elements at Risk**

The area being highly prone to frequent flooding, different types of houses shows different vulnerability. So for this study, houses were categorized into different Types according to the construction materials used in floor, roof and wall. The information required to prepare these elements were collected from the field – questionnaire and also from the secondary source – cadastral data. Similarly, road being source of route for people's general transportation to overall economy of the region is one of the important parts of the study. So, for this study it could also be categorized depending upon materials used to pave the road – asphalt paved, dirt road, gravel paved etc.

- **Economic Elements at Risk**

In this category the elements such as agricultural land, livestock's and different types of crops as being the main source of income to the people are included. The crops grown in the area are corn, watermelon and beans. Each crop types have its growth stages –sowing, growth, maturity and harvesting. Also, there are critical times during the growing season when the crop is most vulnerable to environmental factors (such as: drought, flood etc.). Thus, upon flooding the agricultural crops have different level of vulnerability and damages at different crop stages, so crops at each crop stages could be identified as different elements at risk.

- **Social Elements at Risk**

As mentioned earlier the population is the most difficult element to be assessed due to varying ability to cope with floods. However, the general classification in terms of gender, age and occupation were done to further analyse vulnerability depending on these classes.

In this way each element at risks were classified and categorized into different types and classes of elements depending upon their characteristics, structures and variability.

4.4.5. Vulnerability Assessment

Vulnerability assessments were done for each element at risks based on their classification into physical, social and economical aspects. Further depending on each characteristics and components of each identified classification of element at risk, vulnerability assessments were done. Also, damage assessments were done for agricultural crops and livestock's. To assess the vulnerability the flood depth and duration is used.

- **Physical Vulnerability**

Physical vulnerability includes vulnerability of houses, roads and railways. To assess the vulnerability of different types of house to flooding, data was collected from 121 households most of which were located near the Rioni river. The way of collecting the sample has already been mentioned in the earlier section 4.3.1. Based on the interviews the scale of vulnerability was assigned for the houses in the study area. The scale of vulnerability was adapted from Marschiavelli, (2008) and modified based on the study area characteristics, (Table 4.2). The vulnerability of houses was determined by the construction materials used in roof, wall and floor.

Table 4.2: Vulnerability Scale for Houses Vulnerability

Vulnerability scale	Description
0 - No damage to the houses	- None of the materials get damaged by a certain level of flood depth. - The repair or replacement of any materials is not needed or required.
0.25 - Damage to the floor	- When the materials get half damaged by a certain level of flood. - Only the repair is needed but not the replacement.
0.5 - Half damaged of wall and floor	- If these two materials get half damaged. - Not needed to replacement but repair is needed because of the half collapse.
0.8 – Complete damaged to the floor, half damaged to the wall and no damage to the roof	- If one of the materials get completely damaged but other is half damaged. - Replacement is needed as repair is not sufficient.
1 – Full damaged	- When all the materials are completely damaged. - Complete replacement as well as repair is required.

To obtain the physical vulnerability map at first the interview house types were overlaid in the flood vulnerability map. After that each house type's vulnerability were compared to the flood depth and duration of that area. Finally the vulnerability curves were used to assign the vulnerability class. The vulnerability value were categorized in three classes i.e. 0-0.30 (Low), 0.30-0.60 (Moderate) and 0.60-1.0 (High) in order to obtain the physical vulnerability.

For assessing the **road vulnerability** the digital dataset of the road that were collected during the field from the municipalities were used. Depending upon materials used to pave the road the road was categorized into two types: paved road - asphalt and unpaved roads – dirt, gravel and slab. Vulnerability was assessed for different types of road. The vulnerability of roads was identified by using the vulnerability scale as mentioned in Table 4.3.

Table 4.3: Vulnerability Scale for Road Vulnerability

Vulnerability scale	Description
0	- No damage.
0.2	- Very low damage and only small holes or pits formed in the road. - Repairing cost is also low.
0.5	- Partly damage in the roads i.e. some part of the roads washed out and the holes or pits get larger. - No need of replacement but the repairing cost is high.
1	- Completely damaged - Need full replacement with high cost

The table was adopted from Dhillon, (2008) and modified based on the characteristics of roads that were identified in the study area. The vulnerability curves of both types of road to flooding were generated by using this vulnerability scale.

- **Economic Vulnerability**

The elements considered in economic vulnerability include agricultural land, livestock's and different types of crops. Since, the agricultural land is used for the crop cultivation so the vulnerability of crops is assessed and the vulnerability of agricultural land could be derived directly from the understandings of vulnerability of crops. The agricultural land vulnerability was generated by using the flood vulnerability map. The land cover map was overlaid in the vulnerability map in order to know the agricultural land vulnerability.

- ***Assessment of Vulnerability of Crops***

To assess the vulnerability of crops to flooding, the **crop calendar** was prepared based on questionnaire result. The crop calendar was used to obtain the detailed information about the different crop types, their sowing, growth, maturity and harvesting stages i.e. time of planting till length of growing season to harvesting season. Information was also collected about critical times during the growing season when the crop is most vulnerable to environmental factors (such as: drought, rain etc.), and date of harvest. From the crop calendar, it could be observed about dependency of each crop stages on the season and their adverse affect by flood (annual, seasonal etc). These various stages of the crops could be treated as different elements at risk. As, all the three stages are subjected to different damage levels that means crops at different crop stages do not bear same damage in terms of monetary value and recovery period. Thus, flooding at different crop stages incur different level of damages and varying amount of losses in terms of monetary value and recovery period thereby affecting their coping mechanism. So, vulnerability assessments were done separately for different crop stages.

After the careful observation of the questionnaire output data regarding duration of flood, the flood duration was dived into three ranges which was 1-3 days, 3-5 days and >5 days for the analysis of the vulnerability in the agricultural crops. The duration was classified into these three ranges because the duration according to the respondent and the level of vulnerability according to them could perfectly be generalized by the range of 1-3, 3-5 and >5 days. Furthermore the agricultural crop damage in-terms of monetary value was calculated based on different degree of vulnerability (very high, high, moderate and low) of element at risk of the crops at different crop stages.

To assess the vulnerability of the crops, the agricultural fields were divided into two sections by the railway track (that joined three municipalities east-west: Poti, Khobi and Senaki,). This railway track acted as the dike as it was elevated high up the ground level (about 1.5 meters). The first section was the area that was near to river till the railway track i.e. northern part of railway and second was the southern part of railway track. The railway acts as barrier during the time of the flood and to some extent prevents the flood water to go across in the upper region of the railway track. Thus, the comparison of vulnerability assessment between the two sections was done.

- ***Assessment of Vulnerability of Livestock's***

Likewise the vulnerability of livestock was assessed based on the questionnaire survey. The information's drawn from the questionnaire outputs for the vulnerability assessments were – types, sizes, number of livestock's and the sheds used for livestock's. The framework for vulnerability assessment of livestock was produced for each type of livestock that were available from each surveyed households. The vulnerability assessments are shown in the result section. Based on the vulnerability of agricultural crops and livestock's, both direct and indirect damages were assessed. Direct losses were quantified but indirect losses were difficult to quantify so the indirect losses were given as stated by the respondent.

- **Social Vulnerability**

The social vulnerability cannot be determined by one factor but the combination of various factors which influence people to be prone to certain hazards. So, for this reason social vulnerability was assessed via multiple factors such as age, group, gender, income, occupation and the household size based on questionnaire outputs. So, for this reason social vulnerability was assessed via multiple factors such as age group, gender, income, occupation and the household size based on questionnaire outputs. The social vulnerability map was generated by combining the information by using the IFF functions in ILWIS. Only level of income, occupation and household's size were taken into consideration to generate the social vulnerability. For example if level of income is low followed by household size >5 and occupation is farmer only then the social vulnerability is high.

- **Overall Vulnerability**

The overall vulnerability was generated by combining physical, social and economic vulnerability as follows:

Overall Vulnerability = Physical Vulnerability+ Economic Vulnerability + Social Vulnerability

In all the above mentioned vulnerability types, all of them have three levels i.e. high, moderate and low. So for each class the number were assigned such as 1 for Low, 2 for Moderate and 3 for High. Thus, the total resulting overall vulnerability values have the possible range from 3 to 9. That means the overall seven classes are possible. Once the class values were assigned, further overall classes were categorized in three classes such as 3-4(Low), 5-7(Moderate) and 8-9(High) to determine the overall vulnerability.

4.4.6. Assessment of Flood Risk Perceptions

Based on questionnaire output, assessment of people's perception about flood depth, duration, frequency, cause and impacts were done. Also the people's perception regarding flood control mechanisms and also their reason to stay in that area despite knowing about annual flood problem were evaluated.

To assess people's perception about flood impacts, four categories of flood risk perceptions were used – (1) normal, (2) disturbing but still Manageable, (3) unmanageable and (4) disastrous. "Normal" means that the community thought that the flooding is one of the common events and it is not susceptible to any kind of damages. "Disturbing but still manageable" means that the flood is not disastrous but has detrimental effect on their lives e.g. loss of agricultural crops, damage in shelter of livestock's etc. "Unmanageable" means that the flood has detrimental circumstances as a consequence of flood with higher depth and duration. "Disastrous" in this case indicates the uncontrollable flood resulting in total loss of agricultural land, livestock's, buildings and other infrastructures. This might require total replacement for recovery after impacts of floods.

Also, the local knowledge on the possible causes and season of flooding was analyzed. People's perception on damage caused by frequent annual floods and disastrous floods in the interval of 5-10 years was evaluated based on the individual household interviews. Also, the main reasons of their stay in that area were analyzed despite the area being highly prone to flooding. And, finally the perception based on the local government and their duties and activities to control the damage due to floods were analyzed. This analysis also evaluated whether or not there are any positive impacts of flooding in agricultural land.

4.4.7. Assessments of Coping Strategies

From the questionnaire output, coping mechanisms employed by the people to reduce the risk of flooding were assessed. This assessment took into account of three different phases of flooding – before flooding, during flooding and after flooding. The coping mechanisms employed to mitigate flood effects based on economical, physical and social aspects was also analysed.

The data on flood preparation methods employed by the local government and the local people was also collected during interviews. Information was also collected about the level of support and cooperation of the local government to mitigate the flood risks. Also, coping strategy of the local people and the government were assessed for different flood frequencies.

5. RESULT AND DISCUSSION

This chapter focuses on the results and the detailed analysis for each research objectives. The results presented here are the output of each methodologies explained in Chapter 4 in the data analysis section to achieve each research objectives – identification and classification of elements at risk, extraction of flood indicators and preparation of annual flood depth and duration map, vulnerability assessments and damage assessments, assessments of flood risk perceptions and assessments of coping strategies. The results thus obtained are further analysed and discussed in this chapter.

5.1. Land Cover Map

The result of the spectral classification using the supervised maximum likelihood classification for the different land cover classes in the study area is shown in figure 1. Six different classes were generated from the image classification such as Forest, Agriculture, Water Body, Settlements, Sand and Grassland.

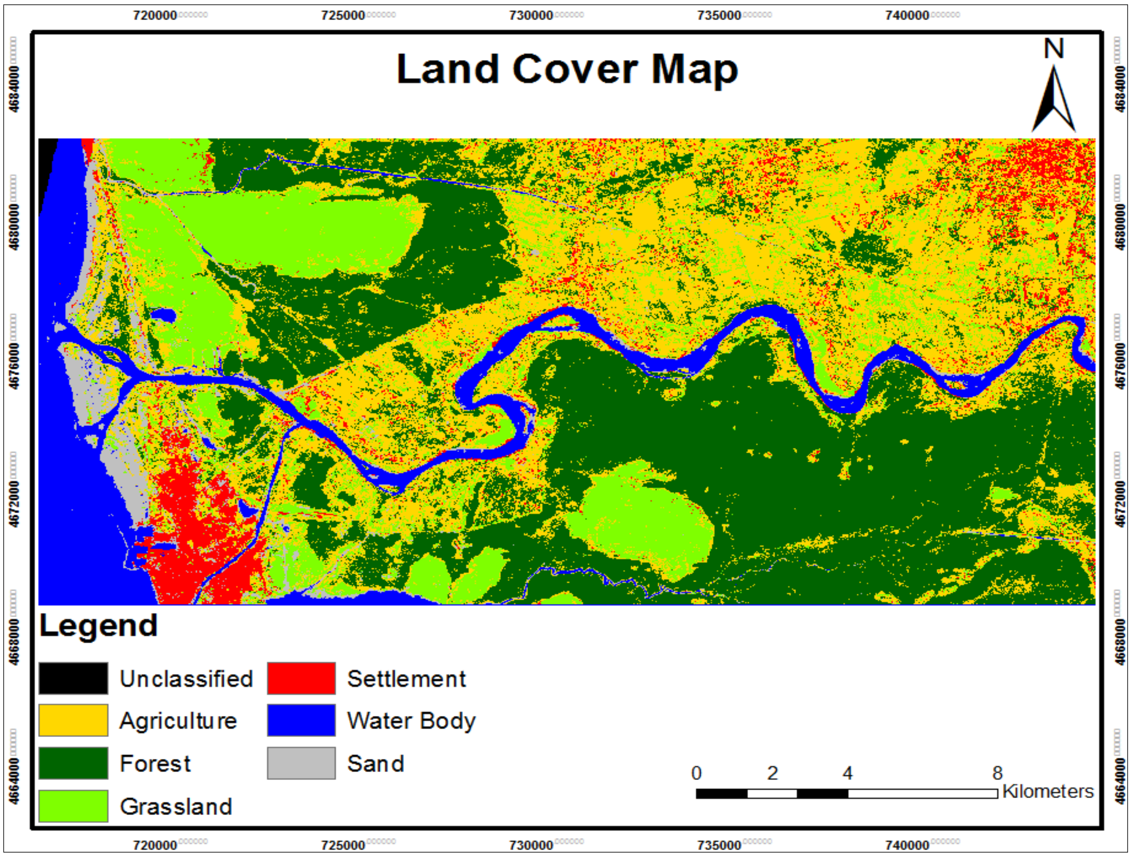


Figure 5.1: Land Cover Map of Study Area

According to the result forest cover is about 36 percent which is the largest unit, followed by land cover class agriculture which covers about 30 percent. The sand covers the smallest area along the coast of the Black sea which is approximately 3 percent of the area. While the settlements area covered 5 percent and water body about 10 percent of the total area. Table 5.1 and Figure 5.2 shows the composition of different land cover types in the study area.

Table 5.1: Land Cover Composition

	Land Cover Class					
	Agriculture	**Forest**	**Grassland**	**Settlements**	**Water Body**	**Sand**
Number of Pixel	518835	612127	251426	86292	160285	56389
Area (Sq.km)	11,673.79	13,772.86	5,657.09	1941.57	3,606.41	1,268.75
Percentage	30.78	36.32	14.91	5.12	9.51	3.34

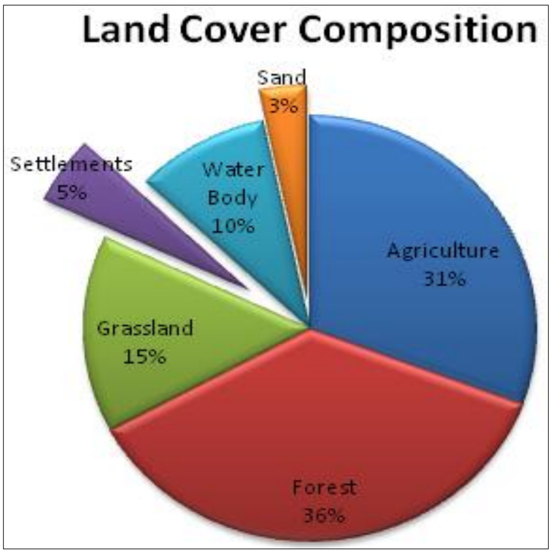


Figure 5.2: Graphical Representation of the Land Cover Composition

5.1.1. Accuracy assessment of Land Cover classification

In agriculture 58 cases were found in the sample data/field observation i.e. reference, while the classification result yielded 67 cases (at the corresponding field observation point) and out of which 43 were agreed (Correct). Likewise in water body there were 16 field observation cases and also 16 classified results but the corrected number is 13. The overall land cover error matrix is shown in table 2. Also the table 5.2 shows the spectral classification result of the image using the training data set which was collected during the field work periods.

Table 5.2: Land Cover Overall Error Matrix

Class Name	Agriculture	Forest	Grassland	Settlements	Water Body	Sand	Total
Unclassified	0	0	0	0	3	0	**3**
Agriculture	43(64.18%)	6	6	6	0	6	**67**
Forest	0	13(86.67%)	2	0	0	0	**15**
Grassland	4	0	18(81.82%)	0	0	0	**22**
Settlements	7	1	0	15(60.00%)	0	2	**25**
Water Body	3	0	0	0	13(81.25%)	0	**16**
Sand	1	0	0	0	0	15(93.75%)	**16**
Total	**58**	**20**	**26**	**21**	**16**	**23**	**164**
Producer's Accuracy	**74.14%**	**65.00%**	**69.23%**	**71.43%**	**81.25%**	**65.22%**	

5.1.2. Land Cover Accuracy Report

The error matrix result from this classification shows that the producer's accuracy is around 74 percent in agriculture but the user accuracy is less i.e. about 64 percent as shown in table 5.2. This may be due to the misclassification of agricultural into grasslands, forests and settlements. But mostly nearby the river area there is grassland up to around 100 meters but in the image mostly they all were classified as agriculture. The reason is that the image used in this study was taken in august 2005 when the crops were in the maturity stage (bigger in size) and at the same time the size of grasses will also have some height which as a result the grassland were classified as agriculture in the image.

The high classification accuracy of forest (87%) may be due to the careful selection of homogeneous training fields. The homogeneity of forest was very good because in the forest area there were no other land cover classes nearby. The forest areas get mixed only with the grassland but in small amount. So the confusion between the forest and other land cover classes is reduced due to the high homogeneity within the forest class.

While in case of settlements the user accuracy is 60%. This could be because of the wide feature space of the settlement class. The spectral variation in the settlement class is quite high. It almost overlaps all other classes in feature space. Mainly the settlements get mixed up with the agriculture and this is because that most of the area is having the agriculture nearby the settlements. This is quite obvious as settlement area is composed of almost all land cover such as water body, grassland and agriculture. This resulted in high producers and low user accuracies. Except for the forest, grassland and sand rest of the land cover classes have less user accuracy this may be due to the error while collecting the sample point from the field or also the error from the GPS. But in case of water body the both the accuracies are same (81%).

Overall Accuracy = (43+13+18+15+13+15)/164)*100 =71.34%

The overall classification accuracy is approximately 71 percent. This may be due to the several reasons such error in training data selection, less homogeneity of the fields and also small size of the fields. Also it may be because of the fields which are having the mixed pixels. The main reason for such a low accuracy in the result is the difference in the temporal data in image and in reference data. The image used in this study was taken in the year 2005. But the field work was conducted in the year 2010. While interviewing with the local people it was found that in the year 2005 there was big flooding and after that many farmers put their agricultural land bare and used for grazing purpose. This resulted the error in the sample points in the field, most of the agriculture land was sampled as grazing land in the field. So the changes in land cover make the result less accurate.

Also the possibility of mix-mapping of grassland as agriculture and agriculture as grassland also contributes in decreasing the accuracy. In addition the selected training data for agriculture may be less homogenous than that of the grassland. So the ultimate result may be reduction in the accuracy. These all may be the reason for low accuracy.

5.1.3. Land Use

The main land use type is mainly agriculture. So from the land cover map, only the land use on agricultural land was taken into consideration. The agriculture land uses were further classified into two types i.e. the commercial farming and the small farming land (only use for the home consumption). The commercial farming were identified and added in the land cover map while rest of the area in agriculture land cover class is the small holders farming. Those lands were used by the people for the production of their home consumption. The land use map of the study area along with land cover is shown in figure 5.3.

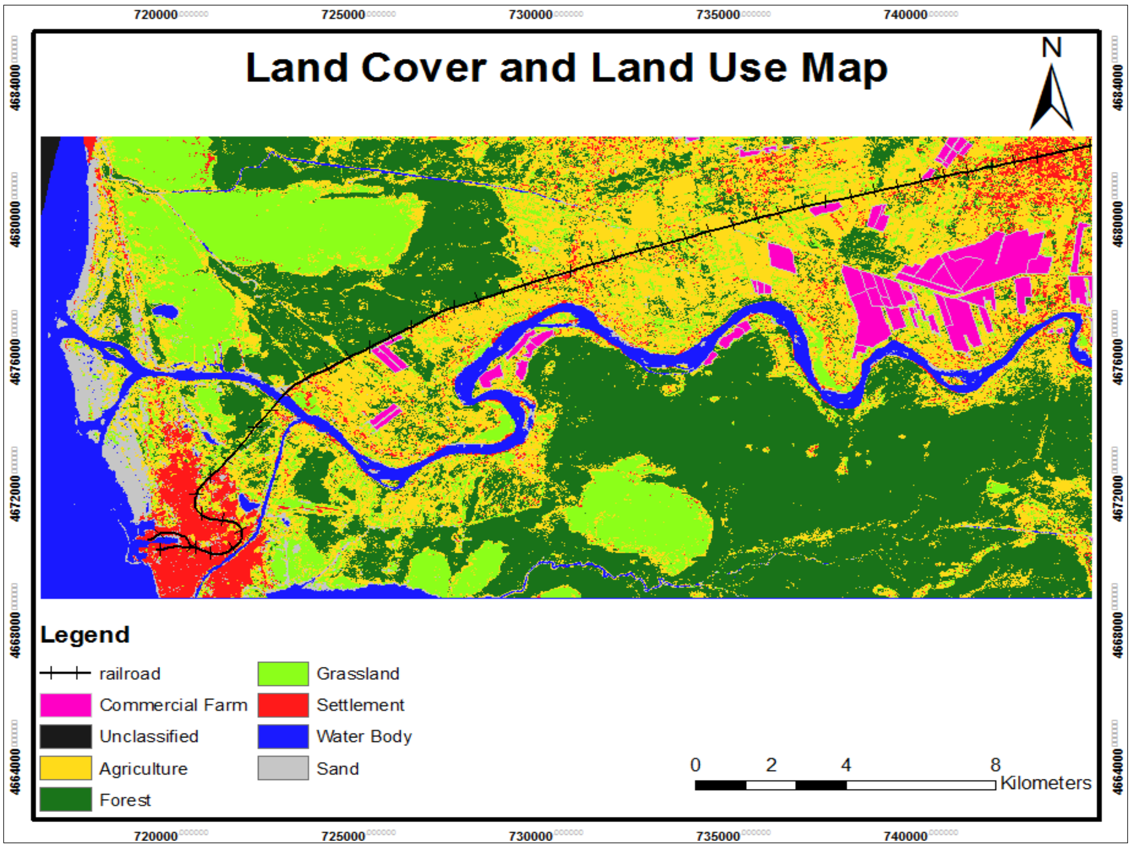


Figure 5.3: Land Use map of Study Area with Land Use

5.2. Return Period Estimation by using the Gumbel's Method

The Gumbel Variate and the return period are calculated from the discharge data by using the Gumbel method as mentioned in the methodology section. To calculate the return period and the discharge the discharge data for the period 1939-1990 was obtained from National Environment Agency (NEA) of Georgia. The analysis carried out for extreme events is shown in table 5.3.

Table 5.3: Record of annual maximum discharge from the year 1939-1990s

Year	Discharge	Sorted	Rank	Left Prob	Right Prob	TR	Y=-ln(-ln(left Prob)
1943	979	979	1	0.02	0.98	1.02	-1.36
1944	1010	1010	2	0.04	0.96	1.04	-1.16
1948	1150	1150	3	0.06	0.94	1.07	-1.03
1945	1160	1160	4	0.08	0.92	1.09	-0.92
1942	1190	1190	5	0.1	0.9	1.11	-0.83
1946	1220	1220	6	0.12	0.88	1.14	-0.74
1949	1250	1250	7	0.14	0.86	1.17	-0.67
1965	1290	1290	8	0.16	0.84	1.2	-0.59
1969	1310	1310	9	0.18	0.82	1.23	-0.53
1947	1400	1400	10	0.2	0.8	1.26	-0.46
1973	1440	1440	11	0.22	0.78	1.29	-0.4
1972	1480	1480	12	0.24	0.76	1.32	-0.34
1954	1490	1490	13	0.27	0.73	1.36	-0.28

1939	1520	1520	14	0.29	0.71	1.4	-0.23
1952	1520	1520	15	0.31	0.69	1.44	-0.17
1955	1530	1530	16	0.33	0.67	1.48	-0.11
1985	1550	1550	17	0.35	0.65	1.53	-0.06
1986	1552	1552	18	0.37	0.63	1.58	0
1971	1650	1650	19	0.39	0.61	1.63	0.05
1940	1670	1670	20	0.41	0.59	1.69	0.11
1984	1690	1690	21	0.43	0.57	1.75	0.17
1957	1720	1720	22	0.45	0.55	1.81	0.22
1951	1740	1740	23	0.47	0.53	1.88	0.28
1975	1780	1780	24	0.49	0.51	1.96	0.34
1953	1790	1790	25	0.51	0.49	2.04	0.4
1959	1820	1820	26	0.53	0.47	2.13	0.46
1964	1850	1850	27	0.55	0.45	2.23	0.52
1941	1920	1920	28	0.57	0.43	2.33	0.58
1950	1930	1930	29	0.59	0.41	2.45	0.65
1961	2030	2030	30	0.61	0.39	2.58	0.71
1960	2190	2190	31	0.63	0.37	2.72	0.78
1970	2240	2240	32	0.65	0.35	2.88	0.85
1967	2250	2250	33	0.67	0.33	3.06	0.93
1958	2280	2280	34	0.69	0.31	3.27	1.01
1968	2280	2280	35	0.71	0.29	3.5	1.09
1974	2280	2280	36	0.73	0.27	3.77	1.18
1966	2330	2330	37	0.76	0.24	4.08	1.27
1983	2480	2480	38	0.78	0.22	4.45	1.37
1962	2520	2520	39	0.8	0.2	4.9	1.48
1980	2650	2650	40	0.82	0.18	5.44	1.59
1956	2850	2850	41	0.84	0.16	6.13	1.72
1989	2920	2920	42	0.86	0.14	7	1.87
1963	3000	3000	43	0.88	0.12	8.17	2.04
1988	3020	3020	44	0.9	0.1	9.8	2.23
1990	3150	3150	45	0.92	0.08	12.25	2.46
1981	3160	3160	46	0.94	0.06	16.33	2.76
1982	3430	3430	47	0.96	0.04	24.5	3.18
1987	3640	3640	48	0.98	0.02	49	3.88

The Gumbel method shows very high correlation i.e. correlation coefficient of 0.9922 between annual discharge 'Q' and Gumbel Variate 'Y' as shown in the Figure 1. The equation shown below in the Figure 5.4 shows the best-fit line drawn for the obtained Gumbel Variate values for different discharge (has slope of 0.0017 and the y-intercept of '-2.8187'). The regression (R^2) value for the trend line is 0.9844 is high enough to make the best-fit for the two dependent variables 'Y' and 'Q'. And, the obtained trend line of best fit is used to calculate the discharge for different return periods. So the Gumbel method is best fitted for calculating the probability of discharge.

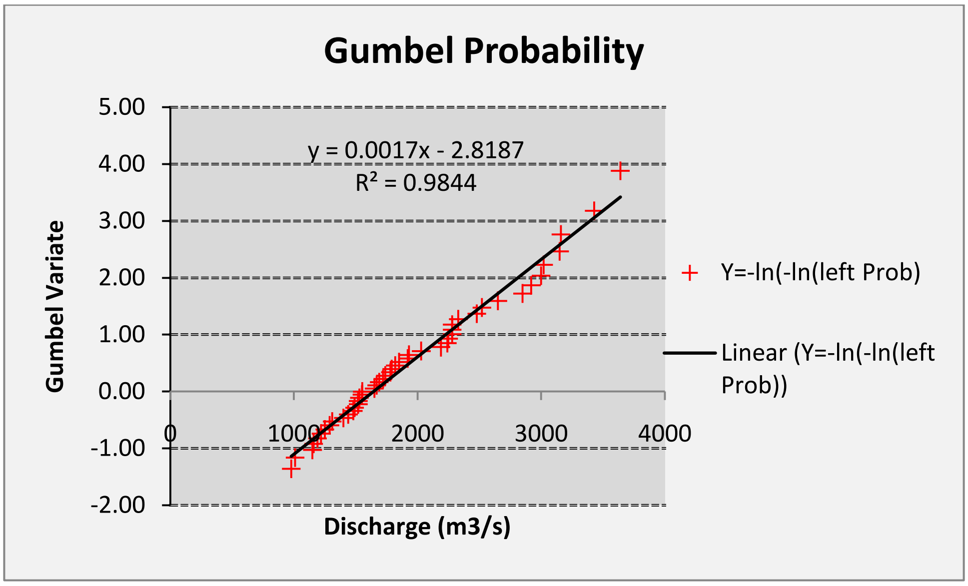


Figure 5.4: The Gumbel Probability

The result predicted discharge of 1.05 year return period flood is 1005.12 m^3/s as shown in table 5.4. Which means the discharge of 1005.12 m^3/s is most likely to occur annually. While for 5 years return period the predicted discharge is 2540.41m^3/s, for 10 year 2981.59 m^3/s, for 100 year 4363 m^3/s and 4775.71 m^3/s for 200 return periods. The discharge of 1987 flood was 3640 m^3/s. This result shows that the flood of 1987 with estimated discharge of 3540.41m^3/s has the return period of 25 years meaning that the flood of the magnitude of 1987 can occur once every 25 years. With increase in the number of return periods the discharge amount also increased significantly as shown in figure 2. We understand that the larger the number before 'year flood', the greater will be the effect on river levels and on anything out on the river's flood plain.

Table 5.4: Return Period of Different Discharge obtained from the Gumbel Method

Return Period (Years)	Right Probability (P_R)	Left Probability (P_L)	Gumbel Variate(Y)	Discharge (m^3/s)
1.05	0.95	0.05	-1.11	1005.12
1.25	0.80	0.20	-0.48	1375.71
1.5	0.67	0.33	-0.09	1605.12
2	0.50	0.50	0.37	1875.71
5	0.20	0.80	1.50	2540.41
10	0.10	0.90	2.25	2981.59
25	0.04	0.96	3.20	3540.41
50	0.02	0.98	3.90	3952.18
100	0.01	0.99	4.60	4363.94
200	0.01	1.00	5.30	4775.71

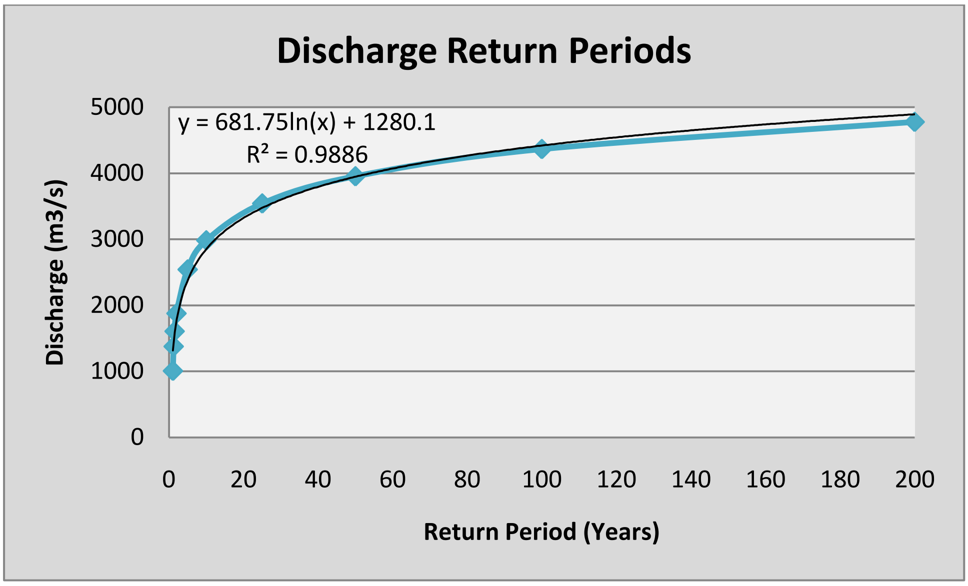


Figure 5.5: The Graphical Representation of Discharge Return Period

In this research this analysis was used to know the reoccurrence period of one of the disastrous flood i.e. 1987 flood and also to use in flood hazard map. It also helps in analyzing the magnitude of flood which has return period of 100 years. But in general this method will also help in designing the dike, bridge, culvert and also some flood control measures. It also helps to determine the economic values of floods. Likewise it will also make easy to demarcate the flood plains so that the major preferences should be given to that specific area. Furthermore it will also help in determining the effect of encroachment on the flood plains.

5.3. Annual Flood Depth and Duration and 1987 Flood Depth and Duration Map based on the Local Knowledge

5.3.1. Annual Flood Depth Map

In the annual depth map as shown in the Figure 5.6 it could be well figured out that there are four different depth classes based on the flood water depth- 0-0.5m, 0.5-1m, 1-1.5m and 1.5-2m. The annual flood depth map shows that the compartment 3 and 6 have the flood depth class ranges from 0 to 0.5. While the compartment 1, 4, 7 and 9 experienced the flood depth class ranging from 0.5 to 1. But in the whole compartment 7 the flood depth range is same i.e. 1 to 1.5. Likewise the compartment 2, 5 and 8 has the flood depth class ranges from 1.5 till 2 meters. For the rest of the areas no surveys were conducted due to inaccessibility to the area but the compartments were demarcated based on the digital elevation model (DEM).

As mentioned in the methodology (section 4.4.3), the area were categorized in three major compartments - the southern part of the Rioni river and the northern part which were further categorized into two compartments (by taking the railway track as a reference point) which are the southern part of the railway track till the end of the dike and the northern part. The annual flood depth map shows that in the southern part of the river the depth ranges from 1.5 to 2 meters. In the south western part i.e. around 40% of the area is inundated by the water depth of 1.5 to 2 meters annually whereas 60% of the area in the east has the water depth of 0.5 to 1 meters annually. This is because that the south west part of the area consists of many water channels and also the local elevation of the area is low. While the south-eastern part of the area has higher elevation compared to the south west and also the channels are not present in this area but the water depth reaches to 1 meter due to the weak points in the dike.

Similarly, in the northern part of the river that was divided into two sub-compartments shows that the depth class is varied. In the northern part of the railway track the whole areas have the same depth ranges i.e. 0.5 to 1 meter. The main reason is due to the presence of many channels in this whole area. Although it can be seen that this part of the study area is far from the Rioni river and also the railway track acts as obstruction but the water level is high compared to the southern part of the railway track. The main reason for this is due to the presence of water channels and also the presence of river Khobi in the northern part above this area as shown in the figure 1. Also in the southern part of the railway track, south east end of the study area (compartment '5') suffers very high flood depth which is due to the presence of river Tshivi to its east and also the dike is completely destroyed in that area.

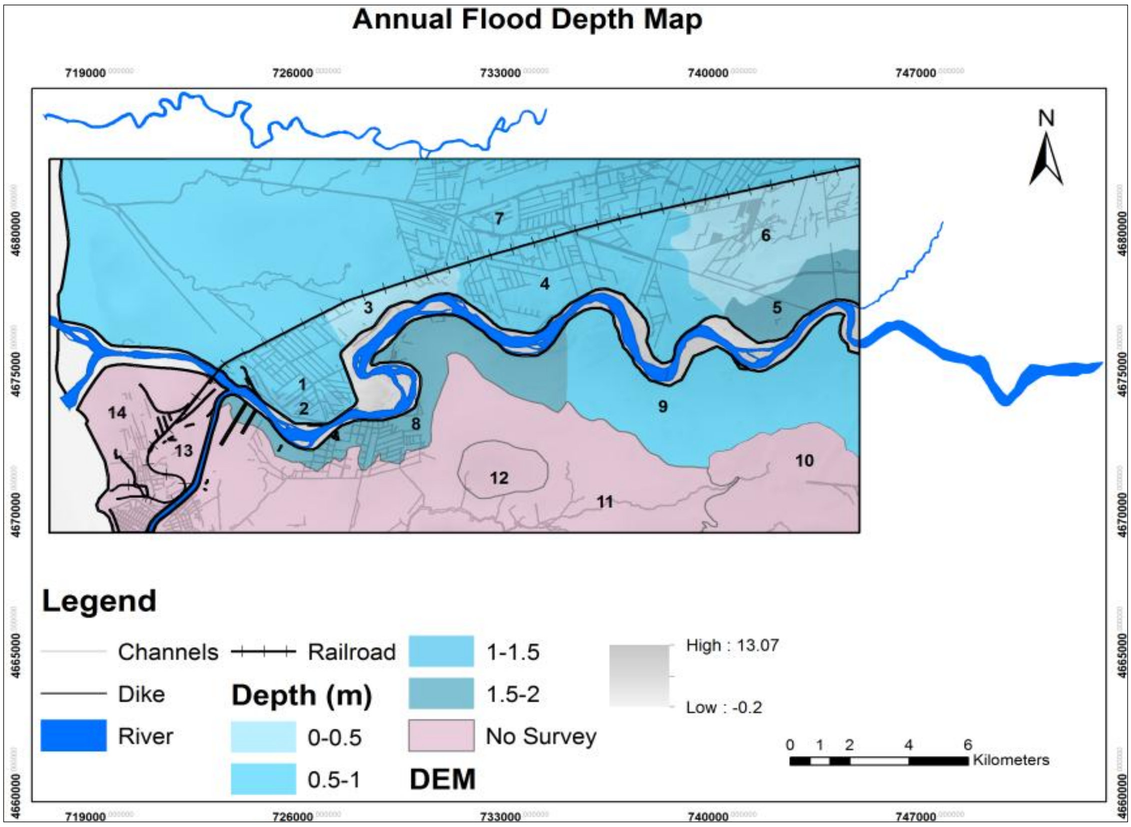


Figure 5.6: Annual Flood Depth Map based on the Local Knowledge

From the figure 5.7 shows that the total areas which had the water depth of 0 to 0.5 meter are around 24 sq.km (combined area of compartments 3 and 6).The large portion of the study area i.e. 134 sq.km experience the flood water depth of 0.5 to 1 meter annually (combined area of compartments 1, 4, 7 and 9). Annually around only 2sq.km (compartment 2) is covered by 1 to 1.5 meters and 25 sq.km is inundated by the flood depth of 1.5-2 meters (compartments 5 and 8). The different compartment value that was assigned in the flood depth map is shown in table 5.5.

Compartments	Depth(m)
1	0.5-1
2	1.5-2
3	0-0.5
4	0.5-1
5	1.5-2
6	0-0.5
7	1-1.5
8	1.5-2
9	0.5-1
10,11,12,13,14	No Survey

Table 5.5: Depth corresponding to the compartments

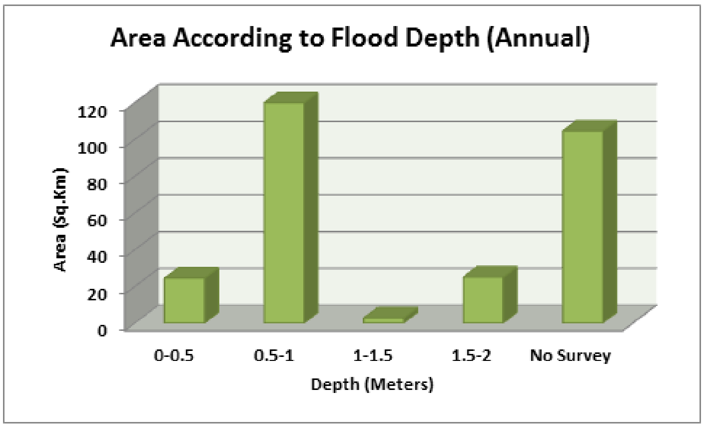


Figure 5.7: Area under Different Flood Depth

5.3.2. Annual Flood Duration Map

The annual flood duration map shows three different classes of duration i.e. 1-3, 3-5 and greater than 5 days as could be seen in the Figure 5.8. The compartments 1, 3, 5 and 10 are subjected to the floodwater duration of more than 5 days annually. While in compartments 2, 6, 7 and 9 the water stay up to 1-3 days. Likewise in compartments 4, 8 and 11 the water stays till 3 to 5 days annually.

As mentioned in the annual flood depth, in the southern part of the Rioni river the area is also divided into two compartments based on the flood duration. The annual flood duration map shows that in the southern part of the river the duration ranges from 3 to greater than 5 days. In the south western part i.e. around 40% of the southern area is inundated by flood water for greater than 5 days annually whereas 60% of the area in the east has the water duration of 3-5 days annually. The reason is also due to the presence of channels in the south west part of the area and the local elevation of the area is also lower than the southern east part. Although the south east part of the areas have high elevation but due to the breached dike the duration of water staying in that area normally ranges from 3 to 5 days annually.

Similarly in the northern part of the river that were further categorized in the two compartments as mentioned above in the annual flood depth maps shows that although the railway tracks acts as the obstruction but also some of the isolated parts (represented by compartment 2, 6, 7 and 9 in Figure 5.8 in the both areas have same duration. This is because that in the mid-southern part (represented by compartment 2) along the river, even though the area is very close to the river there is strong dike that prevents the flood water from the river and due to the high elevation on rest of the areas (represented by compartments 6, 7 and 9). Similarly in some areas in the southern part of the railway track, the track itself acts as the barrier and there is presence of channels and weak (or broken) dikes along the river which helps the water to get accumulated in the area and prevent to pass out from that area which makes the area inundated for the longer duration. While in the northern part of the railway track due to the presence of the river Khobi and also of the channels the water duration become high especially in the west part of the northern region.

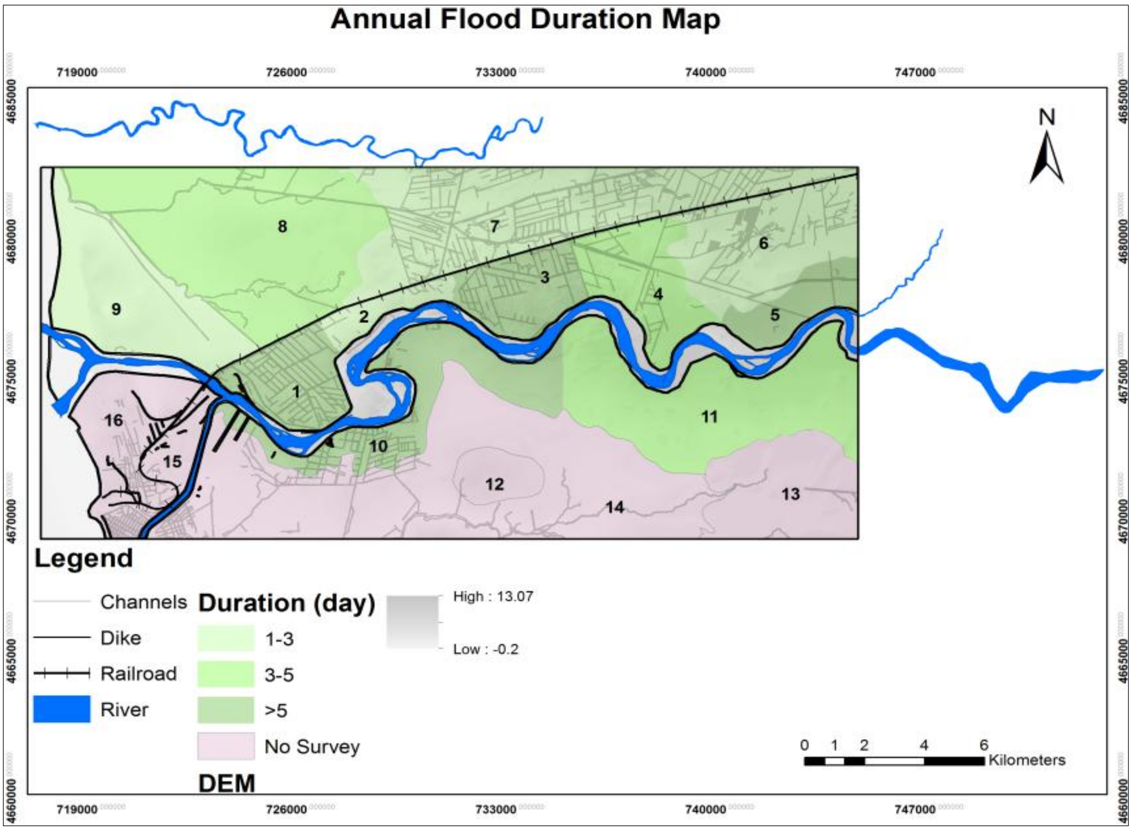


Figure 5.8: Annual Flood Duration Map based on the Local Knowledge

The flood depth is not only the problem but the long duration of the flooding makes the situation even worse. Majority of the area faces low to medium duration of flooding i.e. 1 to 3 and 3-5 days in this study area. The total areas that face the low and medium flood were around 84sq.km and 87sq.km. Around 46 sq.km of area experiences the long duration of flooding which is more than 5 days annually as shown in figure 5.9. The different compartment value that was assigned in the flood duration map is shown in table 5.6.

Compartments	Duration(Days)
1	>5
2	1-3
3	>5
4	3-5
5	>5
6	1-3
7	1-3
8	3-5
9	1-3
10	>5
11	3-5
12,13,14,15,16	No Survey

Table 5.6: Duration corresponding to the compartment

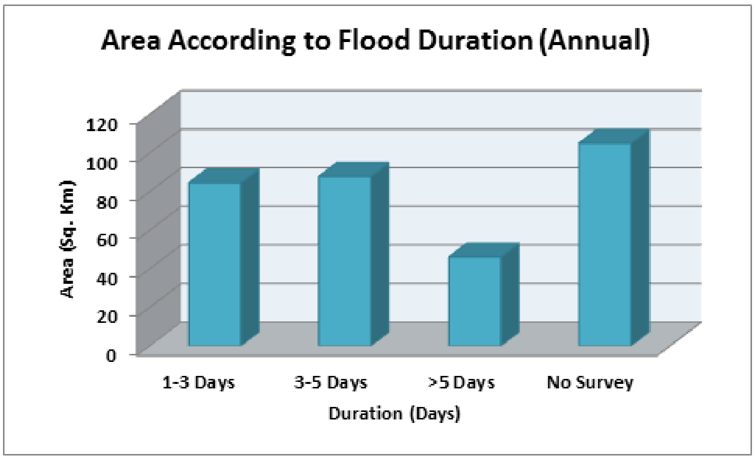


Figure 5.9: Area under Different Flood Duration

5.3.3. 1987 Flood Depth Map based on Local Interview

The flood depth map of 1987 shows the water level ranges from 0.5 to greater than 3 meter as shown in the Figure 5.10. In compartment 3 and 5 the water level reached up to the level of more than 3 meters. While in compartment 1, 2 and 4 the water level reached up to 2-3 meters in the year 1987. Likewise the compartment 6 and 7 had the water depth ranging from 0.5 to 1m. From the flood depth map as shown in the Fig 5.10, it can be seen that the southern part of the Rioni river have same water depth in the whole area although the elevation in south eastern part is higher than the south west. This is due to the reason that the flood was highly catastrophic destroying the dikes and back then there were many points where there were no dikes at all. Besides this, the presence of water channels in the south west part and the local elevation of the area being low caused the flood water to easily spread all over the region completely inundating the entire southern region.

However, in the northern part of the river that was divided into two sub-compartments shows that the depth class was varied. In the southern part of the railway track till the dike regions there were isolated areas (represented by compartments 1-5) that experience the depth ranges from 2 to greater than 3 meters in 1987. The south east part of the railway track (represented by the compartment 5) experienced the high flood depth class of greater than 3 m which is because that in the year 1987 in the northern part of the Rioni river the dike were broken and also due to the presence of river Tshivi to the east, the water depth is higher in this region. In the north-west part of the railway track it had the water depth of range i.e. 1.5 to 2 meter although this area being far from the Rioni river and also the railway tract being the barrier for the flood water from Rioni river to enter this region. The main reason is due to the presence of many channels in this whole area and the presence of river Khobi in the northern part above this area as shown in the figure 5.10, also the railway track acts as the obstruction thereby helps in the accumulation of flood water from Khobi river.

The Figure 5.11 shows that the large portions of area i.e. around 64 sq.km of area were covered by 1.5 to 2 meters flood water in the year 1987.

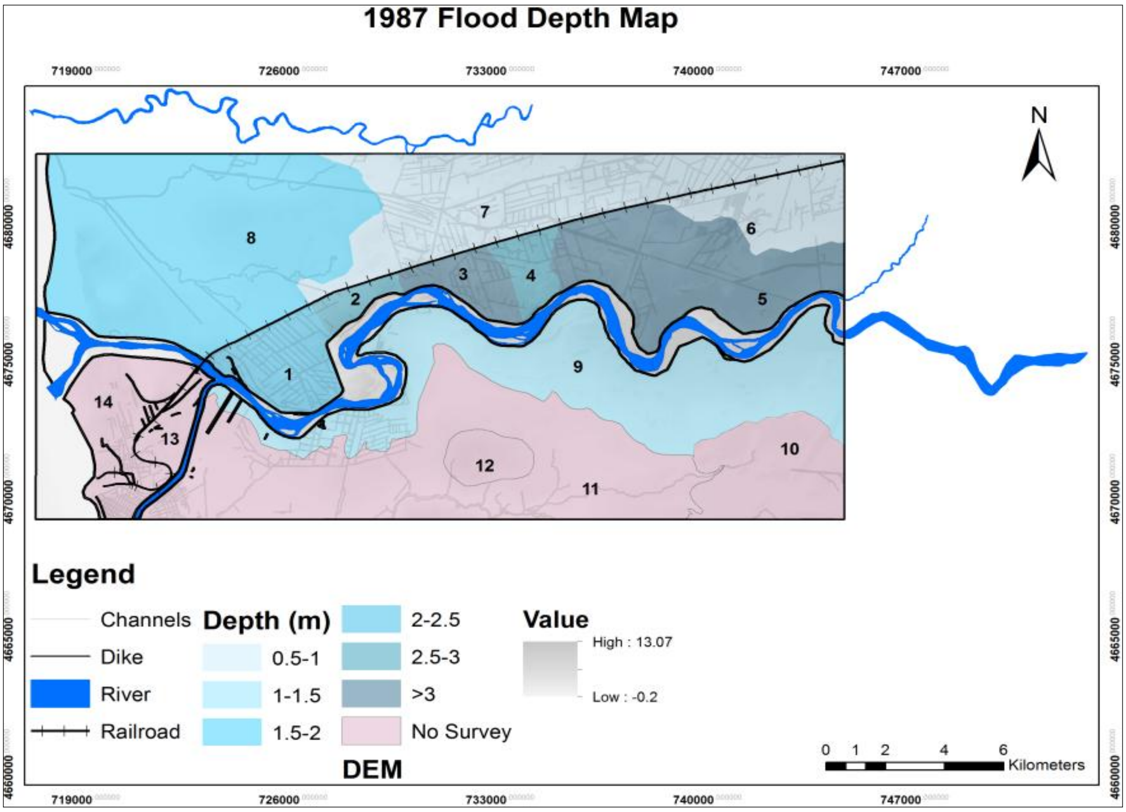


Figure 5.10: **Flood depth map of 1987 Flood based on the Local Knowledge**

While around 51 sq.km covers by 0.5 to 1 meters, 49sq.km is covered by 1 to 1.5 meters, 11sq.km by 2-2.5 meters, around 12sq.km is covered by 2.5-3 meters and around 36sq.km is covered by more than 3 meters of flood depth. The depth value corresponding to the compartments are shown in table 5.7.

Compartments	Depth(m)
1	2-2.5
2	2.5-3
3	>3
4	2.5-3
5	>3
6	0.5-1
7	0.5-1
8	1.5-2
9	1-1.5
10,11,12,13,14	No Survey

Table 5.7: Depth corresponding to the compartments

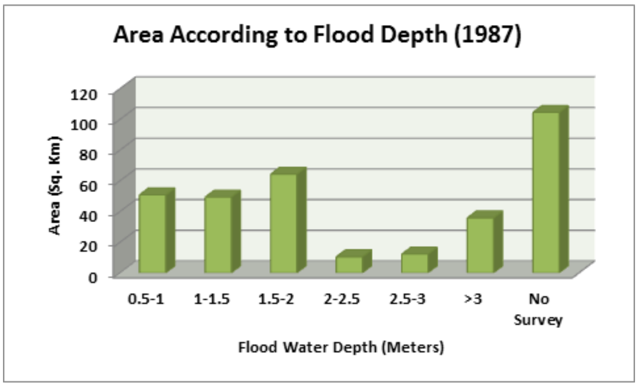


Figure 5.11: Area under Different Flood Duration

5.3.4. 1987 Flood Duration Map

The flood duration map of year 1987 shows- in compartment 2 and 5 the water duration was more than 5 days. While at the compartments 1, 3, 5, 6 and 7 experienced the flood up to 3-5 days. As it can be seen from the figure 5.12 that in the entire northern part of the railway track experienced the flood duration of 3 to 5 days and similarly some of the area in the south east and south west of the railway track (represented by compartments 1, 3 and 5) experienced the same flood duration of 3-5 days as shown in figure 5.12. In the northern part of the railway track, because of the presence of the river Khobi and the railway track acting as the barrier the water duration was up to 5 days. In the southern part of the Rioni river, because of the lower elevation, water channels and due to the obstruction on both sides the water cannot pass out and stay for longer duration. In the north east side of the study area (specifically in compartment 4), the dike was completely destroyed in 1987 so the water depth and duration were greater than 5 days in that region.

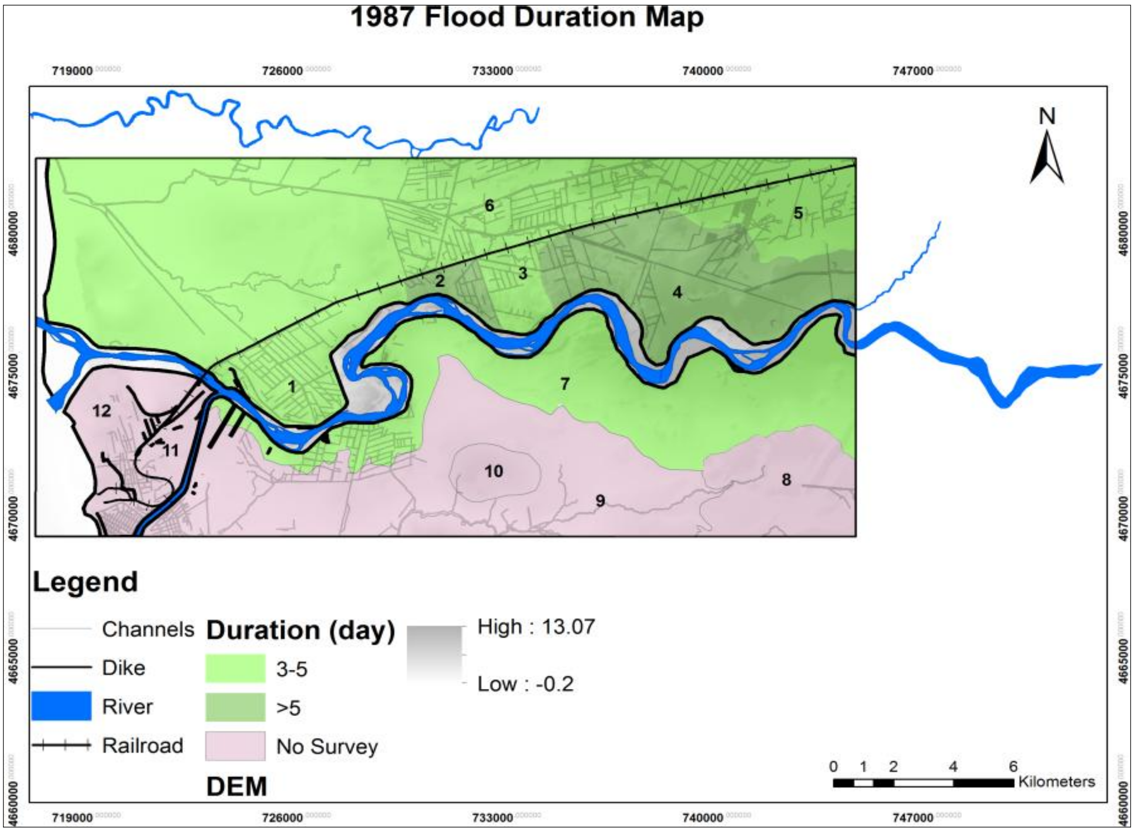


Figure 5.12: Flood duration map for 1987

Figure 5.13 of 1987 flood duration shows that area inundated by flood water for 3 to 5 days duration were 104 sq.km, and around 34 sq.km of area were covered by flood water for more than 5 days. The duration value corresponding to the compartments are shown in table 5.7.

Compartments	Duration(Days)
1	3-5
2	>5
3	3-5
4	>5
5	3-5
6	3-5
7	3-5
8,9,10,11,12	No Survey

Table 5.8: Duration corresponding to the Compartments (1987)

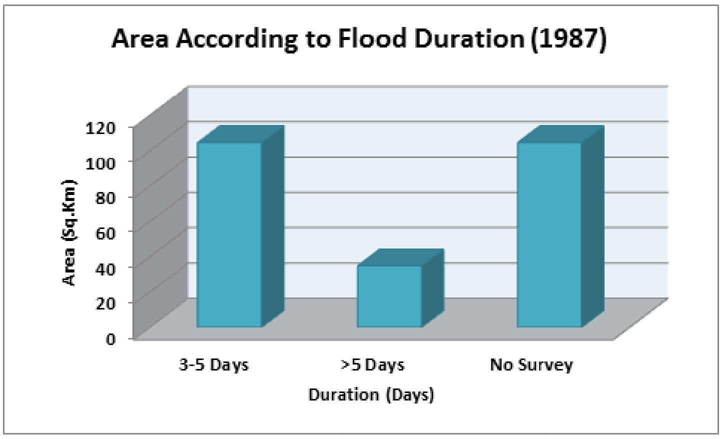


Figure 5.13: Area under Different Flood Duration

5.3.5. Comparison of the Result of 1987 Flood Depth based on Local Interview with the Previous Modelling Study (SOBEK)

The flood depth map of the year 1987 that have been prepared from the local interview (as shown in Figure 5.14) shows that in the North West part of the study area the water depth from the local interview is quite similar with the modelling result. Form the local interview the obtained water depth class was 1.5 to 2 meters while from the modelling the flood depth (as Shown in figure 5.15) of 1.6 to 2.5 meters was estimated. In southern part of the river, the model didn't predict any result. This may be because there were no samples from the southern part. But the result from the interview shows that the water depth ranges from 1-1.5 meters in the southern region. In the 1987 flood map based on local knowledge there were clear boundary between the railway track and its northern and southern part but in the model result there is no clear demarcation between them.

In the central region on south from the railway track, the modelling depth class ranges from 0.01 till 2.5 meters. But the local interview result shows the clear result of only one depth class i.e. 2 to 2.5. The differences may be because of the presence of the water channels and also may be due to interpolation of the results from the modelling.

There is a clear contrast in the modelling water depth result along the river basin in the southern part of the railway track which is indicated from the Figure 5.15 that the flood water depth increases from south to north until railway track. This is clearly different when compared to the local knowledge. The main reason for this is that the modelling result is entirely based on local elevation data (DEM) and does not consider the water channels present in the southern region. These water channels are one of the key indicators following the accumulation of flood water in the study area. Since, the flood depth result based on the local knowledge also considers the water channels and the live interview data's giving the different result than that of modelling.

Also, one another difference could be derived in terms of result interpretation from the previous studies from modelling compared to the result from local interview. Previous studies did not mention the effect of other rivers that aided in higher flood depth in the north-west (from railway track) and south-east region (from railway track) due to flood water discharge from Khobi and Tshisvi river respectively.

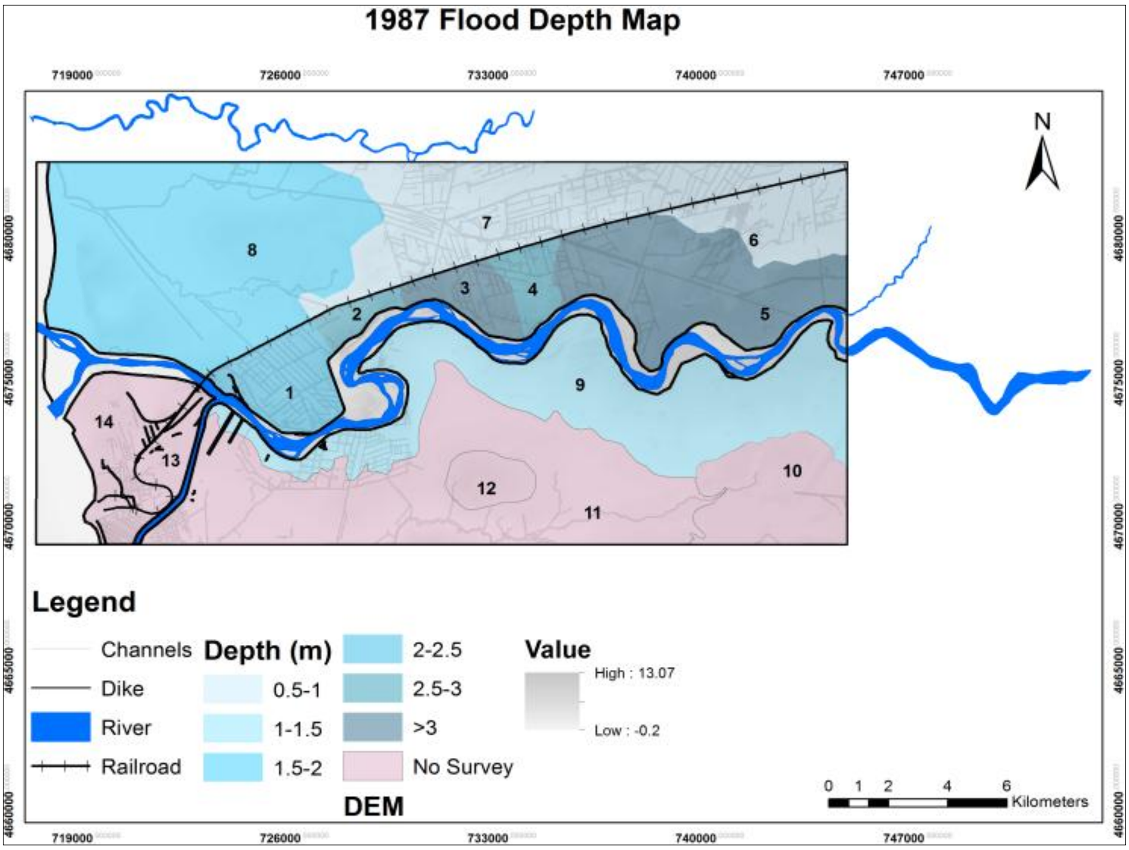


Figure 5.14 Flood depth map for 1987 based on Local Knowledge

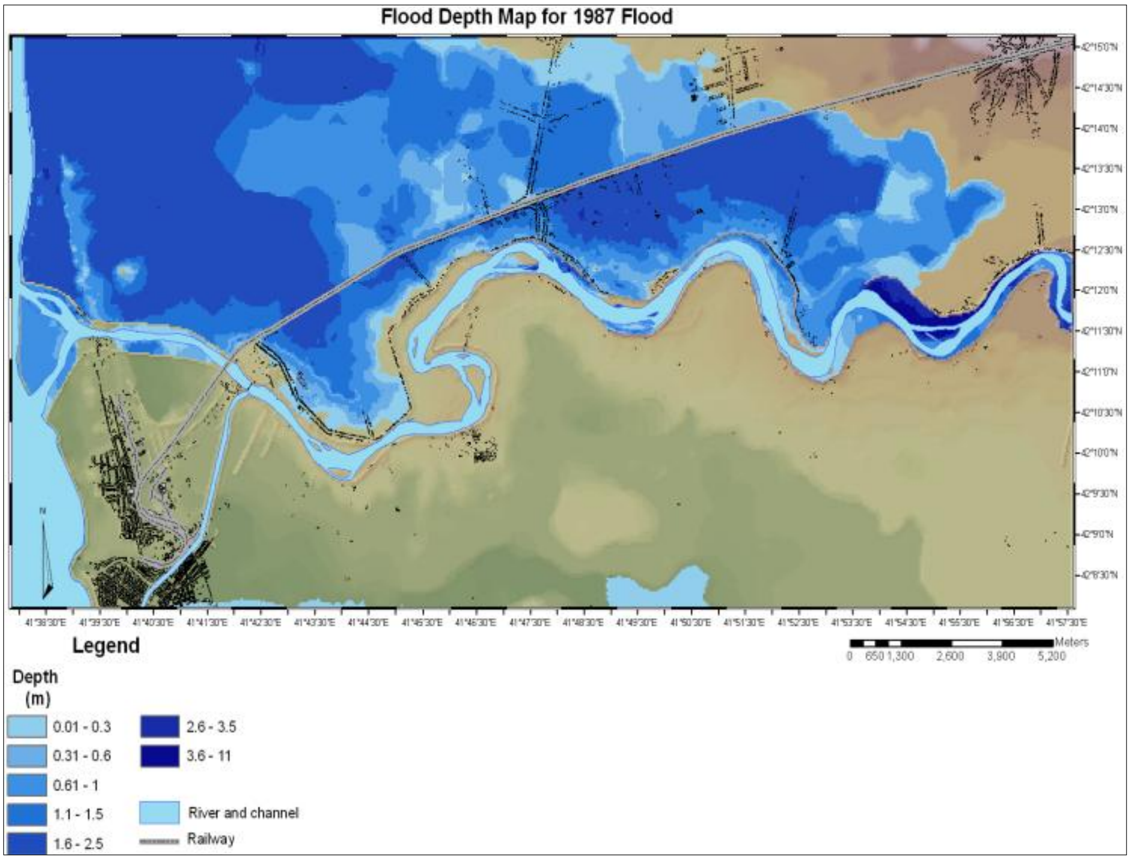


Figure 5.15: Flood depth map for 1987 based on modelling (SOBEK)

Besides those mentioned reasons, some of the differences in the local interview and the modelling result are due to remembrance of the people knowledge regarding 1987 flood events; as people might not have been very accurate and precise about giving the information regarding the flood events that occurred 23 years ago. Also may be due to the uncertainty in the flood modelling. This could be also due to the reason that while collecting the information about flood depth and duration some people might not have taken it seriously so this negligence might have cause the inaccuracy.

5.3.6. Flood Vulnerability Map

By combining flood depth and duration map overall flood vulnerability map is generated as shown in Figure 5.16. The result shows that the area is high and moderately prone to flood hazards annually. As it shows that the south east part of the area is moderately vulnerable while the south west part has high vulnerability to flood. This is because that the south west area has low elevation than the eastern part. Also the presence of channels is high in the south west area which makes the area more prone to flood water. The northern part of the railway track has high to moderate vulnerability. The highly vulnerable region is due to the discharge from the river Khobi during the rainy seasons. Also the presence of river Tshivi in the eastern part aids in high vulnerability in the study area. Similarly, the reason of vulnerability of rest of the region in the study area has been explained in 5.3.1 and 5.3.2. The flood vulnerability map shows that in a whole the study area is moderately vulnerable by annual floods. 27 percent of the area is highly vulnerable to floods while 32 percent is moderately vulnerable and 7 percent is less vulnerable.

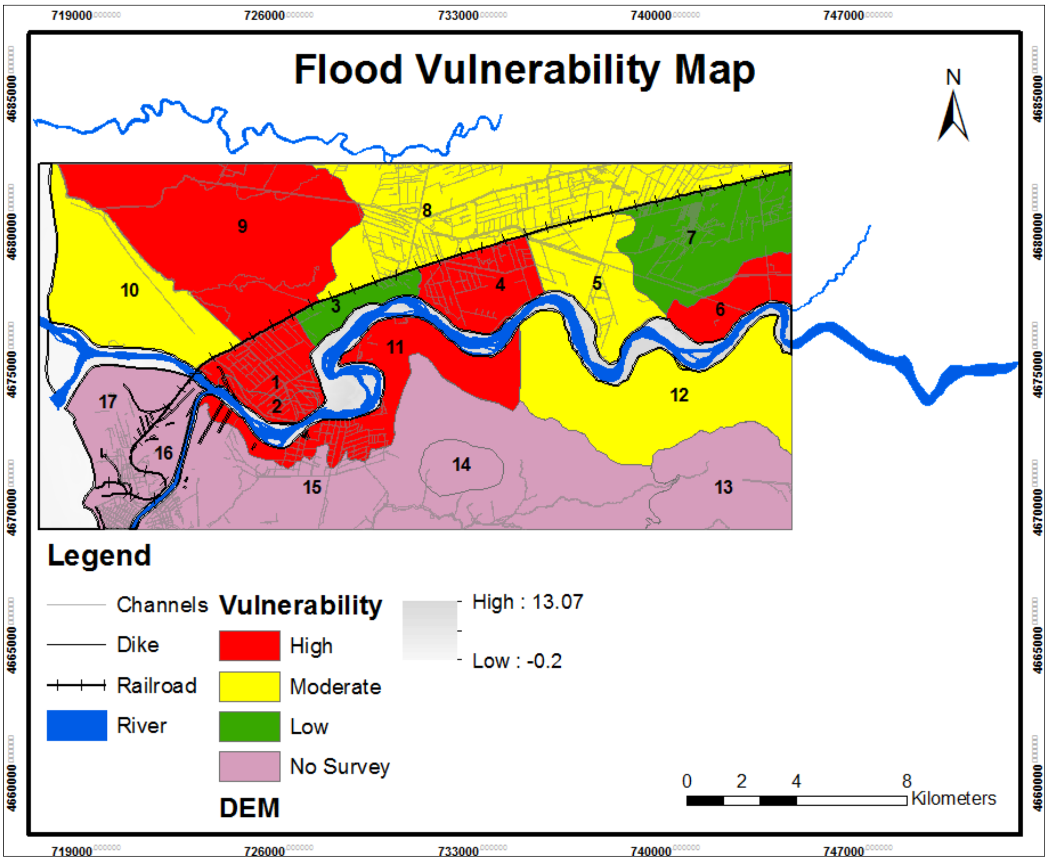


Figure 5.16: Flood Vulnerability Map of Study Area

5.4. Identification and Classification of elements ar Risk

The first stage for the analysis of data is the identification of the elements at risks. From the land cover map and land cover types of the study area and based on the questionnaires output, the primary elements at risk by floods were found to be agricultural fields, different types of crops, livestock's; physical structures such as houses, roads and railways; social elements commonly children, elderly people, female and low income group based on age, gender and occupation. The identified elements at risk were categorized into physical, social, economic and environmental as seen in Table 5.1. However, due to lack of time, environmental elements at risk were not analysed but only identified using Land cover map.

Table 5.9: Categories of Elements at Risk
(Source: Fieldwork)

Classification	List of Elements at Risk	Types
Physical Elements at Risk	Houses	Roof materials: concrete, tin
		Wall material: concrete, brick, ply/tin and wood, wood and stone mix with mud
		Floor materials: concrete, wooden, stone mix with mud
	Roads	Paved road: asphalt
		Unpaved road: gravel, dirt, slab
	Railways	Wood, stone, iron etc
Economic Elements at Risk	Agricultural land	Government and Private
		Land during the plough, perennial crops, mowing stages
	Crops	Maize, water melon, beans
		Crops in the sowing, growth, maturity and harvesting stage
	Livestock	Chickens, turkey, ducks, cow, pig, buffalo, horse, coats, lamb etc
Societal Elements at Risk	Gender	
	Age	
	Occupation	Agriculture only, agriculture and livestock, agriculture with livestock and labour work, commercial farmers
	Income	High, moderate and low
	Household Size	
Environmental Elements at Risk	National park, forest, wetlands Biodiversity, Flora and Fauna	

5.4.1. Physical Elements at Risk

The fieldwork and the interviews carried out with respondents in the field helped in making the inventory of the physical elements at risks in the rural setting. Their descriptions are as follows.

- **Houses**

There were total over 11601 houses in the study area (Table 5.13). During 1987 flood, 2000 houses were completely destroyed. Also, the recent flood of 2010 flooded 100 houses in the study area. So, the houses are also highly prone to flood risk and were identified as element at risk to flood. In the study area, the houses were categorized on the basis of structural characteristics and the construction materials used. The majority of houses were made from stone and wood as the construction materials and secondly with brick and less with concrete.

Wall Material: Commonly the houses in the study area used the construction materials like stone, brick, cement, mud, wood, tin and also concrete (brick/block) as the wall material. Majority of the houses that were surveyed in the study area was made up of wood material and also stone with mud or cement as wall material as denoted by Table 5.10.

Table 5.10: Wall Material of Inventory Houses

Wall Material	Number of Houses	Percentage (%)
Concrete (brick/block)	3	2
Stone/mud/tin	48	40
Wood	60	50
Brick	10	8

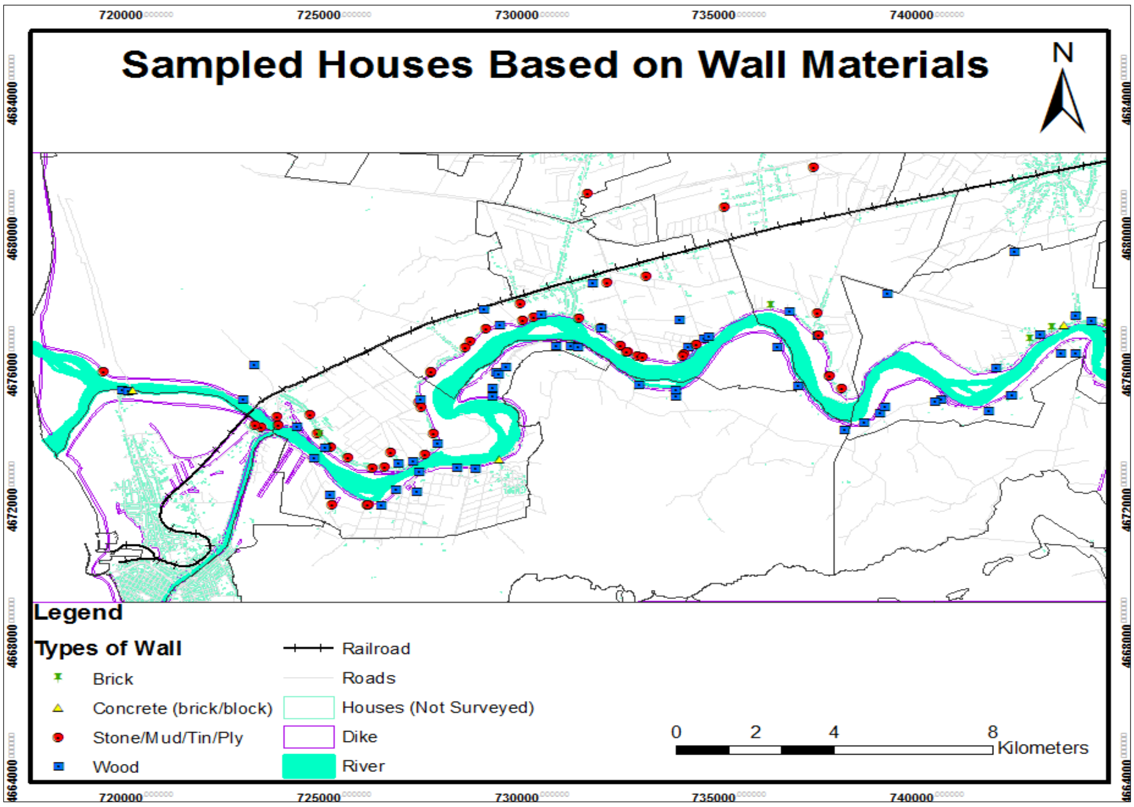


Figure 5.17: Distribution of Wall Types

The wall materials are one of the important parameters to study because the damage resistance of overall house to flood is highly dependent on the wall material of houses (Jones, 2009). If the wall of the houses collapse then there is high chances of roof to fall down. More rigid and concrete the wall material higher is the resistance to damage. The distribution of types of wall is shown in Figure 5.17.

Roof Material: Based on result from the fieldwork only two types of roof materials were found – tin and concrete. Almost around 90 percent of the houses use tin as a roof material as could be seen from the Table 5.11. According to the local people opinions- this type of roof material is more resistant to the flood as the durability of this type of material is high at the low cost of the material i.e. highly economic and also good resistant to rainfall.

Also according to them, the use of tin as a roof material has been their traditional way of constructing the houses in the study area. The roof cannot be directly affected by the flood but it is vulnerable to damage caused to wall material, if the wall is destroyed or weakened by flood then it adversely aid for the collapse of the roof. Figure 5.18 shows the distribution of roof materials in the surveyed houses.

Table 5.11: Roof Material of Inventory Houses

Roof Material	Number of Houses	Percentage (%)
Concrete	3	2
Tin	118	98

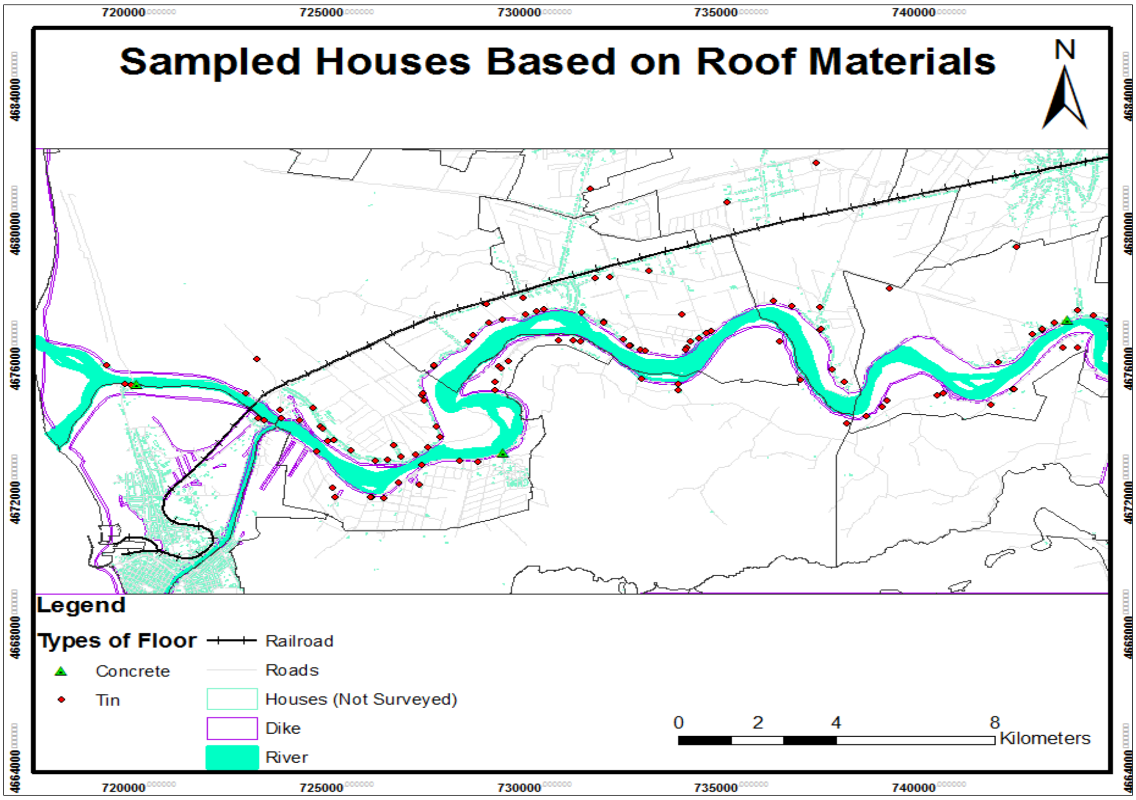


Figure 5.18: Distribution of Roof Types

Floor material: The most common floor material is the wood and stone with mud. From table 5.12 it could be seen that wooden floor materials comprise 58 percent and stone/mud comprise 40 percent. Use of wood as the floor materials was seen to be very common. It was found out from the survey that, as the Kolkheti national park is situated in the proximity of the settlement area in the study area so the local people have easy access to the wood from the national park. So the wood is very common in every household near the Kolkheti national park. The concrete floor is used only in the houses whose financial status is strong enough. Among the interviewed households, the housing structures are 1-2 storied. More than 70 percent of houses are single storied i.e. just have ground floor. Rest are two storied as shown in Figure 5.19.

Table 5.12: Floor Material of Inventory Houses

Floor Material	Number of Houses	Percentage (%)
Concrete	3	2
Stone/mud	48	40
Wood	70	58

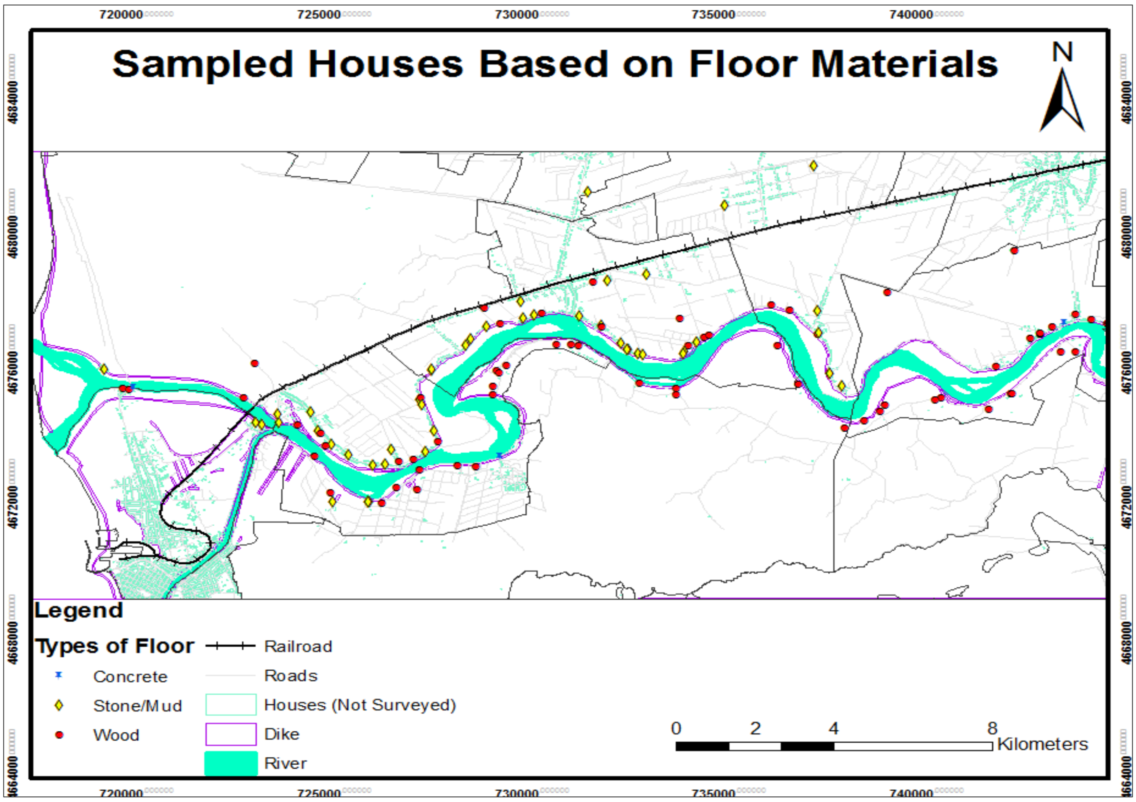


Figure 5.19: Distribution of Floor Types

Different types of houses that are found in the study area are grouped according to the materials used in roof, floor and wall. Four different types of house can be distinguished for further analysis of vulnerability. Figure 5.19 shows the distribution of different types of houses

1. **Type-1:** Construction material used in this type of houses is concrete roof, concrete (brick/block) wall and concrete floor. This type of houses can withstand the flood water for longer time as compared to other types. From the household survey and the corresponding building inventory, only around 2 percent of the suveyed houses were constructetd with this types of materials. Only the people with better financial status could afford this type of houses (Figure 5.20).

Figure 5.20: House Type-1
Source: Field Work

2. **Type-2:** In this type of house the materials used are tin roof, brick wall and wooden floor (Figure 5.21). These types of houses comprise around 9 percent of the total interviewed households. Also, keeping in mind about the sustainable housing, these types of houses were raised to some heights with inlet and outlet for flood water discharge.

Figure 5.21: House Type-2
Source: Field Work

3. **Type-3:** This type of houses use tin roof, tin (also some are wood, ply etc) wall and stone mixed with mud floor. The houses were elevated (around 0.5 meters) above ground level to minimize high flood risk to some extent. This type of houses accounts for about 39 percent (Figure 5.22). This is the most common type of house observed in the study area.

Figure 5.22: House Type-3
Source: Field Work

4. **Type-4:** This type of houses comprises around 50 percent of total houses that were surveyed during the field work. It consists of tin roof, wooden wall and wooden floor (Figure 5.23). To reduce high risk of floods, the houses are raised (1-1.5 meters) above the column due to high probability of frequent flood damages. These types of houses are usually owned by the farmers.

Figure 5.23: House Type-4
Source: Field Work

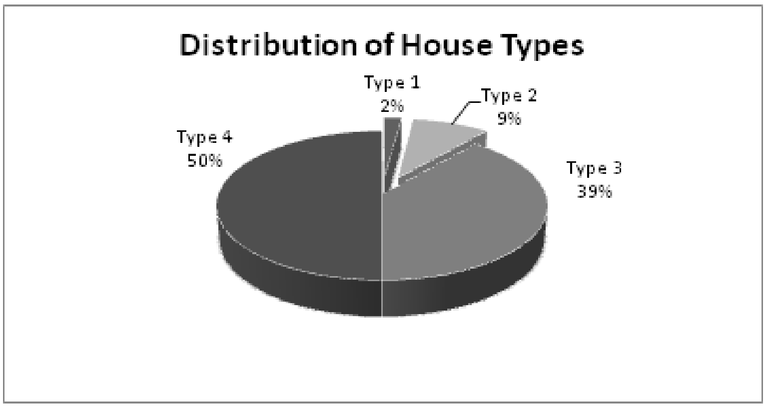


Figure 5.24: Distribution of Types of Houses in the Study Area Based on Survey

Table 5.13 shows the statistics of houses in the area extracted from the cadastral data source and the output from the interviewed houses (121 households). The spatial distribution of the types of houses according to the interviewed houses and the houses in the overall study area are shown in the Fig 5.24 and 5.25 respectively.

Table 5.13: Total Number of Houses and Surveyed Houses

House Types	Total Houses in the area	Percentage	Interviewed Households	Percentage
Type 1	424	3	3	2
Type 2	3440	30	10	9
Type 3	4800	42	48	39
Type 4	2937	25	60	50
Total	**11601**		**121**	

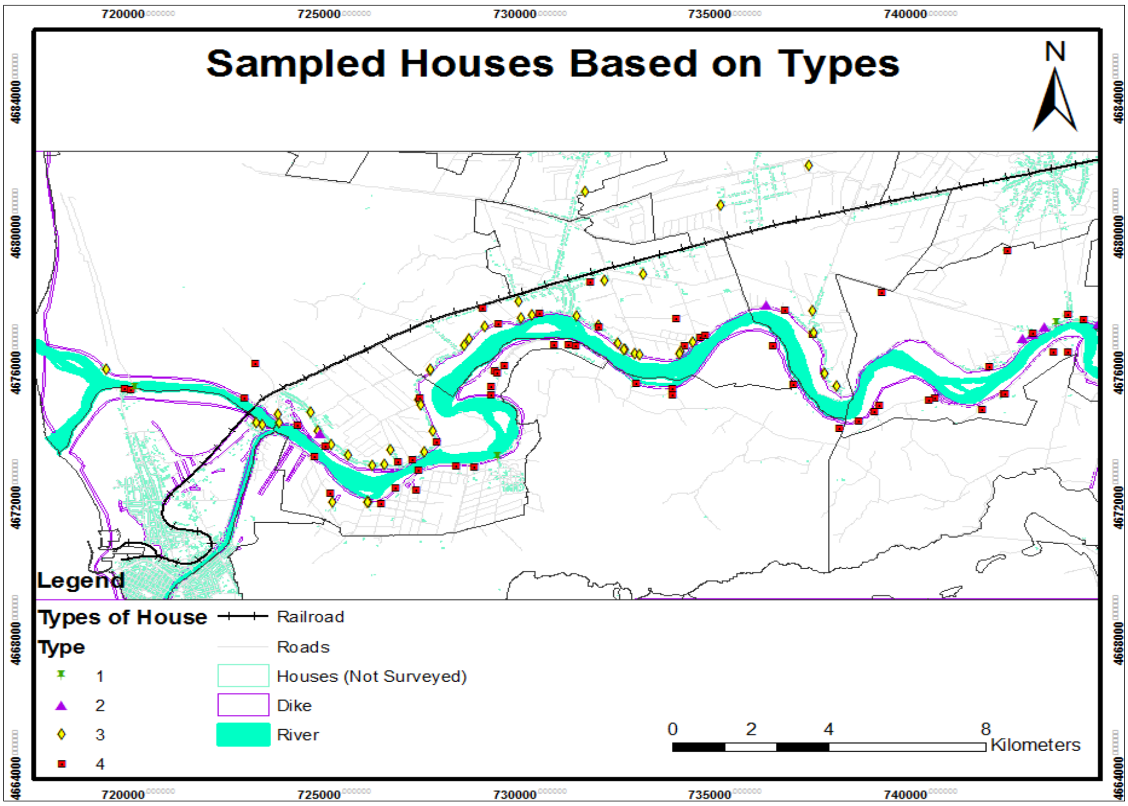


Figure 5.25: Spatial Distribution of Types of Houses in the Study Area Based on Survey

It could be seen from the Fig 5.24 and Fig 5.25 that, house type-3 and 4 are the most common house types. House type-4 is especially located along the Rioni River. They are owned by the farmers with weak economic conditions and because of their location this type of houses are the most vulnerable group.

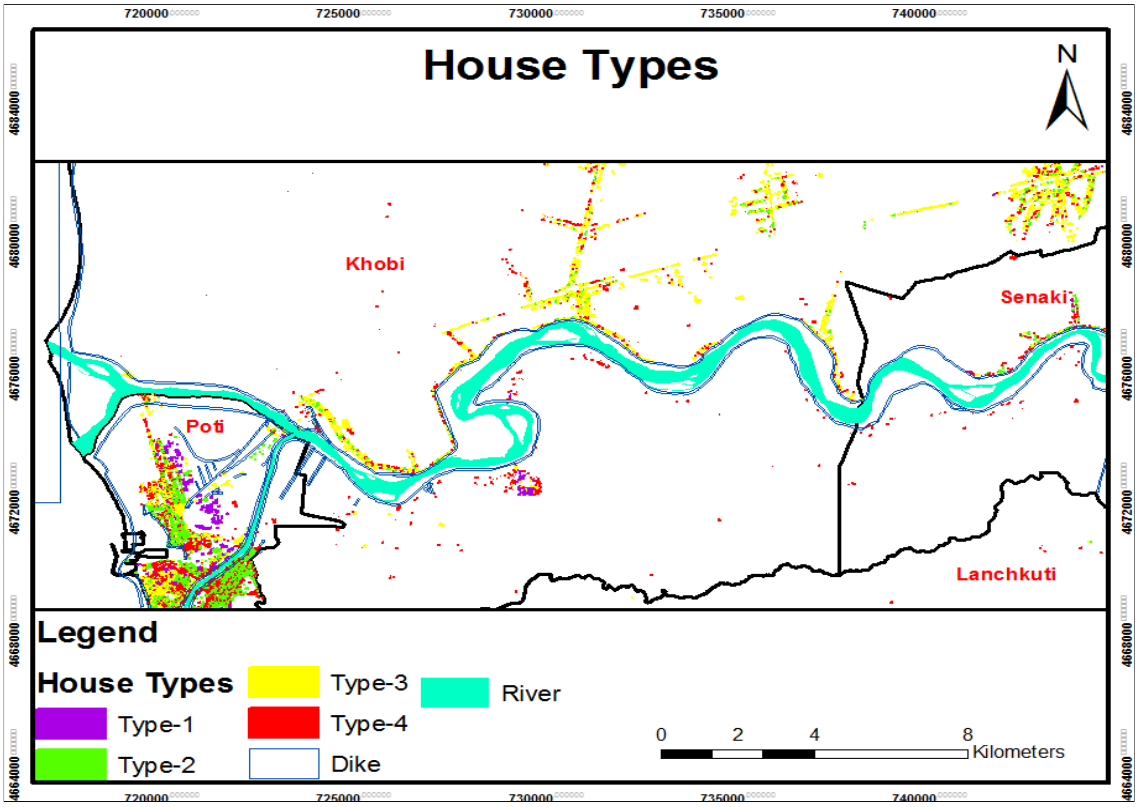


Figure 5.26: Spatial Distribution of Types of Houses in the Overall Study Area Based on Cadastral Data

- **Roads and Railways**

Roads and railways are identified as one of the key elements at risk because it is used as the source of route for people's general transportation and emergency situation. Roads become inaccessible at the time of flooding and the level of damage depends on the construction materials of road types.

Based on the road inventory and direct observation, most of the road that lies in the study area is gravel paved road, dirt road and slab roads. Only in some part there are asphalt roads. Although there were 4 different types of roads i.e. gravel, dirt, slab and asphalt but it is very difficult to delineate all four types of road in the map. As dirt, slab and gravel road comprise roads small in length and found in chunks and are used mainly for pedestrians and livestock's unlike asphalt roads which are used as primary highway. Table 5.14 shows the roads with respect to the road types.

Table 5.14: Total Length of Road Types

Road Types	Length in Meters
Unpaved Road	653372
Paved Road	84213

So, based on the usages, length and the damage incurred on different types of roads, it is generalized into two different road types – paved road and unpaved road. Paved road consist of asphalt paved road whereas unpaved roads consist of dirt, gravel and slab road types. The study area has large number of unpaved roads than paved roads. Based on cadastral data of the study area, around 89 percent of total roads are unpaved roads and only 11 percent of total roads are paved inside the study area.

Unpaved Roads: The roads that fall under this type are made from the mixture of mud and gravels, slab or just simply mud as shown in Figure 5.27, 5.28 and 5.29. Generally these types of roads are not longer in length as compared to the paved roads as unpaved roads were found distributed in small chunks over the study area. These types of roads are highly susceptible to damages caused by heavy rainfall during the flooding period as the flood water could easily scrape and wash away the layer from the road surface making it damp and muddy.

For this type of road the maintenance cost is relatively less than the paved roads. Among the gravel, slab and dirt road in this type; the dirt roads is highly vulnerable to the rains. There are high chances of the vehicles to get stuck because of the mud. These unpaved roads are commonly used for the pedestrian and also for the animals

Figure 5.27: Gravel Road (Source: Fieldwork)

Figure 5.28: Dirt Road

Figure 5.29: Slab Road

Paved Roads: These types of roads are mainly made from asphalt or bitumen (Figure 5.30). The roads that contain the asphalt or bitumen are generally constructed for the high volume primary highways. In the study area we found that the highways that join the Poti, Khobi and Senaki municipality and only in the centre of the municipality falls in this category of road. Also, this road lies beside and along the railway track. As compared to the unpaved roads the maintenance cost for these types of road is much higher.

Figure 5.30: Asphalt Road
Source: Fieldwork

The **Railway** joins the three municipalities Poti, Khobi and Senaki. The total length of railways inside the study area is 719820 meters. Figure 5.31 shows the spatial distributions of roads and railway in the study area. As could be seen from the Figure 5.31, the railway passes across the study area. Since the railway track is elevated to around 1.5 meter, the railway acts as barrier during the time of the flood and to some extent prevents the flood water to go across in the upper region of the railway track.

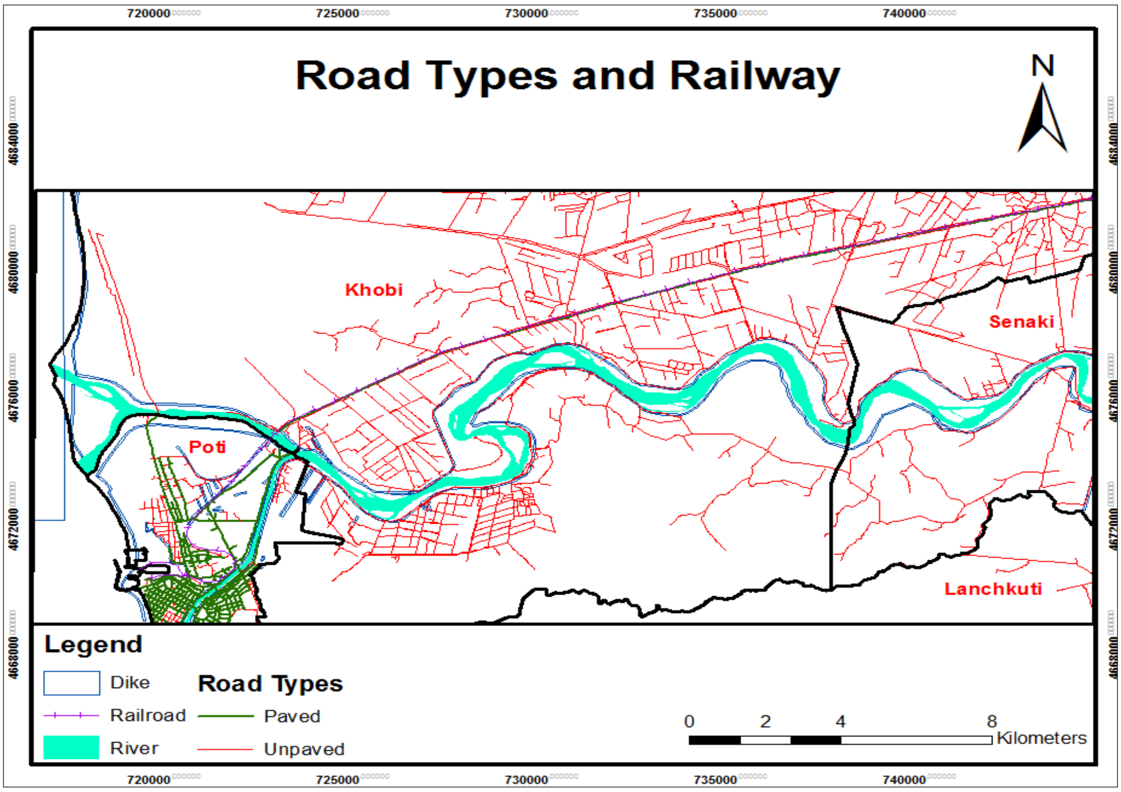


Figure 5.31: Spatial Distribution of Types of Roads and Railway in the Study Area

Note: In this figure, the railway track is seen to be overlapped with the paved road since paved road is beside the railway track. So, the paved road is also located along the line shown by railroad.

5.4.2. Economical Elements at Risk

The common economic elements that were identified in the study area are agricultural lands, field crops, and livestock's. Also, as discussed earlier each crop type has its own growth stages –sowing, growth period, maturity, and harvesting time. And there are critical times during the growing season when the crop is most vulnerable to environmental factors (such as: drought, flood etc.). Upon flooding the crops at different stages do not bear same damage. Thus, flooding at different crop stages incur different damages and varying amount of losses in terms of monetary value and recovery period thereby affecting their coping mechanism.

- **Agricultural lands**

In Senaki out of total land of 522 sq.km, 4.4 percent of land is used for the agricultural purpose. Similarly, in Khobi out of total land of 659sq.km, 4.4 percent of land is use for the agriculture.

Table 5.15: Areas Used for Agricultures in Khobi and Senaki Municipality

Municipality	Villages near to the Rioni	Agricultural land (Hectares)		
		Government	Private	Fellow
Khobi	Chaladidi	928	1062	428
	Patara Poti	917	943	207
	Sagvichio	313	857	113
Senaki	Teklati	1364.2	1374.8	380
	Zemo chaladidi	1343	308	350
	Akhalsopeli	869	1551	581

Table 5.15 shows the land distribution near the vicinity of Rioni River that is used for the agriculture. Most of the governmental land are bare and used for grazing but almost all the private land are used for agriculture.

- **Crop Types**

The main crops grown in the study area are corn followed by beans and water melon. However, corn is the major crop occupying 95% of the total crop production in the areas, Figure 5.32. According to local people the land is favourable for growing corn and this has been the traditional way of their agricultural practice. Some farmers stated that frequent flooding can be beneficial since corn requires lot of water. Few people stated that due to their weak financial condition and since corn seed being widely available and economic production they are mostly limited for corn production.

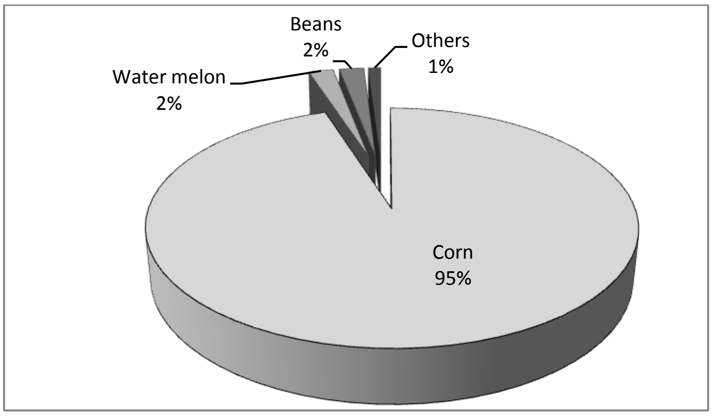


Figure 5.32: Different Types of Crops in the Study Area

- **Crop Stage**

Field crops at different growth stages e.g. sowing, vegetative growth, maturity and harvesting period comprise different levels of risk. For this reason crop calendar for the area is prepared based on the interview data. The resulting crop calendar is shown in Table 5.16. From the crop calendar, it could be seen that the sowing phase of corn starts in May. This however means local farmer starts the corn cultivation during the start of the May or during the end of May, while the growth time begin from the June till July and maturity takes place in August. The final stage i.e., harvesting starts from September till the end of October but some people also harvest the crop in beginning of November.

May is also the sowing period for both water melon and beans. The crops are harvested in September till October. According to the local farmers there is no crop rotation so once the crops are harvested they put their land bare i.e. period of November till April, during which the land is used as grazing area for the livestock. From the crop calendar, it is easy to derive and analyse the damage and vulnerability if the flood occur during each period of months. So, different crop stages sowing, growth, maturity and harvesting comprise different element at risk of crop life cycle.

Table 5.16: Crop Calendar for Different Types of Crops

Crop Types	Crop Calendar (Months)											
	January	February	March	April	May	June	July	August	September	October	November	December
Corn					Sowing	Growth		Maturity	Harvesting			
Water melon					Sowing		Growth	Maturity		Harvesting		
Beans					Sowing	Growth	Maturity		Harvesting			

- **Livestock**

Apart from growing field crops the farmers also keep livestock such as cows, pigs, chickens, turkeys, horses, buffalos, goats and ducks (Figure 5.33).Based on the size of livestock's and considering the level of vulnerability they were categorized into three: Category -1, Category-2 and Category-3. Under Category-1, horse, cow and buffalo are included. The size of animal sheds and the shed's cost are high. Category-2 includes animals such as goat, lamb and pig. The category-3 includes poultry such as chicken, turkey and ducks.

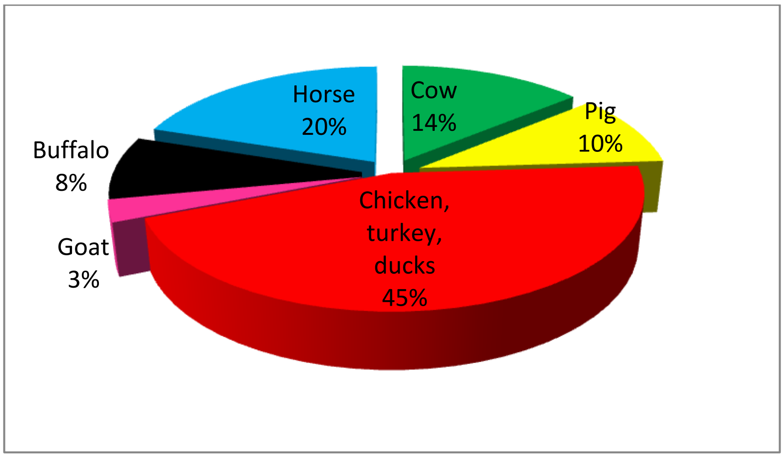


Figure 5.33: Types of Livestock in the Study area

It was seen from the questionnaire output that each respondent in total 121 household has at least one livestock. From Figure 5.34 it could be seen that more number of respondents own more number of livestock's i.e. greater than 20 of Category-3, 26 respondents have poultry farm which consists more than 20 of chicken, turkey or ducks.

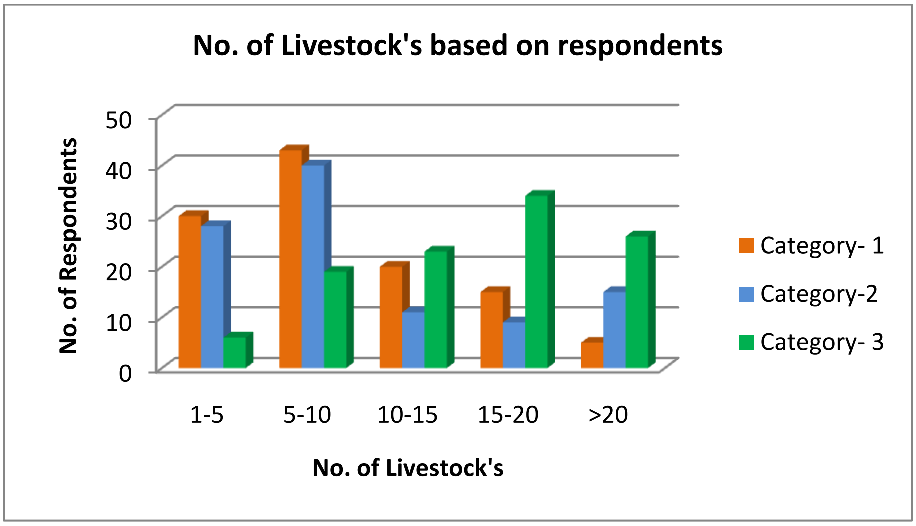


Figure 5.34: Number of livestock's based on Respondents

According to direct observation of cattle sheds and questionnaire output it was found that - most commonly the animal sheds were located near the house i.e. within the same proximity of the area of the house of the farmers. It was also found that some of the large farm holders who live near the Rioni river basin and owns large number of livestock's keep their animals like cow, buffalo, and horse (category-1) in the outer-dike areas between the dike and Rioni River that has open grassland for their grazing.

Most commonly, the livestock's that falls in the category 2 and 3 were kept in the animal shed that were built about 0.5 meters above the ground level. However, the category 1 animals were kept in the animal sheds in the ground level beside the farmer's house. According to the respondents, grazing areas for livestock's belonging to category 1 and 2 were primarily the inner side of the dike which has open pasture land and in the forest. Livestock's were also grazed on the land after the field crops have been harvested.

5.4.3. Societal Elements at Risk

The people living in the area fall under social vulnerability which is very difficult to assess because each individual person has different ability to cope with the floods and any other types of hazards. The effect of flood to the local population is determined by their social and economic profile - that includes gender, age, occupation and source of income. Thus, the characteristics of the people at risk i.e. societal elements at risk are separated into: gender, age, occupation and source of income.

- **Gender**

Although regardless of gender both male and female population could be identified as the element at risk. But, based on the survey it was seen that female seems to be more vulnerable than male as they require help and assistance to evacuate during flooding. The population statistics of the study area shows that female population (53 percent) is higher than the male population (47 percent) (Table 3.1). The detailed discussion of societal elements at risk is presented in the further section.

Regarding gender statistics of respondent, from the household survey conducted in 121 houses, male respondents (67.24 percent) was higher than female respondents (32.75 percent.). As this survey was conducted during the harvest period of the crops i.e. month of September and most of the farmers being male, the male farmers who were working in the agricultural field located beside their house were the major respondents.

- **Age**

Most of the respondents mentioned that the most vulnerable age groups are the children up to the age of 10 years and the elderly people above the age groups of greater than 60 years. Since the settlements area is very old and thus the majority of local people according to their traditions are involved in the labour and farming and the age groups of 56-65 years are involved rather than the age groups of youth. The most productive group in this rural community in the agricultural sector is age group 36-65 years

- **Occupation**

Different kinds of occupation of the people in the study area reflect the base of social and economic culture. Since the study area being rural area, agriculture remains the principal occupation. The climatic conditions and location is more suitable for agricultural activities and livestock. However, agriculture is the principal occupation which makes around 48 percent. Other sources of income for each household are shown in the Table 5.17.

Table 5.17: Respondents Distributions based on Occupation

Occupation	Percentage
Agriculture only	48.27
Agriculture and Livestock	29.31
Agriculture and other works (Labour Work)	18.96
Commercial Farmers	3.44

- **Vulnerability Assessment of Elements at Risk**

After the identification of elements at risk it is required to estimate the degree to which the identified element is at risk. According to Merz *et.al.,* (2010), flood damage is influenced by several factors such as flood depth, flow velocity, flood duration, flood contamination and also the resistant factors such as building types, preparedness mechanism and coping strategies. In the present research s only the flood depth and the duration are employed to assess the vulnerability of elements at risk. From the results obtained from the interviews the flood depth of 0.5, 1, 1.5 and 2 m are considered. Similarly flood duration of 1-3, 3-5, >5 days are considered.

5.5. Vulnerability of House Types to Flooding

In assessing physical vulnerability of the houses parts of the building such as wall, floor, ceiling, roof, structural column, window, door, number of floors etc need to be considered since the construction materials used for constructing various parts of the houses determine the level of vulnerability. In this research the physical vulnerability of houses is based on damage to wall, floor and roof as identified in the previous section 5.1.1.1. The vulnerability scale is mentioned in Table 4.2. The vulnerability is expressed on the scale of 0 to 1; 0 meaning no loss at all and 1 meaning complete loss. The Vulnerability level of each house types is shown in Appendix 4.

5.5.1. Vulnerability of House Type-1: Concrete Roof, Concrete (brick/block) Wall, Concrete Floor

Only around 3 percent of total houses in the study area are of this type. Because of the concrete construction materials, these types of houses are less vulnerable to floods. The vulnerability curve of house type-1 based on the questionnaire output could be seen in Figure 5.35. This type of houses can withstand the flood water for longer time as compared to other types. But the vulnerability increases with the increase in water depth and duration. As it could be seen from the vulnerability curve below that till the flood water level of 0.5 meters there is no damage at all. This have been nullified either due to the elevation of houses above ground level in most cases or due to the construction material of floor basement and wall which is concrete.

When the water height reaches up to two meters, the maximum vulnerability attained is 0.35. That means, it might cause small cracks in the wall but this totally depends upon the duration of flood. If the vulnerability reaches up to 0.35 then only repair and maintenance is needed for the recovery.

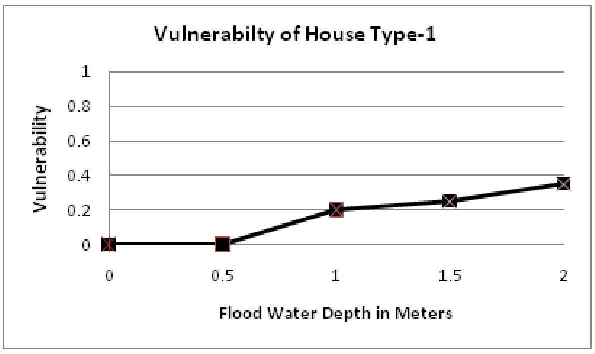


Figure 5.35: Vulnerability Curves for House Type-1

5.5.2. Vulnerability of House Type-2: Tin Roof, Brick Wall, Wooden Floor

About 30 percent of total houses in the study area are made of tin roof, brick wall and wooden floor. Because of the wall material (brick) the house is less vulnerable to flood risks. But the material used in the floor makes it more vulnerable to flood relative to house type 1 for higher flood depth. In some parts of the study area the houses are built up to around 0.5 meter above the ground level with inlet and outlet for flood water discharge. This greatly reduces the vulnerability of this type of houses. Elevating the house is the traditional way of living as mentioned by some people and also some of them mentioned that this is the mitigation measure from the flood problems.

This type of house have wooden floor so the increase in water depth and duration leads to the weakening the wood and damage the floors. The vulnerability curve of house type-2 based on the questionnaire output could be seen in Fig 5.36. When the water depth reaches up to 1.5 meters then both floor and wall get partially damaged and the vulnerability reaches up to 0.45. Since wall is made of bricks it prevents from the total collapse of the houses and only some repair is required after the flood.

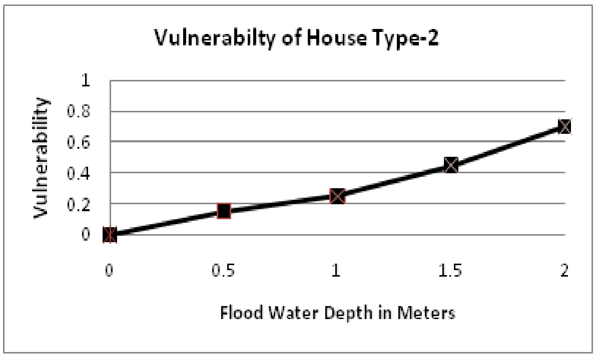


Figure 5.36: Vulnerability Curves for House Type-2

5.5.3. Vulnerability of House Type-3: Tin Roof, Tin (Some are wood, ply) Wall, Stone Mixed with Mud Floor

These houses are more vulnerable because the materials used - tin and mud are not very resistant to the flood. In the initial stage of flood the water will create the dampness but with increase of the flood depth and duration the houses will be more vulnerable. These types of houses are highly susceptible to damage even if flood water is not too deep. The vulnerability curve of house type-3 based on the questionnaire output could be seen in Figure 5.37.

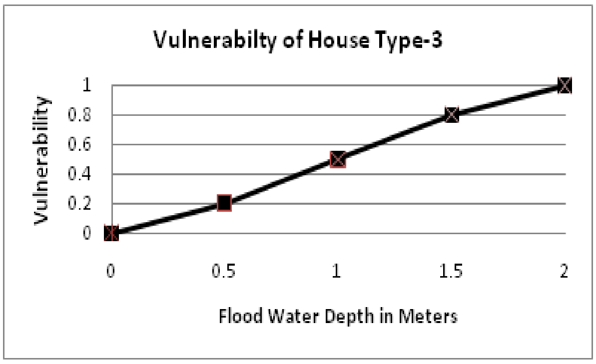


Figure 5.37: Vulnerability Curves for House Type-3

As it could be seen from the vulnerability curve, vulnerability increases linearly with the increase in the water depth. When the water depth increases the wall made up of tin, ply or wood starts to lose the strength and eventually when the water depth reaches to 2 meters for long duration of time the wall gets collapsed destroying the entire house. The complete replacement is required for the recovery.

5.5.4. Vulnerability of House Type-4: Tin Roof, Wooden Wall, Wooden Floor

These types of houses are highly vulnerable to floods since these houses are mainly located near the Rioni river as shown in Figure 5.25. It was found that most of the farmers with low economic condition own this type of house. Considering the coping capacity i.e. recovery from the disaster, this house type is assessed as being the most vulnerable house type among all other types.

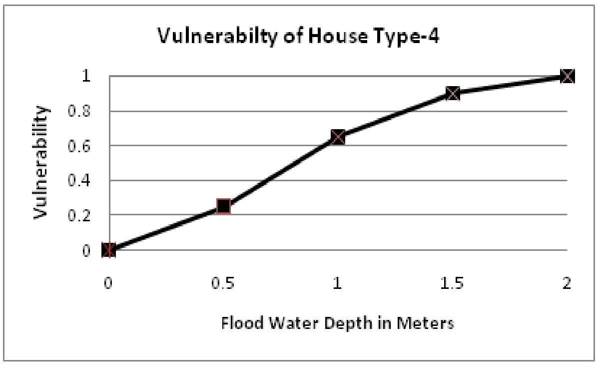


Figure 5.38: Vulnerability Curves for House Type-4

Houses with wooden floor and wall are very sensitive to moisture and they cannot withstand the flood water for longer duration of time. When the water gets a chance to seep into the bottom of the wooden flooring, it dries the wood boards and it becomes almost impossible to get dry out eventually weakening the wood and damage the houses. The level of vulnerability is higher at each flood water depth in this type of houses. The vulnerability curve of house type-4 based on the questionnaire output could be seen in Figure 5.38. When the water reaches up to 1.5 meters the vulnerability is 0.9 meaning the complete collapse of wall and the floor. So the repair is not sufficient, replacement is necessary.

The physical vulnerability of the study area shows that the area is having the moderate vulnerability as shown in Figure 5.39. The figure shows that around 47 percent of houses are moderately vulnerable, 39 percent is highly vulnerable and 14 percent is low vulnerable to flood. In the figure it shows that mainly in the south west part and north west part of the Rioni river the houses seems to be highly vulnerable to floods. This is due to the reason that in that area mostly there are the houses that fall under the type 3 and 4. Also the local elevation of this part of the study area is lower than other part as well as there is presence of high number of channels. Figure 5.39 represents the spatial distribution of physical vulnerability.

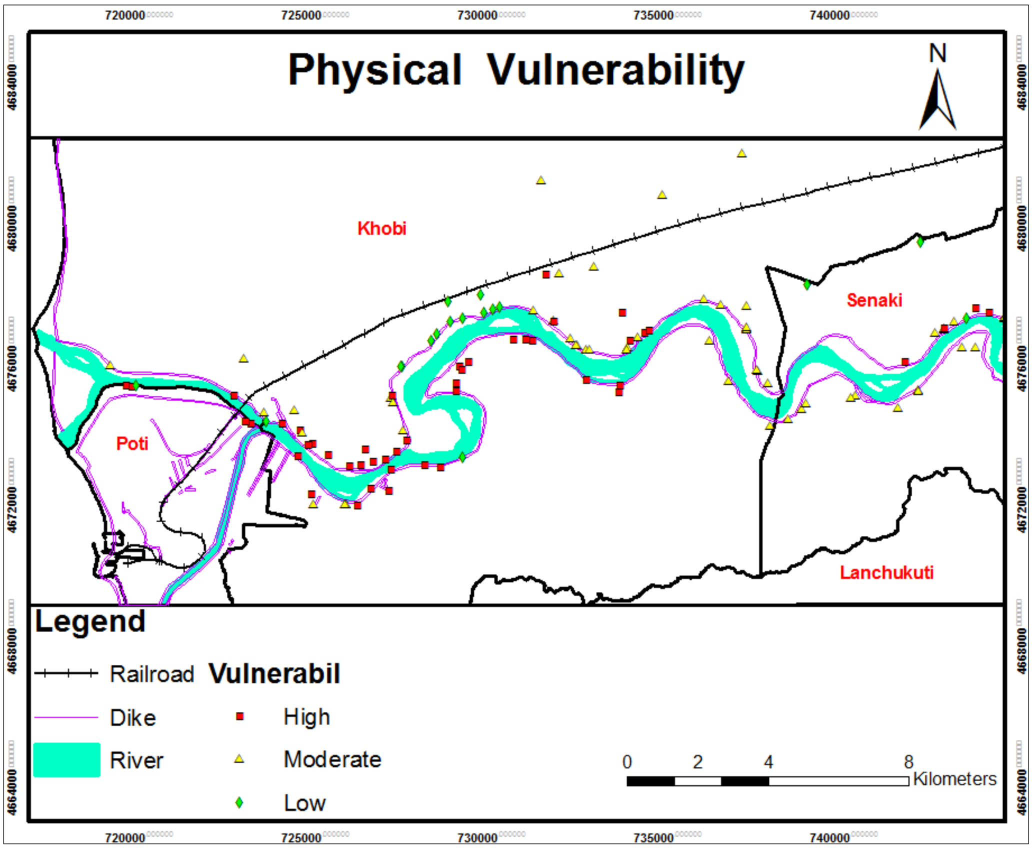


Figure 5.39: Vulnerability of all House Types

5.6. Vulnerability of Roads and Railways to Flooding

Roads and railways are very important infrastructure and damage to them will affect people's access to relief effort, markets, water supply. As identified and categorized in Section 5.4.1, among the two categories of road found in the study area, the paved road - asphalt or bitumen road is less vulnerable as compared to the unpaved roads - gravel, dirt and slab road. During flooding the gravel and dirt roads get easily damaged as the increased runoff of flood water could easily sweep mud and stones. In case of the slab paved roads the slabs get broken during flooding. The Paved road gets damaged if the water stays stagnant for longer days and the water contains high amount of debris. The vulnerability of roads is assessed by using the vulnerability scale from 0 to 1 as described in table 4.3. The Vulnerability level of each road types is shown in Appendix 4.

5.6.1. Vulnerability of Unpaved Roads

In the study area 89 percent of the total roads are unpaved which are vulnerable to flooding. These roads are either made up of slab, mud or gravels. These types of roads are mainly used by pedestrians and animals. During heavy rainfall and flood there is formation of pits on slab and gravel road. In the dirt road, the water sweeps away the upper layer and makes it marshy and the road becomes inaccessible. However, the recovery cost is not very high compared to paved road.

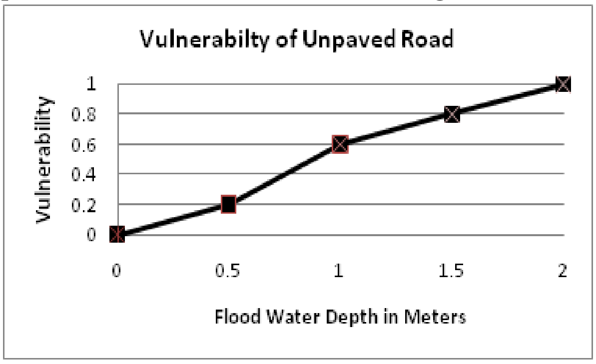


Figure 5.40: Vulnerability Curves of Unpaved Road

According to the respondents, once damaged these types of roads are usually maintained and managed by the local community themselves. Figure 5.40 shows the vulnerability curve of unpaved road based on the questionnaire output. As the depth of the flood water increases, it causes more damage to the unpaved roads. Lower depth and duration of water also damages this road. When the water height reaches 0.5 meters pits and holes are formed on the roads making the vulnerability level of 0.2. In this case the repair cost is lower. As the depth of water increases to 2 meters the vulnerability reaches up to 1 with complete damage and need full replacement of layer of the road which results in high cost.

5.6.2. Vulnerability of Paved Roads

These types of roads are less vulnerable than the unpaved roads because of the materials used to construct these roads – asphalt or bitumen. The roads that contain the asphalt or bitumen are generally constructed for the high volume primary highways. This type of road is maintained by the government and is less vulnerable than that of unpaved roads. Figure 5.41 shows the vulnerability curve of paved road based on the questionnaire output. As can be seen from the figure the water depth of even 1 meters cause very less damage compared to the unpaved roads which can be even neglected. But with increase in water height and duration of the water the roads become vulnerable. Even when the water level reaches up to 2 meter, the road gets less or partial damaged but the repairing cost is very high.

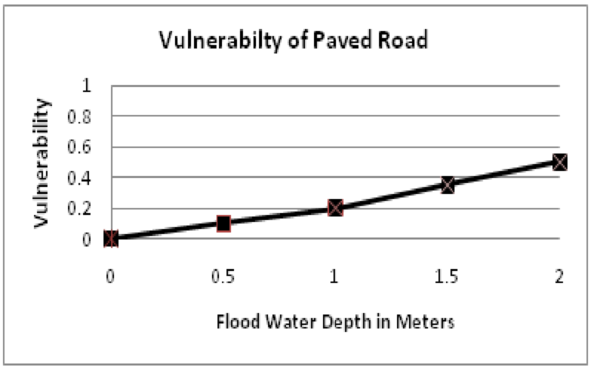


Figure 5.41: Vulnerability Curves of Paved Road

5.6.3. Vulnerability of Railways

For **railways** the flood water doesn't seem to make much harm as compared to the roads. In the study area the railways were constructed by elevating above the ground surface so as long as the flood water doesn't exceed 1-2m it will not damage the railways. But if the water level exceeds 1-2m and is very catastrophic then it will damage railways as well. The railway line is shown in Figure 5.39.

5.7. Economic Vulnerability

In this study area the agricultural crops are only limited to corns (95%) and only in few areas there are beans (2%) and watermelon (2%) cultivation. Once the crops are harvested there is no crop rotation and the lands were used as a grazing land for the livestock. Besides corn cultivation they have alternate source of economy which is livestock. Thus, the overall economic vulnerability is determined by vulnerability of agricultural crops and livestock vulnerability.

- **Vulnerability of Agricultural Crops to Flooding**

To assess the vulnerability of crops to flooding water depth and duration were taken into account. Three types of crops are grown in the area i.e. Corn, Beans and Water Melon. And it could be seen from the Crop Calendar in Table 5.16 that crops are grown during the period May till October during which flood is most likely to occur. As discussed above different crop stages have been identified as having different risk level. So, vulnerability of each crops at different crop stages are calculated. As, this study area experiences frequent and annual floods, degree of depth and duration varies and may not be always disastrous. Flood duration is categorized into 1-3 days, 3-5 days and more than 5 days to analyse the vulnerability of field crops. Based on the local people's perception, the vulnerability for each type of crops was calculated.

The damage increases significantly with increase in water level and duration. It is mentioned that following the 1 to 3 days of flooding it is found that there is reduction in net carbon dioxide assimilation and leaf conductance. The crop calendar shows the different stages of time of crops. On basis of that the local people also provided the damage in terms of monetary value if the flood occurred in different crop stage. Here the vulnerability was measured by using the vulnerability scale of 0 to 1; where 0 means no damage and 1 means total damage or total loss of the crop.

5.7.1. Vulnerability of Corn at Various Crops Stages

As compared to other crops, corn seems to be less vulnerable to floods due to plant height which varies from 1.5 to 2.5 m. If the corn is hybrid then the plant height is shorter otherwise the height is higher. But the hybrid corn is cultivated only in some parts of the area. The vulnerability of corn at each crop stages is estimated based on the questionnaire output. Figure 5.42, 5.43, 5.44 and 5.45 show the vulnerability of corn at different crop stages and at different duration of flooding. The corn vulnerability was assessed based on losses incurred at certain water depth and duration as shown in table 5.18. From the vulnerability curve of corn for different water depth and duration it was found that vulnerability increases with increase in water depth and duration i.e. prolonged saturation of soil affects growth of corn. But, it is observed that vulnerability is not same for different crop stages. Sowing stage and Growth stage is much more critical than maturity and harvest stage. Corn is very sensitive to flooding in its growth stage i.e. early vegetative stage.

Table 5.18: Vulnerability Scale for Corn Crops to Flooding

Corn Crops in Different Stage	Water Depth (m)	Water Duration(Days)		
		1-3	3-5	>5
Sowing	0.5	20-25% crop loss	50-60% crop loss	100% crop loss
	1	50 %crop loss	70-80 %crop loss	100% crop loss
	1.5	70-80% crop loss	90-100 % crop loss	100% crop loss
	2	100% crop loss	100% crop loss	100% crop loss
Growth	0.5	30-40% crop loss	70-80% crop loss	100 % crop loss
	1	50-70% crop loss	100 %crop loss	100 %crop loss
	1.5	70-100 %crop loss	100 %crop loss	100 %crop loss
	2	100 %crop loss	100 %crop loss	100 %crop loss
Maturity	0.5	5 %crop loss	10-20 %crop loss	20-25 %crop loss
	1	40 %crop loss	45-55 %crop loss	80 %crop loss
	1.5	85 %crop loss	90 %crop loss	100 %crop loss
	2	100 %crop loss	100 %crop loss	100 %crop loss
Harvesting	0.5	10 %crop loss	15-25 %crop loss	35 %crop loss
	1	35-45 %crop loss	60 %crop loss	70 %crop loss
	1.5	90 %crop loss	100 %crop loss	100 %crop loss
	2	100 %crop loss	100 %crop loss	100 %crop loss

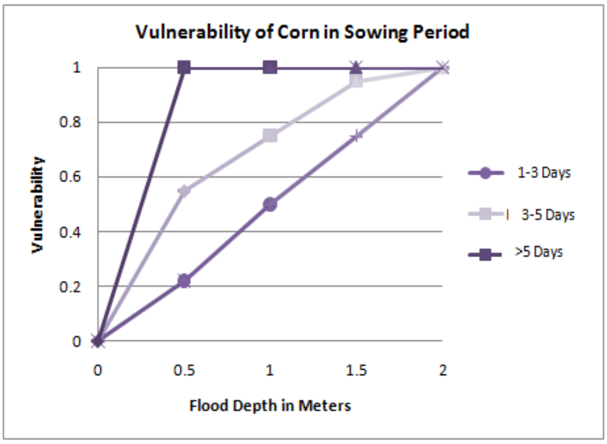


Figure 5.42: Vulnerability Curves of Corn in Sowing Period

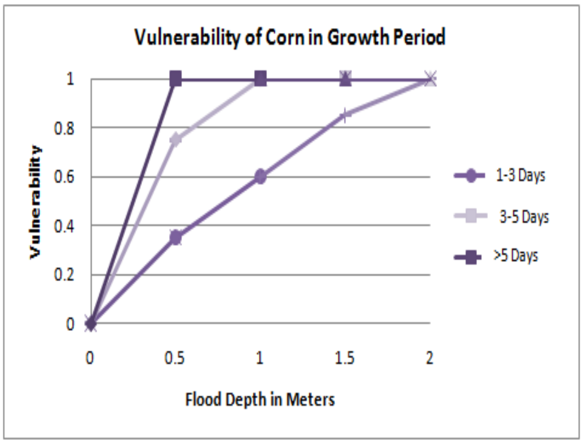


Figure 5.43: Vulnerability Curves of Corn in Growth Period

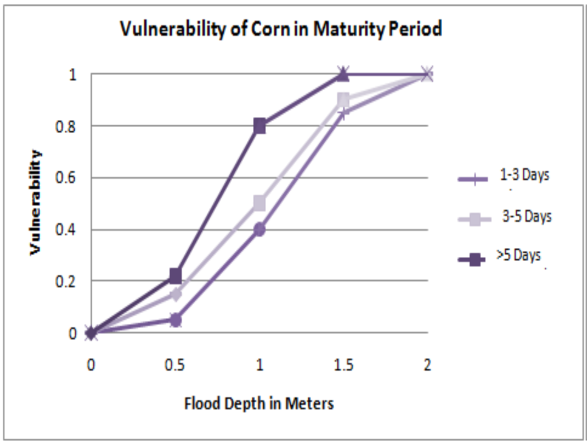


Figure 5.44: Vulnerability Curves of Corn in Maturity Period

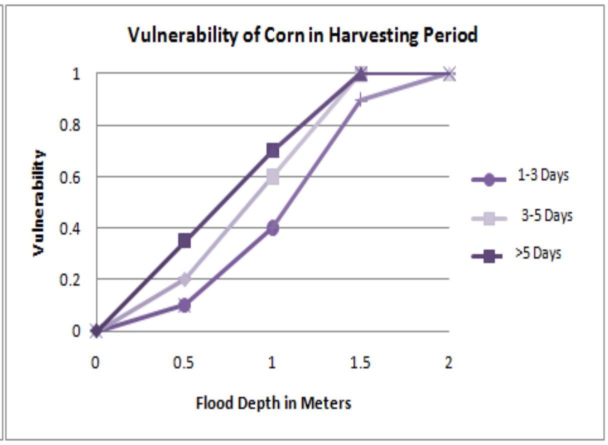


Figure 5.45: Vulnerability Curves of Corn in Harvesting Period

During sowing stage, corn can survive for 2-4 days under flooded conditions. Also moderate movement of water allows some oxygen to get to the plants that keeps plant to respire and alive, thus reduces flood damage. And if the water is drained out after 1-2 days then there is high chance that the corn can survive. Once the corn reaches the maturity stage then flooding will not cause any noticeable amounts of damage if the temperature is cool enough but if the temperature is greater than 77 degree F then the noticeable damage is caused by the flooding. According to the farmers, when the flooding occurs during the maturity stage, damage is mainly due to delay in harvesting; more than the damage by flood.

Research has shown that in the flooded soil, the oxygen level reaches zero after 24 hours and plant is unable to perform critical life sustaining functions – uptake of water and nutrient is halted, growth of root is halted etc. Few farmers stated that even the flood doesn't kill the plants outright it might have long term negative effect on performance on later stage. For example: the excessive moisture at early stage of growth might retard root development and this might affect later during the dry season as root systems might not have been developed sufficiently.

5.7.2. Vulnerability of Watermelon at Various Crop Stages

The water melon plants are vine-like (scrambler and trailer) and at maturity will drag the vine down if not individually supported. Based on survey output, some farmers used netting to support fruit crops at maturity and also some used small branches of tree to support the plants. The water melon cannot resist the water for more than 2-4 days. After that the plants start to decay. The vulnerability of watermelon at each crop stages is estimated based on the questionnaire output. Figure 5.46, 5.47, 5.48, 5.49 shows the vulnerability of watermelon at different crop stages and at different duration of flooding. The watermelon vulnerability was assessed based on losses incurred at certain water depth and duration as shown in table 5.19.

Flooding and excessive rainfall when accompanied by other environmental factors – temperature, affect the watermelon at each stage of growth. However, growth and sowing stage is regarded as highly critical stage of watermelon. Because, if the flood occurred during sowing stage then the germination of seed can be reduced causing seed rot. If the plant is submerged for more than 2-4 days during the growth stage then it will totally damage the plant. Growth stage is the most critical stage of the watermelon cultivation. Also the periods of wet and warm weather increase the possibility of foliar disease like anthracnose and downy mildew. Also, excessive flood water during the maturity stage can cause a physiological disorder, decrease the sugar content of melon and also might result in burst of the fruit. During the harvesting stage, however the crop is not as vulnerable as its preceding stages but the entire return on investment on the crop is at this stage. If the crop is damaged in the harvesting phase then the farmer suffers the highest damage. Watermelon is highly vulnerable than corn because watermelon is grown in a vine-like mostly in the level of the ground unless it is supported.

Table 5.19: Vulnerability Scale for Watermelon Crop to Flooding

Watermelon Crops in Different Stage	Water Depth (m)	Water Duration(Days)		
		1-3	3-5	>5
Sowing	0.5	20-30 % crop loss	50-60 % crop loss	90-100 % crop loss
	1	40-60 % crop loss	70-80 % crop loss	100 % crop loss
	1.5	90-100 % crop loss	100 % crop loss	100% crop loss
	2	100% crop loss	100% crop loss	100% crop loss
Growth	0.5	40-50 % crop loss	70-90 % crop loss	90-100 % crop loss
	1	50-70 % crop loss	100 % crop loss	100 % crop loss
	1.5	100 % crop loss	100 % crop loss	100 % crop loss
	2	100 %crop loss	100 %crop loss	100 %crop loss
Maturity	0.5	20-30 %crop loss	50-70 %crop loss	70-90 %crop loss
	1	45-55 %crop loss	70-90 crop loss	90-100 %crop loss
	1.5	80 %crop loss	80-100 %crop loss	100 %crop loss
	2	100 %crop loss	100 %crop loss	100 %crop loss
Harvesting	0.5	20 %crop loss	50 %crop loss	70 %crop loss
	1	55-65 %crop loss	70 %crop loss	85-95 %crop loss
	1.5	80 %crop loss	90 %crop loss	100 %crop loss
	2	100 %crop loss	100 %crop loss	100 %crop loss

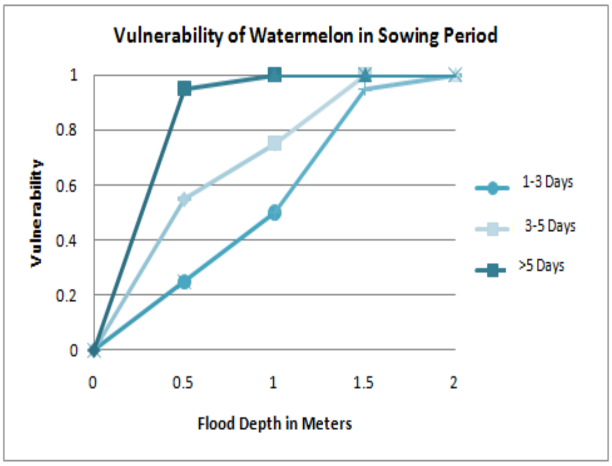


Figure 5.46: Vulnerability Curves of Watermelon in Sowing Period

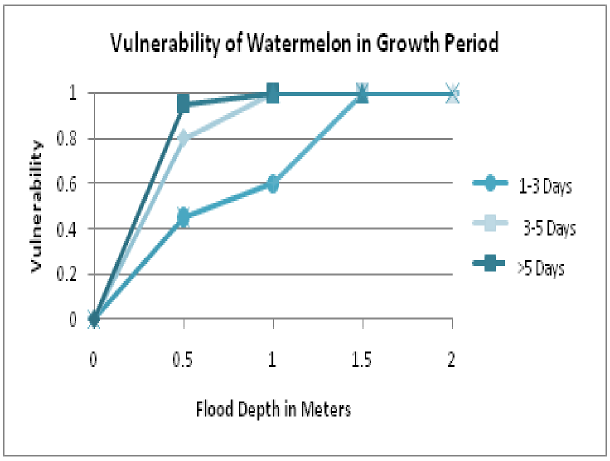


Figure 5.47: Vulnerability Curves of Watermelon in Growth Period

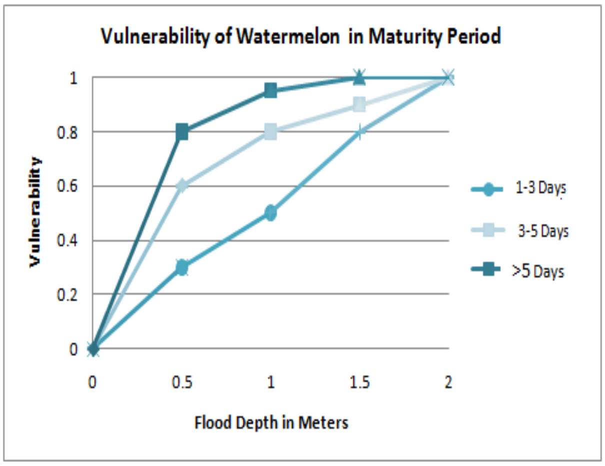


Figure 5.48: Vulnerability Curves of Watermelon in Maturity Period

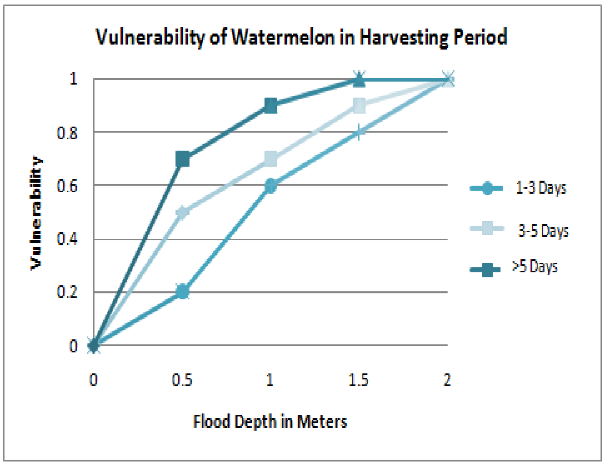


Figure 5.49: Vulnerability Curves of Watermelon in Harvesting Period

5.7.3. Vulnerability of Beans at Various Crop Stages

The vulnerability of beans at each crop stages is estimated depending on the questionnaire output. Figure 5.50, 5.51, 5.52, 5.53 shows the vulnerability of beans at different crop stages and at different duration of flooding. The beans vulnerability was assessed based on losses incurred at certain water depth and duration as shown in table 5.20.

The beans crops are not much vulnerable to floods as compare to the water melon plants. It can resist the water for longer duration than the water melon as shown in table 5.19 in the maturity and harvesting phase. The beans crops can tolerate the water up to the 1 meter height up to 4-5 days duration of time during maturity and harvest stage. Usually the height of the beans crop field in this part of study area varies from 0.5-1 meters.

Similar to corn, prolonged saturation of soil affects growth of beans and the vulnerability curve of the beans increases with increase in water depth and duration. But, it is observed that vulnerability is not same for different crop stages. Like Corn, growth stage and maturity stage of beans is much more critical than maturity and harvest stage. Beans are very sensitive to flooding in its growth stage. During sowing stage, beans can survive for 2-4 days under flooded conditions.

Similar to corn, the moderate movement of water allows some oxygen to get to the plants that keeps plant to respire and alive, thus reduces flood damage. If the flood depth is more than 1 meter and the flood duration is more than 3 days then there is 70-80 percent of crop damage, the potential damage to beans include the breakage and lodging of stem, swelled seeds due to moisture which leads to splitting of pod, spouting and rotting of seeds and contamination with mud. Beans are more vulnerable than corn and less vulnerable than watermelon.

Table 5.20: Vulnerability Scale for Beans Crop to Flooding

Bean Crops in Different Stage	Water Depth (m)	Water Duration(Days)		
		1-3	3-5	>5
Sowing	0.5	30 % crop loss	40 % crop loss	100 % crop loss
	1	60-70 % crop loss	70-90 % crop loss	100 % crop loss
	1.5	75-85 % crop loss	90-100 % crop loss	100% crop loss
	2	100 % crop loss	100% crop loss	100% crop loss
Growth	0.5	40-50 % crop loss	80-100 % crop loss	100 % crop loss
	1	80 -100% crop loss	100 % crop loss	100 % crop loss
	1.5	100 % crop loss	100 % crop loss	100 % crop loss
	2	100 %crop loss	100 %crop loss	100 %crop loss
Maturity	0.5	30 %crop loss	40-50 %crop loss	65 %crop loss
	1	50-65 %crop loss	75-85 %crop loss	80-90 %crop loss
	1.5	90 %crop loss	95%crop loss	100 %crop loss
	2	100 %crop loss	100 %crop loss	100 %crop loss
Harvesting	0.5	20 %crop loss	40-50 %crop loss	60 %crop loss
	1	50 %crop loss	70-80 %crop loss	90 %crop loss
	1.5	70 %crop loss	100 %crop loss	100 %crop loss
	2	100 %crop loss	100 %crop loss	100 %crop loss

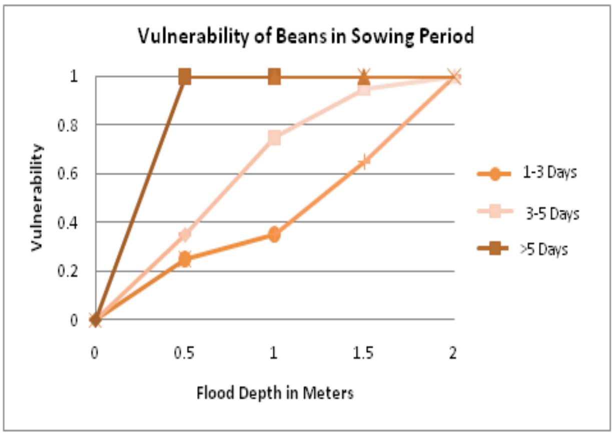


Figure 5.50: Vulnerability Curves of Beans in Sowing Period

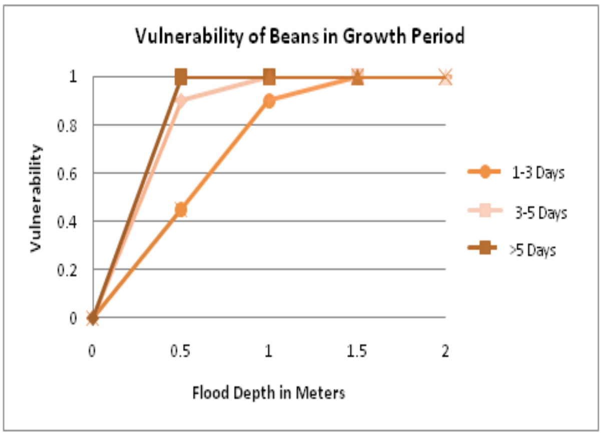


Figure 5.51: Vulnerability Curves of Beans in Growth Period

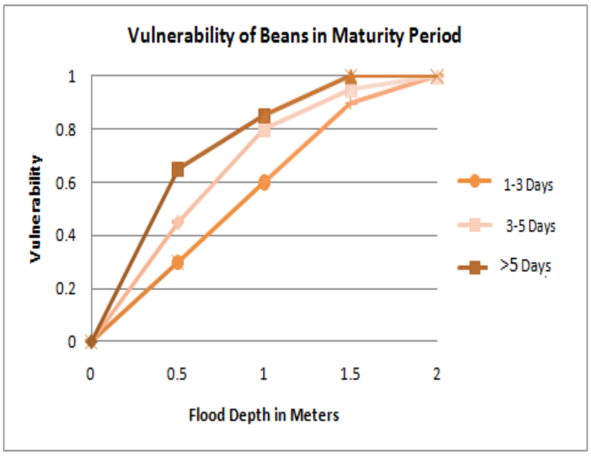


Figure 5.52: Vulnerability Curves of Beans in Maturity Period

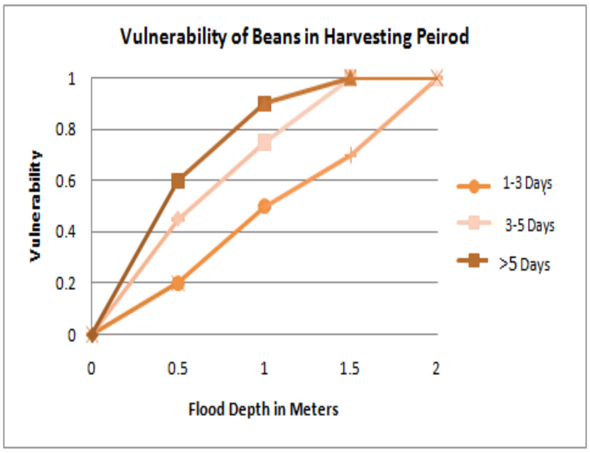


Figure 5.53: Vulnerability Curves of Beans in Harvesting Period

5.8. Livestock Vulnerability

Along with physical structures and people who directly get affected by floods, animals too are caught up in the disaster. In the study area the secondary occupation being animal husbandry and also the local farmers keep the livestock's as their domestic pets or as park animals (working animal used as transportation of weight loads during harvest stage of the crop) and also for dairy products and meat; livestock's are also among the vulnerable group to flood. Flood emergency preparedness is very important for livestock because of their size, shelter, feed requirement and needs of transportation. From the survey it was found that the lack of flood preparedness plan for livestock's increases their vulnerability. As mentioned in the section 5.4.3, the common livestock that were found in the study area are categorized into three types based on their size. The vulnerability of each category of livestock are explained as follows

5.8.1. Category-1

Under this category the livestock are cow, buffalo and horse. According to the survey, as their size is large than rest of the categories, the vulnerability of these livestock is less as compared to other category at less flood depth and less flood duration. Even though these categories livestock are less vulnerable to flooding at less water depth and duration but if there is damage then it of high economic loss as compared to others. Mostly these categories of animals are grazing animals. As the flood depth and the duration increases, the vulnerability of animals belonging to this category also increases significantly. Lack of proper sheds, foods and cold temperature, makes them highly vulnerable to flooding. The grazing areas were primarily the inner side of the dike which has open pasture land and also in the forest, and also in the agricultural land after the harvest period of crops.

According to the local people they also leave their animals in nearby open grassland inside the Kolkheti national park for grazing. One respondent mentioned that, her 3 cows died due to flash flood in 2005 inside the national park while she left them for grazing. So, during the flooding time there is high chance of animals to get stuck in the forest and die. Also, according to farmers if the animals survived then it is their huge challenge to feed them as their main traditional feed – straw and forage are not available due to the floods. This even adds more to the vulnerability to this category of livestock's. Also, if the farmers have to follow emergency evacuation they have to leave the animals behind during the time of flooding. So, animals belonging to this category becomes the most vulnerable as they could not be carried along during the rescue operations.

5.8.2. Category-2

Sheep, goat and pig fall under this category. Animals are smaller in size and they are kept in farmer's houses or animal sheds that are built at about 0.5 m above the ground level. The animals are slaughtered for meat. During the time of flooding these animals are more vulnerable than the ones of category one. But during the evacuation process the people can carry their livestock belonging to this category with them, which in turn reduces their vulnerability. Although, it is difficult to carry or take with oneself compared to animals belonging to category-3, most of the respondents mentioned that they usually take their livestock of this category as they believe it is some sort of assurance for their household and add valuable asset in the household after the consequence of the flood effects. However, if they were not rescued then it is definitely highly vulnerable than category-1 even at less flood depth and duration. The main grazing land being open pasture land and the agricultural land after the harvest period of crops, it is very difficult for the local farmers to feed the survived livestock as their grazing land might get damaged severely.

5.8.3. Category-3

The livestock that fall in these categories are smaller in size and includes chicken, turkey and ducks which are mainly used for the egg and meat purposes. This category of livestock is more vulnerable to floods than other categories of livestock's. But most of the respondents mentioned that during the time of flooding they take their chickens, ducks and turkeys with them during evacuation as much as possible thereby decreasing the livestock's vulnerability. Since, this category of animal's acts as the productive asset, the local people generate cash after selling these livestock. Thus, this category of livestock acts mainly as their recovery asset aftermath the flood events. So, it was very common to carry the animals belonging to this category during their evacuation. However, when we compare the prices of each category animals the animals that fall under the category 1 and 2 have high price than category 3 animals i.e. in general the price of 15-20 livestock belonging to Category-3 is equivalent to 1 of Category-1 (source: fieldwork).

From the analysis and from figure 5.34 it could be seen that the Category-3 which is poultry is owned in large numbers (>15) by more respondents. Category-1 and Category-2 is owned in moderate numbers i.e. 5-10 on average. The category-3 animal seems to be more vulnerable than category 1 and 2 as discussed in section 5.8. However as discussed category-3 animals could be carried along oneself during evacuation as recovery asset aftermath the flood. But the market price of this animal being very low compared to category-1 and 2, aids in increasing economic vulnerability. Even in case of category 1 and 2, they are vulnerable to flood with high depth and duration even causing higher economic loss. Thus livestock vulnerability is complex to analyse as their vulnerability completely rely on their owners, category of livestock's, their numbers and animal sheds. For simplification, to quantify livestock's vulnerability in this study number of livestock's and their category is considered. So, in this study vulnerability increases from category-1 to category-3 and also increases as number of livestock's decreases.

5.9. Overall Economic Vulnerability

After considering vulnerability of agricultural crops and livestock's the overall vulnerability is determined. In this study area around 45 percent of the people have high economic vulnerability followed by 36 percent moderate and 19 percent low. In general, we can conclude that this area is having the high economic vulnerability. This is because that most of the people are involved mainly in the agriculture. Also in this area there are high numbers of small scale farmers and mostly they are residing nearby the river which also adds to the vulnerability by declining the agricultural revenues and rise in poverty during the flooding time. While the majority of livestock is mainly the category 3 animals with less monetary value in the market. Figure 5.54 shows the economic vulnerability of the study area.

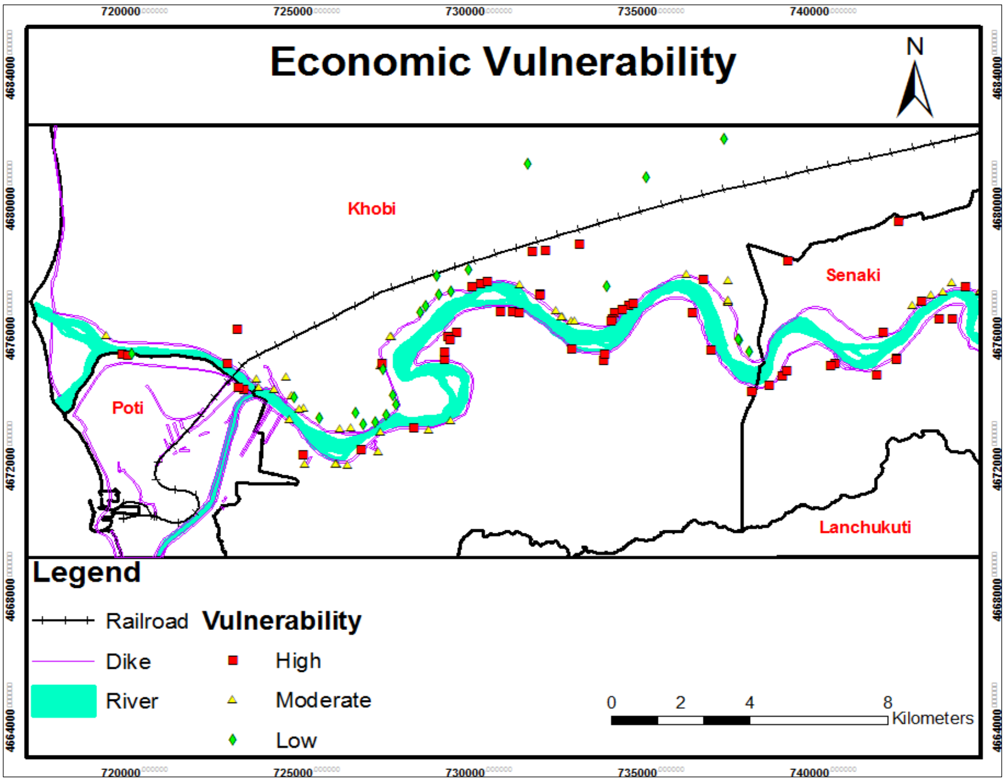


Figure 5.54: Economic Vulnerability of the Study Area

5.10. Damage Assessment

Damage assessment is quantified according to the characteristics of each element at risk, their cost and also their vulnerability. The loss of each crops are estimated based on direct questionnaires with the local people who were victims of flood and the secondary data that were collected from the different municipalities. Damage of crops or livestock's have both direct and indirect losses that are assessed in the following

5.10.1. Direct Damage and Indirect Damage

The damage can be direct or indirect. According to Dutta, *et al.,* (2001) direct flood damage relates to the loss of an object or a property caused by direct contact of flood water. While indirect damage are caused by interruption and disruption of economic and social activities, loss in production that occurs because of the consequences of the direct floods. As a consequence of the loss in agricultural crops and livestock's it too causes adverse effects on their by-product - agricultural products and loss of milk and dairy products.

Flood water containing sediments also affects fertility of the soil which may lead to decline in agriculture production. One of the respondent stated that his large hectare of land was no more cultivable due to flood of 2008. The main damage was during the harvesting time when the harvested crops were still in the crop field for threshing, cleaning and drying. Other damage includes the straw, fodder (by-product of corn, beans) that was used to feed the animals, stored grains etc.

During flooding, the damages on agricultural fields were primarily caused by flooding followed by heavy rains, roaming and unattended livestock's in the agricultural land and delayed harvest. Also devoid of harvest labour who may be either hired labour or family who either moved away for safety or injured could also cause damages on agricultural crops. These are direct damages caused by flood. Other direct damage includes loss of stored crops, seed, stored and animal fodder, animal sheds, tools, land structures, and other infrastructures.

In case of livestock, the direct damage included collapse of animal sheds, lack of grazing land and lack of food to animals. Collapse of animal sheds resulted in death of animals due to lack of shelter for animals to be kept at night.

Indirect losses include loss of milk and dairy products and loss of poultry or egg production. Also, most of the farmers who doesn't own their own land and who depend on their labour for survival – (engaged in land preparation, sowing, and harvesting crops of other's) get affected due to floods.

5.10.2. Agricultural Damage Calculation

Agricultural crop damage has been calculated based on different level of vulnerability at different crop stages. Table 5.10, 5.11, 5.12 indicates the loss of crops in percentage at different flood depth and duration based on the questionnaire output, using this table.

- **Corn Damage Estimation**

The damage for corn was estimated from the interview data. The depth and duration was used to assess the damage of corn. Table 5.21 shows the investment made by farmers at various crop stages. The average cost at each stage varies depending upon whether they hire any labour or work on their own. At sowing stage the investment is made on - seed, fertilizer and labour (for harrowing, ploughing and to put manure on the field). At growth stage the investment is made on - labour cost for removal of weeds, similarly at maturity stage - cost is for the pesticides, manure etc and during harvest stage – labour cost thereby adding to the cumulative value of cost on the crop. Thus, if the flooding occurred during each stage, with increase in each stage of crops the loss of amount will be higher.

Table 5.21:Investment in Different Stage of Corn

Crop Types	Crop Stages	Months	Cost/ha (Gel)	Cumulative Cost
Corn	Sowing	May	400	400
	Growth	June-July	200	600
	Maturity	August	200	800
	Harvest	Sept-Oct	300	1100

Note: 2 Gel (GeorgianLari) ~ 1 Euro

Market price of Corn:

Crop weights Per Hectare :	**4 tons**
Price Per ton :	**600 (Gel)**
Total Crop Price Per Hectare :	**2400 (Gel)**
Total :	**2400(Gel)**

This market figure is also based on the market price of corn as stated by farmers. Since, the total harvested corn per hectare is 4 tons, and 600 Gel per ton makes 2400 Gel per hectare. Thus the total profit they could make after selling the entire crop is 1300 Gel per hectare. For the flood of about 1 meter and duration of 3-5 days, the loss of corn per hectare could be computed using the table 5.21 and table 5.18.

Table 5.22: Cumulative Cost of Corn

Crop Stages	Vulnerability (crop loss)	Cost/ha (Gel)	Cumulative Cost/ha (Gel)	Loss/Hectare (Gel)
Sowing	70-80%	400	400	280-320
Growth	100%	200	600	600
Maturity	45-55%	200	800	360-440
Harvest	60%	300	1100	660

Table 5.22 gives the loss per hectare when the flood of 1 meter strike corn field till 3-5 days. Loss per hectare gives the total loss when the flood strikes on that particular stage.

Watermelon Damage Estimation

The watermelon comprise total of only 2 percent and the crop field of watermelon is located far from the river basin. The investment is less compared to corn. But the watermelon is highly vulnerable to flood than the corn, section 5.4.2. But the return on investment for the watermelon is high as compared to the corn and beans. Per hectare the total cumulative cost is around 800 Gel as seen from the Table 5.23. Similar to corn, referring to the degree of vulnerability of watermelon, Table 5.19 and the cost required on the watermelon investment the total damage could be estimated at various stages of the crops.

Table 5.23: Investment in Different Stage of Watermelon Crops

Crop Stages	Months	Cost/Hectare(Gel)	Cumulative Cost
Sowing	May-June	300	300
Growth	July	200	500
Maturity	August	100	600
Harvest	Sept-Oct	200	800

<u>Market price of Watermelon</u>:

Crop weights Per Hectare : **7 tons**
Price Per ton : **800 (Gel)**
Total Crop Price Per Hectare : **<u>5600 (Gel)</u>**
Total : **5600 (Gel)**

This market figure is also based on the market price of watermelon as stated by farmers. Since, the total harvested watermelon per hectare is 7 tons, and 800 Gel per ton makes 5600 Gel per hectare. Thus the total profit they could make after selling the entire crop is 4800 Gel per hectare which is much higher relative to corn but the effect of flood is inevitable. However, any low to moderate damages would even cause profit compared to the minimal investment made. As, discussed above in section 5.7.2 vulnerability of watermelon, watermelon is highly vulnerable to flood at each stage of flood.

- **Beans Damage Estimation**

Similar to watermelon, beans comprise total of only 2 percent and the crop field of study area and is located far from the river basin. The investment is less compared to corn. Though the vulnerability seems equal to corn during sowing and growth stage but vulnerability of beans is higher at maturity and harvest, section 5.7.3. Per hectare the total cumulative cost is around 700 Gel as seen from the Table5.24.

Similar to corn, referring to the degree of vulnerability of beans, Table 5.12 and the cost required on the beans investment, the total damage could be estimated at various stages of the crops for different flood depth and duration.

Table 5.24: Investment in Different Stage of Beans Crops

Crop Stages	Months	Cost/Hectare(Gel)	Cumulative Cost
Sowing	May	200	200
Growth	June	200	400
Maturity	July	200	600
Harvest	August	100	700

<u>Market price of Beans</u>:

Crop weights Per Hectare : **2 tons**

Price Per ton : **400 (Gel)**

Total Crop Price Per Hectare : **<u>800 (Gel)</u>**

Total : **800 (Gel)**

This market figure is also based on the market price of beans as stated by farmers. Since, the total harvested bean per hectare is 2 tons, and 400 Gel per ton makes 800 Gel per hectare. Thus the total profit they could make after selling the entire crop is 100 Gel per hectare. Damage at any crop stage would significantly affect the total return on investment since the margin of profit is very less.

5.10.3. Agricultural Land Vulnerability

Most of the agricultural land in the study area lies in the high vulnerability zone as shown in figure 5.55. Mainly the agricultural land is in the northern part of the Rioni river. In the southern part the area is mostly covered by the forest and also by the grassland rather than the agricultural land because that area is the part of the national park. Mainly, the time of cultivation of crops starts during the starting time of floods (May-June). When the flooding strike during sowing stage, then aftermath the flood event few farmers re-cultivates the crops but some of them could not re-invest because of their weak financial status. The amount of crops affected increases with increase in the flood return periods. The higher return periods give large flood volumes and affect large area which as a result increases the loss.

So in order to make this agricultural land less vulnerable to floods there should be continuous cleaning of the water channels so that the water get back to the river easily. Intensive drainage system should be implemented which as a result throw out the surplus water during the flooding.

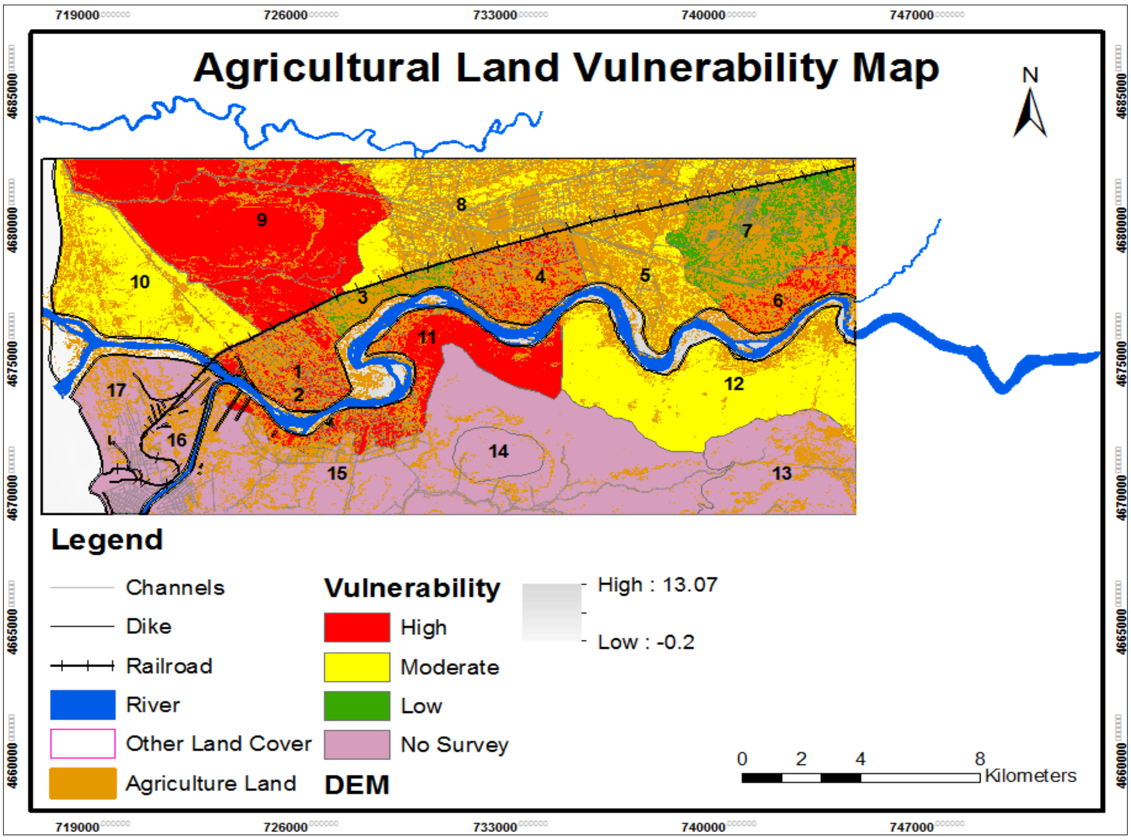


Figure 5.55: Agricultural land Vulnerability

5.11. Social Vulnerability

Social vulnerability is defined as the susceptibility of persons or groups lacking the capacity to cope with, anticipate, resist and recover from the impact of the hazard. As mentioned in the section 5.1.3 that vulnerability is not homogenous within an area there are several factors that determine people more vulnerable than the others; it varies according to gender, age, occupation, level of income, household size, exposure and the level of preparedness.

5.11.1. Age and Gender of the Household

According to the respondents the elderly people ranging from the age group of 56 and above and also the children are amongst the vulnerable group. As mentioned by Blaikie, (1994) young population under the age of 25 are commonly strong and energetic age-group and positive aspect of the young population is their potential of the necessary political will and the vision of mobilization to protect their settlements against disaster risk. However, based on the interview data, as the local farmers of age group 36-45 were mainly involved in physical intense jobs such as farming and labour; they were able to resist difficult physical situations required for mobilization and evacuation. So, the age group of 36-45 years is also regarded as less vulnerable age group.

In this study area, the female population is higher than the male, as seen in the section 5.4.3. The elderly people, children and woman are regarded as the vulnerable group because they require help and assistance to evacuate. Based on local people, this group of people tends to have low mobility or skill required to escape like swimming on the flood water. During interview one of the local residents said that when there was heavy rainfall and when he received early symptoms of flooding he used to send his wife and children to the neighbouring village. According to him, he was able to cope with the floods but the woman and children cannot. So he usually evacuates his family from the house. However, some of the local people insist that since women basically are more involved in storing foods, household activities such as preparation of meals and other domestic affairs; this make them quick in decision making during the flooding time to save their belongings in order to evacuate keeping in mind the sustainability after the flood.

5.11.2. Level of Income and Household Size

This is amongst the most important vulnerability factor to determine if the particular household is vulnerable or not. The level of income is not only related to the financial capacity of household to recover from the hazard but also the financial preparedness to mitigate flood hazard. The household with high level of income is definitely less vulnerable due to their higher coping capacity to flood hazard.

Since, the source of income in this study area is mainly agriculture – corn production and also livestock's, the level of income depends on whether the people are commercial farmer or the small farmer. Small farmer has minimal level of income accompanied by small farm land and less number of livestock's compared to commercial farmer who own large farm land. The level of income is characterized into 3 scale – low (50-100 Euro), moderate (100 – 150 Euro) and high (>150 Euro). Table 5.25, shows that majority of the households (96 out of 121) had low level of income. That means majority of the people is characterized by very low income – 200-300 GEL (Georgian Lari) equivalent to 100-150 Euro per household per month. Majority of the people (Almost 80 per cent) own less than 1 hectare of land on which they cultivate corn.

For small farmer, the return on harvested crop is around 2-3 tons of corn per annum. Similarly, for commercial big farmers, the return is 5-7 tons of corn per annum. The market value of corn according to them is 250-300 Euros per ton. Also, despite having large hectares of agricultural land for corn production, they only get return of 2-3 tons of corn per annum because they suffer from frequent annual flooding that declines their total corn production. Thus it could be stated that the major population in the study area is characterized by very low in income and are highly vulnerable to flood risk.

Table 5.25: Income per interviewed households

Income level of household (Euro) per month	Number of households	Income level
100-150	96	Low
150-200	20	Moderate
>200	5	High

Their average family sizes being 4-5 struggles for their basic living with the income they currently possess. If the household size is higher and the income is low then this category of household is often hit hardest by the disaster. The average level of income of each household being low (100-150 Euro per month) and the household size being 4-5 which manifolds that the people have fewer resources to cope and makes the people vulnerable to floods. Based on the household survey, most of the low income people lived in house type 3 and located near the river basement which makes it more vulnerable to floods. Figure 5.56 illustrates the spatial distribution of respondent with different level of income of the people in the study area according to Table 5.25.

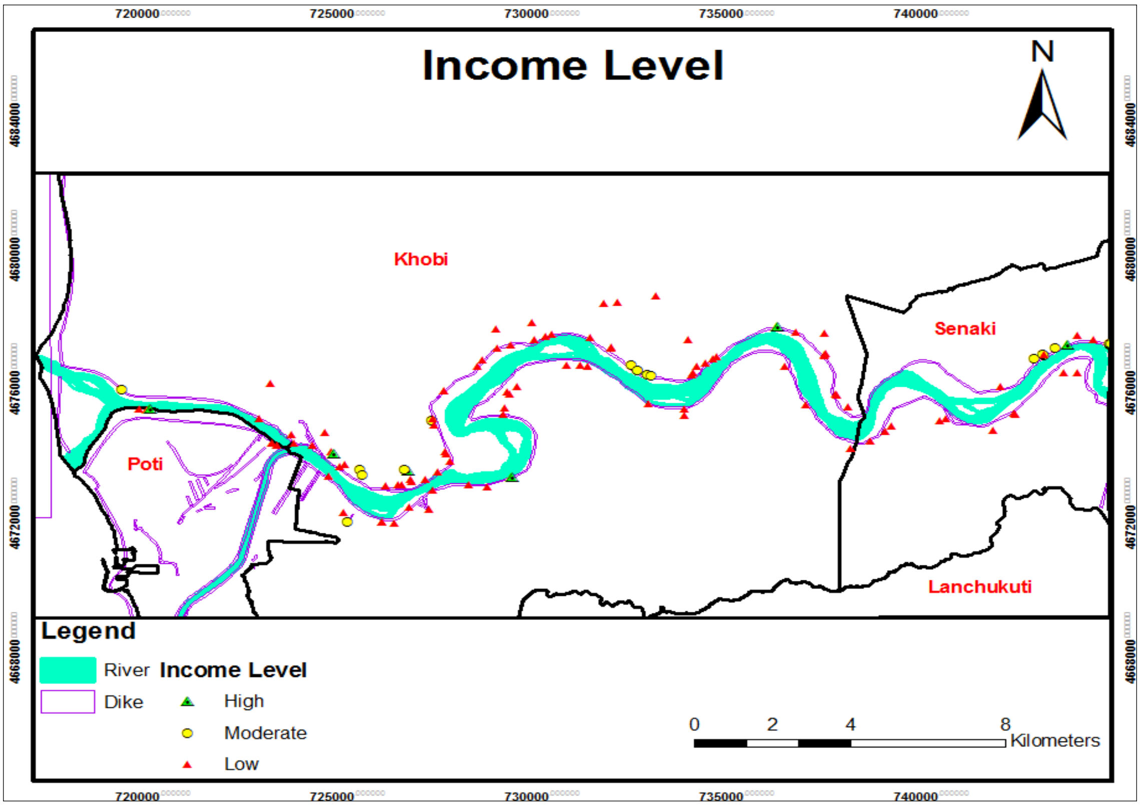


Figure 5.56: Income Level Distribution

5.11.3. Occupation

Agriculture is the major occupation of people in this area as mentioned in Section 5.4.3. However, in addition to agriculture, people adopt other occupations as well – animal husbandry and labour works. Four different combinations of occupations were commonly found in the study area – "agriculture only", "large scale commercial farming", "agriculture & livestock" and "agriculture, labour and livestock". It was found that the household who only has agriculture as occupation is among the most vulnerable group of people because of the lack of alternative saving sources when flooding damages their crops.

It was found that average family size being greater than 4, some members in the household also gets involved in different occupation other than agriculture. And, since crop rotation is not done in the agricultural land in the study area and period of overall corn cultivation is from May till October; so during rest of the months some people get involved in other type of occupation such as labour works. The occupation is an important dimension of the vulnerability as it decides the level of income of each household. Almost every people have their own land whether small or large. In some parts there are also the large commercial farmers who hold large part of the land. Table 5.17 shows that 48 per cent of the total respondents had only agriculture as their occupation. Thus during the time of flooding their farming livelihood will become very difficult as their farmland is inundated by flood.

Large commercial farmers are among the least vulnerable group in the study area. As, they own 4-5 hectares of land and also possess large number of livestock's (more than 20). Figure 5.56 show that they have high level of income (> 200 Euro per month). From the questionnaire survey with commercial farmers it was found that they had very high coping capacity and they are also aware and capable of proper monitoring and making the flood preparedness plans. According to one of the large commercial farmers, the dike near their farm was broken by the floods and they appealed to the government to reconstruct it but the government denied by saying that they do not have proper fund to reconstruct it.

Then after, they reconstructed the dike on their own. This shows that the large commercial farmers have the capacity to withstand the damage of floods to some extent.

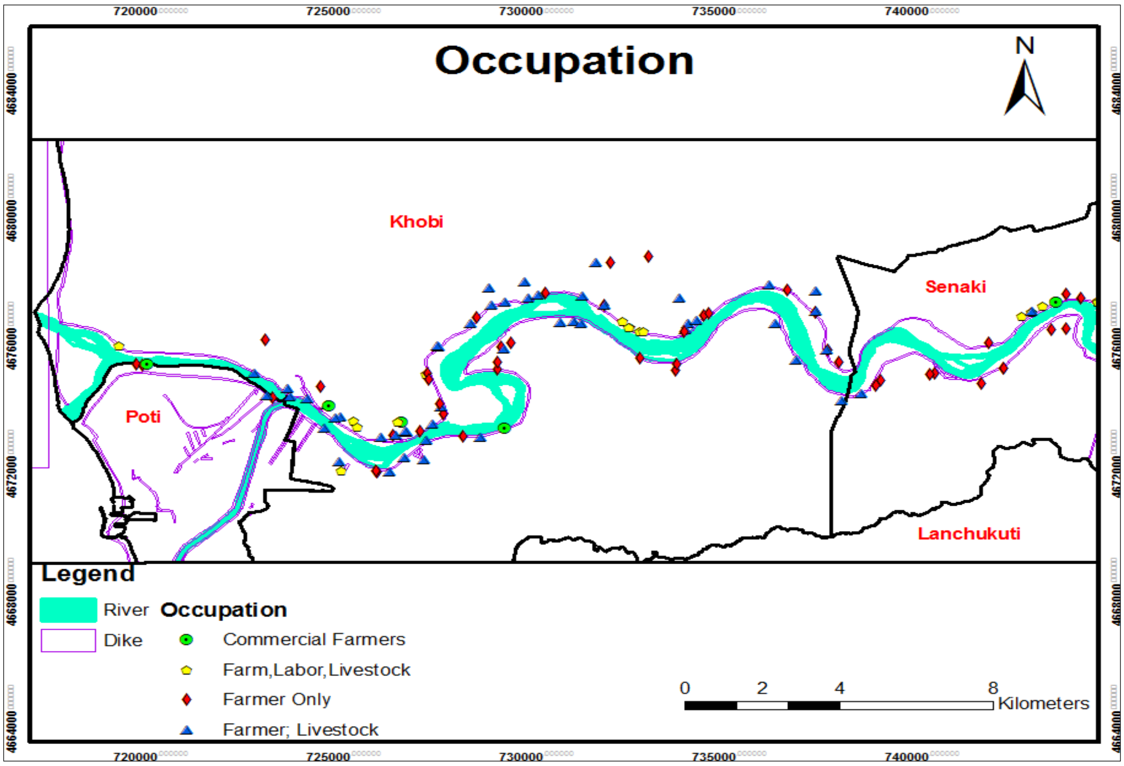


Figure 5.57: Types of Occupation

The second major occupation that was found mainly in this area was the animal husbandry – livestock's. Generally the local people have the occupation of animal husbandry – livestock in addition to agriculture. Almost every respondent was found to have at least one livestock, but it was found that only 29 percent had it as the occupation, rest possess livestock's for their own consumptions of dairy products, eggs and meat but not as commercial occupation. This group of people who adopt livestock's as their occupation is less vulnerable than the people who only have the agriculture as their source of income. According to them, if they suffer total loss of agricultural crops due to flooding then they have alternate source to cope with the flood by selling their livestock's and buy the necessary recovery requirements.

Figure 5.57 shows the spatial distribution of household with different occupations. The vulnerability is differentiated on the basis of marginal value of income. The household which have alternate source of income – labour work and livestock's as an employment are relatively less affected by floods than the household depending solely upon their agricultural crops because they can resist and recover from flood and also cope with it as their alternate income might not be influenced by flood.

In this research the social vulnerability was estimated through the parameters – occupation, household size and level of income. The social vulnerability was expressed as mentioned in the methodology section 4.4.5 (Social Vulnerability). Figure 5.58 shows the spatial distribution of social vulnerability of 121 households in the study area. By using the information from the surveys it can be concluded that maximum numbers of households are on the edge of high vulnerability. Because of their low income and large household size and also no alternate source of income makes the people more vulnerable.

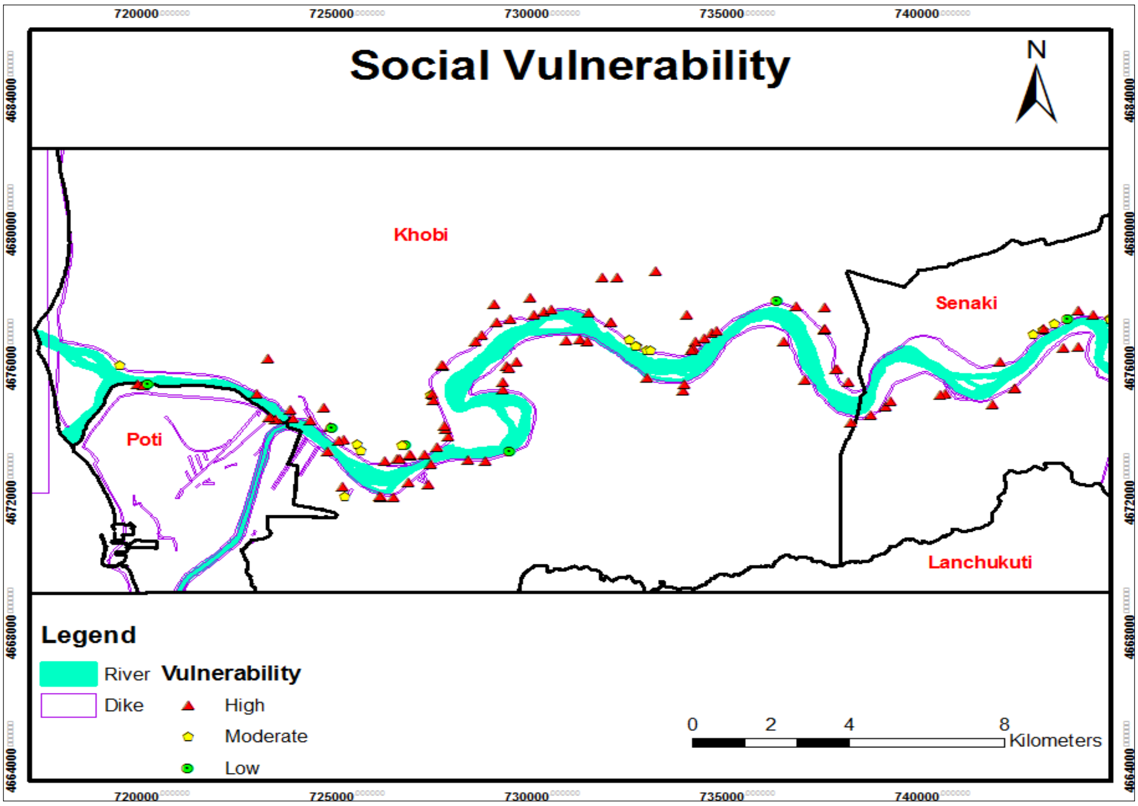


Figure 5.58: Social Vulnerability of the Local People

As stated by Fothergill (2004), the people who are living in poverty are more vulnerable than the rich people to the hazards impacts. As the poor people have less money to contribute in hazards preventive measures, to buy the emergencies supplies and the recovery efforts. Even the poor people have substandard houses, cannot communicate and also they do not have access to the critical lifelines services which add them in the more disadvantageous and more vulnerable groups.

In the study area there are also the household with low social vulnerability. This category of the people is especially large commercial farmers. There were also some household having the moderate social vulnerability. This category of the farmer has one or more source of income so they have the alternate choice and they can use them during the recovery time of floods. Based on the different indicators used to assess the social vulnerability in the study area it shows that higher the social vulnerability the greater the sensitivity to flood impacts and less capacity to respond. The table 5.26 summarize the socioeconomic characters that influence the social vulnerability based on the local people.

Table 5.26: Socioeconomic Indicators that Influence the Social Vulnerability

Socio-economic Characteristics	Description	Increase or Decrease of Social vulnerability
Gender	- In case of gender, the female often need some help from male to evacuate from the floods. So the male can recover faster than women.	Male: **Decrease** Female: **Increase**

Age	- Age shows the indication of the capacity of movement of people during the time of flooding. For instance, the children and elderly people need some help to evacuate from the floods.	Children, Pregnant women, Handicapped, old people etc: **Increase** Young people: **Decrease**
Occupation	- The people who have only agriculture source as an occupation makes them more vulnerable to flooding as they don't have other source of occupation. - Similarly for the commercial farmers they have farms as well as other source of occupation. So one get influence by flood then they will use other to cope with the floods.	Farmers only: **Increase** Commercial farmers: **Decrease** Farmers and livestock: **Decrease/ Increase**
Income	- People whose level of income is less suffers more after the flooding as they can't afford the cost of reconstruction, relocation etc. - People with high level of income recover more quickly from the loss by using their financial resources.	Low income: **Increase** High Income **: Decrease**
Household Size	- If the level of income is less and the household size is bigger than there will be limited resources available to cope with the floods and makes the people vulnerable. - Similarly, if the household size is medium and the level of income also high then they can easily cope form the floods.	Household Size bigger: **Increase** Household Size smaller: **Decrease**

5.12. Risk Perception

For risk analysis people's perception is very important. In the study area, the risk perception of people on flood varies. This depends on gender, age, household location, occupation, level of income and coping strategies of the local people. The parameters considered to study people's flood risk perceptions were flood depth, duration, cause, damage, frequency, reason of staying in that area and the flood control measures.

5.12.1. People's Perception about the Level of Flood

Depending on the location the flood water level can vary. Some part of the area experienced high level flooding while some experienced less flooding. Based on the people's perception when the water level reaches up to the knee they consider that as a flood (Figure 5.59). The water depth varies depending on the distance to the dike near the river. Beyond the level of dike the level of annual floods was mostly ranges up to 0.5 – 1.5 meter. People's perception on flooding depends on the depth of flood water. Around 75 percent of the respondents consider flooding if the water level is at least at the level of knee and less than the knee level they consider it as normal. Few people who reside in the area since last 50-60 years mentioned that they had experienced the flood level higher than 2 meter.

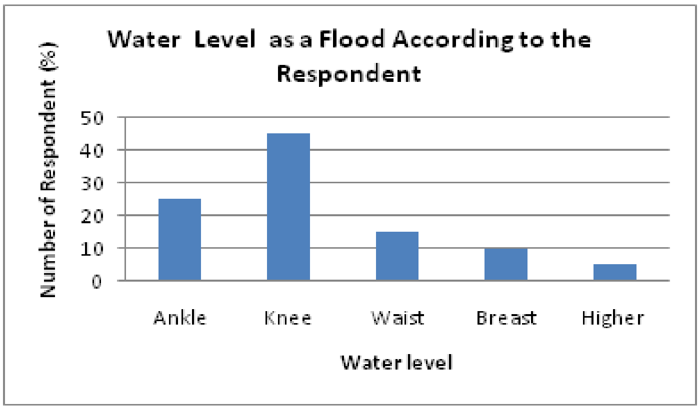


Figure 5.59: People's Perception about the Water Level as Flood

During interviews the local people were asked to determine the level of flood risk such as normal, manageable, unmanageable and disastrous, section 4.4.6 considering water depth and duration. Many responded that they are well adapted to annual floods. Floods with water level up to ankle for 3-5 days and even flood level of up to knee for 1-3 days were regarded as normal floods, Table 5.27. Flood was considered disturbing but still manageable if it has detrimental effect on agricultural crops and damage to livestock's shed. Likewise, the people consider the flood as unmanageable if the flood caused partial damage of agricultural crops, buildings (type 3 and 4), unpaved roads, livestock's and other infrastructures and if the people have to move out to neighbouring region. The flood is called disastrous when the flood resulted in total loss of agricultural land, livestock's, buildings and other infrastructures. This might require total replacement for recovery after impacts of floods.

Table 5.27: Community Perception about the Flood

Water Depth (Human Scale)	Duration (Days)		
	1-3 days	3-5 days	>5 days
Ankle (0.1-0.2m)	Normal	Normal	Disturbing but still Manageable
Knee (0.2-0.5m)	Normal	Disturbing but still Manageable	Disturbing but still Manageable
Hip (0.5-1m)	Disturbing but still Manageable	Unmanageable	Unmanageable
Breast (1-1.5m)	Unmanageable	Disastrous	Disastrous
Higher (>1.5)	Disastrous	Disastrous	Disastrous

5.12.2. People's Perception about the Duration of Flood

Flood duration in the study area varies from 1 – 7 days, Figure 5.60. The more the duration of water the more damage it will cause as could also be seen from Table 5.27. Even at flood depths of 1-1.5 meter but the flood duration of about 3-5 days result disastrous. The duration of devastating flood of 1987 was around 15 days. After that flooding incident, the local people haven't experienced similar highly catastrophic floods with such high duration of 15 days. However, they experienced flood annually but the frequency and the duration of the flood is not that large enough to be highly catastrophic.

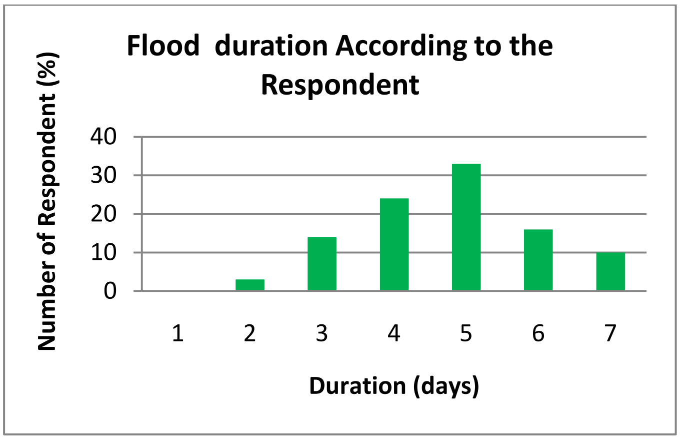


Figure 5.60: People's Perception about the Duration of Flood Water

From the overall analysis of duration of the flood it shows that the water duration mainly stay in the study for about 5 days. And there is varied range of perception about the flood duration which is because of the reason that the whole area will not experience the same depth and duration of flood during the same flood event. And also the local elevation of the area is also varied which makes the differences in perception of the people.

5.12.3. People's Perception about the Cause and Frequency of Floods

According to the local people they urged that there are two common types of occurrence of flood in this area. One is flood caused by the rainfall and snow melt which is called pluvial floods. Other is the alluvial floods which are caused by the breakdown of the embankment. Almost 50 percent of the people mentioned that the main cause of flooding is the high rainfall and snow melting. While around 25 percent mentioned that the sedimentation in the channels is also one of the major causes. The other causes are overflow of river water and dike failure. In the rainy season the water level of the river increases in the periphery of the Rioni thereby adding more water to the Rioni causing floods. Almost all of the people had same perception about the cause of the flood. Some people also mentioned that the channels were full of sedimentation and the water cannot flow and stagnate in the land surface for longer duration and cause flooding. Table 5.28 presents the number of respondents based on the local perceptions on cause of flood.

Table5.28: Cause of Flooding in the Study Area

Causes of Flood	Respondents (%)
Heavy rainfall and Snow melting	50
Sedimentation in the channels	25
River water overflow	15
Dike failure	10

The area has two flooding periods: one in May till June and another in end of September till October. All the respondents consider that the flooding is the annual problem of this area and occurs twice in a year. Also the cause of flooding is similar to both periods of the years.

5.12.4. People's Perception about Staying in the Area

When asked to the local people about the reason to stay in the area even when the area is vulnerable to annual floods, they stated that they had no choice and that was the only property of their life. Around 55percent of the respondents stated that they were living in that area since their birth so they could not think of leaving their birth place. Some people said that their houses and the agricultural land were inheritances from their ancestors and they were staying there to continue their traditional way of living.

While 20 percent of the respondents mentioned that because of their poverty and lack of financial resources they were not able to afford other property in other areas.

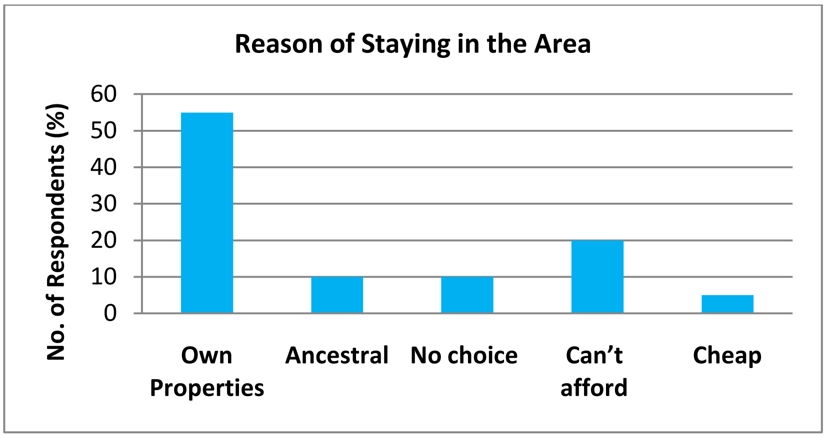


Figure 5.61: People's Perception about the Reason of Staying in the Study Area

Figure 5.61 shows the reason of local respondents staying in the study area. In one village of Khobi municipality – region between Patara Poti and Sabadjo called Sachochuo, government have provided the land near the river to the local people. These people were originally from other region and had been the victims of the landslide in their previous settlement areas. The people who were staying in this land as a refugee stated that they had no alternative for their shelter to move out to other secure region as they completely rely only on the property provided by government. So they were plight to stay there despite being vulnerable to flood risk.

5.12.5. People's Perception about the Flood Control

Regarding the questions about the flood control, it was found that some of the people were completely unaware of any preventive measures of flood risks. About 75 percent of the respondents stated that the floods could be controlled by increasing the height of the dike and also strengthening the capacity of the dike. About 15 percent people thought that if the government constructed and maintained the dike every year before the flooding season then there would be less chance of flood risks. And the rest 10 percent of the respondents were totally unaware if the flooding could even be controlled. Also, 2 commercial farmers among the total respondents were found to repair the dikes on their own for their own flood preparedness.

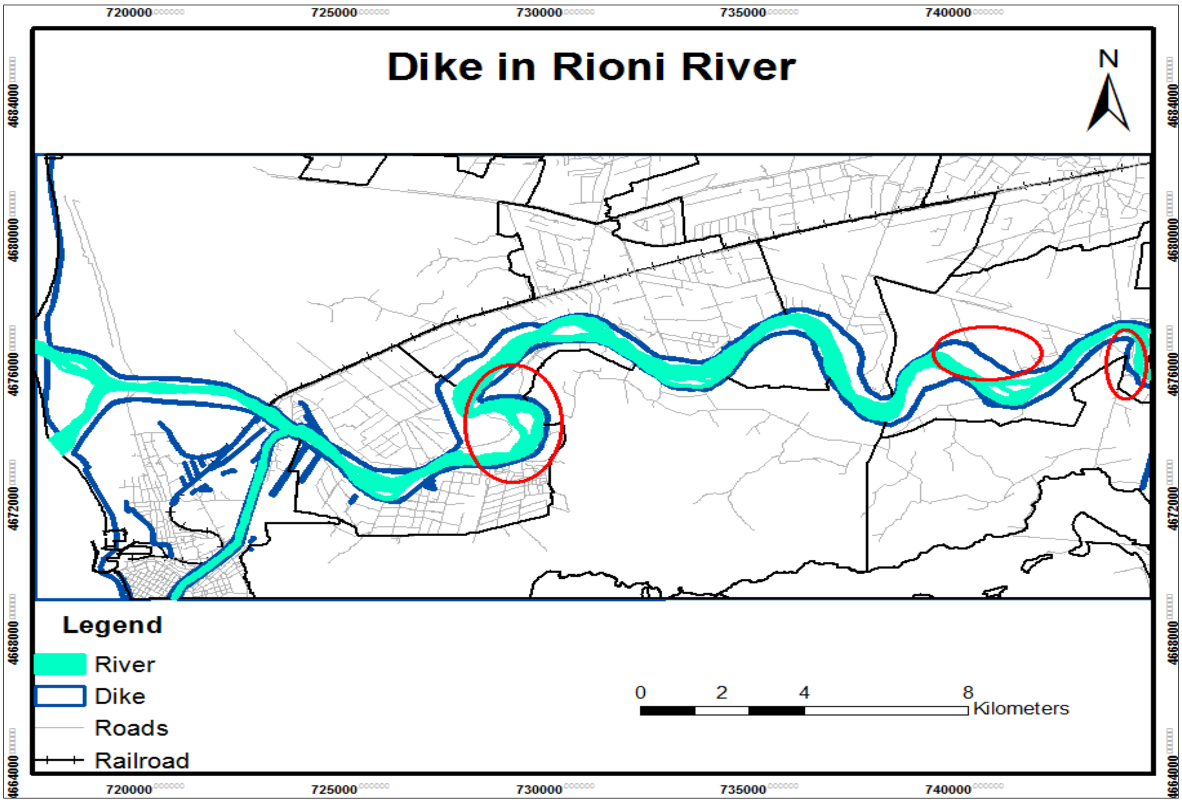


Figure 5.62: Dike along the Rioni River

Figure 5.62 shows the dike that is along the Rioni river. The red circle shows the locations of the dikes that are destroyed by the cattle grazing, trees and bushes on top of dike etc.

5.12.6. Flood Risk Perception of Local Government

As mentioned above about the causes, damage, level and duration of the floods and the reason of stay in the flood prone areas by the local people it could be stated that the flood is one of the most common and frequent problems in this area. Upon interviewing with the local government personnel they stated that the government were also well aware with this problem of annual flooding. But due to the lack of the proper funds and finances of the local government they were not able to provide the required preventive measures to avoid flood risks and build the proper infrastructure to avoid flood affects.

The local people stated that if the government put some effort in strengthening the dike almost 50 percent of flooding problems would be resolved. Other preventive methodologies that could be provided by local government were widening of river banks to give more room for the river, continuous cleaning of the channels before the rainy seasons; put some early warning system etc. However, the government claimed that they lack sufficient budget to provide enough money for such flood preparedness and flood risk reduction plans. But, in some areas – Sachochuo, the government seems to monitor the flood and if the dike was damaged then the government reconstructed the dike but not on a continuous basis.

The results of this research have clearly shown that perceptions of risk play a pivotal role in local resident's response to flood events in the Lower Rioni River Basin and consequently, hold many implications for decision makers. Also at the same it was found that the awareness among the people about the flood risk is completely at zero level. As they thought that the flooding is the annual problem and it is the natural event and they cannot do anything in that. This could be due to the reason that when major flood do not occur for long periods of time then the perceptions towards the risk tends to diminish.

In accordance with the analysis of responses from flooded area residents throughout the survey, a number of specific factors commonly emerged that play a major role in influencing the perceptions of local people about the flood risk in the Rioni river basin.

- The role of Geographic Location which play a major role in influencing the risk perceptions. As the people who are staying near the river perceived differently than the people staying far from the river. The disastrous flood of the year 1987 has major impacts in the northern part rather than the southern part of the Rioni river but this is the extreme scenarios. So most of the people only focus in the northern part of the Rioni river neglecting the southern part. The local people also perceive that the policy and knowledge of flood is too narrow which is because that the decision makers are not living in the rural area and they are making the decisions. So until unless the people didn't face any hazards by themselves they cannot able to know the pain of hazards. While at the mean time the people also thought that the decisions used to make without consulting/considering the local communities people and their input. This all factors directly or indirectly influence the perception of the local communities.

- It is also noted that the past flood experience is also an influencing variable in the perception towards the flood risk. The 1987 flood event made significant damages in this area. While at the mean time most of the people they thought that 1987 level flood or larger will not recur in one's lifetime. This is due to the reason that the local people haven't a better understanding of probability and magnitude of the flood.

  Lopes, (1992) mentioned that most people often neglect that a disaster could happen to them or could happen where they are. But only those people who had actually experienced a flood or other disaster where they lived were likely to confess that they thought a disaster could happen to them where they lived. So the people who faced the 1987 flood thought that the disastrous flood can occur. Also some of the people also mentioned that the flood event will never be forgotten and are permanent memories for them. So if the government and local people didn't adjust their perceptions accordingly to the new situations that arise they may be more vulnerable by underestimating larger magnitude flood events.

- In the study area not all the people have faces the disastrous flood of 1987 and they don't have ideas about the flood. So if the government provide some disaster images of 1987 or some documentary related to that flood are shown to the people then the people will get some knowledge about the flood risk. If some of disaster images will provide to the people which can also aid in preparedness and response activities. This is also one of the factors that hampered the people perception about the flood risk.

5.13. Coping Mechanisms

The poverty of the people has made the area vulnerable to the flood events which numbers have increased during last year's (from interview with the local government). While at the same time also the area make the people in the line of poverty. As it is already mentioned that the flood occurs twice in a year in this area. It is thus important to study the different coping mechanisms adopted by the local communities. This research tries to find the various coping mechanisms adopted by the local people before, during and after the flooding based on economical, physical and social aspects.

5.13.1. Local Community Coping Mechanisms

One of the common coping mechanisms applied by the community before the flooding was the construction of houses with basement level lifted to 0.5-1 m above the ground so that the water cannot get into the house upon flooding. This is also the traditional way of living in this area. By constructing the houses in such ways, they have two main advantages i.e. prevention of the house from the frequent flooding with less water depth and second is the avoidance of the humidity.

In some part of Sagvichio, the people help maintenance of the dike by placing sand bags, stone or soil. The commercial farmers with good economic condition used to repair dikes damaged by - improper grazing of livestock's, also planting of trees in the dikes, and the human interferences in the river basin. Some farmers channelize the path of flood water to minimize the agricultural damages.

During the flooding, when the water level starts to rise, people keep their necessary and valuable belongings where water cannot reach easily in the higher place in the house. If the houses are multi-storied then they put their belongings on upper floors and if the house is single floored then they keep their belongings to their neighbours or relatives houses. In some part of the study area the local people assign among themselves for surveillance duty of twenty-four hour during the period of flooding to get the continuous information about the rise in water level which determined the necessary coping actions. For example, if the water level tends to increase unmanageably then the entire family looks for an emergency evacuation and move to the neighbour village along with their important belongings and livestock's that could be carried along. Evacuation takes place when the water level starts to rise above the level of breast (1-1.5 m).

Some people dwelling near the Rioni river basin recalled about the impulsive rise of water level when they required immediate evacuation without any alarms during 2008 flood. One of the respondents said that when there was heavy rainfall and when there were symptoms of high flood he used to send his wife and children to the neighbouring village. According to him, he was able to cope with the floods but the woman and children cannot. This shows how the gender and age affects the social vulnerability and coping mechanism. During the evacuation process the people usually carry their light weight livestock's such as chicken, turkey, ducks, goat etc along with other valuable and easy to carry assets with them. This usually adds some sort of assurance for their household and add valuable asset in the household after the consequence of the flood effects as they could earn cash after selling them.

During the interview, most of the people mentioned that depending upon the water level and duration of floods their coping mechanism and recovery time from damages differ. If the flood water is deeper (1-1.5 meter) but the duration doesn't exceed 1-2 days then the first step they do is to remove the mud and sediment deposits from the house. In case of high level of damage usually they sell their saved goods such as agricultural crops, machineries, livestock's and other tangible assets to cope and recover from the damages – repairing of houses, re-cultivate agricultural crops etc. However, majority of the people in the area have very low income meaning they do not possess sufficient resource to cope and recover from the flooding. As most of low income people dwells in the house type -3 and 4 which are much more vulnerable even to low magnitude floods.

Local Government Coping Strategies

The local government is also not able to provide help to the flood victims due to lack of finance. They also explained that due to insufficient finances and lack of budget with the local governments they were not able to reconstruct the dike on a continuous basis. However, damages due to annual flooding may not be severe.

Since there is no government support they have to cope on their own. In some areas - Sachochuo (region between PataraPoti and Sabadjo) the government monitored the flood. The noticeable thing observed was that the local government gave more priorities to the resettlement area for the landslide victims. And if the dike was damaged the government reconstructed the dike because the government had invested a lot for this resettlement area. The different phase of the coping strategies applied were analyzed and listed in Table 5.29.

Table 5.29: Different Phase of Coping Mechanisms

Flooding Stages	Coping Strategies Adapted by the Locals
Before Flooding	1. Put sand bags in the damaged dike
	2. Stock and store foods and cash for the usage in difficult times
	3. Construction of dikes in some part by the government
	4. Repairs of dikes by commercial farmers
	5. Increase the level of the house from the ground so that water cannot enter the house.
	6. Some respondents prefer to do nothing
During Flooding	1. Put the personal goods in the higher place or neighbouring place
	2. Evacuate the children, woman and handicapped people
	3. Assign 24 hour duty to obtain the information about the water level
	4. Put the sand bags and stone or soil in the broken dike area
	5. Guard their house
	6. Helping each other to evacuate from the floods
	7. Some respondents prefer to do nothing
After Flooding	1. Construction of dike by local government
	2. The local people themselves construct the broken dike and also clean the channel to let the water to the river again
	3. Remove the mud from the houses
	4. Saved and stocked goods and assets were sold in order to repair the houses, fulfil basic needs and re-cultivate the agricultural croplands
	5. Drying the wet clothes, furniture and other household equipments
	6. Some respondents prefer to do nothing

5.13.2. Factors Responsible to Influence the Current Coping Mechanisms

The lack of flood specific policy in this region of Georgia shows the weakness in the current coping mechanisms to deal with the flood risk (from interview with the local government). According to the Slaymaker, (1999) due to the absence of good management policy of flood; it results in fragmented efforts that lead to the poor coordination and results in flood coping mechanisms. Due to the lack of policy there are no clearly defined responsibilities for flood management related institutions nor there is inter sector collaboration. Wisner, *et.al.,* (2002) mentioned that assessing the risk and vulnerability can play a major role in identifying the people and property that are at risk to the flood hazards. However in the study area there is also lack of assessments of risk and vulnerability of flood hazards in the region which diminishes coping mechanisms.

From the interview with the local government it became clear that the regional government did not undertake the required preventive measures such as construction of dikes, storage dams, installation of flood warning systems etc, due to the lack of funds. From the result obtained from the coping strategies against flood hazard in the lower Rioni river basin it shows that there is lack of appropriate measures to counteract the affect of flood hazard. The main reasons were found out to be:

- Lack of the flood specific policy
- Weak institutional capacity
- Poor infrastructures

All these weakness intimidate the effectiveness and sustainability of the coping mechanisms. In order to strengthen the coping mechanisms against flood risk it is necessary to address these challenges to make the coping sustainable.

5.13.3. Some Recommended Coping Mechanisms in this Western part of Georgia

With the history of floods and the periodic occurrence of extreme hydrologic events in this part of the western Georgia, the coping strategy employed by local people and the government is not sufficient to minimize the flood risk. The recommended coping mechanisms is entirely based on the interview with the local people and the local authorities as well as analyzing the past flood events. Thus this research will help to address the future strategy which can be implemented in the area to cope up with the flood hazard and the measures which can be taken to minimize the risk. To minimize the negative impacts of the floods, the coping mechanisms measures can be divided in two groups: structural measures and non-structural measures.

The **structural measure** includes:

1. **Storage Dams:** The large storage dams can contribute for the reduction of floods if some part of its storage capacity is reserved for floodwaters during the wet season. In this study area the water demand is high in terms of natural irrigation on agricultural crops so the storage dams can contribute to significant role in flood risk reduction. Also there are some tributaries near the main Rioni river - Khobi and Tshivi river which aid to significant discharge in river water during flood. Also the storage dams could counteract small floods by completely absorbing all the water but has limited impact with large floods. On the other hand, there is also a perverse effect due to the way most storage dams operate. One common negative effect is that the storage dam can become breeding grounds for disease vectors like mosquitoes (which causes malaria), snails (which causes Schistosomiasis) etc. This has not only negative environmental impacts but also eliminates the “routine” of the floods from the people’s minds and memory, so they are socially and psychologically less prepared for the large floods.

2. **Dikes:** Dikes acts as a protection against floods. The presence of dike is a good solution that had worked well in the past controls and may continue to do so in the future. In this study area the government had already constructed the dikes along the river. But the problem is that the dike was constructed around 15 years ago and due to lack of maintenance there are many weak points in the dikes which make the local people residing along the river at great risk. Also in some part of the study area near Senaki there is need of more room for rivers to minimize the flood risk.

The present practice of grazing cattle in the dike region is also one of the primary causes to destroy dikes - due to their heavy weight. And the local people use heavy trucks for the transportation of woods and logs from the bank of river which are collected from national park across the river ultimately weakens and destroys the dike. Thus for the mitigation of dike destruction, the control mechanisms for unmanaged cattle grazing by prohibiting dike areas for grazing and restricting heavy trucks to enter dike region could be implemented. So if the responsibility and policies for the maintenance is clearly defined then the dike will be strong enough to acts as a barrier. At the mean time also the repairing/maintenance of the dike should be done before the beginning of the rainy seasons to strengthen its capacity.

The **non-structural** coping mechanism measure includes:

1. **Flood zoning:** Flood zoning defines the flood risk associated to different zones along the river basin. The probability of occurrence of 1987 flood was once in 25 year by Gumbel's method. It is one of the fundamental steps to better cope with the floods. By doing this the local authorities will be responsible for the planning risk incurred by the existed activities in the flood plain. This as a result will be helpful for the better preparation of the emergency and evacuation plans. As discussed in flood hazards map different obstructions, local interviews for depth and duration of annual floods and local elevation data were studied to find compartments based on degree of flood risks. This flood zoning could be the good basis to identify coping mechanisms to be applied to different flood zones i.e. compartments by the local officials or government.

2. **Flood plain management:** The settlements, agriculture, tourism or industrial activities that are mainly located in a flood plain are always subject to a measure of risk. Therefore, the local government have to be careful in starting or expanding human settlements or economic activities in the flood plain. Some of the activities are obviously very easy to say but difficult to implement and remain as a guiding principle. Therefore it is also important to define who is responsible for making the decisions such as the district's administrative, the provincial government or the minister of the area. The main question is not so much about which body makes the decision but the decision is made with full knowledge of all its implications, using the studies and analysis prepared by various other institutions, including the flood zoning studies.

3. **Flood warning systems:** Flood warning system is vital tool to minimise the damages caused by floods, providing a forecast with days or hours in advance of the areas that are going to be flooded, water levels and eventually water velocity. The forecast allows for a series of measures and interventions, removal of equipment and evacuation of population etc. After the 1987 catastrophic flood in this area, the local people proposed the local authorities to implement the early warning systems. But, since then there had not been such catastrophic flood that made the local government overlook the need of flood warning system. Until now there is no early warning systems installed in this area. Therefore to minimize the flood damages from catastrophic floods as well as annual floods, flood warning systems should be installed.

4. **Emergency and evacuation plans:** The installation of flood warnings is a first phase of a process that must be continued by the local authorities. Also the reinforcement of dikes, alert notices to the population and preparation of temporary shelters and mobilisation of resources are the emergency and the evacuations plans that the government authorities should be prepared of.

5. **Education and raise awareness:** One of the important related issues is to raise the awareness of people in relation to floods and to promote education programs at all levels. This makes the

population in general more prepared to face small-large floods and to react adequately when they occur. Also the **insurance** is sometimes suggested as a measure to minimise the consequences of floods.

The satellite imagery is equally important along with the photos and videos captured during the catastrophic floods which can be used as source of analysis for further studies. One can draw the conclusion that this part of the western Georgia will continue to face large floods in the future. Floods cannot be avoided but more and continuous efforts have to be made to mitigate their adverse impacts. The combination of structural and non-structural coping mechanisms measures should have to be more resilient by the careful analysis of the past floods. Skilled human resources are essential, focussing more and investing in education, training and research to the local people and also the local authority's personnel are vital for the flood risk reduction.

From all these recommendation we can say that making the diagnosis is easier than finding solutions. At the same time finding the solution turns easier than implementing them. This study area has a long way to go to improve significantly its preparedness to manage the floods that will continue to occur in the future.

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The conclusions drawn from this research are summarised according to the specific objectives as follows:

Specific objective 1: To identify the elements at risk in the rural area of Georgia (Rioni River Basin).
The major elements at risk due to flooding in Rioni river basin can be grouped into physical (houses, roads and railways, agricultural land), economic (crops (at different growth stages i.e. sowing, growth, maturity and harvesting) and livestock and social (gender, age, occupation, income and household size).

Specific objective 2: To determine the vulnerability of elements at risk and of people living in the flood plain area.
Physical vulnerability: Houses made of tin roof, tin/ply/stone/mud wall, stone and mud floor (type-3) and tin roof, wooden wall, wooden floor (type-4) were found to be highly vulnerable. These houses were owned by farmers with low economic condition and were mostly found along the river basin. With regards to roads the unpaved roads were found more vulnerable since they can be easily damaged and the local government also do not have enough funds for repair works. The study shows that around 39percentof total sample houses are highly vulnerable, 47percentmoderately vulnerable and 14percentlow vulnerable. In general the physical vulnerability of the study area can be considered moderate to high.

Economic vulnerability: Three types of crops are grown in the area -corn, beans and watermelon. The watermelon and beans were found more vulnerable than the corn under standing water. Vulnerability is not same for different crop stages – sowing, growth, maturity and harvest. Sowing and growth stages were found to be highly vulnerable as this stage was regarded very critical in the crop cultivation for all three types of crops. Regarding livestock chickens, ducks and, turkey are more vulnerable than large sized animals e.g. cows, buffalo, goat, lamb and pigs. But the vulnerability of category-3 (chickens, duck and turkey) and category-2 (goat, lamb and pigs) could be decreased significantly, as people can carry them during the time of evacuation. The area has high vulnerability which may be due to agricultural as being the only source of occupation of the local people. Also in this area there are high numbers of small scale farmers and mostly they are residing near the river.

Social vulnerability: The children (up to 10 years), woman and the elderly people (older than 60 years) were found to be more vulnerable, as they need some help or assistance to evacuate from the floods. The area has high social vulnerability because of low income level of the people, large household size (at least 5) and only agriculture as being their occupation. The people who have only agriculture as an income source are more vulnerable than others. Also, mainly the house type 3 and 4 are owned by these groups of people.

The overall vulnerability shows that the area has high vulnerable (approximately 51 percent) followed by moderate vulnerability (41 percent) and low vulnerability (8 percent)

Specific objective 3: To analyse people and government's perception towards the flood risk in the lower Rioni river basin.

The local people's perception regarding flood depth and duration varied according to location of study area. The annual flood water reached up to the knee level (0.5 meter) in most part of the study area and the flood lasts for almost 5 days. The flood vulnerability map shows that in a whole the study area is moderately vulnerable by annual floods. 27 percent of the area is highly vulnerable to floods while 32 percent is moderately vulnerable and 7 percent is less vulnerable.

Specific objective 4: To identify the coping strategies employed by the local people and the local government.
The coping mechanisms employed by the local community were keeping sand bags in the place where the dike was destroyed. Also uplifting the house was one of the common coping mechanisms. During the flooding time the people used to assign 24 hours duty to obtain the information about the water level. Government authority also provide for the repair of the dike but only at resettlement area - Sachochuo (region between Patara Poti and Sabadjo). The flood risk management strategies have not been developed for this region and there is no spatial planning for regional development.

The study shows that the major factors influencing the coping strategies were the lack of flood specific policy, weak institutional capacity and the poor infrastructures in the area. To make the coping strategies more sustainable there is need of some structural measures such as storage dams as well maintenance of old dikes and restricting grazing and the entry of heavy vehicles in the dike region etc. The study also found that the other non structural measures that need to implement are flood zoning, flood plain management, warning system installation, emergency and evacuations plans and also education & raise awareness programs

Most of the areas have high vulnerability followed by moderate and low vulnerability. Also the majority of the agricultural land lies in the high vulnerable zone. The research results have comparable results obtained by the modelling result using SOBEK (Tamar). The main reason for this is that the modelling result is entirely based on local elevation data (DEM) and does not consider the water channels present in the various study regions and also other water discharge sources. The second approach is in identifying the elements at risk. Mainly in the literature it shows that the crops and their different stages were not considered as elements at risk. But this study attempts for the granular level of study approach to identify different stages of crops as new added elements at risk for the rural risk assessment in agricultural crops. Also the vulnerability of crops in each crop stages was determined in this study. Thus the way of analyzing the approach has shown that the overall result is good and can be used for further assessing the rural risk.

6.2. Contribution of this Research

- The annual flood depth and duration map that is prepared in this research can be used by the local people and the government to select the areas for implementation of flood management policies.
- The identification and categorization of elements at risk in the rural context can be used further for the classification of elements at risk.
- The vulnerability assessment of houses, roads, agricultural lands, crops on different stages like sowing, growth, maturity and harvesting, livestock and the socioeconomic characteristics can be used further for flood risk assessment. The vulnerability assessment can be used for estimation of damage risk calculation in future to the similar types of works.
- The local people perception's regarding flood hazards can be used to address flood disasters effectively in the study area.
- The coping strategies adopted by the local people can be useful for local government in understanding the behaviour of the people during floods.

6.3. Research Limitations

- Due to the absence of images and data about the recent flood extent and damages it was difficult to estimate the actual damage to the agricultural land, crops and the livestock.
- In some cases there is a variation in the response of the people towards the questions within the same study location which posed some difficulty in analysis.
- As translation was required to conduct the interview in the field. So, it was difficult to comprehend each single detail answered by the respondent during interviews by translator.
- Due to the limited time only 121 surveyed were conducted. More fieldwork samples would have made the results better and accurate.

6.4. Recommendations

- In order to minimize the risk the collaboration between the local government and the affected community is necessary.
- This research is mainly based on local knowledge and there is active participation of the local people. So this research method can be adopted by the local government to extract the information of the flood risk perception and different coping mechanisms used by the local people to support the flood management.
- The government should pay attention in the coping mechanisms and add some early warning system so that the local people get some aid in the coping mechanism to minimize the risk.
- The use of dikes for cattle grazing and other human activities should be restricted.
- The water channels should be cleaned and maintained to reduce the flood impacts.
- The national government should implement a flood specific policy immediately in order to give direction to the flood management.
- The regional government should carry out the flood risk assessment in this region to identify the systems, infrastructures and services at risk. The reason is that once the risk is identified it will help to enhance the implementation of the mitigation and the preparedness measures.
- Also the institutional capacity of flood management related agencies should be strengthened.
- It is essential to develop awareness among the people about flood risk and make them conscious about the flood damage potential of the area.

LIST OF REFERENCES

Abramia, G., Dr. Jorde, I. K., & Biegert, A. (2009). *Country Chapter: Republic of Georgia*: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.

ADPC. (2004). *Community-Based Disaster Risk Management: Field Practioners Handbook*. Thailand: ADPC.

ADPC. (2005). *A Primer: Integrated Flood Risk Management in Asia*.

ADPC, & USAID. (2005). *A Primer: Disaster Risk Management in Asia*.

Al-Mashidani, G., Lal, B. B. P., & M.F., M. (1978). A Simple Version of Gumbel's Method for Flood Estimation. *Hydrological Science-Bulletin-des Sciences Hrdrologiques 23*, 373-380.

Alomatu, S. (2009). *Rural Flood Risk Assessment for Nam Chun, Thailand.*

Anderson, J. R. (2001). *Risk Management in Rural Development* (Reviwe Report). Washington , D.C. : World Bank.

Andjelkovic, I. (2001). *Guidelines on Non-Structural measures in Urban Flood Management*. UNESCO, Paris: International Hydrological Programme.

Bakker, M. H. N. (2006). *Transboundary River Floods: Vulnerability of Continents, International River Basins and Countries*. Unpublished Phd.

Bakker, W. H., Feringa, W., Gieske, A. S. M., Gorte, B. G. H., GrabMaier, K. A., Hecker, C. A., et al. (2009). *Principles of Remote Sensing* (4th ed.). Enschede: The International Institute for Geo-Information Science and Earth Observation (ITC), The Netherlands.

Bakx, J. P. G. (1995). Digital Image Processing of Remotely Sensed Data.

Blaikie, P., Cannon, T., Davis, I., & B, W. (2003). *At Risk: Natural hazards, people's vulnerability and disasters*. London: Routledge, London.

Bohle, H. G. (2001). Vulnerability Article 1: Vulnerability and Criticality. *Newsletter of the International Human Dimensions Programme on Global Environmental Change*.

Browitt, C. W. A., & Merriam, P. A. (1993). *Natural Disasters: Protecting Vulnerable Communities*. London: Thomas Telfort.

Buchele, B., Kreibich, H., Kron, A., Thieken, A., Ihringer, J., Oberle, P., et al. (2006). Flood-risk mapping: contributions towards an enhanced assessment of extreme events and associated risks. *Natural Hazards and Earth System Sciences, 6*, 485-503.

Burton, I., K.;, R. W., & W, G. F. (1978). The Environment as Hazards. *What are Natural Hazards*,

Campbell, B. J. (2007). *Introduction to Remote Sensing* (Fourth ed.). Spring Street, New York: The Guilford Press

CEOS. (2003). *The Use of Earth Observing Satellites for Hazard Support: Assessment and Scenarios* United States of America.

Chambers, R. (2006). Vulnerability, Coping and Policy: (Editorial Introduction). *IDS Bulletin, Institute of Development Studies, 37*, 33-40.

Coburn, A. W., Sspence, R. J. S., & Pomonis, A. (1994). *Vulnerability and Risk Assessment* (2nd ed.). Cambrigde: UNDP.

de Klerk, P., Haberl, A., Kaffke, A., Krebs, M., Matchutadze, I., Minke, M., et al. (2009). Vegetation history and environmental development since ca 6000 cal yr BP in and around Ispani 2 (Kolkheti lowlands, Georgia). *Quaternary Science Reviews, 28*(9-10), 890-910.

Dhillon, R. K. (2008). *Flood Damage Assesment and identification of Safe Routes for Evacuation using a Micro-level approach in a part of Birupa River Basins, Orissa, India.* ITC, IIRS, Enschede.

Dixit, A. (2003). Flood and Vulnerability: Need to Rethink Flood Management. *Natural Hazards, 28*, 155-179.

Drury, A. S. (1993). *Image Interpretation in Geology* (Second ed.). London: Chapman & Hall

Dutta, D., Herath, S., & Musiake, K. (2001). *Direct Flood Damage Modeling Towards Urban Flood Risk Management* Japan: The University of Tokyo.

Dwyer, A., Zoppou, C., Day, S., & Roberts, S. (2004). *Quantifying Social Vulnerability: A Methodology for Identifying those at Risk to Natural Hazards*: Geoscience Australia.

EM-DAT. (1991-2005). Number of Natural Disasater by Type. In T. O. C. I. D. Database (Ed.). Brussels: Université Catholique de Louvain, Belgium.

Enarson, E. (2000). *Gender and Natural Disasters*. Geneva: Infocus Programme on Crisis Response and Reconstruction.

Febrianti, F. (2010). *Flood risk perception and coping mechanisms of a local community: A case study in part od Surakarta city, central Java province, Indonesia.* University of Twente; University of Gadjah Mada University, Enschede, Indonesia.

FEMA. (1997). *Multi-Hazard: Identification and Risk Assessment* United States of America.

FEMA. (2003). *Federal Guidelines for Dam Safety: Glossary of Terms*.

Fothergill, A., & Peek, L. A. (2004). Poverty and Disasters in the United States: A Review of Recent Sociological Findings. *Natural Hazards, 32*, 89-110.

Gibson, J. P., & Power, H. C. (2000). *Introductory Remote Sensing: Digital Image Processing and Applications*. London: Routledge.

Guarin, P. G. (2008). *Integrating local knowledge into GIS-based flood risk assessment.*

Heijmans, A. (2004). *Mapping Vulnerability*. UK: Earthscan, UK.

IFRC. (2005). Disaster Management Retrieved from http://www.ifrc.org/what/disasters/about/types/index.asp

IPCC. (2007). *Climate Chage 2007: Imapcts, Adaption and Vulnerabaility*. Cambridge, UK.

ISDR. (2004). *Living with Risk: A global review of disaster reduction initiatives*. Geneva, Switzerland

ISDR. (2009). Terminology on Disaster Risk Reduction 1-35. Retrieved from http://www.unisdr.org/eng/terminology/terminology-2009-eng.html

ITC. (2010). *GI Science and Earth Observation: A Process-Based Appraoch*. Enschede, Netherlands: ITC.

Jones, C. P. (2009). Flood Resistance of the Building Envelope.

Kan, I., Kimhi, A., & Lerman, Z. (2006). Farm output, non-farm income and commercialization in rural Georgia. *Electronic Journal of Agricultural and Development Economics, 3*, 276–286.

Kelly, C. (2009). *Local Government Disaster Preparedness Assessment Limbe and Montrouis Watersheds* USAID.

Kliesen, K. L. (1994). The Economics of Natural Disasters. *The Principle of Loss Assessment*,

Lillesand, M. T., & Kiefer, W. R. (2000). *Remote Sensing and Image Interpretation* (4th ed.). United States of America: John Wiley and Sons.

Linderholm, W. H., & Leine, M. (2004). An Assessment ofTwentieth Century Tree-Cover Chages on a Southern Swedish Peatland Combining Dendrochronoloy and Aerial Photograph Analysis. *Wetlands, 24*(2), 357-363.

Lopes, R. (1992). *Public Perception of Disaster Preparedness Presentaions Using the Damage Images*. Alexandria: American Res Cross National Headquaters, Disasater Service.

Malilay, J. (1997). *Floods*. New York: Oxford University Press.

Marschiavelli, M. I. C. (2008). *Vulnerability assessment and coping mechanisms related to floods in urban areas: A community based case study in Kampung Melayu, Indonesia.* University of Twente; University of Gadjah Mada, Enschede, .

Mather, M. P. (1987). *Computer Processing of Remotely Sensed Images: An Introduction* Bury St Edmundsbury, Suffolk St Edmundsbury Press Ltd. .

MediaNews. (2010, 17-10-10). Overflowing River Floods homes in Western Georgia. *MediaNews*. Retrieved from http://medianews.ge/index.php/en/content/48396/

Merz, B., Kreibich, H., Schwarze, R., & Thieken, A. (2010). Review Article "Assessment of Economic Flood Damage". *Natural Hazards and Earth System Sciences, 10*(8), 1697-1724.

Minang, P. A., & Mccall, M. K. (2006). Participatory GIS and Local Knowledge Enhancement for Community Carbon Forestry Planning: An example from Cameroon. *Participatory Learning and Action, 54*, 85-92.

Murshed, A. M., Borst, D., Grunthal, G., Heneka, P., Hofherr, T., Kreivich, H., et al. (2007). Comparative Risk Assessment of Natural Hazards: Where do the Opportunities lie in Catastrophic Precaution. *Disaster Reduction in Climate Change*.

Nelson, S. A. (2008). River Flooding. Retrieved from http://www.tulane.edu/~sanelson/geol204/riverflooding.htm

Nichols, P. (1991). *Social Survey Methods: A Field Guide for Development Workers* (Vol. 6). Oxford: Oxfam

Nott, J. (2006). *Extreme Events: A Physical Reconstruction and Risk Assessment* Cambridge, UK: Cambridge University Press.

OCHA. (2005). *OCHA Situation Report No. 1* (Situation Report). Georgia.

Petersen, M. (2001). Impacts of Flash Floods. In H. J. Gruntfest E (Ed.), *Coping with flash floods* (Vol. 77): NATO Science Series.

Plapp, T., & Werner, U. (2006). Understanding Risk Perception from Natural Hazards: Examples from Germany. *RISK 21 – Coping with Risks due to Natural Hazards in the 21st Century*, 101-108.

Polsky, C., Schröter, D., Patt, A., Gaffin, S., Long, M. M., Neff, R., et al. (2003). Assessing Vulnerabilities to the Effects of Global Change: An Eight-Step Approach. *Environment and Natural Resources Program*, 5-9.

Ranyard, R., W.R;, C., & Svenson, O. (1997). *Decision Making: Cognitive models and Explanations*. London: Routledge.

Reacher, M., McKenzie, K., Lane, C., Nichols, T., Kedge, A., Iversen, A., et al. (2004). Health impacts of flooding in Lewes: a comparison of reported gastrointestinal and other illness and mental health in flooded and non-flooded households. *Communicable Disease and Public Health, 7*, 1-8.

Reynard, N. S., Prudhomme, C., & Crooks, S. M. (2001). The Flood Characteristics of Large U.K. Rivers: Potential Effects of Changing Climate and Land Use. *Climatic Change, 48*(2), 343-359.

Rossi, G., Harmancioglu, N., & Yevjevich, V. (1994). *Coping with Floods* (Vol. 257). Dordrecht: Kluwer Academic, The Netherlands

Schanze, J., E;, Z., & Marsalek, J. (2006). *Flood Risk Management-Hazards, Vulnerability and Mitigation Measure* (Vol. 67). Amsterdam: Springer, Netherlands.

Short, M. N. (2009). Remote Sensing Tutorial. *Image Processing and Interpretation*. Retrieved from http://rst.gsfc.nasa.gov/Sect1/Sect1_16.html

Slaymaker, O. (1999). Natural Hazards in British Columbia: An Interdisciplinary and Inter-Institutional Challenge. *International Journal of Earth Sciences, 88*(2), 317-324.

Smith K, & D, P. N. (2008). *Environmental Hazards: Assessing Risk and Reducing Disaster* (Vol. Fourth). New York Taylor and Francis e-Library.

Straatsma, M., Ettema, J., & Krol, B. (2010). Flooding and Pakistan.

Subramanya, K. (2008). *Engineering Hydrology* (Third ed.). New Delhi: McGraw-Hill.

Talani, G. (2003). *Rural area selection system for development.*

Tatashidze, Z., Bondyrev, I., & Tsereteli, E. (2006). *Environmental Security and Sustainable Land Use* The Netherlands: Springer.

Tsamalashvili, T. (2010). *Flood Risk Assessment and Mitigation Measure for Rioni River.* University of Twente, Enschede.

Tsiklauri, I. (2004). *National Report on the Role of Ecosystems as Water Suppliers Georgia* (Seminar Report). Geneva.

Tso, B., & M.P., M. (2009). *Classification Methods for Remotely Sensed Data* (Second ed.). Boca Raton, London: CRC Press, Taylor & Francis Group.

Twigg, J. (2004). Good Practices: Disaster Risk Reduction Review Mitigation and Preparedness in Development and Emergency Programming. *Humanitarian Practice Network (HPN).*

UN, I. (2005). *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters*. Paper presented at the World Conference on Disaster Reduction. Retrieved from http://www.unisdr.org/eng/hfa/docs/Hyogo-framework-for-action-english.pdf

UNDP. (1994). *Vulnerability and Risk Assessment* Cambridge.

UNISDR. (2004). Living with Risk: A Global Review of Disaster Reduction Initativies

USAID, A. (2010). *Urban Governance and Community Resilience Guides* (Vol. 2): ADPC.

van Westen, C., Kingma, N., & Montoya, L. (2009). *Multi-hazard risk assessment: Distance Education Course, Guide book* Enschede, Netherlands: ITC.

W.M.O. (2008). *Urban Flood Risk Assessment: A Tool for Integrated Flood Management*.

Watson, J. K., Arkedis, J., & Zakout, W. (2006). *Mainstreaming Hazard Risk Management into Rural Projects*. Washington, D.C. : The World Bank.

Wilson, M. E. (1990). *Engineering Hydrology* (Fourth ed.). London: Macmillan Education Ltd.

Wisner, B., & Adams, J. (2002). *Environmetal Health in Emergencies and Disasters*. Geneva, Switzerland World Health Organization (WHO).

APPENDIX

Appendix 1: Sample Questionnaires

Date		
Name of the interviewer		
Age		
Sexe		
Location		
GPS Coordinates		
No. of years of stay in that location		
Job (source of income)		
Actual Land Cover		

Elements at Risk Inventory

Agricultural Functions	
Livestock	
Flood Depth	
Flood Duration	
Flood Depth	
Flood Duration	
Houses	
Floor Material	
Roof Material	
Wall Material	

Floods

• How long have you been staying in this place?
• Have your agricultural fields flooded?

• What type of flood do you face at this place?
• What is the maximum height of the flood that had ever occurs?
• Which month does the flood occurs (Periods) in which year?
• What is the cause of flooding in this area?
• Where do you place the things when flood strike?
• When the last flood was occurs?
• How frequent you experience the flood in your area?

Flood Types	Year	Water Depth	Duration (days)

S.No.	Crop Calendar												
	Crop Types	Months											
		Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
1													
2													
3													

Sowing (S) ***Growth (G)*** ***Maturity (M)*** ***Harvesting (H)***

Level of damage of Agricultural crops to Flooding

S. No.	Crop Types	Water Height (m)	Duration of Flood (Dwyer, *et al.*)		
			1-3	3-5	>5
1					
2					

S. No.	**House Types**	**Water Height (m)**	**Duration of Flood (Dwyer, *et al.*)**		
			1-3	3-5	>5
1					
2					
3					
4					
5					

Damage Calculation

S. No.	Crop Types	Sowing	Growth	Maturity	Harvesting
1					
2					
3					
4					
5					

Standard Package value in practice (Agriculture)
Crop types (1 Hectare) = X, 1X= (How much Price)
Damage based on the stages of crop growth
Expenses: Seeds, Labor, Weeding, Fertilizer, manure

Risk Perceptions

- Which level of water they used to consider as a floods?

- Which height of water and duration of flood you considered as?
    1. Normal (cm) (Days)
    2. Disturbing but still manageable (cm) (Days)
    3. Unmanageable (cm) (Days)
    4. Disastrous (cm) (Days)
- How often you used to experience the floods?

- If remember which was the last disastrous flood in that place?

- What was the extent of the flood?
    a. Local b. community c. Whole area

- What was the level of the flood?
    a. Ankle b. Knee c. Waist d. Breast e. Higher

- What are the causes of the flood?

- In which seasons the flooding commonly occurs?

- Does the flood occurs annually or once in 2, 3, 5, 10 etc years?

- How much damage does the short and long term floods used to cause?

- What action do you implement in you agricultural lands and in your house to avoid or minimize the damage and loss from floods?

- What does the farmer think about the national park?
  a. Nuisance b. Threat c. something to conserve d. Others

- Are there any positive impacts of flood in the agricultural areas?

Coping Mechanisms

- What is the reason of living in this area?
    1. Cheap
    2. Ancestral properties
    3. Own properties
    4. Better access
    5. Others
- Have you applied any flood coping mechanisms? If yes then what are they? If no then what is the reason?

Before Flooding	
During Flooding	
After Flooding	

- What do you think about the floods in this area?
- Nuisance b. Catastrophe c. Normal
- Can you continue working during the floods?
- Where does your family evacuate during the floods?
- What measures do they take to mitigate the floods hazards?

  Long term flooding

  Short term flooding
- What kind of damage happened to the agricultural land and national park?

To the local government and the stakeholders

- What are the coping strategies applied for floods by the local authorities in this area?
- How people are prepare, respond and recover in coping with floods?

- How serious is the floods for this community?

- What kind of strategies applied to face the flood and minimize the flood?

Appendix 2: Annual Discharge Data of Rioni River from the Year 1939- 1990.

Annual discharge		
S.No.	Year	Disharge,m^3s^{-1}
1	1939	1520
2	1940	1670
3	1941	1920
4	1942	1190
5	1943	979
6	1944	1010
7	1945	1160
8	1946	1220
9	1947	1400
10	1948	1150
11	1949	1250
12	1950	1930
13	1951	1740
14	1952	1520
15	1953	1790
16	1954	1490
17	1955	1530
18	1956	2850
19	1957	1720
20	1958	2280
21	1959	1820
22	1960	2190
23	1961	2030
24	1962	2520
25	1963	3000
26	1964	1850
27	1965	1290
28	1966	2330
29	1967	2250
30	1968	2280
31	1969	1310
32	1970	2240
33	1971	1650
34	1972	1480
35	1973	1440
36	1974	2280
37	1975	1780
38	1980	2650
39	1981	3160
40	1982	3430
41	1983	2480
42	1984	1690
43	1985	1550
44	1986	1552
45	1987	3640
46	1988	3020
47	1989	2920
48	1990	3150

Appendix 3: Rainfall Data from the Year 2005-2010

Meteorological Station Poti (mm)												
Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	88.8	162.6	274.7	137.2	75.0	184.5	312.7	516.8	375.8	795.8	151.3	72.3
2006	197.5	96.8	91.5	87.9	56.9	42.5	164.7	17.8	24.2	260.4	194.1	161.1
2007	132.5	43.8	106.0	130.4	35.9	309.1	100.1	116.7	182.9	180.6	459.9	25.6
2008	252.4	56.6	75.0	57.8	181.0	253.3	530.6	81.0	460.1	193.0	112.4	135.9
2009	146.4	142.5	131.7	89.1	137.4	121.5	274.1	237.6	665.2	96.4	241.8	157.4
2010	123.0	118.3	180.4	62.9	40.8	103.8	158.1	160.9				

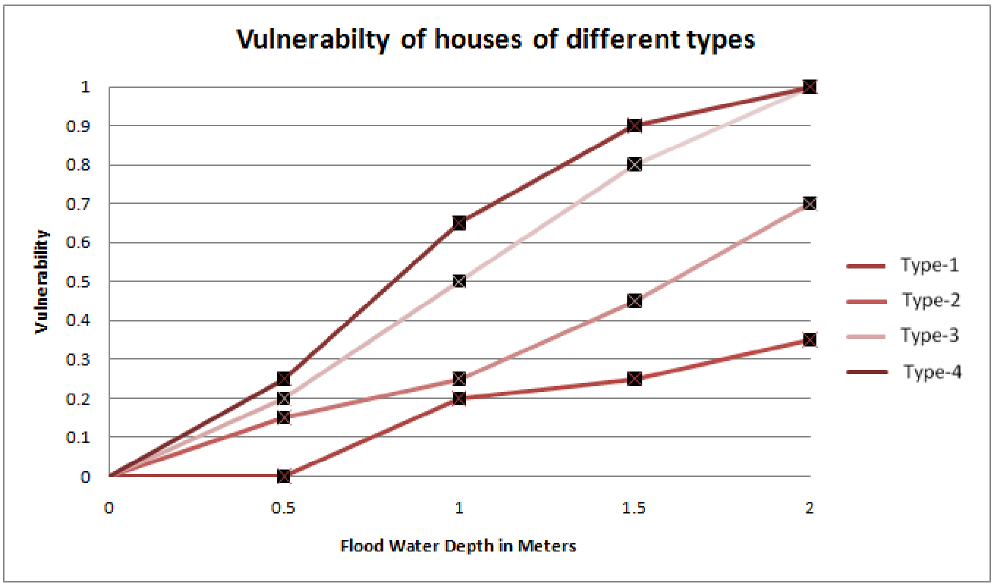
Appendix 4: Vulnerability Values of Different House Types and Roads

Flood Depth	Type 1	Type 2	Type 3	Type 4
	Vulnerability	Vulnerability	Vulnerability	Vulnerability
0	0	0	0	0
0.5	0	0.15	0.2	0.25
1	0.2	0.25	0.5	0.65
1.5	0.25	0.45	0.8	0.9
2	0.35	0.7	1	1

- **Roads**

Water Heights	Unpaved Road	Paved Road
0	0	0
0.5	0.2	0.1
1	0.6	0.2
1.5	0.8	0.35
2	1	0.5

- **Comparison of Vulnerability Curves of Different type of Houses**



- **Comparison of Vulnerability Curves of Different type of Houses**