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Flood Adaptation Strategies under Climate Change in Nepal: A Socio-hydrological Analysis

A dissertation

Submitted by

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Certificate of Dissertation

I certify that the ideas, investigations, analysis, results, discussions, and conclusions reported in this dissertation are entirely my own work, except where otherwise acknowledged. I also certify that the work is original and has not been previously used to earn academic awards.

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List of Publications/Awards during the PhD Study Period

1. List of Peer Reviewed Publications

- **Devkota, R.P.,** Maraseni, T.N., & Cockfield G., An assessment of willingness to pay to avoid climate change induced flood, *Journal of Water and Climate Change (accepted).*
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- **Devkota, R.P.**, Maraseni, T.N., Cockfield, G. & Devkota, L.P. (2013). Flood Vulnerability through the Eyes of Vulnerable People in Mid-Western Terai of Nepal, *Journal of Earth Science and Climate Change*, vol. 4, no. 1, pp. 1-7.
- **Devkota, R.P.**, Maraseni, T.N., Cockfield G. & Devkota L.P. (2013). Indigenous Knowledge for Climate Change Induced Flood Adaptation in Nepal, *The International Journal of Climate Change: Impacts and Responses*, vol. 5, no.1, pp.35-46.
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- **Devkota, R.P.,** Cockfield, G., Maraseni, T.N., Bhattarai, R., Devkota, B. (2012). Assessment of Gases Emission from the Operation of the Semi-aerobic Landfill Site by Solid Waste of Kathmandu Valley, Nepal, *Environmental Research Journal*, vol. 6, no. 3, pp. 182-186.
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2. Awards

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Abstract

While climate change is global in scale, developing countries and their people tend to suffer the earliest and the most because of their weak economies and low levels of resilience and adaptive capacity. Increases in the frequency and intensity of extreme events such as floods, droughts, fires, pests and diseases are creating tremendous challenges in natural and social systems. Because of the special climatologic characteristics, fragile topography, glacial melting and ever increasing deforestation rates, floods are a particular challenge to Nepal. It is likely that climate change will further exacerbate the problem as the frequency of high intensity rainfall is projected to increase, demanding special attention to flood mitigation and adaptation points of view.

The West Rapti river basin, lying in the mid-western part of Nepal, has the general characteristics of other major river basins in that country. This dissertation examines key elements of the West Rapti Basin as a socio-hydrological system in order to develop recommendations for flood mitigation and adaptation strategies. The specific objectives of this dissertation were to: (1) analyse hydro-climatic time series data and develop probable future climate scenarios for the West Rapti River basin, Nepal; (2) perform hydraulic modeling to assess flood inundation in the study area and develop a flood hazard map; and (3) analyse potential adaptation strategies.

These objectives were addressed through the integration of three forms of analysis: (1) Hydraulic modelling to determine flood return periods and prepared flood zoning and hazard mapping under four climate change induced flood scenarios (current case: Scenario I; flood of 2030: Scenario II; flood of 2070: Scenario III; and flood of 2100: scenario IV); (2) Economic estimation of the willingness to pay (WTP) for flood mitigation in different flood zones (critical, moderate and low flood prone) and the flood scenarios; and (3) Social assessment to identify potential impacts of flooding in the Basin and some of the possible adaptive responses and preferences of the local people in regard to these responses. In addition, the study examined how adaptation strategies may change over time with exposure to climate change scenarios in different flood prone zones.

For the hydraulic modelling, hydro-meteorological time series data enabled investigation of the change in flow-related statistics over time, while spatial data were used to represent the physical settings of the Basin. Contour and land use data were used for flood analysis at different return periods and hydraulic modeling was performed using HEC-RAS to simulate the hydraulic process of the Basin for preparing the flood hazard zones.

With regard to economic and social assessments, a multi-stage, multi-level and multi-stakeholder process was followed. Initially, in consultation with central level stakeholders by way of interviews and local level stakeholders through focus group discussions (FGDs). The FGDs were helpful in identifying and understanding pre-flood, during-flood and post-flood adaptation strategies, both at household and community levels, and pre-testing the semi-structured questionnaire for the household survey. This questionnaire was then administered through 240 randomly selected households from all flood zones and a range of socioeconomic backgrounds. In order to elicit information regarding appropriate adaption strategies and WTPs, flood maps of different flood scenarios were shown to all respondents. Finally, key academicians, civil society and government officials were briefed on the issues and priorities identified from the field level survey, and they were also interviewed for possible policy level interventions.

Analysis of meteorological data shows that the annual average temperature of the study area is increasing at a faster rate than the national (0.06ºC) and global average (0.03°C). Similarly, the intensity and magnitude of rainfall and thus floods is increasing. Similarly, the monsoon season is

shifting more towards the currently defined ‘post-monsoon’ season, highlighting a need to redefine the timing of the monsoon season and to identify appropriate crops, as well as planting and harvesting times for these. It is predicted that the area of critically hazardous flood zone will gradually increase under future flood scenarios.

The average WTP varied by flood hazard zone and, within the zone, by climate change-induced flood scenarios. The average WTP of respondents was highest for the critical flood prone zone, followed by the moderate and low flood prone zones. Similarly, within each zone, average WTP increased with increasingly divergent climate scenarios. As expected, for all scenarios, average annual crop income, livestock income and damage costs were highly positively correlated with average annual WTPs.

As floods are part of their life, local people have adopted various adaptation strategies, both at individual and community levels. At an individual or household level, “construction of drain to divert the floods”, “caring children, elderly people and releasing domesticated animals” and “managing household foods and martials” were the three most prioritised pre, during and post flood adaptation strategies, whereas at community level, “developing flood management plan”, “updating contact information” and “exchanging helps to each other” were perceived to be most important.

This study found that peoples’ ways of thinking and their preferences for particular adaptation strategies changed with exposure to climate change scenarios. For example, a less sever flood scenario I, the simplest and least expensive form of adaptation strategy “bamboo mesh with sand filled bags” was most preferred; however, its perceived importance reduced with exposure to the more severe future flood scenarios. With exposure to an intense flood scenario, the most complex and expensive adaptation strategy “reservoir/flood regulating structures” emerged as the most preferred. The process and results of this study highlight two things: the importance of visual aids to understand the magnitude of floods impacts; and the value of information about projected flood levels and potential risk to enable people to choose appropriate adaptation strategies.

Furthermore, there is poor co-ordination between and within flood related government and non-governmental organisations in Nepal, and flood victims are getting little support from them. Local people are left alone to mitigate and adapt to flooding on their own. Many flood related committees, plans and actions have been initiated and maintained by flood affected people. However, this knowledge and these practices have not been scientifically validated, pointing to a need to address this issue; scientifically validated indigenous and local knowledge and skills have potential to become sustainable flood adaptation options.

This research bears special significance for the West Rapti River Basin as it provides field based evidence to policy makers and other key stakeholders to identify and prioritize areas for flood adaptation, to adopt appropriate policy and programs, and to allocate and justify scarce public and private resources. However, the overall approach and methodological framework for socio-hydrological analysis would be applicable in different parts of Nepal and developing countries, with similar bio-physical and socio-economic conditions and flood problems.

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List of Abbreviation

ADB	Asian Development Bank
AUSD	Australian Dollar
CBS	Central Bureau of Statistics
CRF	Cumulative Relative Frequency
CVCA	Climate Vulnerability & Capacity Analysis
CPN	Communist Party of Nepal
CO_2	Carbon dioxide
CH_4	Methane
CV	Contingent Valuation
DDC	District Development Committee
DEM	Digital Elevation Model
DHM	Department of Hydrology and Meteorology
DWIDP	Department of Water Induced Disaster Programme
DEM	Digital Elevation Model
EEA	European Environmental Agencies
EU	European Union
GIS	Geographical Information System
GCM	General Circulation Model
GLOF	Glacial Lake Outburst Floods
GoN/MOE	Government of Nepal/ Ministry of Environment
FGD	Focus Group Discussion
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HH	Household
I/NGO	International/Non-Government Organization
ICHRAM	International Centrel for Water Hazards & Risk Management
IPCC	International Panel for Climate Change
IUCN	World Conservation Organization
ICIMOD	International Centre for Integrated Mountain Development
KII	Key Informants Interview
LAPA	Local Adaptation Programme of Action
MASL	Mean Above Sea Level
MOF	Ministry of Finance
MOHA	Ministry of Home Affairs
MOEST	Ministry of Environment, Science and Technology
NCVST	Nepal’s Climate Vulnerability Study Team
NAPA	National Adaptation Programme of Action
NOAA	National Oceanic and Atmospheric Administration
N_2O	Nitrous oxide
OECD	Organisation for Economic Co-operation and Development
PVA	Participatory Vulnerability Assessment
SPSS	Statistical Package for the Social Sciences
TKP	The Kathmandu Post
UNFCCC	United Nations Framework Convention on Climate Change
UN/ISDR	United Nations/ International Strategy for Disaster Reduction
UNDP	United Nation Development Programme
USD	American Dollar
VDC	Village Development Committee
WRRB	West Rapti River Basin
WTP	Willingness To Pay
WAI	Weight Average Index

Chapter 1: Introduction

1.1 Background of the Study

The climate is changing with varying levels of impact on people across the world (UNFCCC 2013). While climate change is global in scale, developing countries and their people tend to suffer the earliest and the most because of high vulnerability to climatic stress and low resilience (Comrie 2007). The South Asian region is one of the most sensitive regions, as many countries in the region have weak economies and low resilience and adaptive capacity to the impacts of the changing climate (Stern & Britain 2006). Several studies (Nan *et al*. 2011; Olmstead 2013; Lespinas *et al.* 2014) argue that climate change will have a long-term impact on hydrological regimes, which in turn is likely to affect agriculture and livelihoods, public health and water resources (Maharjan 2011). As in other South Asian countries, increases in the frequency and intensity of extreme events such as floods and droughts, as well as glacier melting processes, are creating tremendous challenges in water resources management in Nepal. However, because of the special climatologic characteristics and topography of the country, floods are a particular challenge to Nepal in the face of climate change, demanding special attention both from mitigation and adaptation points of view.

The average annual rainfall of Nepal is about 1,750 mm, ranging from more than 5,000 mm in the central part of the country to less than 250 mm in the higher Himalaya in the north (DHM 2008). Summer monsoons bring around 80 percent of the annual rainfall with that rain more intense in the east of the country, declining westwards, while the winter rain falls heavily in the north-west and declines to the south-east (Romilly & Gebremichael 2010). While no significant change in the total amount of annual precipitation was experienced between 1971 and 2005, there was a shift to higher intensity rainfall but fewer rainy days (Marahatta *et al.* 2009). Dixit (2003) links increasing probability of an increased frequency of high flows in the country to the direct relationship between rainfall pattern and river flow. The impact of snow and glacier melts resulting from increasing temperatures will further exacerbate the high flow phenomenon in snow fed rivers of Nepal.

Physiographically, Nepal is divided into three major regions: the Mountain region in the North, the Middle Hills and the Plains region, known as Terai, in the south. The difference in altitude is more than 8,000 m within the 200 km north-south width of the country. Almost all rivers in Nepal flow from the Mountain and Hills regions to the Plains region of the country before flowing into India. When rivers reach the plain of the Terai region where the gradients are small the water surface level is relatively high for a given discharge. Because of the low velocity of the flow, the sediment carried by these rivers is largely deposited in this region. The aggradation of the river bed and consequent increase in the water level in rivers results in the overtopping of banks causing inundation of adjoining areas.

The West Rapti River Basin, lying in the Mid-western part of the country, has the general characteristics of major river basins of Nepal except that there is no contribution to flow from melting snow and glacier. It has a catchment area, within Nepalese territory, of about 6,500 km^2 (Pathak *et al*. 2008). Flooding is a recurrent phenomenon in the plains region of the River Basin. Recent floods have damaged physical infrastructure, caused difficulty in mobility, brought about water borne diseases and health hazards, caused fear and trauma in the people, reduced crop production and contributed to other social problems such as migration (Basnyat 2005; Gautam *et al.* 2010). In addition to rainfall patterns, the construction of the Laxmanpur barrage across the West Rapti River and Kalkaluwa Bandh (dyke) on the Indian side and other human interventions on the banks and floodplains are major contributors to flooding in the River Basin (ICHRAM 2008).

Climate change is likely to contribute to increasing flood magnitude and damage to public and private property in this basin (Das *et al.* 2013). Having both long and short term advance information about flood risk can however save many lives and millions of dollars worth of property. This research develops flood scenarios under probable future climate change, assesses the value of information to residents of the West Rapti River Basin and, from those steps, proposes adaptation strategies. This socio-hydrological analysis (Baldassarre *et al*. 2013 and Kandasamy *et al.* 2013) takes two approaches. First, methodologically, the study combines (i) social and economic surveys to determine attitudes and responses to floods with (ii) hydrological modeling. Secondly, the study assumes a dynamic interaction between floods and human decisions: flood events change social and economic choices, while human choices, such as river training work and land clearing, change floods (Safarzyńska *et al*. 2013).

1.2 Statement of Problem

In the last 100 years (1906–2005), average global temperature has increased by 0.74°C and average global rainfall by 5 to 10 percent (IPCC 2007). The annual temperature in Nepal rose by 0.4 to 0.6°C from 1971 to 2005 and rainfall changes across the country varied from -3 to +36 percent (GoN/MOE 2010). High rainfall regions and seasons are generally becoming wetter, whereas low rainfall regions and seasons are becoming drier (Gurung 2010). The linear trend of monsoon rainfall from 1971 to 2005 shows a slight increase in rainfall amount and a temporal shifting of its pattern in recent years (Baidya *et al.* 2008). It now tends to begin later, with irregular, unpredictable and more erratic rainfall causing more frequent flash floods. Both the number of monsoon days, with early onset and late withdrawal, and the intensity of monsoon rain have shown increasing trends (Sharma & Shakya 2006).

Studies show that the adverse impacts of floods are more significant in developing countries such as Nepal, making a weak economy even weaker (Manton *et al.* 2010). This was evident in 2007, when intense rainfall-induced floods in various parts of the country resulted in a huge loss of agricultural land and products.

There were similarly severe floods, in 2008, at Koshi in the eastern part and the West Rapti (Sinha *et al*. 2008). The Mid-western regions of Nepal, where the West Rapti River Basin lies, now experience greater than expected flooding, result in immense damage to lives, properties and serious losses in production every year (Marahatta *et al.* 2009).

People have been facing increased flooding on the banks of West Rapti River over the last few decades (Gautam & Oswald 2008); however, there has been little progress made on minimising the impacts of floods, other than locally developed warning systems. Lack of information on flood scenarios and a lack of effective adaptation measures are likely to mean that, under climate change, the extent of damage due to flooding in the Basin will become increasingly severe. Appropriate flood mitigation and adaptation measures, based on objective analysis, are imperative if the lives and property of people in the plain region of West Rapti River Basin are to be protected.

An integrated approach, coupling climate change and flood adaptation strategies with long term flood information and associated risk analysis, is required for the selection of adaptation strategies (Dawson *et al.* 2011). However, such flood adaptation strategies would also need to include considerations of: cost, given that Nepal is a developing country and incomes in this region are relatively low; the strong economic ties that people have to the flood-prone areas, with few options for alternative income and housing; and the relatively low education levels of the people. An assessment of both technical and socio-economic aspects of each basin is needed in order to provide a sound basis for the development of long term flood adaptation strategies. This research takes a case study approach, exploring floods of various return periods and associated flood impacts in the West Rapti River Basin and projecting forward to include additional impacts that are predicted to result from future climate change.

In particular, there is a need to identify adaptation responses that are acceptable to those people and communities affected by floods. Critical to this analysis is the value of assets likely to be affected by flooding as this helps determine the willingness to contribute, either monetarily, or in kind, to adaptation strategies. Apart from market prices, one indicator of land, and therefore land protection, value is utility (Ali 2007). The utility value of an area is directly related to the nature of the built infrastructure and land use practices and includes the economic output from those resources; hence, these values will change with changes in flood effects. Flood fluxes can vary over time and space (Randolph 2004) as can preferences for flood mitigation and adaptation. In this context, mitigation is about offsetting some of the physical impacts of flood waters, while adaptation is the adjustments made by individuals and communities to continue their livelihood under the flood risks that result from climate change and variability (Grothmann & Patt 2005; Reid *et al.* 2007; Smit & Wandel 2006).

The willingness to pay (WTP) for flood mitigation or amelioration among owners of houses and agricultural and forest lands varies according to individual location, dependency on natural resources, income and social situation (Hall *et al.* 2003).

Furthermore, the level of WTP may also vary with different levels of exposure to flooding. For this study the WTP for flood mitigation by the flood affected people was evaluated and an assessment made of the perception of the community regarding floods and potential climate change impacts on them. It is anticipated that the analyses in this study may provide a sound basis for the appraisal of policy options, allocation of resources and monitoring of substantial government investment in flood management.

This study focuses on the assessment of climate change induced flood dynamics and potential impacts of flooding in the West Rapti River Basin, as well as some of the possible adaptive responses and preferences of the local people in regard to these impacts. This research provides an overall framework for deriving potential mitigation and adaptation strategies to climate change for Nepal in particular and other developing countries in general.

1.3 Goal and Research Objectives

Goal

The overarching goal of this study was to analyse the dynamisms of perceived impacts and flood adaptation strategies in relation to levels of exposure to climate change induced flood scenarios in Nepal.

Specific objectives:

i) To analyse hydro-climatic time series data and develop probable future climate scenarios for the West Rapti River Basin, Nepal.

ii) To perform hydraulic modeling to assess flood inundation in the study area and develop a flood hazard map.

iii) To analyse potential adaptation strategies in order to:

- To determine the WTP of people with and without exposure to flooding in response to different climate change induced scenarios.
- To analyse current flood adaptation strategies and how people change their adaptation strategies in relation to their level of exposure to flooding.
- To rank potential flood adaptation strategies and furnish policy feedback to the different stakeholders.

1.4 Significance of the Study

This study will advance the knowledge of the socio-economics of flooding of vulnerable communities, through the development of a multi-disciplinary framework for assessing a dynamic socio-hydrological system. The information obtained from the study, and the sharing of its results with different stakeholders, will be beneficial in designing appropriate flood adaptation strategies. There has been research on flood forecasting and mapping for developed countries (Parry *et al*. 2009), although the resulting models are based on short time periods and their predictive value is limited (Arnell & Delaney 2006). Developing countries, however, are far behind in using these types of analyses even for short term forecasting and preparation. This research will help policy makers to develop a framework which will: (1) identify priority areas for adaptation policy interventions; and (2) target and justify adaptation funding and programmes. Similarly, this research will provide an assessment of the aspirations of local people, especially indigenous communities, as well as scientific backing to policy makers at government level on possible information about climate change impacts and different flood risk scenarios.

Uncertainty about flood frequencies and severity (Pettengell 2010) and limited knowledge of climate change have heightened the importance of adaptation measures that can avoid and/or mitigate the impacts of floods in settlements and agricultural lands (Revi 2008). Adaptive capacity is presumed to be determined by community characteristics such as income, wealth, equality and social stability, access to infrastructure and natural resources, institutional support and social capital, all of which either facilitate or constrain the ability of a community to deal with climate-related risks (Sutherland *et al.* 2005). It is therefore important to know: how people are adapting to floods and consequent flood disasters; how much they are willing to pay to avoid such flood disasters; and what the key attributes are that affect their WTP. The outcomes of this study will help governments to choose, from among the many alternatives, appropriate adaptation strategies that are both most preferred by local peoples and also most cost-effective.

Even though this research is undertaken in a single catchment in Nepal, the basic methods and framework developed in this research are expected to be applicable elsewhere in the world and the research finding will to be useful in enhancing the existing knowledge in this field to the scientific community.

1.5 Scope and Limitation of the Study

The scope of this study is rain-fed flooding in a region of a developing country where there is high dependency on agriculture and high vulnerability to climate variability. The assumption here is that climate change may influence climate variability, potentially resulting in a range of adverse impacts.

This study utilises the concept of socio-hydrological analysis (Sivapalan et al., 2011; Kandasamy et al 2013; Baldassarre et al 2013), the science of people and water, a new science that is aimed at understanding the dynamics and co-evolution of coupled human-water systems. In socio-hydrology, there are wider ranges of controls related to socio-economic and hydrologic processes at a range of scales.

This study is focused on the perceived impacts and flood adaptation strategies in the Plains region of the West Rapti River Basin, Nepal. While this research utilizes scientific approaches to assess flood scenarios in the study area, it has a number of limitations including:

i) Use of an areal transposition method to estimate flows in the tributaries lying in the Plains region; this method gives only approximate values, since, flows are influenced by runoff which in turn is a function of rainfall, topography, soil characteristics and catchment area.

ii) Use of one dimensional steady flow for the estimation of water levels and inundation depths although flow phenomena are two dimensional and unsteady; this overestimates the inundation depth.

iii) Exclusion of river bed aggradations due to sediment coming from upstream and generated by bank cutting/erosion. This may result in underestimation of the water surface elevation in the river.

iv) Use of relatively coarse contour maps with 20 m intervals in preparing the digital elevation model.

1.6 Organization of the Dissertation

This thesis is organised into nine chapters which capture the major stages and themes of the research. Chapter 1 of the dissertation provides the background to the research, including its aims and objectives, while Chapter 2 presents a review of the existing flood risk literature, with particular focus on the conceptualisation of flood impacts and their modelling. This chapter also presents a review of approaches to flood risk mapping, adaptation measures and possible WTP. Chapter 3 details the study area and Chapter 4 presents the methodological framework used in the research.

Chapter 5 presents climate change scenarios, hydrological modelling and flood risk mapping at different flood exposures for the West Rapti River Basin study area. Chapter 6 and 7 present research findings on the level of WTP of the people for avoiding flood risk and flood adaptation strategies adopted by people living in the West Rapti River Basin, respectively. Discussion of results is presented in Chapter 8 and Conclusions and Recommendations from the research are presented in Chapter 9.

1.7 Conclusion

Developing countries, such as Nepal, are highly vulnerable to flood events and it is likely that this vulnerability will be exacerbated by climate change. While there is some awareness of this threat amongst international and national agencies, there are limited studies of, and methodologies for, analysing local flood vulnerabilities and the socio-economic conditions that will influence responses to flooding. This study aims to develop a methodology for regional assessment, using the West Rapti River Basin of Nepal as a case study. This basin has a history of flood events, resulting in considerable social and economic costs. This work will inform both policy-makers and local adaptation strategy development.

Chapter 2: Understanding Flood Risks under Climate Change

2.1 Introduction

This chapter summarises the information on climate change and its impacts on water resources, rainfall pattern, flood and its impacts, people's willingness to pay for flood control measures and potential flood adaptation strategies and practices. Based on the reviewed literature, the knowledge gaps in this field considering the case of Nepal are identified and listed at the end of this chapter.

2.2 Climate Change and Its Impacts

Climate change refers to a persistent change in the state of the climate and in the mean value and variability of its properties over an extended period of time (IPCC 2007). Climate Change projections from different General Circulation Models (GCMs) show that global temperatures are generally increasing. According to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2001), the global average temperature will increase by 1.4°C to 5.8°C between 1990 and 2100 if levels of greenhouse gas emissions (a key driver of climate change) are not substantially reduced. The level of emissions is mainly attributed to anthropogenic activities, especially the use of fossil fuels in developed and developing countries. An increase in global average surface temperature is very likely to lead to changes in hydro-climatic condition and changes in precipitation (McCarthy 2001; Pant 2012). Marahatta *et al.* (2009) argues that changes in precipitation, temperature and other climatic parameters in a specific area can significantly affect the biophysical and socioeconomic circumstances of that area.

Climate is indicated by average statistics of meteorological conditions (David *et al.* 2011). It refers to the average weather in terms of the mean and its variability over a period of time ranging from months through to thousands or millions of years. Climate is influenced by the fluctuating state of the atmosphere and characterised by variables such as temperature, precipitation, wind, solar radiation, clouds, air pressure and humidity (IPCC 2007).

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) defines climate change as a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC 2007). However, the United Nations Framework Convention on Climate Change (UNFCCC) states that climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (UNFCCC 2001).

This means that communities/regions which are primarily dependent on natural resources for their livelihood are likely to become significantly more socially and economically vulnerable in the coming days due to climate change impacts. This might include many Asian and African countries.

2.2.1 The global context

The earth's global average temperature has risen by about 0.8°C since the 1850s and 0.74ºC in the last 100 years (IPCC 2007). The rate of increase has been 0.074°C per decade over the period from 1906 to 2005, but 0.13°C per decade in the last 50 years (1956 to 2005). This suggests that the world climate is changing more rapidly at present than any time period in the recorded past (Vijaya *et al.* 2011). Figure 2.1 depicts the global temperature trend from 1950 to 2100. It is noticeable that the rate of temperature rise has increased since the 1980s. The black line shows the change in historical global average surface temperature while blue and red line represent aggressive greenhouse gas reduction and business as usual emission scenarios.

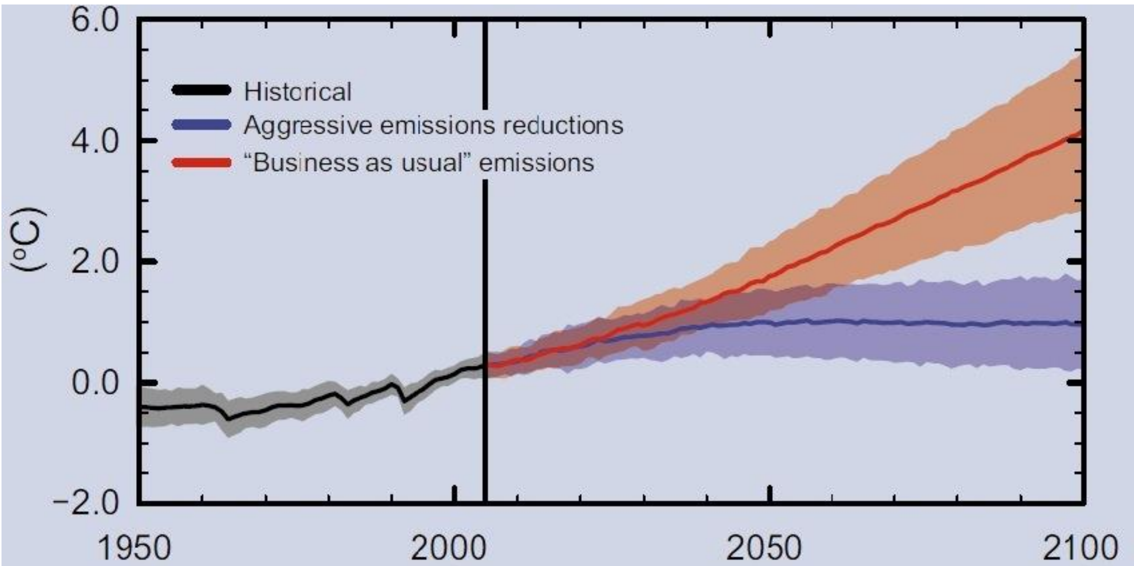

Figure 2.1: Global average surface temperature change (Source: IPCC, 2014)

Global average surface temperature also increased from 0.56 to 0.92°C over the 100 years from 1906 to 2005 (IPCC 2007). The increase in global temperature is attributed to greenhouse gases (GHGs), including CO_2, CH_4, N_2O and halocarbons. Since, pre-industrial times, the atmospheric concentrations of these gases have increased due to various human activities (UNFCCC 2001). Solomon *et al.* (2007) estimate that, between 1970 and 2004, GHG concentrations in the atmosphere increased by about 70%. The increase of these gases has resulted in the warming of both land and ocean surfaces over the 20th century (Joussaume & Taylor 2000).

Global average precipitation increased by 5 to 10 percent during the 20th century, but has decreased by 3 percent on average in much of the sub-tropical zones (IPCC 2007). Trends from 1900 to 2005 indicate that precipitation has increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia and declined in the Sahel, the Mediterranean, southern Africa and parts of southern

Asia (Solomon *et al.* 2007). There has also been an increase in the frequency and intensity of some extreme climate and weather events associated with increasing climatic variability (Gurung & Bhandari 2009).

Climate is part of the daily experience of human beings and the elements of it are essential for food, health and well-being (IPCC 2007). The impacts of climate change are in different regions globally with a rise in sea level, changes in precipitation patterns, a vegetation shift in higher altitudes, and the retreat of glaciers. It is predicted that future climate change will trigger an increase in extreme climatic events and numbers of climate refugees. Due to an increase in temperature and climate induced hazards such as drought, flood and soil degradation, there is a significant risk of a decline in agriculture productivity with subsequent impacts on food security (IPCC 2007).

Researchers working in different fields (e.g. in water resources and agriculture) have identified numerous problems in ecosystems as a result of climate change (Khanal 2009). Changing precipitation patterns (e.g. intense rainfall of shorter duration) results in floods and higher runoff while reducing the ability of water to infiltrate the soil. Shorter periods of infiltration during rain events and longer periods without rainfall lead to decreases in the recharge of groundwater sources. There is global concern that climate change, in concert with changes in the earth surface, will influence the recharging of groundwater and, in the longer run, affect aquifers (Bartlett *et al.* 2010).

Glacier retreat is likely to continue, and many small glaciers may disappear. Flood magnitude and frequency are likely to increase in most regions, while low flows are likely to decrease (Leduc *et al.* 2008). Water quality may also respond to changes in the amount and timing of precipitation. It can be expected that new patterns of runoff and evaporation will affect natural ecosystems. Freshwater ecosystems will respond to altered flood regimes and water levels. Rising sea level could invade coastal freshwater supplies.

Changes in seasonal rainfall patterns may, thus, affect the regional distribution of both ground and surface water supplies for various uses including irrigation and drinking (Khatri & Smith 2006). Reduced water supplies would lay additional stress on people, agriculture and the environment (Khatri & Smith 2007). Exploitation of natural resources, conflicts of interests and poverty dynamics could be sparked by these additional pressures as complex feedbacks between climate change, water availability, population growth and economic growth gather momentum. So, climate change is likely to add to economic and political tensions, particularly in regions that already have scarce water resources (Le Blanc & Perez 2008).

2.2.2 The South-Asian context

Several studies suggest that, among the different regions of the world, South Asia is the most sensitive to climate change (Ahmad 2004); Figure 2.2 shows the surface temperature anomalies for the last 30 years in South Asia with a trend of which provide the increasing temperatures. The projected average temperature increase for South Asia is 3.7°C by 2100 (Kumar and Kamra 2012) which is more than the projected global increase. This region depends very heavily on the monsoon precipitation, as well as water derived from the glacier melts in the Himalayas, for agriculture and other water uses; both of these are affected by climate change. While floods are the most frequent and devastating natural disasters, this region also suffers from other climate related adversities such as storm events and droughts.

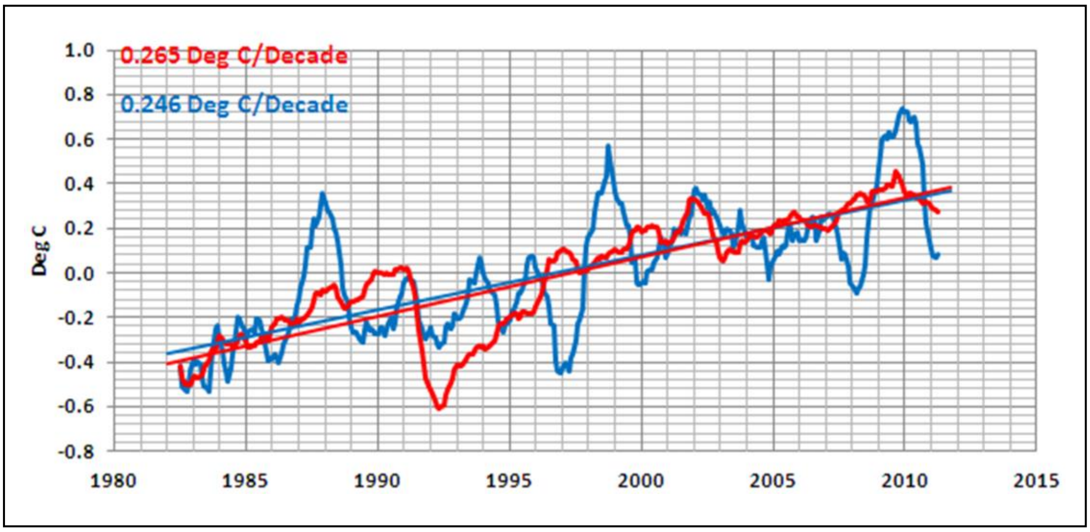

Figure 2.2: Southern Asia land surface temperature anomalies for the last 30 year (Jan 1982 to Oct 2011) Source: IPCC, 2007

The increased frequency of extreme weather events has been attributed to climate change (Watts *et al.* 2011). South Asia have been noticed in over the last century (Ismail *et al.* 2013); in particular, while there has been a decrease in the number of rainy days and total annual precipitation, the frequency and intensity of rainfall events has increased in many areas (García *et al.* 2007). Over the past thirty years, the number of flood disasters has also increased compared to other forms of disaster (Dutta & Herath 2005). Extreme precipitation events exacerbate risks of disastrous phenomena both in upland watersheds, where such events can trigger landslides, and in lower floodplains which are often densely populated (Balica *et al.* 2013).

The impacts of increasing temperatures, more variable precipitation, more extreme weather events, glacier melting and the consequent flash floods are already having major impacts on the economic performance of South Asian countries and on the lives and livelihoods of millions of poor people. Such impacts result not only from gradual changes in temperature and in water resources but also, in particular, from increased climate variability and extremes, including more intense floods, droughts and storms (IPCC 2007).

These changes place increasing pressure on natural resources and the environment and have severe socio-economic implications in South Asia. Decreased water availability and water quality in many arid and semiarid regions, an increased risk of floods and droughts in many regions, increased incidence of waterborne diseases, adverse effects on many ecological systems and increased migration within and across national borders bring both environmental and socio-economic challenges (Baidya *et al.* 2008). Changes in the Himalayas in terms of climate would be a catastrophe across South Asia as it is not just the future of a few mountain communities at stake, but the lives of nearly 1 in 4 people in the world, all of whom rely on the Himalayas for water; Nepal's rivers alone provide water for 700 million people in India and Bangladesh. Crop yields could also be significantly affected (Pradhan 2009; Sonkar *et al.* 2009). It has been feared that if there is less snow in the Himalayas, or the monsoon rains weaken, or the glaciers melt with climate change, then all South Asian farming, industries, water supplies and cities will suffer (SAAPE 2010).

In South Asia, hundreds of millions of people depend on perennial rivers such as the Indus, Ganges, and Brahmaputra-all fed by the unique water reservoir formed by the 16,000 Himalayan glaciers. The current trends in glacial melt suggest that the low flow will become substantially reduced as a consequence of climate change (IPCC 2007). Rees & Collins (2006) believe that, if all Himalayan glaciers disappeared, the impact on water resources would be greatest in the western regions, with a reduction in annual mean flow of about 33% in the west and about 4-18% in the east compared to 1990 levels, because of the climatic differences between the drier western and monsoonal eastern ends of the region.

The Asian continent is much affected by floods and countries such as India, China, Philippines, Iran, Bangladesh and Nepal are extremely vulnerable (Xu *et al.* 2007). The majority of victims of flood disasters are poor people, who suffer most and are the first casualty of such incidents. Asia is struck by 70% of all floods in the world and the average annual cost of floods over the past decade is approximately 15 billion USD (Hansson *et al.* 2008).

2.2.3 Nepal's context

Average temperatures in Nepal are increasing at a rate similar to the phenomenon observed globally. Shrestha *et al.* (1999) analysed temperature data for Nepal over 30 years and 49 stations and showed that average temperature increased consistently and continuously after the mid-1970s (Figure 2.3). The average annual temperature has risen by 0.06ºC from 1977 to 2000. The trend analysis conducted by DHM (2008) shows that average temperature in Nepal increased at a rate of 0.05ºC per year from 1971 to 2005; similarly, Marahatta *et al.* (2009) found that the maximum temperature increased at a rate of 0.05°C per year and the average minimum temperature at 0.03°C per year during the years 1975 to 2005. A recent study by Pokhrel and Pandey (2011) indicates that Nepal's temperature is currently rising by about 0.4°C per decade. Figure 2.3 shows the projected mean annual temperature anomaly for Nepal based on three commonly used warming scenarios. Other studies have shown that the rate of temperature increase is greater at higher altitudes (Baidya *et al.* 2008) and the increase in temperature is higher in winter compared to summer (Shrestha *et al.* 2012).

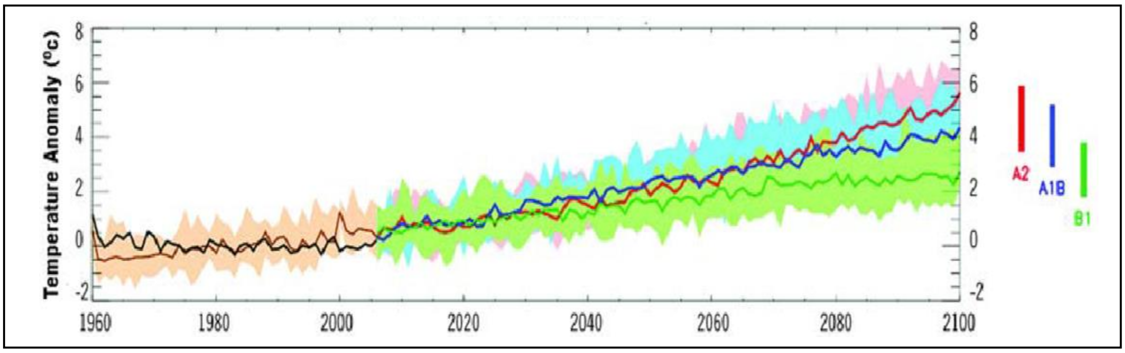

Figure 2.3: Mean annual temperature anomaly (%) for Nepal

Note: The black line shows observed mean annual temperature trend from 1960 to 2006. The brown line and shading shows the multi-model mean and range for models forced with observed GHG. The coloured lines and shading from 2006 onwards show multi-model mean and range of changes under three different emissions scenarios (Source: NCVST 2009).

At present, Nepal is responsible for about 0.025% of annual global greenhouse gas emissions (NAPA 2010) whereas it covers 0.03% land area and 3% of global population. However, it is among those countries at greatest risk from warming due to its fragile mountain ecosystems and nature-based subsistence livelihoods, with the rural poor and women particularly vulnerable (Gautam *et al.* 2009).

A study of the Bay of Bengal region, from Nepal in the north to Malaysia in the south, shows that temperature increase is more pronounced in Nepal compared to other countries (Devkota and Quadir 2006). Agrawal *et al.* (2003) reported that, according to model predictions, both temperatures and annual precipitation in Nepal will increase significantly throughout the 21st century. The aggregated analysis of 15 Global Climate Model (GCM) outputs predicts country-wide, mean temperature increases of 1.4^{0}C, 2.8^{0}C and 4.7^{0}C by 2030, 2060 and 2090, respectively (NCVST 2009; Table 2.1). These multi-model projections predict an increase in the number of hot days and nights, and in the number of heavy rainfall events during the monsoon period (Baidya *et al.* 2008). Likewise, the models identify similar increases in mean temperatures for Western Nepal over the next 20, 50 and 80 years; however, modelling indicate less extreme changes in monthly precipitation and heavy rainfall events compared to the country-wide projections (NCVST 2009; Table 2.1).

Table 2.1: Projected multi-model GCM climate change variables for Nepal and Western Nepal

	Nepal country wide			Western Nepal		
	2030	2060	2090	2030	2060	2090
Change in mean temperature: annual (^{0}C)	+1.4	+2.8	+4.7	+1.4	+2.8	+4.8
Change in frequency of “hot days” pre monsoon (%)[a]	-	+2.5	+43	-	+26	+40
Change in monthly precipitation annual (%)	0	+4	+8	0	+4	+3
Change in precipitation as heavy events: monsoon (%)	+2	+7	+16	0	+2	+6

Changes are relative to the mean for 1970-1999, run using the scenario
Hot days taken as hottest 5% days in the period of 1970 -1999. (Sources: *NCVST 2009*)

There are also varying impacts according to elevation. According to Nepal's Climate Vulnerability Study Team (NCVST 2009), the climate of Nepal is influenced predominantly by the Himalayan ranges and the South Asian monsoon. A study by the Department of Hydrology and Meteorology (DHM 2008) showed that altitude affects annual temperature and precipitation patterns. Up to about 1500 m, annual rainfall totals increase with altitude; thereafter, annual rainfall totals decrease with increasing altitude (Devkota & Quadir 2006). There has also been an increase in the number of flood days in certain rivers in Nepal and a reduction in the dependable flows of certain rivers in the dry season. Figure 2.4 shows the annual precipitation anomaly.

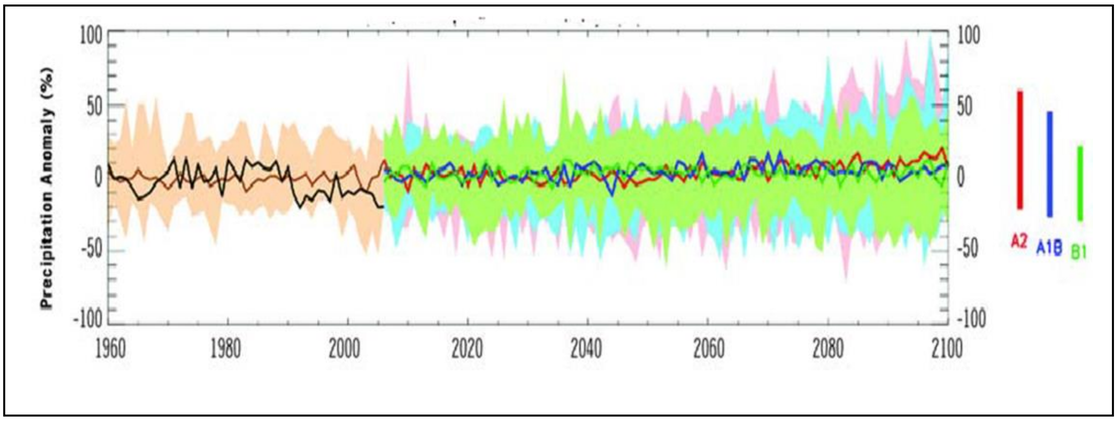

Figure 2.4: Mean annual precipitation anomaly (%) for Nepal

Note: Black line indicates observed mean annual rainfall trend from 1960 to 2006; the brown line and shading represent multi-model mean and range for models forced with observed GHG. Coloured lines and shading shows multi-model mean and range of changes under three different emissions scenarios (Source: NCVST 2009).

An overall increase in mean precipitation of 13 mm per year has been recorded, while the number of rainy days has decreased by 0.8 days per year from 1971 to 2005. A study of monsoon rainfall from 1971 to 2005 shows that there has been an increase of about 2.08 mm/year, although with large inter-annual variation (APN 2005). An increase in summer river flows also suggests higher rates of glacier melt/retreat (Dahal 2006).

The annual mean precipitation in Nepal is expected to rise by 5.0% by the year 2030, 7.3% by 2050 and 12.6% by 2100, so flooding may increase (NCVST 2009). General circulation model (GCM) estimates show a sharp increase in monsoon precipitation of 23% by the year 2100 compared to an increase of only 2.1% in the winter season. Unusual late or pre-monsoon precipitation and more intense rainfall events have caused more runoff. Monsoon rainfall patterns have also shifted from mid-July to late August (Marahatta, *et al.* 2009). With these changes, Nepal has deep concerns about climate change as more than two million Nepalese people depend on climate sensitive sectors such as agriculture, water resources, fisheries and forestry for their livelihood (Garg *et al.* 2009).

The end-point of all climate induced water hazards in Nepal is that the communities are vulnerable to such hazards. Broader climate risks, including natural hazards such as landslides, floods and droughts affect the agriculture-based subsistence livelihood of poor people in Nepal (Regmi *et al.* 2006). The increase in frequency of climatic extreme events such as rainfall causing floods has adversely affected agricultural production (Regmi & Adhikari 2007); mountain settlements are prone to landslides and Terai ones to flooding. This vulnerability is particularly exacerbated during extreme weather events (Lohani 2007).

2.3 Conceptualising Flooding and Climate Change Impacts on Flooding

Long-term changes in the climate are generally accompanied by changes in the frequency of extremes (Carter & Parry 1994; Manandhar *et al.* 2011). Where floods are generated from heavy summer rainfall, the frequency and magnitude of flooding is likely to increase with an increase in precipitation and temperature (Frederick 1999; Malla 2008). Although climate change is a global phenomenon, both its trends and impacts may vary at a local scale. The local hydrology of every river in the world is likely to be affected by climate change in some ways. Changes in river hydrology resulting in increased flooding represent risks, not only to water resources and associated infrastructure but to physical and social assets as well (Gautam 2010).

Rivers and river systems are very important to community and even national development. Rivers and their adjacent flood plain corridors fulfill a variety of functions both as part of the natural ecosystem and for a variety of human uses (Lohani 2007); however, they often also cause great damage and death due to flooding. Flood hazard is the probability of occurrence of a potentially damaging flood event of a certain magnitude within a given time period and area (Brooks *et al.* 2005). Surface water flooding is caused by the volume of water falling or flowing into the surface overwhelming existing drainage systems (ICIMOD 2007; Kazmierczak & Cavan 2011); this includes pluvial flooding that results from high rainfall generated overland flow (Falconer 2009; Werellagama *et al.* 1997). Flooding/flood hazard is also a function of the surface of the land and characteristics of the river basin (Khatri 2007). Surface water flooding is predominantly caused by short duration, intense rainfall occurring locally and/or in upstream areas (Golding 2009; Scheuer *et al.* 2010). As a result, surface floods are often difficult to forecast.

Throughout human history, swelling rivers and floods have taken a heavy toll on properties and lives and have caused more economic losses of infrastructure such as water treatment plants than any other hazard (Pant *et al.* 2002; MOF 2011). High relief, steep slopes, complex geological structures with active tectonic processes and continued seismic activities and a climate characterized by great seasonality in rainfall all combine to make Nepal an area prone to natural disasters and, particularly, water induced disasters such as floods, landslides and glacier lake outburst flooding (Regmi *et al.* 2013).

The interactions between increased greenhouse gases in the atmosphere and hydrological systems are very complex (Figure 2.5). Increases in temperature could result in changes in evapotranspiration, soil moisture, (possibly) chance of soil salinity, and ground water (Maraseni *et al.* 2014; Khatri & Smith 2005). Increased atmospheric CO_2 may increase global mean precipitation as indicated by all GCMs (IPCC 2001;

Maraseni 2007) even though some sub-tropical areas will be generally drier. Increased evapotranspiration enhances the water vapor in the atmosphere and, thereby, the greenhouse effect potentially driving global mean temperatures rise even higher. Possible changes in rainfall, temperature and evapo-transpiration may result in changes in soil moisture (Khatri & Smith 2007) and groundwater recharge and runoff and could intensify flooding (IPCC 2001).

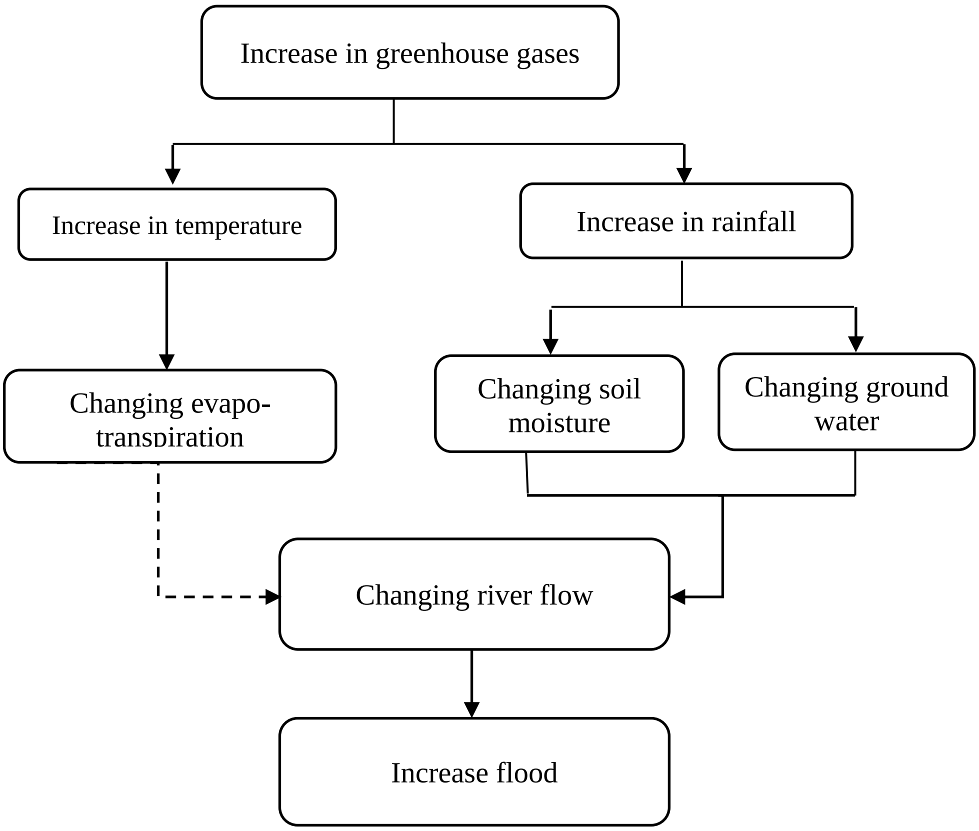

Figure 2.5: Flow diagram on the relationship between climate change and flood

2.4 Climatic Characteristics and River Systems in Nepal

Nepal has two rainy seasons. The more prominent of the two lasts from June to September when the south-west monsoon brings about 80% of the total annual rainfall. The other, which accounts for 20% of annual rainfall, occurs during the winter. The eastern part of the country experiences more rain than the western part. The rainfall is highest in the hilly regions of the central part of the country. It is particularly so at the southern flanks of the Annapurna Range and goes on decreasing both on the northern and southern sides. This is mainly due to the highly variable topography resulting in different orographic effects in the country. Pre-monsoon thunderstorms occur from March onwards as a result of the increasing temperature in the sub-continent (Sharma *et al.* 2000). They are usually strongest in the Terai but can also be high in the hills. They give appreciable amounts of rain in short periods.

Nepal is endowed with abundant water resources. The bodies of water are regarded as key strategic natural resources with the potential to act as the catalyst for the all-round development and economic growth of the country. There are about 6000 rivers in Nepal with a total drainage area of 194,471 sq. km, of which 74% lies within the country's borders. These rivers discharge about 225 billion m^3 of water annually (Bhattarai 2009) to India. As the rivers emerge on to plains from steep and narrow mountains gorges, they spread out with an abrupt gradient decrease that has three major consequences; deposition of bed load, changes in river course, and frequent floods (Gautam *et al.* 2010).

Depending on their source and discharge, rivers in Nepal can be classified into three types: first class rivers (originating from Himalaya), second–or medium–class rivers (originating from the Midlands) and third–or small–class rivers (originating from Siwalik Range). Figure 2.6 shows the four main major river basins in Nepal; the Koshi, Gandaki, Karnali and Mahakali. The rivers for each originate in the Himalayas and carry snow fed flows with significant discharges even in the dry season. The West Rapti, Babai, Bagmati, Kamala, Kankai and the Mechi are medium class rivers. These originate in the Mid-lands or the Mahabharat Range (Mid-mountains in Nepal) and are fed by precipitation as well as groundwater regeneration (including springs). These rivers are also perennial but are commonly characterized by wide seasonal fluctuations in discharge.

In addition to these large and medium river systems, there are many small rivers in the Terai which mostly originate in the Siwalik Range (southern facing small mountains). Monthly flows generally reach their maximum in July-August and decline to a minimum in February–March. About 80% of the total flow occurs during the five months from June to October and the rest during the remaining months. In general, the smaller the size of the river catchment area, the wider is the range of flow fluctuation. Among the medium rivers, West Rapti River is one of the most flood prone rivers in Nepal with a huge impact on life and property.

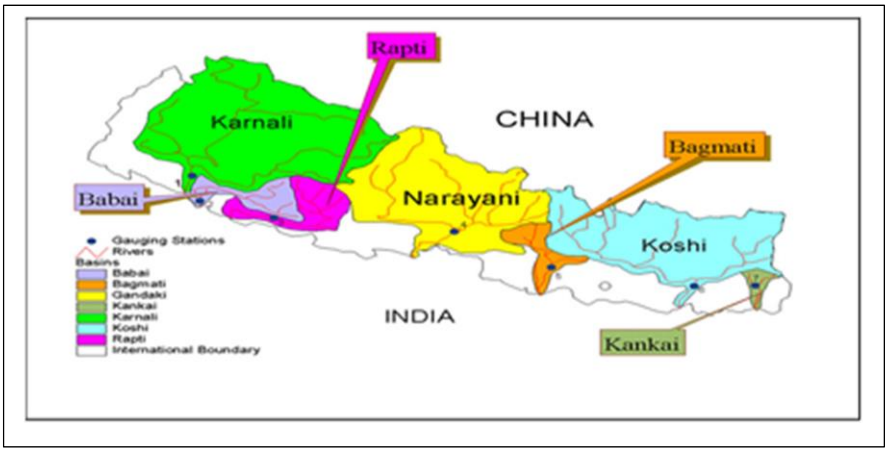

Figure 2.6: The major river basins in Nepal, Source: WECS 2011

2.5 Climate Change Induced River Flood Disasters

River floods have been defined as a general and temporary condition of partial or complete inundation of normally dry land areas from the usual and rapid runoff of surface waters from rainfall. “Flood” is used in a broader sense to cover several river phenomena that cause damage, i.e., inundation of flood plains and adjacent terraces, bank cutting, river channel shifting and debris torrents during high discharge (Agrawala *et al.* 2003).

Floods are the most common natural disasters affecting societies around the world. Liu and Diamond (2005) estimated that more than one-third of the world’s land area is flood prone, affecting some 82% of the world’s population. About 196 million people in more than 90 countries are exposed to catastrophic flooding, and some 170,000 deaths were associated with floods worldwide between 1980 and 2000 (Mosquera and Ahmad 2007). These figures show that flooding is a major concern in many regions of the world. The number of major flood disasters in the world has risen relentlessly over recent time, from less than 10 per decade in the 1950s, ‘60s and ‘70s to 18 in the 1980s and 26 in the 1990s (Mosquera and Ahmad 2007).

The Hindu Kush Himalaya region is called the water tower of Southeast Asia and third pole of the earth due to the large areas of glaciers and permafrost. It provides water resources for more than 1.3 billion people to grow food, produce electricity, sustain industries and provide drinking water. The retreat of mountain glaciers triggered by climate change is putting huge pressure on the scarce water resources of the region and any change in upstream water supply will affect millions of people downstream. Of late, the mountain region is experiencing an increasing frequency and intensity of extreme climate-related events such as glacial lake outburst floods, flash floods, monsoon floods and cloudbursts, which in turn bring down huge amounts of sediment (Werellagama *et al.* 1997) and large boulders thereby causing widespread damage to property and life downstream. It is projected that more variable, and increasingly direct, rainfall runoff will also lead to more downstream flooding (Eidsvig 2011). It has been documented that the floods have affected 3.4 million since 1980, at an average occurrence of once a year (Development Initiatives 2011).

Figure 2.7 shows the percentage of Nepal people affected by the various disasters, with flood accounting the highest 68.3% during 1980–2010. During this period, flood was the most common natural disaster, hitting the nation some 32 times.

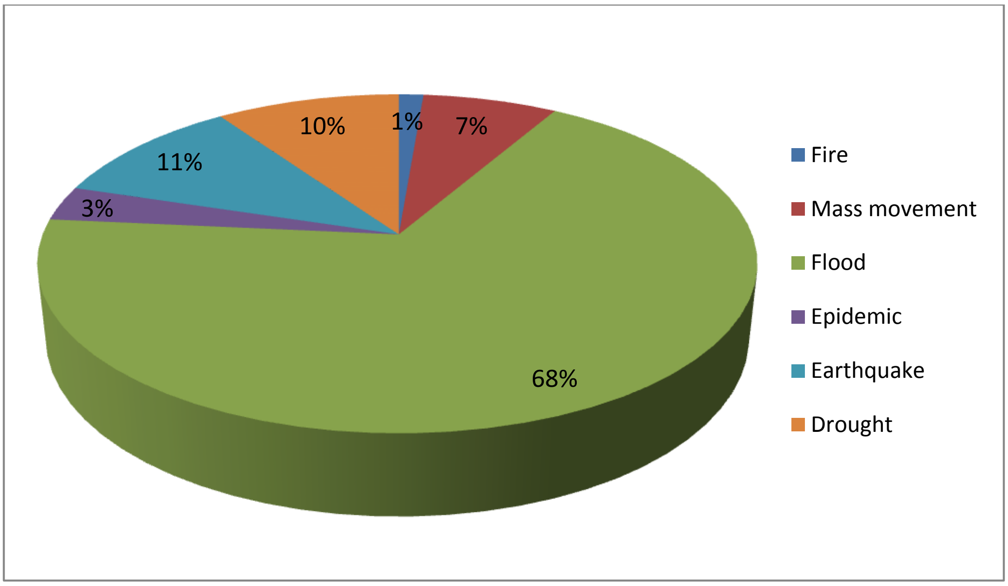

Figure 2.7: People affected by different types of natural disasters in Nepal from 1980 to 2010
Source: Development Initiatives 2011

The intensity and amount of monsoon rains positively correlates with increase in water induced disasters such as floods and landslides. About 29% of the annual number of human deaths and 43% of the annual total loss of property from all different disasters in Nepal are caused by water induced events such as floods, landslides and avalanches (Khanal *et al.* 2007). The climate related disasters have the highest impact on the human lives and property for the years 1954 to 2002 of which floods are the overwhelming problem as shown in Table 2.2.

Table 2.2: Climate related disasters in Nepal (1954–2002)

Disasters	**Killed**	**Injured**	**Homeless**	**Affected**	**Damage US $**
All disasters	20,927	7,794	153,550	7,053,754	1,316,413
Floods	5,003	725	69,350	1,531,125	990,613
Drought	0	0	0	4,400,000	1,000
Extreme Temperature	60	210		210	
Windstorms	97	19	0	184	3600
Climate related disasters	5160	954	69,350	5,931,519	1,004,213
% of climate related disasters	24.7	12.2	45.2	84.1	76.3

(Source: CRED 2003 cited in Regmi *et al.* 2006)

As shown above, floods occur repeatedly in Nepal and cause tremendous losses in terms of property and lives, particularly in the lowland areas of the country. Hence, they constitute a major hazard. Floods that cause substantial devastation in Nepal are triggered by five mechanisms: continuous rainfall and cloudbursts, glacier lake outbursts, landslides and dam outbursts, failure of infrastructure and sheet flooding or inundation as a result of excessive rain, bank overflow, or obstruction to flow from infrastructure development (Dixit 2003; Khanal 2005).

2.6 Impacts of Flood Events

2.6.1 Global and regional flood events

Nine global hydrological models driven by five global circulation models project an increase in flood frequency over half of the land surface, and a decrease in roughly a third of the land surface (Dankers *et al.* 2013). Each year, around the world, there is significant loss of life and property due to floods of which some floods cause massive disasters. For example, more than 145,000 people were killed and 3.7 million were affected by the 1931 flood events in China. The flood of Yellow River during September 1887 killed some 900,000 people in China. Likewise, more than 40,000 people lost their lives in Guatemala in 1949. Major flood events from 2002 to 2012, and their impacts, are provided in Table 2.3.

Table 2.3: Impacts of flood in the world

Year		Killed	Injured	Homeless	Affected	Damage
2012	North Korean	88		62,000	7,053,754	US $1,316,413
2012	Russia	172				
2011	Philippines		2,828			
2011	Cambodia			1.2 million		
2011	Brazil	903				
2010	Southern Africa	141				
2010	China		1,471	230 million		
2010	Rio de Janeiro	212		15,000		US$13.3bn
2010	Queensland, Australia	70			200,000	US$1 billion
2009	Saudi Arabia	100				
2009	Philippines	100				
2009	Turkish	31				
2008	South China	200+				
2007	Sudan floods	64				
2007	North Korea	1,348				
2006	Ethiopia	125				
2006	Philippines	1,144				
2005	China	1,624				
2004	Haiti, Dominican Republic	1,605-3,363				
2004	Brazil	165				
2004	China	1029				
2003	Indonesia	313				
2002	China	1,532				

Source: Joomla, 2012; BBC, 2010, NDRRMC, 2012

All countries of South Asia experience flooding, though the extent and level of damage differ from country to country. Bangladesh is the most affected country. According to Sivakumar and Stefanski (2011), South Asia suffers an exceptionally high number of natural disasters including Nepal where more than 750 million people were affected, leaving almost 60,000 dead and resulting in about $45 billion damage between 1990 and 2008. A flood across Mumbai, (India) in July 2005 left over 700 dead; some areas went under 5 m of water. Another flood in South India occurred in October 2009 where 250 people were killed and 500,000 made homeless. In 2008, most of India was affected by flooding at some stage throughout the year. Assam has suffered regular floods since 1998. Some provinces of Pakistan such as Sindh, Balochistan and Karachi also experience frequent flood events. Table 2.4 summarizes the flood events and damage in South-Asian countries from 2002 to 2012.

Table 2.4: Impacts of flood in the South Asia

Year	Country	Killed	Injured	Homeless	Affected
2012	Nepal	61		2000	
2012	Bangladesh	70		200,000	
2012	India	34			
2012	Bangladesh	100			250,000
2011	Bangladesh			84,000	
2011	Nepal	33			
2011	India	60			4 million
2010	India	180	300		400
2010	Pakistan	1400			3.5 million
2010	Pakistan	2,000			20 million people
2009	India	250		500,000	
2009	Pakistan	26	150		
2008	India	142			
2008	India	2,400			
2007	India	186			19 million
2007	Pakistan	228			
2006	Nepal	36			
2005	India	700			
2004	India	1,503			
2004	Eastern India	3,076			
2003	Nepal	885			
2002	Bangladesh	251			
2002	Nepal	429			
2002	India	489			

Source: BBC 2010, 2012, 2013; DWIDP 2012; Hofer & Messerli 2006; Red Cross 2012

2.6.2 Past flood events in Nepal

Nepal ranks 4th and 30th in the world with regard to relative vulnerability to climate change and flood hazards, respectively (Dangal 2011). Between 1983 and 2005, on average 309 people (32% of total deaths due to natural disasters) were killed annually by water-induced disasters such as flood, landslide and avalanches. About 70% of the families affected by natural disasters in the country are affected by water induced disasters. Nearly 77% of the total losses caused by water-induced disasters-floods, landslides and avalanches-occur in the Terai region where the main water induced disasters are floods (ICIMOD 2007).

The floods of August 2008 in Koshi River, September 2008 in Western Nepal and July and August 1993 in the Bagmati and other rivers were the most devastating floods in Nepal. Nepal has experienced both monsoon and flash flooding. Rainfall variability (unequal rainfall in time and space), topography (steep mountain and flat Tarai) and deforestation (decreasing vegetative cover leading to soil erosion) are the major factors contributing to the floods in Nepal. An inventory of past disastrous events during 1971–

2007, reveals that floods, along with other associated disastrous events (epidemics and landslides), take the largest toll of life every year.

During the period of 36 years (1971–2006), more than 2,846 lives were lost (Figure 2.8); 349 people have been injured; 1041 buildings have been damaged; 196,955 ha of productive land has been lost; 31,117 livestock died; and 3,713 million Nepalese rupees (US$ 59.88 million; 1US$ = NRs62) worth of property have been lost due to floods (NSET 2008). Among the others, the floods of: (1) August 2008 in Koshi River; (2) September 2012 in West Rapti River; and (3) May 2012 in Seti River are some of the prominent examples of devastating floods in recent history of Nepal.

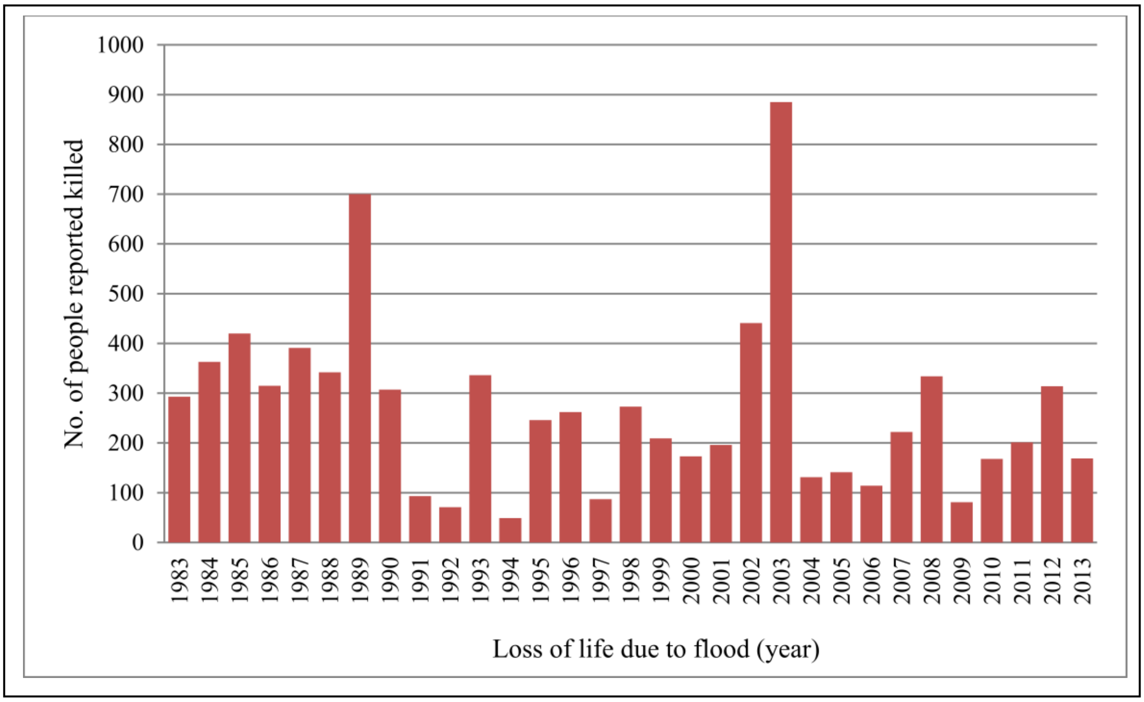

Figure 2.8: Loss of life from floods in Nepal between 1983 and 2013

2.6.3 Flood events in West Rapti River basin

The increasing trend of monsoon rainfall in the Mid-western hills of Nepal that lies in the West Rapti River Basin, is likely to contribute to increased discharge of this river (Aryal & Rajkarnikar 2011). Similarly, the discharge of that river has generally increased due to the increased trend in the amount of rainfall over the Mid-Western Development Region of Nepal (Aryal & Rajkarnikar 2011).

Between 1996 and 2002, 26.9 hectares of agricultural land was lost within the West Rapti catchment area. Moreover, in 2003, six women were injured at Dang and Banke districts due to heavy flooding and thousands of people were displaced due to flooding in the Rapti catchment basin (TKP 2010). Also, in 2004, flooding was a serious problem upstream of the West Rapti River Basin from the Laxmanpur Barrage at Banke and Dang Districts. In addition, during 2005, a total of 125 households on the left bank of the West Rapti River, just upstream of the Laxmanpur Barrage in the Banke district, were flooded (ICHARM 2008).

In the 2006 monsoon season, at least 22 people disappeared, thousands of villagers were displaced and 10 villages were submerged in the plain areas of the catchment. In 2007, Banke and Dang districts lost 60 hectares of agricultural land due to flood. The local administration distributed relief materials to 2400 families. In 2010, more than 16,000 people out of 2,600 households in 33 villages were forced to leave their homes and farmland and live as refugees (TKP 2010). In the West Rapti River catchment, which is the study area of this research, during the flood in monsoon season, at least 11 people lost their lives, thousands of villagers were displaced and nine villages were submerged in the plain areas of the catchment in 2012 (TKP 2012). This clearly reflects that the area is highly flood prone with land, people and other assets all vulnerable to floods.

2.7 Flood Risk, Hazard and Vulnerability

Assessment of the risks from river flooding depends on alternative future population and land use assumptions (Bouwer et al., 2010; te Linde et al., 2011). Risk is the probability of harmful consequences or expected loss resulting from a given hazard (flood in our case), over a specified time period (Dao 2004). Risk is said to be dependent upon three components: hazard, exposure and vulnerability. This concept is widely accepted and applied for research on natural disasters (Crichton 1999; Viecnta and Mesa 2011). Flood risk is a complex interaction of hydrology and hydraulics of the river flow with the potential to cause damage to the surrounding flood plains. The element of risk has both spatial and temporal domains and is also a function of the level of human intervention of the surrounding floodplains. Plate (2002), as cited in Agrawala (2003), described flood risk assessment as requiring a clear understanding of the causes of a potential disaster, which includes both the natural hazard of a flood, and the vulnerability of the elements at risk (e.g. people and their properties). Flood risk assessment is, therefore, about understanding and quantifying this complex phenomenon.

Hazard maps have been prepared for the Sun Koshi and Bhote Koshi catchments in Central Nepal (ICIMOD 2007). The conclusion of this mapping exercise was that there is a high likelihood of flooding and disaster with the development of human settlements within the flood hazard area in those catchments. Natural hazard assessment in Nepal is still in an inventory stage and no serious concern for comprehensive flood risk assessment and hazard mapping was shown until the disaster of 1993. Flood risk assessment in Nepal is still at a very rudimentary stage. Most of the flood protection works are carried out at the local level without preplanning and without considering the problems at a river basin scale.

A hazard is a potentially damaging physical event, phenomenon and/or human activity (UN/ISDR 2004), which may cause loss of life or injury, property damage, social and economic disruption or environmental degradation (EU 2004). Hazard may be described in terms of its magnitude, duration, areal extent etc. In the case of a flood the depth of inundation, duration of inundation and number of times an area gets inundated are the main concern when we talk about the flood hazard.

Vulnerability theory encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC 2014). Vulnerability can however be more directly addressed through individual and community decisions and actions and through external government and agency interventions. Füssel (2007) concluded that climate change vulnerability assessments are performed to increase scientific understanding of climate sensitive systems under changing climatic conditions, to prioritize research efforts to particularly vulnerable sectors and regions and to develop adaptation strategies. According to Füssel, vulnerability assessment combines both natural and social science perspectives.

Vulnerability is a term that describes the susceptibility of a group to the impacts of hazards. It is the degree to which a system is likely to experience harm due to its exposure to hazard. It is determined by the capacity of a system to anticipate, cope with, resist and recover from the impacts of hazard. The concept of vulnerability is based on the various indicators that will influence the level of vulnerability of a community. This study adapts the concept of a vulnerability framework as in Figure 2.9 which will support the analysis of flood impacts and the adaptation strategies for reducing the degree of vulnerability.

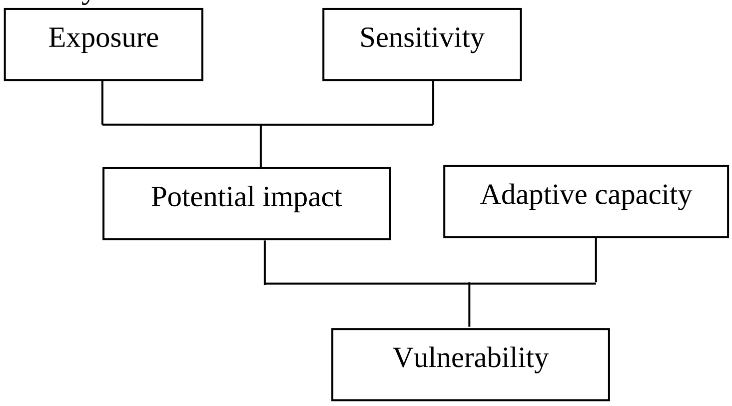

Figure 2. 9: Flow diagram showing the linkages between exposure, sensitivity, adaptive capacity and vulnerability (Source: Marshall *et al*. 2010)

The characteristics of a person or a group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural or man-made disaster- noting that vulnerability is made up of many political-institutional, economic and socio-cultural factors (EU 2004).

The concept of vulnerability is more complex than hazard and exposure and more difficult to assess (Dao 2004; Eidsvig 2011). Vulnerability can be conceptualised in many different ways along a continuum from outcome to contextual vulnerability. Contextual vulnerability is about the susceptibility of a system to disturbance determined by exposure to perturbations, sensitivity to perturbations, and the capacity to adapt (Balica *et al.* 2013). Outcome vulnerability is characterised by the IPCC (2001) definition of the degree to which a system is susceptible to, or unable to cope with particular phenomena such as the adverse effects of climate change, including climate variability and extremes. Vulnerability can also be defined as the inverse of the resilience, where resilience describes the capacity of ecosystems to react against the stress. Thus, vulnerability represents the system's tendency to suffer damage during an extreme event. Vulnerability is also considered as a extent of harm, which can be expected under certain conditions of exposure, susceptibility and resilience (Balica & Wright 2009; Fuchs *et al.* 2011; Hufschmidt 2011; Scheuer *et al.* 2010; Willroth *et al.* 2010).

In the context of climate change, vulnerability can be defined as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC 2007). It is determined by the resilience of a system under stress. Vulnerability analysis increases scientific understanding of climate sensitive systems under changing climatic conditions and helps to prioritize research efforts to particularly vulnerable sectors and regions and to develop adaptation strategies (Braun & Aheuer 2011).

Vulnerability is also classified into biophysical vulnerability and socio-economical vulnerability (Brooks *et al.* 2005). The first one encompasses occurrence of hazard or damage incurred by the system due to action of hazard upon the system while the second one is independent of hazard and it is the inherent current state of the system or community. In the context of flood, vulnerability is the extent to which a system is susceptible to flood due to exposure, a perturbation, in conjunction with its ability (or inability) to cope (Balica *et al.* 2013).

With reference to people, vulnerability can be assessed as the characteristics and situation of a person or group that influence their capacity to cope with, resist and recover from the impact of a natural hazard (Wrachien *et al.* 2011). There have been many studies on vulnerability assessment of natural hazards, especially in the last decade during which many extreme natural disasters, such as Indonesian and Japanese tsunami and hurricanes in USA and Australia, have occurred (Kim & Choi 2013). These natural disasters have led to considerable loss of human life and tremendous socioeconomic costs (Khailania & Perera 2013). However, there have been very limited studies on flood hazards, especially in the context of developing countries, particularly in Nepal (ICIMOD 2007). Most studies in Nepal are based on past information without consideration of climate change and potential future risk of climate change related disaster (Khanal *et al.* 2007).

It is argued that the current challenge in flood damage research is to develop a better understanding of the social dynamics of flood risk perception, preparedness, vulnerability, flood damage and flood management and to take this into account in designing strategies for flood risk management (Messner & Meyer 2006). Lack of participatory flood vulnerability assessment has been identified as one of the major limitation in designing and implementing appropriate adaptation strategies to reduce flood risk (Action Aid 2005).

Participatory vulnerability assessment (PVA) is a qualitative way of analysing vulnerability, which involves the participation of vulnerable people themselves. PVA helps to promote meaningful participation and productive deliberation. PVA empowers or motivates vulnerable people to identify their problems and take appropriate actions. PVA helps to identify and develop relevant and effective projects, policy and programs. Therefore, it is essential for building more sustainable societies (Fazey *et al.* 2007; Folke *et al.* 2005; Kates *et al.* 2001).

Flood vulnerability assessment (Apel *et al.* 2009; Dawson *et al.* 2011; Loucks *et al.* 2008; Plate 2002; Purvis *et al.* 2008) is a multidimensional approach encompassing a large number of indicators. Vulnerability is dependent on the economic wellbeing, awareness of the people living in a society, preparedness and recovery conditions of the community. The poorest in society are disproportionately vulnerable and have less capacity to adapt (Khajuria & Ravindranth 2012). The aims of this study are to assess the perceived surface water flood vulnerability impact at the community level in two southern flood prone districts of Nepal.

2.8 Adaptation Strategies for Flood Control

Mitigation and adaptation are approaches that respectively deal with the cause and effect of climate change. Mitigation focuses on the reduction of greenhouse gas emissions, while adaptation reduces the impacts of global warming. According to the European Environmental Agency (EEA) adaptation involves "policies, practices, and projects with the effect of moderating damages and realising opportunities associated with climate change", including climate variability and extremes, and sea level rise (EEA 2007). Adaptation to climate change is defined by the IPCC as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (Parry *et al.* 2009). Similarly, one of the most comprehensive and quoted definitions of adaptation comes from the IPCC Third Assessment Report which defines adaptation as the "adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli, and their effects or impacts" (IPCC 2007). Thus, adaptation refers to changes in processes, practices or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate" (IPCC 2001).

It involves reducing potential damages of climate change and taking advantage of new opportunities. Through the implementation of adaptation measures, the adaptive capacity of the system increases and the sensitivity reduces, thereby reducing the vulnerability of a society to the impacts of flood due to climate change (Moss *et al.* 2010). Therefore, it can be concluded that adaptation is a policy, practice, or project that has the effect of moderating damages or realising opportunities associated with climate change including climate variability and extremes. Adaptation to unavoidable climate changes, therefore, becomes an important coping strategy, alongside more traditional mitigation strategies (Sgobbi & Carraro 2008). A review by the UNFCCC (2013), indicates that organisation is placing increasing emphasis on adaptation to climate change, through its five-year Nairobi Work Programme, which has the objective of helping countries, and in particular developing countries, in defining and implementing national adaptation strategies.

Therefore, adaptation is a process through which societies are better able to cope with an uncertain future. The IPCC (2007) stated that adaptation can reduce vulnerability where adaptive capacity is intimately connected to social and economic development but is unevenly distributed across and within societies. The UNFCCC (2013) stated that the major risk reduction approach to global climate change is adaptation. Fussel (2007) argues that the emphasis should be given to adaptation as the mitigation process takes several decades while adaptation can be undertaken at local or national level and have more immediate benefits. Climate change especially affects those populations which are already vulnerable and struggle with current climate variability and extreme weather events (O'Brien *et al.* 2004). In developing countries, uninsured economic losses fall on vulnerable households who are particularly dependent on climate sensitive systems such as agriculture and other natural resource-based livelihoods. Despite this, research on adaptation to climate change has mostly focused on responses and their costs (Fankhauser *et al.* 1999; Smit & Wandel 2006; Smith *et al.* 2000).

To understand the social implications of adaptation, it is important to identify how decisions on adaptive responses are made and how adaptive responses are timed with respect to climate change impacts (Spittlehouse & Stewart 2003; Greenberg & Park 1994; Rocheleau 2008) as shown in Figure 2.10. The increased risks of flooding, as a consequence of changes in the climate system, are expected to lead to damage and loss of lives and infrastructure as well as crops and agricultural land in a country like Nepal.

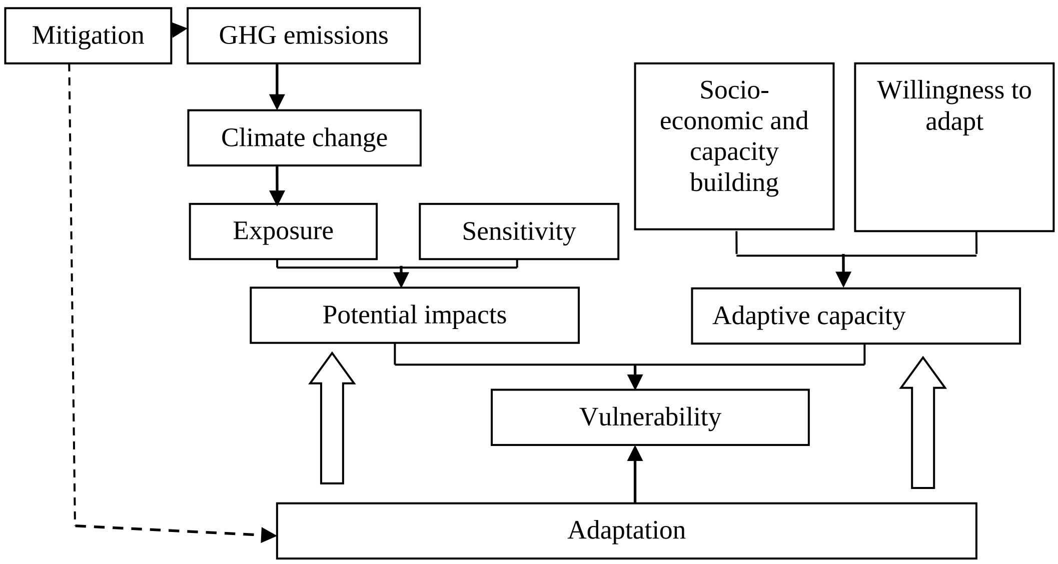

Figure 2.10: Conceptual diagram of interaction between climate change, impacts, vulnerability and adaption (Source: Harley et al. 2009)

The implementation of appropriate adaptation measures increases the adaptive capacity, reduces the sensitivity of a system, and thereby reduces the vulnerability of a society to the impacts of floods (Moss 2010). Therefore, the development of adaptation options requires the assessment of flood impacts and the design and selection of adaptation options in close consultation with stakeholders and experts. Policymakers also play an important role in taking well-considered policy decisions which are aimed at reducing vulnerability to climate change induced flood (IPCC 2007; Füssel & Klein 2006).

Figure 2.11 presents the involvement of various stakeholders in explaining the vulnerability of a system.

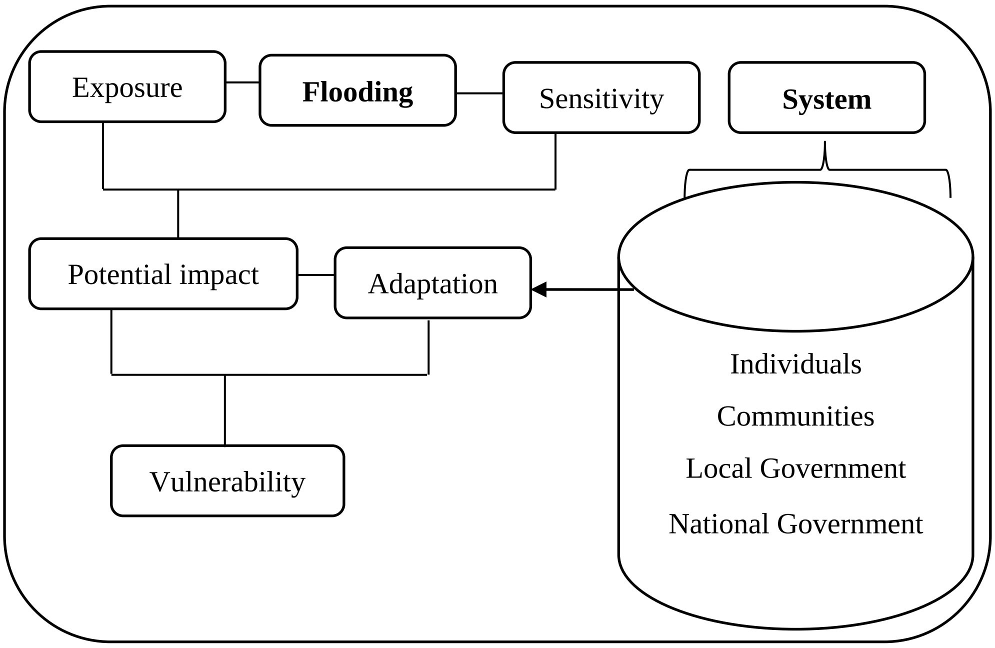

Figure 2. 11: Concept of flooding, vulnerability and adaptation from individual to global system (Source: Adapted and modified from Marshall *et al*. 2010)

According to the IPCC (2007) adaptation assessment refers to the practice of identifying options to adapt to climate change effects and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency and feasibility. Flexibility and cost effectiveness of adaptation measures were found to be the key criteria in decisions around approaches to address both potential changes in climate as well as potentially significant impacts of climate change to ecosystems and natural resources. Table 2.5 provides some examples of key traditional strategies for flood management in Nepal.

Table 2.5: Traditional flood adaptation strategies

	Adaptation strategies	References
Farming	- Traditional erosion control - Changing crop cycles - Use of flood resistant rice in Terai region - Planting more cash crops in winter season - Indigenous seed saving	(Burton *et al.* 2002) (Charmakar 2010) (Tiwari *et al.* 2010) (Manandhar *et al.* 2011)
Land use	- Controlling forest fires - Using marginal land for fodder farming - Controlling erosion maintaining natural flow - Capturing upland forest land	(Rautela 2005) (Charmakar 2010)
House	- Building double storey house - Storing valuable goods on elevated level - Building orientation to avoid storm damage	(Maharjan 2011) Charmakar 2010)
Flood	- Storing seeds on elevated level to avoid flood damage - Rearing cattle on higher grounds - Capturing upland forest land - Temporary migration upland	(Maharjan 2011)
Watershed management	- Preserving trees around water source - Water harvesting from rain and river - Developing irrigation system,	(Tiwari *et al.* 2010)

2.9 Flood Management Strategies Framework

The flood adaptation framework proposed by Palker (2007) is one approach that can be adapted to include climate change. Figures 2.12 and 2.13 provide non-structural and structural flood risk management frameworks, respectively, designed to address climate change induced flood impacts. Knowledge and practices help to reduce risks and impacts. Hence, non-structural measure focus on policies and laws, public awareness, training and education; whereas, structural measures provide the basis for physical intervention (Harries & Penning Rowsell 2011).

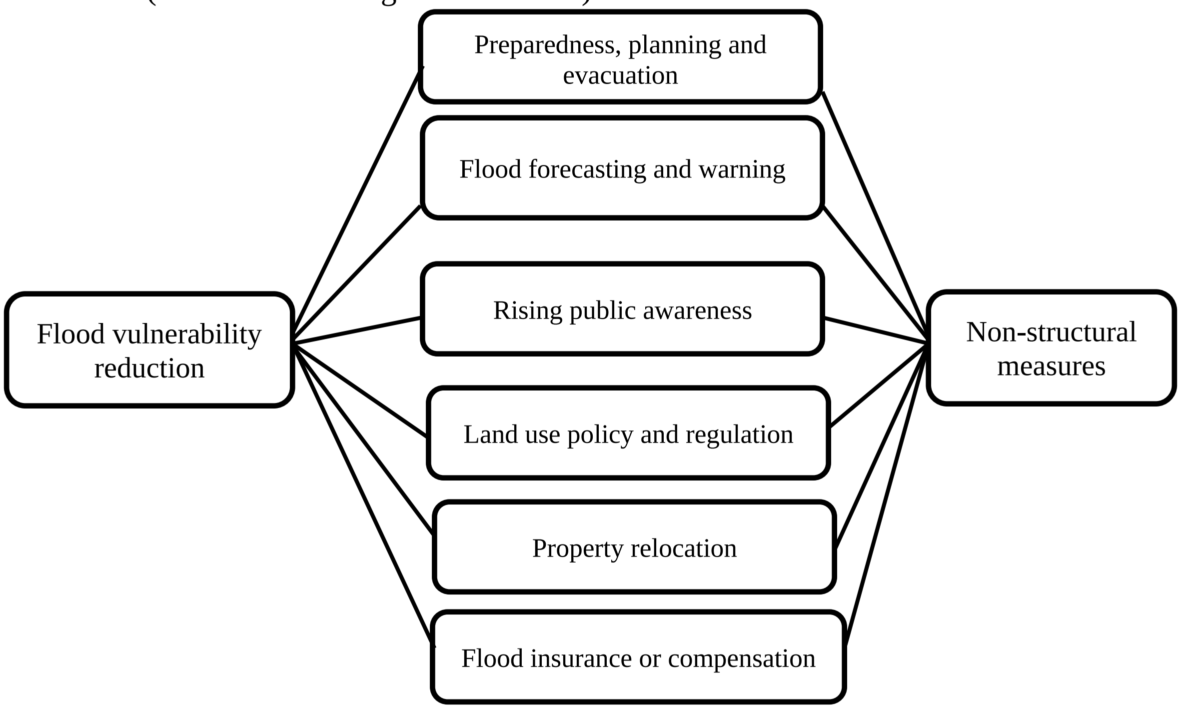

Figure 2. 12: Non-structural flood risk management measures (Source: Palker 2007)

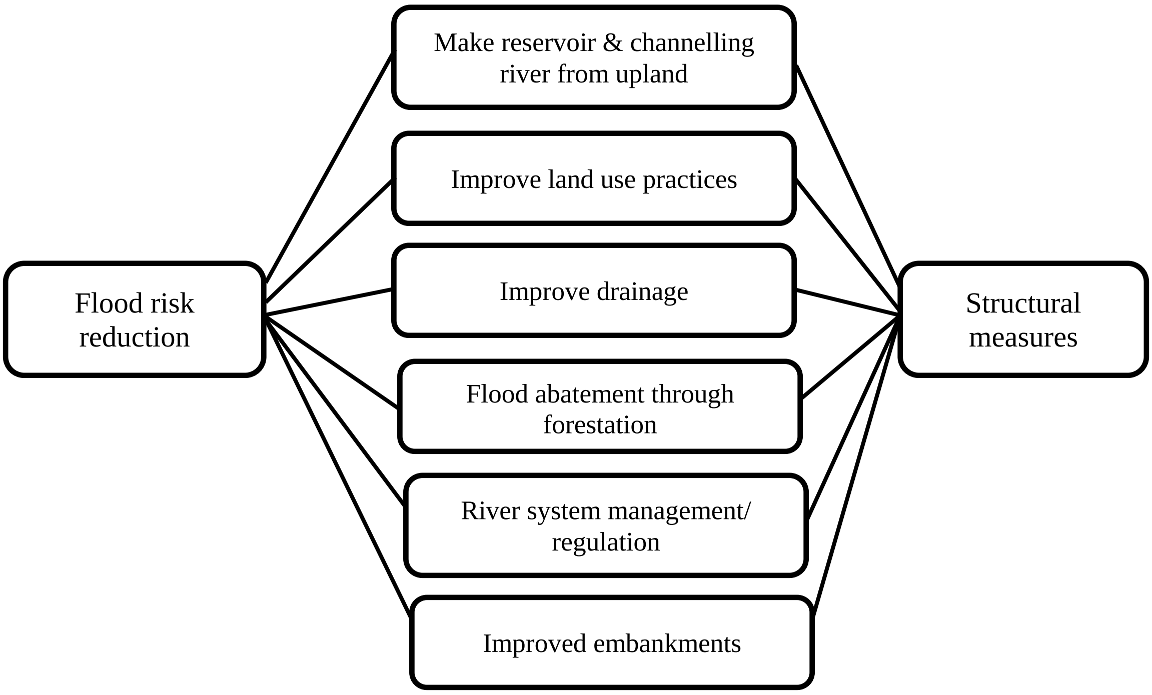

Figure 2. 13: Structural flood risk management measures (Source: Palker 2007)

This could integrate socio-economic and climate change scenarios with long term land use for flood risk analysis. Structural measures provide the basis for physical construction whereas knowledge and practices help to reduce risks and impacts and may win political support for structural changes. Additionally, non-structural measures focus on policies and laws, public awareness, training and education (Harries & Penning Rowsell 2011).

This approach is applied to formulate the flood risk and changes in land use. The flood risk analysis is demonstrated in two ways: (i) exploring the impact of changes to existing planning and insurance systems and (ii) analysing long term socio-economic and climate influences using the socio-economic scenarios for communities.

2.10 Willingness to Pay (WTP) for Flood Mitigation

Water management or flood control is usually a service because the benefits cannot be easily guaranteed for, or confined to, an individual or family. Hence, most flood control actions require some form of collective action. Environmental economists have looked at how changes in the provision of environmental public goods impact upon an individual's utility or welfare by estimating it in monetary terms (Kramer & Mercer 1997). For example, if a government is considering an improvement in a river bank, then an estimation of the WTP for flood control would help government planners and policy-makers choose the preferred flood control option because it provides an estimation of relative value to those affected. There are numerous techniques for estimating WTP and these can be broadly divided into two categories: revealed preference and stated preference methods (Brouwer *et al.* 2006). The former, such as travel-cost and hedonic pricing methods, determine the demand for goods or services by examining the purchase of related goods in the private market place. The latter, such as contingent valuation method and choice experiment techniques, measures demand by examining an individual's stated preference for goods or services relative to other goods and services (Mogas *et al.* 2006).

Flood prevention measures can be described in terms of structural measures which include internal (pumping during rains, sewage management) and external (dikes/dams) flood control measures and 'soft' measures such as early warning systems (Raaijmakers *et al.* 2008). Affected citizens can value and compare the options. The WTP for flood and environmental risk reduction may depend on factors such as risk perception, resource constraints, personality (individual characteristics), current risk levels, and the acceptability of risks (Zhai *et al.* 2006). A theoretical framework for analyzing WTP for flood control is presented in Figure 2.14

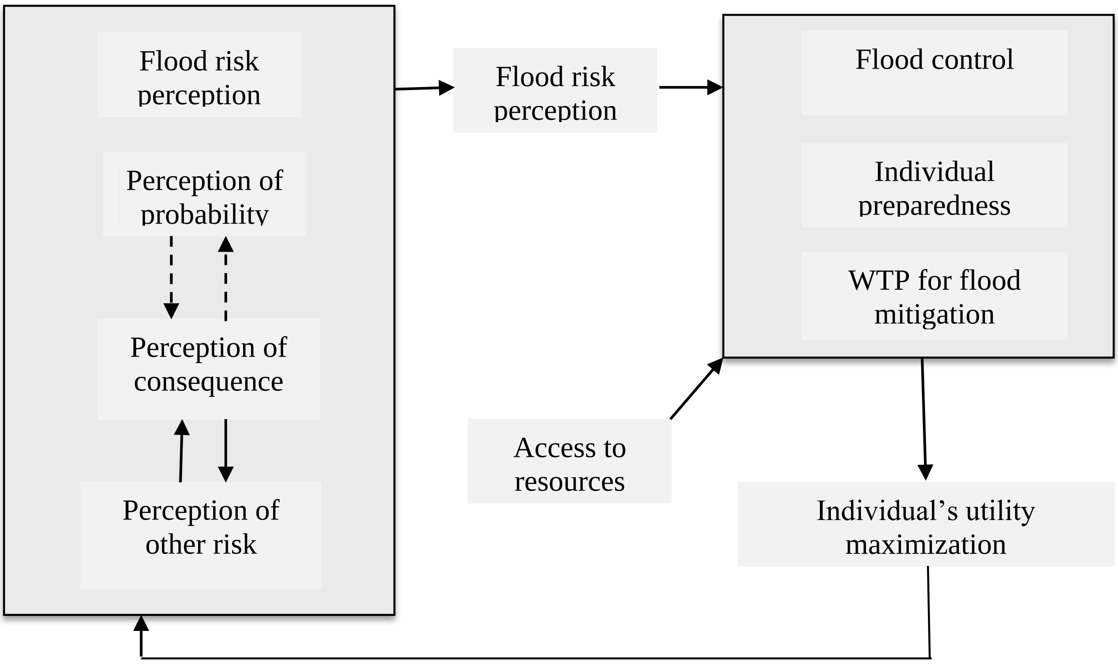

Figure 2.14: Theoretical framework for analyzing Willingness to pay for flood control (Source: modified from Zhai *et al.* 2006)

WTP is further constrained by household income and the disutility from flood risks. These can be measured through higher or lower flood damage costs and risk aversion according to people's attitude to flood protection (Lera *et al.* 2012). Two surveys, one carried out between 1991 and 1994 (Rasid 2000) and one in 1996 (Rasid and Haider 2003), investigated public preferences for flood control and found that a majority of floodplain residents, mainly farmers, prefer regulated flood levels instead of total flood prevention, where the preferred level of inundation corresponds with the flood depth range for cultivation. This research therefore determined "optimum floods" through people's perception. These perceptions are expected to vary, given that an individual's subjective view of the realised risk level was dependent on their experiences with flooding and actual average annual flood damage and their acceptance of this damage. Second, preferences are likely to be heterogeneous towards risk reductions as a result of the economic interests in the floodplain area which may influence people's attitudes to flood risk, income and damage cost. There are no obvious means to assess revealed preferences while stated preference methods could be difficult to apply in the developing world (e.g. Franic *et al.* 2012; Georgiou *et al.* 1997; Whittington 1998) due to lack of education and poverty. This research sought to develop the use of stated preference research in a developing area, subject to flooding.

2.11 Key Research Gaps Identified from the Review of Literature

While climate change is a global issue, it is crucial to understand the impacts of changing temperature and rainfall patterns at the local scale (e.g. significant changes in rainfall pattern which increase flood events) and the implications for society, economy and environment (Kattsov *et al.* 2005; Marques *et al.* 2010). Previous regional studies have mainly focused on the impact of climate change on agriculture (e.g. Ali 2007; Wang *et al.* 2014), water resources (e.g. Aryal & Rajkarnikar 2011) and bio-diversity (e.g. Bisaro *et al.* 2010). Some studies (Hansson *et al.* 2008; Pettengell 2010) have looked at adaptation measures in the agricultural sector. However, very few studies have been carried out on vulnerability and risk assessment of natural hazard (Bajracharya 2011; Dhital *et al.* 1993; ICIMOD 2007; Khanal 2005); lack of information on climate change induced flooding in Nepal has been identified in this study as one of the major limitations in designing and implementing appropriate adaptation strategies to reduce flood risk.

Few scientific studies of flood patterns have been undertaken in Nepal (Shrestha & Aryal 2004; Shrestha 2011), let alone any that include the impacts of climate change. Previous studies also focused on snow fed rivers (Baudo *et al.* 2007; Borga *et al.* 2010) and there is no information on rivers originating from the Lesser Himalaya for which seasonal fluctuation in discharge depend upon rainfall runoff (i.e. rain-fed rivers). Therefore, this research focused on different scenarios of flooding for different return periods under climate change for the West Rapti River Basin. Moreover, this research assessed the perception of the local people living at different locations of the river basin about the impacts of flood, its adaptation strategies and climate change related issues.

This study combined indigenous knowledge and modern technology in exploring flood adaptation/mitigation strategies. This research assessed the level of WTP of the residents for avoiding flood under climate change. As such, it is a novel study for the area. In addition, contingent valuation (CV) studies of flood risks and flood control in general are very rare (Daun *et al.* 2000) even though the application of CV to value changes in individual risk exposure is fairly widespread (e.g. Jones-Lee *et al* 1993; Baron and Greene 1996; Jones-Lee and Loomes 1997; Richard *et al*. 1998). About 35.3% (GoN 2011) of people are under the poverty in this study area, therefore labour value was calculated which is very applicable for other similar areas.

Hansson *et al.* (2008) revealed that the resulting impact of disasters on society depends on the affected country's economic strength prior to the disaster. The larger the disaster and the smaller the economy, the more significant impact. This is especially so in developing countries, where weak economies become even weaker after a natural disaster.

2.12 Conclusion

Floods are the most common natural disasters that affect societies around the world. Liu and Diamond (2005) estimated that more than one-third of the world's land area is flood prone affecting some 82% of the world's population. About 196 million people in more than 90 countries are exposed to catastrophic flooding, and some 170,000 deaths were associated with floods worldwide between 1980 and 2000 (Mosquera-Machado and Ahmad 2007). Globally, the economic cost of extreme weather events and flood catastrophes is severe, and if it rises because of climate change, it will hit poor nations the hardest and consequently, the poorest section of people will bear the brunt of it (Basnyat 2007). The number of major flood disasters in the world has risen relentlessly over recent decades. There were six in the 1950s; seven in the 1960s; eight in 1970s; eighteen in the 1980s; and twenty six in the 1990s (Mosquera and Ahmad 2007).

Communities in different parts of the world have already begun experiencing unusual changes in weather patterns. In both developing and developed countries, the impact of climate change can be much greater for indigenous communities who rely on their immediate environments for subsistence and livelihood and often live in more remote and ecologically fragile areas (UNFCCC 2013). Hence some groups are said to be more vulnerable than others. Globally, the economic cost of extreme weather events and flood catastrophes is significant and there is significant concern that this will increase under climate change. However, while all countries are vulnerable to climate change, the poorest countries and the poorest people within them are most vulnerable and will be most affected (World Bank 2010; Basnyat 2007; Hansson *et al.* 2008).

Chapter 3: An Introduction to the Study Area

3.1 Introduction

This chapter describes the general characteristics of the study area for this research. It starts with the background information and the river characteristics of the West Rapti River Basin, followed by a short note on the climatic conditions and the geomorphology found in the basin. As the study focuses mainly on flood and adaptation issues, this chapter ends with a brief discussion of the demographic conditions of the people of that area.

3.2 Location and Main Features

Nepal is situated between 26º 22' and 30º 27' N and 80º 04' and 88º 12' E. It is about 850 km long from east to west and 193 km wide (north-south) (Pradhan and Pradhan 1995). The elevation varies from 64 to 8,848 masl. Physiograhically, the country is divided into five regions: High Himalayas (High Mountains), Lesser Himalaya, Mountains/Hill (Mahabharat Range), Siwaliks (Churia Range) and the Terai (Plain). Administratively, Nepal is divided into five development regions: Eastern, Central, Western, Mid-Western and Far Western Development Regions. There are four major river basins viz. Koshi, Narayani, Karnali and Mahakali and five medium sized river basins viz. Kankai, Kamala, Bagmati, West Rapti and Babai in Nepal. The West Rapti River Basin (WRRB), in which this study was conducted, lies in the Mid-Western Development Region of Nepal, draining a small part of the Lesser Himalaya, some parts of Siwaliks and major parts of the Terai, as shown in Figure 3.1.

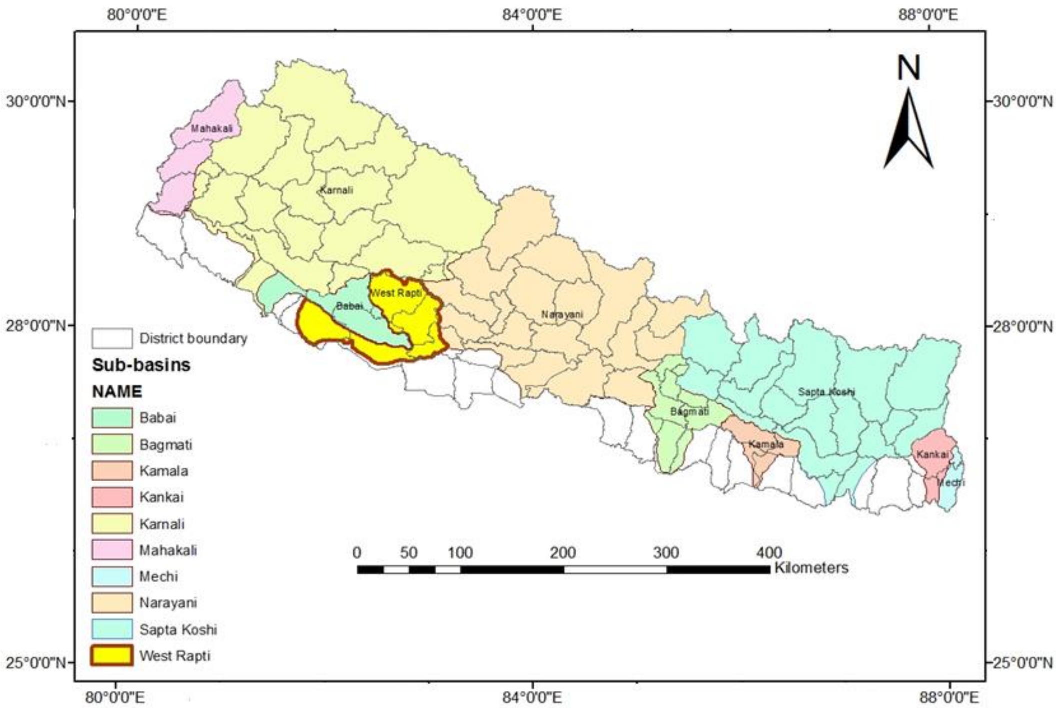

Figure 3. 1: Location of “West Rapti” River Basin

The West Rapti River (WRR) originates in the Lesser Himalaya and flows through the Siwaliks and Terai plain of Nepal before joining the Ganga River in India. The total catchment area within the Nepalese territory is 6,500 km^2 and the elevation varies from about 131 m (at the Indian border) to 3,620 m amsl. About 45% of the basin lies in the mountain area and the rest lies in the plain area.

Geographically, Banke and Dang districts represent Terai and Inner Terai regions, respectively, while Arghakhanchi, Gulmi, Salyan Pyuthan and Rolpa districts represent middle mountain region (Figure 3.2). The main tributaries of the West Rapti River are the Madi and Jhimruk Rivers (Figure 3.3). The basin is bordered in the west by the Babai Basin, in the north by the Bheri Basin (one of the sub-basins of the Karnali Basin), in the east by the Narayani Basin and in the south by the Terai region (Figure 3.3). The source of flow of the West Rapti River is rainfall and groundwater.

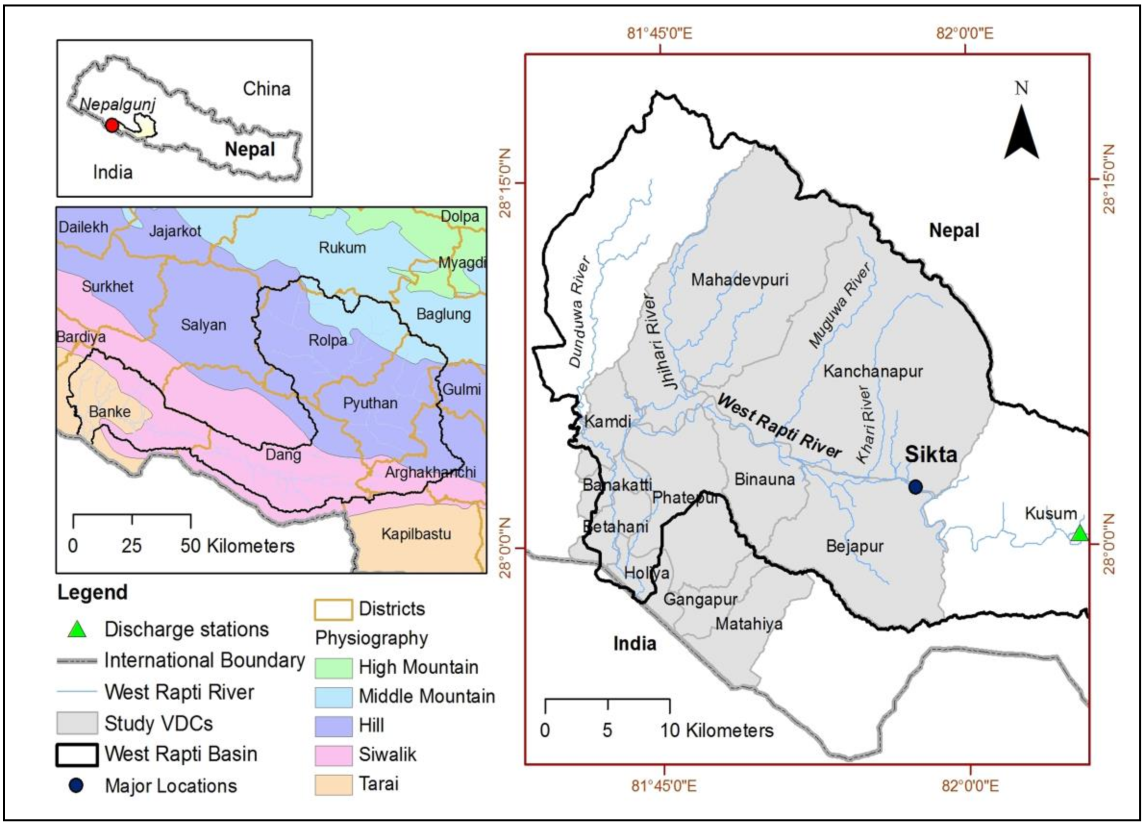

Figure 3. 2: Showing various districts in different physiographic zones in West Rapti River catchment

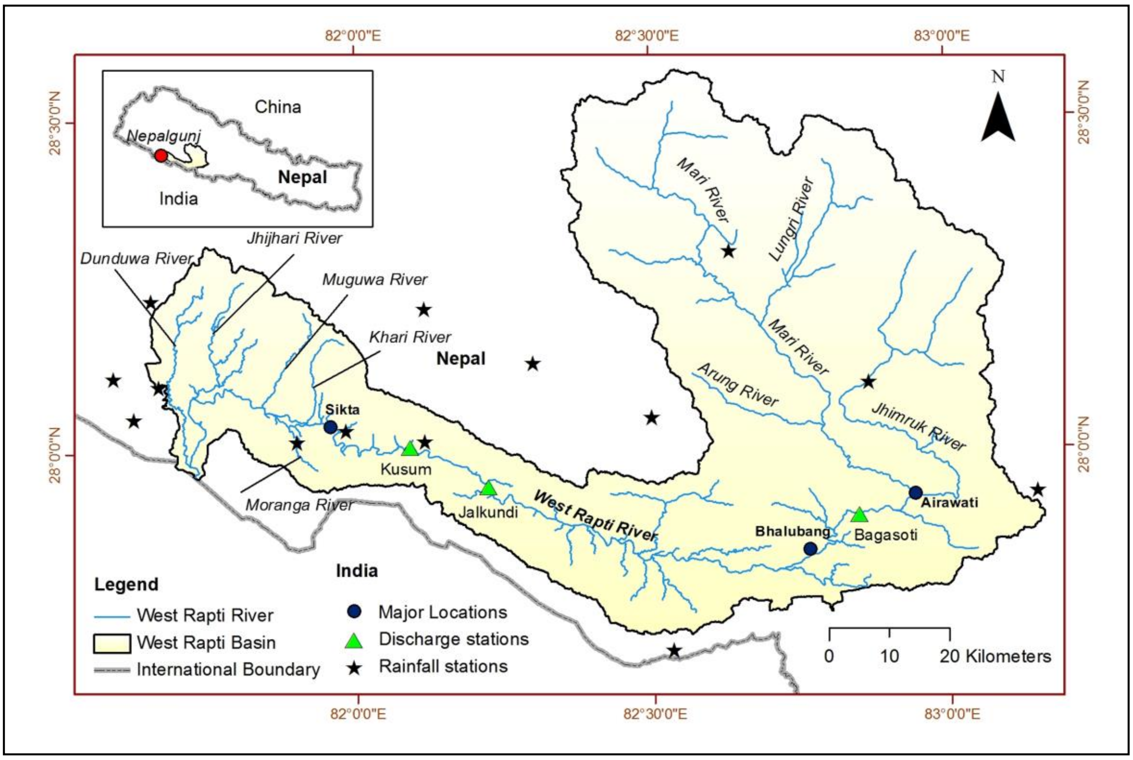

Figure 3.3: Spatial distribution of major tributaries of the West Rapti River

3.3 Geography and Geomorphology

The geomorphological condition of the study area is controlled by structure, lithology, and drainage pattern. Wider upstream river valleys occur along the Madi (Mari) and the Jhimruk rivers (Figure 3.3); likewise, the Rapti River also widens considerably downstream of Bhalubang. The main boundary zone (constituted of some of the landslide prone areas) is responsible for creating the typical landforms of the region. Three major east-west extending thrusts created the current geomorphological features and drainage patterns and are also responsible for creating slope instability leading to landslide and debris flow (refs.). The Rapti River watershed incorporates four major physiographic regions, namely Terai Plain, Siwalik, Mahabharat Range and Lesser Himalayan. As with other areas of Nepal, there are major climatic, topographical and hydrological changes within short distances, moving south to north.

The Terai plains consist mainly of sediments of the Gangetic plain, including sand, silt and clay, which become finer with distance downstream towards the Indian Plains. The water table is about 3 m below the ground surface; however, ground water availability from these aquifers is poor (District profile 2007). The Siwalik Hills are the southernmost mountain range of the Himalaya. Cuesta topography is exhibited with alternating thick beds of sandstones and mudstones. Generally, the range has very rugged terrain with high hills, steep slopes, thin soil cover and deeply dissected gullies, while the lower Siwalik has a smoother and gentler topography characterised by low terraces and alluvial fans supported by the large amounts of sediment carried by the rivers and streams of the region. The majority of the rivers that originate from this range discharge water only during the monsoon period.

The bed material of West Rapti River consists of few medium size boulders, medium to very coarse gravel along with coarse sediment in good proportion at upper reach and coarse and fine sediment at lower reach. In the steep reach between Kusum and Agaiya round boulders and coarse gravel predominate. In some places, conglomerate rocks form the bed of the river (figure 3.3). However, coarse to medium grained sand was found throughout this reach. Downstream of Agaiya up to the Muguwa confluence and beyond, prevalent bed materials are a mixture of coarse gravel and coarse grained sand. At the confluence, the excessive debris deposition has pushed the river towards south affecting the agriculture land of Binauna VDC. Further downstream, the flood plain is deposited with fine sand and silt.

About 38% of the basin area is cropland, 33% forest and 29% grassland. The upper part of the river basin is hilly and mainly forests and grassland with little agricultural land and few settlements. However, the lower part of the catchment area is plains and most of that area is used for farming and settlements; settlement in this lower part of the basin is dense. The structure of the basin, from steep upper areas to a broad plain, is depicted in the Digital Elevation Model Map (DEM) below (Figure 3.4).

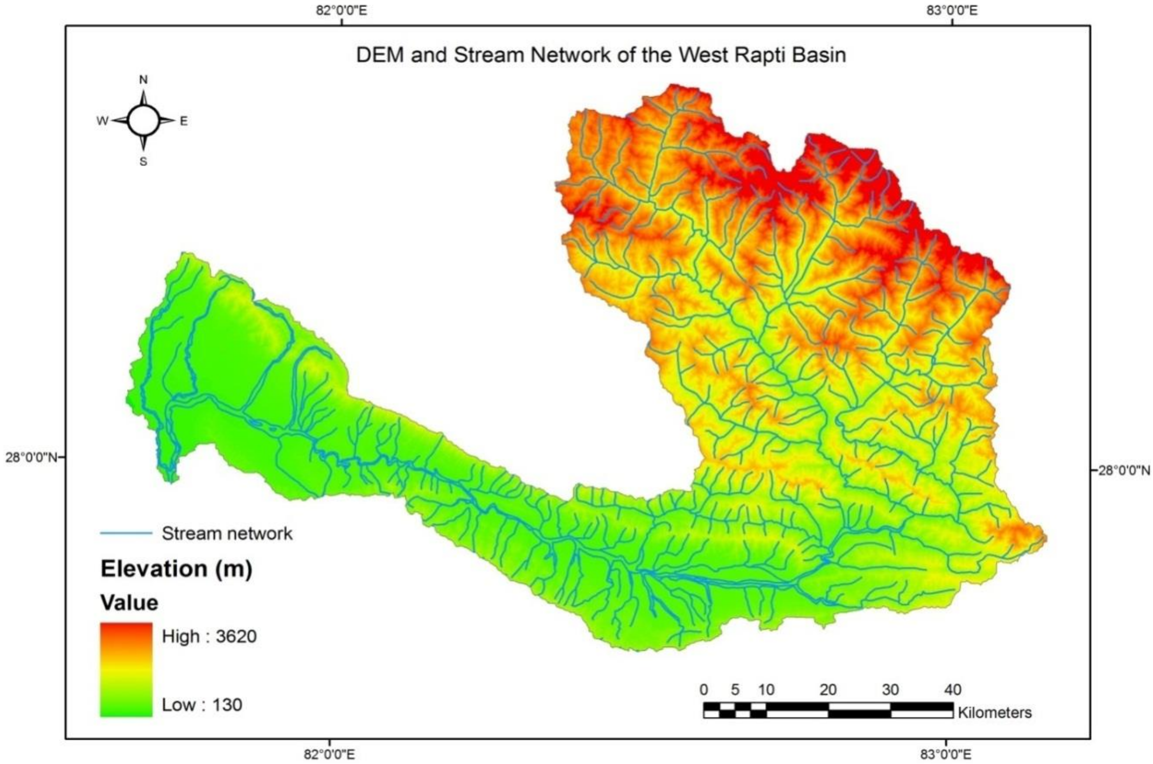

Figure 3.4: DEM of the West Rapti River Basin

3.4 Climate, Rainfall and Runoff

Since the catchment of the river is large and includes areas of the Banke district in the Terai region, Dang in the Inner Terai and areas falling in other districts in the Middle Mountain region, the climatic properties of catchment vary. The climates of the West Rapti river basin are divided into monsoon subtropical in the Terai Plain and Siwalik hills areas and temperate in the Lesser Himalayan area. The climate of the West Rapti River Basin in Banke has three distinct seasons: a warm dry spring; a hot, wet and humid summer, and a cool and normally dry winter. The annual average temperature is 25°C ranging from 15°C in the winter period to 32°C in the summer period. The temperature rises from March to June/July while it decreases from October to January (DHM 2008). A study of climate data from four recording stations representing the inner Terai and mid mountains areas, for the periods of early 1970s to 2000, and one for the High Mountain region, for the period 1988 to 2000, shows a clear warming trend in Nepal (Chapagain *et al.* 2009).

There is also considerable rainfall variability. The dry season ranges from October to May while the rainy season ranges from June to September; more than 80% of the rainfall is concentrated in these four months. Average annual rainfall in the Banke district varies from 1,151 to 2,489 mm; in Dang area, it varies from 1245.5 to 1917.1 mm (DHM 2008).

Runoff and rainfall patterns in this basin are closely linked (Figure 3.5). The rainfall data of Bajuwartar was used in while the flow data of Bagasoti station was used for this figure 3.5. It is mentioned here that the data of Bagasoti are more reliable than those of Jalkundi as per the information of DHM staff. Shrestha (2008) also used the data of Bagasoti instead of Jalkundi as in his research.

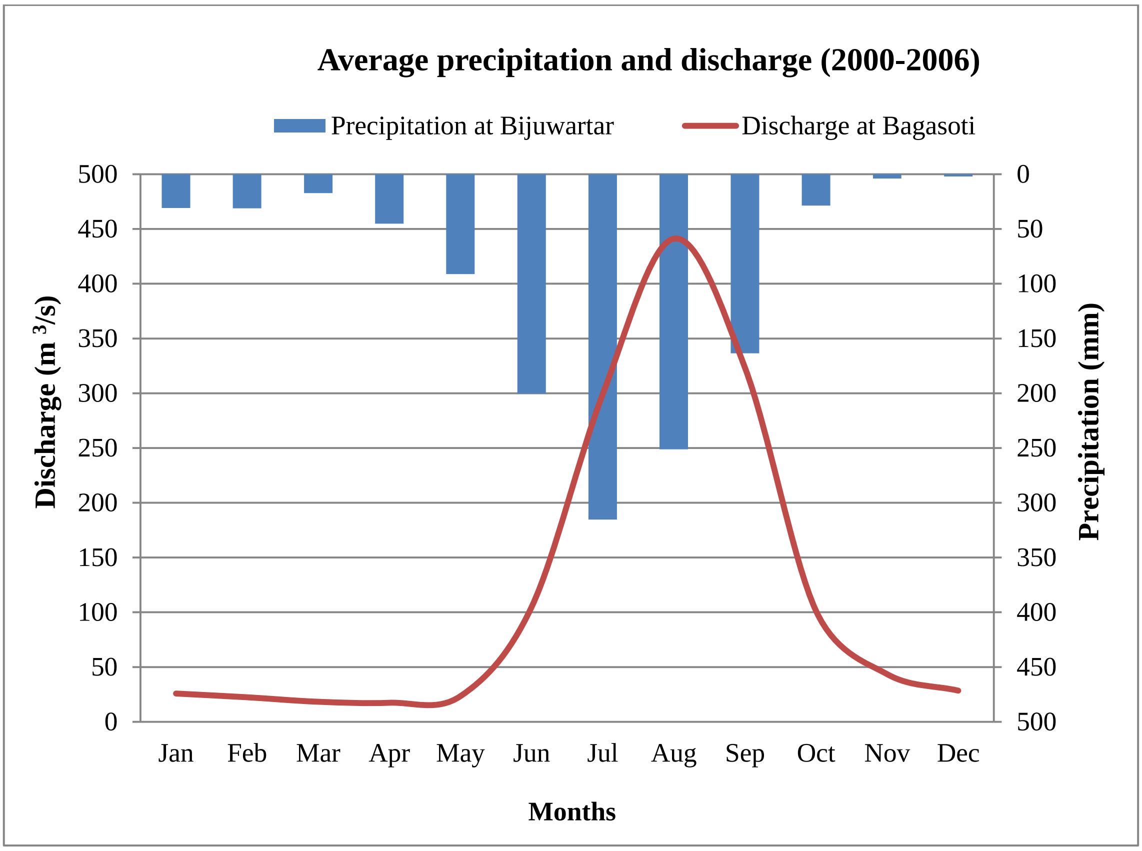

Figure 3.5: Precipitation and runoff in West Rapti River Basin

3.5 Drainage Condition

As this study investigates flood issues, it is primarily focussed in the landscapes of the southern part of the river basin (Figure 3.3) where the topography is flat. Intense rainfall and high flow coming from upstream and the tributaries feeding into this area contribute to significant discharge during the rainy season. The rivers and streams flowing through the upper Siwalik carry a lot of sediment which, when deposited, raises the bed level in the flatter sections of the river basin. Because of the flat topography and fine texture of the soil, drainage is relatively slow in this area. In addition, cross border flow is somewhat constricted by an afflux bund constructed in Indian territory parallel to the Nepalese–Indian border and a gated barrage in the West Rapti River about 2 km downstream of the border. These two structures amplify the flood hazard, especially in the lower part of the catchment.

3.6 Socio-economic Conditions

As noted, the West Rapti River basin has long history of devastating flooding. Every year, during the monsoon season, many people need to be evacuated from the basin because of flood related disasters. Most of the people living in this study area are of the indigenous *Tharu* and *Yadav* communities and over 80% are farmers using indigenous agricultural practices (Dixit *et al.* 2007). More than 90% of the people living in the study area are dependent on agriculture for a subsistence livelihood. Few people are involved in business, teaching, government and private jobs. However, seasonal migration to other district for work occurs.

For this study, two districts (Banke and Dang) were selected. The Banke district covers 2,337 km^2 with 46 village development committees (VDCs) and 1 municipality. More than 50% of the land is forested. The altitude of this district ranges from 610 to 1,236 m, but most of area is relatively flat. According to the 2011 national census, the total population of Banke district is 491,313; the population density is 165 per person km^2; literacy is 57.8%; the average age is 61.4 years; the majority of people are *Tharu, Brahmin, Chhetri, Magar, Gupta, Dalit or Muslim;* and more than 85% of people live in rural areas (District Profile 2007). The breakdown of the VDCs by gender and household distribution are tabulated in *Appendix C, Table C.1*.

The Dang district covers 295,500 km^2 with 39 VDCs and 2 municipalities and has 65% forest and 23.6% agricultural land. The altitude of this district is from 213 to 1058 m and most of area is flat. Total population is 552,583 of which the rural population is 83.3%; population density is 156.5 per person km^2; literacy is 58%; and the majority of the people are *Yadav, Muslim, Dalit* and others. The VDC population breakdown is tabulated in *Appendix C, Table C. 2*.

Both districts are highly populated compared with the national population density of 157 persons per km^2. The literacy rate in both districts is lower than the national average of 65.9%. Caste composition shows that the majority of the population in both districts is indigenous.

3.7 Conclusion

The West Rapti River, originating from the northern face of the Mahabharat Range, has a north-south flow. Unfavourable natural conditions such as fragile geology and steep topography make this river basin one of the most disaster prone basins in the country. The southern parts of the river basin, the Dang and Banke districts, are particularly vulnerable to flood disaster. Intense rainfall, high flow coming from upstream and quite a large volume of water carried by the tributaries contribute to high levels of discharge during the rainy season. More than 80% of the people residing in this basin are indigenous farmers. Each year, thousands of families in the basin are displaced by flooding and suffer damages to productive agricultural land through water logging, river cutting, and sediment deposition. As a result, communities in the West Rapti River Basin are highly vulnerable; this is likely to become more so with increasing climatic variation. Therefore, the aim of this study is to provide relevent information to the local people and support the policy feedback to policy makers.

Chapter 4: Research Design and Methodology

4.1 Introduction

This chapter consists of three main sections: the research design, data sources, and the approach and methods used to achieve the objectives set out in Chapter One. Relevant research questions, and the conceptual framework to address these questions along with the corresponding hypothesise, are the major components dealt with in the research design section of this chapter.

Analyses of hydrological, meteorological and socio-economic data are required in order to develop climate change induced flood scenarios and identify possible adaptation responses. The level of Willingness to Pay (WTP) to avoid or mitigate climate change induced flood risk also needs to be determined through the study participants' perceptions and stated preferences; in order to do this respondents need to be presented with relevant hydro-meteorological and physical data. The primary data for the research were collected between February and May 2012 during a field study in Nepal. A multi-stakeholder and multi-level data collection approach, including a house hold survey, focus group discussion (FGD) and key informant interviews (KII) ranging from district level to central level policy makers, was used in this study. The temperature, precipitation and hydrological data were also collected from meteorological stations in this period.

Analysis of past data and projected data to identify trends or shift changes in the statistics on hydro-climatic characteristics of the study area were carried out for the assessment of the flood hazards and risk in the study area. Socio-economic data were analysed in order to identify the level of WTP to avoid the impacts of floods.

4.2 Contextual Background of Data Collection

At the time of the field work, Nepal was in a political transition following a decade long Maoist led insurgency, abolition of the century long monarchy and election of a constituent assembly tasked with drafting a new constitution. Hence, the power of the State had been weakened and there was significant social and political instability. These political changes increased the expectations and aspirations of the people, especially those from marginalised groups such as landless *Dalits* (lower class), marginal *Janajaties* (ethnic groups) and women, who are claiming to have been excluded from the state for generations. Political awareness helped all groups and classes of people to participate during the focus group discussions. Moreover, the participants were equally active in raising issues during the discussion. Social movements of marginalised groups, women, *Dalits, Janajatis, Aadibasis* (indigenous groups) and *Madhesis* (people living in the southern plains) seeking identity, proportional representation, federalism and self-determination, as well as insurrectionary activities of two-dozen non-state armed actors, have contributed to the disruption of state-society relations in an unprecedented manner.

About 80% and 60% of people in Banke and Dang districts respectively of the study area are marginalised groups, *Dalits, Janajatis, Aadibasis* and *Madhesis*. In recent years, these people have unified and raised their voices for greater rights under a proposed new constitution. But, multiple castes, language, religious and ethnicities mean that there is little unity among the *Madhesi* groups. In this context, the field visit started at the end of February and lasted until the 2nd week of May, 2012. The surveys were conducted against a background of social and political unrest. The constituent assembly mandate expired, without a final constitution being agreed, in May 2012. As a result, a number of ethnic and other groups and communities were dissatisfied and demonstrations against the situation took place. The study area (i.e. Banke and Dang districts) was affected by also strikes (*Nepal Banda*). As a result, public transportation was unavailable and local research assistants involved in data collection had to use their own bicycle or motorcycle to go from house to house; however, this did not affected data collection.

In addition, there is an open border with India adjoining the study area, which enabled several unidentified armed groups to move around the area, kidnapping new people in the area for ransom. It was therefore impossible to securely provide prior information to local people about the focus group.

Nepalese society has many challenges and limitations. In the rural areas of the country, more than half of the population is illiterate. Therefore, survey questions were carefully designed and the survey was conducted through face to face interviews, which are relatively time consuming. Nepalese society is strongly based on class, caste, gender and ethnicity, and unequal power relations prevail across generations with many people from the lower caste and class or women generally hesitant to talk or take part in interactions with the higher class or new people. In order to overcome this culturally constrained situation, the researcher first got acquainted with younger people with exposure to more recent social ideas, belonging to the same castes or classes; this approach facilitated introductions to the family members who were to be interviewed.

In Nepalese society, men are household heads and represent the household in all societal activities, meaning that survey samples and results can be skewed. Thus, the researcher was careful to ensure the participation of women in the household level questionnaire survey. To prepare women to take part in the household survey, the male counterpart of the household was first approached to gain his confidence before approaching the female member of that house. In addition, the researcher spent most of the time in the study area as a paying guest in houses in flood prone areas. This approach provided an opportunity to interact with local people and extract more accurate and reliable information; to understand their cultures, values and practices; and to observe the flood affected areas and properties. Further, hiring a local research assistant who understood the local context helped facilitate the focus group discussions and interviews.

The researcher also benefited from having previous research and consultancy experience, with particular engagement with local government, in different locations of Nepal. These established linkages and the confidence earned from past work experiences also facilitated approaches to policy makers as key informants at both the central and local levels. The integration and coordination of the questionnaire survey, FGD) and (KII) allowed triangulation of the surveyed information.

4.3 Research Design

4.3.1 Research question

As outlined in Chapter 1, the overarching goal of the research is to investigate local community perceptions of the impacts of floods and flood adaptation strategies in relation to the level of exposure to different climate induced flood scenarios in the West Rapti River Basin. In order to achieve this goal, several specific objectives were developed. This section discusses various methods used to address this research aim and specific objectives.

4.3.2 Conceptual model of the study

Based on knowledge gaps identified through the literature review, a conceptual model has been developed for the purpose of this study (Figure 4.1). It provides the theoretical basis for a climate change induced flood assessment approach encompassing changes in rainfall pattern and the frequency and magnitude of extreme events. Flood zonation and hazard maps of the study area formed the basis for the collection of socio-economic data for assessing people's perceptions of vulnerability, their WTP to mitigate the impacts of flood and appropriate adaptation strategies for various flood zones and scenarios. Relative preferences for selected adaptation strategies were determined through the WTP under the climate change flood scenarios from a range of potential adaptation strategies for different future flood exposures (2030, 2070 and 2100).

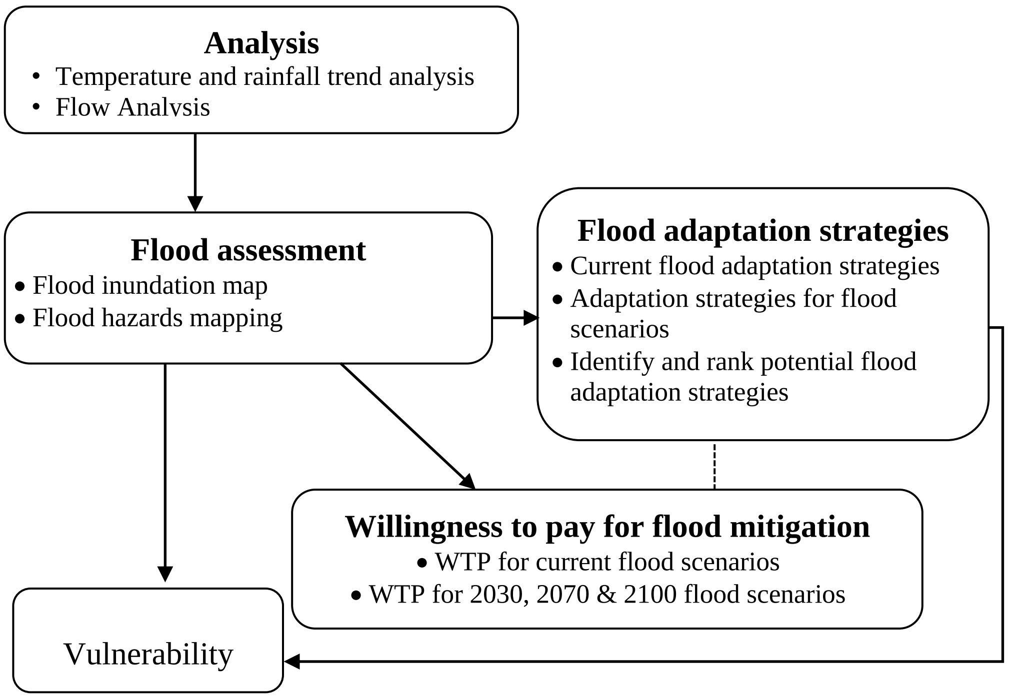

Figure 4.1: Conceptual model of the study

This study carries out hydraulic modelling and assesses the WTP of flood affected people to explore strategies for adaptation to increased flood risk in the West Rapti River Basin (a local problem) due to climate change (a global issue). This research is, thus, a fusion of scientific and indigenous knowledge which can be replicated in other regions.

4.4 Methodological Approach

The methodological approach taken in the study is summarised in the research flow diagram shown in Figure 4.2. This approach took the average rate of change of climatological variables and assessed probable changes in climatological statistics (average, standard deviation, maximum value) over time. Hydraulic modelling was used to estimate the inundation characteristic of the flood plain and the resulting hydraulic model was used for flood hazard zoning. The willingness to pay of the people at different flood zones was assessed to provide background information for devising the flood adaptation strategies.

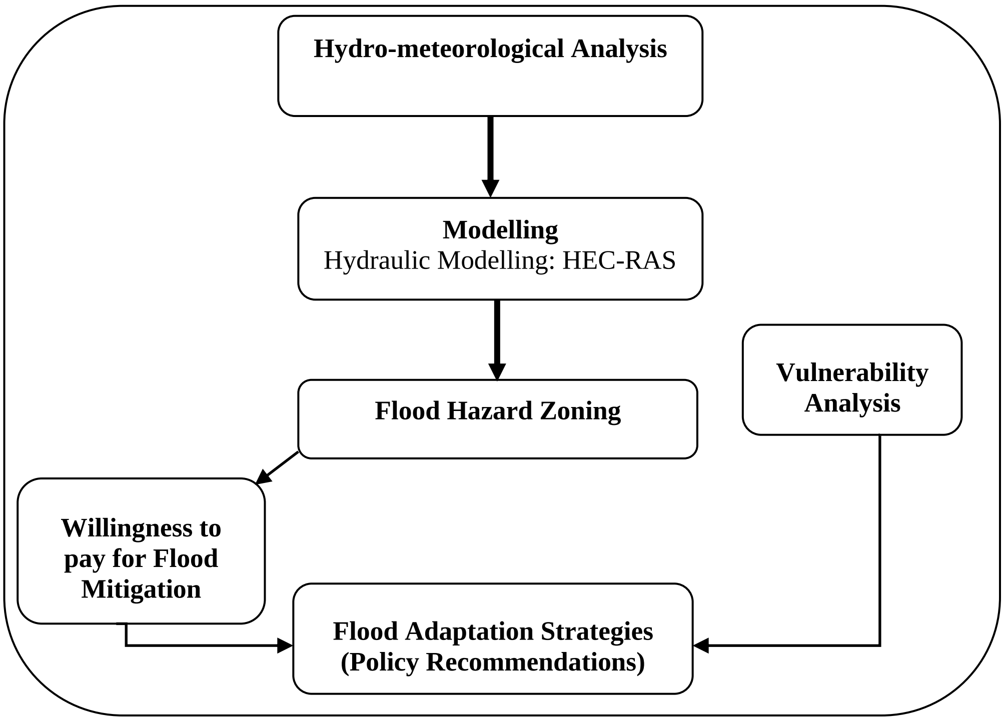

Figure 4.2: Methodological approach of the study

Time series (hydro-meteorological) and spatial data (physical and socio-economic) were used in this study. Hydro-meteorological and physical data required for the trend analysis of hydro-meteorological variables and hydraulic modeling were collected from relevant government departments and previous studies. Socio-economic data necessary for the assessment of perceived impact on climate change and adaptation strategies were collected in the field level through the household (HH) questionnaire survey. Data were also collected from multi-sectoral and multilevel (local to central policy makers) stakeholders through FGD and KII. This approach enabled triangulation as well as a basis for the development of flood adaptation strategies.

4.5 Data Collection

The research aimed to understand both the socio-economic conditions of the people and the river dynamics. It is rooted in critical perspectives of social science together with empirical evidence of flood dynamics and socio-economic realities in the field (Greenberg & Park 1994; Rocheleau 2008). Primary data sources and secondary data obtained from secondary sources (i.e. government departments and relevant literature) are shown in Figure 4.3.

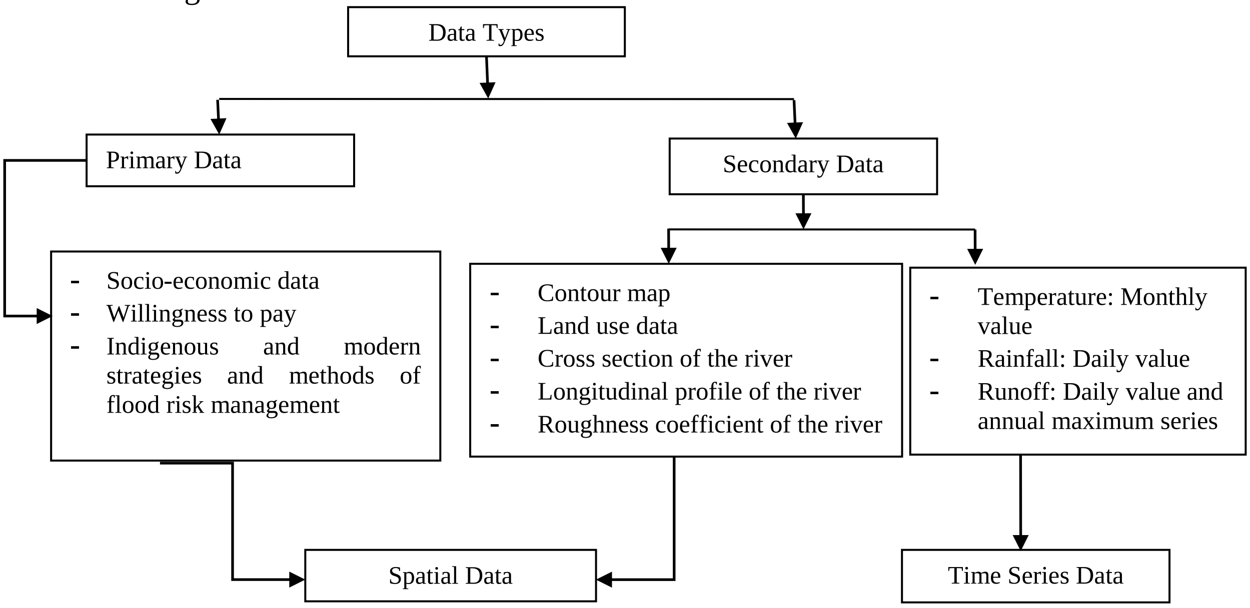

Figure 4.3: Types of data used in the study

4.5.1 Hydro-meteorological data

Time series and spatial data were required to capture the spatial variation and trend in the data over time. Hydro-meteorological time series data were obtained from relevant departments to enable investigation of the change in the statistics over time (i.e. trend analysis), while spatial data (contour map, cross sections of the river etc.) were used in the hydraulic model to represent the physical setting of the basin. Contour and land use data were obtained from the Department of Survey and river cross sections and longitudinal profiles were obtained from Osti *et al.* (2008). Inundation results from the hydraulic model were used to assess the degree of flood hazard in the study area.

4.5.2 Methods of socio-economic data collection

Primary data sources included data collected in the field from focus group discussions, semi-structured questionnaire household survey, key informant interviews, and structured multilevel policy makers' surveys. The socio-economic status of the study area was derived from the district profile prepared by District Development Committees (DDC) and data from Central Bureau of Statistics (CBS) and other national/international organizations. Information on past flood events and damages were collected from different governmental and non-governmental organizations working in the area.

Flood risk information was collected across groups at various levels viz. household level (questionnaires survey), community level (focus group), district level and national level (key informant) in order to capture the perceptions of the people directly affected by flooding on the degree of flood impacts (Figure 4.4).

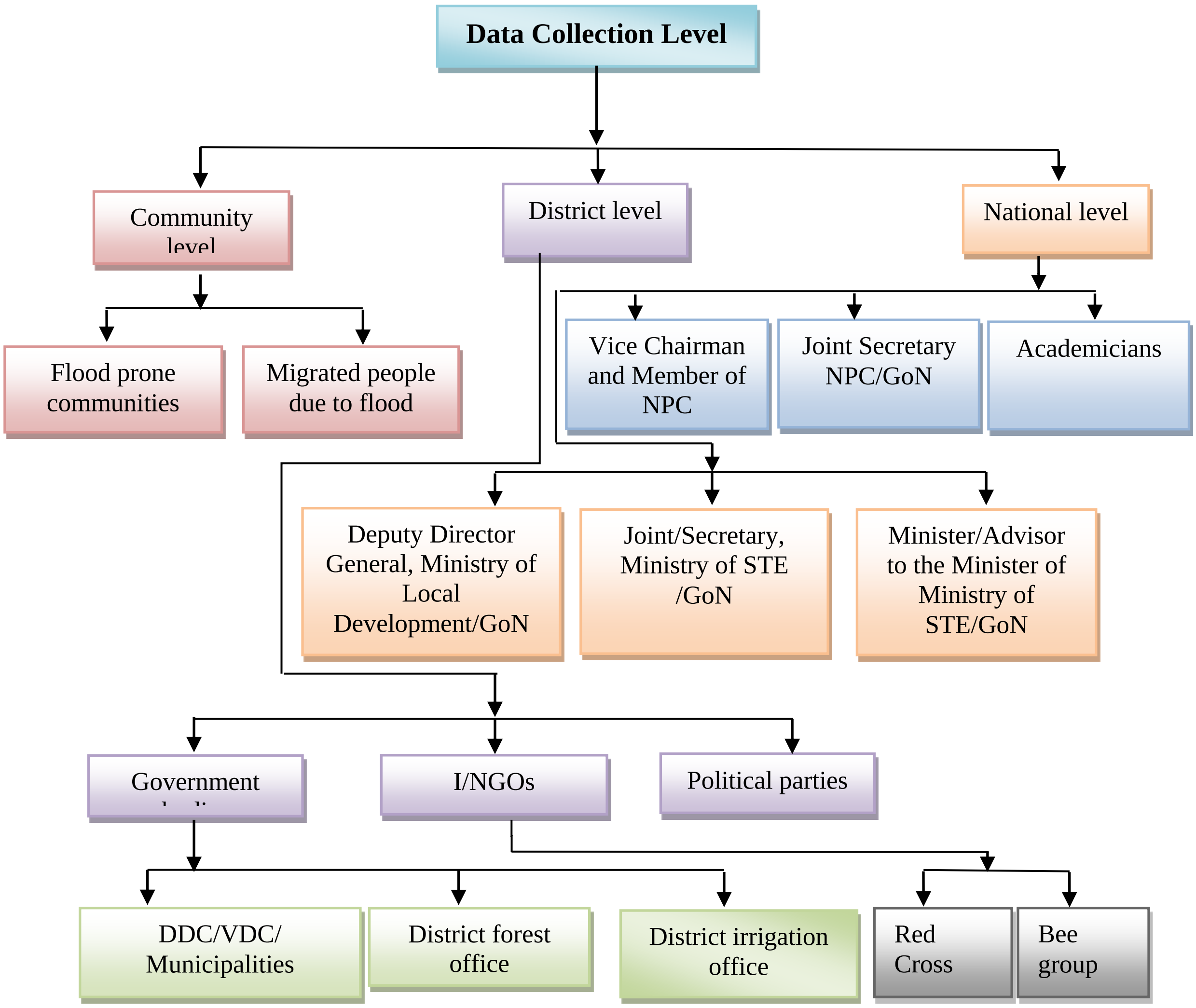

Figure 4.4: Showing data collections from central to local levels offices and their key respondents

Note: NPC = National Planning Commission; GoN = Government of Nepal; STE = Science, Technology and Environment; I/NGOs = International/National Non-Governmental Organizations; DDC = District Development Committee; VDC = Village Development Committee

i) Questionnaire survey

Face to face interviews were used to conduct the household level survey. This was essential as most of the respondents were illiterate, the postal service was not reliable and internet facilities were not available in the study area. Rather than a conventional structured question and answer method, face-to-face interviews were used, enabling open-ended conversations where the researcher sought the answers to questions through subjective interpretation of the participant's individual responses (Neuman 2003; Powell & Single 1996).

Pre-testing of the questionnaires ensured that the questions were understood by the respondents and that they were in presented in a logical order. Pre-testing also ensured that the questions were not culturally, socially or politically sensitive to the extent that this would deter respondents.

Key field survey data collected included: (1) Willingness To Pay data for flood mitigation; (2) socio-economic data for flood vulnerability assessment and finding the relations between WTP and socioeconomic conditions; (3) indigenous and contemporary flood mitigation and adaptation strategies; (4) selection and rankings of pre-flood, during-flood and post-flood adaptation strategies; and (5) changes in potential flood adaptation strategies associated with levels of exposure to flood scenarios.

Prior to the Household (HH) survey, the study area was classified into three different zones or strata based on the extent of previous flooding (i.e. depth of the inundation and the frequency of flooding) as discussed in the next section. These are identified as: the critical flood prone zone (Zone 1); moderate flood prone zone (Zone 2); and low flood prone zone (Zone 3). The total HH numbers in each zone were derived from the District Development Committee profile (DDC 2007). In total, there were 720 HH in the three flood zones; 144 in the critical zone; 274 in the moderate zone; and 302 in the low flood prone zone.

Initially, stratified random sampling with proportion of HH numbers was considered as a basis of allocating the sampling effort in each zones. However, for obvious reasons, the critical flood prone zone has more serious flood related problems than the other two zones. Therefore, more samples were taken from zone 1 (36%) than from zone 2 (30%) and zone 3 (25%) (Table 4.1). In each of the zones, households were allocated a number and households to be sampled were selected randomly using a random number table so that each and every household had an equal chance of being selected. Finally, 210 households were selected to participate in the Household (HH) semi-structured questionnaire survey. Prior to conducting the household survey, the questionnaire was pre-tested with the focus groups and translated into Nepalese language.

Table 4.1: Number of sampled houses in three flood prone zones

Zone	Strata	Total no of HHs	Sampled HHs	Percent of total HH sampled
1	Critical flood prone zone	144	52	36.1
2	Moderate flood prone zone	274	82	29.9
3	Low flood prone zone	302	76	25.2
Total		**720**	**210**	**29.2**

ii) Focus group discussion

Focus group discussions (FGDs) are a form of interview conducted in a group of people having common relationship, experience or interest to a focus group topic (Gray 2004; Kane & O'Reilly-De 2001; Walter 2009). These are of a group in FGDs ranges from 6–15 individuals (Babbie 2004; Greenbaum 1988; Neuman 2003). Such discussions, if properly constructed, provide opportunities for marginalised groups (in this study, women, *Dalits, Janajatis, Aadibasis* and *Madhesis*) to express their views more freely (Borghi 2007; Gilmour & Fisher 1991); hence, the reason they were considered for information collection and analysis in this study.

Five focus group discussions (FGDs) were conducted in the flood prone areas. People who have first-hand experience in flood adaptation strategies, such as farmers, foresters, VDC secretaries, school teachers and members of local NGOs, were invited to participate in the FGDs (Table 4.2). In total, 71 people participated in the FGDs. The selected locations, numbers of participants and details of participants' involvement are presented in Table 4.2.

Table 4.2: Location and number of participants of focus group discussions

Banke District				
Location			**No. of participants**	**Participants' involvement**
VDC	*Ward no.*	*Village*		
Holiya	7	Priparawa	13	Local people (mainly farmers, both land owners and land less)
Gangapur	9	Newajgau	21	Local people (mainly farmers, both land owners and land less)
Kamdi	7	Balapur	14	Representative from forest user group, youth group, women group, local NGOs, school teacher, VDC secretary and Ex-chairman
Dang District				
Lalmatiya	3	Puranobazer	12	Local people (mainly farmers, both land owners and land less)
Sohanpur	3	Barwagaun	11	Representative from forest user group, youth group, women group, local NGOs, school teacher, VDC secretary and Ex-chairman

A set of discussion topics was developed (Table 4.3). To ensure consistency, the same set of topics was used across the three groups. Each discussion lasted about three hours, with 20 minutes allocated to each topic. Two persons were involved in this activity, one as a facilitator and another to take notes. Following the discussion, the notes of the research team were consolidated to create a consensus description of the focus group results. Some of the information (for example, vulnerability indicators) was used to refine the household survey questionnaire.

Table 4.3: Topics for focus group discussions

1. History of major flood events in the last 100 years
2. Indigenous knowledge for early warning system
3. Highly inundated area and major flood impact sectors
4. Flood vulnerability indicators and vulnerable areas
5. Pre-flood, during flood and post flood adaptation strategies
6. Flood adaptation strategies for different flood exposures
7. Non-structural/structural flood risk management measures
8. Monetary value of domestic animals (buffalos, cows/ bulls, goats, chickens, ducks, pigs) and crops in Banke and Dang districts
9. Monetary value of land (upland/lowland)/Kattha near the West Rapti River in Banke and Dang districts

iii) Key informant interviews

Key informant interviews (KII) were carried out to supplement, triangulate and validate the information received from the household survey and FGDs. Key informants were selected for both the district and national level (*Appendix B*).

District level discussion/interview

Interviews of key people who were heads of relevant organisations and were directly involved in policy formulation and implementation in the district, viz. government bodies, I/NGOs and politicians, were taken to assess their views and plans for flood adaptation strategies under climate change scenarios. These organizations work both directly and indirectly in this sector from the planning to the implementation level.

National level discussion/interview

Several ministries and National Planning Commissions are directly and indirectly involved in climate change mitigation policy and planning including around flood related issues. Views and perspectives on flood impacts and adaptation measures, as envisioned by researchers and policy makers (academicians, personnel working in National Planning Commission and government ministries and departments) who were expert and or/responsible for national level policy and planning, were collected.

Both district and national levels personnel were selected for interview on the basis of their current responsibilities, experiences and expertise at the community level, as shown in Figure 4.4. Information on key informants and their organisations are presented in Appendix B. A set of key informant interview topics are given in Table 4.4.

Table 4.4: Topics for key informant interviews

1. What should be done to minimise climate change induced flood effects in the context of Nepal?
2. What will be the best effort to minimise future loss from flooding?
3. What should be done to enable flood victims (whether they have to provide manpower or any financial support as per their property lost) to initiate remedy work?
4. What are effective flood adaptation measures for different flood exposures (short term and long term)?
5. What steps should be initiated to implement flood adaption strategies (short term and long term) effectively?
6. What steps should be initiated to formulate plans and policies for different flood exposures and adaption strategies (short term and long term)?

iv) Experts' level discussion

In order to develop a framework for existing and potential flood adaptation strategies, experts and politicians, as well as policy makers, were consulted. All of them had at least Bachelor degrees in a relevant discipline and were working in a relevant field. A set of discussion topics (Table 4.5) was provided prior to the meeting.

Table 4.5: Topics for discussion at the expert level meetings

1. Discuss the actions to be taken on the issues of climate change mitigation, land-use planning, river training management, planning to develop reservoirs and reduce runoff, flood incident management
2. Discuss and finalise the analytical framework for climate change impacts on flood, vulnerability and adaptation assessment
3. Discuss and finalise the plan and policy for flood adaptation strategies

4.5.3 Walkover survey

A walkover survey was carried out at Gangapur, Matehiya, Holiya, Fattepur, Kamdi and Bettahani VDCs in Banke District and Lalmatiya, Sisaniya, Sohanpur, Chailahi, Rajpur Bella and Satawariya VDCs in Dang district in the month of April from 4 to 26, 2012. This walkover survey provided useful information on: (i) the history of land use/land cover changes; (ii) flood history and major events; (iii) the on-ground reality of the flood problem; and (iv) current flood adaptation practices e.g. flood pain cultivation, plantation at river bank etc. within the study area. Photographs and GPS locations of visited areas were also taken for the biophysical interpretation of the study area.

4.6 Hydraulic Modelling

Hydraulic modeling was performed to find the inundation depth caused by floods of different magnitudes to enable preparation of flood hazard maps for the study area. The Hydraulic Engineering Center's River Analysis System (HEC-RAS) was used to simulate the hydraulic processes of the basin.

4.6.1 Estimation of flood flow

The flood flows of different return periods were estimated using the observed annual maximum series of gauging stations. The Gumbel's method (Gumbel Distribution) is the most widely used probability distribution function for extreme values in hydrologic and meteorological studies for prediction of flood peaks and maximum rainfalls. This method is widely applied for flood analyses (Linsley *et al.* 1949; Johnstone & Cross 1949; Subramanya 1994; Ven 2010). In this study, floods of different periods were estimated by fitting the Gumbel distribution to the observed data. In this method, the variate QT (flood peak discharge with a recurrence interval, T) is estimated by:

$$Q_T = \bar{Q} + K\sigma_{n-1}$$

Where:

$\bar{Q}$ = Average value of the data

σ_{n-1} = standard deviation of the sample of size (n) $= \sqrt{\frac{\sum(Q-\bar{Q})^2}{n-1}}$

K = frequency factor expressed as

$$K = \frac{y_T - \bar{y}_n}{S_n}$$

In which y_T = reduced variate, a function of T and is given by

y_T = - $\left[ln.\, ln\frac{T}{T-1}\right]$

$\bar{y}_n$ = reduced mean, a function of sample size n, and

S_n = reduced standard deviation of function of sample size n

To use the method, one has to refer to a table of values (Subramanya 1994) to determine y_n and S_n.

4.6.2 Hydraulic modeling using HEC-RAS model

While there are a number of hydraulic models, such as Flood Wave Dynamic Model (FLDWAV) and Dynamic Wave Operation (DWOPER), HEC-RAS, MIKE 11, Storm Water Management Model (SWMM) etc., the HEC-RAS model used in this study is one of the most tested, widely used (NWS 2007; URS 2009; Basnyat 2008) and convenient hydraulic models; it is also freely available. This model gives the water surface elevation for a given flood of certain return period. The computation considers the flow as a gradually varying steady flow. The results from this analysis were used to establish the flood prone areas and develop the flood inundation mapping for the study area.

4.6.3 Flood inundation mapping

The hydraulic analysis, using the HEC-RAS software, and flood inundation mapping involved the following steps:

i) Preparation of the geometric data:

a. Preparation of the Digital Elevation Model (DEM): The DEM of the West Rapti Basin was prepared from a contour map (at 20 m intervals) obtained from the Department of the Survey (1996) and the recent Shuttle Radar Topography Mission (SRTM) map (for the lower Terai Region). The current West Rapti stream was digitised from recent Google Earth imagery and converted into a stream vector for use in the Geographical Information System (GIS). These data were then used to make the final DEM for the flood inundation mapping using the 'Topo to Raster' tool in 3D Analyst in GIS.

b. Pre- River Analysis System (RAS) processing: The following steps were carried out in pre-RAS.

   i. Preparation of the river centre line theme and the assignment of the river name and reach name.
   ii. Preparation of the river bank theme: this was carried out using the digitised river bank from the Google Earth imagery.
   iii. Preparation of the flow paths: the centre flow path, which represents the river main channel, was assigned in the map; the left and right bank flow paths were drawn based on an estimation of the elevation that flooding can reach.
   iv. Development of the cross sections: cross-section lines were created for the river system.

ii) Preparation of the flow data:

Flow data were estimated at the upstream boundary, for return period of 2 and 100 years, using the Gumbel Method. The flows of tributaries entering into the main river were estimated using an area transpose method (details in Chapter 5, Section 5.4).

iii) Model development

The following steps were applied to create the hydraulic model using HEC-RAS.

1. Starting a new project
2. Importing the geometric data prepared through pre-RAS processing
3. Entering the flow data and normal flow as the lower boundary condition
4. Setting the parameter value for the Manning roughness coefficient (The Manning roughness coefficient is often denoted by *n* and is an empirically

derived coefficient dependent on surface roughness. Based on flow characteristics and type of surface roughness, river value of n = 0.035 (Chow, 1973) is used. The used coefficient is directly affecting the river discharge velocity in each cross-section (both velocity and roughness coefficient has inverse relationship).

iv) Performing hydraulic calculations

This was done by running the HEC-RAS model.

v) Extracting simulation results

The simulation results were extracted to find the water depths at different locations of the Basin; these were used to prepare the flood inundation map and flood hazard maps.

vi) Validation of the simulation result

The HEC-RAS model developed for the study area was validated by comparing simulated results of the 2008 flood and the inundation depth reported by the respondents living there. This was done by changing the roughness coefficient of the channel and flood plain areas until the simulated results were fairly close to the observed values of water depths at different locations in the Basin.

4.6.4 Flood hazard map

The depth of inundation, duration of inundation and number of times an area is inundated (i.e. frequency of flood events) are the main indicators of flood hazard, as discussed in Chapter 2. Since the simulation was done under steady state flow conditions in which inundation time cannot be estimated, the inundation time of a flood of a certain magnitude hitting a certain area was, thus, assumed to be implicitly included in the depth of flood. Even considering inundation depth and frequency of flooding, the study area can be divided into any number of hazard zones which carry little meaning to the common people and the policy makers. To make the zonation process simple and readily understandable to policy makers, the following two criteria were used.

A) Criteria I: Inundation depth

If the inundation depth is more, the disturbance to the people will be higher. The levels of severity in relation to inundation depths are defined in Table 4.6.

Table 4.6: Criteria and condition of inundation depth

SN	Criteria	Condition	Remarks
1	There is little disturbance to daily human activities and little significant damage to crops or settlements	<0.3 m	Impacts: Manageable, as the flood hazard does not pose a risk to human lives or property. Level of Risk: Low
2	Daily activities are impeded and there is damage to crops and settlements	0.3–1.0 m	Impacts: Tolerable, as this flood hazard does not pose a threat to human lives but destroys the property of the people (e.g. crops). Level of Risk: Moderate
3	Daily activities are severely impeded, settlements are highly affected and there is significant damage to crops.	>1.0 m	Impacts: Very difficult to tolerate and with long term impacts. Level of Risk: High

B) Criteria II: Flood frequency and zoning

Climate change affects the return period (i.e. the average length of time in years between flood events) and increases the intensity and, potentially, the impact of extreme events. In this study, two and 100 year return periods were calculated in order to assess the effect of climate change on flooding. The study does not attempt to analyse climatic variability. So, the 2 year and 100 year return period floods refer to the probability of flood events occurring once in every two years and once in every 100 years, respectively. If an area is frequently hit by floods (i.e. with a return period of up to 2 years), there is likely to be major disruptions to settlement and human activities in that area, while if an area is rarely hit by floods (i.e. with a return period of 100 years or more), then that area could be considered safe. Based on these two parameters, a region can be divided into three areas as:

Disturbed Area: the area experiences flooding at least every two years (i.e. 2 year flood return period).

Moderately Disturbed Area: the area experiences flooding less frequently, on average, than every two years but more frequently than once every hundred years.

Safe Area: the area rarely experiences flooding (i.e. 100+ year return period).

In order to avoid complexity, the study area was classified, depending on the extent of the inundation depth and the frequency of flooding, into the following 3 main types of flood hazard zones (Table 4.7).

1. Critical flood hazard zone

The areas which have been frequently hit by even small floods at a return period of less than or equal to 2 years and where inundation depth reached a level which made rescue operations difficult (>1.0 m depth). Both factors are critical in this zone.

2. Moderate flood prone zone

Areas not falling, by definition, in the critical and low flood prone zones were kept in this zone. Areas where one of the critical factors, but not both, for Zones 1 and 3 occurs are also accepted in this zone.

3. Low flood prone

In this zone, flooding occurs very rarely and the inundation depth is also quite low (<0.3 m). Both factors are in within tolerable limit and this zone can be considered a relatively safe area given the overall situation in the study area.

Table 4.7: Criteria of zonation for flood hazard mapping

	Frequency of inundation		
Inundation depth (m)	**≤2 years (frequent)**	**2 – 100 years (moderate)**	**≥ 100 years (rare)**
<0.3 m (Safe)	Moderately hazardous	Moderately hazardous	Less hazardous
0.3–1.0 m (Moderate)	Moderately hazardous	Moderately hazardous	Moderately hazardous
>1.0 m (High)	Critically hazardous	Moderately hazardous	Moderately hazardous

4.7 Vulnerability Assessment Method

Flood vulnerability assessment (Plate 2002; Loucks *et al.* 2008; Purvis *et al.* 2008; Dawson *et al.* 2008; Apel *et al.* 2009) involves a multidimensional approach encompassing a large number of indicators. Vulnerability is dependent on the economic wellbeing and awareness of the people living in a society and the preparedness and recovery conditions of the community. The poorest are disproportionately vulnerable and they have less capacity to adapt (Khajuria and Ravindranth 2012). Therefore, socio-economic data were used for the assessment of vulnerability, given flood management and indigenous knowledge on flood adaptation strategies. In the beginning, a list of vulnerability indicators developed by Dixit *et al* (2007) for similar types of river cahtchments, but different socio-economic contexts, was used. These indicators were presented to participants, and they were then asked to add, delete and modify the indicators based on their own circumstances and experiences. They came-up with 37 indicators. They were then further requested to narrow these down and select only those indicators that were most relevant to the local area based on the past flood history. Finally, 25 key indicators were unanimously selected (Table 4.8). These indicators were then grouped according to seven different parameters. The selected indicators were administered through a total of 240 household interviews where participants were randomly selected from within the three flood hazard zones/strata identified as in Section 4.6.4. During the field work (Feb–May, 2012), the key person of each surveyed household was requested to rate selected parameters on a 1–5 scale in which 1 indicated very low vulnerability and 5, severe vulnerability (Table 4.8). These responses (scores) were then summed to estimate the overall weightings of the seven parameters.

Table 4.8: Parameters and their indicators for vulnerability assessment

Parameters	SN	Indicators	Parameters	SN	Indicators
Physical	1	Frequency of flooding	**Economic**	14	Agricultural production
	2	Damage to agricultural land		15	Land holding
	3	Bank cutting/sand casting		16	Value of housing
	4	Damage to physical infrastructure e.g. bridges, roads etc.		17	Sources of income
	5	Pollution of drinking water sources		18	Food security
	6	Transportation and mobility	**Access resources**	19	Access to water
	7	Housing near the river banks		20	Access to forest
	8	Settlements near the river banks		21	Access to service center
	9	Change in direction of flow	**Communication**	22	Communication
	10	Damage of land by flood	**Gender perspective**	23	Group formation
Social	11	Access to education		24	Participation of women
	12	Activities of household head	**Psychological**	25	Psychological
	13	Mobility of the people			

In addition, eleven experts working in the flood sector were asked to distribute weights to these parameters so that the total sum of weights was 100. Here, unlike the household survey, the weighting was given on the basis of its importance in the context of Nepal rather than the basis of flood vulnerability. Finally, from the given weightings, the average weight for each parameter was calculated.

The vulnerability categories and their range, with small modifications, were taken from Dixit *et al.* (2007) then expanded for the 25 vulnerability indicators (Table 4.9). The scores of all 25 indicators were summed for each household and evaluated against the range; then, the numbers of households within particular vulnerability categories were determined.

Table 4.9: Vulnerability categories and their range for 25 indicators

Rank	Vulnerability categories	Magnitude	For 25 indicators (score)
V	Severe	4.0–5.0	101–125
IV	High	3.0–4.0	76–100
III	Moderate	2.0–3.0	51–75
II	Low	1.5–2.0	38–50
I	Very low	1.0–1.5	25–37

4.8 Willingness to Pay for Flood Mitigation

Contingent valuation (CV) approaches are perhaps the most promising approach for the estimation of the willingness to pay of local people in flood prone areas for different flood mitigation activities under different flood scenarios; however, it has not been previously attempted in the case of floods in developing countries. The CV method has suffered from some methodological issues and criticisms (Ojeda et al. 2008) but those issues can be overcome by following the comprehensive set of guidelines developed by the National Oceanic and Atmospheric Administration (NOAA) Panel (Hanemann 1996) and accepted within the US legal system and by the World Bank (Hanemann 1996; Arrow *et al.* 1993; Carson et al 2008). Moreover, in developing countries, where most people are under- or un-employed and thence their income levels are very low, using 'labour-day' as a unit of WTP is a promising approach. In this study, the NOAA Panel guidelines (as discussed below) were strictly followed and WTP for mitigating floods under different flood scenarios were estimated with the use of man-day as a measure of WTP. In developing countries like Nepal, where the opportunity cost of people is very low in some seasons, WTP in terms of man-day is a promising approach (for detailed discussion, please see Chapter VI and Chapter VIII, Section 8.5).

WTP is a well-established means of economic valuation. Surveys designed to find WTP must contain a scenario or description of the (hypothetical or real) policy or program the respondent is being asked to value or vote on. The setting provides the context for eliciting information (sometimes detailed) related to WTP. In other words, the scenario is intended to give the respondent a clear picture of the "good" that he or she is being asked to value. One approach is to construct a scenario in which the environmental attribute is threatened and then ask respondents how much they would be willing to pay to protect it. The survey must follow either an open-ended question or a bidding game or a referendum question approach or a contingent ranking for eliciting value or a choice for the respondent (Maraseni *et al.* 2008).

Survey methods include telephone surveys, mail surveys, and personal (face-to-face) interviews methods. Personal interview is the best approach for receiving a high rate of response. This method also makes it easier for the respondent to clarify questions and their responses to the questionnaire and is a more convenient approach for the respondents compared to telephone or mail surveys. Therefore, a face-to-face interview method was applied in this study. Such interviews should also include one or more follow-up questions to ensure that respondents understand the choice they are being asked to make or to discover the reasons for their answer. Survey data are often used to develop statistical relationships between WTP and variables such as the income, age, and education level of respondents. The validity of the CV survey can then be assessed by determining if WTP varies in reasonable ways (Zhai 2006).

Critics of contingent valuation point to studies showing that the wording of questions in a CV questionnaire, or even the order in which questions are asked, can have significant impacts on the answers. The survey process itself can introduce bias in responses, which raises questions about relationships between survey responses and willingness to pay. In this study, all of these factors were taken into consideration when both designing the survey instrument and collecting information.

(i) Scenario development: Four flood scenarios were proposed: the current flood scenario; a flood scenario for 2030; a flood scenario for 2070; and a flood scenario for 2100 (detail is given at *Appendix E, Section VII*). However, in order to avoid confusion, no mention was made of years and respondents were simply briefed as to the four flood scenarios. All flood scenarios were shown on a map and also on a laptop. Through this process, respondents were quickly able to calculate their damage costs under different flood scenarios and elicit their WTP accordingly.

ii. Pre-testing of questionnaire and its final setting:
In order to elicit the WTP of respondents, a bidding game or referendum method was used. During the reconnaissance survey the wording of question was pre-tested and refined using words/language which was locally appropriate to the group of people being surveyed.

The wording of the question was as follows: Would you vote in favour of reducing your annual loss due to flood in terms of labour days each year to protect life and properties?

Yes No

If 'yes', what will be the highest amount/labour days you would pay per year?

Flood scenarios	Scenarios 1	Scenarios 2	Scenarios 3	Scenarios 4
WTP in labour days				

If 'no', why do you say 'no'? What is the least amount/labour days you would pay?

Flood scenarios	Scenarios 1	Scenarios 2	Scenarios 3	Scenarios 4
WTP in labour days				

iii. Respondents' characteristics:
In order to triangulate the validity of the WTPs, WTPs were cross-checked with the estimated (by respondents) damage costs of flood to agricultural crops and livestock, and impacts on their total income. Correlations were estimated between key attributes and WTPs and appropriate statistical tests were conducted to see whether there were any statistically significant differences in WTPs associated with gender, education, age, location (depth of waterlogged), income and damage cost classes.

4.9 Assessment of Flood Adaptation Strategies

In the beginning of the focus group discussions, participants were asked to prepare a list of flood adaptation strategies for three periods (viz. pre-flooding, during flood and after flooding) that have been adopted over the past 10 years. Then, they were requested to select only those adaptation strategies that were most preferred. These most preferred strategies were then included in questions for the household survey. During the field visit, the key person of the household was requested to rank selected flood adaptation strategies on a 1–5 scale, where 1 was the least preferred option and 5 the most preferred option. The adaptation strategies for each climatic scenario were then ranked, based on total scores, from strategies that were most preferred to those that were least preferred overall (Maraseni and Xinquan 2011).

People's perceptions of flood impacts were tested through an assessment of local awareness levels and mitigation and adaptation knowledge. As described earlier, sample households were randomly selected from within three flood prone zones (Critical, Moderate, and Low or Safe) and flood risk communities (high, medium and low risk). Flood adaption strategies were ranked for each flood scenario. The information collected from the questionnaire survey was analysed using SPSS. The perceptions of the respondents were measured on a 1–5 Likert scale.

The mean ratings were compared and Imperial tests (Pearson's chi-square test, t-test, F-test etc.) were applied to test the differences in the perception of the different groups of respondents (Gravetter & Wallnau 1995). All perception related questions/issues were ranked based on the Weighted Average Index (WAI). Highly ranked perceptions were given higher weightage and vice versa. For example, in a 1–5 scale (1 for very low and 5 for very high) perception questions, “very high”, “high”, “medium”, “low” and “very low” perceptions were given weightages of 5, 4, 3, 2 and 1, respectively.

$$\text{Weighted Average Index (WAI)} = \frac{F_1 x W_1 + F_2\, x W_2 + F_3 x W_3 + F_4 x W_4 + F_5 \text{ x } W_5}{F_1 + F_2 + F_3 + F_4 + F_5}$$

$$\text{WAI} = \frac{\sum \text{Fi } x \text{ Wi}}{\sum \text{Fi}}$$

Where,
F = frequency of the respondents
W = weight of each scale
i= weight (for example, in a most preferred to least preferred question, +5= most preferred, and 1 for least preferred).

4.10 Conclusions

This chapter has outlined the methods used in this study to address the specific objectives. These include: analysis of time-series temperature and rainfall data to identify key trends; application of the Gumbel method and HEC-RAS modelling to perform hydraulic analysis and flood hazard mapping; and questionnaire survey and key informants/experts interviews conducted to assess the perceived flood vulnerability, the WTP of people for various flood mitigation/adaptation approaches, the ranking of potential flood adaptation strategies; and the preparation of policy feedbacks to different levels of stakeholders. Table 4.10 shows the specific objective and methods applied in this study.

Table 4.6: Summary table of the methodology

Objectives	Specific methods
• Analyse time series data	• Trend analysis
• Perform hydraulic analysis	• Gumbel method • HEC-RAS Modelling:
• Develop a flood hazard map • Assess the perceived flood vulnerability	• HEC-RAS version GIS application • Questionnaire survey/ vulnerability mapping
• Determine the WTP of people with and without the exposure flood scenarios	• Questionnaire survey • Key informants/experts • Focus group discussion
• Analyse current flood adaption strategies • Analyse the change in perception of adaptation strategies with exposure to flood scenarios.	• Questionnaire survey • Key informants/experts • Focus group discussion
• Rank potential flood adaptation strategies • Prepare policy feedbacks to different level of stakeholders.	• Key informants/experts • Review of the rules and regulation/ policies/ guidelines/strategies

Chapter 5: Perceptions and Modelling of Climate Change and Flooding

5.1 Introduction

This chapter first presents the results of people's perception of climate change as obtained from the questionnaire survey given in appendix H and compares those with key climatic data for the West Rapti River Basin. Then, the results from the hydrological modelling of flooding under the four climate change scenarios are presented, showing the flood prone area (zones) and risks and hazard areas; this is then linked to the people's perceptions of impacts and an assessment of their relative vulnerability. This chapter lays the foundation for assessing the willingness to pay for various flood mitigation options from which policy and management recommendations are then derived.

5.2 Climate Change Scenarios Analysis

5.2.1. Temperature: trends and people's perception

a) Observed Trend

Temperature data for the 35 years from 1973 to 2008 obtained from the Department of Meteorology and Hydrology were used in the climate trend analysis. The average annual mean temperature for this period was 25.4ºC. The lowest and highest annual mean temperatures in the study area were, respectively, 23.5ºC in 1983 and 26.7ºC in 2007. While annual temperature means have fluctuated, there was a positive trend overall, with an average increase of 0.025ºC/year, over the time period investigated (Figure 5.1).

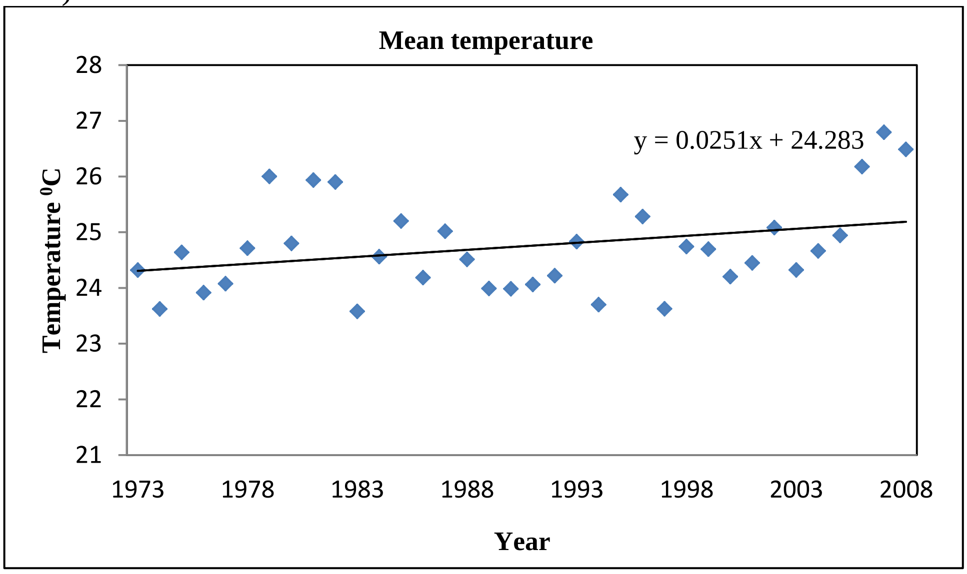

Figure 5.1: Trend of annual mean temperature in West Rapti River Basin

Figure 5.2, similarly, shows a positive trend in annual mean maximum temperatures for the study area. Overall, the average annual mean maximum temperature for the period from 1973 to 2008 was 43.9ºC, and ranged from 39.9ºC in 1990 to 46.8ºC in 2008. The annual mean maximum temperature trend over the period was an increase of 0.039ºC/year.

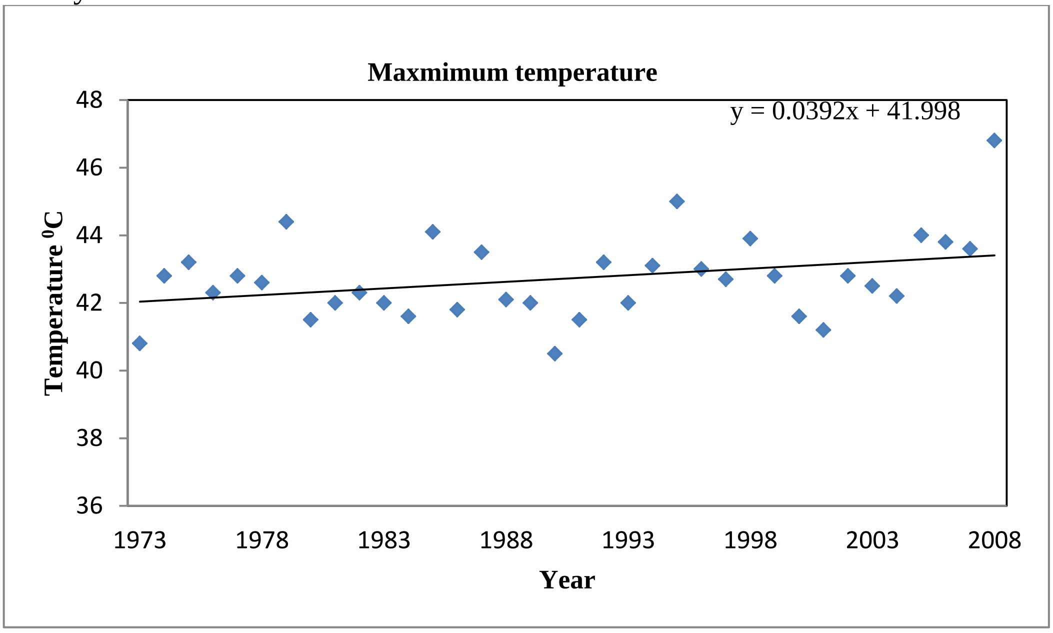

Figure 5.2: Trend of annual mean maximum temperature in West Rapti River Basin

The trend in annual mean minimum temperature was also positive for the years, 1973 to 2008 (Figure 5.3). The average annual mean minimum temperature was 3.3ºC with the lowest annual mean minimum temperature of 0.9ºC in 1976 and the highest annual mean minimum temperature of 7ºC in 1977. The annual mean minimum temperature trend over the period was an increase of 0.043ºC/year. The trends of maximum and minimum temperature for summer (March-May) and winter (December –February) seasons are given (*Appendix D, Figure D.1 and D.2*).

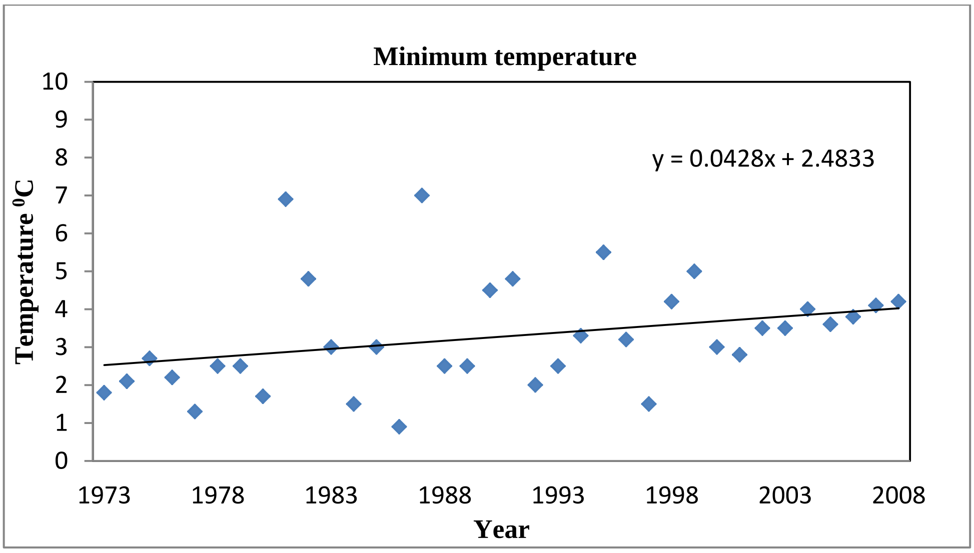

Figure 5.3: Trend of annual mean minimum temperature in West Rapti River Basin

b) People's Perceptions about temperature

People's perceptions of temperature change over the past two decades are presented in Figure 5.4. The majority of survey respondents mentioned that there had been an increase in both the summer (63.7% of respondents) and winter (52.7% of respondents) temperatures. However, some of respondents (16.7%) felt that there had been a decrease in temperature in summer and a sizeable number of people (36.4%) said that winter temperatures had decreased compared to past temperatures. Similarly, 8.3% and 4.4% of respondents perceived that there had been no change in temperatures during summer and winter, respectively, while 11.3% and 6.5% of the respondents were not prepared to say, either way.

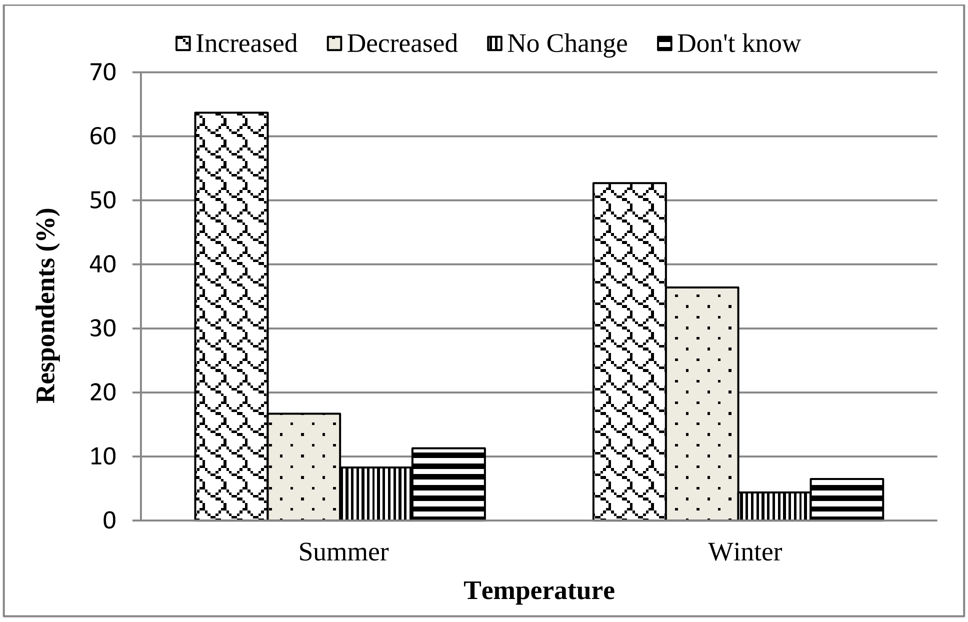

Figure 5.4: Perception of respondents (N=240) of the recent temperature compared to 20 years ago

5.2.2. Precipitation: trends and people's perceptions

a) Observed Anomaly

Rainfall data over 37 years (1971–2008), from Kusum, Sika, Koilabas and Libang Gaun stations, were analysed to investigate rainfall trend within the study area. These stations cover the whole catchment. Over the period, average annual rainfall increased by 0.22 mm per year across the study area. However, the seasonal variation in the rainfall at these stations is very high. The contribution of rainfall during the monsoon season accounted for about 83% of total annual rainfall while pre-monsoon and post-monsoon season rainfall accounted for, on average, about 10% and 7%, respectively; these results closely resemble the situation for the whole country (Marahatta *et al.* 2009).

Figure 5.5 indicates that the average annual rainfall fluctuated significantly at all of the rainfall stations. The maximum rainfall anomaly was observed at Koilabas where 76% more than the long-term average annual rainfall for the 1971–2008 period was received in 2000 and 67% less than the long-term average fell in 1991 (Figure 5.5c). The highest average annual rainfall was recorded at Koilabas station (2930 mm in 1998) and the lowest at Kusum station (460.2 mm in 1977).

Figure 5.5 shows the average annual rainfall anomaly across all four stations located in West Rapti River basin. Overall, average annual rainfall increased by 0.25 mm/year bewteen 1971 and 2008.

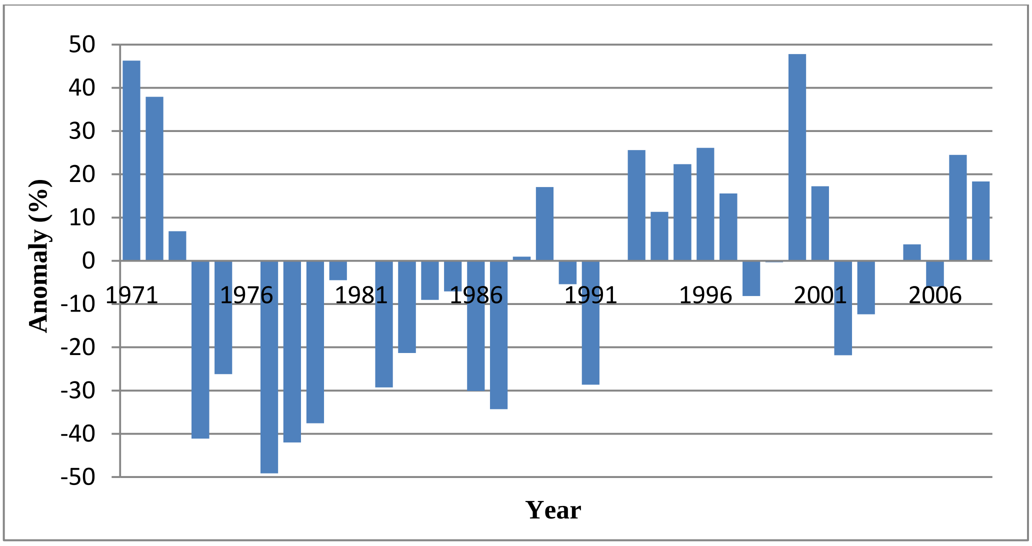

Figure 5.5 (a): Kusum station (elevation: 190m)

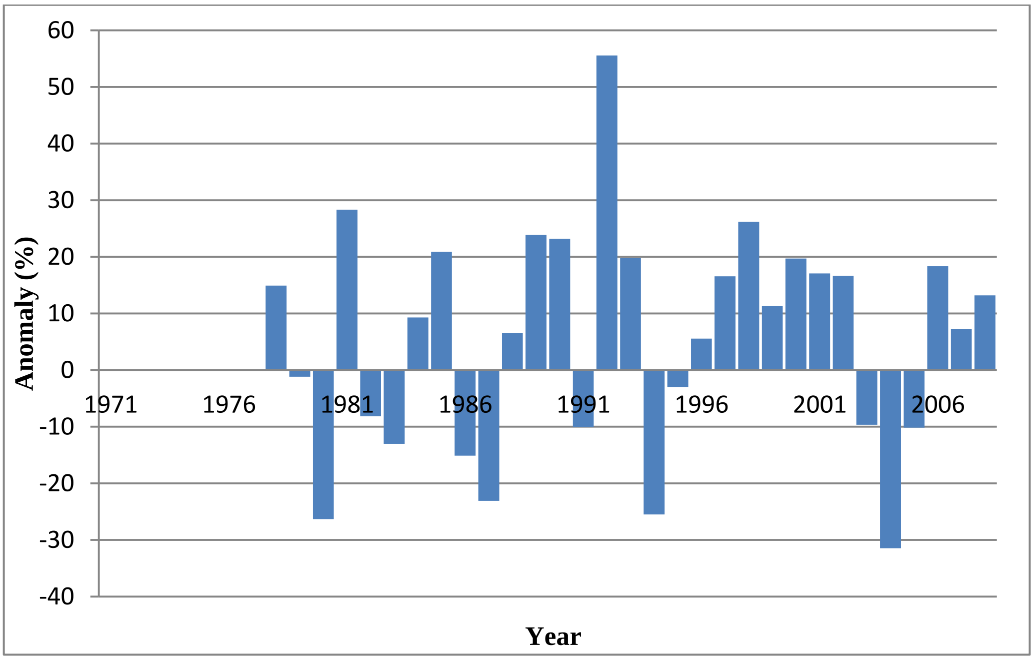

Figure 5.5 (b): Sikta station (elevation: 195m)

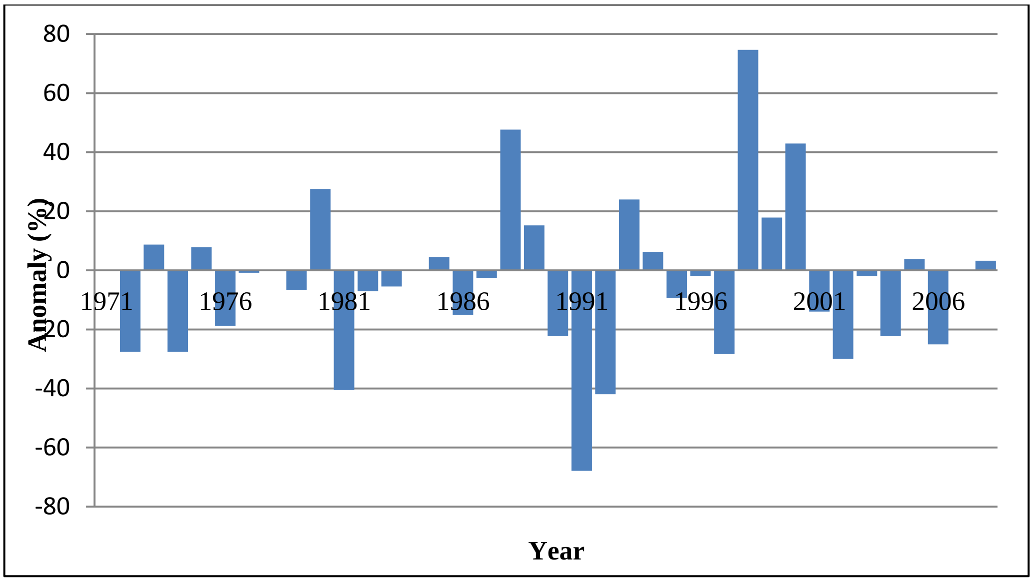

Figure 5.5 (c): Koilabas station (elevation: 320m)

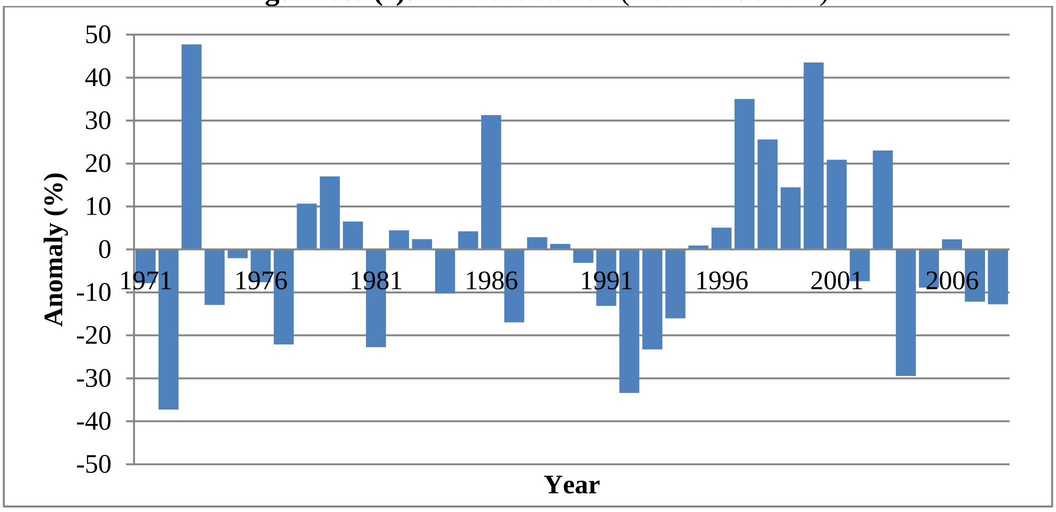

Figure 5.5 (d) Libang Gaun station (elevation: 1270 m)

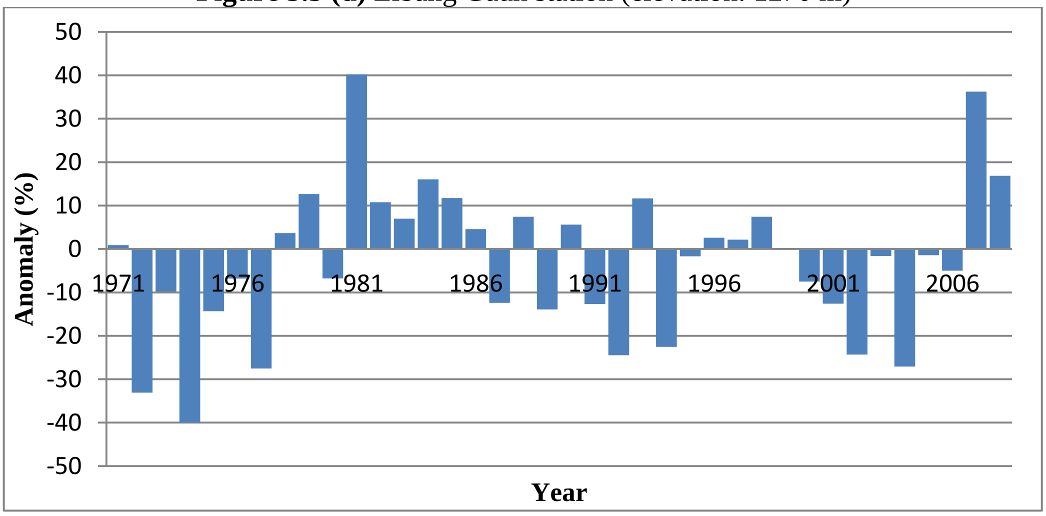

Figure 5.5 (e): Average rainfall of Kusum, Sikta, Koilabas, Libang Gaun stations

Figure 5.5: Anomaly in average rainfall in the West Rapti River Basin

b) Observed Seasonal Rainfall Trends

Pre-monsoon

While average annual rainfall increased across the Basin from 1971 to 2008, pre-monsoon (March–May) rainfall decreased on average by 0.06 mm annually (Figure 5.6)

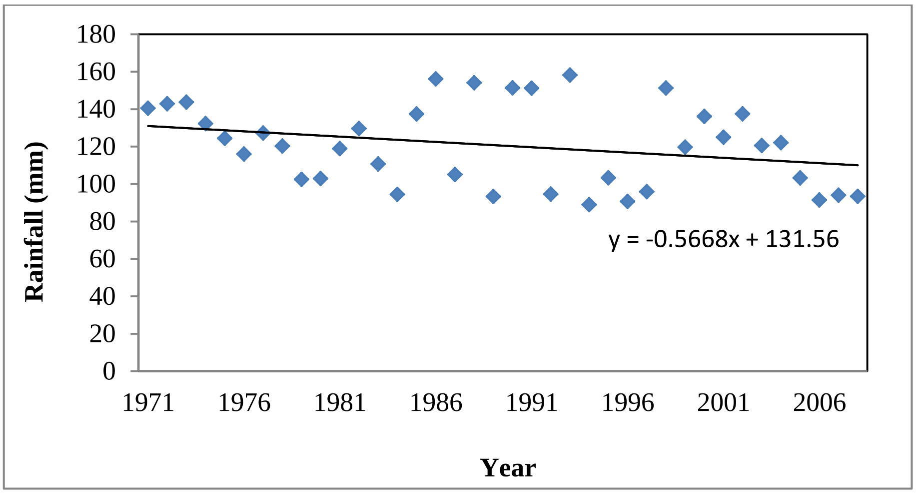

Figure 5.6: Trend of pre-monsoon rainfall in West Rapti River Basin

Monsoon season

The general trend for monsoon (June-September) rainfall, averaged over all four stations of West Rapti Basin, was slightly positive, increasing by 1.08 mm annually from 1971 to 2008 (Figure 5.7).

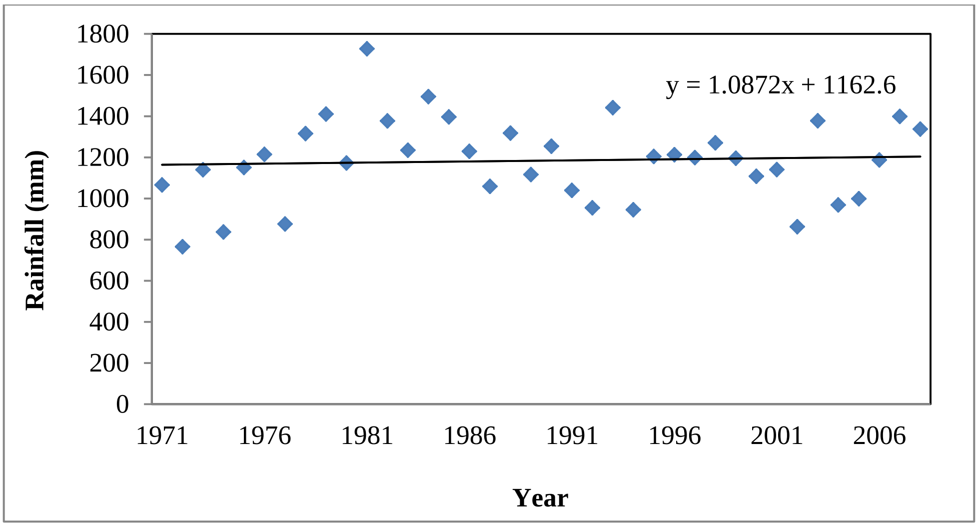

Figure 5.7: Trend of monsoon rainfall in West Rapti River Basin

Post-monsoon

The trend for average post-monsoon (October–February) rainfall was also positive with an annual increase of 1.68 mm from 1971 to 2008. This is a potentially significant shift in the timing of rainfall and is likely to impact on cropping times for several crops.

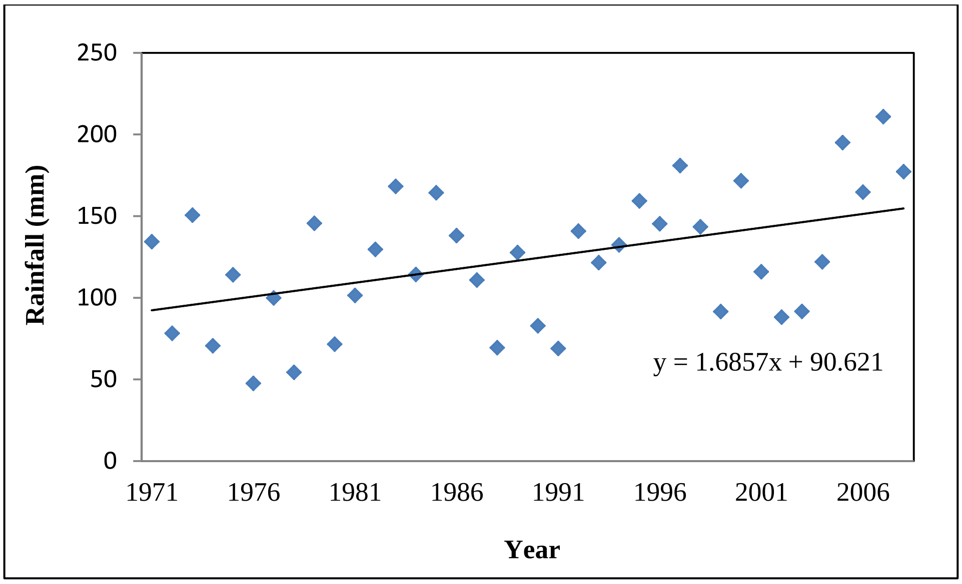

Figure 5.8: Trend of average post-monsoon rainfall in West Rapti River Basin

c) People's Perceptions of Change in Monsoon Season

Even within the scientific community, there is debate over the timing of the onset and end of the monsoon season (Maharatta *et al.* 2009). In order to assess the perception of people living in the study area, the question was asked whether they felt the change in the beginning and end of the rainy season had affected their agricultural and other activities over the last 20 years. Table 5.1 shows that about 88% of the respondents stated that there had been a change in the beginning and ending time of the monsoon season over the last 20 years.

Table 5. 1: Perception of respondents on the change in the start and end of monsoon rainfall

People's perception	Yes	No	Don't know
Change in beginning and ending of monsoon as compared to 20 years ago (%)	88.3	6.3	5.4

Source: Household survey, 2012

Respondents were also asked to rate their perceptions about the impact of rainfall related climate change indicators (Figure 5.9 and Figure 5.10). Of the total number of respondents (N=240), 47.1% and 44.2% believed that "rain with storms/hail" and "changes in cloud/haze/mist level", respectively, had increased, whereas 25.4% and 40% of respondents argued that they had decreased; 16.7% and 6.7% of the respondents felt that there had been "no change" (Figure 5.9). Similarly, about 52.1% and 39.6% of respondents stated that "heavy rain within a short period" and "unpredicted/unusual rainfall pattern" had increased, respectively, whereas 23.8% and 27.1% perceived that they had declined. Moreover, 13.3% and 23.3% of respondents believed that there were no changes in these indicators while 10.8% and 10%, respectively, had no idea (Figure 5.9).

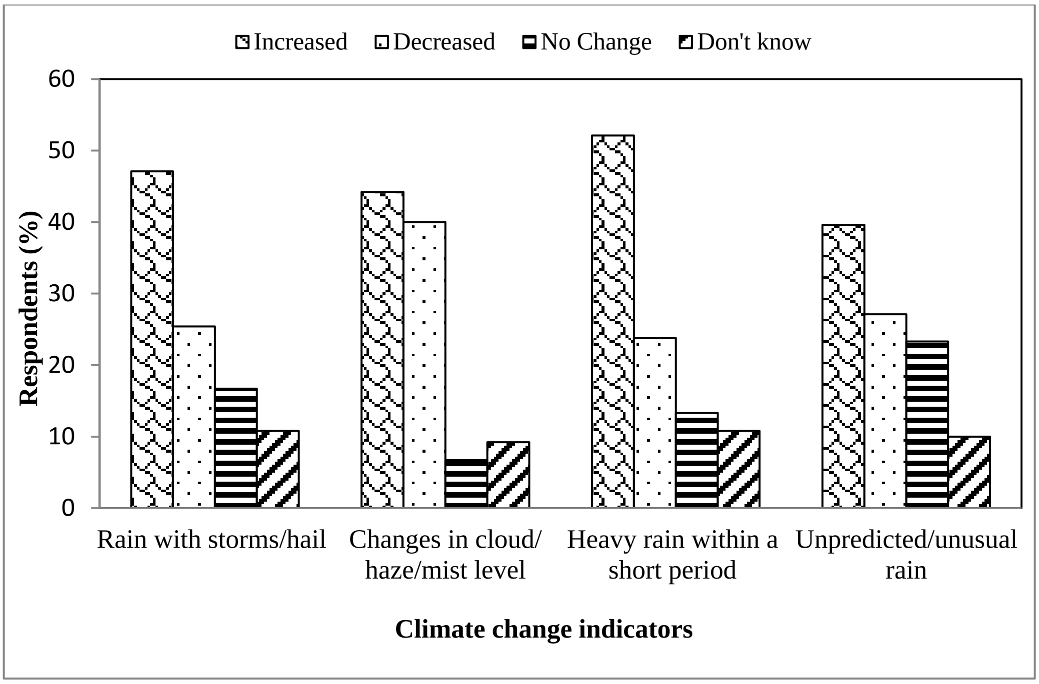

Figure 5.9: People's perception on climate change indicators

Approximately 20% of survey respondents believed (6.7% strongly agreed and 14.7% agreed) that there has been a shift towards an earlier start to the monsoon (i.e. an increase in pre-monsoon rain) in recent years as compared to the past; whereas, 30% did not believe (18.4% disagreed and 10.4% strongly disagreed) that this was the case (Figure 5.10). A majority (49.8%) of respondents felt that they could not say either way as the onset of the monsoon occurred early in some years and late in other years.

More than two thirds of the respondents (20% strongly agreed and 47.5% agreed) felt that the amount of monsoon rain has increased over the last two decades. Only 10.8% said that they did not feel there had been any increase in monsoon rainfall (10.4% disagreed and 0.4% strongly disagreed). About one fifth of the people (21%) were neutral on this issue. Similarly, the majority of respondents (86.4%) either strongly agreed (54.3%) or agreed (32.1%) that the monsoon season had been extended and that post-monsoon rainfall had increased. This situation may force climatologists and meteorologists to redefine the monsoon season.

Likewise, 57.1% of respondents either strongly agreed (17.8%) or agreed (39.3%) that the "annual rainfall" has increased whereas 13.7% of respondents either disagreed (8.9%) or strongly disagreed (4.8%) with this statement.

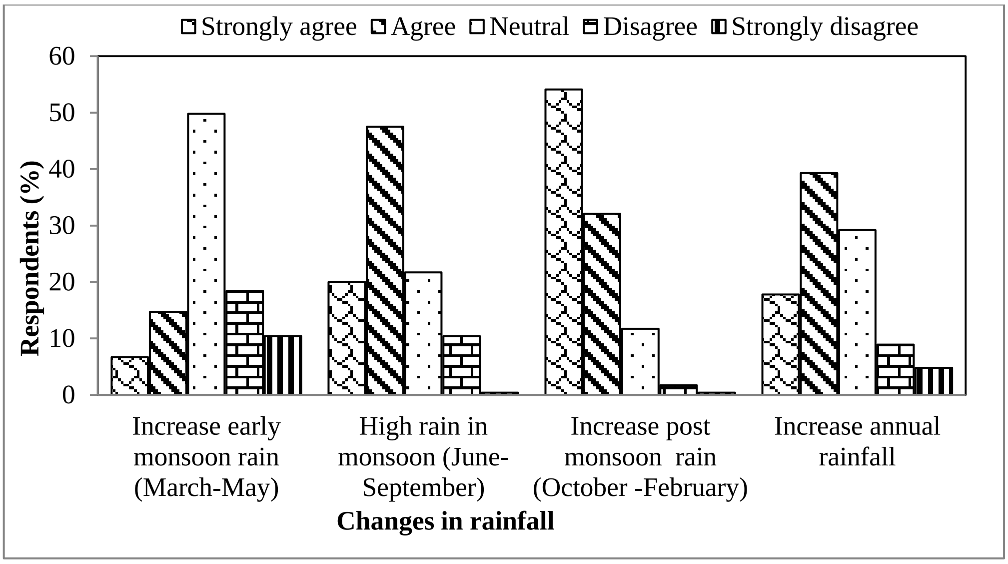

Figure 5.10: Perception of respondents (N=240) of the recent rainfall pattern compared to 20 years ago

The findings on temperature and rainfall were generally consistent with the people's perception of events, with some exceptions. Peoples' perception on rainfall revealed that most of them felt there had been a change in the climatic pattern. In particular, most of the respondents mentioned that the monsoon season had been shifting to a later time.

5.3. Rainfall and Flooding

The West Rapti River is purely rain-fed and runoff within the Basin follows the rainfall pattern. Therefore, flooding in the plains region of the catchment is the result of high intensity rainfall. The hydrograph at Bagasoti for the September 2008 flood event is given in Figure 5.11, along with the rainfall data at Bajuwartar, the closest meteorological station. The link between rainfall and runoff events can be clearly seen in this figure.

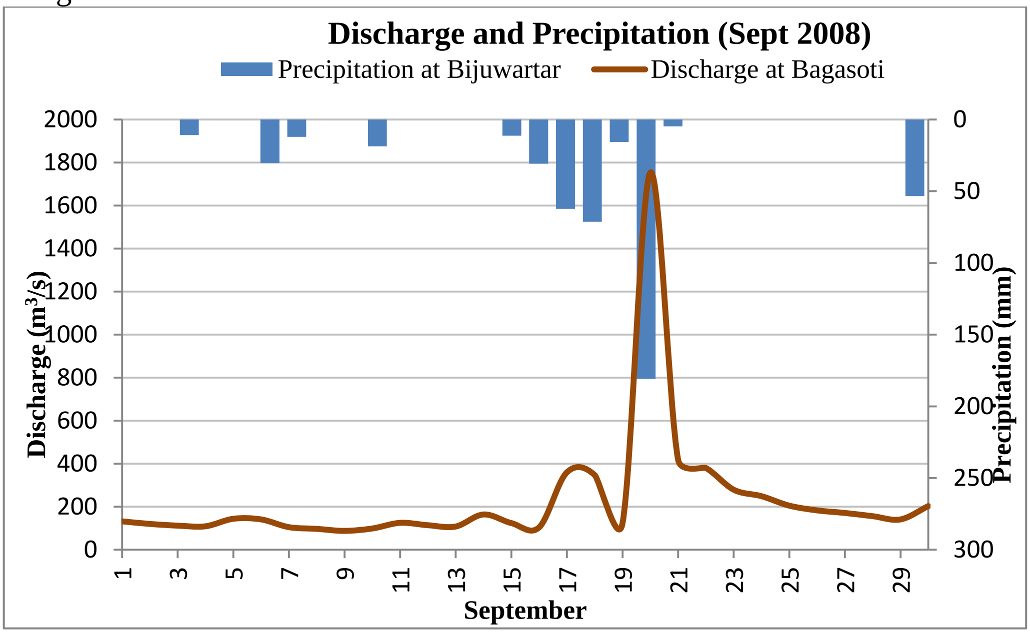

Figure 5.11: Hydrograph of 2008 flood event

5.4 Flood Assessments under Climate Change

5.4.1 Flow analysis: magnitude and frequency of floods

A Gumbel distribution was fitted to the observed annual maximum flow data (instantaneous flow) of Bagasoti gauging station to obtain the flow for 2, 30, 70 and 100 year return periods, as required for the flood hazard zonation (discussed in Chapter IV, sub-section 4.6.4). In order to obtain the tributary and overland flow contributions for these return periods, an areal transposition method was employed, based on the flow value of the Bagasoti data. Flow values thus obtained are given in Table 5.2.

Table 5. 2: Estimated flows at different points in the river (m^3/s)

SN	**River**	**Current**		**2030**		**2070**		**2100**		**Remarks**
		2 year	**100 year**	**2 year**	**100 year**	**2 year**	**100 year**	2 year	100 year	
1	West Rapti	2633	9128	4186	16339	4529	16887	4845	17343	Bagasoti (U/s boundary)
2	Shukhar	44	149	70	267	76	276	81	283	Tributary contribution
3	Overland flow	5	20	8	36	9	37	9	38	Overland area contribution
4	West Rapti	2682	9297	4264	16642	4613	17199	4935	17664	Main river
5	Khairi	5	18	8	32	9	33	9	34	Tributary contribution
6	Overland flow	5	17	8	30	9	31	9	32	Overland area contribution
7	West Rapti	2692	9332	4280	16704	4630	17264	4953	17731	Main River
8	Moranga	32	109	51	195	55	202	59	207	Tributary contribution
9	Overland flow	31	106	49	190	53	196	57	201	Overland area contribution
10	West Rapti	2755	9547	4380	17089	4739	17662	5069	18139	Main River
11	Muguwa	42	144	67	258	72	266	77	274	Tributary contribution
12	Overland flow	94	327	149	585	162	605	173	621	Overland area contribution
13	West Rapti	2891	10018	4597	17932	4973	18533	5319	19034	Main river
14	Jijhari	123	427	196	764	212	790	226	811	Tributary contribution
15	Overland flow	46	159	73	285	79	294	85	302	Overland area contribution
16	West Rapti	3060	10604	4865	18981	5263	19617	5630	20148	Main river
17	Dundwa	9	32	14	57	15	59	17	61	Tributary contribution
18	Overland flow	129	446	205	798	222	825	237	847	Overland area contribution
19	West Rapti	3198	11082	5085	19837	5501	20502	5884	21056	Main river

5.4.2 Hydraulic modelling

a) Validation of the Model Results

Validation of the hydraulic simulations, derived from using the HEC-RAS model, was done by determining inundation depths at various locations lying in the plains area of the river catchments (Figure. 5.12). This was done using the flood flow of 2008 and the inundation depths that people of the study area observed during the flood. This flood was chosen as it was one of the more recent and disruptive floods that had affected people living in the study area.

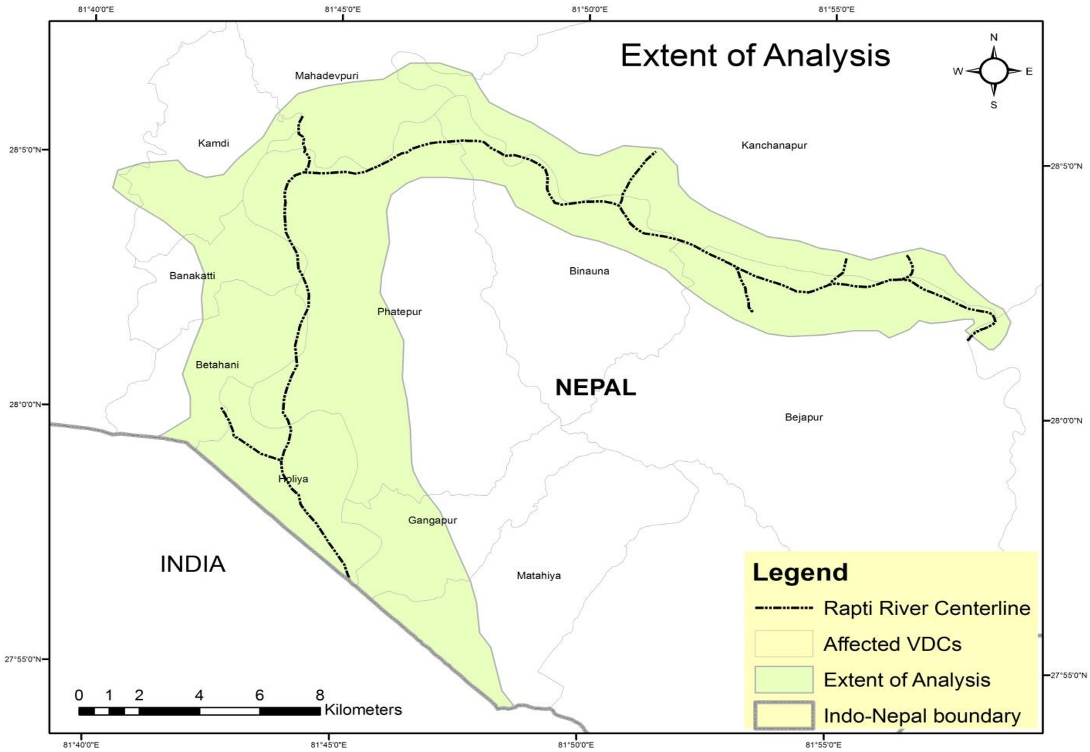

Figure 5. 12: Map showing the extent of flood inundation using the flood of 2008

Figure 5.13 shows the inundation depths estimated for the 2008 flood. The main flooded areas were categorized into three zones representing areas where inundation depth was (i) less than 0.3 m; (ii) between 0.3 and 1 m; and (iii) more than 1 m. The depths reported by people during the field survey were close to the values given by the modeling study. This suggests that the parameters used in the models and the assumptions made in the simulation process are satisfactory and that the model can be used to determine the inundation depths for the flows of our interest.

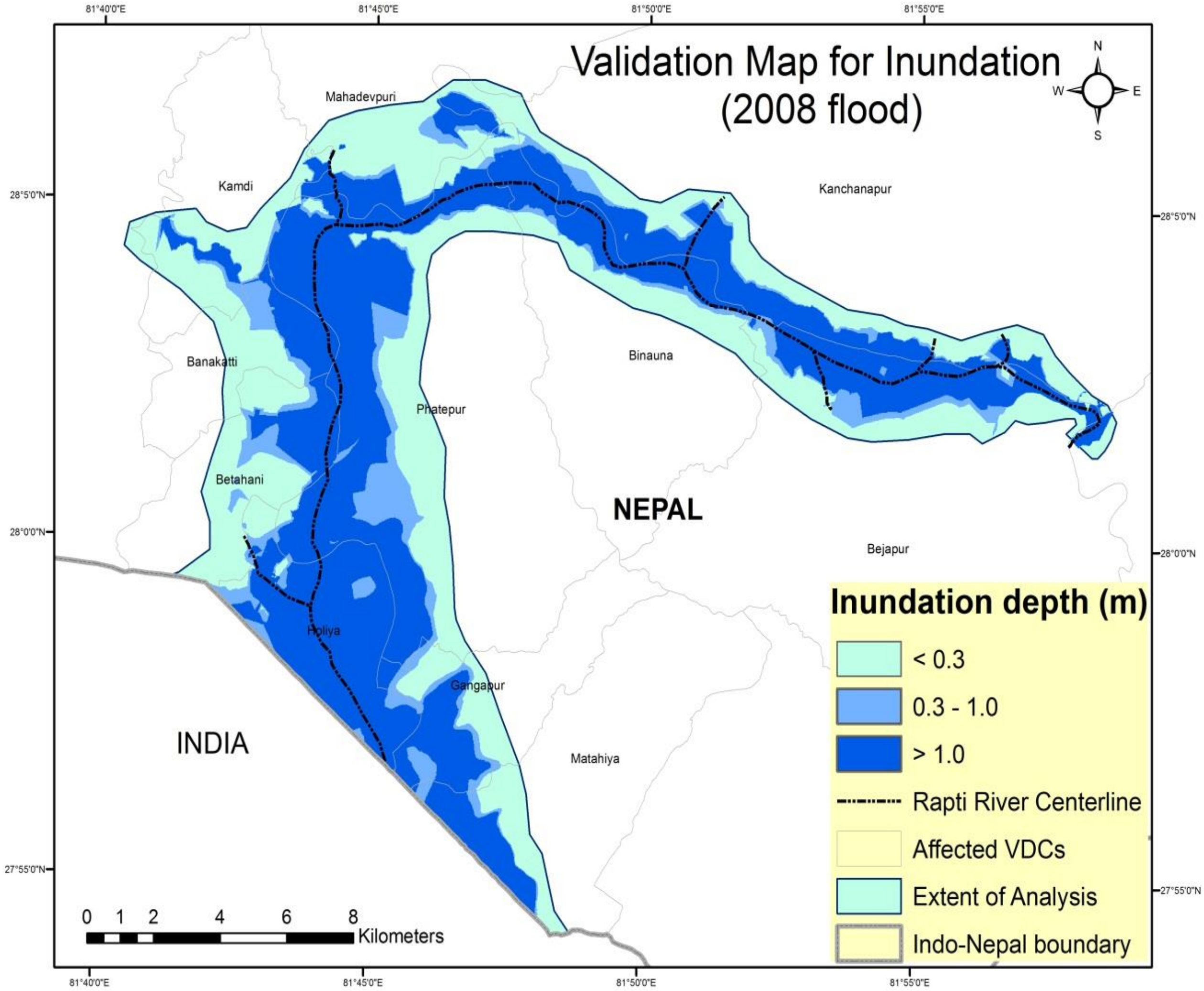

Figure 5.13: Estimated flood inundation depths for the flood of 2008

b) Simulation of floods

Simulations for four scenarios (Scenario I: Present Case, Scenario II: 2030 Case, Scenario III: 2070 Case and Scenario IV: 2100 Case) were done to determine the inundation depths at various locations of the catchments. It was done for 2 year and 100 year return periods of floods (as discussed in Chapter IV, Section 4.6.4), with flow considered as a spatially varying steady state. It is noted here that the future floods for these return period were calculated by multiplying the present floods by certain multiplying factors. These multiplying factors were obtained from the flood values of 25 and 50 year return periods estimated by NDRI (2012) through log transformation method. It is noted here that the multiplying factors thus calculated for 2 year floods for 2030, 2070 and 2100 came to be 1.59, 1.72 and 1.84 respectively while for 100 year floods they came to be 1.79, 1.85 and 1.90 respectively for 2030, 2070 and 2100 floods. The inundation depths at various locations for each case are given in Appendix E.

5.4.3 Flood hazard mapping

Floods are a common phenomenon during the monsoon season of every year in the study area. As such, there is almost no settlement or agricultural area which is not affected by flooding of some sort. It is, therefore, prudent to classify the flood areas into critically hazardous, moderately hazardous and less hazardous zones from the point of view of flood impact based on the frequency of flooding and the depth of inundation. Based on the criteria (Criteria I and II) given in Chapter IV, Section 4.6.4, flood hazard maps were prepared for current climatic scenario 2030, 2070 and 2100 (Figure 5.14, 5.15, 5.16 and 5.17) climatic scenarios taking into account the depth and frequency of flooding. Table 5.3 indicates the areas and proportion of these zones lying within the VDCs of the Basin. This assessment shows that 60.8 km^2 of the study area is in the critically hazardous flood zone, while 63.4 km^2 and 58.1 km^2, respectively, are in the moderately hazardous and less hazardous zones for current scenario. Similarly, for 2030, 77.7 km^2 lies in the critically hazardous zone, while 128.24 km^2 and 7.56 km^2 in moderate and less hazardous zones respectively. For 2070, about 82.77 km^2 is in the critically hazardous flood zone, while 130.5km^2 and 7.95 km^2 in moderate and less hazardous zones respectively. For 2100, about 85.81 km^2 is in the critically hazardous flood zone, while 148.5km^2 and 10.33 km^2 in moderate and less hazardous zones respectively. It can be seen that the total critical hazard area is increasing continuously in future *(Appendix F, Table F1, F2, F3 and F4).*

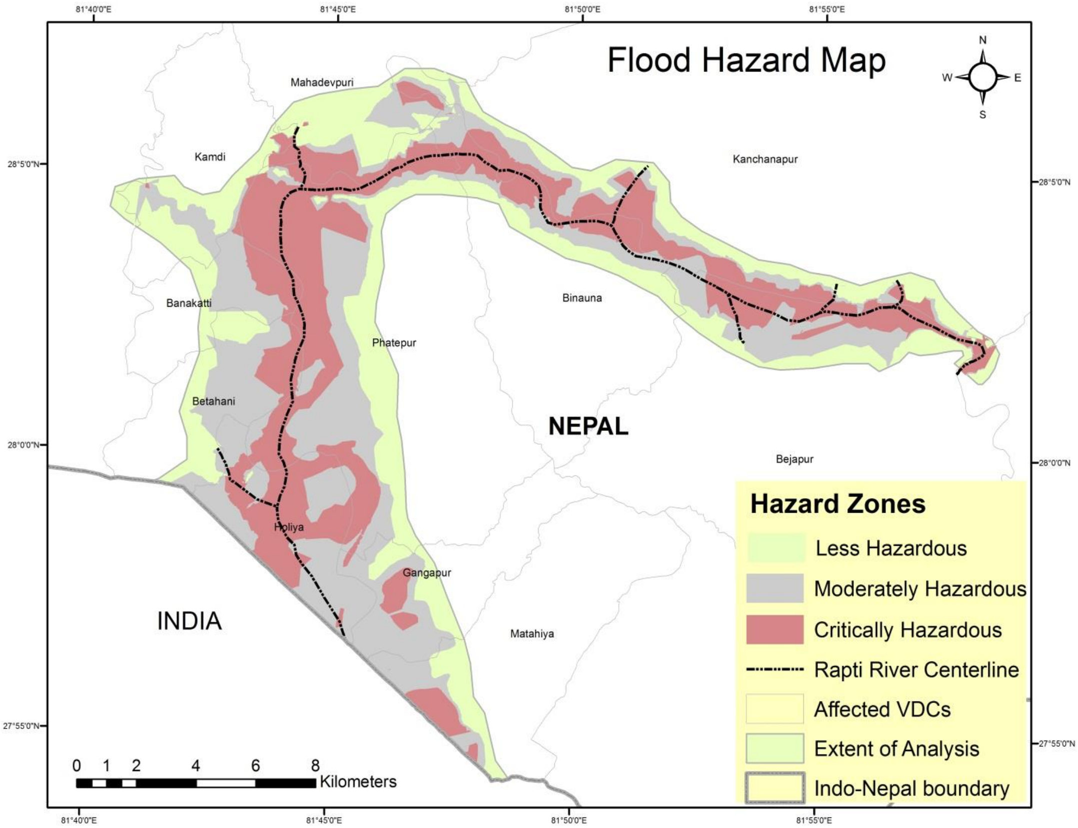

Figure 5. 14: Three different flood hazard zones under current climatic scenario

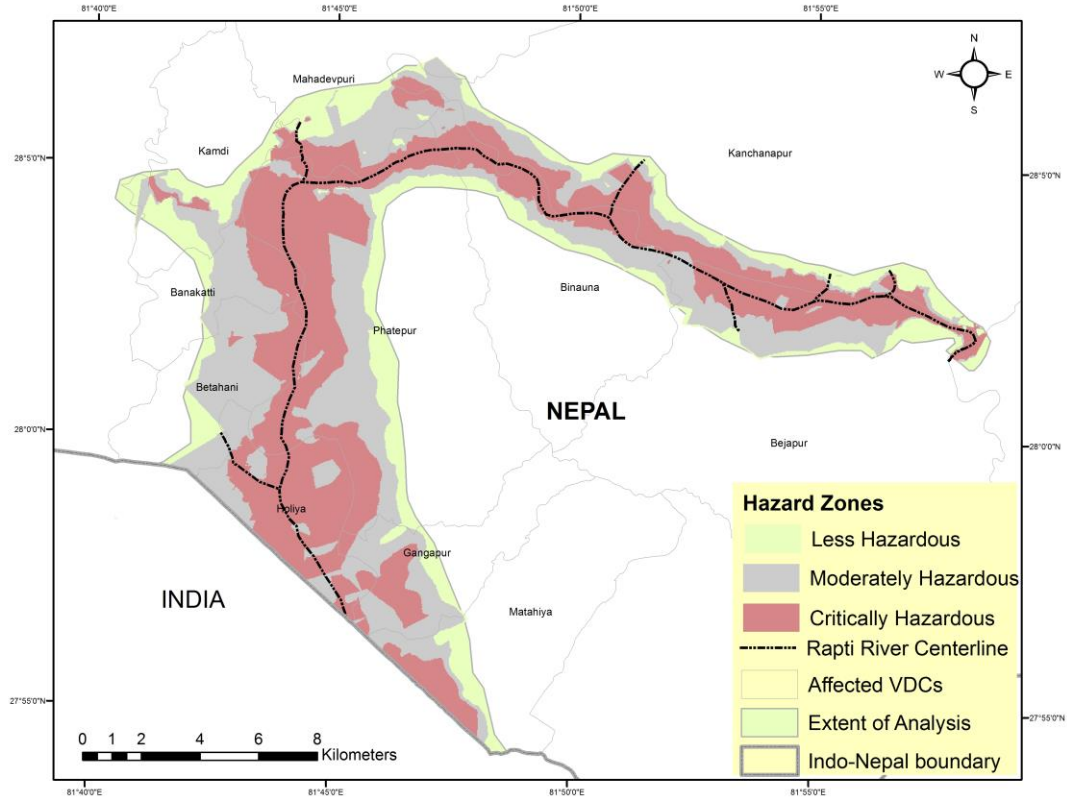

Figure 5. 15: Three different flood hazard zones under 2030 climatic scenario

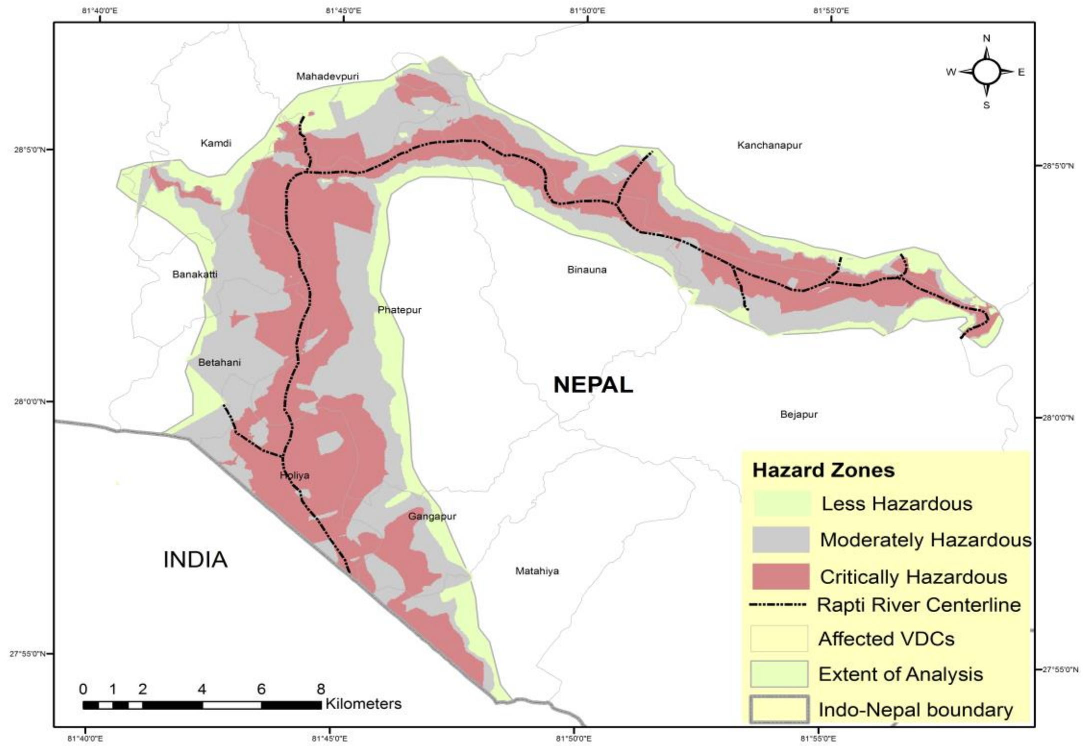

Figure 5. 16: Three different flood hazard zones under 2070 climatic scenario

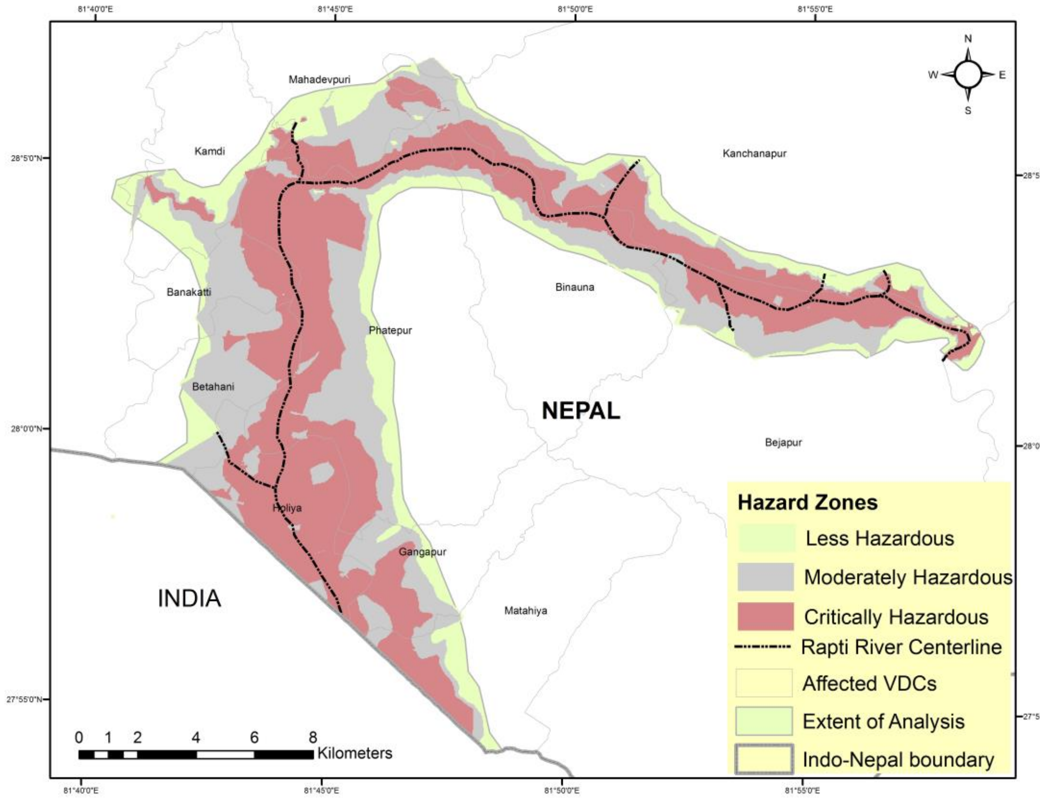

Figure 5. 17: Three different flood hazard zones under 2100 climatic scenario

(b) People's perceptions of the flood assessment

5.4.4 People's perceptions on the causes of flooding and its impacts

People's views were explored to elicit their perceptions of the causes of flooding. At first, FGDs revealed a number of major parameters that induced flooding in the study area. Participants in the Household survey were then asked to rank these parameters on a 1 (the smallest cause of floods) to 5 (the biggest cause of the floods) scale. "Changing rainfall pattern due to climate change" was perceived as the main cause of flooding, with a weighted average index (WAI) of 4.3 (Table 5.3). This was followed by "deforestation" (WAI=4.0). Similarly, "poor land management" and "traditional agricultural practices" were ranked equal third most important, with a WAI of 3.4. People in the study area believe that "boulder and sand extraction" was the least influential in causing flooding, ranking this factor last when compared with the other potential causes. However, overall, all five factors scored greater than a WAI of 3.0. Therefore, perceptions of causes (and indeed causes) could vary spatially but people believe that climate change is the major culprit. However, unlike other factors, climate change cannot be controlled by local people.

Table 5.3: Respondents perceptions on causes of flooding

Caused of flooding	Very big cause	Big cause	Moderate cause	Small cause	Very small cause	WAI	Ranks
Change in rainfall pattern due to climate change	146	39	38	14	3	4.3	I
Deforestation	70	113	39	12	6	4.0	II
Poor land management	22	93	88	26	11	3.4	III
Traditional agricultural practices	40	87	45	54	14	3.4	IV
Boulder and sand extraction	13	68	104	42	13	3.1	V

Source: Household survey, 2012

Similarly, perceived rainfall effects on some of important livelihood activities (daily activities, fuel collection, planting and collecting time and agricultural activities) were evaluated. The impacts of higher rainfall were perceived in "floods", followed by "daily activities" and "plantation/harvest time" (Figure 6.18). About 44.6% (107) of the respondents believe that high rainfall has a "very high impact" on flood intensity, and another 35% and 18% believed that this has a "high impact" and a "moderate impact" on flood, respectively. About 25% and 18% of the respondent thought that the high rainfall had a "very high impact" on their daily activities and on agricultural activities (plantation and harvesting), respectively. A large number of people considered that high intensity rainfall had a moderate impact on the occurrence of landslides. This is to be expected as the majority of the study area is plains and landslides are not an issue.

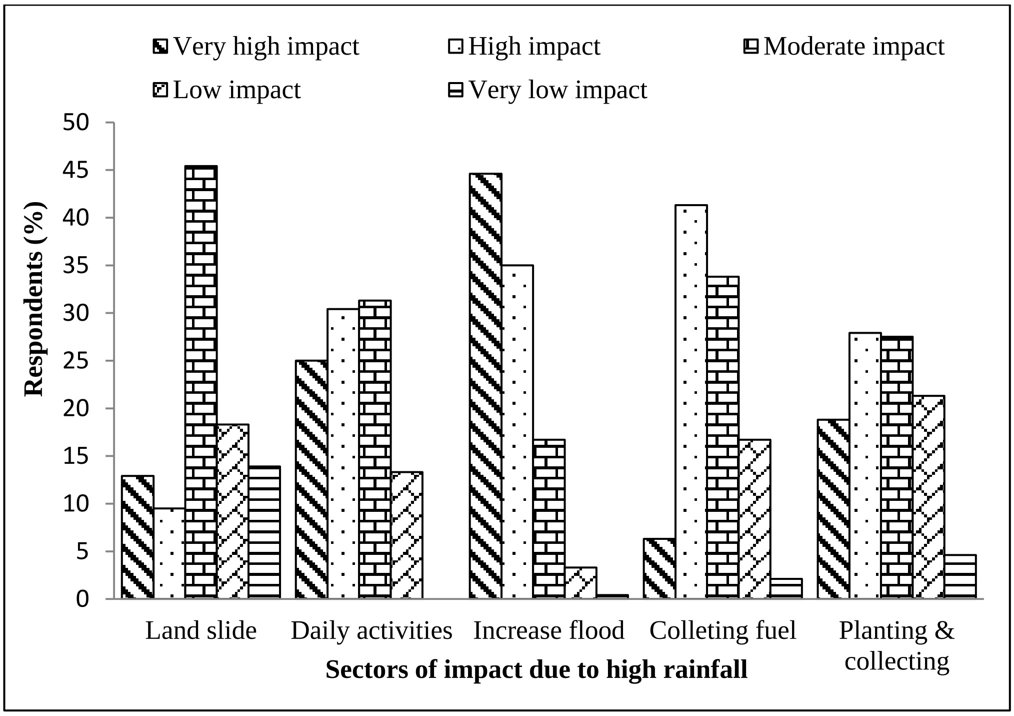

Figure 5. 18: Respondents' perception on the impact of high rainfall on different activities

Furthermore, respondents' perceptions of the impacts of floods on different goods, services and activities were also evaluated (Table 5.4). Five major flood impacts were identified through the FGDs. The levels of impact in these five areas were assessed against 1 to 5 scales, where 1 is very low and 5 is very high. The respondents' perceptions were then ranked based on their cumulative relative frequency (CRF).

The results indicate that the respondents considered all these five areas as significantly affected. However, agricultural land, houses and settlements and drinking water sources were the ones identified as most severely affected by floods (CRF=>80% indicates moderate to very high impact). Although impacted by flooding, grass and wood collection activities and domestic animals were ranked 4th and 5th among these five areas.

Table 5. 4: Respondents' perceptions of impacts of flood on different goods, services and activities

Responses	Agriculture land			Houses & Settlement			Drinking water sources			Grass &fuel collection			Grass &fuel collection		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
Very high	89	37.1	37.1	22	13.3	13.3	111	46.3	46.3	22	9.2	9.2	45	18.8	18.8
High	89	37.1	74.2	67	42.9	56.3	50	20.8	67.1	67	27.9	37.1	49	20.4	39.2
Moderate	48	20.0	**94.2**	99	33.3	**89.6**	42	17.5	**84.6**	99	41.3	**78.3**	72	30.0	**69.2**
Low	12	5.0	99.2	42	7.5	97.1	30	12.5	97.1	42	17.5	95.8	57	23.8	92.9
Very low	2	0.8	100	10	2.9	100	7	2.9	100	10	4.2	100	17	7.1	100
Rank	**I**			**II**			**III**			**IV**			**V**		

Source: Household survey, 2012

5.4.5 Flood impacts on rice production

Table 5.5 presents the perception of people on the impacts of flooding on rice cultivation in the West Rapti River Basin. Approximately 52% of the respondents mentioned that they had had to re-cultivate the land after flooding whereas 48% said they did not. Of the respondents who re-cultivated, 33% had experienced increased crop yield, 11% said there had been no significant change and 56% had experienced a decrease in crop production (Table 5.6).

Table 5. 5: Response of participants on "will you be able" to cultivate rice after flood

Cultivation of crops	No. of respondents	%
Yes	109	52
No	101	48
Total	210	100

Source: Household survey, 2012

Table 5. 6: Perception of the respondents on the effect of flood on rice production

Production effect	No. of respondents	%
Increase	36	33
Decrease	61	56
No change	12	11
Total	109	100

Source: Household survey, 2012

Of the 36 respondents who mentioned that their rice production had increased after flooding, about 50%, 39% and 11% mentioned that their production increased by up to 25%, 25-50 and 50-75%, respectively (Figure 5.19). They believe that the alluvial soil deposited by flooding is very fertile and, consequently, they do not need to apply more fertilisers. As a result, not only is there an increase in production but, at the same time, production costs decrease.

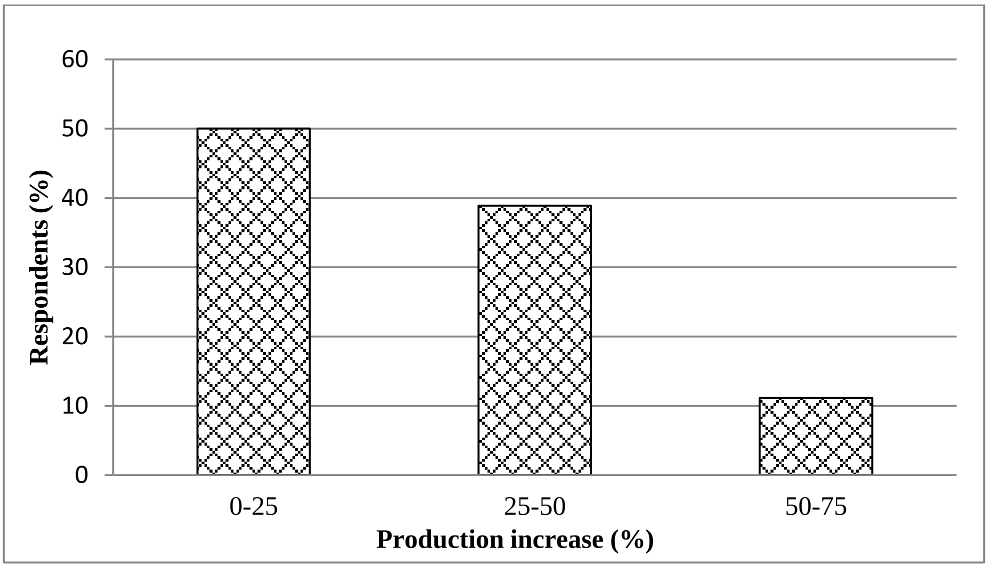

Figure 5.19: Respondents' perceptions of increased rice production (N=36) after flooding

Of the 61 respondents who mentioned that their rice production decreases after flooding, about 41% felt that their rice production decreased by 50-75% (Figure 5.20). Unlike the previous group, this group believed that the top and fertile soil is washed away by floods and, as a result, they need to increase fertiliser inputs. In spite of this production risk, they are still encouraged to cultivate rice for three main reasons: the availability of free family labour with almost zero opportunity cost; no alternative to rice cropping; and "hand to mouth" issues.

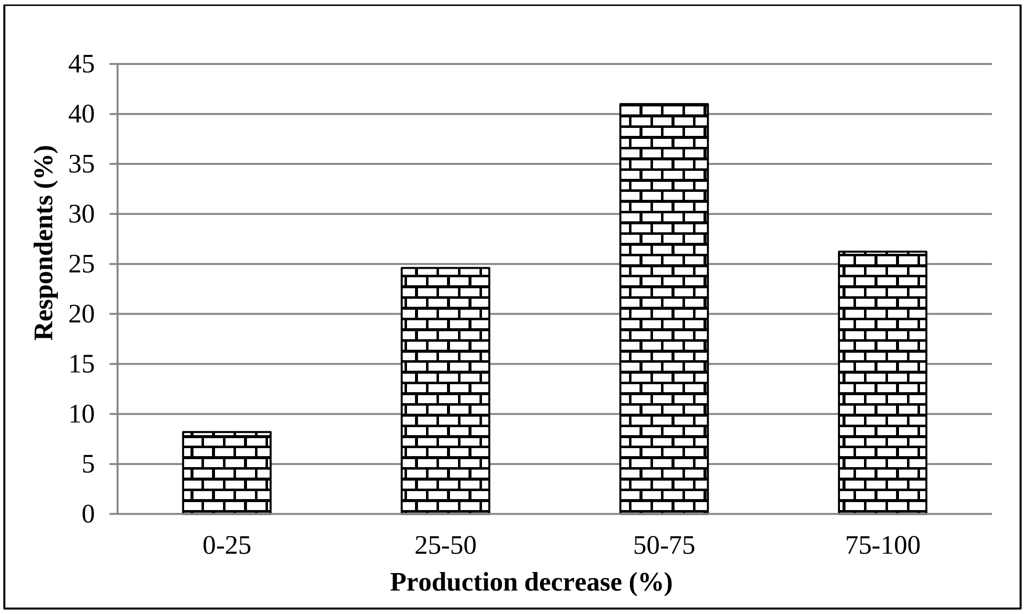

Figure 5. 20: Respondents' perceptions of decreased rice production" (N=61) after flooding

5.4.6 Flood risk level and migration from home

Table 5.7 presents a classification of respondents on the basis of their responses on the flooding. Responses show that each household in the study area was affected by the flood one way or other. On the basis of flood response, there are three types of people: those who temporarily migrate during flood periods; those who stay in the same area at risk; and those who have permanently migrated. Of the 240 household survey respondents, 39.2% reported being temporarily displaced from their houses due to flooding, 48.3% reported living in their house at risk and the remaining 12.5% of households reported that they had permanently migrated from their original home.

Table 5. 7: Types of respondents on the basis of their response to flooding

Classification of respondents	Number	%
Temporarily migrated	94	39.2
Stayed in the area at risk	116	48.3
Permanently migrated	30	12.5

Source: Household survey, 2012

Of the total of 94 respondents who temporarily migrated due to the flooding, 33% migrated for two to three days and 32% migrated for four to seven days. Similarly, 12% and 7% of the respondents migrated for eight to 14 and more than 15 days, respectively. About 16% of respondents shifted from their home for one day (Figure 5.21).

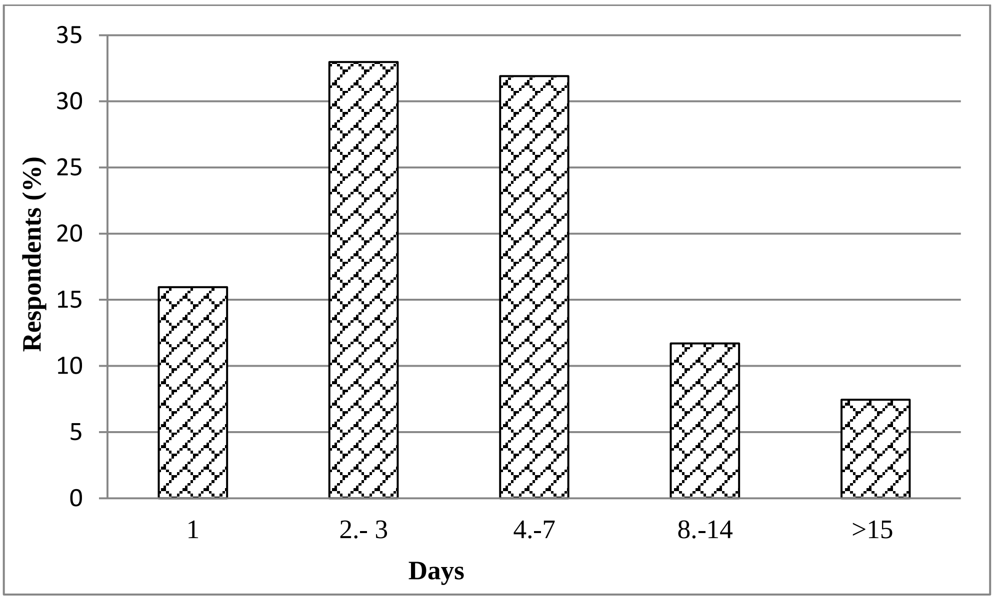

Figure 5.21: Maximum number of days of temporary migration in the study area (N=94)

Of the 94 respondents who reported temporary migrating, about 31% migrated to a public place (i.e. school, Red Cross building, temple etc.), 27% migrated to relatives' houses, 24% to nearby neighbours' houses and the remaining 18% to other places such as road side areas, nearby forests and open space (Table 5.8).

Table 5. 8: Migrated respondents and their placement after the flood event (N=94)

Place of shelter	No. of the respondents	%
Relatives' house	25	26.6
Public place	29	30.9
Neighbours' house	23	24.5
Others (road side, nearby forest area, etc.)	17	18.1
Total	94	100

Source: Household survey, 2012

5.4.7 Perceived flood frequency and magnitude level

Perceptions of flood frequency from the perspectives of the respondents was analysed. Approximately 80% of the respondents faced flood problems every year. Similarly, about 15% of the respondents mentioned that flooding returned every five years. Local people were also asked about the average duration of water logging in their area during the flood season. The results are presented in the figure 5.22. Responses logging duration varied from less than one day to more than 4 days. About 44% of the respondents reported that they faced a water logging problem for one to two days following flooding and another 39% faced the same problem for three to four days.

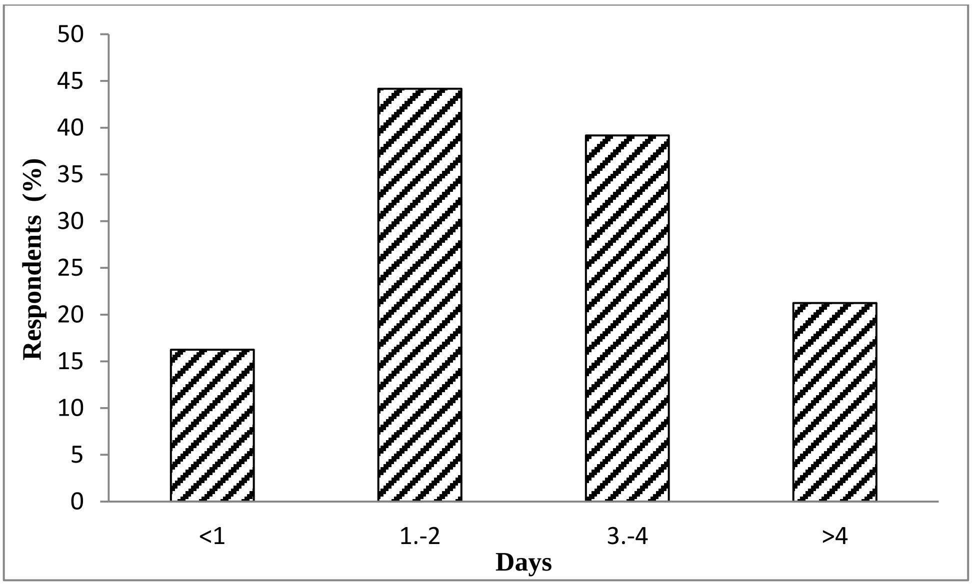

Figure 5. 22: Duration of water logging after rain" perceived by respondents (N=240)

Respondents were also asked about the maximum depth of water during the flooding season. Of the total number of respondents, about 39.5% mentioned that the depth of water ranges from 0.3 to 1 m whereas 25.7% of the respondents mentioned depths of <0.3 m and 34.7% mentioned depths of >1 m (Figure 5.23).

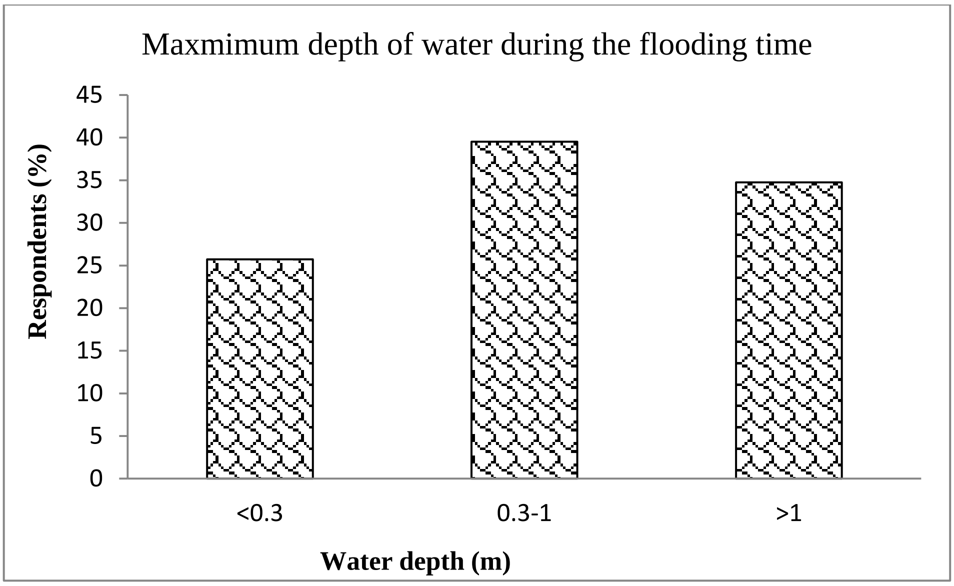

Figure 5. 23: Respondent's perception on the maximum water depth during the flooding time

5.5 Flood Vulnerability Through the Eyes of Vulnerable People

Vulnerability analysis was carried out, based on the perceptions of the people in the study area. As discussed in Section 4.7, 25 vulnerability indicators were considered, (Table 5.9). Vulnerability was quantified on a scale of 1 to 5, where 1 indicates factors that are perceived by the survey respondents to contribute least to vulnerability and 5 indicates those that contribute most; ranks were then classified into three levels of vulnerability: severe (5), high (4) and moderate to very low (3-1).

The number of respondents and their perceptions of the importance of factors which affect flood vulnerability are presented in Table 5.10. Two thirds of the respondents (163 persons out of 240) nominated the frequent occurrence of flooding as the main factor causing severe vulnerability to the people living in the study area. This was followed by bank cutting, the proximity of houses to the river and the lack of transportation facilities, which were ranked second, third and fourth, respectively, as other main indicators which accounted for flood vulnerability. More than 25% of respondents believed their level of vulnerability due to these factors was severe. The other factors were thought to have less to do with flood vulnerability. For example, about 75% of the people thought that communication played a relatively minor role (moderate to very low) in reducing their flood vulnerability. This may be due to a lack of awareness and education as it is recognised elsewhere that a lack of communication may increase vulnerability (Quade & Judy 2011). Similarly, the formation of groups to deal with flood disasters, access to service centers and the participation of women in flood related disaster were also given low weights with regard to flood vulnerability.

Table 5. 9: The magnitude of the range of the vulnerability categories (Ranking)

SN	Indicators	Severe (5)		High (4)		Moderate to very low (3–1)	
		Number	%	Number	%	Number	%
1	Frequency of flood	163	67.9	30	12.5	47	19.6
2	Bank cutting	88	36.7	88	36.7	64	26.7
3	House near the river banks	86	35.8	74	30.8	80	33.3
4	Transportation and mobility	60	25.0	99	41.3	81	33.8
5	Damage of agricultural land	51	21.3	135	56.3	54	22.5
6	Pollution of drinking water sources	37	15.4	62	25.8	141	58.8
7	Damage to structure	35	14.6	125	52.1	80	33.3
8	Mobility of the people	33	13.8	64	26.7	143	59.6
9	Psychological	30	12.5	76	31.7	134	55.8
10	Damage of land by flood	30	12.5	60	25.0	150	62.5
11	Agricultural production	28	11.7	77	32.1	135	56.3
12	Value of house	26	10.8	80	33.3	134	55.8
13	Change in direction of flow	25	10.4	72	30.0	143	59.6
14	Access to education	24	10.0	91	37.9	125	52.1
15	Sources of income	24	10.0	78	32.5	138	57.5
16	Food security	23	9.6	77	32.1	140	58.3
17	Settlement near the river banks	22	9.2	122	50.8	96	40.0
18	Access to forest	21	8.8	68	28.3	151	62.9
19	Land holding	19	7.9	69	28.8	152	63.3
20	Activities of household head	15	6.3	89	37.1	136	56.7
21	Access to water	15	6.3	56	23.3	169	70.4
22	Women participation	13	5.4	66	27.5	161	67.1
23	Group formation	13	5.4	61	25.4	166	69.2
24	Access to service centres	14	5.8	58	24.2	168	70.0
25	Communication	13	5.4	48	20.0	179	74.6

Of the factors contributing to severe and high flood vulnerability, four fifths of the people considered the repeated occurrence of flooding as the main contributor to flood vulnerability in the study area. A majority of respondents thought damage to agricultural land (78%), bank cutting (73%), damage to structures (68%), the proximity of houses to the river (67%), lack of transportation facilities (66%) and the proximity of settlements to the rivers (60%) are the other main indicators which contribute to flood vulnerability. The remaining indicators were considered of lesser importance with regard to flood vulnerability in the study area.

The average magnitude of each indicator is shown in Figure 5.24. Of the selected indicators, “frequency of flood” received the highest average score with a mean ranking of 4.3, indicating that it was perceived to be the most significant indicator of flood vulnerability. This was followed by “bank cutting/sand casting” (3.9) and “damage to agricultural land” (3.8). There are 16 indicators with a mean perceived vulnerability ranking between 3 and 4. These indicators can be taken as factors which contribute to a moderate level to flood vulnerability in the study area as per the respondents. The rest are of low importance in people's perception, having scored, on average, less than 3 in the vulnerability ranking. Facilities for communication was scored lowest with a mean ranking of 2.5.

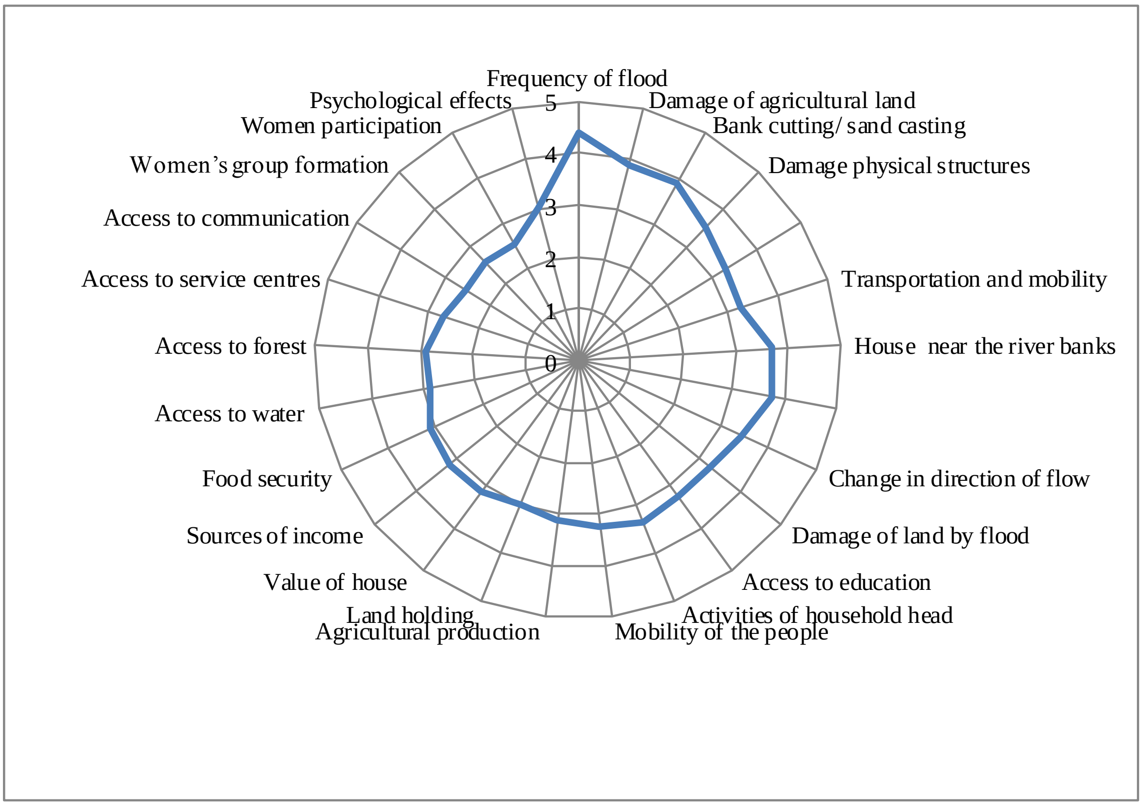

Figure 5. 24: Average levels of perception of different vulnerability indicators (N=240)
Note: The blue solid line represent average value.

The perception (rank) of relevant indicators was then summed to estimate the overall scores of seven parameters (physical, social, economic, access to resources, communication, gender perspectives and psychological) discussed in Section 4.7 and shown in Figure 5.25. The "physical" parameter had a mean value of 3.6, the highest rating parameter among the seven parameters. By contrast, "communication" scored lowest with a mean cumulative ranking of 2.5. The "social" (3.3), "economics" (3.2) and "psychological" (3.1) factors all scored average cumulative rankings of more than 3. However, it is noted here that the "physical" parameter includes 11 indicators while "psychology" has only one indicator. Low rankings for "access to resources (2.8), "gender perspectives" (2.6) and "communication" (2.5) indicate that they were perceived to be of lesser importance in terms of people's flood vulnerability.

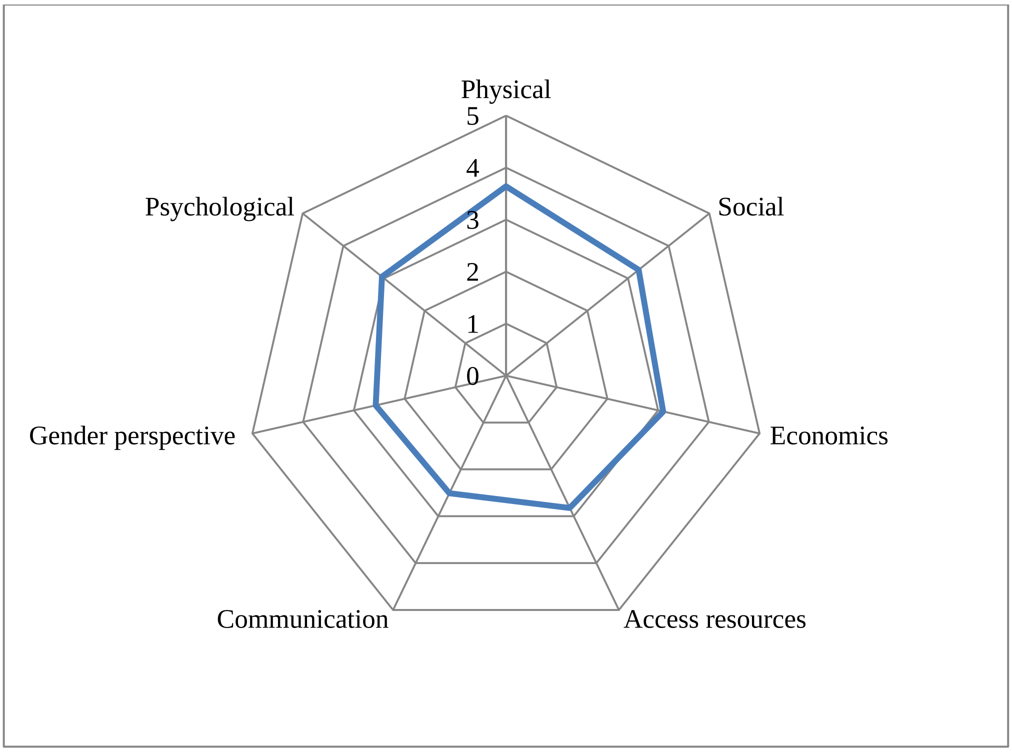

Figure 5.25: Mean cumulative rankings of different vulnerability parameters
Note: The blue solid line represent average value

Average weighed scores for seven parameters: flood experts perception

The average weighted scores of eleven flood experts for the seven parameter groupings are presented in Table 5.10 (as discussed in 4.7). Among the seven parameters, experts scored the “economic” parameter highest with an average weighted score of 26.3% followed by “physical” (20.6%) and “social” (15%). The “psychological” parameter received lowest weighting (7.7%).

Table 5.10: Average weighed scores of flood experts for seven parameters (N=11)

S.N	Parameters	Average weighed scores (%)
1.	Economic	26.3
2	Physical	20.6
3	Social	15.0
4	Access resources	11.1
5	Communication	10.0
6	Gender perspective	9.3
7	Psychological	7.7
Total		100.0

These results indicate a major difference in perceptions of flood vulnerability between the common people and policy makers, with the household survey showing that physical parameters are considered the most important factors at the community level while the experts ranked economic parameters highest

Number of households with different vulnerability levels

The scores of all 25 indicators were then summed for each household (possible score range: 25–125); each household was then classified, on the basis of its total vulnerability score, into one of five vulnerability classes (Table 5.11). Table 5.11 shows the number and percentage of households in the study area within each of these vulnerability categories. Of these, 23 households (9.6%) were found to be exposed to a severe level of flood vulnerability while 116 households (48%) fell into the high vulnerability category; the remaining 101 household (42.1%) were in the moderate vulnerability category. None of the households were found to be in the low or very low vulnerability categories.

Table 5. 11: Number of households with different vulnerability levels

Rank	Vulnerability categories	Magnitude (Range 1–5)	Score (Range 25–125)	No. of household	%
V	Severe	4.0–5.0	101–125	23	9.6
IV	High	3.0–4.0	76–100	116	48.3
III	Moderate	2.0–3.0	51–75	101	42.1
II	Low	1.5–2.0	38–50	0	0.0
I	Very low	1.0–1.5	25–37	0	0.0
Total				240	100

5.6 Conclusion

The temperature of West Rapti River basin is increasing at a faster rate than the national and global average. Similarly, the intensity and magnitude of rainfall is increasing and the monsoon season is extending; these trends were evident both in the recorded data and in the majority of local people's perceptions. Hydraulic modelling enabled analysis of the flow and the magnitude and frequency of floods in this river basin. Based on the frequency of flooding and the depth of flood inundations, a flood hazard map was produced which enabled the study area to be divided into critically, moderately and less hazardous flood zones, enabling prioritisation of the area for flood risk. Flood vulnerability was assessed based on people's perceptions. Two third of the respondents perceived that "frequent occurrence of flood" was the main factor underpinning the severe vulnerability of the people.

Chapter 6: Willingness To Pay for Flood Risk Mitigation

6.1 Introduction

Socio-economic factors, such as age, gender, education level, income levels and flood damage cost, influence the level of willingness to pay (WTP) of respondents. This chapter discusses the results of the household survey with regard to the demographic and economic data and the WTP to avoid different climate change-induced flood scenarios. It also investigates differences in WTP among age, gender and education groups and the relationships between WTP, different income types and flood related damage costs incurred.

6.2. Key Statistics of Respondents

As in previous chapters, a total of 240 households were interviewed in the survey component of this research. Of these, 210 households were interviewed for the purpose of assessing WTP; the remaining 30 households were excluded in the WTP study because they were already permanently displaced from the flood hazard areas due to flooding.

Of the 210 respondents, 56.7% were male and the rest were female. In terms of age, the respondents were divided into four different groups as shown in Table 6.1. The ages of the respondents ranged from 21 to 65 years and the number of the respondents in each age group was more or less equal.

Table 6.1: Classification of respondents by age group

Age	Number	%
<35	46	22
35-44	59	28
45-55	48	23
>55	57	27
Total	210	100

Source: Household survey, 2012

Family Size

Table 6.2 shows the family size of the respondents; the largest family was found to have 18 members and the smallest had one member only. The average size of families in the study was 8.2 which is remarkably higher than both the national (4.8) and district (7.9) averages (CBS 2012). Almost two thirds of families in the study had more than 7 members. This indicates that the people of the study area prefer to live in a group. Joint and extended family is typical of the culture and values of the indigenous people in Nepal and elsewhere in the world.

Table 6.2: Family size of the respondents in the study area

Family size	Number	%
1-3	14	6.7
4-6	61	29.0
7-9	73	34.0
>9	62	29.5
Total	210	100.0

Source: Household survey, 2012

Education

More than half of the people involved in the study were illiterate (Table 6.3); this is significantly higher than the national average of 23.08% (CBS 2011). Even among the literate, almost 60% did not go to secondary school and only 2% had obtained a university level education. These data indicate that the study area falls well below the national average.

Table 6.3: Education level of the respondents in the study area

Education level	Numbers	%
Literate	98	46.7
Illiterate	102	53.3
	Literate	
Informal	18	18.4
Primary	41	41.8
Secondary	22	22.4
Higher secondary school	15	15.3
University	2	2.0
Total	**98**	**100**

Source: Household survey, 2012

Occupation

The people participating in the study largely depended on agriculture for their livelihood. Almost all the respondents were either directly involved in agriculture or engaged in the agricultural labour force. A small number of respondents (7.5%) were involved in small businesses such as running tea shops and selling agricultural products. Very few people (<1%) were employed in government services (e.g. as teachers and police). The study area is similar to that of the whole of Nepal in terms of economic activities; more than 80% of the Nepalese population is engaged in agriculture which supports a subsistence livelihood. The agriculture sector is also the second largest contributor (33%) to GDP (ADB 2009).

6.3. WTP of Respondents by Age, Gender and Education Level at Different Flood Scenarios

As discussed above (Chapter IV Section 4.6.4 and Chapter V Section 5.4.4), this study developed different flood scenarios (Appendix E1, E2, E3, and E4) for the whole study area based on the flood return period and the extent of the inundation depth. The study area was further divided into three different flood severity zones (critical, moderate and low flood prone). Furthermore (as discussed in the methodology chapter IV, Section 4.8), four flood scenarios were developed; these were: Scenario I=current flood situation, Scenario II= potential flood levels for 2030; Scenario III= potential flood levels for 2070; and Scenario IV= potential flood levels for 2100.

Socio-economic factors such as age, gender, education level, income level and flood damage cost influence the level of WTP. In the following sections, the mean WTP of respondents, by age, gender, education levels, flood zone and damage cost, is analysed and their statistical significance is tested. Correlations between WTP and different types of incomes and flood related damage costs are also analysed.

The results of this study indicate that people of different age groups have different WTP (Table 6.4). For all flood scenarios analysed, mean WTP was highest in the 35 to 44 year old age group and was lowest in the age group below 35. Mean WTP between different age groups were statistically significantly different (p=<0.05) in all four flood scenarios. As expected, the WTP of all age groups increased with flood severity (from Scenario I to IV). For example, the average WTP to mitigate a Scenario I flood for the age group 35–44 was 4.57 man-days/year and increased by 110% to 9.61 man-days/year to mitigate the Scenario IV flood (Table 6.4 and *Appendix Table G1*).

Table 6.4: WTP by age for four different flood scenarios

Age group	**Mean/Std. Deviation**	**WTP (man-days/yr) for scenario I**	**WTP (man-days/yr) for scenario II**	**WTP (man-days/yr) for scenario III**	**WTP (man-days/yr) for scenario IV**
<35 (N=46)	Mean	3.80	5.59	7.19	9.29
	Std. Deviation	1.56	2.16	2.68	3.25
35-44 (N=59)	Mean	4.57	6.18	7.87	9.61
	Std. Deviation	1.67	2.21	2.75	3.44
45-55 (N=48)	Mean	4.38	6.09	7.72	9.54
	Std. Deviation	1.78	2.80	2.96	3.56
>55 (N=57)	Mean	4.28	5.59	7.54	9.44
	Std. Deviation	1.62	2.16	3.04	3.31
F-value		4.85	6.92	5.39	4.56
Significance		**0.009**	**0.001**	**0.005**	**0.012**
Total (N=210)	Mean	4.23	5.94	7.56	9.46
	Std. Deviation	1.67	2.44	2.85	3.36

Note: Scenario I=current flood situation, Scenario II= Potential flood level for 2030; Scenario III= Potential flood level for 2070 and Scenario IV= Potential flood level for 2100

Similarly, average WTP was found to differ between the male and female survey respondents for all four scenarios. In all four scenarios, the mean WTP of male and female groups were statistically significantly different (p=<0.05), indicating that the women were more serious about responding to future flood scenarios than the men.

Table 6.5: WTP by gender for four different flood scenarios

Gender	Mean/Std. Deviation	WTP (man-days/yr) for scenario I	WTP (man-days/yr) for scenario II	WTP (man-days/yr) for scenario III	WTP (man-days/yr) for scenario IV
Male (N =117)	Mean	4.29	5.85	7.50	9.45
	Std. Deviation	1.67	2.38	2.82	3.37
Female (N =93)	Mean	4.15	6.06	7.63	9.46
	Std. Deviation	1.67	2.51	2.90	3.36
F-value		4.85	6.92	5.39	4.56
Significance		**0.009**	**0.001**	**0.005**	**0.012**

Note: Scenario I=current flood situation, Scenario II= Potential flood level for 2030; Scenario III= Potential flood level for 2070 and Scenario IV= Potential flood level for 2100

While the proportion of literate and illiterate respondents was almost the same, average annual WTP varied with education level with literate people more willing to contribute compared to illiterate people (Table 6.6 and *Appendix Table G1 and G2*). Higher levels of WTP amongst literate people was expected (Maraseni *et al.* 2008), as they were better able to calculate the long term benefits of their small investments and were more serious about responding to the risk of flooding.

Table 6.6: WTP by literate and illiterate people at different flood scenarios

Literacy		WTP (man-days/yr) for scenario I	WTP (man-days/yr) for scenario II	WTP (man-days/yr) for scenario III	WTP (man-days/yr) for scenario IV
Literate (N=106)	Mean	4.30	6.02	7.75	9.68
	Std. Deviation	1.64	2.33	2.57	3.30
Illiterate (N=104)	Mean	4.15	5.87	7.37	9.24
	Std. Deviation	1.70	2.55	3.11	3.42
Total (N=210)	Mean	4.23	5.94	7.56	9.46
	Std. Deviation	1.67	2.44	2.85	3.36
F-value		4.85	6.92	5.39	4.56
Significance		**0.009**	**0.001**	**0.005**	**0.012**

Note: Scenario I=current flood situation, Scenario II= Potential flood level for 2030; Scenario III= Potential flood level for 2070 and Scenario IV= Potential flood level for 2100

6.4. Willingness to Pay by Flood Zones

Whether there are any differences in WTP between the respondents living in different flood prone areas is a key question for policy makers. In order to answer this question, as noted, the study area was divided into three flood severity zones (low, moderate and critical) and WTP were assessed for each zone and for all four flood scenarios.

As expected, the average WTP of respondents was highest within the critical flood prone zone and the lowest in the low flood prone zone (Table 6.7). Similarly, the average WTP of respondents increased from Scenario I to Scenario IV. The average WTP of respondents between the different zones were statistically significantly different ($p<0.05$), as were WTPs within the flood hazard zones for the various scenarios ($p>0.05$).

Table 6.7: Willingness to pay by flood zones

Flood prone areas (Zones)		WTP (man-days/yr) for scenario I	WTP (man-days/yr) for scenario II	WTP (man-days/yr) for scenario III	WTP (man-days/yr) for scenario IV	**F value**	**Significance**
Critical flood prone (zone 1; N=54)	Mean	4.67	6.93	8.37	10.22	4.51	**0.004**
	SD	1.74	2.77	3.21	3.47		
Moderate flood prone zone (zone 2; N =83)	Mean	4.34	5.81	7.73	9.76	2.93	**0.009**
	SD	1.73	2.18	2.59	3.27		
Low flood prone (zone 3; N=73)	Mean	3.78	5.37	6.77	8.55	3.13	**0.006**
	SD	1.44	2.26	2.68	3.22		
F value		4.85	6.92	5.39	4.56		
Significance		**0.009**	**0.001**	**0.005**	**0.012**		
Total (N=210)	Mean	4.23	5.94	7.56	9.46		
	SD	1.67	2.44	2.85	3.36		

Note: Scenario I=current flood situation, Scenario II= Potential flood level for 2030; Scenario III= Potential flood level for 2070 and Scenario IV= Potential flood level for 2100

6.5. Income of Respondents by Flood Prone Zones

WTP for flood mitigation actions could also be influenced by income level, especially those incomes which are directly affected by flooding. Among the different source of incomes, farm and livestock are major sources of income in the study area and are highly impacted by floods. Table 6.8 presents the survey results for average farm and livestock incomes within each flood zone. The highest average farm and livestock income was reported by respondents within the critical flood prone area, followed in turn by those in the moderate and low flood prone areas. This may in part be due to the larger size of farms and higher reliance on farming and livestock activities in the critical flood prone area compared to other areas.

Table 6.8: Farm and livestock income by flood zones

Flood prone areas (Zones)		**Farm income (US$)**	**Livestock income (US$)***
Critical flood prone (zone 1; N=54)	Mean	1652	218
	Std. Deviation	952	244
Moderate flood prone zone (zone 2; N=83)	Mean	1228	211
	Std. Deviation	779	213
Low flood prone (zone 3; N=73)	Mean	1132	164
	Std. Deviation	538	206
Total (N=210)	Mean	1328	197
	Std. Deviation	780	219

**Note: Conversion rate: US$1 = NRs92 (Date 25/04/2012)*

Correlation between WTP and farm and livestock incomes

As discussed in Section 5.4.5, agriculture land is highly impacted by floods. Therefore, it is expected that the higher the level of income from livestock and farming, the greater will be the WTP. As a result, there should be a positive correlation between WTP and these types of income. Results indicate that, for all four flood scenarios, the average annual WTP was positively correlated with both farm income and livestock income (Table 6.9) and all correlations were statistically significant (p=<0.05).

Relatively poor correlation (0.28) was found between WTP and livestock income as compared with farm income (0.61). This may be because, if people know in advance that a flood is coming, they release (set free) their livestock; the implication being that there is less chance of losing livestock assets with floods. However, on many occasions, livestock losses have occurred where flooding occurs without warning (e.g. in the middle of the night) and the people's first priority is to escape. In the case of agriculture, floods have two major impacts: (i) in the short term, farmers lose agricultural produce from the land; and (ii) in the longer term they may lose their land altogether or the land is degraded for agricultural activities. These could explain why people in the study area are willing to pay more for flood management activities that protect their farm land from floods than those that protect livestock.

Table 6.9: Correlation between income and WTP at various flood scenarios (N=210)

Income sources		**WTP for scenario I**	**WTP for scenario II**	**WTP for scenario III**	**WTP for scenario IV**
Farm income	Pearson Correlation	0.61	0.65	0.62	0.57
	Sig.	**0.000**	**0.000**	**0.000**	**0.000**
Livestock income	Pearson Correlation	0.28	0.13	0.17	0.15
	Sig.	**0.000**	**0.071**	**0.015**	**0.035**

Note: Scenario I=current flood situation, Scenario II= Potential flood level for 2030; Scenario III= Potential flood level for 2070 and Scenario IV= Potential flood level for 2100

6.6. Average Annual Damage Cost of Respondents by Flood Zones

Another factor that critically affects the WTP of respondents is flood related damage costs already incurred (Zhai 2006). The WTP for different flood zones and average annual damage in the last 5 years is shown in Table 6.10. As expected, the low flood prone zone has the lowest average annual damage per family (US$88) in the last 5 years. The average damage cost is higher in the moderately affected zone and highest in the critically affected zone. The mean WTP of these three zones are statistically significantly different (p=0.000) at over 99.99% confidence level.

Table 6.10: Average annual damage in last 5 years by flood zones

Flood prone areas (Zones)		**Average annual damage cost in last 5 years (US$)**
Critical flood prone (zone 1; N=54)	Mean	147
	Std. Deviation	100
Moderate flood prone zone (zone 2; N=83)	Mean	106
	Std. Deviation	75
Low flood prone (zone 3; N=73)	Mean	88
	Std. Deviation	57
Total (N=210)	Mean	110
	Std. Deviation	80
Significance (p-value)		**0.000**

Correlation between average annual damage and WTP at various flood scenarios

The correlation between WTP and flood related damage costs incurred was calculated to validate whether respondents' WTP for the four different flood scenarios are real and logical (Table 6.11). For all scenarios, average annual damage costs were found to be highly positively correlated with average annual WTP (Pearson's; r = 0.59–0.71; p = 0.00).

Table 6.11: Correlation between average annual damage and WTP at various flood scenarios (N=210)

	WTP for scenario I	**WTP for scenario II**	**WTP for scenario III**	**WTP for scenario IV**
Pearson Correlation	0.67	0.71	0.67	0.59
Sig.	**0.000**	**0.000**	**0.000**	**0.000**

Note: Scenario I=current flood situation, Scenario II= Potential flood level for 2030; Scenario III= Potential flood level for 2070 and Scenario IV= Potential flood level for 2100

Summary of willingness to pay

Average annual household farm income is about US$1,328, while half of the households have an income of less than US$500 (Table 6.12). In addition, average annual livestock income is US$197. The total farm and livestock income is slightly higher than the national average (US$1,256). More than 50% of the flood plain residents included in the sample appear to live below the poverty line (<US$2 per day).

So far, all the WTP figures have been given in man-days/year. In Table 6.12, these are converted to US$ (*US$1 = NRs92)*. The average WTP of respondents decreased from flood prone zone 1 to 3 and, within each zone, WTP increased from Scenario I to Scenario IV. As noted, the average WTP for Scenario IV was the highest (equivalent to US$36), followed by Scenario III (US$28), Scenario II (US$22) and Scenario I (US$17). Considering the scale and magnitude of flood damage, these figures seems realistic.

Table 6.12: Summary of willingness to pay

Flood prone areas	**Sample size**	**Income (US$)**		Ave. flood damage (last 5 years)	**Willingness to pay (US$)**			
	House hold no.	Farm	Livestock		Scenario I	Scenario II	Scenario III	Scenario IV
Zone 1	54	1652	218	147	18	26	31	39
Zone 2	83	1228	211	106	16	22	23	37
Zone 3	73	1132	164	88	14	20	20	32
Total	210	1328	197	110	17	22	28	36

6.7 Conclusion

The research findings presented in this chapter show that socio-economic factors such as age, gender, education level, income levels and recent flood damage costs influence the level of WTP of the respondents. Average WTP varied by flood hazard zone and, within the zone, by climate change-induced flood scenarios. The average WTP of respondents was the highest for the Critical flood prone zone, followed by the Moderate and Low flood prone zones. Similarly, within each zone, average WTP increased from Scenario I to IV. In addition, WTPs were positively correlated with livestock and agricultural crop incomes and incurred flood damage costs. Information about WTP for different zones and flood scenarios provides an evidence-base which will help decision makers to develop and implement robust and equitable flood mitigation plans and programs.

Chapter 7: Adaptation Strategies for Flood Risk Reduction

7.1 Introduction

This chapter deals with the people's perceptions of early warning systems, flood forecasting techniques and flood adaptation strategies in the West Rapti River Basin of Nepal. Assessment and ranking of flood adaptation strategies were conducted for pre-flood, during flood and post flood situations, both at the household and community level.

7.2 Early Warning System

The locally managed early warning system operating in the study area was found to be very popular as a flood management strategy. Of the 240 survey respondents, 191 (80%) were aware of this system and had been actively using it. However, about 20% of the total respondents were still not familiar with the system, mainly due to their distant location from the river system.

During the field survey, focus groups were asked to nominate the most common flood warning methods in the study area; these were later ranked in terms of their value within the household survey. Four types of early flood warning methods were commonly used in the study area: (1) door to door communication; (2) sirens/alarms at the river; (3) mobile/SMS; and (4) shouting. Perception about the effectiveness of these methods is presented in Table 7.1. Among them, "sirens/alarm" was found to be the most effective means for flash flood warning (Weighted Average Index = 4.6), followed by SMS (WAI = 4.3). Communicating the warning by shouting was ranked third (WAI = 3.6), while "door to door communication" method, which is relatively laborious, time consuming and hard to implement, was regarded as the least effective of these methods (Table 7.1).

Table 7.1: Effectiveness of flash flood early warning methods in West Rapti River Basin, Nepal (N=240)

Responses	Most effective	Highly effective	Moderately effective	Less effective	Least effective	Weighted average index WAI	Ranks
Sirens/ alarm	164	56	16	3	1	4.6	I
Mobile/SMS	134	65	31	8	2	4.3	II
Shouting	27	100	95	16	2	3.6	III
Door to door communication	17	39	58	101	25	2.7	IV

Source: Household survey, 2012

Focus groups were also asked to list the modes of communication of flood warning they believed would be most reliable in the future. They eliminated two commonly used methods, "door to door communication" and "shouting", and added three more methods: "newspaper"; "radio/FM"; and "television". These five methods were then presented in the household survey in order to assess people's preferences. Overall, the existing alarm and SMS approaches were found to be the most accepted and considered the most effective methods, followed by FM Radio, TV and newspaper

(Table 7.2). These three methods received cumulative relative frequency (CRF%, from most preferred to moderately preferred).

Table 7.2: Most reliable media for transforming early warning information in West Rapti River Basin, Nepal (N=240)

Responses	Alarm			Mobile/SMS			Radio/FM			TV			Newspaper		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	165	68.8	68.8	23	9.6	9.6	8	3.3	3.3	14	5.8	5.8	16	6.7	6.7
VeP	56	23.3	92.1	80	33.3	42.9	113	47.1	50.4	79	32.9	38.8	23	9.6	16.3
MeP	15	6.3	**98.3**	105	43.8	**86.7**	83	34.6	**85**	44	18.3	**57.1**	54	22.5	**38.8**
LsP	3	1.3	99.6	30	12.5	99.2	31	12.9	97.9	42	17.5	74.6	111	46.3	85
LeP	1	0.4	100	2	0.8	100	5	2.1	100	61	25.4	100	36	15	100
Rank	**I**			**II**			**III**			**IV**			**V**		

Source: Household survey, 2012

Note: (MoP = Most Preferred, VeP = Very preferred; MdP = Moderately Preferred; LsP = Less Preferred; and LeP = Least Preferred, F= frequency, RF = frequency in %, CRF = Cumulative relative frequency in %.

Regarding the question of which organisation should bear the responsibility for establishing early warning systems, more than 40% of the respondents mentioned that government should be responsible for this. In contrast, 30%, 25% and 4% of survey respondents mentioned that community people, international/national non-government organization (such as Red Cross, United Nations), and local clubs/ groups, respectively, should be responsible for establishing the early warning system (Table 7.3). Overall, people clearly think that the government should be responsible, and is also is more capable than other institutions/groups, for this type of activity and for its sustainability.

Table 7.3: Preference of organization for establishing early warning systems in West Rapti River Basin, Nepal

Responsible organization	Number	%
Local clubs/groups	9	3.8
I/NGO	61	25.4
Government	100	41.7
Community people	70	29.2
Total	240	100

Source: Household survey, 2012

7.3 Flood Forecasting Techniques

Flood forecasting can save lives and property. Communities are enriched with indigenous knowledge in terms of flood forecasting. In the study area, people have been practicing five main flood forecasting techniques over past decades, as identified through the focus group discussions. The respondents' perceptions of these techniques are given in *Appendix H, Table H.1*. The cumulative relative frequencies (CRFs) of a range of flood forecasting techniques are presented in Figure 7.1

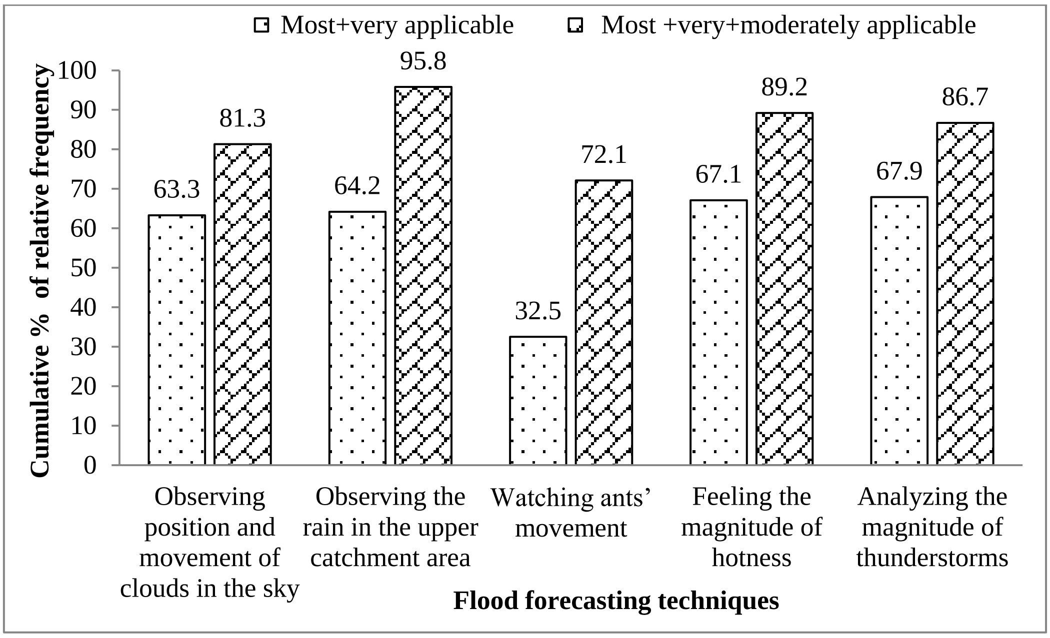

Figure 7.1: Respondents' perceptions of different flood forecasting techniques in West Rapti River Basin, Nepal (N=240)

Indigenous forecasting methods listed in Figure 7.1 were ranked on the basis of the frequency (F), relative frequency (RF) and cumulative relative frequency (CRF) of participant's responses. The data show that all five techniques rated more than 70% CRF and are therefore assumed to be commonly used in the study area. Consequently, any one of them could be used in the absence of others. However, on average, some are more preferred than others: "observing the rain in the upper catchment area" is ranked first (CRF = 95.8%), followed by "feeling the magnitude of the hotness" (CRF= 89.2%), "observing the position and movement of cloud" (CRF = 86.7%), and "analysing the magnitude of thunderstorms in the sky" (CRF = 81.7%).

7.4 Flood Adaptation Strategies

In the West Rapti River basin study area, people generally reported managing flooding using their own knowledge and skills. It was observed and reflected during the interaction that people have a close affiliation with the nature of floods in the region. However, people were found to be concerned about the risks posed by flooding caused by uncertain and erratic rainfall.

The study also found that different flood management schemes/techniques have been developed for pre-flood, during flood and post flood periods. Some strategies are at the household level and some are at the community level. In the following sections, these are discussed separately.

7.4.1 Flood adaptation strategies at household level

Pre-flood

Most people interviewed in the West Rapti River Basin study consider flooding to be a part of their lives. The respondents were found to be mentally ready to face and struggle with possible flood disasters and well prepared accordingly at both individual and household levels. Four activities, such as raising the floor of the house, constructing drains around property, moving property to safe locations and keeping emergency materials, were identified during the focus group discussions as major pre-flood adaptation strategies. Survey respondents ranked these pre-flood adaption strategies against a 1–5 scale (from least preferred to most preferred).

Among these four key pre-flood management strategies, constructing drains to dispose of flood water around the house and other infrastructure such as tube wells, cow sheds or even agricultural plots, was ranked first (CRF = 93.8%), followed by keeping property in safe places (CRF = 90.8%) and raising the bottom floor of the house (CRF = 89.2%) (Figure 7.2; see *Appendix H, Table H.2* for details). Making arrangements for emergency materials (e.g. keeping plastic sheets, tents, rope, rubber tubes, empty drums, torchlight, etc. especially during the monsoon as part of emergency store) was ranked last; however, even then it received a CRF of 82.5%. All four strategies appear to be considered important as all had a CRF of >80%.

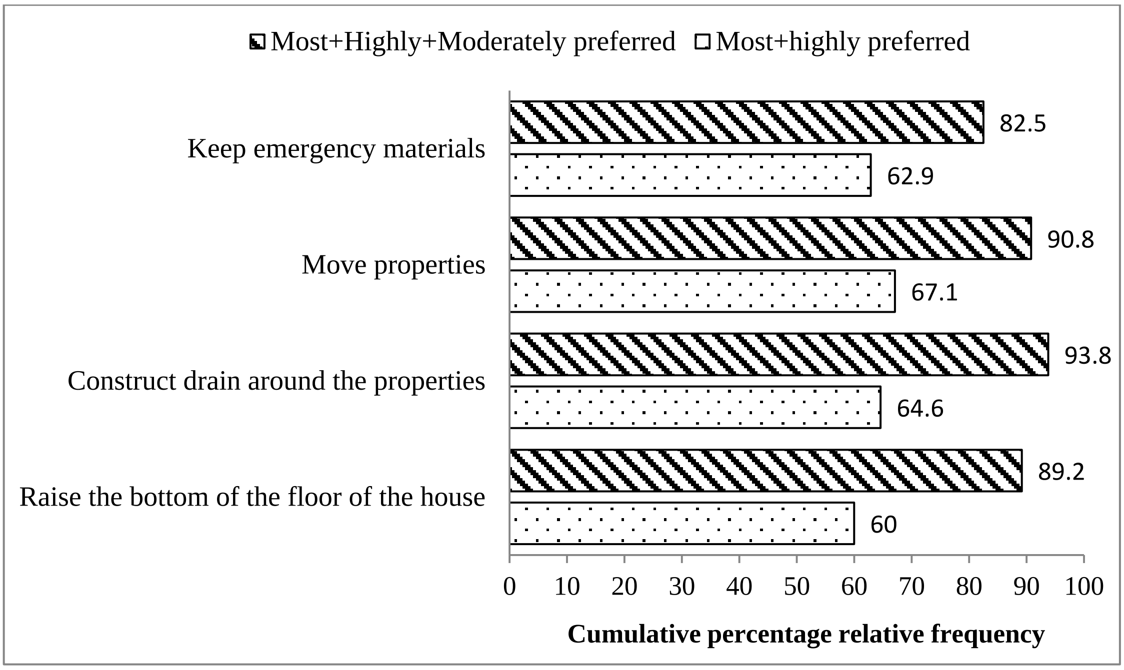

Figure 7.2: Preference of pre-flood adaptation strategies in West Rapti River Basin, Nepal

During flood

Five major activities were identified as key adaptation strategies during flooding (Figure 7.3): caring for children and elderly people and releasing domesticated animals; taking valuable property; using sand bags to divert flood waters; standing/sitting on the roof of houses or climbing trees; and shouting and escaping. Respondents' preferences for these different strategies and their ranks are given in *Appendix H, Table H.3*.

Among these five strategies, based on CRF values, caring for children and elderly people and releasing domesticated animals were ranked highest (CRF = 95.0%), while taking valuable property was ranked second (CRF = 91.7%). The use of sand bags to divert water was ranked third (CRF = 81.3%), and climbing onto the roof of houses or into trees was ranked fourth (CRF = 75.0%). Despite these preference rankings, all strategies were considered important as all scored >75% CRF.

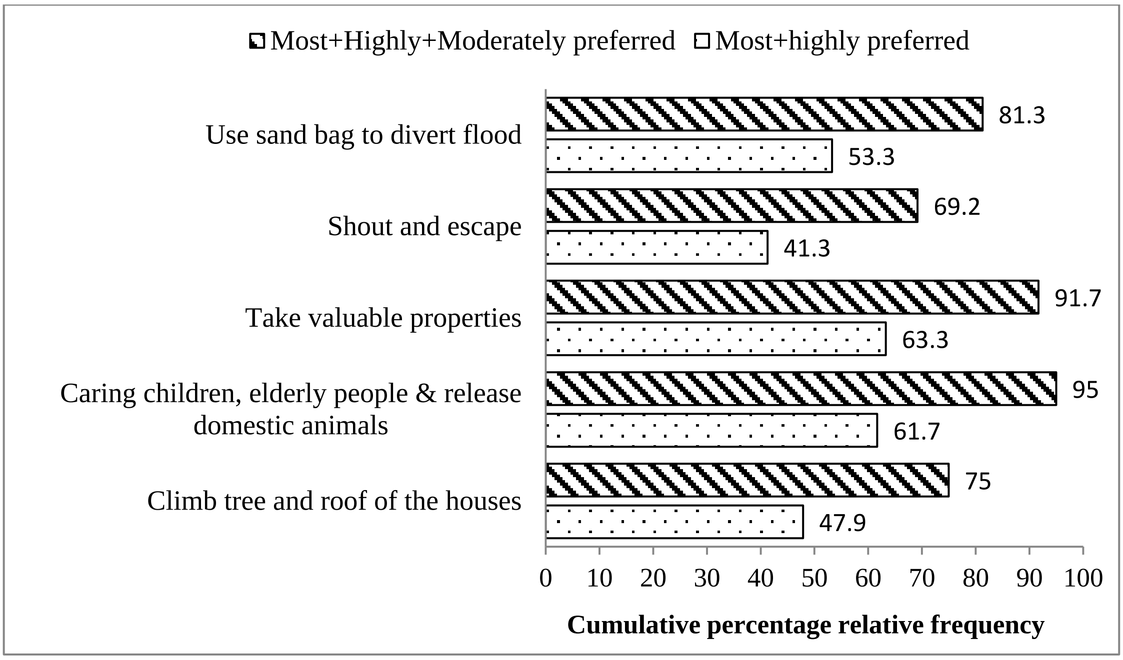

Figure 7.3: During flooding adaptation strategies in West Rapti River Basin, Nepal

Post flood

When the water level decreases to a safer level, people return to their houses and take measures, which they think appropriate and within their reach, to rehabilitate following flooding. During this stage, they informally assess the damage caused by the flood so that an immediate plan can be made for action on a priority basis.

Repairing the house, managing food, making temporary shelter and repairing the hand pump for drinking water are major practices carried out by flood affected people in the study area after flooding. Figure 7.4 shows the ranks of post-flood adaptation activities based on people's perceptions. Based on CRF values, people reported their top priority as repairing the house (CRF = 94.0%), followed by managing food (CRF = 92.1%), making necessary arrangements for clothes to wear and other materials, such as mats, which are used daily (CRF = 92.1%) and repairing hand pumps for drinking water (CRF = 79.6 %) (detailed dataset are in *Appendix H, Table H.4).* People dry their belongings in the sunlight. The elderly and women are mostly involved in separating good grain from damaged grain. People often borrow from others to ensure that they have warm clothes for family members and food to eat during this period. In practice, all these activities are carried out simultaneously, where possible, to ensure a quick return to normal life.

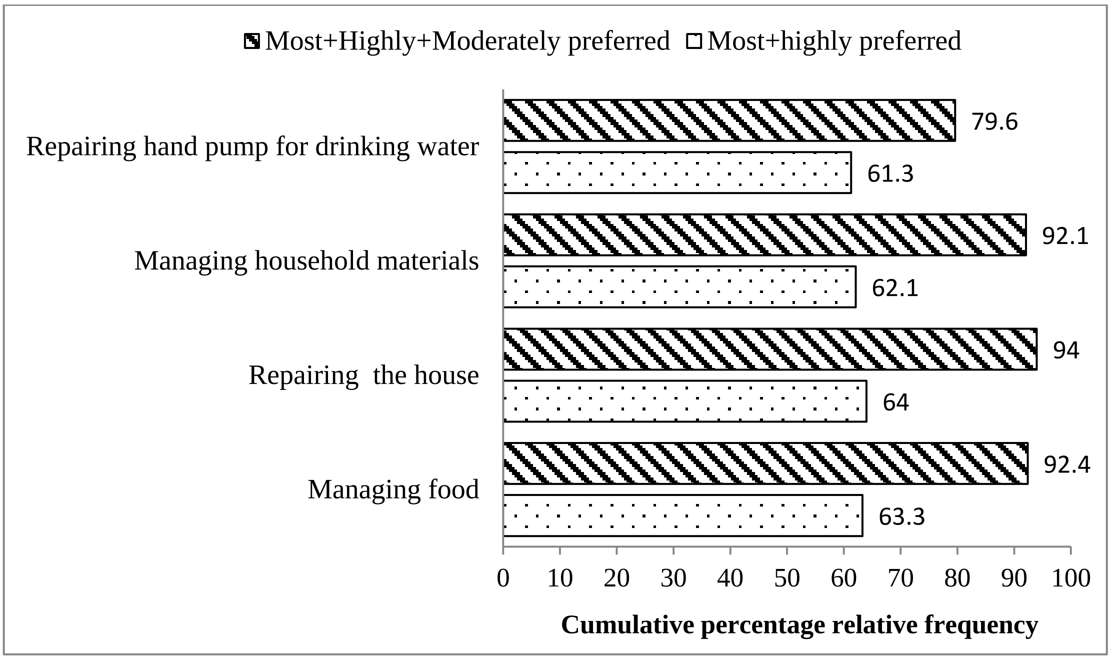

Figure 7.4: Post-flood adaptation strategies in West Rapti River Basin, Nepal

7.4.2 Community level flood adaptation strategies

In the sections above, the household level flood adaptation strategies discussed are generally performed spontaneously by individual households. There are several other adaptation practices which are collectively performed at the community level and are, therefore, termed community level flood adaptation strategies.

In general, each year, people in the study area gather and discuss flood adaptation strategies before the start of monsoon season. During these gatherings, people evaluate past flood events and adaptation strategies and prepare future flood adaptation strategies. This study documented those strategies through the focus groups discussion and ranked them according to the respondent's perceptions so as to understand how individual respondents value community level strategies. As at household level, these strategies are targeted for pre-flood, during flood and post-flood situations.

Pre-flood

The main community level activities carried in this phase are: (i) preparation of a flood management plan which includes the identification of shelters for evacuation during flood, preparation of evacuation routes, methods for the dissemination of flood information, number of sand bags to be prepared and identification of places to keep them, dividing the role and responsibilities of each household or person etc.; (ii) keeping contact information for the community people; (iii) pre-assessment of the magnitude and scale of flood risk; and (iv) training people and preparing them to evacuate people and properties during the flood. People within the study area thought that the "flood management plan" was the most useful adaptation strategy (WAI = 3.7), followed by "pre-assessment of flood risk" (WAI = 3.3). "Keep contact information" was ranked third (WAI = 3.2) whereas "produce human resources" was ranked lowest (WAI = 3.1) (Table 7.4). However if we combine the most useful, useful and the moderately useful levels, all these strategies account were supported by more than 80% of the people of the study area implying all these strategies are useful for one reason or another.

Table 7.4: Pre-flood adaptation strategies at the community level (figure represents the percentage of 210 respondents) in West Rapti River Basin, Nepal

Activities	Most useful	useful	Moderately useful	Less useful	Least useful	WAI	Ranks
Develop flood management plan	56.7	20.5	17.1	4.8	1	3.7	**I**
Pre-assessment of the flood risk	17.1	45.2	31.9	4.3	1.4	3.3	**II**
Keep contact information	12.9	43.8	35.7	6.7	1	3.2	**III**
Produce human resources/trained manpower	13.3	39	33.3	13.3	1	3.1	**IV**

Source: Household survey, 2012

During flood

The three identified adaptation strategies during the flood period were “developing communication mechanisms”, “managing food and logistics” and “caring for the health and hygiene of affected people” (Table 7.5). Ranking of these during the household survey indicated that “developing communication mechanisms” at the community level was considered the most necessary adaptation strategy (WAI = 3.6), followed by “caring for the health and hygiene of affected people” (WAI = 3.4), with “managing food and logistics” in the relocated area ranked third (WAI = 3.2). However, all of these strategies were highly regarded by the majority of survey participants with more than 80% of respondents scoring these as moderately–highly necessary.

Table 7.5: During flood adaptation strategies at the community level in West Rapti River Basin, Nepal (figure represents the percentage of 210 respondents)

Responses	Most necessary	Necessary	Moderately necessary	Less necessary	Least necessary	WAI	Ranks
Perfect communication at community level	49.5	23.3	20	7.1	0	3.6	**I**
Health and hygiene of the affected people	17.6	39	26.7	15.2	1.4	3.4	**II**
Food and logistics	28.6	39	29	2.9	0.5	3.1	**III**

Source: Household survey, 2012

Post-flood

Of the post flood adaptation strategies, “exchange help” (labour, storage food, settlements etc.) was ranked as the most applicable strategy (WAI = 3.7), followed by “equal distribution of resources” (WAI = 3.5), “co-ordinate with government and other agencies” (WAI = 3.4) and “prepare temporary settlement” (WAI = 3.3).

Table 7.6: Post flooding adaptation strategies at the community level in West Rapti River Basin, Nepal (figure represents the percentage of 210 respondents)

Responses	Most applicable	Very Applicable	Moderately applicable	Less applicable	Least applicable	WAI	Ranks
Exchange help	57.1	12.9	24.8	4.3	1	3.7	**I**
Equal distribution of resources	30.5	44.3	16.7	8.1	0.5	3.5	**II**
Co-ordinate with government and other agencies	22.4	43.8	30	2.9	1	3.4	**III**
Prepare temporary settlement	20	45.2	29	5.2	0.5	3.3	**IV**

Source: Household survey, 2012

7.5. Flood Adaptation Strategies for Different Flood Scenarios

In the preceding sections, survey results on flood adaptation strategies at the household level and people's perception on current adaptation practices at the community level were presented. Respondents' preferences for these existing strategies were evaluated for pre flood, during flood and post flood situations. This section investigates perceptions about strategies to be followed to deal with the current flood scenario as well as probable future flood scenarios (Figure 5.14, 5.15, 5.16, 5.17 and *Appendix E1, E2, E3 and E4*) that may eventuate with climate change

Survey participants were asked to rate their perceptions of different flood adaptation strategies for each of the four flood scenarios on a five point scale, as previously in the household survey. For each of the flood adaptation strategies, frequencies, relative frequencies and cumulative relative frequencies of scores were calculated; strategies were then ranked on the basis of CRF for the most preferred (MoP), very preferred (VeP) and moderately preferred (MdP) levels.

7.5.1 Flood adaptation strategies

The most plausible adaptable strategies explored in the study were:
(i) Changing farming practices. This includes changing the types of crops grown (e.g. cultivating flood resistant crops, planting more cash crops in the winter season and growing crops with short crop cycles) and enhancing landholders' farming capacity through the training.

(ii) Land use management. Land use management covers local level erosion control by land levelling; making land for building construction higher than the surrounding land wherever possible; using marginal land for fodder farming; making temporary arrangements to limit the extent to which river water invades agricultural fields or housing.

(iii) Household level preparation and management. This includes building double storey houses; making arrangement so that valuable goods can be stored at elevated levels; and positioning buildings to avoid storm damage as much as possible.

(iv) Controlling flood levels and food storage. This strategy includes constructing drainage around house so that flood waters cannot easily enter the house; storing seeds and food stuffs at elevated levels to avoid flood damage; rearing cattle on higher grounds; and migrating temporarily to upland areas.

(v) Watershed management. This includes preservation of forested areas of the catchment and trees around water sources; taking landslide and erosion control measures in the hilly area of the river basin; rain and flood water harvesting; and developing irrigation systems.

7.5.2 Adaptation strategies for current flood scenario (Scenario I)

Perceived preferences for the strategies for the current scenario (i.e. Scenario I. Figure 5.16) are presented in Table 7.7. "Household level preparation/management" was the most preferred adaptation strategy for this scenario with the highest ranking (CRF = 85.7%). It is followed by "controlling flood level and food storage" (CRF = 81.9%), "change farming practices" (CRF = 81.0%), "land use management" (CRF = 80.9%) and "watershed management" (CRF = 80.0%). Again, since CRF of all strategies are 80% or more and the differences between them are small, we can conclude that all are considered important.

Table 7.7: Adaptation strategies for current flood scenario, Scenario I, in West Rapti River Basin, Nepal

Responses	**Household level preparation /management**			**Controlling flood level & food storage**			**Change farming practices**			**Land use management**			**Watershed management**		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	35	16.7	16.7	52	24.8	24.8	25	11.9	11.9	67	31.9	31.9	24	11.4	11.4
VeP	91	43.3	60.0	64	30.5	55.2	72	34.3	46.2	34	15.2	47.1	77	36.7	48.1
MdP	54	25.7	**85.7**	56	26.7	**81.9**	73	34.8	**81.0**	71	33.8	**80.9**	67	31.9	**80.0**
LsP	24	11.4	97.1	24	11.4	93.3	35	16.7	97.6	32	16.2	97.1	38	18.1	98.1
LeP	6	2.9	100	14	6.7	100	5	2.4	100	6	2.9	100	4	1.9	100
Rank	**I**			**II**			**III**			**IV**			**V**		

Source: Household survey, 2012

Note: MoP = Most preferred; VeP=Very preferred; MdP = Moderately preferred; LsP= Less preferred LeP= Least preferred & 'F' is frequency, 'RF' is relative frequency (%) and 'CRF' is cumulative relative frequency (%)

7.5.3 Adaptation strategies for 2030 flood exposure (Scenario II)

Participants were presented with the probable flood scenario for 2030 and asked their views on adaptation strategies in that flood situation (Table 7.8). "Household level preparation/management" again scored highest (CRF = 88.5%). This was followed by "watershed management" (CRF = 83.8%), "controlling flood level & food storage" (CRF = 83.3%) and "change farming practices" (CRF = 83.0%), while "land use management" ranked fifth (CRF = 82.4%). The higher ranking of "watershed management" from fifth in Scenario 1 to second rank implies that it is likely to be considered of increasing importance for flood Scenario II. As in Scenario I, CRFs of all strategies were more than 80%.

Table 7.8: Flood Adaptation strategies for Scenario II in West Rapti River Basin, Nepal

Responses	Household level preparation /management			Watershed management			Controlling flood level & food storage			Change farming practices			Land use management		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	33	15.7	15.7	39	18.6	18.6	39	18.6	18.6	11	5.2	5.2	16	7.6	7.6
VeP	88	41.5	57.5	51	24.3	42.9	64	30.5	49.0	72	34.0	39.2	87	41.4	49.0
MdP	65	31.0	**88.5**	86	41.0	**83.8**	72	34.3	**83.3**	92	43.8	**83.0**	70	33.3	**82.4**
LsP	18	8.6	97.1	29	13.8	97.6	33	15.7	99.0	28	13.7	96.7	36	17.1	99.5
LeP	6	2.9	100	5	2.4	100	2	1.0	100	7	3.3	100	1	0.5	100
Rank	**I**			**II**			**III**			**IV**			**V**		

Source: Household survey, 2012

Note: MoP = Most preferred; VeP=Very preferred; MdP= Moderately preferred; LsP= Less preferred LeP= Least preferred & ‘F’ is frequency, ‘RF’ is relative frequency (%) and ‘CRF’ is cumulative relative frequency (%)

7.5.4 Adaptation strategies for 2070 flood exposure (Scenario III)

“Household level preparation/management” remained the highest priority and the most preferred adaptation strategy for Scenario III (*Appendix E, Figure E.3*) (CRF = 90.0%) (Table 7.9), followed next by “watershed management” (CRF = 89.0%), “land use management” (CRF = 88.6%), “controlling flood level & food storage” (CRF = 86.2%) and “change farming practices” (CRF = 81.0%).

Table 7.9: Flood Adaptation strategies for Scenario III in West Rapti River Basin, Nepal

Responses	Household level preparation /management			Watershed management			Land use management			Change farming practices			Controlling flood level & food storage		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	15	7.1	7.1	35	16.7	16.7	11	5.2	5.2	54	25.7	25.7	48	22.9	22.9
VeP	92	43.8	51.0	79	37.6	54.3	89	42.4	47.6	51	24.3	50.0	81	38.6	61.4
MdP	82	39.0	**90.0**	73	34.8	**89.0**	86	41.0	**88.6**	65	31.0	**81.0**	52	24.8	**86.2**
LsP	16	7.6	97.6	21	10.0	99.0	21	10.0	98.6	32	15.2	96.2	27	12.9	99.0
LeP	5	2.4	100	2	1.0	100	3	1.4	100	8	3.8	100	2	1.0	100
Rank	**I**			**II**			**III**			**IV**			**V**		

Source: Household survey, 2012

Note: MoP = Most preferred; VeP=Very preferred; MdP= Moderately preferred; LsP= Less preferred LeP= Least preferred & ‘F’ is frequency, ‘RF’ is relative frequency (%) and ‘CRF’ is cumulative relative frequency (%)

7.5.5 Adaptation strategies for 2100 flood exposure (Scenario IV)

The probable flood information for Scenario IV (*Appendix E, Figure E.4*) was provided to the household survey participants to investigate any change in people’s perceptions of flood adaptation strategies. Based on their insight on the potential flood damage, it was found that the respondents had changed their adaptation strategies for this case, ranking the strategies differently than previous cases. Based on the CRF for ‘most appropriate’ to ‘moderately appropriate’ level strategies (Table 7.10), “watershed management” now had the highest value (CRF = 89.5%) and was the most preferred adaptation strategy, followed by “land use management” (CRF = 88.1%), “household level preparation/management” (CRF = 87.6%), “change farming practices" (CRF = 86.8%) and "controlling flood level and food Storage" (CRF = 83.3%).

Table 7.10: Flood Adaptation strategies for Scenario IV in West Rapti River Basin, Nepal

Responses	**Watershed management**			**Land use management**			**Household level preparation /management**			**Change farming practices**			**Controlling flood level & food storage**		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	44	21.0	21.0	77	37.3	37.3	18	8.6	8.6	65	31.0	31.0	19	9.0	9.0
VeP	88	41.9	62.9	47	23.7	61.0	85	40.5	49.0	66	31.4	62.4	78	37.1	46.2
MdP	56	26.7	**89.5**	57	27.1	**88.1**	81	38.6	**87.6**	51	24.4	**86.8**	78	37.1	**83.3**
LsP	17	8.1	97.6	10	4.1	92.2	23	11.0	98.6	22	10.5	97.3	32	15.2	98.6
LeP	5	2.4	100	18	7.8	100	3	1.4	100	6	2.7	100	3	1.4	100
Rank	**I**			**II**			**III**			**IV**			**V**		

Source: Household survey, 2012

Note: MoP = Most preferred; VeP =Very preferred; MdP = Moderately preferred; LsP = Less preferred LeP = Least preferred & 'F' is frequency, 'RF' is relative frequency (%) and 'CRF' is cumulative relative frequency (%)

7.6. Structural Flood Adaptation Strategies for Climate Change Induced Flood Scenarios

7.6.1 Possible adaptation strategies

The following are major potential structural flood management measures, which can be used to control the flood in the study area or prevent bank erosion/cutting or both.

(i) Bio-engineering:

Bio-engineering (Photo: 1) measures are an effective method applied to control mass wasting due to river bank cutting by flowing water or preventing flood water entering adjoining lands (Rauch & Acharya 2007). Water resistant and densely growing plants (such as bamboo and *Acacia nilotica*) may be grown on the banks of the river and are highly effective either alone or in combination with small scale engineering structures (Rai 2008).

Photo 1: Bio-engineering

(ii) Embankment including bio-fencing/river training structures:

Using bio-fencing/river training structures (Photo: 2) to create embankments may prevent the spread of flood waters over adjoining lands. Such embankments or walls are often constructed parallel to the river banks to confine the flood waters within the cross section available between them. They are usually constructed with earthen material, using engineering principles and are therefore costly.

Photo 2: Embankment including bio-fencing/river training structures

(iii) Bamboo mesh/mat with sand filled bags:

This type of structure also prevents the spread of flood water over adjoining lands and checks bank cutting. However, it is generally made locally using indigenous technology. Bamboo (Photo: 3) or any other wooden materials which are available locally at low cost are used to form mats. The mats are used to support the sand filled bags so that they are not swept away by flowing water.

Photo 3: Bamboo mesh/mat with sand filled bags

(iv) Gabion wall/spurs:

Spurs or gabions (Photo: 4) or any revetments fall under this category. These structures are used to protect riverbanks from erosion and thereby to stabilize the river course. Spurs are structures usually constructed on the riverbank normal to the dominant flow direction or at an angle pointing up stream or downstream. Gabion walls are constructed parallel and adjacent to the river bank. Both gabion walls and spurs are generally made of mesh of wires filled with stones and are of different sizes.

Photo 4: Gabion wall/spurs

(v) Reservoir/flow regulating structures:

These include multipurpose reservoirs (Photo: 5), one function of which is to control flooding by regulating or diverting flow using structures such as weirs/barrages and irrigation channels. Reservoirs are, generally, created in the river by the construction of a dam. The dam's function is to retain excess water during periods of high flow and to enable use of the stored water during drought (low flow) periods. This type of structure protects the area downstream from the damage due to floods. It may also include check dams constructed in tributaries.

Photo 5: Reservoir/flow regulating structures

7.6.2 Structural flood adaptation strategies for flood Scenario I

Table 7.11 presents the survey results for preferences for structural flood adaptation strategies for the current flood situation, Scenario I. "Bamboo mesh with sand filled bags" was the most preferred option (CRF = 90.5%). This was followed by "reservoir/flow regulating structure" (CRF = 88.6%), "gabion wall/spur" (CRF =

86.7%) and "making embankment including bio-fencing/river training" (CRF = 86.2%). "Bio-engineering" was the least preferred adaption strategies among these structures for the current flood situation.

Table 7.11: Preference of structural flood adaptation strategies for flood Scenario I in West Rapti River Basin in Nepal

Responses	Bamboo mesh with sand filled bags			Reservoir/flood regulating structure			Gabion wall /spurs			Embankment with bio- facing /river training			Bio-engineering		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	17	8.1	8.1	70	33.3	33.3	29	13.8	13.8	41	19.5	19.5	15	6.3	6.3
VeP	92	43.8	51.9	51	24.3	57.6	81	38.6	52.4	75	35.7	55.2	82	34.2	40.4
MdP	81	38.6	**90.5**	65	31.0	**88.6**	72	34.3	**86.7**	58	27.6	**82.9**	61	25.4	**65.8**
LsP	18	8.6	99.0	20	9.5	98.1	25	11.9	98.6	32	15.2	98.1	61	25.4	91.3
LeP	2	1.0	100	4	1.9	100	3	1.4	100	4	1.9	100	21	8.8	100
Rank	**I**			**II**			**III**			**IV**			**V**		

Source: Household survey, 2012

Note: MoP = Most preferred; VeP=Very preferred; MdP= Moderately preferred; LsP= Less preferred LeP= Least preferred & 'F' is frequency, 'RF' is relative frequency (%) and 'CRF' is cumulative relative frequency (%)

7.6.3 Structural flood adaptation strategies for the 2030 flood Scenario

The perception of respondents on structural flood adaptation strategies for Flood Scenario II is given in Table 7.12. "Bamboo mesh with sand filled bags" was most preferred (CRF = 93.6%), followed by "making embankment including bio-facing/river training" (CRF = 90.5%), "bio-engineering" (CRF = 86.2%) "gabion wall/spurs" (CRF = 85.7%), and "Reservoir/flood regulating structure" (CRF = 64.2%).

Table 7.12: Preference of structural flood adaptation strategies for flood Scenario II in West Rapti River Basin in Nepal

Responses	Bamboo mesh with sand filled bags			Embankment with bio- facing /river training			Bio-engineering			Gabion wall /spurs			Reservoir/flood regulating structure		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	18	8.6	8.6	32	15.2	15.2	18	8.6	8.6	36	17.1	17.1	21	8.8	8.8
VeP	100	47.6	56.2	88	41.9	57.1	81	38.6	47.1	88	41.9	59.0	75	31.3	40.0
MdP	78	36.4	**93.6**	70	33.3	**90.5**	82	39.0	**86.2**	56	26.7	**85.7**	58	24.2	**64.2**
LsP	13	5.7	99.5	20	9.5	100	20	9.5	95.7	23	11.0	96.7	71	29.6	93.8
LeP	1	0.5	100	32	15.2	15.2	9	4.3	100	7	3.3	100	15	6.3	100
Rank	**I**			**II**			**III**			**IV**			**V**		

Source: Household survey, 2012

Note: MoP = Most preferred; VeP=Very preferred; MdP= Moderately preferred; LsP= Less preferred LeP= Least preferred & 'F' is frequency, 'RF' is relative frequency (%) and 'CRF' is cumulative relative frequency (%)

7.6.4 Structural flood adaptation strategies for the 2070 flood scenario III

Table 7.13 presents the preference of the people on structural flood adaptation strategies for Scenario III. "Reservoir/flow regulating structure", "embankment protection with bio-facing/river training", "bamboo mesh with sand filled bags", "gabion wall/spur" and "bio-engineering" ranked first to fifth, respectively, with CRF values ranging from 96.7% down to 80.0% of survey participants.

Table 7.13: Preference of structural flood adaptation strategies for flood Scenario III in West Rapti River Basin in Nepal

Responses	**Reservoir/flood regulating structure**			**Embankment with bio- facing /river training**			**Bamboo mesh with sand filled bags**			**Gabion wall /spurs**			**Bio-engineering**		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	54	25.7	25.7	54	8.6	8.6	45	21.4	21.4	75	35.7	35.7	32	15.2	15.2
VeP	89	42.4	68.1	89	47.6	56.2	74	35.2	56.7	53	25.2	61.0	73	34.8	50.0
MdP	60	28.6	**96.7**	60	37.6	**93.8**	74	35.2	**91.9**	58	27.6	**88.6**	63	30.0	**80.0**
LsP	6	2.9	99.5	6	5.7	99.5	15	7.1	99.0	22	10.5	99.0	30	14.3	94.3
LeP	1	0.5	100	1	0.5	100	2	1.0	100	2	1.0	100	12	5.7	100
Rank	**I**			**II**			**III**			**IV**			**V**		

Source: Household survey, 2012

Note: MoP = Most preferred; VeP=Very preferred; MdP= Moderately preferred; LsP= Less preferred LeP= Least preferred & 'F' is frequency, 'RF' is relative frequency (%) and 'CRF' is cumulative relative frequency (%)

7.6.5 Structural flood adaptation strategies for the 2100 flood Scenario IV

"Reservoir/flow regulating structure" was the most preferred adaptation strategy (CRF = 97.1%) for the 2100 future flood scenario, followed by "embankment protection with bio-facing/river training" (CRF = 94.8%), "bamboo mesh with sand filled bags" (CRF = 94.3%), "bio-engineering" (CRF = 91.9%) and "gabion wall/spur" (CRF = 90.5%) strategies.

Table 7.14: Changes in the preference of structural flood adaptation strategies for scenario IV

Responses	**Reservoir/flood regulating structure**			**Embankment with bio- facing /river training**			**Bamboo mesh with sand filled bags**			**Bio-engineering**			**Gabion wall /spurs**		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	157	74.8	74.8	71	33.8	33.8	84	40	40	39	18.6	18.6	82	39	39
VeP	45	21.4	96.2	86	41	74.8	64	30.5	70.5	79	37.6	56.2	62	29.5	68.6
MdP	2	1	**97.1**	42	20	**94.8**	50	23.8	**94.3**	75	35.7	**91.9**	46	21.9	**90.5**
LsP	5	2.4	99.5	11	5.2	100	9	4.3	98.6	13	6.2	98.1	19	9	99.5
LeP	1	0.5	100	0	0	0	3	1.4	100	4	1.9	100	1	0.5	100
Rank	**I**			**II**			**III**			**IV**			**V**		

Source: Household survey, 2012

Note: MoP = Most preferred; VeP=Very preferred; MdP = Moderately preferred; LsP= Less preferred LeP= Least preferred & 'F' is frequency, 'RF' is relative frequency (%) and 'CRF' is cumulative relative frequency (%)

7.7 Adaptation Strategies Based on the Views of District Level Stakeholders

Face to face interviews were conducted, using structured questionnaires, with the district level officers and politicians who were directly involved in preparing district level flood management plans and programmes and responsible for the implementation of plans and programs relating to natural disasters. During the interviews, their views of key climate change induced flood adaptation strategies were requested. Five common responses were:

- Reduce the impacts of climate change on water resources by reducing greenhouse gases emission from human activities;
- Land-use planning, involving proper management of forest land, agricultural land, grazing land and built up areas;
- Develop reservoirs or dams in the upstream catchment area and planting bushes and grasses in and around villages to reduce erosion runoff;
- River training management by promoting bio-engineering, the construction of gabion walls, the use of bamboo matting and river regulation to reduce the flood risk; and
- Flood incident management, involving establishing flood-forecasting and warning systems in the river and communicating flood information/warnings to local communities.

One District Forest Officer (DFO) had some different views. He emphasized forest conservation and flood control measures through the public awareness programs and afforestation and reforestation activities along a 50 m buffer along river banks and, most importantly, in the upstream parts of the catchment. The DFO further stressed the importance of afforestation/reforestation activities as a no-regret option which has both adaptation (flood control, erosion control etc.) and mitigation benefits.

Regarding the greenhouse gas emission reduction responsibility, all the district level stakeholders had the same view: (1) this should be shouldered by developed nations who have damaged the earth and endangered the livelihoods of many; and (2) for Nepal, mitigation should be a long term strategy, but in the short term we need to focus on institutionalising and improving current flood adaptation strategies. In their own words “unfortunately, mitigation is a dream and adaption is a reality”. Therefore, there should be more focus on adaptation rather than mitigation in the context of Nepal. It helps to enhance the capacity of people to combat flood risk.

7.8 View of Central Level Policy Makers

At the end of the field survey, different central level disaster policy management makers, such as the Minister, Secretaries and Directors General, were interviewed with structured questionnaires. They expressed their views on flood adaptation for Nepal in general and for the West Rapti River Basin in particular. In fact, surprisingly, most of their “concerns/suggestions” and the “research gaps” identified in this study through intensive literature review were in common. As a result, most have been addressed through this study. As the author took these concerns/suggestions as a “means of justifications of this research” and “guidance for further research”, they are summarised below:

- The need for hydro-meteorological diagnostics to assess the magnitude of climate change (trends in rainfall and temperature and hydrological flows) in Nepal. (This was done in this study.)
- The need to assess probable flood scenarios under climate change and to develop adaptation strategies for such floods. (This was done in this study.)

- The need to change the design standards for flood management structures where necessary given the analysis above. The magnitude of major floods (e.g. 100 year and 500 year return period floods), which historically had a low probability of occurrence, may occur more frequently in the future. Hence, current design standards for river embankment work for flood protection may need to be upgraded to cope with an increased frequency of major flood events under climate change. (This issue is recommended for further study.)
- The need to assess flood impacts on different sectors e.g. power generation, agriculture and industries, employment, livelihoods of poor people etc. and design sector appropriate and effective adaptation strategies. (This issue is recommended for further study.)

Many issues highlighted by the central level policy makers are incorporated by this study and those which are not included are recommended for further study. They are applicable in formulating flood management policies.

7.9 Conclusion

The result shows that there were large changes in preferences in terms of flood adaption measures associated with the relative scale and magnitude of projected flooding. When the respondents realized that the flood problems are predicted to become more severe in the future, they selected strategies which were more appropriate for adaptation to the level of flood hazard. For example, the adaptation strategy “household level preparation/management" was ranked first while presenting the current Scenario I flood risk to the respondents. But, when the Scenario IV flood level was presented to the respondents, their first preference moved to “watershed management”. The realisation was also found in both the district level practitioners and central level policy makers towards effective flood adaptation measures. This helps government and other stakeholders to choose appropriate short-term, medium-term and long-term flood adaptation strategies among the many alternatives. It also informs the development of climate change induced flood adaptive management practices, through an iterative process of decision making in the face of uncertainty.

Chapter 8: Discussion of Results

8.1. Introduction

This chapter is divided into four sections in which the following are discussed: (i) the results of the analysis of observed trends and people's perceptions of climate change; (ii) the results from: flood analysis; analysis of trends in rainfall and runoff; magnitudes and frequencies of floods; flood hazard mapping; and vulnerability assessment; (iii) the results from the analysis of willingness to pay for the flood mitigation based on age, gender, education level, income and incomes sources; and (iv) the results relating to the early warning system and flood adaptation strategies at household and community levels. The flood adaptation strategies for different levels of exposure to flooding are also discussed at the end of this chapter.

8.2 Temperature and Precipitation

Climate change is becoming a major concern to mankind but many people, often those who are most vulnerable, are not aware of the real consequences of global warming. Climate change is recognised as a major threat, especially, to rural communities that are highly dependent on natural resources (Charmakar 2010). Nepal is among the most vulnerable of nations (Sapkota *et al.* 2011) although it makes a negligible contribution to global greenhouse gas emission. In Nepal, temperatures at higher altitudes are increasing much faster than those at lower altitudes (NAPA 2010); similarly, precipitation at high altitude shows a higher rate of increase whereas no significant trends have been observed in precipitation occurring at low altitudes (Marahatta *et al.* 2009; Shrestha *et al* 2011). The numbers of days with heavier precipitation are increasing despite a decreasing trend in the total annual number of rainy days, indicating an increasing likelihood of floods and landslides. Lybbert and Sumner (2012) report that a strong summer monsoon with heavy precipitation is associated with high temperatures over the southern Asian land area. Temperature is one of the most important actors in the global hydrological cycle and any change in the temperature regime, therefore, induces a shift to new balance conditions in the hydrological cycle that impacts all of its components (Manandhar *et al.* 2011). The temperature and precipitation trends identified in this study are concurrent with the conclusions of above studies.

8.2.1 Temperature: is the actual trend concurrent with people's perception?

The mean annual temperature for the study area during the 35 year period from 1973–2008 was 25.4ºC and ranged from 23.5ºC (1983) to 26.7ºC (2007). The maximum temperature recorded in the study area was 46.9ºC in 2008 while the minimum was 0.9ºC in 1976. Annual mean daily maximum temperatures ranged from 39.9ºC to 46.9ºC with an overall mean of 43.9ºC whereas variation in annual mean daily minimum temperatures was between 0.9ºC and 7ºC with an overall mean minimum temperature for the period of 3.3ºC. Annual variations, both in annual maximum and minimum temperatures, were higher than that of the average. As the average value of a variable is generally compensated for the extremes values in hydro-climatology, it is natural to have less variation in annual average temperature when compared to maximum and minimum temperatures.

The annual mean, minimum and maximum temperatures all showed increasing trends over the period interrogated; these included a 0.039ºC per year rise in the mean daily maximum temperature and a 0.042ºC per year rise in the mean daily minimum temperature. The average annual temperature of the study area has also increased by 0.042ºC per year. This trend is in agreement with the findings of previous studies (ICIMOD 2007; Timsina 2011) which have reported a 0.2–0.6ºC per decade rise in temperatures in Nepal.

Other studies (Aryal & Rajkarnikar 2011; Pokhrel & Pandey 2011) have also indicated that average annual temperature in Nepal has risen by 0.06ºC per year between 1971 and 1994; these studies also reported temperature increases of 0.06°C to 0.12°C per year for most of the Middle Mountain and Himalayan regions and increases of less than 0.03°C per year for the Siwalik and Terai regions. Baidya *et al.* (2008) analysed both annual minimum and maximum temperatures for the years 1981 to 1998 and found that annual maximum temperature increased at a higher rate (0.057ºC per year) than annual minimum temperature (0.025ºC per year). Similar trends were also found on the other side of the Himalayas on the Tibetan Plateau where the temperature trend was less than 0.005ºC per year at elevations lower than 500 m but more than 0.03ºC per year at elevations higher than 4000 m (Agrawala *et al.* 2003). These values were close to the annual average land-surface temperature trends for the globe (i.e. 0.011ºC –0.022ºC per year) and for the Northern Hemisphere (i.e.0.018ºC–0.031ºC per year) for the period 1976–2000 as reported by the IPCC (2007). In the context of Nepal, projected temperature increases by the 2090s are about 0.7°C higher in Western and Central Nepal than in Eastern Nepal (NCVST 2009).

Evidence of temperature rise was consistent with people's perceptions. As compared to 20 years ago, people perceived that there had been an increase in both summer and winter temperatures. Similar results have been reported by Bhusal (2009), Regmi *et al.* (2010) and Tiwari *et al.* (2010). Local people perceived that cooler days are decreasing and extremely hot days are becoming more pronounced compared to 20–30 years back (Piya *et al.* 2012) which are verified with trends of summer and winter seasons. In conclusion, the temperatures in Nepal are increasing at a faster rate than the global average. Furthermore, high-altitude regions are warming faster than low-altitude ones.

8.2.2 Precipitation: is the actual trend concurrent with people’s perception?

The observed precipitation in different locations (i.e. Kusum, Sika, Koilabas and Libang Gaun) across the study areas exhibited different characteristics. The 35 years (1973–2008) average annual precipitation change at Libang Gaun, which is located at an elevation of 1270 m, was 0.88 mm. This rate of change is higher than the rate of change precipitation at Kusum (0.05mm) located at elevation of 190 m. This shows that the rate of precipitation is more in higher altitude. This result is in consistence with other research findings (Gautam & Dulal 2013; Sharma 2009; Shrestha, *et al.* 2012). In mountains and hills, the monsoon rainfall is mainly orographic in nature, resulting in considerable variation in rainfall with elevation. The inner valleys frequently receive much less rainfall than the adjacent mountain slopes (Shrestha *et al.* 2012, Adler *et al.* 2003).

Anomalies in rainfall are also quite different in different locations. At Kusum the maximum rainfall recorded was 2076.6 mm in 2000. This was nearly 50% more than the long term annual average rainfall of 1345 mm for that location. The minimum rainfall at this location was 460 mm in 1977, which was almost 50% less than the annual average rainfall. Further, this area received less rain continuously for about two decades (1973–1992), with the exception of the year 1990. In other locations, such a long period of low rainfall cannot be seen. However, the range of rainfall anomaly is of similar magnitude to that of other locations (Sikta, Koilabas and Libang Gaun). Moreover, in some years it reaches close to 75% at Koilabas in 1998. The variation in precipitation may be attributed to the altitudinal variation and diverse landscape pattern of the catchment, covering the lesser Himalayan, Middle Mountain, Inner Terai and Terai regions.

The seasonal variation in rainfall is also high. Analysis of rainfall revealed that more than 80% of annual precipitation occurs during the monsoon season in the study area. The rainfall of the pre-monsoon and post-monsoon seasons accounts for only about 10% and 7% of the total rainfall, respectively. This seasonal variation is commonly observed all over the country as rainfall occurs due to the south-west monsoon which lasts between June and September. The humid monsoon air coming from the Bay of Bengal is forced to rise as it meets the high hills and mountains in Nepal. Orographic effects are prominent and govern the pattern of rainfall over the country. The amount of rain falling on the windward and leeward sides of the mountains can be quite different. Most of the plain areas of the basin is somewhat affected by the leeward effect; this explains why the rainfall is high in Libang Gaun and low in the Kusum and other low lying areas. The months of October to May are dry and rainfall is sporadic. In the winter, rainfall is caused by weather systems originating in the Mediterranean region; these reach Nepal in the dying stages and cause rainfall in the western part of the country.

The average annual precipitation trend based on the observed rainfall in all stations within the study area was an increase overall of 0.25 mm/year over the 35 years investigated. Precipitation trends were also analysed for the pre-monsoon (March–May), monsoon (June–September) and post-monsoon (October–February) periods. Precipitation in the post-monsoon season increased significantly, while the pre-monsoon precipitation had decreased in the recent years. This result was in agreement with results of previous studies in other parts of Nepal (Duncan *et al.* 2013; Baidya *et al.* 2008; NCVST 2009). The post monsoon rainfall showed an increasing trend up to 4 mm/year for most of the Mid-Western Development Region and the southern parts of the Eastern, Central and Western Development Regions (Nepal 2009; WECS 2011). This study found that there had been a significant increase in post-monsoon season rainfall which was affecting the hydrological cycle and influencing river flooding.

Most of the people of the study area felt that events like “rain with storms/hail”; “heavy rain within a short period” and “unpredicted/unusual rain” had increased in recent years. However, their level of certainty varied with regard to various events. They were certain that there had been an increasing number of heavy rainfall events within a short period than other events; however, people were less sure whether the level of cloud/haze/mist was decreasing or increasing. This shows that people are more likely to notice those events (e.g. rainfall events) that directly affect their livelihood or daily activities than those that have only indirect impact. It is suggested that, in the study area, capacity development related training and workshops could be useful in building understanding of cause and effect relationships.

Peoples' perceptions on climate change showed that most of the people felt there had been a change in the climatic pattern. More than 88% of the respondents mentioned that the monsoon season has been shifting and that both the start and end of the monsoon was now later than 20 years ago and that the timing of rainfall was also changing. It is worth noting here that the people's perception of rainfall characteristics was in good agreement with the observed data. Baidya *et al.* (2008) and Marahatta *et al.* (2009) also found that the timing of the monsoon was shifting and that there was evidence of increasing variability in rainfall patterns with untimely rainfall events, late monsoon start, and high intensity rainfall during the monsoon season becoming increasingly common in more recent times.

The survey respondents also perceived that the amount of rainfall occurring both annually and in the monsoon/post monsoon seasons had been increasing in recent years, but that this trend was more pronounced in the post monsoon season. They also felt that early monsoon rainfall had decreased. These perceptions are supported by trends in the rainfall data. These shifts potentially indicate a need to redefine the monsoon season and crop planting and harvesting times. This is an important issue in a country like Nepal where over 80% of people are farmers and have very limited irrigation facilities. Most farmers are highly dependent on monsoon rainfall for their farming. Therefore, identification of the right species and the right time to plant are critical factors for farmers' livelihoods and wellbeing. A targeted research and development program from government and donor organisations is crucial.

This study is not the only study to report these increases in rainfall in the monsoon and post-monsoon seasons, and the decrease in the pre-monsoon seasons. Other studies have also shown the increase in monsoon rainfall for the years 1971 to 2005 (Baidya *et al.* 2008). Sharma (2009) concluded that the number of monsoon days, with early onset and late withdrawal, as well as the intensity of monsoon rain, has an increasing trend. Also, Shrestha *et al.* (2012) concluded that the associated effects of climate change, such as increase in dry period, intense rainfall, flood, landslides, forest fires, glacial retreat etc., have already been observed.

According to the NCVST (2009), increasing temperature generally results in an increase in water holding capacity of the atmosphere that leads to a change in precipitation pattern and an increase in atmospheric moisture. Botzen *et al.* (2009) reported that heavy rain with high wind velocity correlates with higher temperatures. Therefore, increase in temperature in the study area can be expected to cause an increase in unusual rainfall and more intense storms.

8.3 Hydrology and Flood Hazard

This study evaluated the perceptions of the local community regarding the causes of floods and potential impacts of climate change induced floods following a brief discussion of rainfall and runoff relationships and floods and flood hazard mapping. A range of factors influencing flood vulnerability were also investigated.

8.3.1 Basin hydrology

Rainfall and runoff relation

The physical representation of a watershed was accomplished with a basin model and hydrologic elements were connected in a dendritic network to simulate runoff processes (Werellagama *et al.* 1997) to simulate the flow process and assess the response of such flow process. The annual mean rainfall of Nepal is 1,857.6 mm. Due to the topographic variations and aspect of locations, mean annual rainfall varies from more than 5,000 mm to less than 150 mm (ICMOD 2007). The hydrology of Nepalese rivers closely follows the rainfall pattern. The flow is quite high in the months of July to September. It is followed by a period of recession during the months of October and November. The flow in the river becomes very low during the months of December to April. Pre-monsoon rain increases the flows in May and early June. This characteristic is clearly seen in the Rapti River hydrology. It has a long term annual average flow of about 120 m^3/s, with the highest monthly flow of about 440 m^3/s occurring in August and the lowest flow of about 17 m^3/s in April. Almost 73% of the flow occurs in the months of July to September (average = 354 m^3/s) while 10% of the flow occurs in the post monsoon months of October and November (average flow = 72 m^3/s). The winter flow accounts for less than 8% of the total flow (average = 22 m^3/s) while the pre-monsoon flow including that of June accounts for the remaining 9%. These figures show that the West Rapti Basin receives a lot of water in the monsoon season but is relatively dry in the winter months. The system could potentially benefit from the installation of a reservoir type of structure at a suitable location upstream of the plain area (i.e. upstream of Bhaluwang), if the government wants to use its water optimally for irrigation and other useful purposes. This would store the excess water available in the monsoon season for use in other seasons of the year; it would also help to control flooding during the monsoon season.

Floods are triggered by many factors such as continuous rainfall and cloudburst, glacial lake outburst, landslides creating temporary dams followed by outburst and dam breaching. However, the main cause of floods in the West Rapti River Basin is rainfall, particularly during high rainfall events associated with the monsoon season. For example the flood of September 20, 2008, on which date a daily flow of 1753 m^3/s was observed at Bagasoti, occurred when 181 mm of rain fell in 24 hours (120 mm was the daily average on that date). Due to this heavy rainfall, the West Rapti River Basin experienced a major flood event that destroyed 142 houses, permanently displaced people and accounted for economic losses totalling millions of rupees. Similar kinds of extreme flood events were also recorded in 1984, 1989, 1998 and 2012. The 2012 flood in the West Rapti River killed at least 11 people, destroyed 2,200 households and submerged nine villages (Gautam & Dulal 2013).

These data show the existing need for flood adaptation planning to mitigate the flood damage in the basin. However, rainfall intensity is likely to increase further under future climate change and flood events are predicted to become more severe in coming years. Flood adaptation strategy to deal with such flood is, thus, of upmost importance for this basin.

8.3.2 Flood hazard mapping

Flooding has many disruptive effects on human settlements and economic activities. The long term effect of flooding basically includes the economic effect or physical damage and casualties of people and livestock. Once the threat to a community or a city is recognised, counter measures to mitigate them are sought. Since the role of the flood hazard map is to recognise the level of flood risk in an area, it helps to develop processes to ensure quick and smooth evacuation at the time of floods.

The study area was classified into critically, moderately and less flood prone zones based on flood frequency and inundation depth and a flood hazard map was prepared based on these three zones. The inundation map prepared was found to be in good agreement with the qualitative information obtained from the local residents during the field survey. Inundation maps for 2, 30, 70 and 100 year floods were prepared from the model results.

There are 11 VDCs within the study area which had been inundated to some degree. The flood-prone area accounted for about one fifth of the total area of these VDCs. Out of these, five VDCs were inundated by floods over more than 50% of their area; four had between 10% and 50% of their area inundated; and two VDCs were inundated less than 10%. Holiya is the only VDC which was completely inundated. Out of the total flood prone area of 182.2 km^2, critical, and moderate and less flood prone areas were 60.8 km^2 (7.5% of the total area), 63.35 km^2 (7.8% of the total area) and 58.05 km^2 (7.2% of the total area) respectively. Almost 50% of Holiya VDC falls under critical zone followed by Phattepur with one fourth of its area falling under critical category. In addition, for 2100, about 85.81 km^2 is in the critically hazardous flood zone, while 148.5km^2 and 10.33 km^2 in moderate and less hazardous zones respectively. The areas which was flood prone at different levels of severity, i.e. critical, moderate or less were almost equal in terms of their physical dimensions; however, flood impacts varied with the zones in line with the severity of flood hazard. The most affected settlement areas were those located in the close vicinity of the river. Similar results have been reported from other parts of the world (e.g. Netherlands, Iceland, Australia) (Sturgess and Branson 2002; Disaster Management 2010; Tucci 2007; Herbert 2011). This assessment provides decision makers with a basis for the appraisal of policy options, allocation of resources and monitoring performance of substantial government investment in flood management.

As a flood hazard map was not previously available for the study area, this study attempted to develop flood induced hazard maps that could reveal potential risk zones. This map will be useful in informing disaster reduction strategies. Detail study on human-water systems is important to complement the temporal and spatial analyses of flood (Brouwer *et al.* 2007; Baldassarre *et al.* 2013 and Sivapalan *et al.* 2011).

8.4 People's Perception on Flood

8.4.1. Causes of flood and its impacts

Nepal has a fragile geology and steep topography making it one of the more disaster prone countries in the world. It is also characterised by high relief and high intensity monsoon rainfall. Climate change, resulting higher surface temperatures, changes in precipitation patterns, floods, severe landslides, soil erosion, hailstones and drought, have impacted agricultural sectors in Nepal in the recent years. These changes have shifted farming practices and negatively impacted crop production (Werallagama 2005).

The main causes of flood identified by local people during Focus Group Discussions (FGDs) were intense rainfall due to climate change, deforestation, unplanned land use/management and extraction of boulders and sand from the river bank. The response received from the household survey was that the recurring floods in the study area were caused by intense rainfall that might be attributed to climate change followed by deforestation.

Flooding in the West Rapti River is mainly associated with high flows in the tributaries (ephemeral rivers originating from the Siwalik Range). Ephemeral rivers are rain fed rivers whose flow solely depends on rainfall and runoff into those rivers. The perceptions of the people on the cause of flooding is, thus, quite rational. In all cases of major flooding, such as the flood event of 2006, in which 10 villages were flooded, several houses were washed away and at least six people lost their lives or that of 2008, in which about 142 households were forced to leave their houses permanently or that of 2010, in which more than 16,000 people from 2,600 households in 33 villages were forced to leave their houses and farmland and live as refugees (TKP 2010), the study area received unusually very high rainfall.

Forest cover reduces the velocity of overland flow reaching the river and helps to enhance percolation because of loose top soil and high retention time (Green 2010). In the absence of forest cover, rain falling on barren land accumulates and flows rapidly towards the river; as a consequence, water levels increase rapidly in a short period of time. Deforestation, as perceived by the people in this study, is a significant cause of flooding in this river basin. Between 1990 and 2010, Nepal lost an average of 59,050 ha of forest with a deforestation rate of 1.23% per year (FAO 2010). The deforestation rate in Banke and Dang districts is especially high as many squatter settlements exist in these districts. Forest loss is one of the top political issues in Nepal. In the fragile area of the upper catchment of the West Rapti River basin, high erosion during intense rainfall yields a significant sediment load to the river which is transported to the lower catchment and deposited in the agricultural land as well on the bottom of the river.

In the study area, there are no proper irrigation facilities and individual farmers have developed small irrigation canals, making it easier for flood waters to enter agricultural lands during the monsoon season. In addition, unplanned land use and extraction of boulders and sand from the river bank make river banks unstable and are a major reason for river course change (Pivot & Martin 2002).

Construction of infrastructure without due consideration for the safe passage of the flood waters is a further cause for the augmentation of the flood problem in the study area. It was observed in the field survey that physical infrastructure such as roads and culverts had obstructed the natural flow of the tributaries in many places. For example, road construction in Holiya, Phattepur, Kathkuinya and Gagapur VDCs of Banke district has resulted in water logging. The majority of the people believed that this has increased the flooding problem as there is no proper drainage system. The culverts constructed in few places are also not in a suitable location. Focus group discussions and key informants interviews indicated several additional causes of flooding, including increased livestock numbers and overgrazing on limited land in the upper catchment area (Churia range); this has aggravated soil erosion and promoted flooding downstream because of sediments deposited in the river bed, which in turn results in bed level rise reducing the flow carrying capacity of the river.

The construction of the Laxmanpur barrage across the West Rapti river and Kalkaluwa Bandh (dyke) on the right bank of the lower West Rapti river on the Indian side, as well as other human interventions on the banks, were other causes of flood hazards at Bethani, Holiya, Fattepur, Gangapur and Mataihiya VDCs of Banke District, as stated by Gautam & Dulal (2013). These constructions obstruct the flow of the river when there is a high water level in the river.

Climate change is believed to be the main cause of erratic and high intensity rainfall. People's perceptions of the impacts of such rainfall on their livelihoods were ranked, based on responses to the household survey. The major impacts were on collecting fuel, crop damage, planting and harvesting times, daily activities and landslides, as also reported by Sharma and Shakya (2006). Survey respondents also felt there was a direct positive relationship between rainfall and flooding and more than 80% of the respondents felt that rainfall has a very high impact on flooding in their area.

Difficulty in collecting fuel wood and crop damage problems were ranked in the high impact categories because firewood is the major source of the energy for the rural population, where overall 83% of fuel is sourced from forests in Nepal. Similarly, during the monsoon season, flooding damages most of the crops to some extent. Disturbances to "daily activities and "landslide" were ranked of lower importance, possibly as schools are closed during the monsoon season and most people are busy on the farm and do not feel that their activities are obstructed by rain. Also, as this survey was conducted in only two districts, Dang (Inner Terai) and Banke (Terai), where there is a low incidence of landslides, they were given low priority.

Respondent's perception on the impacts of flood on different goods, services and activities such as: (1) agricultural land; (2) houses and settlements; (3) drinking water sources; (4) grass and wood collection; and (5) domestic animals were assessed and ranked based on the level of the severity of flood impact on them. Cumulative Relative Frequency (CRF) values up to moderate impact (i.e. sum of RF of 'very high' plus 'high' plus 'moderate' ratings) for the three sectors: agricultural land, houses and settlement and drinking water sources, totalled over 80%. Agricultural land and crops were affected even by small floods during the monsoon season as most of the agricultural lands are adjacent to or near the rivers; this is similar to observations reported in Gautam and Phaiju (2013). Furthermore, housing structures, particularly in densely settled areas, aggravate flooding as they also obstruct the water flow (Gautam & Dulal 2013). During the monsoon season, houses and settlements in the study area may be inundated for up to 3 or 4 days. Drinking water sources, which are mostly dug wells, are often affected by floods as the flood water enters the well and contaminates it. The respondents correspondingly prioritised these as highly flood affected sectors with CRF values of 94% for agriculture land, 90% for housing and settlements and 85% for drinking water.

Vulnerability to flooding may vary spatially and temporally. Different types of houses in the same area may have different levels of vulnerability according to the mode of construction. It was observed that groups such as the Terai Dalits, Janajatis and Muslims are often poor landless households living in thatched houses in low-lying areas and are, consequently, highly affected by and highly vulnerable to flooding; similar observations have been reported in Berkes (1998) and Shaw *et al.* (2009). Small-scale farmers near main rivers, whose land has been washed away or covered by large amounts of sediment causing loss of income and livelihood, are also regarded as highly vulnerable (Merz *et al.* 2007).

The people living in the study area strongly believed that the changing pattern of the monsoon, with the extreme weather conditions common in recent years, was responsible for the more extreme flooding and consequent damages to physical infrastructure such as houses, schools, sub-health post, roads, culverts, marketing centres, gabion embankments, spurs, hand pumps as well as productive agricultural lands, and loss of livestock (Gautam & Phaiju 2013). The increasing flood frequency also eroded the social assets such as neighbourhood, brotherhood, labour exchange system, and strong bonds of kinship (ICHARM 2008). However, the major impact of floods was on loss of livelihood. Many poor and indigenous people living along the flood plains, with few resources to manage floods, have suffered most through loss of homes, crops, animals, livelihoods and even their lives in floods.

8.4.2 Flood impacts on rice production

Rice is the basic foodstuff of the Nepalese people, especially in poor and rural areas. However, frequent flooding in recent years has damaged the productive agricultural land through standing water, river bank cutting, and sediment deposition in paddy lands, leading to heavy loss of crop production. Between 1996 and 2002, 26.9 ha of agricultural land have been lost in this catchment area, resulting in the decrease in the total rice production of the region (Gautam 2007).

About 52% of household survey respondents reported that they cultivated the land after flooding. Of these, about 33% said that their crop yield increased after flooding by up to 75% in some cases. They believe that the alluvial soil deposited by floods is highly fertile (Power & Prasad 2010; Uddin Mahtab & Karim 1992). However, the majority (56% of respondents) experienced a decrease in crop production. Of the 61 respondents who mentioned that their rice production had decreased after the flood, 41% said that their rice production had decreased by 75–100%. Paul (1984) also found similar results in a study in Bangladesh. In many cases, in spite of reduced production, they still cultivate rice after flooding because of three main reasons: availability of free family labour with almost zero opportunity cost; no alternative to rice cropping; and hand to mouth problem (Rosenzweig *et al.* 2001). To assist farmers to cope with this challenge, there may be potential either to develop new genetic varieties of rice and/or cultivate seasonal crops such as watermelon, cucumber, pumpkin, peanuts etc. in flood prone areas. These crops may be especially suitable for poor and marginalised people who cannot invest large sums of money. Demonstration plots with diverse varieties of crops could be a useful way to motivate flood-affected farmers to diversify their cropping and minimising their vulnerability to flooding. This could be a useful flood adaptation example to the people living in similar situation in other parts of Nepal and the world.

8.4.3 Flood risk and migration

Migration, whether temporary or permanent, has always been a traditional response, or survival strategy, of people confronting the aftermath of flooding. For example, survey respondents reported that, after the heavy flooding of 1985, people in the study area started to migrate seasonally in order to seek alternative income source. This study indicates that those who live in low lying areas and along the river bank are likely to be particularly vulnerable to flooding, while those who have land only along the river bank are most likely to be landless within few years. The type of housing is important. Thatched houses in critical flood prone zone are likely to be severely damaged by flooding, while those families who have two-storey houses made from concrete and stone/bricks are safe to some extent. Hence, it is likely that flooding disproportionately forces poorer people either to migrate elsewhere or engage in off-farm activities to support their livelihood, although there are number of push and pull factors which drive migration (Werellagama *et al.* 2005). This study revealed that push factors may be on the rise in the study area where the primary cause behind this migration is recurring floods.

In the study area, three types of people: those who temporarily migrated; those who stayed in the same area facing risk; and those who permanently migrated were recognised. Of the 240 respondents, 12.5% had permanently migrated due to the big flood event of 2008 and 39% had temporarily migrated. Of the latter, about 80% of the respondents reported that they had migrated for 1–7 days and another 20% migrated for >8 days. These people sheltered in a relative’s house, public places such as schools, Red Cross buildings, temples, neighbours houses and other places such as along the road side or in nearby forest areas (Maharajan *et al.* 2011). Day by day their economy worsened and they experienced difficulties meeting their basic needs. Those who permanently migrated to another places had lost their livelihoods in the flooding. Those whose houses were of more permanent construction often remained living in their houses even though the flooding continued for some time.

The survey respondents also provided information on the seasonal migration that normally peaks during November–January after harvesting paddy rice and sowing winter crops. As far as possible, male family members try to stay at home to rejuvenate their houses and secure their housing before the seasonal migration. The main reasons for the seasonal migration are: (i) Failure of crop production due to continuous flooding, inundation and sedimentation; increasing population pressure has contributed to land fragmentation and people are not in a position to share cropping or get or access additional land on a rental basis; (ii) fewer local opportunities: there are fewer opportunities to work as on-farm labour or in alternative off-farm activities in the villages. People in these communities have, traditionally, been dependent on farming and, historically, people used to plant two crops each year; however, recent flooding has reduced the extent to which this happens. Therefore, most of the time they either sit idle or migrate to other places in search of a source of income; (iii) Loss of livestock: there are many cases where people have been forced to leave their village and/or farms when there has been an outburst of an unknown disease in the local livestock and/or community; and/or (iv) Lack of basic needs: reduced crop production is a significant cause of migration within the villages of the study area.

Nepal is a male-dominated society and a house without a man has several problems. Leaving highly vulnerable people at home, such as women, children and old-aged people, has an enormous psychological and emotional cost. As a result, many members of migrating family become victims of stress related disease such as diabetes, high blood pressure etc. Samuels *et al.* (2006) and Maharajan *et al.* (2011) suggest river basin management and flood mitigation measures should be implemented to alleviate these issues. Moreover, diversification of farming; income and employment generation activities; and counselling facilities at local level could be valuable.

8.4.4 Flood vulnerability

As stated by Wrachien *et al.* (2011), vulnerability is a factor of the characteristics and situation of a person or group that influence their capacity to cope and/or adapt. Vulnerability in the context of this research study can be taken as the diminished capacity of an individual or group to anticipate, cope with, resist and recover from the impact of the flood hazard. Floods in the study area have increased the vulnerability of the local people by damaging: i) the physical structures such as houses, water supply, schools, hospitals, and transportation facilities; ii) the social fabric of communities because of migration, difficulties in accessing education and health facilities; iii) economic conditions through degradation of agricultural land and its productivity, market value and/or income generating capacity and creating difficulties in terms of access to forest resources and animal production. Psychological stress can also be significant.

People’s perceptions were that bank cutting and damage to agricultural land were the two phenomena making them most vulnerable. These factors accounted for more than 70% of reported vulnerability. The two aspects are directly linked to the economics of agriculture based livelihoods. This study shows the necessity of recognising people's concerns and their sensitivity to flood induced consequences which in turn make them vulnerable.

There is a greater possibility of housing being affected by a flood if it lies near the river due to either bank cutting or the intrusion of flood waters into the house. A house not only provides essential shelter a basic requirement for living but is the main asset of rural people (Gautam & Phaiju 2013). The loss of their house, thus, brings significant hardship. This is why people place high weightings on "house near the river" as a main factor of vulnerability. It is, therefore, necessary to consider these factors while formulating plan and policy, making strategies to reduce the economic vulnerability to flooding of the people living in the study area.

People in the study area also suffer psychological problems due to flooding. Other reasons contributing to vulnerability were poor social networks and institutions, inequality and lack of integration of different sectors to cope with the hazard. This study found that the majority of people were interested in selling their property and moving to a safer place.

This study clearly shows that people living in the study area are concerned with the “recurring flood” that is making their livelihoods increasingly difficult. Responses showing that “bank cutting” and “houses near the river” were highly ranked also show their concerns for their future existence due to flood. Similarly concerns for loss of agricultural production and mobility showed people's wish for flood control in the West Rapti River to save their settlements and livelihoods.

In terms of vulnerability, the average household survey score for the economics parameter ranked third after physical and social. However, in the expert weightings, economics was believed to be the most important parameter, showing a critical gap in policy makers’ recognition of the problem in the field. There is, therefore, a need, in developing policy, for direct consultation with the local people.

Although, previous studies dealt with climate change vulnerabilities and impacts assessment, this research has further enriched and explored the understanding of differential vulnerabilities and impacts of climate change in relation to underlying socio-economic causes. As described by the theory related to social and political economy approach, it is important to analyse and understand the underlying causes of vulnerability and impacts of climate change in the socio-economically differentiated and inequitable society (Hagan 1990; Kelly & Adger 2000). The research revealed that impacts of climate change and vulnerability of community are complex process determined by combined effect of both climatic and non-climatic factors. However, climate change enhanced risks and uncertainties to the communities who were already surviving under socio-economic vulnerabilities (IPCC 2014).

Vulnerability assessment and mapping of flood risk are prerequisites for flood management. Use of both scientific knowledge and the experiences and perceptions of the local people in vulnerability assessment makes the predictions more effective (Devkota *et al., 2013)*. A number of institutions, ranging from governmental to non-governmental organisations and even the private sector, are involved in flood risk management in this study area. However, there is a lack of coordination among these organisations. Department of Water Induced Disaster Prevention, a government body of Nepal, is working on planning and implementing strategies to address water induced disasters that include flood disaster prevention activities. At the river basin level, the people’s embankment programme is being implemented at the community level with bio-engineering, bamboo matting, stone fencing and sand filling activities carried out during the monsoon season. Similarly, Nepal Red Cross Society, the Banke and Dang districts and local non- government organisations are active in local level activities to mitigate flood impacts and provide relief to flood affected communities. They also provide training such as rescue operations and first aid and raise awareness for flood risk reduction within at-risk communities. Coordination of these activities among such organisations, as envisioned in National Strategy for Disaster Risk Management in Nepal (NSDRM 2009), would make flood hazard management (prior, during and post flood event) more effective.

8.5 Willingness to Pay

In this section, the Willingness to Pay (WTP) for flood mitigation of the people of the study area to avoid or mitigate flood impacts is discussed. A discussion of the WTP of people of different age, gender or their educational level for four different flood scenarios (i.e. current (Scenario I) and probable scenarios of 2030 (Scenario II), 2070 (Scenario III) and 2100 (Scenario IV)) is presented, followed by a discussion of how willing people of different flood zones were to contribute to flood mitigation initiatives/activities under these four climate change scenarios.

8.5.1 Willingness to pay by age, gender and education level

This study analysed willingness to pay (WTP), by people who were in different age groups and who had different educational levels, to mitigate flood disasters for the four flood scenarios. Results showed that the WTP of the people was higher if they were aware of the risk of flood disaster and if they could be convinced of the importance of mitigating the flood disaster risk for their benefit (economic, socio-cultural and psychological) and overall prosperity. These figures support the need for policy makers to involve local people in disaster risk reduction and climate change adaptation planning so as to put in place proper policies and formulate convincing strategies. The increase in the standard deviations of the data in these cases also supports this hypothesis, indicating that people are more certain of the real situation they are encountering right now than of the outcomes of hypothetical future scenarios. Embedded in the standard deviations are a range of factors such as the level of consciousness, capacity to pay and human psychology.

WTP was found to be lowest in people below 35 years of age and highest in the age group of 35-45. The respondents who were below 35 years of age accounted for 17% of the total respondents; their overall response might have been because the people of this age group did not have good jobs and were planning to migrate either to nearby cities or move to India for employment. Young people living in this area feel that they face a critical lack of basic needs due to flood and its impacts. For example, there are several cases where children were not able to go to school because of flooding. A 29 year old female respondent who was interviewed reported that her children, along with those of her neighbours, were unable to go to school because they could not cross the flooded stream near their school. This is serious where families aspire for better lives and better futures for their children, but are unable to ensure that they can get the education he/she needs because of flooding. People of the “under 35 year” age group are in their mid-career and want to escape from this situation.

People in the ‘35–45 year’ age group might be more settled and so see less possibility for migrating to other places. Furthermore, most of them might see the possibility of making their places better through undertaking appropriate flood mitigation measures. The high value of standard deviations, on the other hand, indicates that there was differing perception even in this group. However, since the WTP values of the different groups were relatively close, we can conclude that their general perspective on flood risk management was similar.

Information on global climate change was modest and highly variable, though some of this positively and significantly influenced WTP. In the study by Li *et al.* (2009), WTP was significantly related to gender, political ideology, income and perceived damaged. Interviewing both men and women, as was done in this research, provides a reliable estimate of how they individually and collectively value insurance or mitigation measures against flood risk.

Results of this study show that WTP in scenario I was greater for males than for females, while WTP was higher for females for all other scenarios. It can be taken that males are, generally, more concerned for the present than the future. However, the differences in WTP values were not so great that we can draw any outright conclusions about this. Since females involved in the study spent more time on household work where they are involved in cooking, fetching water, collecting fire wood and grass for animals, it can be surmised that females are more concerned about the impacts of climate change. This may be the reason for the sharp rise in the value of WTP from current case (Scenario I) to the case of 2030 (Scenario II). In Nepalese society, females are still considered to have less knowhow; hence, it is encouraging to know that the female population is also willing to pay more to reduce suffering due to flood hazards, now and in the future when such events may be aggravated by climate change.

It was found that more than 50% of people living in the study area were illiterate. Of the total number of literate respondents, less than 40% had above secondary level education. WTP was found to be significantly higher in literate people in all cases indicating that literate people may be more likely to be able to assess flood risk and potential damages, as well as the long term benefit of small investments in flood management (Maraseni *et al.* 2008). These findings are similar to those of Dietz *et al.* (2007), in which they reported that WTP was strongly influenced by education, environmental awareness and household income. It demonstrates the need for awareness-raising campaigns targeting illiterate people including the younger generation, women and marginalised people.

Natural disasters including flood disasters may increase in terms of frequency and severity in the future as a result of climate change. WTP can be used as an explanatory variable to know the perceptions of the local people for flood risk management to reduce economic losses of the area. It is, however, affected by the geographical condition and socio-economic characteristics. For example, people with high levels of income were willing to pay more. Assessment of WTP can be an important and effective tool for evaluating the probable involvement of local people and to inform decisions around responsibilities for future flood risk management. The results of this study are encouraging in the sense that the level of WTP for devising strategies on flood management under climate change conditions was found to increase consistently over time, from the current scenario to future scenarios of 2100, irrespective of age, gender or literacy. As stated by Solomon and Johnson (2009) and confirmed in this study, valuing climate protection through willingness to pay is a valuable approach to flood and climate risk reduction.

8.5.2. Willingness to pay at different flood zones

The average willingness to pay (man days/yr) to mitigate flood problems was determined in three flood zones (critical, moderate and low) and four flood scenarios. As expected, on average, WTP was found to be highest in people living in the critical flood zone and least in the low flood prone zone. This result was valid for all scenarios and increased with the level of risks they perceived (i.e. WTP was lowest for the current case and highest for the more extreme 2100 Scenario).

WTP varied with income level within flood hazard zones. The relationship between income and average WTP for various scenarios was positively correlated with farm income and livestock income. The income from farms was found to be highest for

Zone 1; the people living in this zone have comparatively more land and irrigation is easier because of being very close to the river. This increases the chance of producing rice crops, and therefore improving livelihoods. Moreover, two crops per year are possible due to the greater availability of water in the area near to the river. Furthermore, the soil is also highly fertile in this zone due to regular river deposition of alluvial soil. Local people also can grow cash crops such as watermelon, cucumber, and pumpkin in the floodplain area. With increasing distance from the river, more and more land becomes rain fed and rice production decreases as do the chances of growing other cash crops. At the same time, cropping frequency goes down. On average, the flood damage cost in the study area was $US110 per household per year. Most flood damage cost was due to property and crop damage, followed by loss or damage to livestock. The results support the argument that the higher the damage the greater is the WTP.

Climate related damage is more likely to increase in coming decades. Tol (2002) estimated that the global average costs of climate change damage lay between 2% and 3% of global GDP. Information about how much of this damage would be flood-related is not available and an appraisal of climate change related flood damage would be very useful (Zhang *et al.* 2006). The influence of climate change on WTP for disaster insurance is required so that insurers can assess the future profitability of offering coverage against damage caused by natural disasters (Liebe *et al.* 2011; Lytle & Poff 2004). The effects of climate change for flood mitigation is accomplished by eliciting insurance demand under different scenarios of increased flood probabilities due to climate change and varying levels of expected flood damage (Zhai *et al*. 2006; Botzen & Van 2009; Wertenbroch & Skiera 2002).

There are several studies (Meyerhoff 2006; Blamey 1998; Hoffman and Spitzer 1993) on WTP. Such studies help to identify and apply economic instruments to environmental management (O'Connor 1996). Botzen & Van (2009) found that WTP increases with the increase in flood damage. However, the damage cost could vary on both spatial and temporal scales. Floods in a place with high value property and at the time of harvesting crops would incur more damage. Therefore, WTP estimates derived from perceived impacts of all potential costs are very useful for developing flood mitigating policies, programs and projects (Morss *et al*. 2005; Blocker & Rochford 1986). So far, while offering WTP value, people are usually asked to consider the physical property losses only, and not the health and psychological costs of flooding. A comprehensive WTP study which considers all those direct and indirect costs could be very useful.

8.6 Flood Adaptation Strategies

Flood forecasting techniques, early warning systems and community based flood management systems can save many lives and properties. In the study area, communities are enriched with indigenous knowledge on flood forecasting, early warning systems and flood management practices. Though people have inadequate knowledge of the technical aspects of these issues, they have a range of practical solutions, earned through previous experience of flooding. Timely information on the magnitude of flood hazard (flood forecast) and dissemination of such information to the wider flood risk community in time (through early warning mechanisms) would help them to prepare their flood adaptation and management strategies. In this section, a brief discussion on indigenous knowledge of flood forecasting is presented, followed by a discussion of people's perception of early warning systems and their flood adaptation strategies. The section concludes with some observations of how flood adaptation strategies might change with exposure to future flood scenarios.

8.6.1 Indigenous knowledge on flood forecasting

The techniques people of the study area have been employing for generations, and believe to be useful for flood forecasting, include observation of: (1) rainfall in the upper catchment area; (2) magnitude of hotness; (3) magnitude of thunderstorms; (4) colour, position and direction of clouds; and (5) movement of ants.

People strongly believe that if there is rainfall in the upper catchment area, there is a high possibility of flooding. In particular, high intensity rainfall over longer periods of time during the monsoon season can be devastating. Communities expressed opinions that rainfall in the Terai region (where they are living) alone would not induce high flood levels (Devkota *et al.* 2013). The magnitude of flow in a river is mainly attributed to the intensity of rainfall and the duration of such rainfall in a catchment; the higher the intensity and longer the duration of rainfall, the greater the flow in the river (Shaw *et al.* 2009).

Likewise, perceptions were that, if the monsoon season is particularly hot, there is a very good chance of rainfall and floods. High temperature escalates evapotranspiration which ultimately triggers heavy rainfall and floods (Nyong *et al.* 2007). Similarly, the indigenous people think that the magnitude of the thunderstorms is another indicator of possible rain and consequent flood. They also report assessing the chance of heavy rainfall by noting the position of cloud in the sky. Communities have a belief in a saying that if black cloud is located in the eastern side of the sky and if there is no mobility of this cloud at all, then there will be a heavy rain within an hour. Therefore, the colour and direction of clouds are very important for local people. Black clouds contain high amounts of moisture and are a good indicator of highly humid air in the atmosphere and the possibility of having rain.

Similarly, if they see thousands of ants moving in a row i.e. leaving their present location then they believe that there is a possibility of heavy rainfall in a day or so. However, this indicator was considered the least reliable of the five main techniques reported. Besides these five major forecasting techniques, people also expressed the belief, to some extent, that abnormal behaviour shown by some animals (e.g. unusual fly movements, strange crying of frogs, jackals or swans) also provide an indication of heavy rainfall and the possibility of loss of life of humans and livestock due to flooding. In addition to these above mentioned techniques, it is also established practice to interpret strange rumbling sounds coming from the riverside as an indication of imminent flooding. Once confirmed that there is flood, there is a general practice of shouting loudly to notify other people.

8.6.2 People's perception of early warning systems

Early warning systems can reduce flood risks and save the lives of many people and their property such as homes, land and domestic animals. Such as system should provide a clear message to those people who are at risk and stimulate them to take actions. The most preferred early warning method used by people in this study was either a siren or alarm system as: (i) the sound produced by sirens or alarms can easily be detected and identified; (ii) there is no need for expensive instruments nor an educated person to operate it; (iii) it is equally effective whether one is at home or in fields; and (iv) warnings can be delivered to a larger mass of people within a short period of time. Moreover, it is also extremely cost effective.

Mobiles/SMS were ranked as the second most effective method for delivering warnings about flash flooding. Nowadays, all levels of people, whether poor or rich, keep a mobile phone with them at all times; mobile phones are also very cheap and within the reach of poor people. “Shouting” was the third most popular choice as, again, it is a way of quickly transmitting messages; however it is effective only for small areas. Door to door information sharing was considered difficult, not only because it is time consuming, but also it is not possible to assign a person for this task in a difficult situation; as a result, it is the least preferred method for flood warning.

Respondents also ranked the mode of communication for transmitting early warning information. As in the case of other early warning systems, “alarm” and “mobile/SMS" were ranked highly as effective means of communication. The discussion above is equally applicable here. People in the study area are poor. They have limited transportation and poor access to newspapers and other forms of mass communication. More than half the people are illiterate, so do not read or write; they often cannot afford to buy TV or radios and extensive power outages mean that, even for those who do own such equipment, these are not reliable information sources. As a result, these were less preferred options for the delivery of early flood warnings because of timely accessibility and affordability issues.

In the past, people used indigenous knowledge and traditional practices for flash flood warning systems, such as assigning flood watching volunteers from the village and door to door communications (Basnyat 2006). These days, people have access to mobile phones, which are cheap and handy and carried by most people; mobiles enable easy communications between people through direct conversations or text messaging. Information can be easily passed through mobile system however the reliability is still inadequate. Previous studies by Gunasekera (2004) and Gautam & Dulal (2013) shows that an effective flood early warning system also requires improvements in weather warnings with the need to determine the appropriate lead time for warnings and to improve the accuracy of warnings and forecasts, particularly in monsoon season. Therefore, getting the right information to the right people at the right time and right place is very important for flood risk reduction (Rogers & Tsirkunov 2010).

Flash flooding is common in a country such as Nepal where high volumes of water flow in a short duration due to intensive rainfall. Floods also often carry large rocks and huge amounts of mud and other debris. Flash floods in the West Rapti River are often the result of ‘cloudburst’ upstream in the catchment (e.g. in Pyuthan and Rolpa districts). Sirens/alarms at the river are the most effective system for providing flash flood warning. According to Social Development Officers, flooding in the river is not due to heavy rainfall in Banke district but is due to extreme rainfall in Rolpa and Puthan both of which lie in the upstream area. They advise that setting up the early warning system in those areas not only helps to minimise the loss of lives and property but is also an effective approach for people living in poverty and ignorance. Academicians from National Academy of Science and Technology, Nepal, have a similar opinion that an 'early warning system is an effective way to minimise losses of lives and properties in West Rapti River basin'. However, environmental experts warned that the existing early warning system is not sufficient for communicating to local people, and that a new cost effective and appropriate technology is required to save the lives and properties of the people living in the flood prone areas.

During the author's stay at the flood prone area as a paying guest, he found that the transmission of early warning knowledge for upcoming floods can be shared and passed from one generation to the other. As in many societies with strong oral traditions, new generations of children are given knowledge of past events including flood events through storytelling and the knowledge they receive is embedded in their memory. Such type of information transfer practices occur in the West Rapti River Basin.

8.6.3 Perception of the people on flood adaptation strategies

Various dimensions of flood impacts are often ignored in the pre-flood period. Floods have potential to cause significant loss of life and property and result in huge cost in the post-flood recovery period. A penny of investment and a thread of pre-flood management activity can save a pound and bundle of socio-economic strain in post-flood situations.

Pre-flood adaptation strategies include prevention, mitigation, and preparedness activities. These activities generally involve developing action plans for pre, during and post flood period, capacity building, training and awareness. Similarly, the capacity of the people and the community to withstand flooding during a flood event depends on their awareness of the risks and understanding of appropriate responses, (e.g. running away from the home or staying within a house considering the nature of flood, caring for children and old people and diverting floods where possible etc.) The foremost priority in the flood and immediate post-flood period is to minimise loss of life by undertaking rescue efforts for affected people and providing medical treatment. People who are trapped under destroyed buildings or isolated due to floods need immediate assistance. Policies and strategies for the post flood phase should be designed to ensure a speedy return to normalcy and the mitigation of any long-term consequences of the flood.

This study was found that the majority of people in the study area accept flood events as a part of their life. They are aware of the possible magnitude and frequency of flooding and its capacity for destruction. Furthermore, they are mentally prepared to face the challenges and struggle associated with flooding and prepare accordingly at the individual and family level. People also expressed a view that there was little alternative to living with the flood when there was no support from external agencies. There is a saying that "the snake and the river don't run straight". Proverbs such as this create a common knowledge and shared understanding of the change related to frequent flood events. It helps to build a sense of community and solidarity within the village and communities. The perception of the people regarding the effectiveness of flood adaptation strategies during pre-flood, during flood and post-flood period at household and community level are discussed below.

a) Household level flood adaptation strategies

Pre-flood adaptation strategies

The main strategies reported for pre-flood adaptation were raising the bottom floor of the house, construction of drains around the properties, moving equipment etc. to safe locations and managing essential materials for an emergency. People create small drains around each plot of paddy land and house, as poor drainage systems are recognised as the foremost reason for flooding. In order to let the water to go out of these areas, outlets of appropriate sizes are placed at suitable places in all agricultural land, especially in paddy land which is the first priority of the local people for pre-flood stage. Similarly, raising the bottom of the floor of the house was also reported as another important and appropriate strategy (second preference) to save lives and properties. It is now common practice in the region to raise the base of homes and cattle sheds much higher than the ground level using stones and mud are used to make a foundation, above which thatched house and sheds are made. In the past, people used to have open wells for collecting drinking water. Recently, with the fear of water contamination, people replaced wells with hand pumps. However, water may still be contaminated in these systems. Therefore, very recently in order to prevent ground water from contamination, the height of the platforms of newly installed hand pumps has been raised above ground level. Within homes, safe storage of valuable items such as ornaments, cash, cloths, stove, jute sacks and utensils is also given higher priority. People usually collect and keep important documents and utensils in a safe place, wherever possible, either within the house or in the house of close neighbour/kin. They also have a supply of plastic sheets, tents, ropes, rubber tubes, empty drums, and torchlight for emergencies. These are all considered as pre-flooding adaptation strategies.

During the focus group discussion, some respondents mentioned additional adaptation strategies, such as raising beds (especially for highly vulnerable people such as children and elderly people); making bamboo baskets to keep poultry dry during the flood; and storing sufficient food materials (beaten rice, salt, sugar, noodles, dried fish and vegetables, potato chips and pulses) for the monsoon season. Moreover, locally available herbs and medicinal plants are widely used in the study area. Herbal tea/mint tea and herbal medicines are given to children and old people ones so that they can be protected from the effects of cold (Maraseni 2008). The uses of *Azadirachta indica*, also known as Neem tree, leaf for treating fever and skin disease are also common practices (Maraseni and Cockfield 2011, Dawadi *et al.* 2013). Furthermore, garlic and bojho (rhizome of *Acorus Calamus*) are widely used for treating people suffering from cough, flu and gastric problems. Therefore, as an adaptation strategy, local people ensure that these materials are available before a flood occurs. Use of locally available herbs as medicines shows their strong belief on these products for healthcare and storage of same shows pre-flood adaptation.

During flood adaptation strategies

Among the five potential during-flood adaptation strategies, local people gave "caring for children and elderly people" “taking valuable properties” and "releasing domesticated animals” as their first, second and third priorities, respectively. Children and elderly people are often the first victims during flooding mostly because of their innocence, inability to run fast and their health and physical vulnerabilities. People share and use rescue and relief materials such as rubber tubes and family fishing boats to rescue people. Likewise, taking valuable properties such as gold, silver and ancestral heirlooms goods are also important for them for obvious reasons. In addition, release of animals from sheds increases the chance of their survival by allowing them to swim. Saving animals is of the utmost important for their livelihood as they can receive ready cash by selling them and their products (meat and milk).

According to a District Forest Officer (DFO), the transport of affected communities to safer places is crucial during a flood and, therefore, an adaptation preparation plan should be made and rescue emergency services mobilised in such situations. During that time, schools are usually closed and youths are assigned to monitor the flood at night. A local politician added that flood hazard measurement devices and disaster rescue activities should be in place to reduce flood hazards. The integrated approach combining services from different levels and organisation effectively helps to reduce flood risk.

Post flood adaptation strategies

According to the respondents, after returning home after a flood they are socially, mentally and physically upset because they are worried about how to manage day to day life. Respondents ranked their preference for the four potential post-flood adaptation strategies (i.e., repairing of the house, managing food, making temporary shelter and repair hand pump for drinking water). The cumulative relative frequency (CRF) of these activities shows all of them are necessary to bring their lives back to normal conditions. However, based on the relative importance, repairing the house and managing food were ranked at first and second position. Both are basic requirements for human existence, but their relative priority depends upon the flood magnitude, the condition of houses and the physical set up. Some houses could be partially damaged and some others could be fully. The houses, whether partially or fully damaged, are built with materials like bamboo, rope, hay and wood. Bamboo and wood are collected from nearby forest, so in this case the role of community forest user group is crucial. People whose houses are totally damaged stay in their neighbours’ or relatives’ homes for some time. The primary task for them is to manage accommodation for children and elderly people. In addition, managing drinking water is equally important for the families (Gautam 2008). In most of the floods, hand pumps and traditional wells in many locations are completely defunct and people give priority to repairing them for obtaining drinking water.

b) Flood adaptation strategies at community level

The field study ascertained that managing flood through indigenous knowledge is an interesting feature in the study area. It was observed and reflected during the interaction with the local people that they have close affiliation with the flood and its nature. However, due to uncertain and erratic rainfall, people were found to be afraid of the risks posed by floods. The people of the West Rapti River Basin, who experience frequent flood events, have developed different flood management techniques at community level for pre-flood, during flood and post flood period; some of these are discussed below:

There is a common practice of communities gathering for discussions on flood adaptation strategies before the monsoon season. These community level strategies are designed for pre-flood, during-flood and post-flood situations. Pre-flood adaptation strategies were a) preparation of flood management plan; b) keeping the contact information for community people, c) pre-assessment of the flood risk and d) training people and making them prepared to evacuate people and properties during the flood. Usually, this plan is carefully developed with the lessons learned from previous flooding.

In Nepal, such practices of developing and implementing plans at the community level are common in many sectors. They may be either development related works such as community forest, community level road construction and irrigation channel for water supply (Adhikari *et al.* 2004; Kellert *et al*. 2000; Rahaman & Varis 2005) or disaster risk reduction activities such as community level flood management (Gautam 2007; Practical Action 2009). Involvement of community people in flood management is very important (Broekx *et al*. 2011; Evans *et al*. 2002; O‘Leary *et al.* 2006; Sharma & Shakya 2006) for several reasons: plans are practical and implementable; the process provides ownership of the plans to the local community; and it is most effective. Involvement of the local people from the beginning of the policy formulation to the implementation and feed-back stages is a sustainable solution for flood management (RECHAM 2011, Devkota *et al. 2014*). Moreover, keeping contract information of the local people at flood prone area is very important because it will be easier to organise evacuations during the flood and to manage resources for them.

Similarly, three identified adaptation strategies for during flooding were: i) developing communication mechanism; ii) managing food and logistics that include taking affected people to safe locations for shelter and providing them with meals and blankets; and iii) securing the health and hygiene of affected people. As the WAI of all options were greater than three, all proposed strategies were perceived as vital. However, developing communication mechanisms between upper and lower catchments seems more important than other two, as this communication provides important clues as to the scale and magnitude of potential rain and flooding. As a result, downstream people would get enough time to do the necessary preparation to avoid/minimise possible losses; for example, people have a fairly accurate idea that a danger level flood at Kusum station (upstream) will take six hours to reach at Holiya (downstream) station. Taking the status of the health and hygiene of the affected people and providing first aid treatment for injured people are also equally important for saving lives.

Use of mobile phones has become very popular in Nepal in recent years, although they were not introduced into the country until 2000. Currently, about two thirds (66%) of Nepal’s population is using mobile phones (NTA 2013) as a means of communication and information sharing, indicating an important means of communicating information for flood management (Filatova *et al*. 2011; Hansson *et al.* 2008; Plate 2002). This study found that people of the study area are fans of mobile phones, as they found mobiles a useful communication tool for flood related information.

Popular post flood adaptation strategies included exchanging help, the distribution of resources, co-ordination with government and other agencies and temporary settlements. Among them, exchanging help (such as labour, money, stored foods, clothes) from family to family and community to community was ranked the first strategy. It is a reflection of Nepalese culture which is cohesive in nature. People mainly live together in rural communities, performing religious activities together and lending food and money when necessary. Similarly, equitable distribution of the resources given by Red Cross and local governments was ranked in second position. Likewise, co-ordination with government and other agencies and preparation of temporary settlements were also considered important.

8.6.4 Flood adaptation strategies for probable climate change induced floods

This section discusses how local people in the study area deal with long-term climate change impacts and how their adaption strategies change with exposure to climate change scenarios. Flood adaptation strategies for the four climate induced flood scenarios were identified and ranked through the focus group discussions and respondents, respectively. Five adaptation strategies identified were: (1) Changing farming practices; (2) Land use management, (3) Household preparation/management; (4) Controlling flood level & food storage; and (5) Watershed management. During the household survey, flood information for different scenarios was provided and then these strategies were ranked for different flooding scenarios. A summary of changes in the preference of adaptation strategies with the exposure to different of flood scenarios are presented in Table 8.1.

Table 8.1: Changes in the preference of adaptation strategies with the exposure to different flood scenarios

Flood scenarios	Watershed management	Change farming practices	Land use management	Household level preparation /management	Controlling flood level & food storage
Scenario I	V (80.0)	III (81.0)	IV (80.9)	I (85.7)	II (81.9)
Scenario II	II (83.8)	IV (83.0)	V (82.4)	I (88.5)	III (83.3)
Scenario III	II(89)	V (81.0)	III (90.0)	I (88.6)	IV (86.2)
Scenario IV	I (89.5)	IV (86.8)	II (88.1)	III (87.6)	V (83.3)

It is worthwhile to mention here that “household level preparation/management”, the lowest level of flood adaptation strategy, is within a realm of a household member in terms of control and dimension. Controlling flood level and food storage around one's property is slightly higher in level, as it involves storing of food for the future (temporal domain) and controlling the flood level around the house and their own agricultural land (spatial domain) which are broader than the household level preparation. In terms of the horizon (temporal and spatial) and magnitude of strategies, change in farming practices and land use management are of even higher levels. The top among these strategies is watershed management which demands multi-sectoral management and multi-stakeholder involvement. When the whole catchment is managed with proper planning and appropriate techniques, the level of risk is decreased. It is the reason why it is considered as one of the best options among various strategies and appropriate in rural contexts (Brooks *et al.* 2012; De Groot *et al.* 2010; Marchi *et al.* 2010).

Peoples' choice of flood mitigation strategies mainly depends on the current needs of the people and their knowledge of harm. Current needs govern current choices while the basis of future choice is generally made on the degree of the impact or perceived risk of the hazard. This can be clearly seen from the ranking made by the people for Scenarios I and IV.

"Household level preparation /management" was ranked first for Scenario I while in Scenario IV "Watershed management" was ranked highest. "Watershed management" was felt to be an important strategy, as it was second ranked even in Scenarios II and III. People may have realised that the mounting flood risk is increasing with time and that such risk can be reduced only through catchment management. When the risk is considered as of low level, people try first to adapt to it at the personal and household level. However, when the risk level increases, people look for alternatives or higher levels of adaptation (Terpstra & Gutteling 2008; Yodmani & Center 2001). The perceptions of people in the study were found to be in agreement with these findings: as the flood risk increases from Scenario I to Scenario IV, the movement in choice of strategies changed accordingly.

Another interesting change in preferences was noticed for "controlling flood level and Food storage" strategy. This was the second preferred strategy for the flood Scenario I and gradually moved to lower part on the list of preferred strategies with progression through to Scenario IV. Decreasing preference for this strategy could be due to the loss of hope in this strategy's effectiveness as enough food cannot be safely kept in high flood conditions and controlling such a flood with small scale efforts is useless. Hence, government of Nepal should initiate food storage facilities in high flooding areas. The preference level for land use management also jumped in the latter flood scenarios (Scenarios III and IV). The basis of the choice is similar to that presented in the above paragraph.

It could be argued, from the above discussion, that when people have more information, they will do long term planning and formulate long term strategies. This indicates the value of providing information on the potential risks associated with climate change induced flood using various scenarios to help people choose appropriate adaptation strategies (Jones & Boyd 2011; Manandhar *et al.* 2011).

8.6.5. Structural flood management adaptation strategies for four climate change induced flood scenarios

In the previous section, a discussion was presented on non-structural flood adaptation strategies based on the rankings for four different climate induced flood scenarios. In this section, the same procedure was followed for structural flood adaptation measures.

Table 8.2 shows the overall summary of preferences for structural flood adaptation strategies. All potential structural measures i.e. "bio-engineering", "embankment/river training", "bamboo mesh with sand filled bags", "gabion wall spurs" and "reservoir/flood regulating structure" (Table 8.2) received a score over 80%, showing people's acceptance of a range strategies for flood protection. However, preferences for these measures changed with exposure to the four flood scenarios.

Table 8.2: Changes in the preference of structural adaptation strategies with the exposure of different level of floods

Flood scenarios	Bio-engineering	Embankment/river training	Bamboo mesh with sand filled bags	Gabion wall /Spurs	Reservoir/flood regulating structure
Scenario I	V (65.8)	IV (82.9)	I (90.5)	III (86.7)	II (88.6)
Scenario II	III (86.2)	II (90.5)	I (93.6)	IV (85.7)	V (64.2)
Scenario III	V (80.0)	II (93.8)	III (91.9)	IV (88.6)	I (96.7)
Scenario IV	IV (91.9)	II (94.8)	III (94.3)	V (90.5)	I (97.7)

River embankments of sufficient height and storage reservoirs of adequate capacity can contain the flood waters within the river. Since these structures protect the adjoining land mass where people are farming and have their settlements, they are considered major and reliable flood control structures. Among other structures, "gabion wall /spurs" are considered another effective structure. However, these require stones of sufficient quantity. Other measures can save adjoining lands from small floods.

Table 8.2 shows that the preference for "bamboo mesh with sand filled bags" becomes less attractive with the severity of flood. This finding is in line with Ahmad & Simonovic (2000), Plate (2002) and Smith (2013) who also reported that people felt safe from high flood problems if they can have strong structures like embankments and reservoirs. There is evidence that such large engineering structures are becoming a preferred option by many for future flood adaptation strategies. "Construction of gabion wall/spurs" and "bamboo mesh with sand filling bags" are also effective in minimizing the effects of floods, soil erosion and river bank cuttings. However, both are temporary in nature and need regular maintenance. In addition, stone is not available in the lower part of this river basin (Rajbhandari *et al.* 2011), therefore "gabion wall/spurs" strategies is not a preferred option for local people. Similarly, embankment protection with bio-fencing/river training is widely practiced in many river basins. There are two main reasons for applying this method. First, the roots of trees hold the soil and reduce the velocity of water flow in hilly regions. Second, people mainly use medicinal/multipurpose (Maraseni 2012) plants for bio-fencing (Fonzen & Oberholzer 1985; Neupane & Thapa 2001) such as *Jatrophacurcas, Azadirachtaindica*, *Sapium insigne*, *Vitex negundo* and fodder plants like *Artocarpus lakoocha*, *Fleminigia congesta*, *Bauhinia variegata* and *Bauhinia purpurea* for bio-fencing; hence, such plantings serve multiple purposes.

8.7 Conclusion

Socio-hydrological analysis as adopted in this study has already been used to explore the co-evolution of human-water systems (Sivapalan *et al.* 2011 and Kandasamy *et al.* 2013). The findings on climate change trends, flood zoning and hazard mapping based on the flood return period and vulnerability assessment were discussed. Similarly, the level of WTP for flood mitigation by age, gender, education level were discussed and whether there is any statistically significant relationships between WTPs and crop income, livestock income and flood damage costs was examined. These discussions are made for three flood zones and four climatic scenarios. Furthermore, discussion on indigenous knowledge on flood forecasting, early warning system and various dimensions of flood impacts on household and community level were made. Why people preferred certain types of structural and non-structural flood adaptation strategies than others was discussed.

More importantly, how and why people change their preferred adaptation strategies with the exposure of potential future flood scenarios was examined. However, in this process, they often felt that they were left alone, and were not getting adequate support from the government public or private sectors. Even a small level of support, such as information on rainfall patterns and flood scenarios, could help them enormously in flood planning and management, and the selection of suitable crops and their cultivation and harvesting times.

From observing current flood management plans and adaptation strategies, it can be said that the integration of indigenous, technical and local knowledge will be extremely useful for reducing flood risks. Indigenous people have knowledge about the history and nature of floods in their local landscape through observations and experiences of floods, close ties with their environment for survival, and an accumulated understanding of their environment through generations. This knowledge is transferred from mouth to mouth and from generation to generation. This is important because past experiences and understandings about floods will help them to figure out the present and cope with the future.

Similarly, technical knowhow is very important for structural measures of flood control, such as river regulation and reservoirs in the upper catchment and erecting retaining walls (levees) along the riverbank. Moreover, technical knowledge is equally important for scientific validation of indigenous and local knowledge and practices.

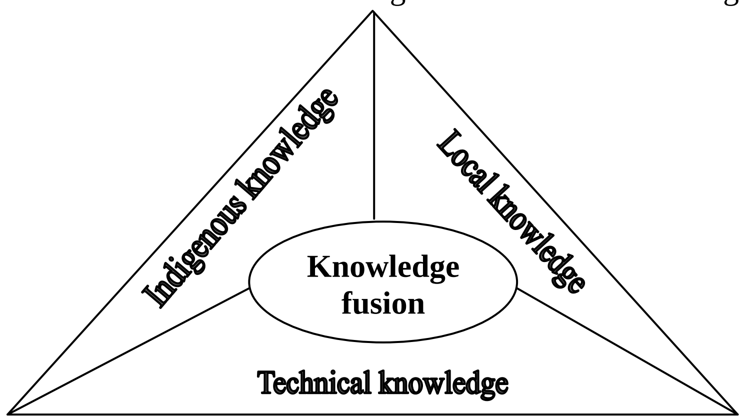

Figure 8.1: Fusion of indigenous, local and technical knowledge, an ideal way of flood management

On the other hand, local knowledge is evolved from learning by doing approach. Mainly, local knowledge is evolved from the fusion of knowledge and practices from migrant and indigenous communities (Figure 8.1). Migrant communities may have less knowledge about the local area than the community who has already been settled for a long time. However, such people may have had similar experiences in other parts of the country which might have been tackled through new and innovative ways.

Indigenous and local people always prefer to use locally available resources for flood control and as a result they are truly sustainable. Scientific validation of these measures through technical inputs would make them scientifically robust, socially acceptable, economically feasible and environmentally friendly. Therefore, the fusion of these three knowledge is critical for flood adaptation in this century.

Chapter 9: Summary, Conclusions and Recommendations

9.1 Introduction

The previous chapters of this dissertation present background information, a critical review of the literature, a description of the research site, methodological approach, findings and discussions for this research. This chapter presents a summary and conclusions of the thesis, and then puts forward some policy implications, research contributions and further research issues.

This research identified some common and site-specific research issues with reference to climate change induced flood adaptation strategies by integrating three components: i) a technical component: application of a hydraulic modelling technique to assess flood hazard and prepare a flood hazard map; ii) Economic component: willingness to pay for flood mitigation; and iii) Social component: flood adaptation strategies.

This research has implications on several theories related to flood assessment, willingness to pay, vulnerability, and climate change adaptation. In the technical part, flood magnitude of various return periods was estimated, and flood hazard maps were prepared based on flood zoning. In the economic part, the willingness to pay by people for different flood scenarios and from different zones was assessed. This provides a basis for the appraisal of policy options, allocation of resources and monitoring performance of substantial government investment around flood issues. Adaptation strategies revolved around the climate change induced flood dynamisms and their potential impacts in the West Rapti River Basin. Some possible adaptive responses and the preferences of local people in response to those floods were evaluated.

This research has attempted to link a local problem (flood problem of the study area) with national policy on disaster management (policy recommendations). It also showed that adaptation strategies are dynamic in nature and that willingness to pay for flood adaptation measures varies temporally and spatially; i.e. strategies change over time with exposure to climate change information (in this case, future flood scenarios) and are different in different flood prone zones. This research provides an overall framework for deriving potential flood adaptation strategies resulting from climate change for the West Rapti River Basin of Nepal in particular; this framework provides a basis for devising adaptation strategies under climate change conditions for developing countries in general.

9.2 Summary and Conclusions

The purpose of this integrated research was to (a) analyse time series hydro-climatic data; (b) perform flood hazard zoning and develop hazard maps of the study area; (c) assess the vulnerability of communities in the Basin; (d) determine the level of WTP of local people for flood mitigation; and (e) analyse potential adaptation strategies under climate change. All results and discussion (Chapters V to VIII) are linked to these objectives and nested within each other and relevant conclusions were drawn in this chapter. This section presents a summary of some of the major findings and conclusions.

Climate change: trends and people's perception:
Analysis of temperature and rainfall data of meteorological stations lying within the West Rapti River Basin, as well as peoples' perceptions, confirms that both maximum and minimum temperature have increased over recent decades at a rate of 0.039ºC and 0.42ºC, respectively, while the rainfall patterns have become more erratic. Moreover, average temperatures have increased at a faster rate in the West Rapti River Basin than in other parts of Nepal or globally overall. Average precipitation has increased annually by 0.88 mm, while the trend in monsoon and post-monsoon seasons showed an annual increase of 1.08 and 1.68 mm, respectively. Changes in precipitation change the flow of the river. As the erratic nature of precipitation events are very likely to increase with climate change the probability of high flood events are likely to increase in the future. This in turn will amplify flood risks. Majority of the respondents (86.4%) agreed that the monsoon season has been pushed further and post-monsoon rainfall has increased; this was supported by observed rainfall data. Local people have perceived the late onset of monsoon with a delay in the planting and harvesting season by a month which has impact on cropping time and phenology, which in turn affects rotation practices. This changing phenomenon necessitates climatologists and meteorologists to redefine the monsoon season in Nepal. Similarly, people believed that rainfall intensity and magnitude had increased to a greater extent in the monsoon and post-monsoon seasons than in the pre-monsoon season and that this may increase the incidence of extreme events like floods in this river basin. Therefore, traditional way of flood management may be insufficient.

It is very difficult to identify specific causes of climate change induced flood risk but these events are likely to be the results of climate factors. The actual trend shown by the recorded data and the perceptions of the local people are in good agreement with each other, which has increased the reliability of the findings. The implications of this finding is mainly on climate change policy, and the implementation modalities of the National adaptation programme of action and Local adaptation programme of action in Nepal.

Flood zoning and hazard mapping:
Flood is common during the monsoon season in the study area. People strongly believe that climate change is inducing high intensity rainfall within shorter periods, subsequently creating increased flood problem in this basin. Similarly, over grazing, slash and burn practices in the upper catchments, continuous forest depletion, construction of infrastructure without assessing the monsoon flood and narrow drainage capacity of the torrents are major causes of flooding at local levels. The devastating floods and incessant rains in this basin cause extensive damage to standing crops, physical and social infrastructure, environment, people's lives and livelihood and weaken the capacity of rural poor. The analysis provided herein showed that combining scientific facts and figures with local people's opinions would provide a basis for more reliable and relevant investigations of climate change induced flood risk.

The flood assessment and hazard zoning methods has theoretical contributions for theories of hydrological analysis and hazard risk assessments. Hazard maps depict the area under different levels of danger posed by floods in the study area. Based on the depth of flooding and frequency of occurrence, hazard maps were developed for the study area, dividing the area into critically, moderately and less hazardous zones; these zones were found to be in good agreement with people's perception. The results of hydrological modelling revealed that about 60.8 km^2 of the study area falls into a critical flood hazardous zone while 63.35 km^2 and 58.05 km^2 is in the moderately and less hazardous zones, respectively. The analysis showed that the greater flood problem existed in locations where the relative elevation of the area is low and close to the river. The flood hazard was found to be more detrimental for settlements and agricultural land. In the delineated flooded areas, higher flood depths were marked in Holya, Ganagapur and Matehiya Village Development Committees, especially during high magnitude floods. The findings reveal the need for a holistic analysis relating flood risk to the socio-economic condition of the people residing in that area. Short term and long term flood risk analysis is crucial for the management of flood risk which varies with both topographic and socio-economic conditions.

Vulnerability assessment:

The additional theoretical implication of this research is for theories related to vulnerability, impacts and adaptation to climate change. They were useful to enhance understanding on differential vulnerabilities, impacts and adaptations to climate change. Vulnerability assessment and mapping of flood hazards are prerequisites for flood risk management. Use of both scientific knowledge and the experiences and perceptions of the local people in vulnerability assessments helps to formulate effective adaptation strategies. About 80% of the respondents perceived that the main cause of vulnerability to them was the recurrent flooding. “Frequency of flood” received the highest score while more than 60% of the people perceived “damage to agricultural land”, “river bank cutting”, “damage to structures”, “houses close to the river”, “transportation facility” and “settlements near the rivers” are the other main indicators of flood vulnerability for local people in the West Rapti River Basin. These findings can be useful for making effective flood management strategies, policies and plans.

This research also provides a basic research framework for preliminary flood vulnerability assessments which can be applied in several other catchments in Nepal and abroad that have similar socioeconomic, topographic, edaphic and climatic conditions. In addition, a number of institutions, ranging from governmental to non-governmental organisations and even the private sector are involved in flood risk management in the study area. However, there is a lack of coordination amongst these organizations. Coordination among such organisations could make flood hazard management within the Basin more effective. Therefore, integrating diversified technological options, including skills development and awareness and capacity building in flood affected communities, into mainstream development practices can reduce disaster risk and vulnerability.

Willingness to pay (WTP) for flood mitigation:

Socio-economic factors such as age, gender, education, income level and flood damage cost influences the level of WTP for flood mitigation. The average annual WTP of: (1) the 35–44 years age group was higher than that of other age groups; (2) women were found to be more willing to pay than males; and (3) literate people were found to be more willing to pay than illiterate people. Similarly, income levels and the extent of flood damage costs influenced WTP at various flood scenarios. The WTP of the people from the critical flood prone zone was found to be higher than that of the people from the moderately flood prone zone and low flood prone zone in all scenarios. Similarly, as expected, the average WTP of respondents increased from Scenario I to Scenario IV. The average annual WTPs were significantly positively correlated with annual farm income, livestock income and flood-related damage costs.

This finding provides a rational basis for the appraisal of policy options and resources allocation. This finding supports moves to promote public-private partnerships for reducing flood risks. Similarly, this assessment is likely to be one of the several sources of evidence that decision makers may employ while making difficult and often highly contested long term planning and flood risk management decisions. Moreover, this empirical study could be a model study for other similar catchments and developing countries.

Flood adaptation strategies:

As a pre-flood adaptation strategy, the “constructing drain” to divert the flood water around the house and other properties like tube wells, cow sheds or even agricultural plots was ranked first. Whereas the "caring for children and elderly people", and the “repairing the house” were ranked as first preference of the during and post-flood adaptation strategies, respectively. At household level, people have developed several strategies in response to changed environmental conditions over time. Similarly, community people gather and prepare flood adaptation strategies such as “developing and refining management plan”, “updating contact information”, and “pre-estimating flood risk” prior to the monsoon season. These strategies were prioritised mostly based on traditional and indigenous knowledge, skills and experiences. The impacts of climate change induced floods are likely to increase in the future. However, there is still some uncertainty about this. This fact challenges the adaptation capacities of local communities. Due to the very limited knowledge of climate change, flood impacts and flood adaptation strategies, the people’s perception for selecting adaptation measures differed, focusing on short-term impacts and may have been reactive in some cases. The overall findings of this research depicted the importance of the identification and assessment of locally-relevant flood adaptation strategies. It is expected that these findings can help governments to choose adaptation strategies to mitigate the flood risks that are both effective and preferred by local people in vulnerable areas.

Similarly, preferences for probable climate change induced flood adaptation strategies at different exposure levels were ranked from scenarios I to IV. “Household level preparation / management” was ranked first in scenarios I to III whereas in Scenario IV, the first preference moved to “watershed management”. Similarly, preferences for structural flood adaptation strategies were also ranked differently for different flood scenarios. The “bamboo mesh with sand filled bags” was the most preferred adaptation strategy for scenario I whereas “embankment/river training” obtained the highest value as the most preferred adaptation strategy for scenario IV. This indicates that people had realized that the flood risks are likely to increase under climate change and that such risk can be reduced only through higher level adaptation strategies. It was found that the perceptions of flood adaptation strategies changed with different flood scenarios (i.e. flood information). The more preferred strategies for flood adaptation today become less attractive when people realize that the flood problems are likely to become more severe in the future. Major engineering structures such as embankments and flood controlling reservoirs rate more highly as preferred choices when people realise the need to deal with high flooding problems. Therefore, the value of climate change and flood information is very high. This information led people to choose more appropriate adaptation strategies to avoid catastrophic flood events.

In recent years, climate change adaptation and environmental policies have been increasingly focused on water resources and agricultural sectors in Nepal. The Government of Nepal has not given priority for climate change induced flood adaptation policies and strategies. Therefore, there is a big gap between policy development and implementation and institutional responsibilities from the bottom to top levels of government. There is also a lack of clarity in defining the scale of vulnerability and flood adaptation planning. Moreover, climate change policies do not currently provide for flood adaptation strategies. The traditional mindset of government officers and a lack of well-defined authority to deal with flooding are causes of poor policy implementation in Nepal. There is a need for a holistic and more coordinated system for flood management not only in this West Rapti River Basin but also for other river basins in Nepal.

9.3 Research Contribution

9.3.1 Contribution to literature/methodology

The assessment of social perceptions backed by technical results lie at the centre of the methodology for this research. Integration of scientific technique with the socio-economic conditions of the people to assess adaptation strategies under climate change is a major contribution in terms of methodology. The method used in this study to quantify the qualitative data can be considered as a useful addition to the scientific literature.

There are a number of analyses on the general trend of rainfall and temperature at the global scale while detailed studies focusing on particular areas can also be found, although mainly in the developed world. Studies on the scale of climate change and its consequences is normally lacking in developing countries like Nepal. The meteorological data analysis in this study was carried out with sufficient level of detail to enable the identification of multi-decadal trends in a range of climatic variables in the Rapti River Basin. Assessment of the flood hazard through hydraulic modelling and incorporating people's perceptions on flooding and its induced hazard has capacity to advance scientific knowledge in this area. Moreover, very limited research was found in the literature regarding the integration of both the natural phenomenon of climate (e.g. rainfall patterns under climate change), and people’s perceptions. The combination of robust physical data with peoples' perceptions could be of interest and use to the scientific community, especially in Nepal and globally too.

The application of WTP in terms of man-days or labour-days is rare in the developing world and is novel to this region. This is very useful for developing countries that is something they can contribute easily (culturally acceptable too), where a man-day is very easy to explain and commonly understood. Therefore, the introduction of man-day or labour-day in WTP research is a novel and applicable methodological approach. The average WTP of respondents was greater in the critical flood prone zone than in moderate and less flood prone zone. This applied equally for all flood scenarios. This research has further explored and enriched the understanding of differential impacts of climate change in relation to flood hazard zones and underlying socio-economic causes of vulnerabilities. This finding informs the fair allocation of resources.

As this research is a fusion of scientific and socio-economic knowledge, it supports decision makers in formulating policies and climate change adaptation strategies. The research has implications for well-established concepts related to climate change induced flood vulnerability and adaptation. Moreover, the framework and method used in this research is expected to be applicable for local communities globally, and can be replicated in other river basin elsewhere in the world.

The research revealed that impacts of flooding and flood induced vulnerability on people are complicated. It is difficult to separate the effect of climatic and non-climatic factors. However, climate change imposes additional risks and uncertainties to households and communities. One of the major contributions of this research is to enhance understanding of the local level evidence and people's experiences on climate change induced flooding, its impacts and adaptation strategies. This research is undertaken at catchment level; however, the methodological approach is relevant for small, medium and large catchments.

9.3.2 Contribution to policy and practices

The analysis of rainfall showed a delay in the onset and end of rainy days associated with the monsoon season. This was validated both by recorded data as well as people's opinions. The finding of this research challenges the existing definition of the monsoon season. These research findings suggest that policy level discussion is required for re-defining the monsoon seasons.

Hydrological modelling of the West Rapti River provides information on the level of flood hazard in the Basin. This study has classified the flood prone areas into critical, moderate and less hazardous zones from the flood impact point of view, based on flood frequencies and depth of inundation. This assessment provides decision makers with an evidence base for the appraisal of policy options, allocation of resources and monitoring performance of substantial government investments in flood management.

The government of Nepal is working on disaster management policies and strategies at both local and national levels. Their main thrusts are to make the public (community) aware about natural disasters and to bring them into the management process. It is believed that the output of this research will help policy makers to integrate the community participation aspect into their flood risk management policy development, planning and implementation. More importantly, this may provide policy feedback to enable review of existing flood adaptation practices and implications for different levels of stakeholders.

The findings of the vulnerability analysis provide a basis for designing effective flood adaptation strategies. Moreover, there may be ancillary benefits that may arise from decreasing vulnerability. This study helps empower local government institutions and local people in flood management.

Climate change policy in Nepal is targeted to address the impacts of climate disasters; however, there is currently a lack of an applicable framework and practical understanding. The climate change policy and institutional frameworks in Nepal are lacking the pre-flood, during flood and post flood adaptation strategies. This research identified and ranked flood adaptation strategies; the findings of the research support the development of clear policy, provisions and strategies for rural people.

Moreover, the outcome of this research in terms of the preferences for particular flood adaptation strategies for various scenarios helps policy makers to review alternative flood adaptation strategy options. This research indicates the needs to transfer climate change induced flood information to indigenous and local communities to aid in capacity building and enrich the existing knowledge base of the people. This is an additional contribution of this study.

This research depicted that after receiving the full information on the level of severity of the future flood problems, respondents shifted their strategies, from a relatively low level of adaptation to higher. In the context of climate change and its dynamic nature, this result helps government to choose appropriate adaptation strategies among many alternatives for managing upcoming flooding. A multiple-purpose reservoir upstream that can store the excessive water in monsoon helps to reduce flood and collected water can be used for other purpose during dry season.

The variation of average WTP of respondents in different flood prone zones and scenarios indicate different levels of perceived severity. This may have big policy implications for the design of participatory flood management plans in the river basin. People’s participation, based on perceived impacts and WTP, increases the sense of ownership over flood management programs and practices, making such plan more socially acceptable and thereby economically viable.

9.4 Recommendations for Further Research

From the overall findings and discussion, the following recommendations for further studies are proposed.

i) Using downscaled climate data from different climate models and scenarios, hydrologic simulations to assess floods of different return periods into the future should be carried out. Two dimensional unsteady flood modelling is to be done to capture the two dimensional nature of flooding to assess inundation levels in the Basin.

ii) The research suggests the need to examine local level opportunities to generate resources for climate change adaptation. Further research should be carried out to identify appropriate flood tolerant crops and their cultivation and harvesting methods.

iii) This research considered the WTP for flood mitigation of the local people for different flood scenarios. Further research is needed to determine how much investment would be required to achieve proposed flood mitigation under different flood scenarios, and whether the total funds the people are willing to pay is enough to cover these costs. Similarly, detailed cost-benefit analysis for different flood mitigation or management options would guide policy makers in identifying appropriate options and help seek funds to implement the same.

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Appendix A
Existing flood warning system

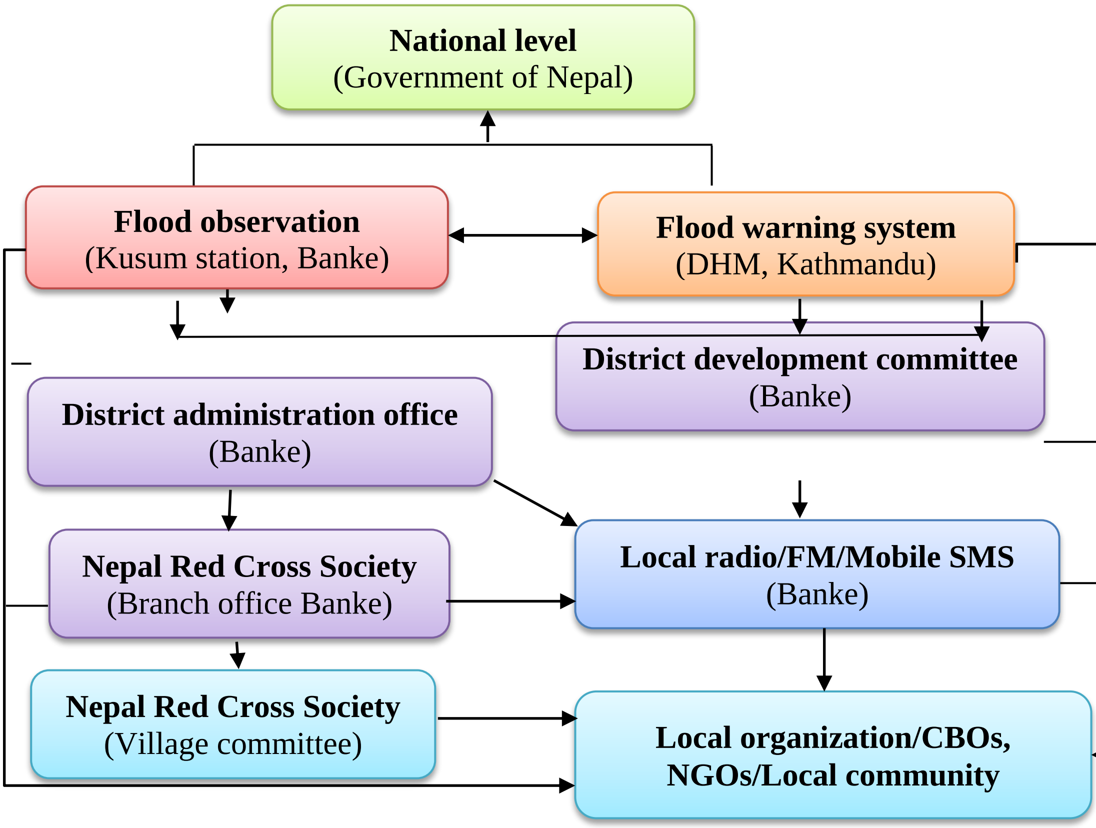

Figure A.1: Existing early warning system at West Rapti River

Appendix B

Table B.1: Key informants and representative organization

Level of informants	Key informants	Organization
District Level	Local Development Officer	District Development Committee, Banke
	Social Development Officer	District Development Committee, Banke
	Associate Forest Officer	District Forest Office, Dang
	District Forest Officer	District Forest Office, Dang
	Executive Director	Bheri Environmental Excellence Group (BEE-Group), Local NGO, Banke
	District Incharge	Unified CPM (Maoist), Banke
	District Secretary	CPN, UML, Banke
	District Secretary	Nepali Congress, Banke
National level	Minister	Ministry of Science, Technology and Environment (MOEST), Government of Nepal
	Advisor	MOEST, Government of Nepal
	Joint-Secretary and Head	Climate Change, MOEST Government of Nepal
	Senior Divisional Engineer	Department of Water Induced Hazard Control, Ministry of Local Development, Government of Nepal
Cross cutting planning/policy level	Joint Secretary	National Planning Commission, Government of Nepal
	Member	National Planning Commission, Government of Nepal
	Vice chairman	National Planning Commission, Government of Nepal
Academician	Scientist/Expert	National Academy of Science and Technology, Nepal
	Professor	Tribhuvan University
	Expert/Researcher	Tribhuvan University

Appendix C

Table C.1: VDCs, populations and household distribution in the Dang district

SN	VDC	Total				Ethnic Groups
		HHs	**Pop^n**	**Male**	**Female**	
1	Lalmatiya	4,475	21,389	10,236	11,153	Tharu, Brahmin, Chhetri, Magar, Gupta, Dalit & Muslim
2	Sishaniya	3,259	17,670	8,448	9,222	Tharu, Brahmin, Chhetri, Magar, Dalit and others
3	Sonpur	2,640	13,589	6,571	7,018	Tharu, Brahmin, Chhetri, Magar, Dalit and others
4	Chailahi	4,291	20,696	9,874	10,822	Tharu, Brahmin, Chhetri, Magar, Dalit and Muslim
5	Satbariya	2,501	13,370	6,453	6,917	Tharu, Brahmin, Chhetri, Magar, Yadav and Dalit
6	Gangaparaspur	2,031	10,972	5,366	5,606	Tharu, Chhetri, Brahmin, Dalit and
7	Bela	2,055	11,245	5,409	5,836	Tharu, Yadav, Chhetri, Brahmin, Gurung, Magar, Dalit and Muslim
8	Rajpur	2,418	13,792	6,842	6,950	Tharu, Yadav, Chhetri, Brahmin, Gurung, Magar & others

Table C.2: VDCs, populations and household distribution in the Banke district

SN	VDC	Total				Ethnic Groups
		HHs	**Pop^n**	**M**	**F**	
1	Bethahani	1,456	8,141	4,310	3,831	Yadav,Muslim, Dalit and others
2	Gangapur	1,030	5,805	2,999	2,806	Yadav,Muslim, Dalit and others
3	Holiya	1,115	6,290	3,315	2,975	yadav,Muslim, Dalit and others
4	Kamdi	1,841	9,853	4,788	5,065	Tharu, Dalit , Yadav, Muslim and others
5	Kanchanapur	1,703	8,858	4,240	4,618	Tharu, Brahmin, Chhetri, Magar, Yadav and Dalit and others
7	Matahiya	1,400	7,740	4,073	3,667	Tharu, Dalit, Yadav, Muslim and others
8	Phatepur	2,839	16,967	8,288	8,679	Tharu, Dalit, Yadav, Muslim and others

Appendix D

Trend of summer and winter mean maximum and minimum temperature

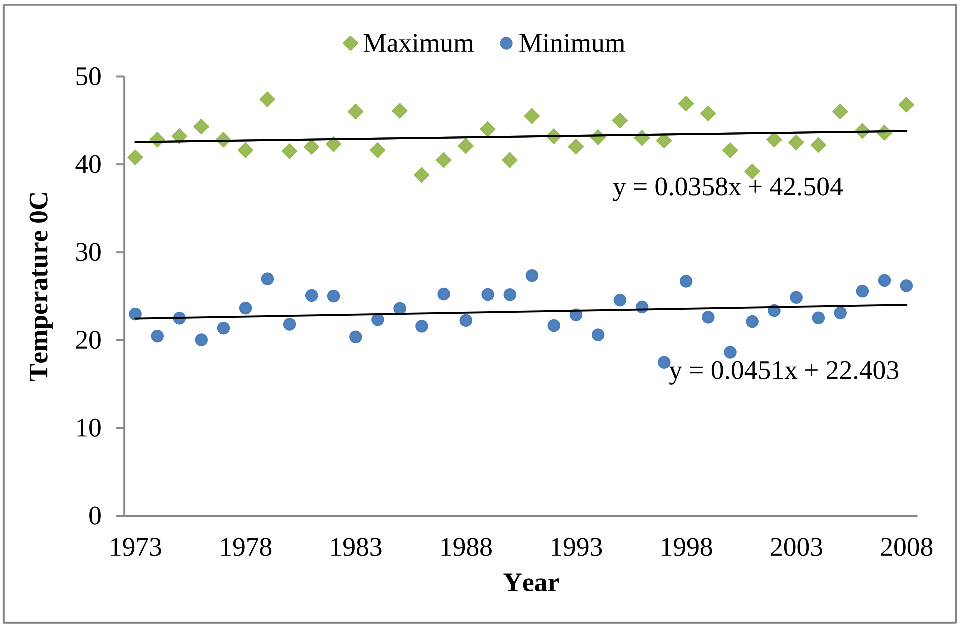

Figure D.1: Trend of summer mean maximum and minimum temperature

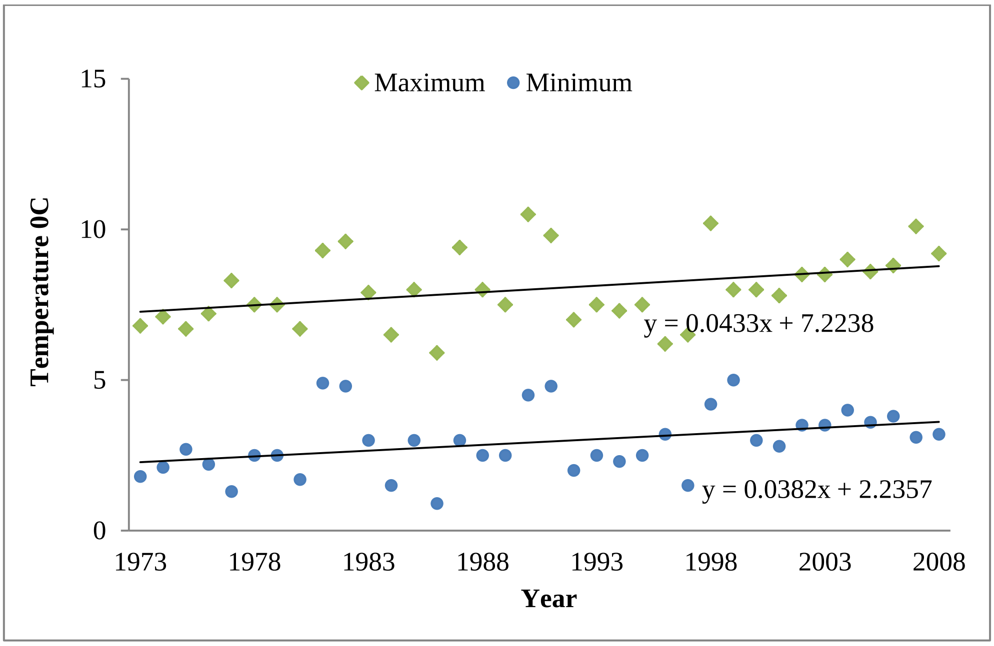

Figure D.2.: Trend of winter mean maximum and minimum temperature

Appendix E

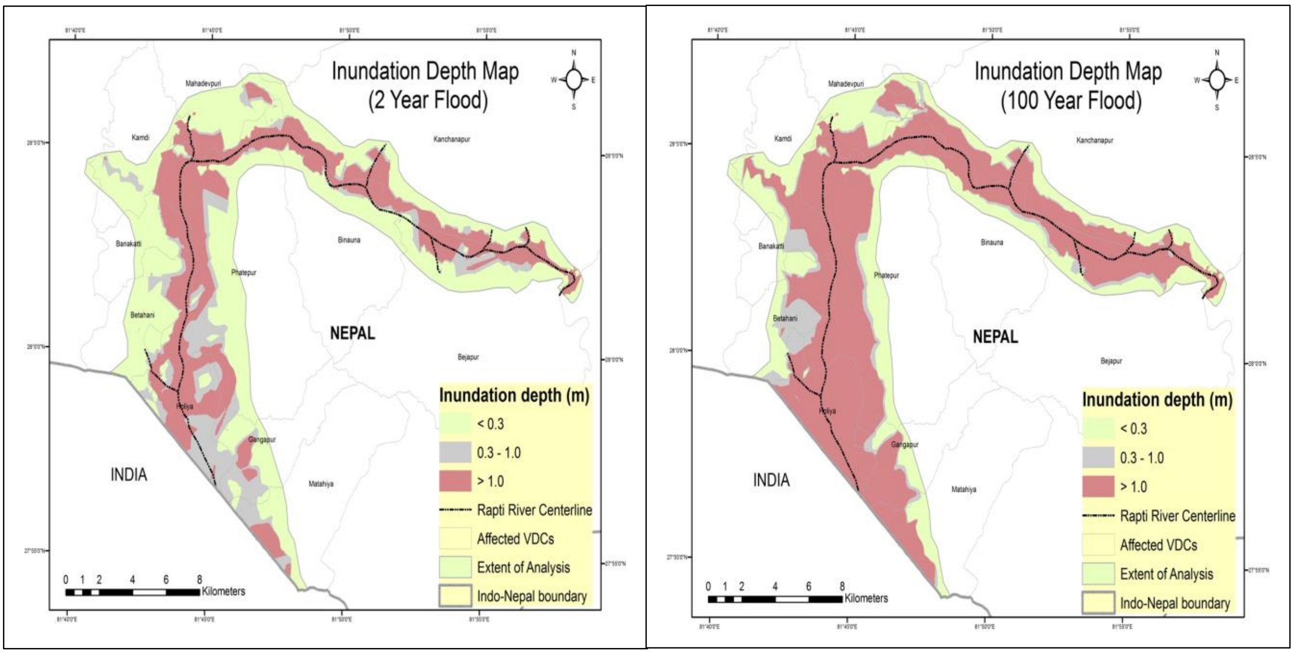

Figure E1: Estimated flood inundation depth of current scenario (Scenario I)

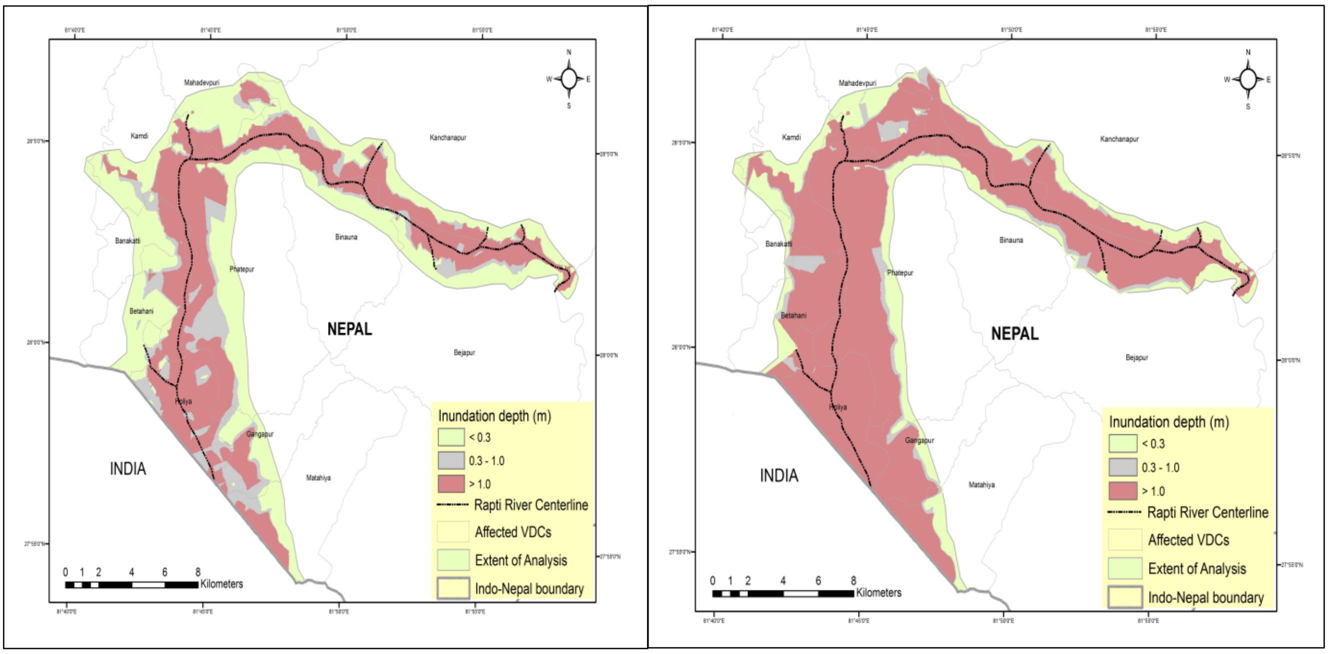

Figure E2: Estimated flood inundation depth of 2030 scenario (Scenario II)

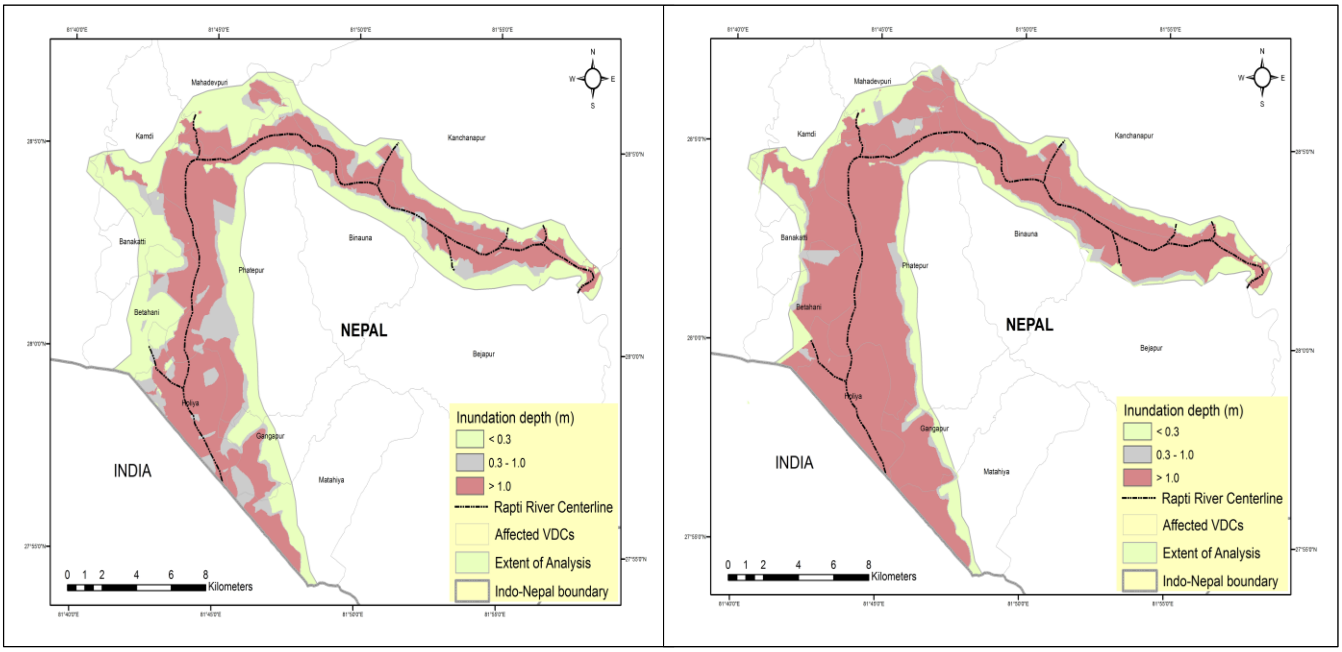

Figure E3: Estimated flood inundation depth of 2070 scenario (Scenario III)

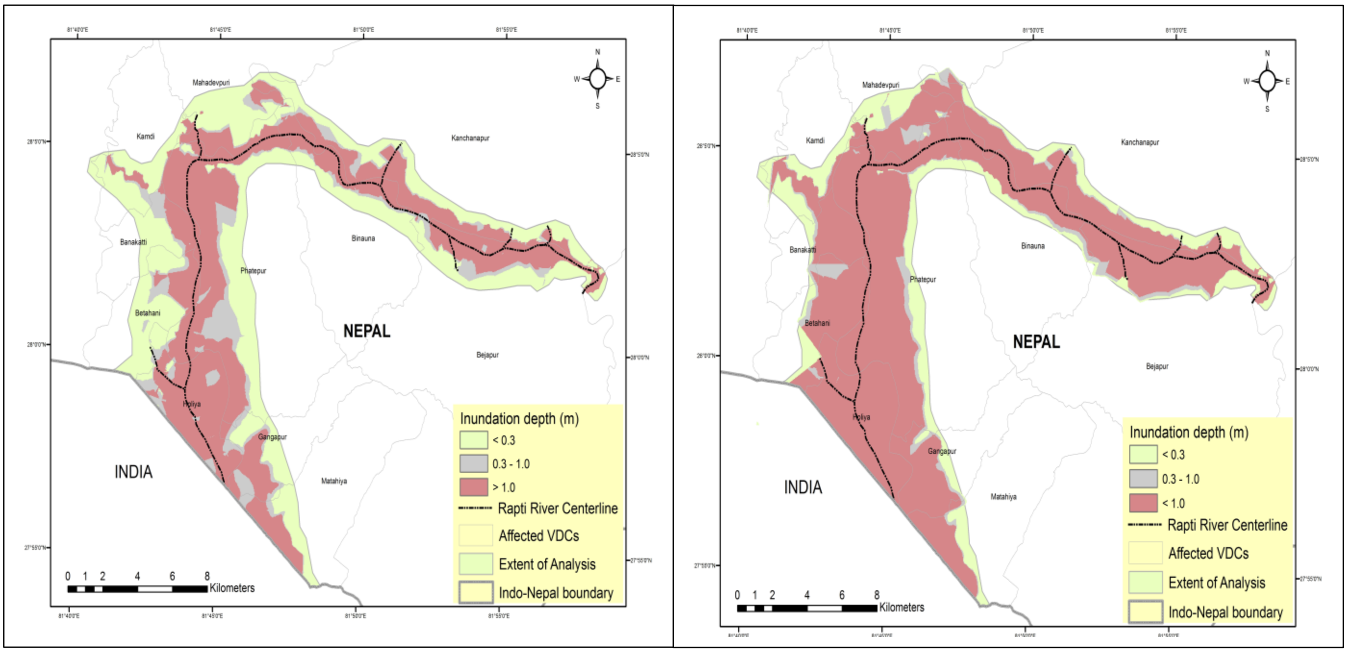

Figure E4: Estimated flood inundation depth of 2100 scenario (Scenario IV)

Appendix F

Table F1: Hazardous areas of flood affected VDCs based on flood hazard mapping for current scenarios.

Flood Affected VDCs	Total VDC Area (km^2)	Hazardous Area (km^2)						Total Hazardous Area (km^2)
		Critical	% of Total VDC Area	Moderate	% of Total VDC Area	Less	% of Total VDC Area	
Mahadevpuri	190.5	2.9	1.5	2.5	1.3	6.6	3.5	12.0
Kanchanapur	259	7.9	3.1	6.3	2.4	10.5	4.1	24.7
Kamdi	24.5	0.4	1.6	2.2	9.0	6.4	26.1	9.0
Binauna	42.7	4.9	11.5	4.2	9.8	4.6	10.8	13.7
Phatepur	79.2	21.3	26.9	13	16.4	11.7	14.8	46.0
Banakatti	13.3	2.4	18.0	3.7	27.8	1.8	13.5	7.9
Bejapur	108.5	6.6	6.1	7.0	6.5	5.1	4.7	18.7
Betahani	19.0	2.4	12.6	6.9	36.3	5.1	26.8	14.4
Holiya*	17.5	8.7	49.7	8.8	50.0	0.1	0.3	17.5
Gangapur	19.3	1.4	7.3	5.9	30.6	2.9	15.0	10.2
Matahiya	36.2	1.9	5.2	2.9	8.0	3.3	9.1	8.1
Total	**809.7**	**60.8**		**63.4**		**58.1**		**182.2**

Table F2: Hazardous areas of flood affected VDCs based on flood hazard mapping for 2030

Flood Affected VDCs	Total VDC Area (km^2)	Hazardous Area (km^2)						Total Hazardous Area (km^2)
		Critical	% of Total VDC Area	Moderate	% of Total VDC Area	Less	% of Total VDC Area	
Mahadevpuri	190.5	3.4	1.8	4.24	2.2	1.1	0.6	8.74
Kanchanapur	259.0	11.8	4.5	18.67	7.2	1.35	0.5	31.82
Kamdi	24.5	0.93	3.8	5.04	20.6	0.6	2.4	6.57
Binauna	42.7	4.05	9. 5	10.54	24.7	0.48	1.1	15.07
Phatepur	79.2	26.35	33.3	39.37	49.7	1.17	1.5	66.89
Banakatti	13.3	2.3	17. 3	7.89	59.3	0.3	2.3	10.49
Bejapur	108.5	6.8	6.3	3.3	3.0	1.7	1.6	11.8
Betahani	19.0	2.6	13.7	14.48	76.2	0.2	1.1	17.28
Holiya	17.5	12.45	71.1	4.95	28.3	0.1	0. 6	17.5
Gangapur	19.3	3.9	20.2	13.3	68.9	0.3	1.5	17.5
Matahiya	36.2	3.12	8.6	6.46	17.8	0.26	0.7	9.84
Total	**809.7**	**77.7**		**128.24**		**7.56**		**213.5**

Table F3: Hazardous areas of flood affected VDCs based on flood hazard mapping for 2070

Flood Affected VDCs	Total VDC Area (km^2)	Hazardous Area (km^2)						Total Hazardous Area (km^2)
		Critical	% of Total VDC Area	Moderate	% of Total VDC Area	Less	% of Total VDC Area	
Mahadevpuri	190.5	3.72	1.9	5.32	2.8	1.13	0.6	10.17
Kanchanapur	259	12.3	4.7	18.73	7.2	0.8	0.3	31.83
Kamdi	24.5	1.69	6.9	4.63	18.8	0.76	3.1	7.08
Binauna	42.7	4.53	10.6	10.59	24.8	0.53	1.2	15.65
Phatepur	79.2	26.95	34.0	39.69	50.1	1.3	1.6	67.94
Banakatti	13.3	2.24	16.8	8.07	60.6	0.41	3.1	10.72
Bejapur	108.5	6.9	6.3	3.6	3.3	2.1	1.9	12.6
Betahani	19.0	2.78	14.6	14.78	77.8	0.21	1.1	17.77
Holiya	17.5	13.88	79.3	3.52	20.1	0.1	0.6	17.5
Gangapur	19.3	4.6	23.8	15.17	78.6	0.31	1.6	20.08
Matahiya	36.2	3.18	8.8	6.58	18.2	0.3	0.8	10.06
Total	**809.7**	**82.77**		**130.68**		**7.95**		**221.4**

Table F4: Hazardous areas of flood affected VDCs based on flood hazard mapping for 2100

Flood Affected VDCs	Total VDC Area (km^2)	Hazardous Area (km^2)						Total Hazardous Area (km^2)
		Critical	% of Total VDC Area	Moderate	% of Total VDC Area	Less	% of Total VDC Area	
Mahadevpuri	190.5	3.52	1.8	10.27	5.4	0.45	0.2	14.24
Kanchanapur	259	12.33	4.8	21.69	8.4	0.89	0.3	34.91
Kamdi	24.5	2.81	11.5	6.67	27.2	1.71	6.9	11.19
Binauna	42.7	4.81	11.3	10.79	25.3	0.66	1.5	16.26
Phatepur	79.2	26.69	33.7	45.53	57.5	1.13	1.4	73.35
Banakatti	13.3	2.54	19.1	8.26	62.1	0.74	5.6	11.54
Bejapur	108.5	7.1	6.5	3.7	3.4	2.1	1.9	12.9
Betahani	19.0	2.9	15.3	15.69	82.6	1.89	9.9	20.48
Holiya	17.5	14.68	83.8	2.73	15.6	0.1	0.57	17.5
Gangapur	19.3	4.9	25.4	15.82	81.9	0.33	1.7	21.05
Matahiya	36.2	3.53	9.7	7.39	20.4	0.33	0.91	11.25
Total	**809.7**	**85.81**		**148.54**		**10.33**		**244.67**

Appendix G

Table G.1: Willingness to pay by age

zone	Age		WTP (man-days/yr) for Scenario I	WTP (man-days/yr) for Scenario II	WTP (man-days/yr) for Scenario III	WTP (man-days/yr) Scenario IV
Critical flood prone (zone 1)	<35 (N=10)	Mean	5.40	7.20	8.60	11.00
		Std. Deviation	1.897	3.910	2.989	2.867
	35-45 (N=16)	Mean	4.50	6.88	8.38	10.63
		Std. Deviation	1.713	2.306	3.202	3.557
	45-55 (N=9)	Mean	3.78	6.67	7.33	9.11
		Std. Deviation	1.563	3.317	3.162	3.887
	>55 (N=19)	Mean	4.84	6.95	8.74	10.00
		Std. Deviation	1.675	2.345	3.478	3.590
	Total (N=54)	Mean	4.67	6.93	8.37	10.22
		Std. Deviation	1.737	2.767	3.206	3.468
Moderate flood prone zone (zone 2)	25-35 (N=21)	Mean	4.67	5.90	8.10	10.38
		Std. Deviation	1.592	2.047	2.234	2.655
	35-45 (N=20)	Mean	3.70	5.20	7.20	9.10
		Std. Deviation	1.625	1.642	2.375	3.523
	45-55 (N=21)	Mean	4.48	5.90	8.00	10.10
		Std. Deviation	2.089	2.644	2.966	3.548
	55-65 (N=21)	Mean	4.48	6.19	7.62	9.43
		Std. Deviation	1.537	2.272	2.801	3.355
	Total (N=83)	Mean	4.34	5.81	7.73	9.76
		Std. Deviation	1.734	2.178	2.590	3.267
Low flood prone or Safe Zone (zone 3)	25-35 (N=15)	Mean	3.87	5.60	7.07	7.60
		Std. Deviation	1.407	2.849	3.195	4.014
	35-45 (N=23)	Mean	3.39	5.04	6.35	8.52
		Std. Deviation	1.270	2.163	2.308	2.574
	45-55 (N=18)	Mean	4.56	5.67	7.11	9.11
		Std. Deviation	1.504	2.401	3.160	3.513
	55-65 (N=17)	Mean	3.41	5.29	6.71	8.82
		Std. Deviation	1.372	1.724	2.229	3.005
	Total (N=73)	Mean	3.78	5.37	6.77	8.55
		Std. Deviation	1.436	2.258	2.680	3.219
Total	25-35 (N=46)	Mean	4.57	6.09	7.87	9.61
		Std. Deviation	1.669	2.795	2.746	3.441
	35-45 (N=59)	Mean	3.80	5.59	7.19	9.29
		Std. Deviation	1.562	2.159	2.681	3.254
	45-55 (N=48)	Mean	4.38	5.96	7.54	9.54
		Std. Deviation	1.782	2.657	3.038	3.555
	55-65 (N=57)	Mean	4.28	6.18	7.72	9.44
		Std. Deviation	1.623	2.213	2.963	3.311
	Total (N=210)	Mean	4.23	5.94	7.56	9.46
		Std. Deviation	1.667	2.435	2.848	3.359

Table G.2: Willingness to pay by level of education

Zone	Education level		WTP (man-days/yr)			
			Scenario I	Scenario II	Scenario III	Scenario IV
Critical flood prone (zone 1)	Illiterate (N=32)	Mean	4.63	6.63	7.88	9.63
		Std. Deviation	1.561	2.803	3.554	3.748
	Informal (N=4)	Mean	4.00	6.50	9.00	10.00
		Std. Deviation	2.828	3.000	3.830	3.651
	Primary (N=9)	Mean	4.89	8.00	9.78	12.00
		Std. Deviation	2.028	2.646	2.108	2.236
	Secondary (N=5)	Mean	5.60	7.20	8.40	10.00
		Std. Deviation	1.673	1.789	2.191	2.828
	Higher Secondary (N=4)	Mean	4.00	7.00	8.50	11.50
		Std. Deviation	1.633	4.163	3.000	3.786
	Total (N=54)	Mean	4.67	6.93	8.37	10.22
		Std. Deviation	1.737	2.767	3.206	3.468
Moderate flood prone zone (zone 2)	Illiterate (N=40)	Mean	4.20	5.65	7.40	9.60
		Std. Deviation	1.911	2.434	2.762	3.365
	Informal (N=7)	Mean	4.00	5.71	8.57	10.86
		Std. Deviation	1.155	1.380	.976	4.298
	Primary (N=22)	Mean	4.36	5.82	7.64	9.18
		Std. Deviation	1.590	2.218	2.871	3.187
	Secondary (N=13)	Mean	4.92	6.31	8.46	10.62
		Std. Deviation	1.754	1.797	2.184	2.631
	Higher Secondary (N=1)	Mean	4.00	6.00	8.00	10.00
		Std. Deviation	.	.	.	.
	Total (N=83)	Mean	4.34	5.81	7.73	9.76
		Std. Deviation	1.734	2.178	2.590	3.267
Low flood prone or Safe Zone (zone 3)	Illiterate (N=32)	Mean	3.56	5.25	6.63	8.31
		Std. Deviation	1.413	2.200	2.803	3.095
	Informal (N=7)	Mean	4.29	5.14	6.29	7.71
		Std. Deviation	1.380	1.574	2.430	3.729
	Primary (N=15)	Mean	3.60	5.47	7.20	9.07
		Std. Deviation	1.724	3.159	3.189	3.369
	Secondary (N=8)	Mean	3.75	5.00	6.50	7.75
		Std. Deviation	1.282	2.138	2.563	3.770
	Higher Secondary (N=9)	Mean	4.67	6.22	7.33	10.22
		Std. Deviation	1.000	1.563	2.000	2.333
	University (N=2)	Mean	3.00	5.00	6.00	7.00
		Std. Deviation	1.414	1.414	2.828	4.243
	Total (N=73)	Mean	3.78	5.37	6.77	8.55
		Std. Deviation	1.436	2.258	2.680	3.219
Total	Illiterate (N=104)	Mean	4.13	5.83	7.31	9.21
		Std. Deviation	1.701	2.525	3.050	3.429
	Informal (N=18)	Mean	4.11	5.67	7.78	9.44
		Std. Deviation	1.605	1.847	2.557	3.989
	Primary (N=46)	Mean	4.22	6.13	7.91	9.70
		Std. Deviation	1.750	2.746	2.950	3.238
	Secondary (N=26)	Mean	4.69	6.08	7.85	9.62
		Std. Deviation	1.692	1.998	2.395	3.201
	Higher Secondary (N=14)	Mean	4.43	6.43	7.71	10.57
		Std. Deviation	1.158	2.377	2.199	2.652
	University (N=2)	Mean	3.00	5.00	6.00	7.00
		Std. Deviation	1.414	1.414	2.828	4.243
	F-value		4.845	6.921	5.387	4.560
	Significance		0.009	0.001	0.005	0.012

Table G.3: Education level respondents by flood zone

Flood prone areas (Zones)		Education level						Total
		Illiterate	Informal	Primary	Secondary	Higher Secondary	University	
Critical flood prone (zone 1)	No. of Respondents	32	4	9	5	4	0	54
	% within zone	59.3	7.4	16.7	9.3	7.4	0.0	100
	% within EL	30.8	22.2	19.6	19.2	28.6	0.0	25.7
Moderate flood prone zone (zone 2)	No. of Respondents	40	7	22	13	1	0	83
	% within zone	48.2	8.4	26.5	15.7	1.2	0.0	100
	% within EL	38.5	38.9	47.8	50.0	7.1	0.0	39.5
Low flood prone (zone 3)	No. of Respondents	32	7	15	8	9	2	73
	% within zone	43.8	9.6	20.5	11.0	12.3	2.7	100
	% within EL	30.8	38.9	32.6	30.8	64.3	100	34.8
Total	No. of Respondents	104	18	46	26	14	2	210
	% within zone	49.5	8.6	21.9	12.4	6.7	1.0	100
	% within EL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: EL= Education level

Appendix H

Table H.1: Respondents' perception on different flood forecasting techniques (N=240)

Responses	Observing position and movement of clouds in the sky			Observing the rain in the upper catchment area			Watching ants' movement			Feeling the magnitude of hotness			Analyzing the magnitude of thunderstorms		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	103	42.9	42.9	46	19.2	19.2	17	7.1	7.1	35	14.6	14.6	60	25.0	25.0
VeP	49	20.4	63.3	108	45.0	64.2	61	25.4	32.5	126	52.5	67.1	103	42.9	67.9
MdP	43	17.9	**81.3**	76	31.7	**95.8**	95	39.6	**72.1**	53	22.1	**89.2**	45	18.8	**86.7**
LsP	40	16.7	97.9	8	3.3	99.2	52	21.7	93.8	17	7.1	96.3	29	12.1	98.8
LeP	5	2.1	100	2	0.8	**100**	15	6.3	100	9	3.8	100	3	1.3	100
Rank	**IV**			**I**			**V**			**II**			**III**		

Table H.2: Preference of pre-flood adaptation strategies

Responses	Raise the bottom of the floor of the house			Construct drain around the properties			Move properties			Keep emergency materials		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	98	40.8	40.8	44	18.3	18.3	74	30.8	30.8	56	23.3	23.3
HeP	46	19.2	60.0	111	46.3	64.6	87	36.3	67.1	95	39.6	62.9
MdP	70	29.2	**89.2**	70	29.2	**93.8**	57	23.8	**90.8**	47	19.6	**82.5**
LsP	25	10.4	99.6	9	3.8	97.5	20	8.3	99.2	37	15.4	97.9
LeP	1	0.4	100	6	2.5	100	2	0.8	100	5	2.1	100
Rank	**III**			**I**			**II**			**IV**		

Table H.3: During flooding adaptation strategies

Responses	Climb tree and roof of the houses			Caring children, elderly people & release domestic animals			Take valuable properties			Shout and escape			Use sand bag to divert flood		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	56	23.3	23.3	57	23.8	23.8	73	30.4	30.4	25	10.4	10.4	44	18.3	18.3
VeP	59	24.6	47.9	91	37.9	61.7	79	32.9	63.3	74	30.8	41.3	84	35.0	53.3
MdP	65	27.1	**75.0**	80	33.3	**95.0**	68	28.3	**91.7**	67	27.9	**69.2**	67	27.9	**81.3**
LsP	38	15.8	90.8	9	3.8	98.8	9	3.8	95.4	46	19.2	88.3	26	10.8	92.1
LeP	22	9.2	100	3	1.3	100	11	4.6	100	28	11.7	100	19	7.9	100
Rank	**IV**			**I**			**II**			**V**			**III**		

Table H.4: Post flooding adaptation strategies

Responses	Managing food			Repairing the house			Managing household material			Repairing hand pump for drinking water		
	F	RF	CRF	F	RF	CRF	F	RF	CRF	F	RF	CRF
MoP	107	44.6	44.6	43	17.0	18.0	61	25.4	25.4	38	15.8	15.8
VeP	45	18.8	63.3	110	45.8	64.0	88	36.7	62.1	109	45.4	61.3
MdP	70	29.1	**92.4**	72	30.0	**94.0**	72	30.0	**92.1**	44	18.3	**79.6**
LsP	17	7.1	99.6	13	5.4	99.2	15	6.3	98.3	42	17.5	97.1
LeP	1	0.4	100	2	0.8	100	4	1.7	100	7	2.9	100
Rank	**II**			**I**			**III**			**IV**		

Note: MoP = Most preferred; VeP=Very preferred; MdP= Moderately preferred; LsP= Less preferred LeP= Least preferred & 'F' is frequency, 'RF' is relative frequency (%) and 'CRF' is cumulative relative frequency (%)

Appendix I
Household Survey Questionnaires - 2012

My name is Rohini Devkota, PhD Candidate at University of Southern Queensland (USQ), Toowoomba, Australia. My research is about climate change induced flood adaptation. You are invited to participate in the following important research project entitled "Flood Adaptation Strategies under Climate Change in Nepal: A Socio-hydrological Analysis" because you are likely to be suffering from flood problems that need to study and therefore your participation is very crucial for this research. Therefore, I seek your assistance in completing this questionnaire survey. The purpose of this questionnaire survey is to collect vital information that will ultimately explore flood impacts and its adaptation strategies. The survey will take about 40 minutes to complete.

Please be assured that all information provided by you will be treated confidentially and will only be used for research purposes. Also be informed that you have right to withdraw from the research at any time without fear of the consequences and take any previously provided information. Your cooperation will be very important in exploring the possible flood risk reduction strategies in Nepal.

If you are happy to participate this questionnaire survey, please affix your signature and date.

Signature………………………… Date……………………

Code no	
Zone	

Section I: General information

QN	Question	Code		Skip
1.1	Name of the respondent? *(Name in Alphabet)*			
1.2	District *(Write District Code)*	Banke	1	
		Dang	2	
1.3	VDC/ Municipality			
1.4	Ward No	*Write Ward No in Digit*		
1.5	Village/ tole			
1.6	Gender	Male	1	
		Female	2	
1.7	Age	Write in number	__ __	
1.8	Size of your family?	Write in number	__ __	
1.9	Occupation	Agriculture	1	
		Government	2	
		Small business	3	
		Wage labour	4	
		Foreign employment	5	
		Other (specify)_________	6	
1.10	Are you indigenous or migrated?	Migrated	1	
		Indigenous	2	→1.12
1.11	If migrated, how long have you been here? OR From which year have you been here	Number of years	___ ___	
		Year of coming	___ ___	
		Where are you from	_________	
1.12	Literacy status	Literate	1	
		Illiterate	2	→2.1
1.13	If literate, highest level completed?	Informal education	1	
		Primary	2	
		Secondary	3	
		Higher secondary	4	
		University	5	

Section II: Income

(a) Q. 2.1: Agriculture Related Income (Last 12 Months)

QN	Question			
2.1	Does any member of this household own any agriculture land?	Yes	1	
		No	2	

QN	Production		Expenditure (in Rs)			
Types of crops	Total production (quintal/Kg)	Price/ (quintal/Kg)	Seed (Kg)	Fertilizer (Kg)	Hired labour /livestock	Other expenditure
Rice						
Maize						
Wheat						
Potato						
Oil seed						
Pulses						
Vegetables						
Fruits						
Others						

(b) 2.2: Livestock Related Income

Please, check whether household owns some kind of livestock or not? (**Tick appropriate box)**

QN	Question		
2.2	Does this household own any livestock, other farm animals, or poultry?	Yes	1
		No	2

2.2.1 Sale/purchase of livestock (Last 12 Months)

SN	**Sale** (Rs)		**Purchase** (Rs)		
Types of livestock	Total no sale	Total income	Number	Price/ unit	Total expenditure
Buffalo					
Cow/oxen					
Goat					
Pig					
Chickens					
Other					

2.2.2 Expenditure on livestock (Last 12 Months)

SN	Feed (Rs)	Medicine (Rs)	Veterinary services (Rs)	Transportation (Rs)	Other expenditure (Rs)
Buffalo					
Cow/ox					
Goat					
Pig					
Chickens					
Other					

(c) 2.3: Income from sale of livestock products (last 12 months)

Product	Total production (litre or kg)	Per unit price	Total income
Milk			
Ghee			
Meat			
Others			

(d) 2.4: Own business – economic activities (last 12 months)

QN	Questions	Code			Skip
2.4.1	Beside from household work such business or activities includes 1. Tea shop/restaurant/ meat shop 2. Vegetable selling 3. Tuition classes 4. Others	Yes		1	
		No		2	
		SN	Activities	Income	
		1			
		2			
		3			

(e) 2.5: Wage income (last 12 months)

No. of household member, who are involved in wage earnings	No. of days in months employed	Cash wage per day (Rs)	Total wage income (Rs)

(f) 2.6: Foreign income

QN	Question	Code			Skip
2.6	In your family, anyone of your family member is foreign employed?	Yes	1	☐	
		No	2		
	Number of people	Income (Rs)/year			

(g) 2.7: Expenditure on household (last 12 months)

QN	Food (Rs)	Medicine (Rs)	Education (Rs)	Transportation (Rs)	Cloths (Rs))	Other (Rs)	Total expenditure (Rs)
1							

Section III: Climate Change Related Information

QN		Code	Skip
QN 3.1	Have you found any changed in following parameters? *(Fill Increasing=1, Decreasing =2, No change=3 and Don't know=4)*	**Code**	**Skip**
3.1.1	Have you noticed any change in temperature during summer?	___	
3.1.2	Have you noticed any change in temperature during winter?	___	
3.1.3	Have you noticed any heavy rain within a short period?	___	
3.1.4	Have you noticed any unusual/unpredicted rain?	___	
3.1.5	Have you noticed any rain with storms/hail?	____	
3.1.6	Have you noticed any change in cloud/ haze/mist level?	___	
3.2	Is there any change in the start and end of monsoon rainfall as compared to past 20 years?	☐	

QN	Question	Code					
3.3	Do you find any change in current rainfall pattern as compare to 20 years ago? *(Strongly agree:5,agree:4,neutral:3, disagree:2 & strongly disagree: 1)*						
	SN	Current rainfall pattern	5	4	3	2	1
	a.	Starting early monsoon (March –May)	☐	☐	☐	☐	☐
	b.	High rain in monsoon season rain (June –Sept.)	☐	☐	☐	☐	☐
	c.	Shifting and increasing post monsoon (Oct. -Feb.)	☐	☐	☐	☐	☐
	d.	Increase annual rainfall	☐	☐	☐	☐	☐
	e.	Others	☐	☐	☐	☐	☐

Section IV: Flood Related Information

QN	Question	Code						Skip
4.1	What are the effects due to high rainfall in your area? *(Strongly agree:5,agree:4,neutral:3, disagree:2 & strongly disagree: 1)*							
	SN	Effects due to high rainfall	5	4	3	2	1	
	a.	Landslide	☐	☐	☐	☐	☐	
	b.	Daily activities	☐	☐	☐	☐	☐	
	c.	Increase flood	☐	☐	☐	☐	☐	
	d.	Collecting fuel (wood/dung)	☐	☐	☐	☐	☐	
	e.	Plantation/harvest time	☐	☐	☐	☐	☐	

4.2	In your opinion, what are the major causes of flooding? *(Very strong: 5, strong: 4, moderate:3, weak:2 & very weak: 1)*					
SN	Causes of flooding	5	4	3	2	1
a.	Change in rainfall pattern due to climate change	☐	☐	☐	☐	☐
b.	Deforestation	☐	☐	☐	☐	☐
c.	Poor land management	☐	☐	☐	☐	☐
d.	Traditional agricultural practices	☐	☐	☐	☐	☐
e.	Extraction of boulder and sand	☐	☐	☐	☐	☐
f.	Others ______________________	☐	☐	☐	☐	☐

QN	Question	Code	Skip
4.3	Do you or your business is affected from flood?	YES 1; NO 2 ☐	
4.4	How often do you face flood problem? Please let us know the flood frequencies.		

SN	Face flood problem	
a.	Every year	☐
b.	5 years	☐
c.	>10 years	☐
d.	Other	☐

QN	Question	Code	Skip
4.5	Could you please let us know the duration of water logging?		

SN	Duration of water logging	Code
a.	<1 day	☐
b.	1-2 day	☐
c.	3 -4 days	☐
d.	> 4 days	☐

QN	Question	Code	Skip
4.6	What is the depth of the water logging?		

SN	Depth of the water logging (m)	Code
a.	<0.3	☐
b.	0.3-1	☐
c.	>1	☐

QN	Question	Code	Skip
4.7	Have you lost your properties due to flood?	YES 1; NO 2 ☐	

4.8 Give the following details due to flood damage

QN	Question			Code	Skip
4.8.1	Damage status	Code	Est. avg. damage in last 5 years	☐	
	Completely swept out	1			
	Partly damage in walls	2			
	Water logging inside house	3			
4.8.2	Completely swept out	1		☐	
	Damage	2			
	Water logging inside shed	3			

QN		Bigha	Kattha	Dhur		Code	Skip
4.8.3	Rice	__ __	__ __	__ __		☐	
	Wheat	__ __	__ __	__ __			
	Maize	__ __	__ __	__ __			
	Vegetables	__ __	__ __	__ __			
4.8.4		Bigha	Kattha	Dhur			

4.8.5	Livestock (number)		Injured	Dead	
		Duck	__ __ __	__ __ __	
		Chicken	__ __ __	__ __ __	
		Pigs	__ __ __	__ __ __	
		Sheep/goat	__ __ __	__ __ __	
		Buffalo	__ __ __	__ __ __	
		Cow/ox	__ __ __	__ __ __	
4.8.6	Human loss (Number)	Injured	__ __ __		
		Sick	__ __ __		
		Death	__ __ __		

QN	Question	Code	Skip
	Could you please me know the land use change	Reason for chan	
4.9	Area 10 years before (Kattha) __ ___ ___ Area now (Kattha) __ ___ ___	Flood 1 Others 2	
4.10	What is the total average property loss by in last 5 years flood?	In Rupees______________	

QN	Question	Code	Skip	
4.11	Were you able to cultivate crops in the flooded land again?	YES		1
		No		2
		Migrated		3
4.12	If, yes how did the production affected?	Increase		1
		Decrease		2
		No change in production		3
4.13	Estimated production increase or decrease (%)	0-24		1
		25-49		2
		50-74		3
		75-100		4

QN	Question	Code	Skip
4.14	In what extent, the following items affected by flood? *(Very high:5, high: 4,moderately:3, low:2 and very low:1)*		

SN	Impacts due to flood property	5	4	3	2	1
a.	Households and settlements	☐	☐	☐	☐	☐
b.	Domestic animals	☐	☐	☐	☐	☐
c.	Agricultural land	☐	☐	☐	☐	☐
d.	Fuel (Grass/ wood) collection	☐	☐	☐	☐	☐
e.	Drinking water sources	☐	☐	☐	☐	☐
f.	Other__________________________	☐	☐	☐	☐	☐

QN	Question	Code		Skip
4.15	Due to the flood, did you need to migrate temporally in monsoon season?	YES	1	
		NO	2	→5.1
4.16	How much time did you migrate?			

SN	Time of migration (days)	
a.	1	☐
b.	2 -3	☐
c.	4-7	☐
d.	8-14	☐
e.	>15	☐

		S.N	Place of migration	Code
4.17	Where are you migrated?	1.	Relatives house	1
		2.	Public place (e.g. school)	2
		3.	Neighbours house	3
		4.	Others (road side, near to the forest)	4

Section V: Early Warning System

QN	Question	Code			Skip
5.1	Are you aware of flood early warning systems?	YES	1		
		NO	2		→5.3
5.2	Do you think who would be responsible for establishing an early warning system?				

SN	Responsible for establishing early warning system	Code
a.	Community people	
b.	Government	
c.	NGO/INGO	
d.	Local clubs/groups	
e.	Other	

QN	Question	Code	Skip
5.3	Which media would be the most reliable for transforming early warning information? *(Most reliable: 5, very reliable: 4, moderately: 3, less reliable:2 & least reliable: 1)*		

SN	Most reliable media	5	4	3	2	1
a.	Radio/FM					
b.	Newspaper					
c.	TV					
d.	Mobile phone/SMS					
E	Alarms at river banks/siren					
F	Other					

QN	Question	Code	Skip
5.4	Which media would be the effective for flash flood warning? *(highly effective: 5, significant effective: 4, moderately effective: 3, no effective:2 & highly not effective: 1)*		

SN	Media for flash flood warning	5	4	3	2	1
a.	Door to door knocking					
b.	Sirens/ alarms					
c.	Mobile phone/ SMS					
d.	Shouting					
e.	Other					

Section VI: Adaptation strategies:

QN	Question	Code	Skip
6.1	Are you practicing any flood forecasting measures at local level? *(Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred:2 & least preferred: 1)*		

SN	Flood forecasting measures	5	4	3	2	1
a.	Observing position and movement of clouds in the sky					
b.	Observing the rain in the upper catchment area					
c.	Watching ants' movement					
d.	Feeling the magnitude of hotness					
e.	Analyzing the magnitude of thunderstorms					
f.	Other					

QN	Question	Code	Skip
6.2	What are the preferred pre-flood adaptation strategies at household level? *(Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred: 2 & least preferred: 1)*		

SN	Pre-flood adaptation strategies	5	4	3	2	1
a.	Raise the bottom of the floor of the house					
b.	Construct drain around the house and properties					
c.	Move properties					
d.	Keep emergency materials *					
e.	Others_______________________________					

**(e.g. plastics, torch light, drinking water, dried vegetables, sugar, noodles)*

QN	Question	Code	Skip
6.3	What are the Pre-flood adaptation strategies at community level? *(Most applicable: 5, very applicable: 4, moderately applicable: 3, less applicable: 2 & least applicable:1)*		

SN	Pre-flood adaptation strategies	5	4	3	2	1
a.	Develop flood management plan	☐	☐	☐	☐	☐
b.	Keep contact information	☐	☐	☐	☐	☐
c.	Pre- estimate hazards	☐	☐	☐	☐	☐
d.	Produce human resources and train manpower	☐	☐	☐	☐	☐
e.	Arrange first aid	☐	☐	☐	☐	☐

	Question	Code	Skip
6.4	What are the preferred during flood adaptation strategies at household level? *(Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred: 2 & least preferred: 1)*		

SN	During flood adaptation strategies	5	4	3	2	1
a.	Climb tree and roof of houses	☐	☐	☐	☐	☐
b.	Caring people and release domestic animals	☐	☐	☐	☐	☐
c.	Take valuable properties	☐	☐	☐	☐	☐
d.	Shout and escaping	☐	☐	☐	☐	☐
e.	Use sand bag to divert water	☐	☐	☐	☐	☐
f.	Others________________________________	☐	☐	☐	☐	☐

QN	Question	Code	Skip
6.5	What are the during adaptation strategies at community level? *(Most applicable: 5, very applicable: 4, moderately applicable: 3, less applicable: 2 & least applicable:1)*		

SN	During adaptation strategies	5	4	3	2	1
a.	Perfect communication at community level	☐	☐	☐	☐	☐
b.	Flood & logistic	☐	☐	☐	☐	☐
c.	Health & hygienic of affect people	☐	☐	☐	☐	☐
d.	Others____________________________________	☐	☐	☐	☐	☐

QN	Question	Code	Skip
6.6	What are the preferred post-flood adaptation strategies at household level? *(Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred: 2 & least preferred: 1)*		

SN	Post-flood adaptation strategies	5	4	3	2	1
a.	Manage food	☐	☐	☐	☐	☐
b.	Repair of houses/ prepare temporary shed	☐	☐	☐	☐	☐
c.	Manage house materials	☐	☐	☐	☐	☐
d.	Repair hand pump for drinking water	☐	☐	☐	☐	☐
e.	Others	☐	☐	☐	☐	☐

QN	Question	Code	Skip
6.7	What are the post-flood adaptation strategies at community level? *(Most applicable: 5, very applicable: 4, moderately applicable: 3, less applicable: 2 & least applicable:1)*		

SN	Post-flood adaptation strategies	5	4	3	2	1
a.	Exchange help	☐	☐	☐	☐	☐
b.	Prepare temporary settlement	☐	☐	☐	☐	☐
c.	Co-ordinate with government and other agencies	☐	☐	☐	☐	☐
d.	Equal distribution of resources	☐	☐	☐	☐	☐
e.	Others__________________________________	☐	☐	☐	☐	☐

QN	Question	Opinion		Skip
6.8	In your opinion, What are flood protection measures?	Pre-flooding situation		
		During flood situation		
		Post flooding situation		

QN	Question	Code	Skip
6.9 (a)	Which adaptation strategy do you think is the effective method for current flood exposure? *(Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred: 2 & least preferred: 1)*		

SN	Adaptation strategy for current flood exposure	5	4	3	2	1
a.	Change farming practices	☐	☐	☐	☐	☐
b.	Land use management	☐	☐	☐	☐	☐
c.	Household level preparation /management	☐	☐	☐	☐	☐
d.	Controlling flood level & food storage	☐	☐	☐	☐	☐
e.	Watershed management	☐	☐	☐	☐	☐

QN	Question	Code	Skip
6.9 (b)	Which structural adaptation strategy do you think is the effective method for current flood exposure? *((Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred: 2 & least preferred: 1)*		

SN	Adaptation strategy for current flood exposure	5	4	3	2	1
a.	Bio-engineering	☐	☐	☐	☐	☐
b.	Reservoir/flow regulating structure	☐	☐	☐	☐	☐
c.	Bamboo mesh/mat with sand filled bag	☐	☐	☐	☐	☐
d.	Gabion wall /spurs	☐	☐	☐	☐	☐
e.	Embankment/river training structure	☐	☐	☐	☐	☐

QN	Question	Code	Skip
6.10 (a)	You received the information of flood exposure in 2030, which adaptation strategy do you think? *(Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred: 2 & least preferred: 1)*		

SN	Adaptation strategy for flood exposure in 2030	5	4	3	2	1
a.	Change farming practices	☐	☐	☐	☐	☐
b.	Land use management	☐	☐	☐	☐	☐
c.	Household level preparation /management	☐	☐	☐	☐	☐
d.	Controlling flood level & food storage	☐	☐	☐	☐	☐
e.	Watershed management	☐	☐	☐	☐	☐

QN	Question	Code	Skip
6.10 (b)	You received the information of flood exposure in 2030, which structural adaptation strategy do you think? *(Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred: 2 & least preferred: 1)*		

SN	Adaptation strategy for flood exposure in 2030	5	4	3	2	1
a.	Bio-engineering	☐	☐	☐	☐	☐
b.	Reservoir/flow regulating structure	☐	☐	☐	☐	☐
c.	Bamboo mesh/mat with sand filled bag	☐	☐	☐	☐	☐
d.	Gabion wall /spurs	☐	☐	☐	☐	☐
e.	Embankment/river training structure	☐	☐	☐	☐	☐

QN	Question	Code	Skip
6.11 (a)	You received the information of flood exposure in 2070, which adaptation strategy do you think? *((Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred: 2 & least preferred: 1)*		

SN	Adaptation strategy for flood exposure in 2070	5	4	3	2	1
a.	Change farming practices	☐	☐	☐	☐	☐
b.	Land use management	☐	☐	☐	☐	☐

	c.	Household level preparation /management	☐	☐	☐	☐	☐	
	d.	Controlling flood level & food storage	☐	☐	☐	☐	☐	
	e.	Watershed management	☐	☐	☐	☐	☐	

QN	Question	Code	Skip
6.11 (b)	You received the information of flood exposure in 2070, which structural adaptation strategy do you think? *(Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred: 2 & least preferred: 1)*		

SN	Adaptation strategy for flood exposure in 2070	5	4	3	2	1
a.	Bio-engineering	☐	☐	☐	☐	☐
b.	Reservoir/flow regulating structure	☐	☐	☐	☐	☐
c.	Bamboo mesh/mat with sand filled bag	☐	☐	☐	☐	☐
d.	Gabion wall /spurs	☐	☐	☐	☐	☐
e.	Embankment/river training structure	☐	☐	☐	☐	☐

QN	Question	Code	Skip
6.12 (a	You received the information of flood exposure in 2100, which adaptation strategy do you think? *(Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred: 2 & least preferred: 1)*		

SN	Adaptation strategy for flood exposure in 2100	5	4	3	2	1
a.	Change farming practices	☐	☐	☐	☐	☐
b.	Land use management	☐	☐	☐	☐	☐
c.	Household level preparation /management	☐	☐	☐	☐	☐
d.	Controlling flood level & food storage	☐	☐	☐	☐	☐
e.	Watershed management	☐	☐	☐	☐	☐

QN	Question	Code	Skip
6.12 (b)	You received the information of flood exposure in 2100, which structural adaptation strategy do you think? *(Most preferred: 5, very preferred: 4, moderately preferred: 3, less preferred: 2 & least preferred: 1)*		

SN	Adaptation strategy for flood exposure in 2100	5	4	3	2	1
a.	Bio-engineering	☐	☐	☐	☐	☐
b.	Reservoir/flow regulating structure	☐	☐	☐	☐	☐
c.	Bamboo mesh/mat with sand filled bag	☐	☐	☐	☐	☐
d.	Gabion wall /spurs	☐	☐	☐	☐	☐
e.	Embankment/river training structure	☐	☐	☐	☐	☐

Section VII: Willingness to Pay

i. The Scenario development: You have been experiencing flood for a long time. You may know better than us the cause of floods which could be due to: climate change; unmanaged land use practices; lack of embankment protection; deforestation etc. You are well known the erratic rainfall caused devastating floods in the past years resulting huge loss of public and private properties including agricultural land, livestock, houses, bridges etc. in the West Rapti river basin. You might have still remembered worst flood event occurred in 2006. At that time at least 22 people disappeared, thousands of villagers were displaced and 10 villages lying in the plain areas were submerged. You are also still remembering the flood event in 2008, you know people from 142 households were forced to leave their houses from Holiya Village Development Committee. In 2010, out of 2,600 households, 33 villages, over 16,000 people from Banke and Dang districts were forced to leave their houses and farmlands and had to live as refugees. I assume that you may want to live and work in a flood risk free environment.

Therefore, you may know better than us have local knowledge about the impact of floods to your properties and livelihoods. You may want a sustainable solution to protect your properties from floods and sustain your livelihood. Considering your circumstances, four hypothetical flood scenarios are developed to investigate your perception and WTP for each scenario. Please remember your WTP for flood mitigation under different flood scenarios could be useful for developing and implementing flood mitigation policy and strategies to the government and other policy makers.

Scenario 1, 2, 3 and 4: The Government of Nepal would like to manage flood problem in this river basin. This will help stop: (1) the risk of death of human beings; (2) the loss of your private properties such as houses, agricultural and forest lands, livestock etc., and (3) public lands and infrastructures. By developing flood control mechanism, Nepalese Government would like to guarantee for the protection of all private and public goods. Now let us see four highly likely flood scenarios (in terms of depth of water and its duration) at your locality.[1]

ii. Pre-testing of questionnaire and its final setting:
In order to elicit the WTP of respondents bidding game or referendum method was used. During the reconnaissance survey the questionnaire was pre-tested and refined using locally appropriate words/language in a group of people.

The exact wording of the question was as follows: Would you vote in favour to reduce in your annual loss due to flood in terms of labour days each year to protect life and properties?

Yes No

If 'yes', what will be the highest amount/labour days you would pay per year?

Flood scenarios	**Scenarios I**	**Scenarios II**	**Scenarios III**	**Scenarios IV**
WTP in labour days				

'no', why you say 'no'? What lower amount/labour days you would pay?

Flood scenarios	**Scenarios I**	**Scenarios II**	**Scenarios III**	**Scenarios IV**
WTP in labour days				

Scenario 2: Government of Nepal is planning to establish the early warning system in this catchment area. If you have these systems along the river, you may able to protect lives (your and livestock) and some properties. How much you are willing to pay for setting this technology?

The exact wording of the question will be as follows: Would you vote in favour to minimize annual loss due to flood in terms of money (NRs or labour days) each year?

Yes No

	If 'yes', what will be the highest amount/labour days you would pay?	
Flood scenarios	Labour days	WTP in Rs

If 'no', why you say 'no'? What lower amount/labour days you would pay?

Flood scenarios	Labour days	WTP in Rs

[1] *Please note, four flood scenarios were: current flood scenario; flood scenario for 2030; flood scenario for 2070; and flood scenario for 2100. However, in order to avoid confusion, respondents were not told about years and they were simply briefed as four flood scenarios. All flood scenarios were shown on map and also on laptop. In this process, we believe that the respondents quickly calculated their damage costs under different flood scenarios and elicited their WTP accordingly.*

VIII: Vulnerability mapping

Please, rank the selected indicators on a 1-5 scale in which 1 indicates very low vulnerability and 5 indicating sever vulnerability based on overall flood impacts and previous experience.

(Please rank from Severe=5, high = 4, moderate=3, vulnerable=2, low=1)

Parameters	SN	Indicators	Code
Physical	1	Frequency of flood	
	2	Bank cutting	
	3	House near the river banks	
	4	Transportation and mobility	
	5	Damage of agricultural land	
	6	Pollution of drinking water sources	
	7	Damage to structure	
	8	Mobility of the people	
	9	Psychological	
	10	Damage of land by flood	
Social	11	Agricultural production	
	12	Value of house	
	13	Change in direction of flow	
Economics	14	Access to education	
	15	Sources of income	
	16	Food security	
	17	Settlement near the river banks	
	18	Access to forest	
Access resources	19	Land holding	
	20	Activities of household head	
	21	Access to water	
Communication	22	Women participation	
Gender perspective	23	Group formation	
	24	Access to service centres	
Psychological	25	Communication	