HOUSEHOLDS' FLOOD VULNERABILITY ASSESSMENT IN CONTEXT OF CLIMATE CHANGE

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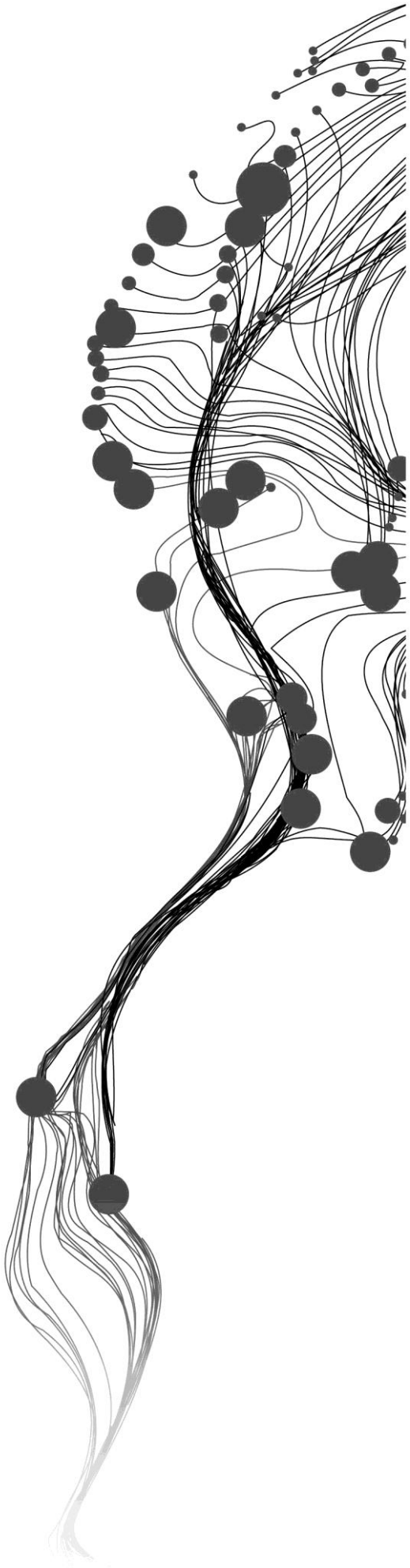

HOUSEHOLDS' FLOOD VULNERABILITY ASSESSMENT IN CONTEXT OF CLIMATE CHANGE

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Enschede, The Netherlands, March, 2011

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Urban Planning and Management

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ABSTRACT

A large number of population (3.5 million) are living in slums in Dhaka. In the context of climate change and considering its local context, the flood vulnerability of Dhaka city is very high. This makes a large number of poor people who have little adaptive capacity, to be highly sensitivity to any kind of climatic changes and external stresses in the environment. To understand the consequences of climate change requires knowledge about the interactions of climate change and other stresses and stressors, and about the resilience and vulnerability of human–environment systems that experience them. With this regards three objectives guided this study to assess the flood vulnerability in the local context of Dhaka: To analyses the current vulnerability context, to develop a contextual framework to assess the flood vulnerability and to apply this framework in the selected study areas in Dhaka. Four scientific methods and techniques were used to achieve these objectives: qualitative interviews, statistical analysis from quantitative data (secondary data), spatial multi criteria evaluation techniques and spatial autocorrelations. In order to identify household stress and, the social and bio-physical conditions of human environment systems, in-depth qualitative interviews were carried out. The results reveal that households in Dhaka had different variations of vulnerability depending on their exposure, sensitivity and adaptive capacity. Moreover, their vulnerability level was aggravated by a combination of non-climate stresses like human and societal poor slum living conditions they were exposed to. Beside the regular disruptions in the daily life due to flooding factors like income, food intake, health were found to affect their resilience and adaptive capacity. The conceptualization and eventual application of the developed framework in the slums of Dhaka illustrates the importance of understanding and developing place-based methods' stress interactions and the characteristics of particular human– environment systems. In conclusion, meaningful analyses of human–environment dynamics require the full participation of local people, their knowledge, perspective, values and behaviour. In this case, vulnerability assessments for communities in Dhaka require in-depth investigations and their active involvement in understanding their human environmental interrelations and their adaptive capacity to climate change.

Key words: Vulnerability, Exposure, Sensitivity, Adaptive capacity, SMCE, Flood, Household, Slum.

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Dedicated to my parents

I am ever indebted to my parents who all through their lives,
in every possible way have tried to make me happy.

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ACRONYMS

BWDB	:	Bangladesh Water Development Board
CUS	:	Centre for Urban Studies
DCC	:	Dhaka City Corporation
DEM	:	Digital Elevation Model
DFID	:	Department for International Development
DFG	:	Deutsche Forschungsgemeinschaft
DIFPP	:	Dhaka integrated flood protection project
DMA	:	Dhaka Metropolitan Area
DMDP	:	Dhaka Metropolitan Development Plan
DRM	:	Disaster Risk Management
DTM	:	Digital Terrain Model
FFWC	:	Flood Forecasting and Warning Centre
GIS	:	Geographic Information System
ILWIS	:	Integrated Land and Water Information System
IOM	:	International Organisation for Migration
IPCC	:	International Panel for Climate Change
ISDR	:	International Strategy for Disaster Reduction
ITC	:	International Institute for Geo-Information Science and Earth Observation
PASW	:	Predictive Analytics Software
PWD	:	Public Works Department
SMCE	:	Spatial Multi Criteria Evaluation
SPSS	:	Statistical Package for the Social Sciences
UN	:	United Nations
US	:	United States of America

1. INTRODUCTION

1.1. Climate change impacts and vulnerability assessment

The impacts of global warming and climate change can be felt worldwide. Changes in the climatic variables and increase in natural hazards have adversely affected the human existence. Such risks are even projected to increase in future.

This poses a big threat to the urban population especially the majority of those residing in close proximity to seas, rivers and hazardous areas within coastal cities. The extent of the impact of these natural calamities will have chance to be enormous in those cities where there are very little resilience as well adaptive capacity are available to mitigate such effects. The most adverse impacts are predicted in the developing world cities because of geographic exposure, reliance on climate sensitive sectors, low incomes, and weak adaptive capacity(Heltberg, Siegel, & Jorgensen, 2009).

In this regard, it is necessary to assess the spatiality of vulnerability to climate change with an aim of formulating better strategies that contribute to risk reduction. There is a need to assess the impacts of non-climatic factors such as population changes and land use changes on cities in the event of changing climate conditions and extreme weather events (R. Nicholls, Wong, Burkett, Woodroffe, & Hay, 2008). This issue needs more redress especially when we are not able to prevent hazards from occurring. According Peters Guarin (2008), the adverse effects of these hazards can largely be minimized by assessing vulnerability and from such proposing and developing new mechanisms to cushion people from them. Consequently, current populations will be better equipped to address not only the present climatic extremes but also future uncertainties (Neil Adger, 1999). This can be achieved through addressing vulnerability in a comprehensive manner.

Vulnerability assessment is necessary in order to reduce the impacts of natural hazard. Many reports have already been published by international organizations and researchers on vulnerability assessment in different scale, and yet vulnerability assessments that are based on the (possible) impacts of climate change on urban environment specifically on certain community are largely missing. Therefore, this research intends to identify certain factors of urban environment which might increase urban vulnerability. Some of these factors include non climatic variables such as: land use change, population change, etc. It is also assumed that poor people will be the main casualty in this regard, because of their little capacity to protect themselves from changing circumstances(Hardoy & Pandiella, 2009). Therefore the result of this research will be a valuable input for local level authority to take appropriate actions, policies, and programmes within the context of changing climate and its resultant impacts on urban environment for a certain community.

1.1.1. Background and Justification

Climate change Impact in developing countries: In recent decade, the world has become highly vulnerable to natural hazards, such as the 2004 Indian Ocean tsunami and very recently the severe floods in Pakistan (2010), the high magnitude earthquake in Haiti (2010), urban flood in Saudi Arabia, Australia and Brazil (2011). Additionally, there is evidence of prominent increases in the intensity of extreme weather events such as heat waves, tropical cyclones, intense rainfall, tornadoes all over the world (Cruz et al., 2007, in IPCC, 2007) Impacts of such natural hazard might have impact on the human survival and well-being food crisis as well food price increase and susceptibility to vector disease, to loss of income and

livelihoods. It is assumed that these impacts will have more effect on developing countries more than developed countries. In a very recent report of World Bank (2010) it is published that within last 3 years all over the world food price has increased 20 % however in Bangladesh the increase is 45% (News CNN, 19 February, 2011).

In this regard, Ionescu et al. (2009) stipulate that "climate change will have varying effect on different groups and sectors in the society for three important reasons: Firstly, the effect will vary according to geographical location. Secondly, there are differences between regions and between groups and sectors in society, which determine the relative importance of such direct effects of climate change. Thirdly, there are differences in the extent to which regions, groups and sectors are able to prepare for, respond to or otherwise address the effects of climate change."Therefore, the countries of developed region will have little impact because of having advanced technological and institutional capacity; on the other hand least developed countries like Bangladesh will face enormous damage especially big cities like Dhaka where all the assets and developments are centralized and a high density and little protection to the anticipated negative effects of climate change exist.

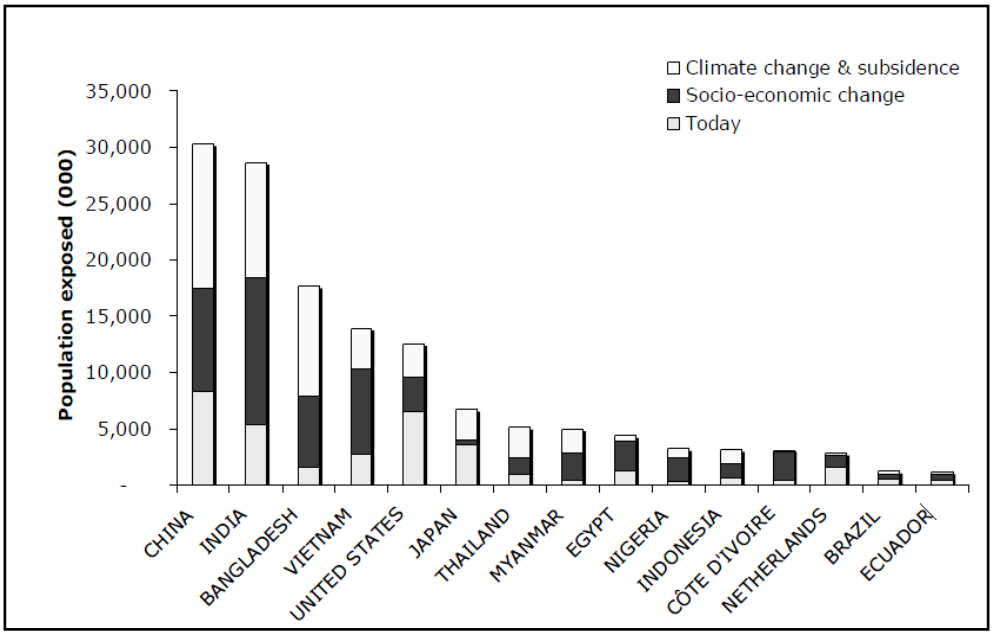


Figure 1-1: Top 15 cities by population exposed today and in the 2070(for scenario FAC)

Source: (Nicholls, 2007)

1.1.2. Vulnerability in mega-urban context:

Urban areas can be seen to be the most "problematic areas" and will experience the most complex and devastating consequences in regard to the impacts of climate change, as they concentrate people, their assets, industries and infrastructure in ways that increase risk and vulnerability (Satterthwaite, 2009).

Rapid urban growth has negative impact on urban environment which places more persons at potential vulnerable condition in small lands that may be unsuitable (hazard prone) for residential development and living. Urban areas provide a number of socio-economic opportunities for jobs and income generation, but are also simultaneously becoming increasingly risky places to live, especially for low-income residents of cities in developing countries (UNEP, 2007). These issues have increased impacts of natural hazards (increasing vulnerability to climate change) inside the cities, depending on its socio-spatial structure. Thus, in a changing urban environment, man-made and natural factors together increased vulnerabilities in cities. Subsequently, cities and urban areas are directly or indirectly causing global environmental problems,

climate change has impacts(frequent flooding, increase in temperature, rainfall) that are being felt at the micro and urban levels(UNEP, 2007).

However, Clarke (2000) says that most of the research work that has been carried out in this field urban areas have given less attention and has concentrated most in rural areas. Worse still, there is a great challenge of scarcity of data on the spatiality of vulnerability. On the other hand, vulnerability is also a subjective matter and can vary depending on people's perception towards hazard. Same circumstances can have different vulnerability outcomes depending on the local contexts. But given the increasing vulnerability to hazards among the urban poor, the consequences of urban floods are gaining increasing attention. In this regards vulnerability assessments will reveal the strengths and weaknesses in the existing adaptive capacities in developing countries in order to reduce the vulnerability to extreme weather events (Mirza, 2003).

Since urban vulnerability to disasters is after all a function of human behaviour and lifestyles, vulnerability assessments in this area can potentially focus on (a) explaining what constitutes urban vulnerability, (b) building a clear nexus between urban vulnerability and environmental degradation, (c) identifying vulnerabilities using assessment tools, and (d) understanding the potential of multi-hazards in an urban context (UNEP, 2007).

The UN report on World Urbanization Prospects has already projects that more than 50 percent of the world's population will be living in cities and almost all the growth of the world's population between 2000 and 2030 is expected to be in the urban areas of less developed countries. According to UN projections, the urban population in Asia is expected to double by 2030.

It was mentioned by Adger (2003) that the poor, mostly in urban and urbanising cities of Asia, are highly vulnerable to climate change because of their limited access to profitable livelihood opportunities and limited access to areas for safe and healthy habitation. Consequently, the poor sector will likely be exposed to more risks from floods and other climate-related hazards in areas they are forced to stay in (Adger, 2003)

1.1.3. Vulnerability Assessment studies on Dhaka, Bangladesh

With regards to climate change and hydrological disasters a number of studies(Ali, 2000; A. Ali, 1996) (Matejka, 2002; Nicholls, 2007; Paul; Alak; Rahman, 2006)focus on the coastal regions of Bangladesh. These studies mainly focus on coastal vulnerability in regards to climate change.

There are very few studies have been done based on flood vulnerability assessment on Dhaka. The following paragraphs summarize the hydrological disaster studies which perceive vulnerability from hazard perspective. Alam (2004) analyzed Bangladesh's vulnerability to climate change. He analyzed five climate change induced challenges for Bangladesh: drainage congestion due to higher water levels in the influence with the rise of sea level, river bank erosion, scarcity of fresh water due to less rain as well as higher evapo-transpiration, frequent floods and long-lasting and extensive drought and salinity in the surface, ground and soil.

An important study on this issue was done by Mirza (2002), he concluded that impacts of global warming are likely to have significant effects on hydrology and water resources of the Gnages, Bramhaputra and Meghna basins and most likely will lead to more serious floods in Bangladesh with a number of negative inference for Bangladesh's flood infrastructure management. The same issues have further detailed by Mirza, and Erickson (2003). They had shown that due to changes in the peak discharges of the Gnages, Bramhaputra and Meghna significant changes in the spatial extent and depths of inundation may occur and also will have rapid changes in inundation, finally changes in land inundation will have impact on

agriculture as well as cropping patterns. They suggested to reduce the impact of increased flood hazard due to climate change to strengthen the flood management system and required changes in policies to adaptation measure in Bangladesh.

1.1.4. Vulnerability Studies related to Socio-Economic Factors

Brouwer, Aftab, and Brander (2006) provided a case study of climate change and flooding in Bangladesh looking specifically at socio-economic vulnerability and adaptation to climate change by exploring the complex relationship between vulnerability, poverty and climate change focusing on household and community vulnerability and adaptive capacity. The report illustrated that households with lower income and less accessibility to natural assets face higher exposure to risk of flooding. Furthermore, inequality in income and asset distribution at community level tends to be highly exposed, implying that individual's (household) vulnerability are correlated with collective (community) vulnerability. The report also found that the people facing the highest risk of flooding are the least well prepared, both in terms of household-level pre and post flood situation.

Another important study that addressed socio-economic factors influencing the vulnerability to climate change is Adger, Huq, Brown, Conway and Hulme (2003). They pointed out that societal vulnerability to the risks associated with climate change may increase social and economic challenges, particularly for those parts of societies are least well prepared. Mutton et al (2004) concentrated on the human vulnerability related to adaptation processes of people who have been displaced by river bank erosion in Bangladesh.
Most of the research focused on climate change impact in coastal area while human vulnerability studies especially on Dhaka have been largely neglected. Still, there is a big gap in GIS based vulnerability assessment in combination with flood vulnerability assessment for slum dwellers in Dhaka.

1.1.5. Relevance to select Study area Dhaka

According to UNHABITAT, (2008/2009) Dhaka, the city of 13 million people, is one of the fastest growing (more than 4 percent annual growth rate) cities in south-east Asia will accommodate 20 million population in near future(2025). The total number of people living in the city means that the negative consequences of climate change are likely to be felt by a large number of people, especially the urban poor who live in flood-prone and water-logged areas (UNHABITAT, 2008/2009).

Climate change scientists and researchers predict that climate change will impact the city by increasing flooding and drainage congestion and heat stress. Whereas, Dhaka has a very low elevation level, 2 to 13 meters from mean sea level (see map in Annex 3). This means that a slight increase in sea level is likely to swallow up larger parts of the city. Additionally, high urban growth rates and high urban densities have already made Dhaka more susceptible to man made environmental hazard.

A survey carried out by Centre for urban studies (2005) in Dhaka have found that around 60 percent of the slums in the capital city have poor or no drainage facilities and are prone to frequent flooding. The problems aggravated during flooding due to poor housing quality and high population density. The study also found that more than one-third of residence of Dhaka is living in a very poor housing where more or less all the structures are very weak to face any kind of natural hazards. Almost all slums are dominated by single-storey structures that increase flood vulnerability. Moreover, slums in Dhaka are highly populated, population density in slums is roughly 200 times greater than the other part of the city, , approximately 80 per cent of the slum population in Dhaka lives in high dense slum clusters of between 500 and 1,500 persons per acre (UNHABITAT, 2008/2009)

From the literature review it is clear that there is an obvious need to develop a contextual framework for vulnerability assessment in context of climate change. Most of the vulnerability studies focus on the

coastal region of Bangladesh while vulnerability assessments in urban areas are largely ignored. The high sensitivity of climate change has been highlighted in the climate change scenarios (IPCC, 2007), but very few studies (Alam, 2004; Mirza, 2003) have actually tried to assess climate change vulnerability in reality. There seems to be no vulnerability assessment framework for Dhaka specifically considering its indigenous socio-economic and spatial dimensions.

1.2. Problem Statement

According to Birkmann (2007) one of the most important aims of developing tools for measuring vulnerability is to help link the gap between the theoretical concepts of vulnerability and day-to-day decision making. Therefore he stressed to view vulnerability as a process. Moreover he said within this process, measures and instruments need to be defined which will allow to assess the past, current, and potential future areas and people at risk or vulnerable. Besides the generation of new and better data for global and local vulnerability and risk assessment, it is also important to strengthen co-operation and exchange between global and local approaches (Birkmann, 2007). The concepts presented by Bohle (2001); DFID (1999) and Turner et al. ,(2003) primarily focused on approaches that were applied within the disaster-risk community; a more intensive exchange of approaches to measure and assess vulnerability between the social-vulnerability school and the global environmental change community is desirable(cited in Birkmann, 2007).

To understand the consequences of climate change requires knowledge about the interactions of climate change and other stresses and stressors and about the resilience and vulnerability of human–environment systems that experience them. In this research, vulnerability is conceptualized as the internal characteristics of a system; how the system reacts with external shock especially when human-environment relation is dynamic. Therefore, vulnerability analysis offers a way of conceptualizing interacting stresses and their implications for particular human–environment systems. This study intends to presents a contextual framework for vulnerability analysis and uses this framework to illuminate examples in Dhaka, Bangladesh. Indigenous poor people in Dhaka city are the focus of this study because their close association to the environments in which they live. The study also illustrate the importance of understanding (and developing place-based methods) stress interactions and the characteristics of particular human– environment systems. Moreover, meaningful analyses of human–environment dynamics require the full participation of local people, their knowledge, perspectives, and values.
Vulnerability assessments for communities in Dhaka require in-depth investigations into the way people living in these areas view as main focus and how these residents perceive the interrelations among climate change, and human environmental change. These might include opportunities for stakeholders in their decision making process concerning about environmental and socio economic changes which option they are going to take towards the way of future development for a sustainable city.

1.3. Overall Objective

The overall objective of this study is to develop and apply a localized contextual framework for an integrated assessment of urban flood vulnerability that focus on climate change and other stresses/stressors of human–environment systems.

1.3.1. Specific objectives

1. To analyze current vulnerability context.
2. To develop a contextual framework at local level.
3. To apply the developed framework in study area.

1.3.2. Research questions for each objective

1. To analyze current vulnerability context

    i. What are the characteristics of local system that makes specific group of people vulnerable in study area?

2. To develop a contextual framework at local level to assess flood vulnerability.

    i. How do social and biophysical conditions of human–environment systems in Dhaka influence the vulnerability of these systems when they are impacted by climate and other stressors?

    ii. What are the stresses and combinations of stresses that make human–environment systems most vulnerable in study area?

    iii. How can a contextual framework be developed from the information gathered?

3. To apply the contextual framework in study area.

    i. What are the local level factors that can be used to assess climate change vulnerability?

1.4. Research Design and Methods

The aim of this study was mainly to find a way how one can work in a scarce data environment in assessing urban vulnerability with regards to climate change. However, in this study, literature review, climate related information, quantitative and qualitative questionnaire survey was the main source of information. This study also aimed to emphasize on the indigenous local people's perception about the stress of their daily life. The contextual framework was developed using analyzed and interpreted qualitative and quantitative data about the sensitivity and adaptive capacity of local indigenous poor people of Dhaka (Figure 1-2) outlines the conceptual framework under which the entire study is based. It presents various phases: the analysis of human-environment relationships, identifying natural and human stress in study area (by means of qualitative and quantitative data analysis), developing a contextual framework from the information gathered and to apply developed framework in study area. Finally a vulnerability analysis was performed in local context considering the impacts of climate change on urban poor in Dhaka.

1.4.1. Analyze the human-environment system in the study area (Dhaka)

To analyze the current vulnerability context in the study area it was important find out the spatial characteristics of the study area and changing trends of the human environment system. Therefore, in chapter 4, this study analysed the flood situation in Dhaka based on secondary data and information gathered from different sources, physical growth and demographic features of the city, rainfall, elevation level, flood proneness and climate change trend and its' possible impact on the city and its' inhabitants.

1.4.2. Identifying household stress in study area in order to select vulnerability assessment indicators

To understand the socio-economic characteristics and daily life stress of the people in the study area, qualitative in depth interview with local people was carried out by means of internet phone calls. To support the qualitative interviews, questionnaire survey data (borrowed from a Flood Hazard Research project, Cologne University, Germany) was used in order to perform statistical analysis and spatial multi criteria evaluation.

1.4.3. Developing contextual framework

All information (spatial and non-spatial, qualitative and quantitative) together helped to develop a contextual framework considering human environment system and people's sensitivity in study area.

1.4.4. Vulnerability level and spatial pattern of vulnerability

In order to perform an overall vulnerability analysis, indicators were developed in chapter 5. After analysing household stress (household sensitivity, adaptive capacity) and spatial dimension of study area (exposure) an overall vulnerability analysis was carried out by means of spatial multi criteria evaluation technique (ITC, 2005) at household level. After obtaining the result of overall vulnerability, spatial autocorrelation method was applied to analyse spatial pattern of household vulnerability. In chapter 3 research methods and techniques will be described in detail.

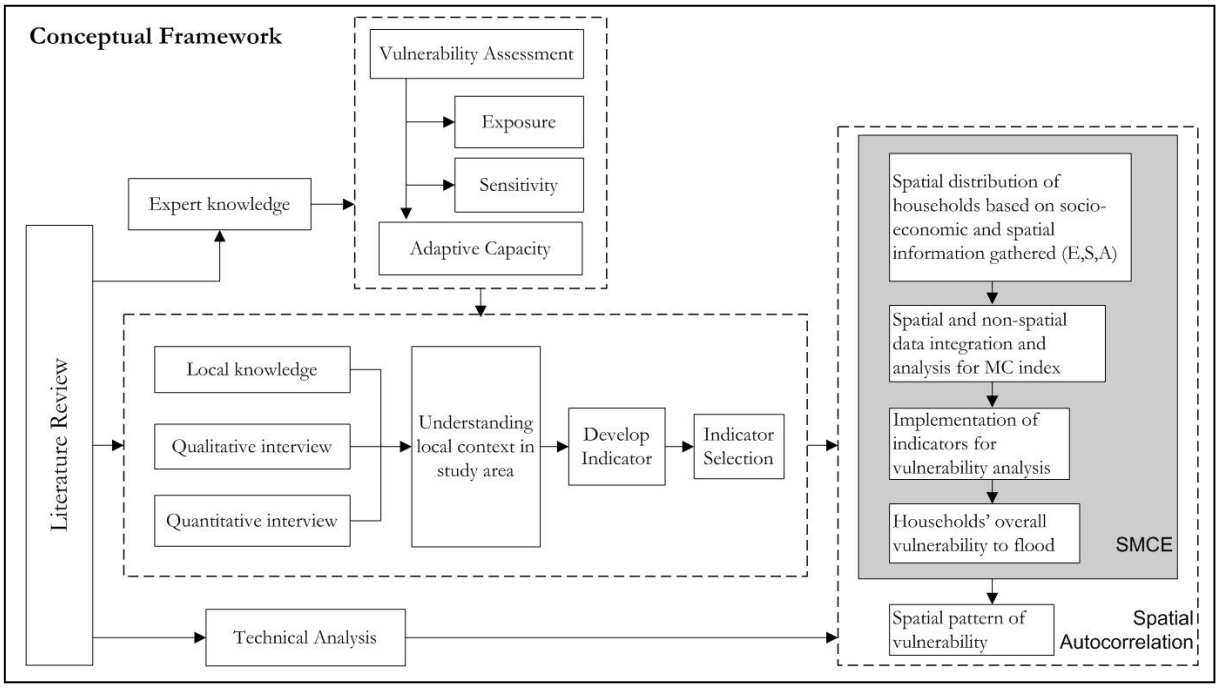


Figure 1-2: Research Conceptual framework

Source: Constructed by Author

2. LITERATURE REVIEW

2.1. Basic Concepts of Vulnerability

Vulnerability is an important component in the disaster risk management cycle. On the contrary vulnerability is probably the most complicated components of multi-hazard risk assessments. Researchers from different scientific disciplines have for a long studied the variables, causes and possible solutions to the issue of vulnerability.

In this regard, this chapter presents an overview on vulnerability; different aspect of vulnerability and its relevance on the disaster management cycle, in particular considering climate change issues. Additionally an elaborated view from a disaster risk management perspective is summed up in this chapter. I end up discussing relevant indicators used in disaster risk management.

2.1.1. Paradigms of risk and vulnerability

The concept of vulnerability originated from social sciences based assessment of disaster risks in the 1970s. At that time vulnerability was mostly related to buildings and structures at risk and how these were damaged by hazards, due to physical forces. The study of disaster and risk has gone through an interesting evolution of paradigms throughout the past decades, in particular rhe behavioural paradigm (Blaikie, 1994), the physical vulnerability paradigm (Cardona, 2003) and the complexity paradigm (Hilhorst, 2003).

2.1.2. Vulnerability in Disaster Risk Management

Key elements of disaster risk management can be classified into two major parts; one the is pre-disaster phase, the other one is the post disaster phase. Vulnerability assessments should take place in the pre-disaster phase. There are four major phases in the pre-disaster phase: risk identification, mitigation, risk transfer and preparedness. Risk identification has four stages hazard assessment, vulnerability assessment, risk assessment and GIS mapping and scenario building(Westen & Kingma, 2010). To assess hazard, risk and to perform GIS mapping and scenario building with spatial information plays an important role. On the other hand to assess vulnerability spatial information is important but it requires the combination of other information. Regarding this issue in this study different indicators are developed based on socio-economic and spatial characteristics of households in study area.

2.1.3. Working definitions of Vulnerability

The starting point for reducing disaster risk and promoting a culture of disaster resilience lies in the knowledge of the hazards. It also lies in knowing the physical, social, economic, and environmental vulnerabilities to disasters that most societies face. Additionally, knowledge of the ways in which hazards and vulnerabilities are changing in the short and long term, followed by action taken on the basis of that knowledge is of utmost importance (UNDP, 2004).

Considering that vulnerability is the main focus of this research, an extended explanation of the evaluation of the definition from different perspective is necessary.

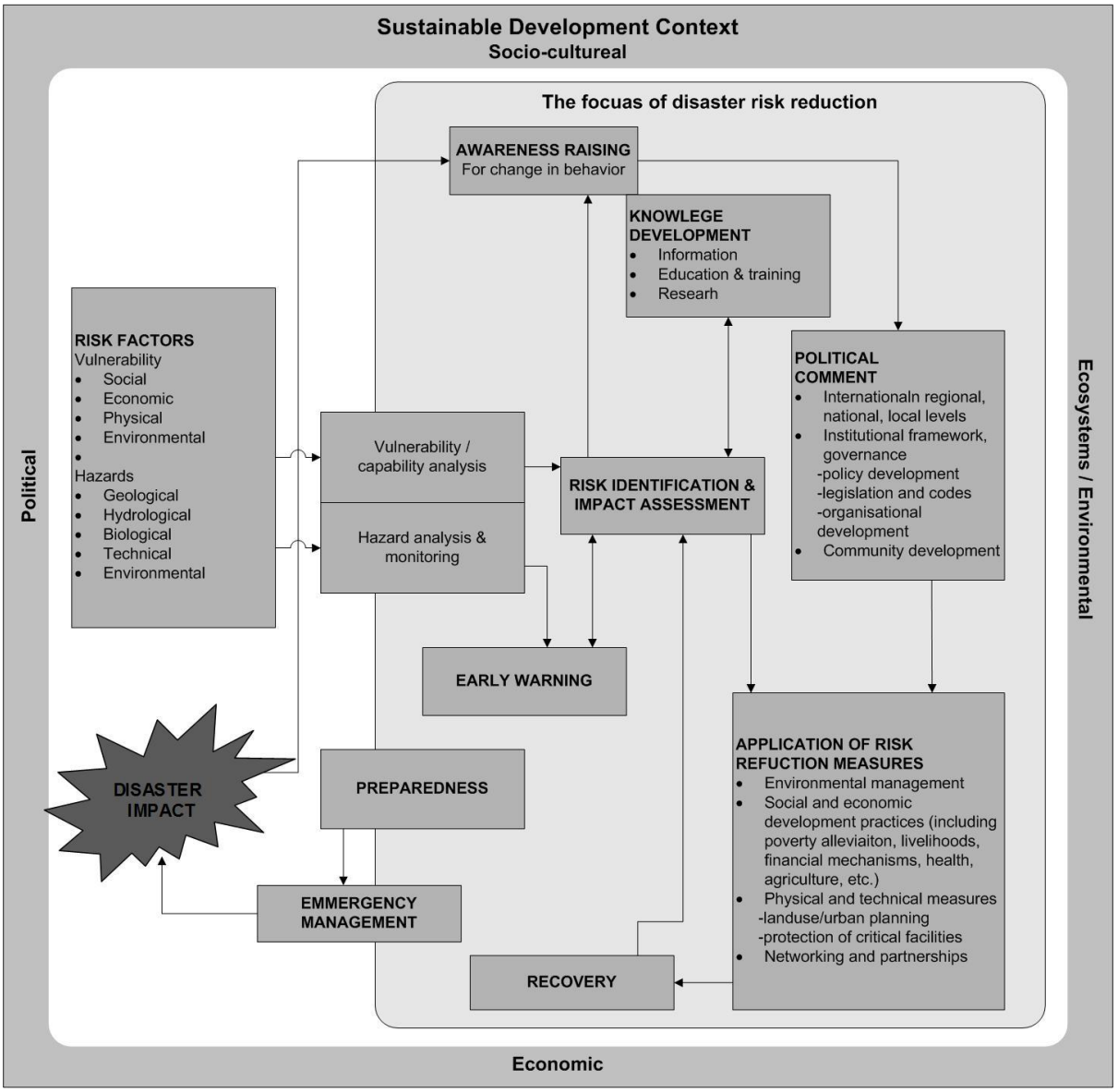


Figure 2-1: The ISDR Framework for Disaster Risk Reduction

Source: (UN-ISDR, 2004, p. 15)

Defining vulnerability

Although there is no universal definition of vulnerability, various disciplines have developed their own definitions about what vulnerability means. In this regard, it is necessary to discuss how vulnerability is defined in the literature and to explore knowledge about other terms that are related to vulnerability. Birkmann (2006) in his book "Measuring vulnerability to Natural hazard" mentioned that scientist in different field aim to measure vulnerability, yet they cannot define it precisely.

Vulnerability is:

"The degree of loss to a given element at risk or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total damage)" (UNDRO, 1991).

"A human condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard" (UNDP, 2004)

"The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. (UN-ISDR, 2004)

Kelly and Adger (2000) defined social vulnerability in terms of the capacity of individuals and social groupings to respond to – that is, to cope with, recover from or adapt to –any external stress placed on their livelihoods and well-being, focussing on socioeconomic and institutional constraints that limit the ability to respond effectively.

However, this research agrees with the definition given by Adger (1996) where he tried to focus on the aspect of vulnerability as a combination of social factors and environmental risk. Moreover, he defined vulnerability to climate change as it involves changes in these parameters over time.

According to Adger and Brown (2009) the basic elements of vulnerability are:

1. **Exposure.** The nature and degree to which a system experiences environmental or socio-political stress.

2. **Sensitivity.** The extent to which a human or natural system can absorb the impacts without suffering long-term harm or some significant state change. This concept of sensitivity, closely related to resilience, can be observed in physical systems with impact response models, but requires greater interpretation in ecological and social systems, where harm and state change are more contested.

3. **Adaptive capacity.** The ability of a system to evolve in order to accommodate environmental perturbations or to expand the range of variability with which it can cope.

Most commonly used concept about risk and vulnerability is depicted by the formula given below where risk is defined as combination of hazard and vulnerability.

Risk = (Hazard*vulnerability/adaptive capacity)

According to the UN report on 'Living with Risk' (UN-ISDR, 2004, p. 16), "The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions."

However, risk is generally defined as the product of the hazard probability and its consequences. It can be viewed as a function of the hazard event, and the vulnerability of the elements exposed, while vulnerability is the intrinsic and dynamic feature of an element at risk.

Several authors (Blaikie, 1994; Cardona, 2003) have proposed various subdivisions of vulnerability by using similar terms. For easy understanding only four types of vulnerability will be considered here.

Physical Vulnerability: The potential for physical impact on the built environment and population. All the physical cultural assets are included in this category (infrastructures, buildings etc)

Economic vulnerability: The potential impacts of hazards on economic assets and processes (i.e. business interruption, secondary effects such as increased poverty and job loss) Vulnerability of different economic sectors

Social vulnerability: The potential impacts of events on groups such as the poor, single parent households, women, the handicapped, children, and elderly; consider public awareness of risk, ability of groups to self-cope with catastrophes, and status of institutional structures designed to help them cope.

Political-Institutional vulnerability: It includes intangible elements such as government structure and decision making, disaster/risk related organizations etc.

2.2. Vulnerability assessment methods and frameworks

Bohle's (2001)conceptual framework of social vulnerability shows

an external and an internal side of vulnerability. The external side involves the exposure to risks and shocks; it describes exposure to hazards as a key component of vulnerability. The internal side refers to coping and the capacity to anticipate, cope with, resist and recover from the impact of a hazard. Vulnerability is the result of interaction between exposure to external stressor and the coping capacity of the affected.

A more elaborate model vulnerability by Turner et al., (2003) is shown below (see Figure 2-2). The model operates at multiple spatial (the world, region and place), functional and temporal scales, where interactions take place. Vulnerability is registered not by exposure to hazards (stresses/stressors) alone but also resides in the sensitivity and resilience of the system experiencing such hazards. The sensitivity to exposure is defined by the human-environmental conditions which is always subjective and dynamic.

It couple and examines vulnerability within the broader and closely linked human environment context. The framework defines exposure, sensitivity, and resilience (as coping response, impact response and adaptation response) explicitly as part of vulnerability. This model has three advantage: Firstly it couples human-environmental system, secondly it facilitates the identification of critical interactions in the human-environment system that suggest response opportunities for decision makers, and thirdly it is open to the use of both quantitative and qualitative data.

However this framework cover a very wide scope of vulnerability since it doesn't says anything about the process to assess vulnerability in a localized context.

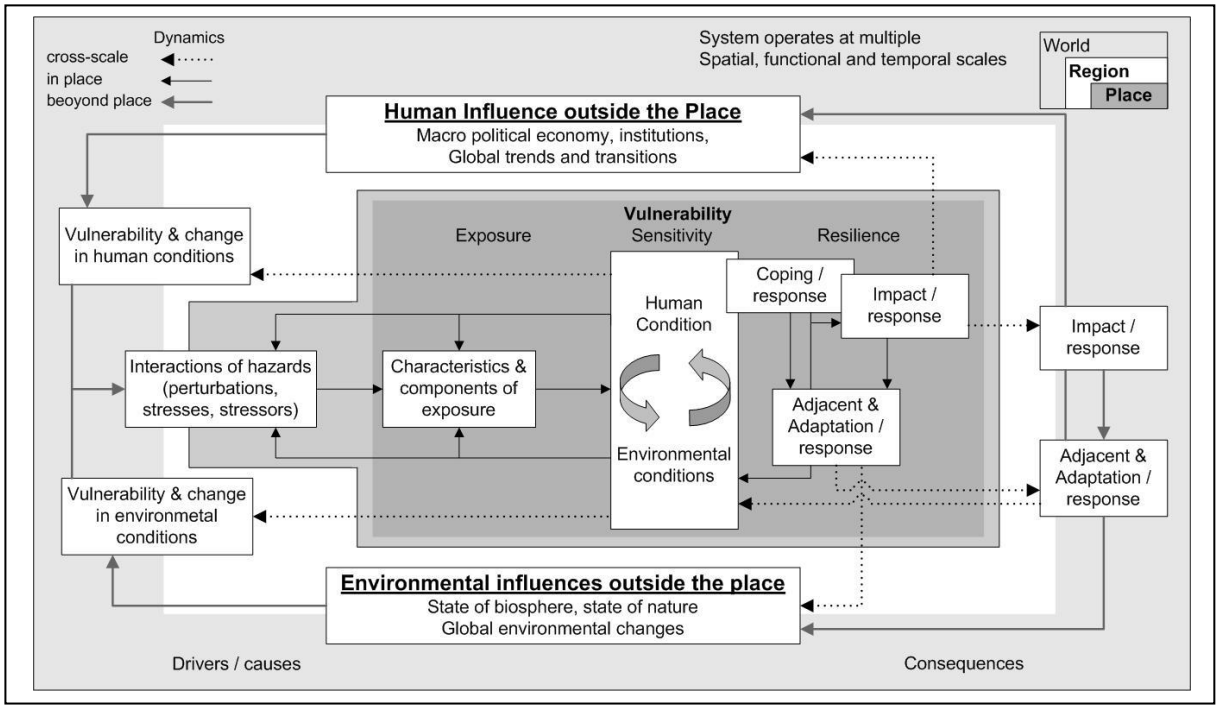


Figure 2-2: Vulnerability framework

Source: Turner et al (2003)

2.3. Measuring Vulnerability: Major Challenges of vulnerability assessment

In IPCC fourth assessment report (2007) it is mentioned more research work is needed in the field of identification of social vulnerability to multiple stressors due to climate change and environmental change. However, in climate change related vulnerability assessment research, the main issue is data scarcity environment in developing country perspective. To fit the global climate scenario in local level environment, it is needed to develop a new approach; therefore, current research seeks an opportunity to develop a new contextual framework to assess vulnerability in the context of climatic and environmental changing circumstances when developing countries are more vulnerable in this regard.

From global change perspective, Schröter, Polsky, & Patt (2005) have proposed an eight step method for vulnerability assessment. The eight steps are:

1. Define the study area in tandem with stakeholders;
2. Become aware of the study area and its contexts;
3. Hypothesize who is vulnerable to what;
4. Develop a causal model of vulnerability;
5. Find indicators for the components of vulnerability;
6. Weight and combine the indicators;
7. Project future vulnerability;
8. Communicate vulnerability creatively.

2.3.1. Level of vulnerability assessment

Fekete et al, (2009) mentioned that scales are an important element in vulnerability assessments. Place-based analysis seeks to detect the vulnerability at a certain locality (e.g., (Turner, et al., 2003)). The terminology scale is the vertical axis along which any objects of interest are ranked, like on a ruler. The term type of scale distinguishes different spatial, temporal or other analytic scales (Gibson C, 2000)

Villagrán de Leon,(2006) developed a framework for decomposing vulnerabilities as illustrated in the diagram below. In this figure, three dimensions of vulnerability can be distinguished; the scale or geographical level (from human being to national level), the various sectors of society ("elements at risk "), and 6 components of vulnerability ("types of vulnerability"). Hazard intensity is not further specified, the method is based on a very high magnitude event.

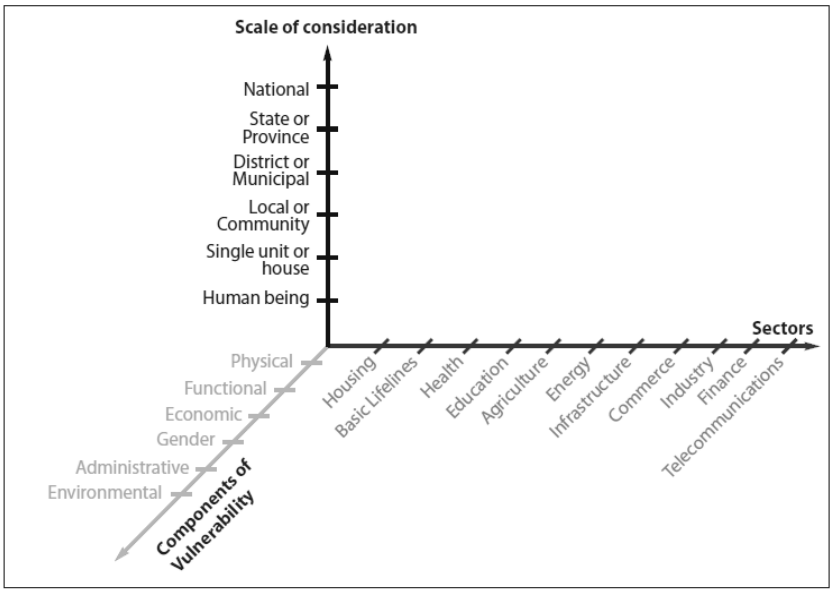


Figure 2-3: Framework for vulnerability introducing the concept of independent dimensions of scale of consideration, components, and sectors (Villagrán de Leon, 2006).

In this study, vulnerability assessment will be based on household level considering the socio economic and spatial variation of the available household based data. The gathering of accurate, reliable and accessible data to estimate and measure vulnerability is a big challenge when dealing with vulnerability assessment at various levels (Brikmann, 2006). In addition one of the main challenges of this study is to identify appropriate characteristics and phenomena that represent susceptibility and coping capacity of elements exposed to floods at the local level using statistical data and new data gathered through a questionnaire based household survey.

Vulnerability assessment at local level describes neighbourhoods or households. It is especially useful to carry out in-depth household surveys to collect important information about the vulnerability of the people. The study on vulnerability of communities exposed to floods at the local level in urban areas encompasses different thematic clusters mainly, human vulnerability.

The local level case study demonstrates advantages in data mining and in capturing the roots of vulnerability. Some issues especially of coping capacities of local residents can only be captured at this spatial level. The local level also allows for the use of extensive household surveys and other participatory methods which help to capture more detailed information complexity can be better captured (Fekete, et al., 2009)

Concurrently, there is a number of difficulties of vulnerability assessment at local level. Transferability of the approach to another level or region implies loss of information, mapping of a river system is severely constrained by data availability, some data are very local specific and therefore complicated to compare with other cities or a region.

3. RESEARCH METHODOLOGY

The objective of this chapter is to present the research methods and techniques that were applied in order to carry out the research. It describes the research methods that were used to collect primary and secondary data. ***At first*** *the data sources and collection techniques are explained then the method that was used to analyze this data sets is elaborated. This combination of methods and techniques was implemented in order to firstly understand the local context that exist in a local system in combination with expert knowledge and secondly the spatial relationships of this system. Secondly it will describe the procedures were taken for handling these local experiences and perceptions scientifically so that it can be used as valuable inputs to assess vulnerability within a framework in a GIS-environment.*

3.1. Conceptual Framework

This research conceptualized vulnerability assessment as the combination of local knowledge and expert knowledge. To develop a contextual framework it is important to integrate both. From the literature expert knowledge gaining starts which end up with the knowledge sharing with the stakeholders in local level. Finally it plays role to understand the local context. Considering these two types of knowledge sharing gives a good platform to develop indicators to assess vulnerability in the local contexts. Therefore it was tried to bring both local and scientific knowledge in one framework. Finally the information collected was implemented by means of analytical power of GI Science.

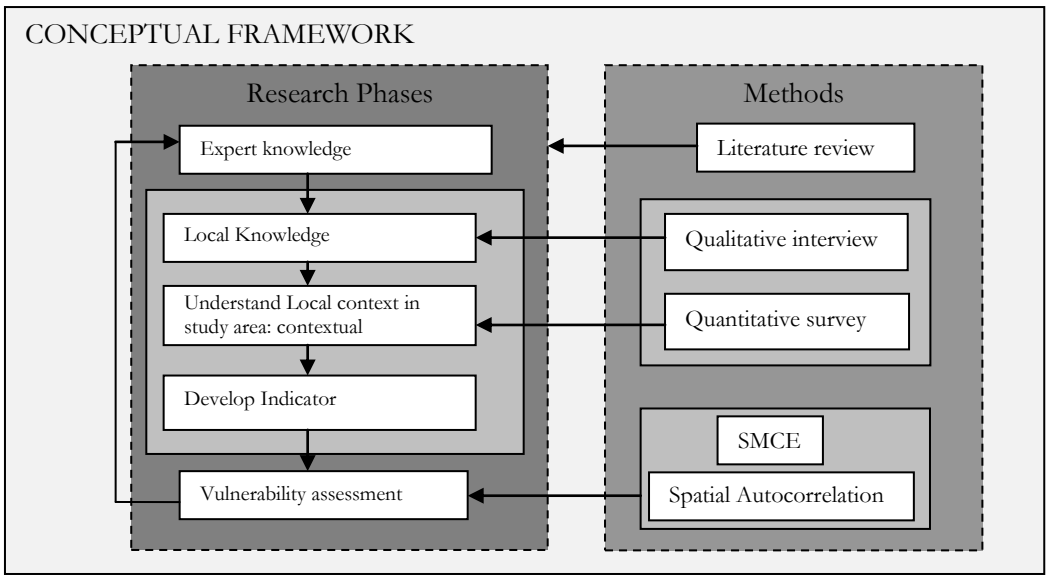


Figure 3-1: Conceptual Framework Source: Author

Different research methods and techniques were used in order to systematically collect and analyze data to answer the research questions properly. A combination of both qualitative and quantitative data collection techniques was considered to be important for this study in order to explore diverse insights in all spatial and non-spatial variables such as peoples' thoughts, perception, local context and understandings of the characteristics, origin and consequences of vulnerable situation within the slum settlement. In order to develop a contextual framework it is important to accomplish an in-depth knowledge about study area. The following section will briefly describe about research methods and techniques were adopted in this study.

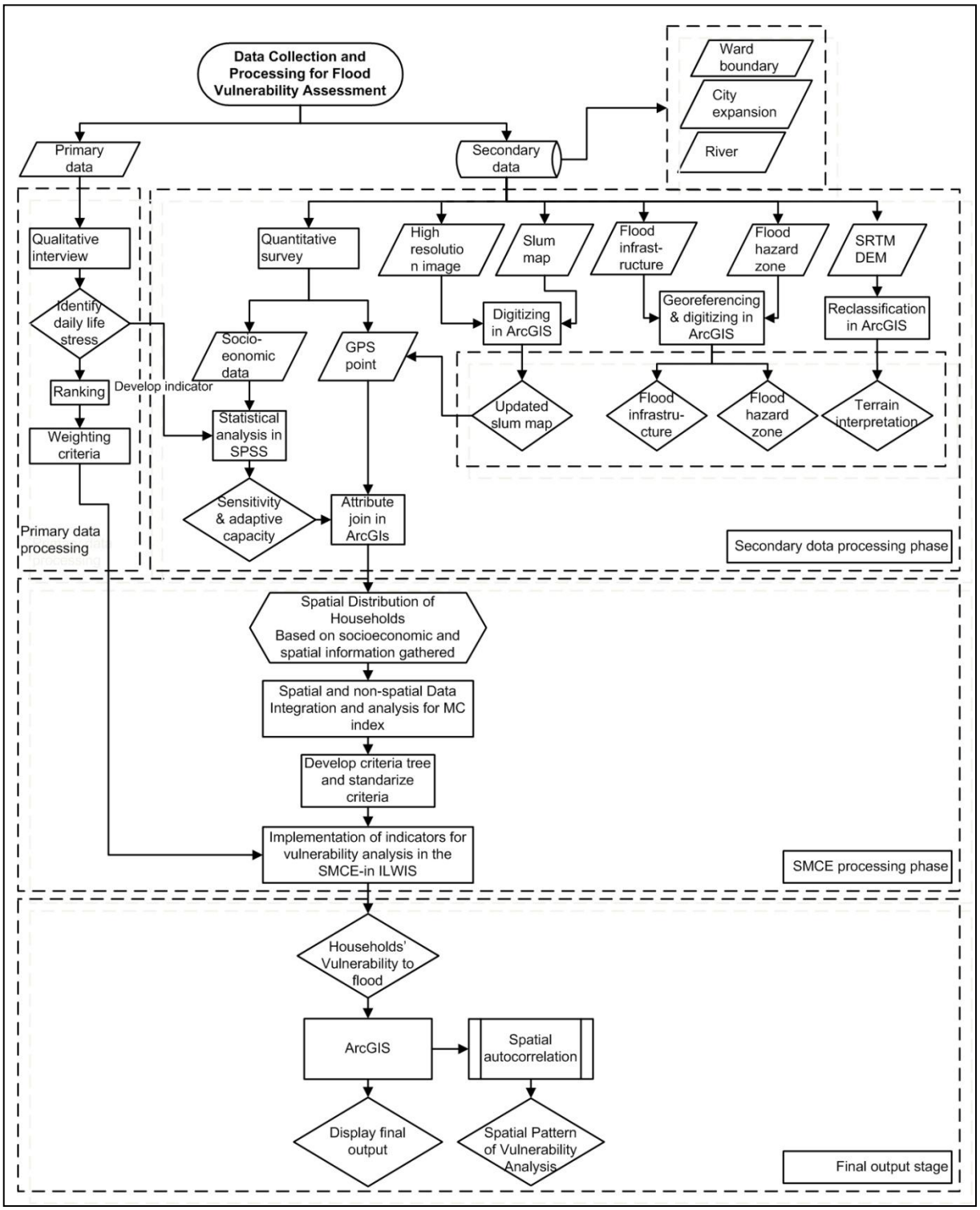


Figure 3-2: Methodological and Technical Framework for Flood vulnerability Assessment in a localized Context

Source: Author

3.2. Data sources and methods taken

3.2.1. Literature review and secondary data collection

According to Kumar (2005) literature review is an integral part of entire research process and makes a valuable contribution to almost every operational step of the research. Therefore to establish theoretical background since the initial stage of the research a considerable amount of time was spent to explore relevant literature, collection and compilation of secondary sources of information and data collection.

This helped to gain an in-depth knowledge beforehand about the study area and problem under study. The secondary data was gathered from the published literatures like journals, books, and articles. In regards to the study area, specific information about the study area were gathered from; other research project ongoing in Dhaka (spatial information in shape file format), Centre for Urban Studies report (2005), International reports published online (UNDP, IPCC), Government website and other published and unpublished relevant reports on Dhaka. This was intended to compliment primary data and fill in the knowledge data gaps that primary data collection methods was not able to address especially the limitation principle researcher has in regards not to visit field during the research.

For GIS analysis secondary data were collected through personal communication with the other research project is ongoing on Dhaka (see Table 3-1.) The spatial information was collected in shape file format which was used to do spatial analysis in GIS environment such as river, DMDP boundary map, slum settlements, and Dhaka city expansion map so on. In some cases data sets are in JPEG format (flood hazard zone, flood and drainage infrastructure) those was digitized and geo referenced by author. In the CGIAR-CSI, Geoportal, 2010 SRTM DEM was downloaded and reclassified in order to analyze the distribution of slum area based on height from mean sea level.

Table 3-1 Data Type and Data Source

Data Type	Description	Source
Spatial	Shp. File: River, DMDP boundary, Expansion of Dhaka city JPEG: Flood Hazard zone, Flood Infrastructure and drainage	The Dhaka-INNOVATE Project, Humbolt University of Berlin, Germany The Urban Livelihoods Project, University of Dortmund, Germany
Satellite Image	Dhaka city, 2005 (Ikonos), SRTM DEM(90m)	The Mega urban Food System of Dhaka, Bangladesh, University of Bonn, Germany, CGIAR-CSI, Geoportal, 2010
Questionnaire survey	625 Households (collected in November December, 2009)	Dhaka Hazard Slum Survey, 2009, University of Cologne, Germany
GPS survey	625 Households	Dhaka Hazard Slum Survey, 2009,University of Cologne, Germany
Qualitative Interview	Will be conducted through Internet phone calls	Researcher (with help of Local expert)
Scientific knowledge	Relevant previous studies	Literature review (Govt. report, International publication; UNDP, IPCC), Books, Journals The megaurban Food System of Dhaka, University of Bonn, Germany
Conventional photos of study area	Flood scenario, housing and services, living condition etc.	Dhaka Hazard Slum Survey, 2009, University of Cologne, Germany, Author.

3.2.2. In-Depth qualitative interview

Main purpose to use qualitative research in this study is to gain insight of the local system which helped to achieve research objective two. In this phase of the study it was needed to understand household stresses and local human environment system which plays significant role to increase flood vulnerability in relation to climate change. According to Thomas (2008): "qualitative research allows the subjects being studied to give much 'richer' answers to questions, and may give valuable insights which might have been missed by any other method."

Dunn (2005) mentioned that the sample size selection in qualitative research is not as important as quantitative research. However, in qualitative research, the sample is not intended to be representative since the emphasis is usually upon an analysis of meanings in specific contexts (Robinson, 1998 cited in Dunn, 2005). It depends on the research purpose and available time and resources. Considering the time and resource limitation therefore twelve household was selected randomly to perform in-depth qualitative interviews. One semi-structured questionnaire (Annex 2) was pre-designed to keep consistency and relevancy during the interview at the same time interviewee was enlightened to share their experience and knowledge in brief. All the qualitative interviews were collected by using internet phone calls. On the other hand one field expert was employed to help in this regard to collect information and manage the situation during interview period. All the interviews were recorded in order to listen several times which enriched the analysis. During listening the interview records researcher took notes and pointed out all important and relevant information was given by interviewee. Later on these information was structured to develop a cause effect relationship and organized into sequential format to identify households daily life stress and its' close association with weather circumstances. During interview sharing daily experience and historical behaviour about the last flood was important aspect to talk with. Being a part of local society and previous work experiences (two years working experience as research assistant) with the same community enabled the researcher to understand the local dialect and the internal characteristics of the local system.

3.2.3. GIS based Quantitative survey (Structured interview at Household level)

This research is based on a detailed questionnaire survey at household level was conducted in November and December 2009 by researchers of the University of Cologne in cooperation with the Universities of Dhaka and Rajshahi in five potentially flood-affected slum settlements. The five study sites were selected to be spatially evenly distributed over Dhaka and to represent different types of slums with respect to flood affectedness.

The questionnaire was pre designed based on DFID livelihood approach (1999) and linked with Turner's vulnerability framework (2003) which covers all aspect of household vulnerability in detail.

Strength and weakness of using predefined questionnaire survey

From the qualitative interview households' daily life stress was identified after that indicators were selected from the questionnaire data set. No doubt this is one of the biggest challenge of this study to use predefined questionnaire from another study but as long the purpose of both study is the same to assess flood vulnerability and this questionnaire is covering all livelihood aspect based on DFID (1999) and following the Turner framework (2003) this study doesn't have any contradiction with this research. Moreover the output of this research can play a vital role to improve vulnerability assessment in local context. Furthermore this type of collaborative research can be a good example of optimal use of resource and time especially for the developing country where resource is very limited. In practice there were some difficulties to use a predefined questionnaire survey though researcher tried to readjust those problem by using proxy indicator. For example there was no direct data about households' awareness level. In this case NGO involvement, illness during last flood was used to asses the households' awareness level. For

more information this questionnaire is covering 425 variables for each household therefore it was capable enough to accomplish the current study. The following section will try to explain the linkage of vulnerability component and five livelihood assets to show current research is supplementary with this questionnaire survey.

3.2.4. Vulnerability context and livelihood assets

The Vulnerability Context encloses the external environment in which people live. People's livelihoods and the wider availability of assets are fundamentally affected by critical trends as well as by shocks and seasonality – over which they have limited or no control (DFID, 1999). The model of Turner et al. (2003) defines the basic elements of vulnerability as 'exposure', 'sensitivity' and 'resilience'. While exposure describes the physical aspect of being prone to be hit by a natural event, sensitivity covers the socio-economic status of the household and resilience is understood as the ability to respond to an event. These three basic elements of vulnerability reside inside the local arena while households' instinctive living condition is combination of five livelihood assets.

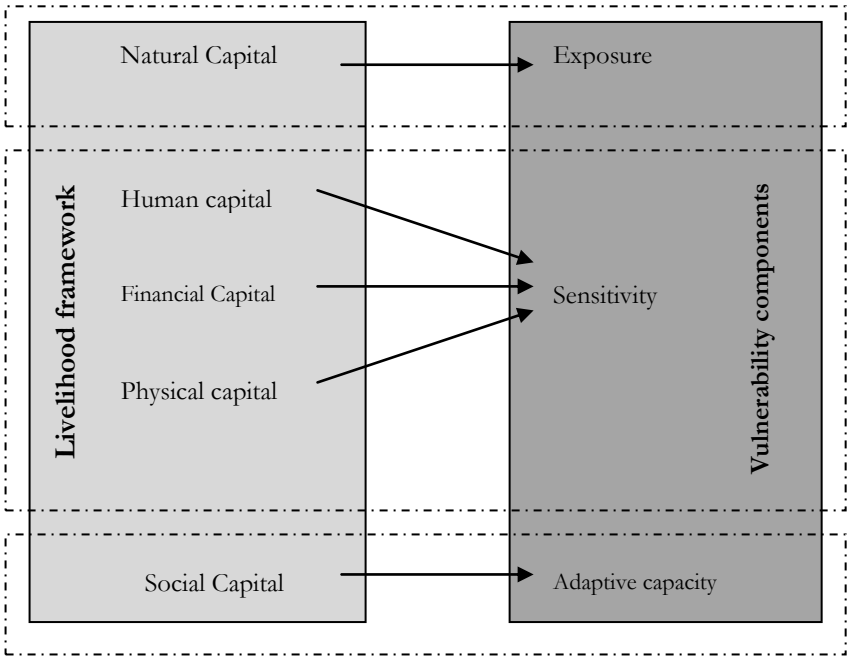
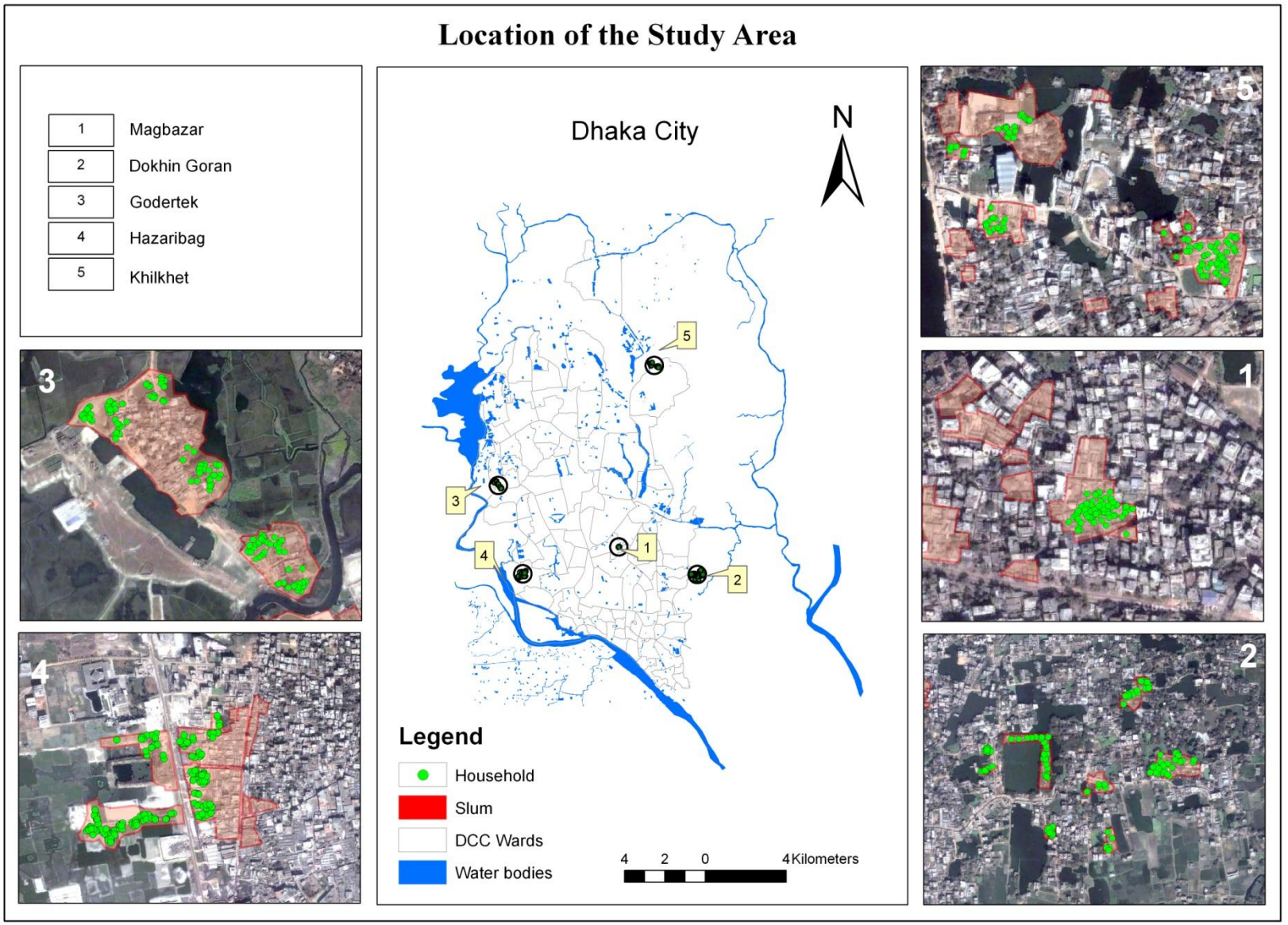


Figure 3-3: Linkage between vulnerability component and livelihood assets
Source: Constructed by author

In order to understand the households' sensitivity and adaptive capacity of the slum dwellers varying in local context of Dhaka, household assets was considered main basis to formulate this questionnaire.
According to the Dhaka hazard slum survey (2009) the descriptions of 5 study sites are: In this survey the reference units of the survey were selected at household's level. The term "marginal settlements" (slums) was taken from the most recent slum survey of the Centre of Urban Studies (CUS, 2006).

Spatial characteristics of study area:
Study site 1:Hazaribag East is protected by the western embankment and Hazaribag West is located in the immediate flood plane of the Buriganga river just outside the western embankment. Study site 2: Godar Tek is also protected by the western embankment of Dhaka city. Study site 4: Maghbazar is located in the centre of Dhaka city. It is protected by embankments and rather consolidated in its social and physical structure. Study site 3(Khilket) and Study site 5 (Dakshingoran) are located in the East of Dhaka and are not protected by any dykes or embankments.



Map 3-1: Location of study area

About 2000 households live in the five study sites; out of these 625 (Table 3-1) have been interviewed. Thus, this survey represents a complete sample of all households that experienced at least one severe flood in the five study areas (Aßheuer, 2009). These household surveys are also spatially referenced.

Table 3-2: Sample distribution at each study site

Study site Name	Sample No.
Hazaribag	198
Godartek	135
Maghbazar	71
Khilkhet	100
Dakhin Goran	121
Total	625

After identifying all relevant characteristics of household vulnerability from qualitative interview this household survey data were used by means of descriptive statistics in order to validate the qualitative interview findings. As it is mentioned before that only twelve in-depth interviews were carried out therefore to give this study more scientific basis this quantitative survey helped to pick only those indicator are really representative for entire study area. In addition, this household survey is the main source of information to analyze household vulnerability using multi criteria evaluation in ILWIS as they are also geo-referenced.

3.2.5. Spatial multi criteria analysis for Flood Vulnerability assessment (SMCE in ILWIS 7.1)

In order to analyze households' flood vulnerability within slum settlement of Dhaka, the Spatial multi criteria evaluation (SMCE) approach was used to identify and analyse the elements that constitute households' instinctive characteristics against flooding, which include the aspects related to the vulnerability component exposure, sensitivity and adaptive capacity. An analysis was performed on the different socio-economic, natural and environmental indicators, and how these determine the diverse impact of flooding inside the system.

In depth qualitative interview were carried out within slum settlements in order to identify and analyse the main aspects of everyday life of households, the way these households are disrupted during flooding and the level of their vulnerability to flood. The GPS survey was used to support the quantitative and spatial analysis of these aspects and explain in households' perspective how these factors were prioritized with a different importance level. During qualitative interview participants were asked to prioritize their problem in respect to flooding condition.

The aspects analysed were related to exposure: distance from river, household living in low land, Hazardous location, sensitivity: socio-economic status, type and number of income sources, total family income, household size, housing types, health condition, sources and access to drinking water, sanitary facilities, access to services (road condition). These condition were considered for both normal and disaster period.

All these aspects of vulnerability were analysed spatially and results were compared in five study area respectively. Vulnerability components, factors and indicators were combined by means of the Spatial Multi Criteria Evaluation (SMCE) method which is available in the ILWIS software.

The theoretical background for the multi-criteria evaluation is based on the analytical hierarchical process (AHP) developed by Saaty in 1980 (cited inWesten & Kingma, 2010) . According to Westen & Kingma (2010) extensive research has been done applying AHP to risk assessment study and they have also mentioned that SMCE module of ILWIS-GIS has capability to implement semi-quantitative model. The first step of this SMCE process decomposes the problem phase which defines the 'criteria tree' consisting of all Spatial and non-spatial factors and indicators. After that it considers standardisation of each indicator that converts different type of values into the one standard 0 to 1. The next step considered the weighting process which employs different method such as pair-wise, direct or rank order available in ILWIS SMCE. In each level of hierarchy there is option for weighting criteria based on its' contribution or performance to goal (Figure 3-4).

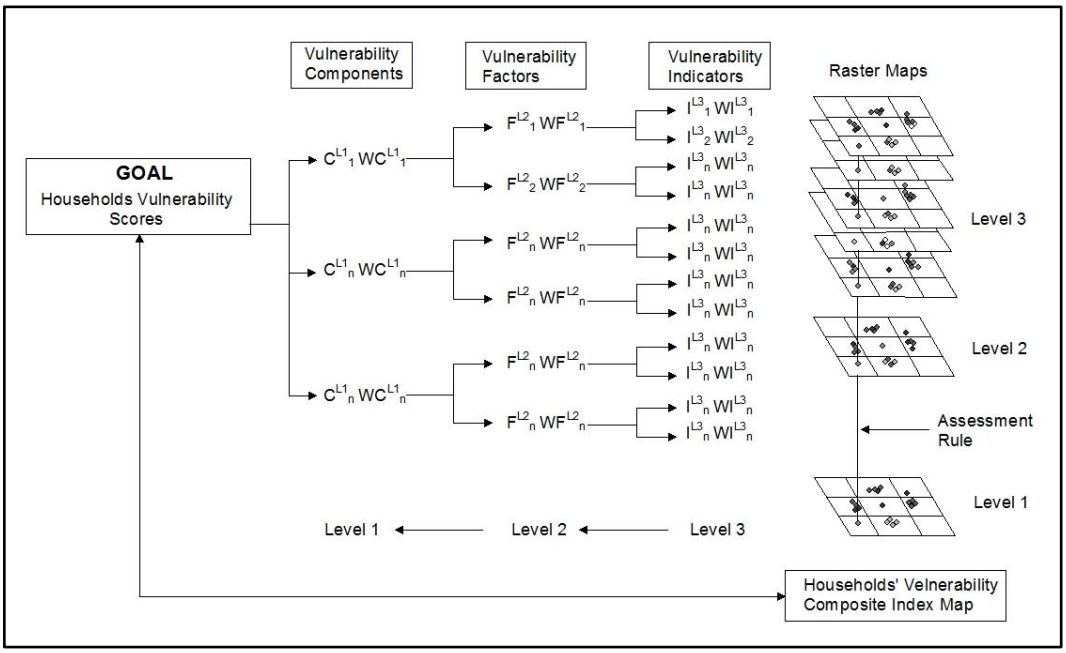


Figure 3-4: Analytical hierarchical process

Source: (Castellanos E. A.; Van Westen, 2007; Westen & Kingma, 2010)

In this study using local knowledge participants from study area were prioritize the criteria and weighing was applied from this result obtained from qualitative interview. In this study the vulnerability score was ranged from value 0 which refers no vulnerability when highly exposed or high sensitivity or less adaptive capacity was considered 1 which refers high vulnerability.

The complete analysis of both the aspects that contribute to the vulnerability of the households in the study area as well as the construction of the Spatial Multi-Criteria modelling for the households in the study area will be discussed briefly in result discussion chapter.

3.2.6. Point pattern analysis (Spatial autocorrelation in ArcGIS 10)

Spatial autocorrelation is a powerful analytic technique (Goodchild cited in Shen, 1994). It is concerned with the degree to which objects at some place on the earth's surface are similar to other objects located nearby. If objects which are spatially close also be likely to be similar in attributes, then the pattern as a whole can be said positive spatial correlation. Conversely, if objects which are close together in space tend to be more divergent in attributes then as a whole it can be said negative spatial autocorrelation is exist. When attributes are not dependent at all then the relationship can be said zero.

"To analyze the spatial distribution of some phenomenon, it is important to know two basic questions: Is the spatial pattern displayed by the phenomenon significant and interpreting? Is it possible to obtain any information on the processes which have produced the observed pattern?" (Cliff & Ord, 1981; Goodchild, 1986 cited in Shen,1994). Spatial autocorrelation is capable to answer these basic questions about the spatial distribution of objects.

Therefore, considering this capability of spatial autocorrelation in this study to analyze the spatial pattern of the household vulnerability within slum area the result was analyzed using spatial auto co-relation method. It is assumed that households' having similar vulnerability score might be closer in spatial extent. Global Moran index value was calculated in each group of household based on this index value it can be concluded whether same level of vulnerable household are clustered or dispersed or randomly distributed. Global Moran index value range is -1 to +1. If the value is close to +1 then pattern is clustered and if the value is close to -1 then the pattern is dispersed. If the index value is near to 0 then the pattern is random. Global Moran index also perform statistical significance test which appear as p value. Less then .05 p value is acceptable and indicates that the result is statistically significant.

4. CLIMATE AND BIO-PHYSICAL CHANGE AND FLOODING REALITY IN DHAKA

This chapter includes the flood situation in Dhaka based on secondary data and information gathered from different source, physical growth and demographic feature of the city, rainfall, elevation level, Flood proneness and climate change trend and its' impact on Dhaka will be described in this chapter in brief.

4.1. Introduction

Dhaka is the largest city in Bangladesh. It is capital of independent Bangladesh since 1971. Dhaka is also a historic city of nearly 400 years. It is dominant in terms of population concentration, economy, trade and commerce, education and administration. According to a UN data sheet, Mega city Dhaka or the Dhaka statistical Metropolitan Area (DSMA), is the 22nd largest urban agglomeration with 19.5 million people in the year 2015.

4.2. Geographical settings

Dhaka is located in central Bangladesh at 23°42'0"N 90°22'30"E, on the eastern banks of the Buriganga River. The city lies on the lower reaches of the Ganges Delta and covers a total area of 153.84 square kilometres (59.40 sq mile).

Dhaka city is surrounded by four different rivers. The surrounding rivers are Buriganga to the south, Turag to the west, Tongi khal to the north, and Balu to the east. The city and adjoining areas are composed of alluvial terraces of the southern part of the Madhupur tract and low-lying areas of the doab of the river Meghna and Lakkha[1]. The elevation level of Dhaka on average is .5 to 12 meters (Pwd) above the mean sea level, and 60 to 70 % of the urbanized areas are at elevation of .5 to 5 meters (Pwd) above the mean sea level. These areas are low lying areas and also used to be as detention basin during flood. Low lands were continuously filled up to build new settlement. The land area above 8 meters above mean sea level covers about 20 square kilometers. The land ranging from 6 to 8 meters above mean sea level covers 75 square kilometers, while 170 square kilometers of Greater Dhaka is below 6 meters above mean sea level.

4.3. Physical growth and demographic trend of Dhaka city

Dhaka with its' large population is the only one mega city in Bangladesh, which provides all of the facilities and people get attracted to migrate here. This is the main factor for population growth of Dhaka. But the city has a big limitation, aerial limitations. Most of the inhabitants of this city are poor. Arial limitation and poor inhabitants combined create a critical situation in this city. Large number of poor population (37.4% population of city are slum dwellers, CUS, 2005) and their vulnerability to different stressors is obviously one of the biggest challenges for this Mega city.

Dhaka is one of the fastest growing cities in the world in terms of population. Its growth has been particularly rapid since 1971, after its transformation from a provincial capital to the national capital of independent Bangladesh. Corresponding to the population growth, Dhaka has also experienced fast physical expansion, much of it without planning guidance or control. Low land and flood retention area

[1] http://en.wikipedia.org/wiki/Dhaka

are the most common place for growing slums and squatters. Trends of population growth with projection unto 2025 are shown in table below.

Table 4-1: Trends of population growth

Year	Population (Rounded)	Area in sq.km	Political Administrative identity Dhaka City
1947	200,000	73	Dhaka City (Capital of East Pakistan)
1971	900,000	323	Dhaka City (Capital of Bangladesh)
1974	1607,000	333	Dhaka Statistical Metropolitan Area (DSMA)
1981	3440,000	401	Dhaka Statistical Metropolitan Area (DSMA)
1991	6844,000	1353	Dhaka Statistical Metropolitan Area(Dhaka Mega city)
2001	9900,000	1353	Dhaka Mega city
2004	12000,000	1530+	Dhaka Metropolitan Development Plan Area/RAJUK Area
2005	12623000	1530+	DMDP/ RAJUK Area
2010	14230000	1530+	DMDP/ RAJUK Area
2015	20000000	1530+	DMDP/ RAJUK Area
2020	25,000,000	1530+	DMDP/ RAJUK Area
2025	30,000,000	1530+	DMDP/ RAJUK Area

Source: Estimates based on Various Census Reports and Islam: Dhaka: From City to Mega city; 1996 and DTCB, 2004(Islam & Shafi, 2008)

4.3.1. Increasing number of slum dwellers

Dhaka city is now determined as a place of investment and a place of activity for the people of Bangladesh. Here everyday lots of people come in search of job and to find out a way of their life. Several studies have proved that one major portion of poor population of Dhaka city is the climate refugee. Friedman(2009) mentioned that every year about 500,000 people move to Dhaka from coastal and rural areas in search of better life. Living and maintaining family life is rather expensive compare to rural area but work availability make people to prefer Dhaka for living. Food price increase and high living cost force the poor migrated people to live in the slum and urban squatters. Slums in Dhaka city have been growing rapidly since 1971. Trend of growth (Figure 4-2) shows that slum population increased two times within last fifteen years and since 1991 the growth rate is very high. These increasing number of slum population are living in the slum area facing several problems. According to International Organization for Migration[2], around 70%people of slum in Dhaka have experience to face some kind of environmental shocks.

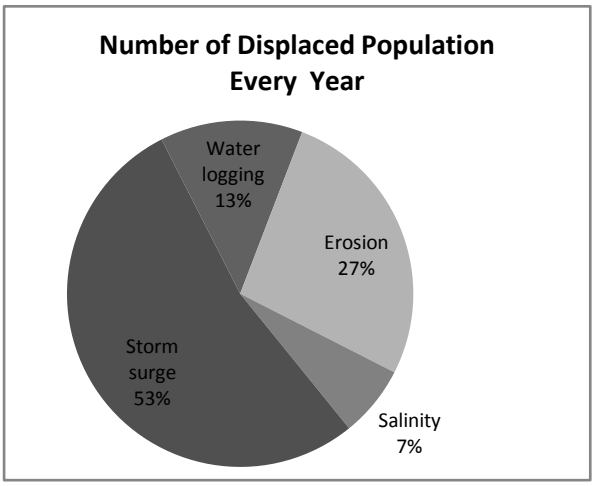


Figure 4-1 Number of Displaced Population per year
Source: (Ahmed, 2008)

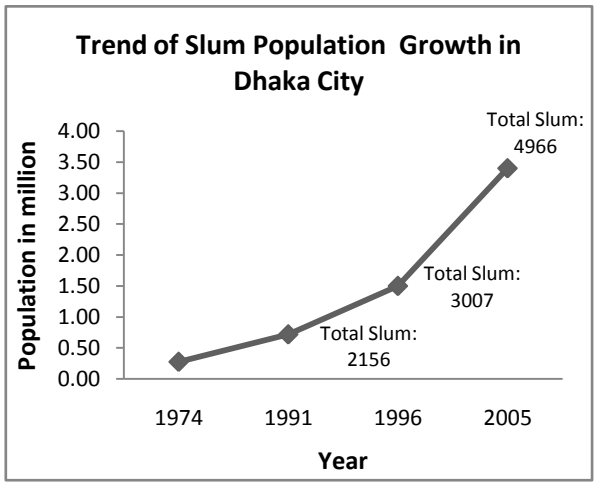


Figure 4-2 Trend of slum population growth in Dhaka city
Source: CUS 2005

[2] http://www.iom.int/jahia/Jahia/activities/asia-and-oceania/south-and-south-west-asia/bangladesh/cache/offonce/#eccm

According to Richard Odingo, climate change will have impact on poverty level increase and food security will be worsening (cited in Davis et al. 2009). There is no doubt if environmentally displaced people from village keep continue to move towards city urban poverty will increase since slums are their potential target for habitation because of their affordability. These people create pressure on land, water as well as limited natural resources of city. In addition, the poor are bound to live in hazardous area like low lying flood hazard prone area occupying marshy land, natural lakes.

4.4. Flood Hazard in Dhaka

Dhaka since its' early days are subject to frequent flooding due to heavy rainfall and spill over from surrounding rivers. Unplanned growth of the city is increasing the major risk of internal water logging which is subject to daily life disruption of city dwellers especially the poor population group when their earning and living is very closely related to climatic condition.

In recent history, Greater Dhaka city experienced major floods in 1954, 1955, 1970, 1974, 1980, 1987, 1988, 1998, 2004, 2007 due to the overflow of surrounding rivers. Among these, the 1988 and 1998 floods were catastrophic.

Flooding due to rainfall is also a severe problem for certain city areas that cause inundation for several days, mainly due to drainage congestion. It is evidence from recent flood history that certain part of Dhaka city has been regularly inundating due to monsoonal rain fall since mid nineteenth. The water depth in some areas is as high as .5 to .6 meters, which creates large infrastructure problems for the city, economic losses in production, and damage to existing property and goods. Moreover it disrupts city dwellers daily life. Every year severe water logging is getting common scenario in monsoon. In recent history August, 2009 due to heavy rainfall and insufficient drainage system severe water logging stopped city life for three days which caused huge suffering and damages for city dwellers. Consequently, the impacts of the riverine floods are more severe cause enormous economic loss and livelihoods disruption of people. This section will briefly describe causes and characteristics of floods in respect to their impact from the last three major floods in 1988, 1998 and 2004.

1988 Flood

Flood in 1988 is considered as among severe floods in flood history of Bangladesh as well as for Dhaka in considering its water depth and duration and spatial extent. 85 percent of the city area was inundated. Expert estimation evaluates this flood as 70 year return period flood. Very few portion of the city remain out of inundation and water depth range was .3 to more than 4.5 metres.

1998 Flood

The main reason for the 1998 flood was excessive rainfall over the catchments area of the Ganges-Brahmaputra- Meghna (GBM) river basin. In addition, high tide caused floodwaters to move away slowly, prolonged in the city for two months. The main causes of flooding inside the protected area were hydraulic leakage, failure to operate the regulators, and lack of timely pumping of accumulated water. In several study it is mentioned that during 1998 flood there was lack of coordination between the Bangladesh Water Development Board and the Dhaka Water Supply and Sewerage Authority. Especially failure to operate of Rampura regulator timely increased flood severity in this year.

2004 Flood

During July and August 2004, devastating floods seriously affected Bangladesh. The north and west-central districts suffered from severe flooding, which continued to spread, eventually reaching Dhaka and other central districts. The floods affected about 38 per cent of Bangladesh and caused extensive damage to crops, physical and social infrastructure, the environment and the livelihoods of 36 million people.

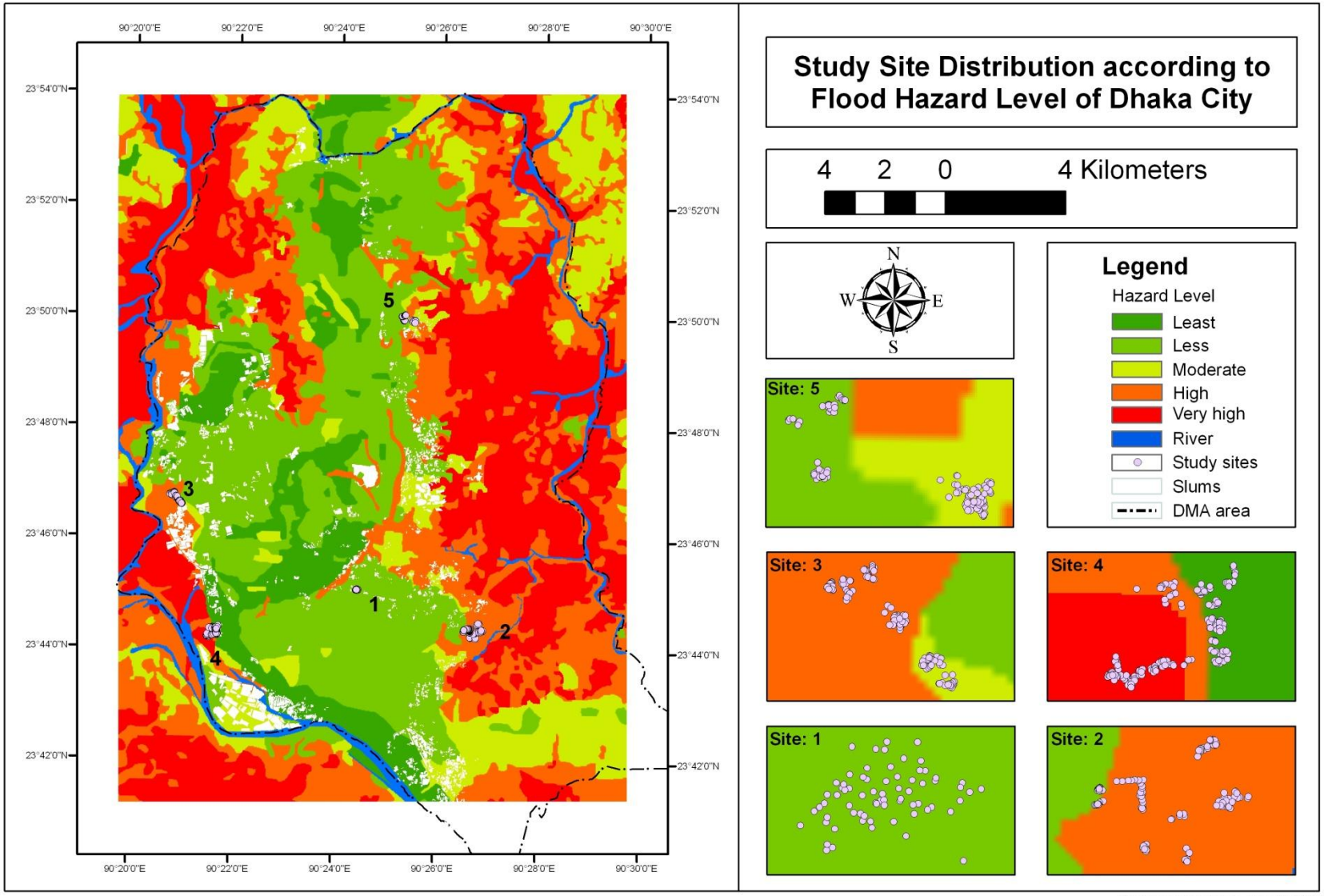
Furthermore, in September 2004 due to intense rainfall another round of flooding occurred in Dhaka and central and south-western districts.

4.4.1. Man made cause of flood hazard in Dhaka

Dewan et al.,(2004) point out three human induced reasons for flooding in Dhaka city: urban development and population growth, encroachment of low land and drainage congestion. Moreover he mentioned massive urbanization is mainly taking place in low land areas of the city which used to be retention pond during flooding season. Another study (Kamal and Midorikawa, 2003 cited in Dewan et al, 2004) shows that out of 194 km low-lying areas in Dhaka city 79 km2 experienced urbanization with different fill thickness. Due to the filling of natural channels it becomes very difficult for the artificial system to carry out vast amount of flood waters in the monsoon. Only 185 km storm sewerage is available for flood flows in the city which is inadequate to bear flood waters from more than 300 km2 area of the city (Shams, 1999 cited in Dewan et al., 2004).

However heavy rainfall induced flooding is not new for Dhaka city. In previous time city used to have its' own natural drainage system to help surface runoff. Therefore effect was less during river level increasing or heavy rainfall induced flooding. Dhaka city is built up in a flood plain with potential number of canals and low lands (jhil) that used to drain water from its upper reaches during monsoon season. However those areas were encroached due to population increases. As a result, those canals and low lands were detached and lost their ability to drain and store flood water. Therefore severe water logging and flooding has become a regular problem for the city dwellers in every monsoon period.

From the discussion above it is clear about the geographical setting, physical expansion, demographic trend and flood reality in Dhaka city. From literature it is evidence that flood in Dhaka is not only a natural phenomena but also resulting cause of uncontrolled human-environment interaction.



Map 4-1: Flood Hazard Zone of Dhaka City

4.4.2. Flood Management system of Dhaka city

After the massive flood of 1988 and 1998 BWDB has taken initiatives to protect Dhaka city from flooding therefore under BWDB[3], Dhaka integrated flood protection project (DIFPP) was taken immediately after the flood of 1988. Under this project several structural measures were taken such as to build embankment, sluice gate, pump station etc. Though during the flood of 1998 those area were protected were also inundated. However, important component of flood protection (for Map see Annex 4) measures are:

Western part of Dhaka city is surrounded by 30 km multi purpose (also used as road) earthen embankment along Tongi khal, Turag River, and Buriganga River. There are 13 sluice gates to control water inside and outside of the embankment. When water level rises above 3.00 m pwd level then gates are closed. There are also 3 pump houses to pump out accumulated water. When water level rises above 3.50 m pwd then pump houses go under operation. 260 ha. ponding area to retain storm water and surface water. When retained water level rises above 3.5 m pwd then water to be pumped out. 8.44 km main canal excavation, 21.65 km canal re-excavation, construction of pipe drains 35 km to drain out internal accumulated domestic sewage & storm water. A large number of low lift pumps are used to pump out accumulated water inside of regulators. The locations of regulators, sluice gates, pump stations, embankments, and raised roads are shown in Map (Annex 4).

Moreover as non structural measures Special flood Monitoring System by FFWC[4] and Dhaka O&M Circle, BWDB (FFWC) runs flood forecasting model and forecast 24 and 48 hours water level. FFWC publish daily flood bulletin in Radio, TV, and newspaper when severe condition arises.

These flood control and drainage measures have brought major changes in the flood management of Dhaka West. The embankment/road in the western part of Dhaka helped to protect more than 50 per cent of the city from the floods in 1998 and 2004 but it causes internal drainage congestion, which becomes severe during heavy rainfall. On the other hand to protect other half (eastern part) of the city a bypass (eastern bypass) road is also under consideration.

4.5. Future climate prediction for Dhaka city

It is expected that frequency and intensity of natural disaster will be increased due to extreme climatic events in Dhaka. Since 1970 to 1989 in every 4 year Dhaka city has experienced at least one major flood incidence. The frequency of major flood occurrence has been increased in every 3 year. Moreover the frequency of one or more severe disasters in a year has become common such as in 2007 Cyclone Sidr and flood, in 2009 Cyclone Aila and Cyclone Bijli. However, in future occurrence of major natural phenomena is assumed to be very common. It is expected that future flood vulnerability of Dhaka city will be worsen due to climate change. Climate change scientists and experts are forecasting that floods with the magnitudes of 1988 and 1998 have chances to occur more frequently.

Rainfall data from the Dhaka station for 1971 to 2005 (Annex 6) show that the annual average rainfall in the city is about 2,120 millimetres, of which about 70 per cent rainfall occurs during June to September. Average rainfall during the winter months (December, January and February) is negligible, less than 2 per cent of annual rainfall. From the study of Alam & Rabbani (2007) it is found that Dhaka's long-term trend in annual rainfall shows no significant change but the trend in seasonal rainfall appears to be erratic. The study predicted from trend analysis that although there is no significant change in annual average rainfall, the number of "days without rainfall" is increasing and this study also found that seasonal rainfall data in both the monsoon (June, July and August) and winter (December, January, February) seasons show a decreasing trend over time. However, these two facts together indicate that the number of days without rain is increasing on the other hand the amount of rainfall at a time is increasing that means more rainfall is occurring in other months of the year and that rainfall intensity is increasing. Therefore suddenly heavy

[3] http://www.bwdb.gov.bd/
[4] http://www.ffwc.gov.bd/

rainfall induced flood has become a common scenario in case of Dhaka which accumulate flood water above its' drainage capacity.

Several author (Ahmed, 2008; Alam & Rabbani, 2007; IPCC, 2007) mentioned that temperature variation, erratic rainfall, flood and water logging, cyclone, climate induced health outbreak, sea level rise 2m-13m these are existing and future threats for Dhaka city has predicted from several study. Therefore, it is crucial that a long-term flood-mitigation and climate change adaptation strategy should be developed for the flood management in and around Dhaka City.

4.5.1. Impacts

If consequence of natural hazard continue to increase as such and city population as well unplanned growth keep continue to increase as it is; in near future nobody can save city from catastrophe and this will not follow any boundary (rich or poor/ planned or unplanned) as every part of city is functioning depending on its' interrelationships. No doubt slum population will be the most sufferer group due to their high susceptibility.

Due to severe flood damage in housing, infrastructure especially road network, national economy is very common and there are several organization published report on physical damage after each major flood. To estimate physical damage due to flooding is easier but human suffering as well as livelihood disruption especially for the marginalized group is not that much easy to quantify. Therefore it is always ignored in literature to looking into the depth how flood is causing slow effect on income generation and health as well contributing difficulties in daily life of slum dwellers. Another important reason to be neglected flood effect on slum dwellers is because if damage is compared in terms of money or contribution in GDP it will be very low. In reality human suffering is very high in slum because of regular flooding which is not comparable in terms of money and it is reality that a large number of populations (37% of total city population) are living in slum.

In 2007 over 90,000 (Bangladesh government estimation) people were affected by diarrhoea within one week during flood. People were suffering due to lack of food, drinking water, and water born diseases. Children and women were the most sufferer group as well elderly people. According to Government of Bangladesh (2007) estimation over 50% of city population, most of them were slum dwellers were badly affected. Slum people they lack knowledge about health so it is very easy to spread out huge epidemic disease as well they are very susceptible during natural hazard and their means of recovery is very low. In several study (see chapter 1 and 2) it is stressed out that vulnerability of Dhaka is higher because of high population density and large number of poor population all over the city.

5. SELECTION OF INDICATORS FOR VULNERABILITY ASSESSMENT

Chapter 5 is mainly a conceptual chapter. Local knowledge in combination with expert knowledge, and statistical analysis were used to identify and analyse different aspects that increase or decrease the households' vulnerability to flood. These are mainly vulnerability component, and therefore the analysis in this chapter examine the way in which the five livelihood assets such as social, physical, financial, environmental factors interact and determine the differential vulnerability to flood found among the studied households. Finally all these information together will help researcher to develop a contextual framework in study area.

5.1. Approaches taken to select vulnerability indicators

Indicators and criteria are key tools for identifying and measuring vulnerability. Scientifically sound indicator is capable enough to indicate the characteristic of a system that can enable decision makers to assess the impact of disasters on population at risk and disseminate the results to decision-makers. Formulating goals is the starting point of selecting indicator while it is necessary to determine the approaches will be taken to select indicator. The following table is a systematisation of selected approaches in this study to develop a sound indicator:

Table 5-1: Approach taken to select indicators

Approach	Application in Real world
Spatial Level	Local community (household)
Function of the approach (Goal/vision)	Identification of vulnerability
Thematic focus on vulnerability	Physical, demographic, social, economic and environmental assets; address root cause (describing the characteristics of human environment coupled system)
Data basis	Questionnaire survey(quantitative), Group discussion and household interview(qualitative)
Target group	Household at risk
Link to goals	Classification of vulnerability (Extremely High, very high, high, moderate, low)
Level of aggregation	Medium, high indicators (group of indicators under each factor score, aggregation into 3 sub-goals and 1 vulnerability index)

Source: Reconstructed by author from Birkmann, (2006)

According to Birkmann (2006) "it is important to know that the term measuring vulnerability does not solely encompass quantitative approaches, but also seeks to discuss and develop all types of methods able to translate the abstract concept of vulnerability into practical tools to be applied in the field." This implies that approaches discussed under measuring vulnerability include not only quantitative indicators and, qualitative criteria to capture all aspects of vulnerability (Turner, 2003).

Therefore, the factors that contribute to a household's flood vulnerability were identified from qualitative in depth household interviews in the study area. These interviews were conducted by the researcher herself by internet phone calls. After identifying the household vulnerability factors or daily life aspect that

contributes to the vulnerability, the indicators were further developed through statistical analysis on the basis of quantitative questionnaire survey.

In this study some indicators are developed based on the past disaster experience of the household. Among the questions asked during qualitative interviews were the following: What are the main aspect of the household's everyday life?, How is their life disrupted by flooding? Why are some of them more affected by flood, while the others are less affected? What are the strengths and weaknesses of the local system that decrease or increase the vulnerability to floods? How are households trying to adapt to these natural phenomena? Based on that, households' vulnerability was identified. In this study it is assumed that the household having more stress or facing more difficulties in daily life are less prepared to natural disasters. During disaster instances they are less capable to protect themselves from external shocks or hazards.

The factors determining the outcome of future events are highly complex and can differ from those already experienced. In this study it was attempted to combine historical data with the current status of household that will help to determine their future vulnerability. In the previous chapter the climate change likelihood effects in Dhaka were explained from secondary data. In this chapter the main focus is on describing the households' reaction to external shocks from the primary data gathered on the past and present flooding experiences of the households.

There is no doubt that life in a slum is full of multiple stresses as people are struggling to earn their daily livings, flood is one common natural disaster that make the livelihoods of slums more difficult, and that push backward the pace of the development of the household.

5.2. Identifying the indicators that contribute to households' vulnerability at local context

Vulnerability is typically described to be a function of three overlapping elements: exposure, sensitivity and adaptive capacity (Turner et al, 2003). Therefore to assess vulnerability it is significant to know all the factors of vulnerability and how they are related to a household's five livelihood assets (DFID, 1999). For example, social vulnerability not only refers to the exposure to a flood hazard, but also to people's sensitivity to flood damages and to their ability to adapt to the effects of that flood. In this study all these aspects of households' vulnerability were depicted from the local context of vulnerability in combination with expert knowledge.

5.2.1. Exposure to Floods in Dhaka

In this study indicators related to exposure mainly derived from expert knowledge. In several study (Bollin & Hidajat, 2006; Villagrán de Leon, 2006) unsafe settlement as well as homes in hazard prone areas(flood hazard zone, reverines, river banks etc.) were massive used indicator for vulnerability assessment.

In urban areas, where the available land for housing is scarce and/or unaffordable for low income groups, the choices for location for habitation are limited (Hardoy & Pandiella, 2009). Several studies (CUS, 2005) proved that slum dwellers in Dhaka tend to be located in low-lying, flood-prone, poorly drained areas, having limited formal garbage disposal and minimal access to safe water and sanitation(refer to chapter 4). Living or working in a hazardous location is directly contributing to increase a household's vulnerability to floods. Flood condition in study area is described as follows:

Flood scenario in study area

It is common in all the study sites that almost 90% of the households have experienced flooding more than once. As study site 2(Dokhin Goran), 3(Hazaribag), 4(Godertek) and 5(Khilkhet) are subject to frequent flooding almost every year. On the other hand, study site 1(Maghbazar) is less exposed to regular flooding because it is well protected by the embankments. However, during the major flood of 1998 all

the study sites were highly affected, even in the Maghbazar slum almost 80% (Figure 5-2) of the households were severely suffered. As study site 3 (eastern part) and 2(Godar Tek) are also protected by the western embankment even if they are not secure from yearly flooding. There are very few houses (in each site around 5 to 10%) that were never flooded.

Flood water height and duration

Depth and duration of inundation(Westen & Kingma, 2010) is an important parameter that makes household in study area more vulnerable in sense of the damage occurring and daily life disruption. The households located in low land area are more likely to have more water height during flood. Other factor such as the amount of rain fall and, a blocked drainage system can lead to a long duration of flood water stagnation. Depending on the water height, household decide to take an initiative themselves e.g when water is in the yard, household can continue their daily life with minor disturbance mosquito or bad smell from water; when ankle or knee depth water is inside house, the household arrange to uplift their bed and other furniture by using brick stones in order to protect them from rotting, when the water depth increases even further than that, then the households might decide to move to other places to save their life. A Long duration of stagnant water causes more damage; when the water duration is up to 3 days it causes only minor damage. But still the situation might be hard to manage for the households, in particular when a sudden flood causes damages to stocked rice and other food items. Stagnant water of more than seven days, mostly two weeks or longer, might cause a major disruption in the household's daily life. For those who take shelter in relative's house for three to seven days, the relation with relatives remains fine; when it turned out to be more than that it started to become worse. Fighting each other and disappointment from relative is common at that time. For the small businessman, a flood duration of more than one month hamper their business and it takes time for them to go back to normal life.

These are the local context of flood scenario in study area derived from qualitative interview. To support these findings a frequency analysis were carried out from the questionnaire survey data and findings are corresponding the to each other. Chart (Figure 5-2) shows that, more than 50% of the houses in Maghbazar, Dokhin Goran, Hazaribag, khilkhet faced a flood water height of 2 feet. In study site 3 (Hazaribag), more than 50% of the houses were flooded with a height of 3 feet. Conventional pictures (Figure 5-1) are showing the daily life condition of the households' during flood in study area.

Flood damage in study area

More than 75% household faced damage during a major flood, while only 20 % did not face any damage. The following graph shows the damage level in the study areas (Figure: 5-3).

From the above discussion it is clear that the entire study site except study site one (Maghbazar) are subject to frequent flooding every year. Although there is variation in the spatial distribution of the household living in highly flood hazard prone areas (see Map: 4-3).

Cause of flooding in study area

The most important reason of flooding in those study area that are frequently affected by floods is their n flood hazardous location. Therefore water stagnation and poor drainage systems make these areas subject to flooding within a very short time due to a even small amount of rainfall. The study areas are mostly low lands that have been illegally occupied by powerful (political) people who construct squatter and slums to rent them out. Another context is that they build bamboo made houses on top of the water over low lying land and then they rent it in cheap price. Usually these places are already flood exposed. The poor people from village after migrating to the city are in search of a place to live. Thus these slums they who come in search of job immediately they search for a place to stay therefore these places they can arrange very fast in a cheap price.

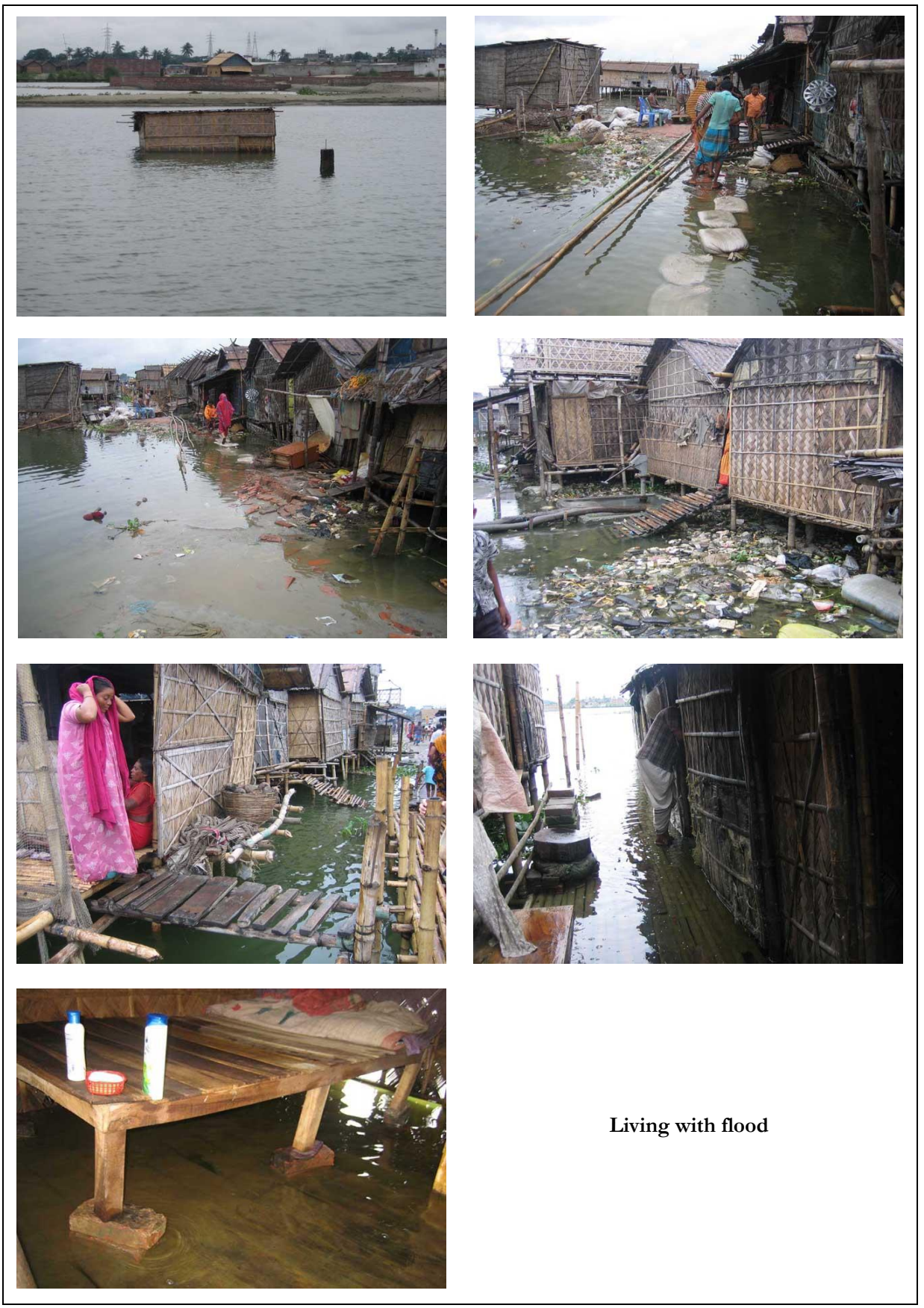


Figure 5-1: Conventional photos of flood situation in study area Source: Dhaka Hazard Slum Survey, 2009

Flood Condition in study area

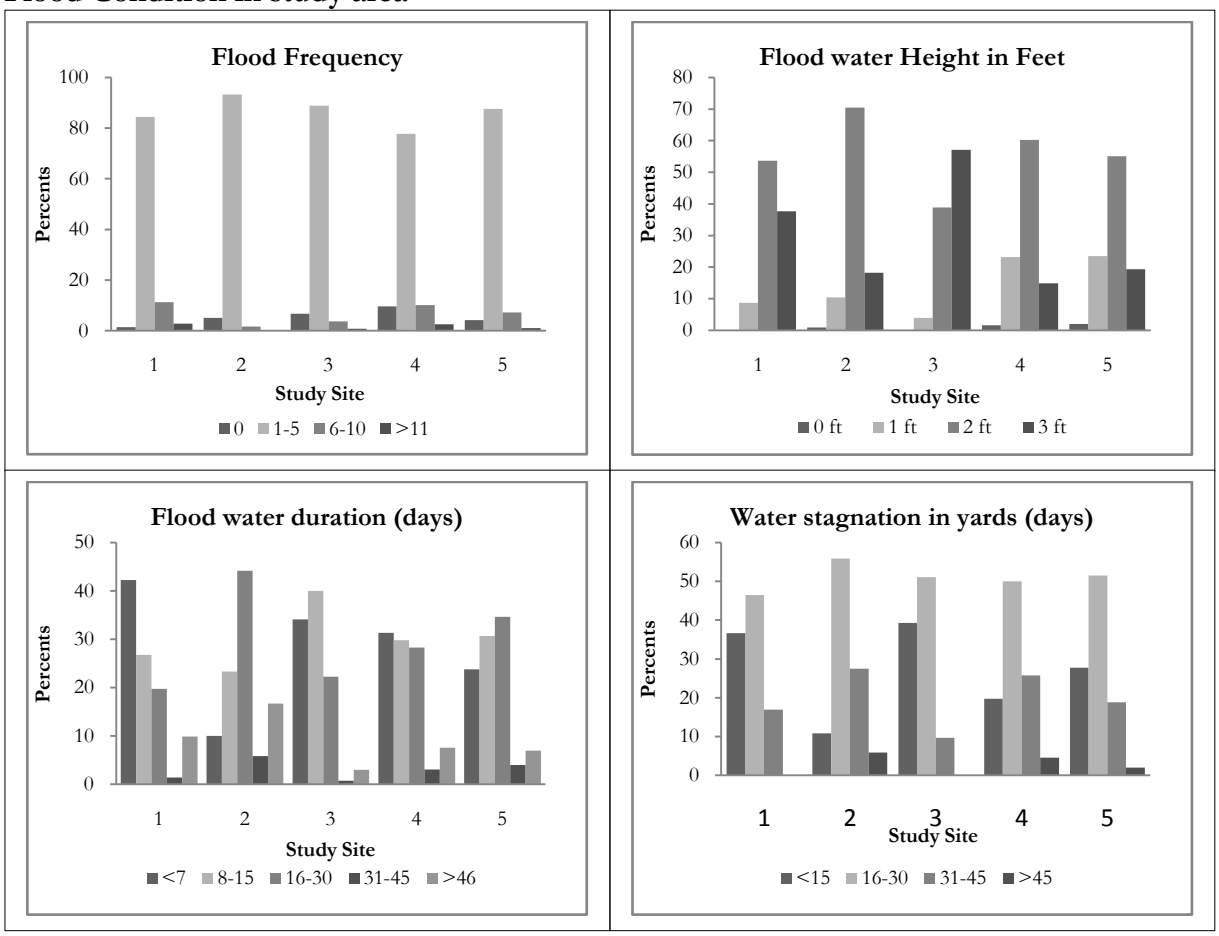


Figure 5-2: Flood condition in study area Data source: Dhaka Hazard Slum Survey, 2009

According to the local people one another reason of flooding is the delay in the opening the sluice gates in times of heavy rainfall, because it benefits the fish businessman, who are among the politically most powerful local people.

5.3. Sensitivity to flooding in Dhaka

In this chapter the socio-economic conditions that determine the sensitivity to flooding are evaluated. To identify household vulnerability at local context, in depth qualitative interviews were conducted. Later on these qualitative data sets were compiled with the GIS-based quantitative survey in which the socioeconomic characteristics of the households as well as the adaptive capacity performed by them were collected and analysed.

The identification and analysis of some of the main aspects of households everyday life, how their daily life disrupt when natural hazard takes place and the extent to which a family is suffering to flood were derived during the qualitative interview. Moreover, it gives an insight into the local system, how nature and biophysical condition in combination with social phenomena strongly influence household's livelihoods as well as the very existence of a family.

5.3.1. Socio-economic condition and its influencing factors and households' vulnerability

A close observation of the people in the study areas was revealed how the socio-economic status and weather condition interact with each other. In addition, it creates a circle of poverty around the household and lead them to more uncertainty in the future.. Household experience is discussed in the following Box 5-1 and Box 5-2to depict the real situation in the study area:

Box 5-1: Interview 1

Interview 1: Flood vulnerability in context of Dhaka

Abu Sufian is a 40 years old poor rickshaw puller residing in Hazaribug slum, which is one of the most flood affected slums in Dhaka. After he lost his small piece of land due to river bank erosion in his village he moved towards Dhaka in search of job. One of his relatives from the village was already living in this slum and helped him to take rickshaw in rent by guaranteeing for him. That relative also helped him to rent land from a land owner to arrange a thatch (jhupri). The Villager Abu Sufian started a new life in the urban settings where everything seemed to be limited for him. Limited income pushed him to a marginalized life where there is no proper access of drinking water, electricity, improper toilet system. The house he made it is not strong enough to protect his family from heavy winter or hot summer as well as seasonal floods.

Exposure and sensitivity: Almost every year during rainy season this area is inundated by flood water, while rain water stagnation is common problem for them in each rainy season. In front of his house the road conditions became worse and he has to go about his work walking through ankle or knee depth dirty water. His wife and children cannot go out since they are trapped inside the house because of rain water stagnation in front of the house. They have to wait to start their daily life until water level goes down naturally.

Adaptive capacity: Abu Sufian's life becomes more stressed by the yearly floods. The last time a major flood occurred in 2004. At that time the water was increasing slowly in one night. By midnight they packed all their belongings underneath of the roof and they moved towards a school shelter with other neighbours. Only women and children were allowed to stay there. Men were not allowed so he was staying on the road where there was no cooking or toilet option not even shelter. He got ill due to frequent rain showers. Inside the shelter centre it was overcrowded and the women were always fighting each other for water and cooking due to high competition and inadequate service. According to him his family's condition was better (!) than others, because his wife and children got a place in shelter centre and he could continue his work. Thus, he was also able to buy food from outside, although the food price increase gave him an extra load on his daily earnings. They managed the situation by reducing the amount of food they ate. His other neighbours who worked inside the slum were not able to work during the flood; some of them did not get into the shelter; some even did not have any relatives in Dhaka and were, thus, worse off. After two months flood condition improved and they came back to their house, which was completely destroyed by flood water; and so were their belongings. At that time he needed to lend 10 thousand taka from the local money lender with a very high interest rate to repair his house. After that he and his wife started to work longer time than before in order to being able to pay back the money. On the other hand, the land owner increased the land rent 5 times because of a high demand of his land. They didn't get any help from the government or any other organization. It took one year for them to pay back the money.

When Abu Sufian was asked whether he thinks that his situation will improve within 5 to 10 years? He answered with a hopeless smile that

"*if things continue like this I can assume my condition getting worse than before. Nowadays everything is getting costly but my income is not improving at all. It is very difficult for me to adjust with price hike moreover my income is not the same all over the year. During very hot summer my income decrease that time usually I have to take loan from my relatives and neighbour. If any of my family members become ill then it cost extra money that time I also need to take loan. Furthermore if everything runs properly the sudden accident (any reason to stop income source) make me break down completely. Last time before flood I don't have any loan at that time I was hoping a better life. That year after flood I lost everything then I lend a big amount of money. Still now I am not able to recover completely from that damage.*"
Source: Own interviews, 2010]

Box 5-2: Interview 2

Interview 2: Influence of weather conditions in a households' daily life

"During rainy season usually I get fewer customers. When it rains heavily I have to keep my business close because I don't have strong shade on top of my head. Water stagnation is a common problem on this road it hamper my business. During rainy season it is very common for me to take loan from my neighbour. I can eat anything or I can starve 1 to 2 days but my daughter she is small she cannot. For her I used to lend I cannot let her starving. Usually I go to one grocery shop near my house they give me rice, potato on loan. I can pay them later when my business starts to run again when my business condition is good. Although I feel shy to ask things without money, when I look at my daughter's face I force myself to take loan. I have born in a landlord's (rich farmer) family. I didn't grow up in poverty. River washed away our whole village then we moved to Dhaka. Since then my fate is here. There is a proverb in our village that river erosion doesn't wash away only land it also wash away your fate (Bangla: nodite khali ghari vangena kopalo vange)."

Tahera (not real name) is 35 years old women rice cake vendor in Goder Tek another flood affected slum. She is not able to do any heavy labour consuming work so she is doing this work. After the river washed away their village she moved to Dhaka in search of a better life. She works hard since morning till evening to earn her daily living. The money she earns at the end of the day is not enough to cover her families basic needs not even handful rice everyday. She is living in a very small house that is made from plastic, tin and bamboo. Her house is not strong enough to protect them neither from heavy rainfall nor flooding. She used to pay 400 taka for this squeeze house where for water she used to go to the next house. For cooking she uses mud oven in front of her door. Everyday she used to collect fire wood or dead leaves from outside for fuel.

Exposure and sensitivity: During the rainy season she cannot work most of the time as she has no roof over her shop. Moreover, heavy rain frequently causes water logging on the embankment road, which become very difficult to pass if it is under ankle depth water; she then gets only very few customers. It also becomes hard for her to collect dry firewood.
Adaptive capacity: For her, it is very common in each rainy season to have less income than normal time which leads her in cut back of nutrition and taking loans to manage the situation. Moreover when a major flood comes, not only is only source of income completely stopped, but also her shop and house completely destroyed. Beside insecure tenancy and poor housing and services her life becomes more stressed due to floods. If her business is interrupted like this for too many days, or if she becomes severely sick herself, then not only her family's food security is at stake, but also her husband's medical treatments and her daughter's education, and thus their future. [Source: own interviews, 2010]

Abu Sufian and Tahera's daily life struggle are very common in slum areas in Dhaka. Their income stability as well occupation is highly susceptible to regular weather conditions.

Box 5-3: Reason to live in slum

It was asked during interviews that why do they leave in slum?

The answer of Abu Sufian was: *"Because this place is cheaper(Bangla: bostite keo ki shohe thahe poysha nai tai thahon lage. English: nobody leave in such a place willingly we don't have money to go to a better place). If we want to rent house in good place with all facility it will cost big amount of money. Those place are for rich people not for us. This place is cheaper because it is close to jhil (low land area). Malik (land owner) made houses on top of this jhil and he rented it in cheap. I earn 2000 taka per month if I want to live in a good place at least I need 20,000 taka income per month. I don't think in my whole life I will be able to live in such good place."*

Therefore household qualitative interview helps researcher to identify nature and human relationship as well as human susceptibility in the study area. After the analysis of the entire interviews household vulnerability aspect was detected, will described in the following session:

Income level, occupation type and education

These are the flood sensitivity aspects that were revealed from qualitative interviews and open discussions with households. All the economic activities that contribute to the family income were listed and classified according to the contribution in vulnerability.

Income

Households with low and irregular income(below international poverty threshold 1.25 $ per day), occupation(insecure and odd jobs) and lower education level are highly sensitive to natural hazard.Not only major flooding but also heavy rainfall including small inundation put them into high difficulties. Those households who are dependant on the only one source of income are highly sensitive compare to the others who has alternative income sources. Heavy rainfall or small inundation is not a severe problem for these household unless they are attacked by major flooding. Even during major flooding they have better capacity than the others. Therefore they are able to retrieve earlier to their normal life without major stress. Looking in-side the system and observing the situation closely it is found that income, education and flood affectedness are related to each other. The sensitivity level will vary due to weather conditions and flood vulnerability inside the community based on these factors. The analysis of the data collected among the slum depicts the variation of households' vulnerability level.

Box 5-4: Poverty is a big stress

"*If I have good earning I can arrange better life for my family*"

Khalek Hossen, a 60 years old vendor head of six members' family, came from Sherpur, while he lost his home in land erosion. Now he is living in a single room called Jhupri house elevated above the water body and sharing hanging latrine with 25 households. Few questions were asked to him:
Ques: What does he think is big problem for their life?
Ans: He replied nothing is problem if he has good income then everything is fine. He is able to change his living condition.
Ques: What he wants to do if he has got satisfactory income?
Ans: He replied at first he will leave this slum and will start to stay in good place.
Ques: What good place stands for him?
Ans: He replied where I can have a good house which will not inundate during flood, I can go to my work without stepping on water; there will be good environment, no bad smell, no mosquito moreover whole day water supply, no need to fight with neighbour for water.

From the above (Box 5-4) a households' urge for better life after having adequate income implies that income has very important role to reduce flood vulnerability by arranging household good accommodation, service provision. Furthermore income is highly related with other means of livelihood assets.

Regarding the relations between everyday life and flood vulnerability it was identified that during the rainy season the daily earning of most of the households' tended to decrease or even stopped if flooding took place. These households are forced to adopt dangerous initiatives to cope with this situation. Cut back in nutrition even begging are those risky initiative they are forced to take identified from household interviews. Also insufficient food intake will might have large affect on human health in long run; while children's are highly affected group in this regards (see figure 5-1 and 5-2). This study also found that those places are constantly subject to frequent flooding or stagnated water are the place for very poor socio-economic group.

Inadequate income even not enough to meet-up the most basic demands concise that eventually they do not have savings or financial backup to help during flooding or crisis time. Moreover, even if the family is aware about flooding or stagnated water situation they are not able to change their place of living or take initiative to avoid flood due to inadequate income. On the other hand, being a part of poorer socio-economic group nobody trust them to give loan (specially big amount) when they are in trouble. Therefore starving (!), begging or depending on relief is their coping mechanism during flood. Even if when they become ill they do not have means to buy medicine or to go to doctor.

Occupation, education

People in the study areas are mostly informal workers. Beside this, the unemployment rate is very high in all study sites. From the chart (Figure:5-3) it is revealed that, in all the study sites most of the household heads are rickshaw puller, but also a very high percentage of household heads has no work at all. In study site5 (Khilkhet), the share of day labourers and rickshaw pullers are almost the same.

Considering type and characteristics, all occupations were classified into four classes. Unemployment status is considered as very highly vulnerable. While day labour, street vendor, rickshaw puller considered as highly vulnerable because they are dependent on daily basis income which is very highly influenced by weather condition in terms of insecurity. The people who are day labourers mostly don't have work during

rainy season in that time they usually change their occupation (rickshaw puling or seasonal vendor) which cause uncertainty in their daily life. During heavy rainfall and water logging some of them don't go for work eventually it decrease their income seasonally and some of them go for work because they might have chance to earn better; ignoring the chance to catch cold and fever as well pneumonia. On the other hand, vendors are the most affected group due to weather condition. Getting few customer, to halt business during rainfall due to not having shade on top is very common which turn them into high income decrease or make them to stop income source for couple of days. Because of their high sensitivity they were considered as highly vulnerable group.

Retailing small shop, security guard, factory worker, and business category was considered low vulnerable. They are comparatively in better condition than the others because of having strong roof on top of shop, or having small backup money to continue few days without earning.

Bus, truck, taxi, car drivers was considered in very low vulnerability. According to local context they have skills as well as better earning; as they are dependant on monthly income. No doubt weather condition effect their work but it doesn't have severe effect on their monthly income or they are able to manage their situation better than the others.

Higher education level gives opportunities for better job as well as better income moreover awareness about hygienic condition and future uncertainty. Therefore illiterate group was considered as highly vulnerable based on high sensitivity, visited and read in primary school comparatively less vulnerable, visited high school and reading in high school considered moderately vulnerable. Above high school (S.S.C, H.S.C, and University) was considered less vulnerable. Education level categories of head of households are highly related with occupation type they have.

Socio-economic condition in study area

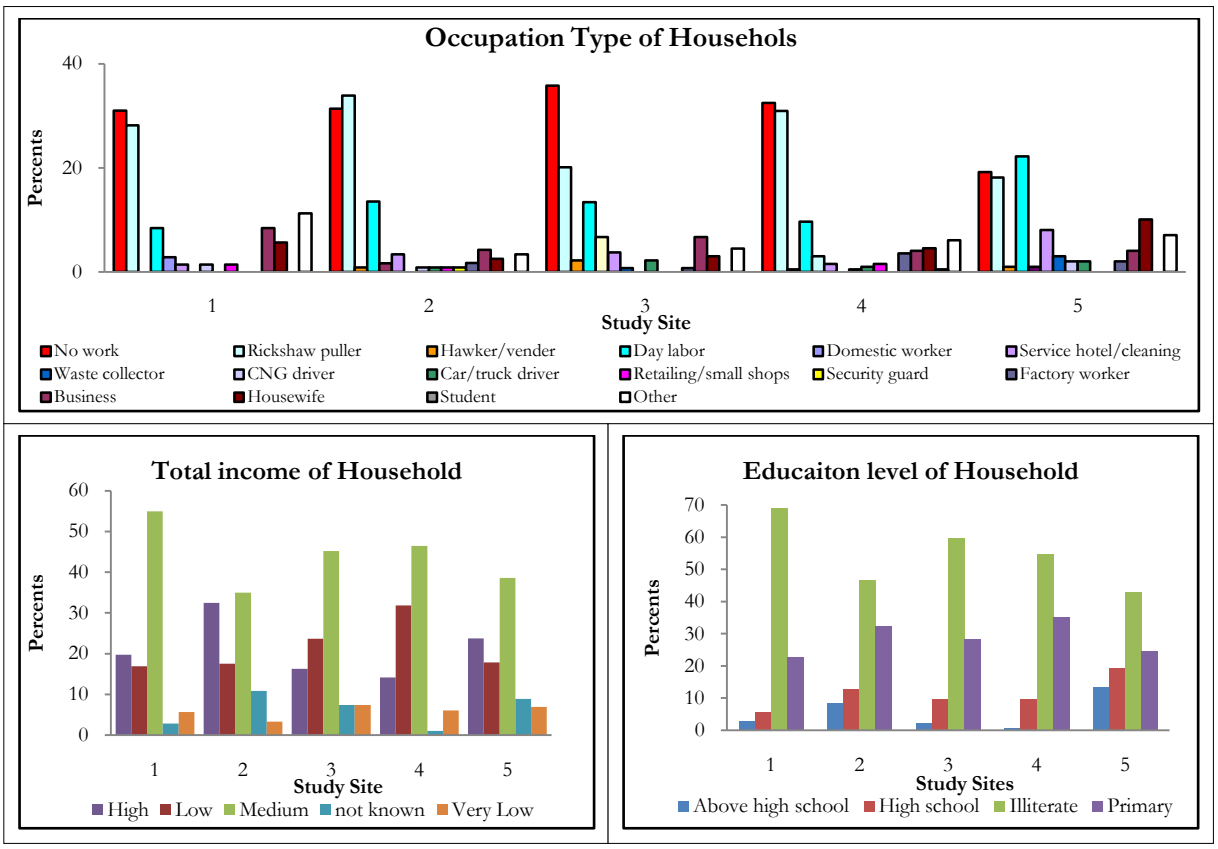


Figure 5-4: Socio-economic condition in study area Data source: Dhaka Hazard Slum Survey, 2009

Demographic characteristics of household

Besides income, occupation and education level there are other conditions which influences a households' daily livelihoods and finally contributing households vulnerability to flood. Such as household head age, dependency ratio, density per room may increase the degree of sensitivity as well.

Large Family, dependency ratio

A large family in particular one with several children, relying on only one earning source (person) are highly vulnerable to flood. On the one hand, large household will have large consumption pattern compare to a small households'. As whole family is dependant on only income source (household head income) therefore, per person income ratio will be very low. On the other hand if main earner of household becomes ill during rainy season or flooding then whole family is in highly measurable condition.

Housing material

The Building material is a very important aspect to consider. Brick buildings or concrete houses are stronger to protect flood damage, while houses made by bamboo and, plastic are weaker. Bricks and concrete are expensive material building materials. Mostly poor income group people are living in houses made by weak material and are thus more likely to be effected by floods. Therefore concrete made walls and roof are considered as good quality housing, which is less affected during floodscompare to other type of housing. Mud plastic, polythene wall and roof condition is considered housing condition as they are very poor in quality and highly susceptible to flood damage. Households living in low land area mostly live in bamboo made houses using bamboo pillar on top of water. Mosquito, bad smell, unhygienic condition are very common there. Mostly underneath the house, the water is dirty from sewerage lines. For children it is also very risky. Sometimes, in absence of parents they might fall down into water and drown.

Road condition

In the study areas, the majority of the roads are muddy. The share of bamboo roads is quite low. Bamboo made roads are considered as worse, muddy is bad, brick and concrete is considered as good in this context. Entrance road using bamboo pillar considered highly vulnerable. In this case mostly they are living on water making house on bamboo pillar; especially for the children it is very risky to play on it.

Table 5-2: Basic Characteristics in study area: Findings from statistical analysis

Local context in study area: Findings from statistical analysis	
Average age of HHH	38 years
Averge density in the study area	3 persons per room
Averge Dependency ratio	2.5
Literacy rate	55% illiterate, 15% visited primary school
Occupation pattern	38% rickshaw puller, 15% domestic worker
Flood Intensity	1998, 2001, 2002, 2004, 2006, 2007, 2008, 2009
Flood water Inundation height	On average 2.5 feet during major floods
Average Flood duration	21 days
Characteristics of basic services in Study area	Percentage of households
Main building material of house	Bamboo and/or plastic: 38 % Tin: 37 %, Brick and/or concrete: 25 %
Supply of drinking water	Shared tap: 64 % Shared tube wells: 25 % Other (tap in house, buying water, ponds): 11 %
Cooking system	Mud oven for cooking 53 % Shared kitchen with gas supply 37 %

Source: Dhaka Hazard Slum Survey, 2009

1. Entrance of a slum house

2. Shop close to low land

3. Bamboo, pillar housing in low lying area

4. Inside a house

5. Opem duming of wastes

6. Childens playing ground

Living and working in hazardous location

Figure 5-5: Conventional photos of housing and environmental quality in study area Source: Author

Water source

The majority of the slum dwellers use common taps. Using common tube well is also a very general issue in the slums. Using pond and river water, buying water from the neighbours or availing inside house water tap is very regular practices in the slums. Private drinking water source means (either piped supply water, own tube well) inside house so it was considered good service. Common usage (piped supply, tube well) of drinking water was considered as bad quality of service. Other water source pond, river, lake, buy from other place was considered as worse condition. For common water source they need to stand for long queue therefore to fight with neighbour is common issues they have.

Other water sources like pond, river, and lake are considered as unhygienic. The people who buy water it is expensive for them and it is difficult to bare. Poor household with monthly income of around 2000 BDT(29 US Dollar) become highly burdened to pay 60 BDT(1 US Dollar) for monthly water charges, while it is not meeting their complete water demand. The context is they buy water only for drinking rest of the household work such as washing utensils, taking bath, cooking, washing cloth they use to go to pond, lake, river (see Figure 5-7). Eventually they got affected by skin disease due to unhygienic water use. During flood problem aggravated more due to wide range of water pollution.

Cooking

Having own stove by using fire wood is quite common practice in the entire study areas. On the other hand using common gas lines also a very general way of use. The values are 50% and 35% respectively. Availing own gas service is quite expensive for a single family to afford. Almost 6% families have this access because of having comparatively better access of financial support. Own gas cooking plate inside house considered good quality service. It represents households' good economic condition. Common usage is highly competitive, increase the chance for social dispute with neighbour, represents poor accessibility. Use of own mud oven is highly susceptible to weather condition. Represent poor service quality. During rainy season it becomes very difficult to collect dry firewood also becomes expensive.

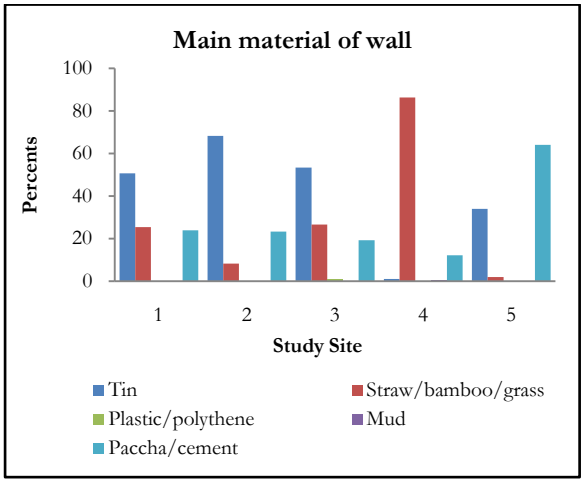
Toilet

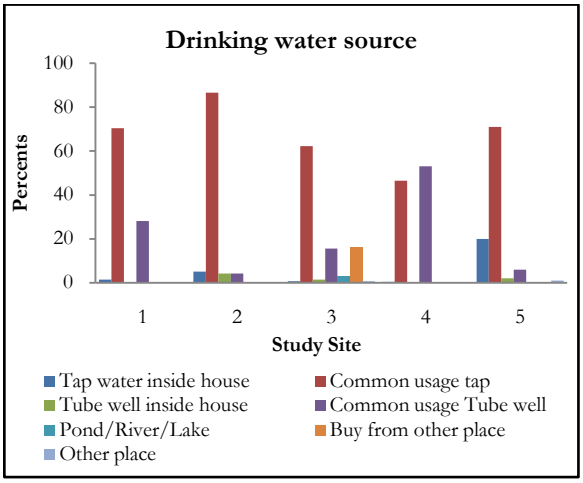
Sanitation is a most important part to assess vulnerability. People having unsanitary latrines would be more vulnerable rather than people having better access of sanitation.

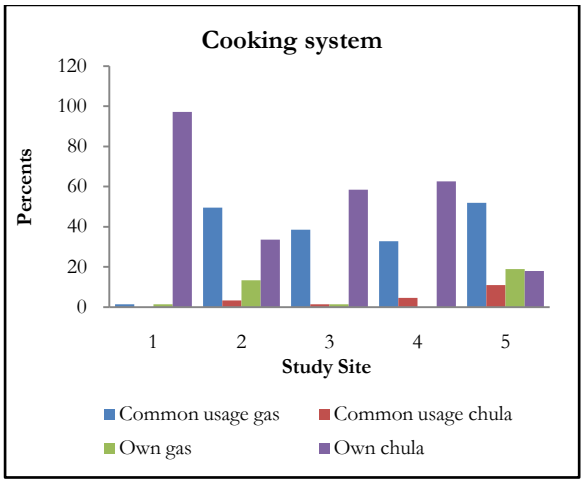
In the study areas most of the slums have public latrines financed by water development board which developed by DSK (Dusto Shasto Kendro). The percentages of people who use public latrines are high in study site 1 as it is 100%, while, in the other study sites the ratio is very high more than 60%. Hanging latrines and private latrines are also common characteristics of study area specially in study site 4 around 20% of the household are using hanging toilet. Modern toilet option considered as good quality. On the other hand public toilet option is considered as bad quality of service (mostly provided by NGO's). Hanging and open toilet considered as worse condition in respect to health awareness and hygiene.

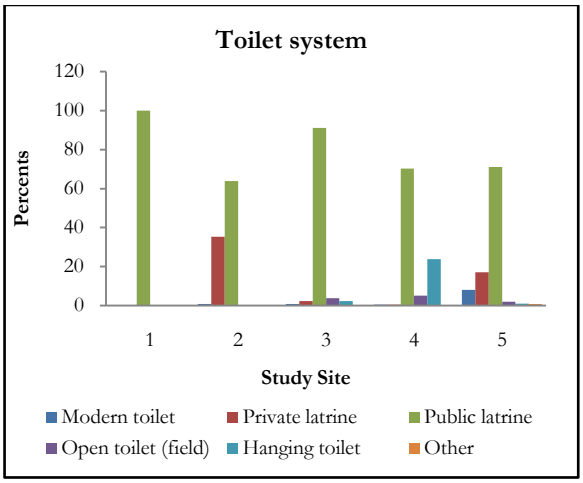
Regarding flood, the availability and quality of basic services such as drinking water and sanitation become crucial in determining the level of disruption experienced by the households. Unavailability of safe drinking water is the main reason to spread disease during crisis time. Particularly children may be more susceptible to diseases and infections. The surface or ground water contamination with human waste or other pollutants make household life more difficult during flood.

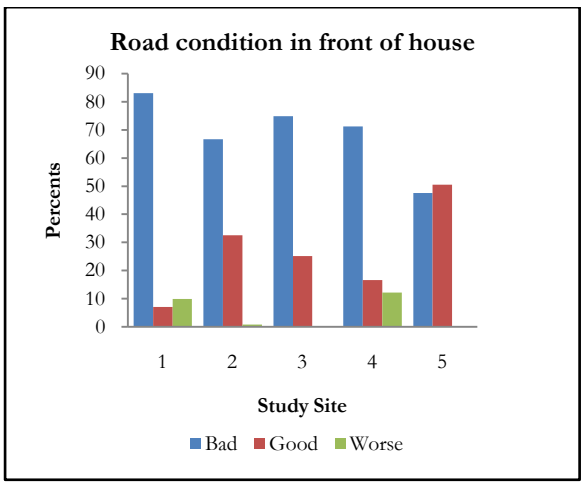
Housing and facilities











Graph summary

- Main material of wall: Tin, straw/ bamboo/ grass.
- Drinking water source: Common usage tape is most dominant source while in site 3 buying water is also significant (20%).
- Cooking system: Own mud oven and common usage gas.
- Toilet system: Public latrine use is most dominant while in site 2 handing toile is in second rank (38%).

Figure 5-6: Housing and facilities in the study area Source: Dhaka Hazard Slum Survey, 2009

Water source: 1. People taking bath 2. Cleaning dishes with dirty water

Cooking system: 3. Community kitchen 4. Own mud oven

5. Left: Hanging toilet
6. Right: Community toilet

Figure 5-7: Conventional photo of housing and services condition in study area Source: Author

5.3.2. Flood Effect in study area

During floods households' suffer from so many problems such as effect on job as discussed before, decrease in income or income source stopped, effect on health, housing damages, water crisis, cooking system damage, finally difficulties in daily food arrangement lead household malnutrition and starving.

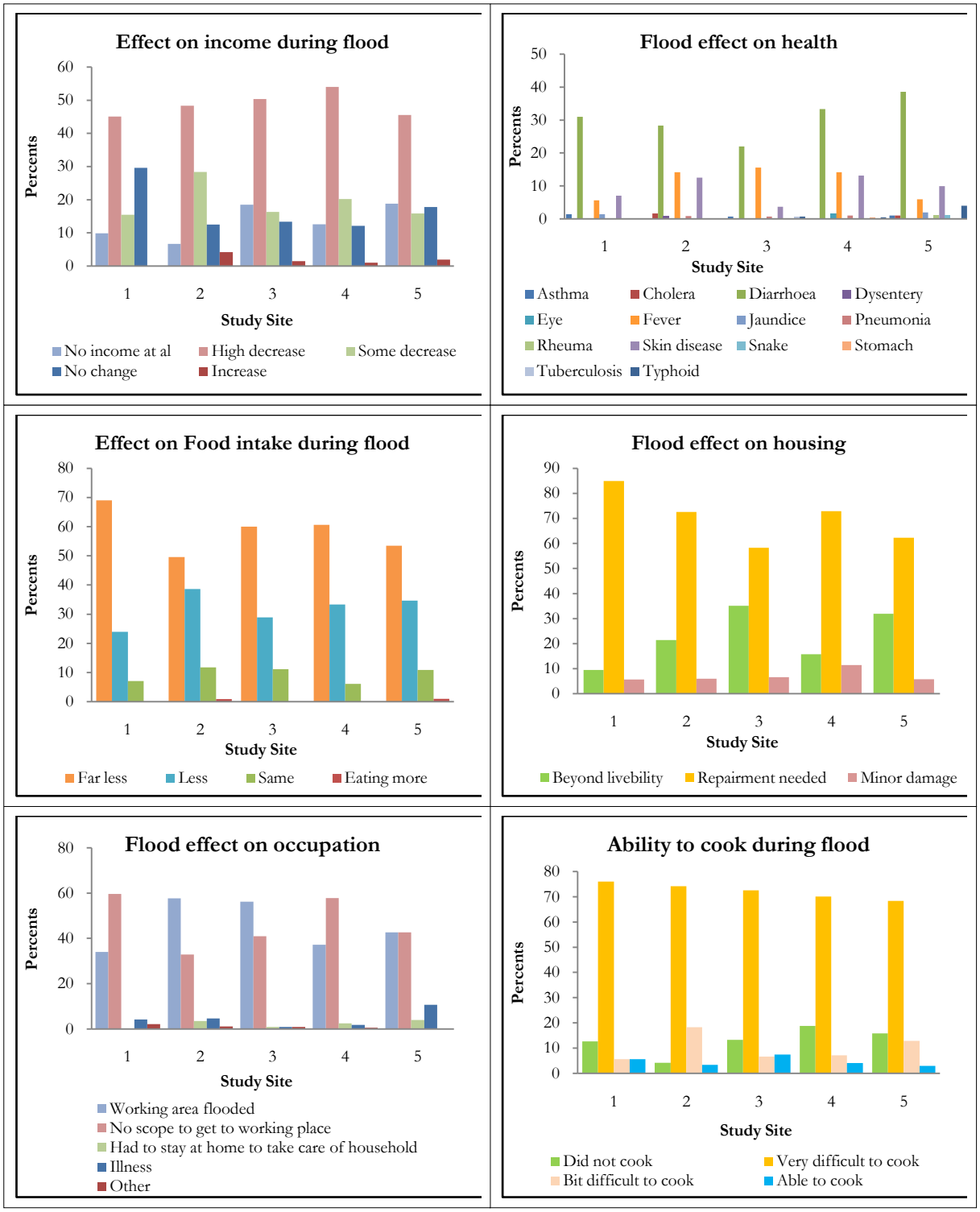


Figure 5-8: Water source, cooking and toilet system Source: Author

Effect on job and household head age

It was mentioned in one of qualitative interview that most of the people who work inside or around the slum area their work are affected during floods due to the fact that the working area is. At that time the ability to change the occupation is one important coping measure for the people in the study areas. Day labourers or vendors change their occupation and for a certain period and try to find other income sources. In this condition old people were found to be more susceptible, because of their physical inability to change their occupation. It pushes them to stop earning in rainy season. In this case they were

considered as most vulnerable group. Households having a comparatively young household head cope capacities under rapidly changing conditions. Therefore, in this study, the household head age is one of the important indicators to measure household vulnerability.

A household head age in between 20-55 (very young and mid age) was considered as capable to change their work. On the other hand, a household head age of 56-85 (old and very old) was considered as less capable to adjust with changing context. The older the household head is, the likely he is to be more vulnerable to floods.

Effects on health

The incidence of diarrhoea, fever and dysentery are the most common health effects during flood in the study areas. The prevalence of diarrhoea diseases in the flood-affected areas is a major concern. Figure 5-5 shows that in all the study sites around 30 percent of the household faced diarrhoea during floods. Suffering from fever and dysentery is also other major concern during flood. Sickness of household member is not only suffering of their health, but also has other impacts such as the need to buy medicine or to go to doctor. If the household head becomes sick then it also disrupts the households' income sources. Then the whole family is in uncertainty at that time.

5.3.2 Adaptive Capacity: Coping with and recovering from floods

Immediate Coping Strategies: Seeking Shelter, Getting Relief Aid

During major floods, taking shelter in a school, a relative's house, or on the road is the most common immediate coping strategy. Household who have relatives in Dhaka are in a better condition to take shelter in their relative's house, while others who move in search of shelter to different places are sometimes refused. Then they stay on road without shelter. Residing in relative's house 7 to 15 days is acceptable but more than reveals that the family relationships might turn worse.

In the local context, the people who go to the shelter centre usually are very poor people as it is not prestigious to go to there. Still, to get a place in a flood shelter centre is highly competitive. In some cases it is only restricted for women. Men are not allowed. In this case women and children take shelter in flood shelter centre and men used to stay on road without any shelter. Flood centres are very crowded. Those who do not have any relatives usually go to the flood centre or those whose social status is very low. Those who Stay on elevated road without any roof on top considered highly vulnerable during floods, taking shelter in flood centre and relatives house considered as low vulnerable , living on the roof of own house, elevated road, on boat is considered highly vulnerable.

During severe flooding the amount of relief that is distributed by the state and NGOs is not sufficient. According to the local people's perspective, relief is highly corrupted by political influence. It often requires political relations to get relief. This power is often misused by the local relief distributors. In general, people are not happy with the relief distribution and most of them are highly disappointed by the government.

Recovering from Floods: Relying on Loans and Savings

Taking loans during or after a disaster in order to deal with the flood damage or to buy food during these difficult times is considered as an important recovery strategy. In most of the cases, households use their personal relationship for taking loans such as from friends, relatives and neighbours. In that case they are more flexible to pay back the loan. They need not to pay any interest rate. Taking a loan from a bank or an NGO required the payment of interest rate, which are often not too high. Many families manage to pay back the loan slowly without big stress. Sometimes employers and landlords also give out a loan to the

households. Taking loans from a local money lender is considered as a risky solution to manage the flood effect. In this case they take loans with very high interest rates and they are forced to pay back, otherwise the interest rate starts to add into a huge loan amount. Finally, it might lead the household into marginality.

This is the extreme case of recovery; to get a big amount of money (common amount of loan 144$) at a time they used to take go to local money lender with high interest rate. Not having any relative or friend as well personal relationship to help is mainly the reason to take loan from money lender. These money eventually they use to repair damaged house, recovery in business, or simply to continue with daily expenses especially when income source is completely stopped due to prolonged flood.
In general, taking a loan helps them to recover from a disaster, but pushes the household back into the cycle of poverty, from which it is hard to escape.

It was found that the personal savings of households help them to recover from hazard impacts quicker. However, higher income and education level is correlated with household savings. It was found that those household having better incomes and a better occupation are well prepared for future. If household are educated they have awareness to save money about future problem might occur. Finally it helps them after hazard to recover from the impact as well as prevent them from other risky adaptive actions such as taking loan from a local money lender with high interest rates. Household having saving shows not only the better capacity of household to reduce hazard impact but also gives assumption about their awareness level against future uncertainties such as natural hazards. Finally it reduces the vulnerability of household from financial perspective.

In the worse case the household who do not have the capacity to take a loan or to save money are forced to begging and even starving. In case of a big flood they might, however, get some relief from the government, NGOs or rich people.

Risk awareness

Besides households' coping capacity, their risk awareness plays a very important role in minimizing the hazard impact during or after crisis moment. Households having better knowledge about hygiene, also have better resistance power during a crisis. Drinking safe water decreases the likelihood of being affected by water borne diseases (e.g. especially diarrhoea). Micro credit programme from NGOs' are very common in study area which encourage them to save a small amount of money for the future or helps them to take a loan. Beside this, the household involvement in health programmes is also common. Therefore, the risk awareness level is considered as a good indicator to measure household vulnerability in the study areas. Savings, household's food preparation practices before the flood shows the households' awareness level.

Social networks for adaptation: Asking for Help

The central government contributes little to the slum dweller's everyday life. Instead their social network that consists of their extended family, friends, relatives and house owners plays a big role in their everyday life, in particular during crisis moments. Although, they sometimes fight with neighbours over issues, such as sharing cooking place, water, etc., it is very common to go to ask for help during crises. Asking for help is thus a common risk mitigation and coping strategy taken by households to recover from the effects of floods. Households having a better adaptive capacity usually have close friends and relatives in the slum, who help them by giving loans, sharing information (to go to shelter centre, searching job), giving them their labour power to repair houses, or by sharing water sources or a cooking place.

5.4 Major Findings from the qualitative interviews to develop indicators and contextual framework

From the above section it became clear that households' physical and spatial position, i.e. their exposure, and their socio-economic conditions, i.e. their sensitivity, together contribute to the vulnerability to natural hazards. The aspect of vulnerability that were identified in the study area, are summarized in Table 5-3 in order to develop indicators and the contextual vulnerability framework as well.

5.3.3. Major findings from qualitative interview

Table 5-3: Major Findings from Qualitative interview

Major aspects of vulnerability in study area summarized in following table (constructed by author based on local context analysis by means of qualitative interview, conventional photo and expertise in local context)

Aspect	Characteristics
Exposure to natural Hazard	Living in most exposed area (Almost every year flood affected and rain water stagnated)
Income	Very low per capita income <27 US Dollar per month, Instability, dependency on daily basis income
Occupation	High rate of unemployment, Insecure job, informality, self employed (working in hazardous location), highly susceptible to natural hazard
Education	Mostly below primary level, High school level considered as educated
Housing and services	Poor housing materials (bamboo, plastic, tin), poor service condition, lack of infrastructure (shared cooking, sanitation, water), very bad road conditions)
Living condition	High density (more than two person living in one room), high dependency ratio
Tenancy	Squatter, land tenure(paying for land and constructing own thatch)
Migration status	climate refugee (migrated from village to the capital city: due to river bank erosion, cyclone or simply in search of better life)
Coping strategies during or after disaster	In better case, taking shelter in school or relatives house; in worse cases, living without shelter on the road; effect on income source (income decrease or completely stopped); effect on daily food intake (going to bed hungry or in worse case begging for food); effect on health, most common disease diarrhoea, fever, cough; Housing damage; loss of valuables
Mid-/longer term adaptation to recover from hazard impact	To take loan is very common (from neighbour, in worse case local money lender with high interest rate) for buying foods or repairing house or restarting business after hazard, other case households' own saving
Relief / Aid	Only little role of the Government or other institutions during or after disasters; great disappointment

Source: Author

5.3.4. Contextual framework

From the close observation in the study area it was identified how social and biophysical condition of human environment system in Dhaka influences the vulnerability of these systems when they are impacted by climate and other stressors. Aforementioned that vulnerability is not a single component that makes human insecure for future it is combination of group of factor and component which refer to insecure human condition to external shock. In an urban environment slum dwellers are facing frequent floods in home and work place which is not only affecting their income, but also affecting their whole system and changing their social behaviour, dignity level and their food habits as well. How much their likelihood to be exposed in near future, how much sensitive they are and how much they are able to adapt with this changing context is not possible to measure exactly but it was tried by studying human nature and their interaction with environment and society in normal and crisis moment by doing qualitative assessment of vulnerability level of these people under this following concept..

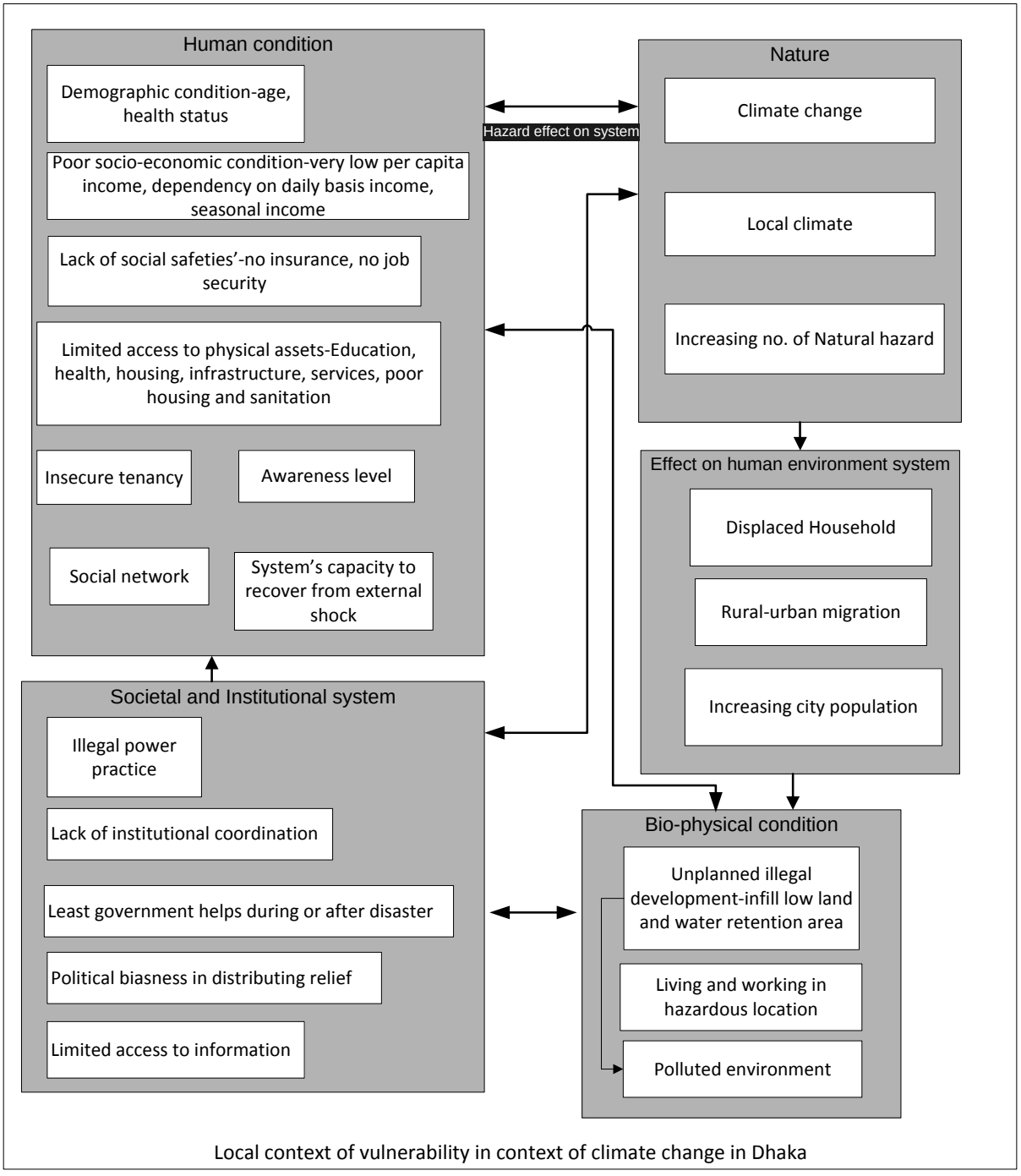


Figure 5-9: Local context of vulnerability in context of climate change in Dhaka
Source: Author

In above figure it was tried to summarize the local context of vulnerability. Therefore identifying explicitly all relevant contributing factors of flood vulnerability in the study area made it possible to carry out semi-qualitative flood vulnerability assessment in local context.

6. SPATIAL ASSESSMENT OF FLOOD VULNERABILITY AT HOUSEHOLD LEVEL

This chapter will discuss flood vulnerability at the household level based on the selected indicators using the spatial multi criteria evaluation technique. On the one hand people are suffering from hardcore poverty, which is an internal aspect of their vulnerability. Beside these, they are also exposed to different external shocks, such as natural hazards, the risk of illness, and unsafe social conditions. Together, these entire factors contribute to the vulnerability level of the households. Residing in the same community, the vulnerability level can vary regarding the individual household's sensitivity and adaptive capacity. This chapter will help to generate knowledge about the human susceptibility to climate change induced flooding. Those who have shown a better capacity to cope with adapt to and recover from flood effects in the past, might also be less affected to probable floods taking place in the future.

6.1. Introduction

Previous chapter 5 discussed the socio-economic, physical and environmental aspects of vulnerability in flood-affected households' daily life. In addition, a GIS-based questionnaire survey shows the spatial distribution of the households, which is based on different individual factors of vulnerability in the five study areas in diverse locations of the mega city. This study is, thus also interested in the spatial extent of vulnerability. The major aim of this chapter is to understand how the spatial and non-spatial factors contribute to the household's vulnerability to floods. Dissecting this information will generate knowledge for the city authorities as well as international organizations, which address the reduction of climate change vulnerability in the mega city of Dhaka. Finding the root causes of vulnerability is the basis to take actions in order to improve the human security of slum dwellers.

One of the important aspects of this study is to describe the functioning of the local system. By describing the household's daily life stress and how they cope with, adapt to and live with flooding and other irregular weather conditions is an important step in the assessment of the household's vulnerability, which gives an indication of their susceptible to hazards in the future.

To achieve this understanding it was important to know the household's conditions by close observation. Although the researcher had limitations to visit the field, previous research experience with these communities in Dhaka and qualitative interviews by using internet phone calls made the researcher confident to actually understand the local context of the vulnerable.

6.2. Flood vulnerability assessment at household level

This study considers households as the vulnerable element. Therefore the aim to do multi criteria analysis is to assess why, how and to what extent slum households may become susceptible to floods.

Identifying those factors that contribute to increases in the daily life stress for household was therefore relevant for this assessment: the availability of resources, their knowledge and their living conditions contribute to their inherent vulnerability to external stresses. Prioritizing each vulnerability component and factors is derived from the qualitative interview. During the qualitative interviews the interviewees were

asked which factors are most important for their households' susceptibility to hazards. Based on this information the vulnerability component and criteria was scored. At this respect it was found that compared to the daily life stress, the flooding problem adds an extra stress on the household and is considered as a `normal´ seasonal difficulty. The households were able to identify floods as a problem, but they believe that if they had less other problems, such as insufficient income, bad quality housing including improper services, then flooding might have less impacts (damage level, uncertainty in income) on their life. According to them heavy rainfall is a problem, but it only becomes a real problem for them when it effects their own earnings. If suddenly weather conditions vary, then it has effects on daily earning and thus on their food habits as well on the existence of total household. The households in the study areas largely belief that, if they have financial support then they are able to minimize severe effects of flood. A flood is considered as 'severe', when it leads to their inability to buy food.

Table 6-1: Vulnerability aspect prioritized from household perspective

Vulnerability aspect	prioritization
Income level/occupation type	1
Living condition: house type, service provision, road condition	2 (house type was given more stress)
Living in exposed area: water logging, regular flooding	3
Means of recovery: loan, savings,	4
Personal relation: friend, relative, neighbour	5
Institutional help	Less priority

Source: Qualitative Interview analysis (Author)

The results of the vulnerability assessment presented here refer to identify the divergence nature of households in their way of life and their spatial distribution. The main goal (vulnerability level of household) was then to develop a method in which the major aspects of vulnerability, which were identified from the qualitative interview by the participants, are measurable in quantitative fashion, too. At first all aspect of household vulnerability were identified in order to develop indicator under each factor and then vulnerability factors were classified into different group based on expert knowledge (from literature socio-economic refer to income, occupation, exposure refer household leaving in hazardous location etc). Later on the vulnerability indicator was developed from the gathered information. After performing the aforementioned procedures, by means of analytical hierarchical method all indicators, factors and vulnerability components were integrated into the spatial multi-criteria model for the final vulnerability assessment.

6.3. Constructing the Multi-criteria Index

The aspects listed in Table 6.1 were rearranged in a 3 level hierarchical model (Table: 6-2). Under each component several factors were divided into different indicator. Each factor consist of several indicators, as follows:

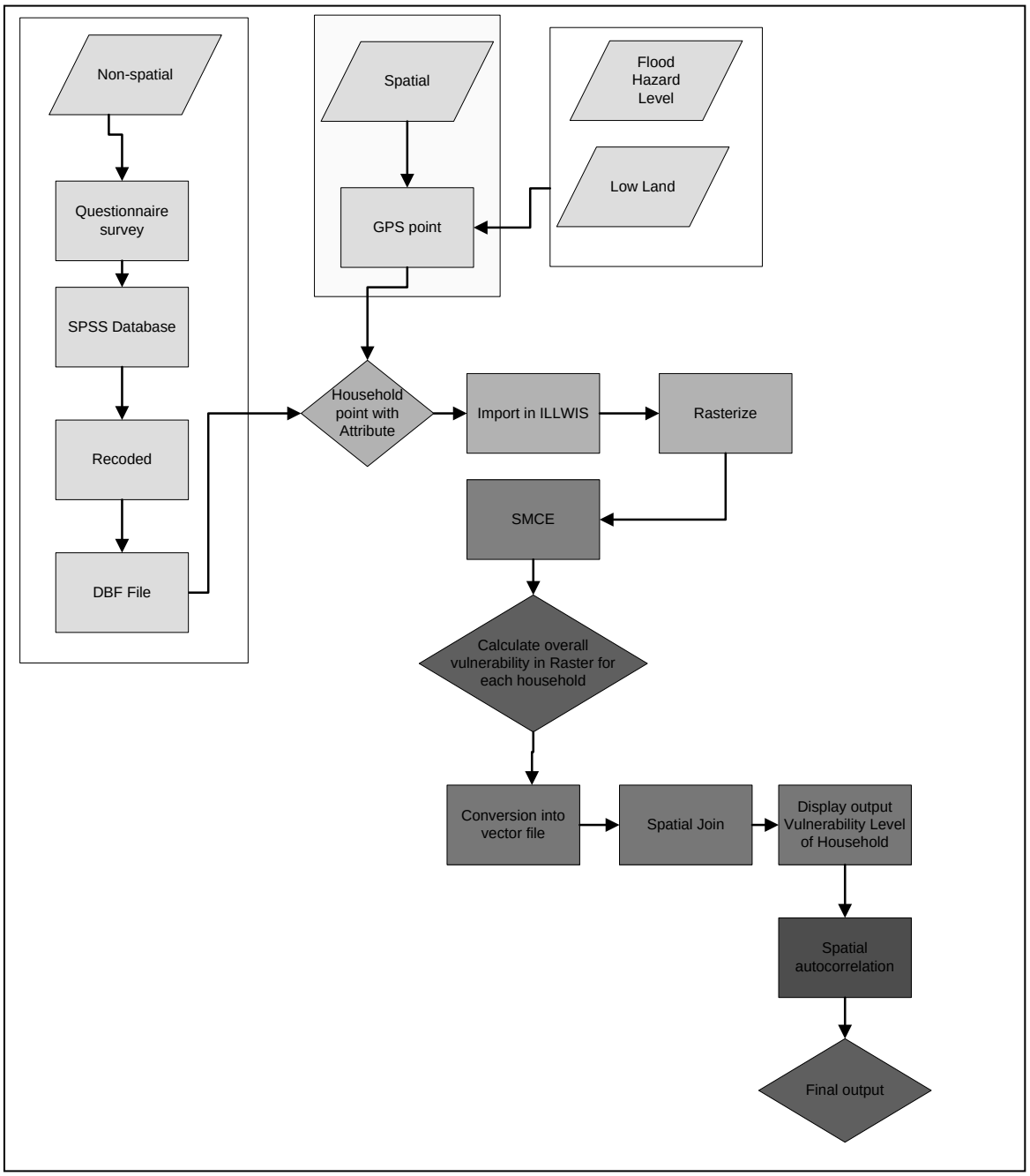


Figure 6-1: Technical Flowchart of spatial assessment of vulnerability, Source: Author

Vulnerability component: As discussed before, according to the vulnerability framework by Turner et al (2003) vulnerability is defined as a combination of exposure, sensitivity and adaptive capacity. Exposure here is the external shocks for a household which is related to living close to a hazardous location. The sensitivity and adaptive capacity of the households are derived from the local context through the combination of qualitative interviews and expert knowledge.

Factors: Under the each vulnerability component several factor were assigned. Aforementioned that vulnerability is not only the cause of one factor it is combination of several factors. Therefore to identify all aspect of vulnerability under exposure, sensitivity and adaptive capacity multiple factors had to be considered such as socio-economic, housing and facilities, risk awareness level, social networks, means of recovery, historical behaviour, and institutional capacity. All of these contribute to the households' vulnerability to floods.

Indicators: Indicators are considered as the part of the factors and contribute to the degree of overall flood vulnerability. A group of quantifiable features have been identified through the analysis in Chapter 5. Based on the qualitative interviews indicators were selected from the quantitative dataset. The quantitative questionnaire survey dataset (provided by the Flood Hazard Project at the University of Cologne)was the main source of information in this phase.

Table 6-2 presents the three major component of vulnerability, a list of the main factors and indicators constituting the vulnerability Index.

6.4. Creating spatial multi criteria model

Not only one factor makes people susceptible to natural hazards. But all factors don't contribute equally to vulnerability. Therefore it is needed to implement spatial multi-criteria to know and determine in which proportion and how every factor and indicator contribute to the total vulnerability. Multi criteria technique has ability to combine information from different scientific fields. It can combine all information and can sum it up for decision or problem analysis. Finally, an overall output value is given.
By using Multi criteria technique it is possible to measure total value of vulnerability for each household considering all vulnerability factor that contribute in human vulnerability.

6.4.1. Procedure followed

In this study at first (in chapter 5) it is discussed households' characteristics which influence to increase or decrease household vulnerability. After that the statistical datasets (SPSS file) were linked with the household GPS-point files in order to carry out a spatial analysis. After that these vector files were exported as a raster layer to perform spatial multi criteria analysis using the ILWIS software. Then data sets were prepared to perform the final multi criteria analysis in raster environment. Therefore each household point was transformed into a raster cell.

According to the procedure for the SMCE, aforementioned in chapter 3, the 'Goal' of the current analysis was to firstly identify how vulnerable to flood the households are and secondly to see the spatial pattern of vulnerability at the five study sites. For implementing spatial multi criteria evaluation techniques according to the AHP procedure three steps need to be followed. First phase is structuring the problem into a hierarchy. Second step is the weighting procedure using direct, pair-wise ranking methods comparing the criteria and the combination is associated to the multiplications of the hierarchical levels. Here every criteria becomes a raster layer and every pixel becomes an alternative. Each level of hierarchy can consider as goal phase as such level one is final goal, level two sub-goals or objectives. Each level of criteria tree will be assigned by using different weight. This process mainly generates the values for the layers of the intermediate levels which are obtained by using the summation process considering the performance of the indicator for the alternative at lower levels of the criteria tree. The criteria tree was created by following the structure of three level hierarchic process of AHP model. The vulnerability component, the factors and indicators in one criteria tree are fully presented in Table 6-2.

6.4.2. Characterizing, Standardising and weighing the criteria

The methods for characterising, standardising and weighing criteria were followed according to the analytical hierarchical steps. The first step is to determine the negative or positive contribution of the criteria for the proposed goal was carried out for each and every indicator. In this case when higher values contribute to make household unit more vulnerable to flooding 'indicator' was considered as benefit and for defining cost it was vice versa. An example of this procedure is given by the analysis of two indicators in which the income and house type were classified by giving different values (Figure 6-2). The following graph is showing the standardize process. If the criteria play a positive role then the criteria is considered as a benefit. In the same way, if criteria play a negative role then the criteria is considered as cost. For

instance, higher income decreases the households' vulnerability, therefore this factor is considered as a cost criterion. Taking loan with a high interest rate increase household vulnerability therefore these criteria considered as benefit criteria.

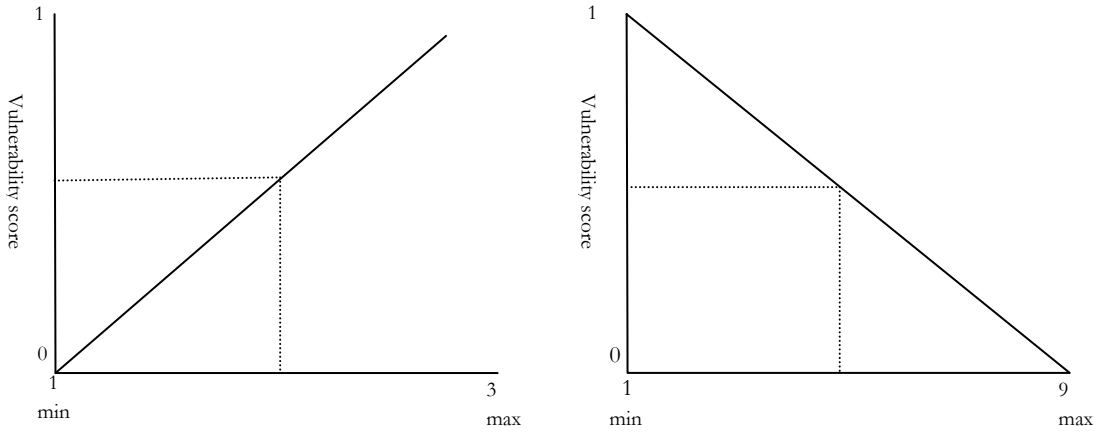


Figure 6-2: Benefit (Left) and cost (Right) criteria

After finishing the procedure of determining cost/benefit for the indicator in the criteria tree standardization process was the next step taken. From the Table 6.2 it can be said that the criteria used in this analysis largely vary in their characteristics and the way of contributing into the vulnerability level of the household. Therefore it is necessary to follow the standardisation procedure to bring all criteria in same scale or measurement level in order to make them comparable to each other. In the current vulnerability assessment study the standardisation procedure was performed at the indicator level which implied that each individual indicator was standardised by setting the limit from 0 ('not vulnerable') to 1 (as 'highly vulnerable'). Then linear interpolation techniques were used to assign the criteria from minimum to maximum values.

After finishing the standardising process for all the indicator the next step was the weighting process which was meant to determine the importance of different criteria based on its' contribution in overall vulnerability score. This analysis was carried out from the lower to higher levels of criteria tree. The starting point was the determination of weights between the three vulnerability components (final goal). Afterwards weighting was performed between the factors or sub goal level and finally the weighing of the criteria itself. The procedure of weighing criteria in SMCE is facilitated by several tools such as 'Pair wise Comparison', 'Direct Weight' and 'Rank Ordering' derived from the Analytical Hierarchical Processing (AHP) (ITC, 2005). Apart from this the method being used the sum of weights which should be always be 1 as the final result.

The weighting system in multi criteria technique is its' plus point, but at the same time has some weaknesses, too. On the one hand, we can make a decision and prioritize our factors and set a specific emphasis. On the other hand, weighting the factors is always subjective. Different person can have different perception to prioritize criteria for the same decision problem.

In this study to avoid this problem to prioritize the criteria it was asked to the interviewee in their view, which one do they think is most important problem making them more vulnerable to floods. It was very interesting to know that all of them prioritized their sensitivity to flooding. It is important to note that local people they do not have any idea about the term vulnerability or any vulnerability component as such exposure, sensitivity or adaptive capacity.

Table 6-2: Vulnerability component, Factors, indicators involved in the spatial assessment of households flood vulnerability in Dhaka, with the Weights used at each level with description

Vulnerability component (Total value: 1)	Factor	Indicator	Benefit/ Cost	Description
Exposure (.30)	Living in hazardous location(1.00)	Flood hazard Level (1.00)	B	Household living in flood hazard zone is most exposed to flood
Sensitivity (.45)	Socio-Economic(.61)	Income Level (.33)	C	The higher the income level the less sensitivity to hazard
		Occupation type of head of household(.33)	C	The better the occupation the less sensitivity
		Literacy level of head of household (.16)	C	The more educated the less sensitive
		Dependency ratio(.10)	B	The more dependency ratio the more sensitive
		Density per room (.03)	B	The higher density the higher sensitivity
		Age of Head of household (.06)	B	Household head age> 60 is more sensitive
	Housing condition and Service Provision(.28)	House Type (.46)	B	Good quality housing less sensitivity
		Drinking water source (.26)	B	Accessibility to drinking water source reduce sensitivity
		Cooking option (.10)	B	Accessibility to cooking option reduce sensitivity
		Toilet provision (.10)	B	Accessibility to toilet provision reduce sensitivity
		Road condition in front of house (.10)	B	Good condition of entrance road to house refer less sensitivity
	Historical flood effect(.11)	Effect on cooking (.10)	C	Less effect less sensitive
		Effect on Food (.33)	C	Less effect less sensitive
		Effect on Income (.33)	C	Less effect less sensitive
		Flood damage level (.16)	C	The higher the damage level the more sensitive
		Household member had to take shelter in other places (.06)	C	Household need to vacant house refer high susceptibility
		Shelter duration (.03)	B	Household need to take longer duration of shelter are refer to more sensitivity
Adaptive capacity(.25)	Awareness level(.25)	Savings (.52)	C	Having saving means household is aware about future problem
		Housing preparation before flood (.10)	C	Housing preparation means household has is aware about future problem and also shows better capacity
		Food preparation before flood (.10)	C	If yes then higher awareness level
		NGO membership (.27)	C	If yes then higher awareness level in terms of knowledge sharing about health safety, savings or scope of getting loan
		Illness (.10)	B	Household member got ill during last flood refer less awareness as well as high sensitivity

Vulnerability component (Total value: 1)	Factor	Indicator	Benefit/ Cost	Description
	Social network(,25)	Relative living in slum (.33)	C	Relative living in slum means better household has better social network
		Relation with neighbour (.33)	C	Good relation with neighbour means better social network
		Help from others during last flood (.33)	C	Household got help from others shows better social network as well as better capacity
	Household capacity(.25)	Saving amount (.52)	C	The more the saving amount the better capacity
		Household duration of stay in study area (.06)	C	The longer the duration the better capacity
		Recover time after flood (.21)	B	The longer the recover time refer less capacity
		Shelter place during flood (.21)	B	Safe shelter refer more capacity
	Others(.25)	Taking loan (.15)	C	Taking loan refer household capacity to recover
		Loan interest rate (.40)	B	High interest rate create negative impact
		Taking loan from whom (.40)	B	Loan source refer household capacity
		Flood forecast (.06)	C	Receiving flood forecast refer institutional capacity

Source: Constructed by author (for more explanation about indicator see chapter 5)

As the spatial multi criteria evaluation technique is a weighted summation process, it sums up all values obtained from analytical hierarchical process and then creates a final output map. In this study vulnerability is combination of exposure, sensitivity and adaptive capacity when exposure and sensitivity is the reason to increase vulnerability and adaptive capacity is reducing vulnerability score. Simply put: exposure and sensitivity are benefiting criteria and adaptive capacity is a cost criteria. Therefore to simplify the technical problem another criteria tree was prepared to calculate final vulnerability score from these three map exposure, sensitivity and adaptive capacity generated from first criteria tree. Following figures (Figure 6-3 and Figure 6-4) provides an illustration of the entire process:

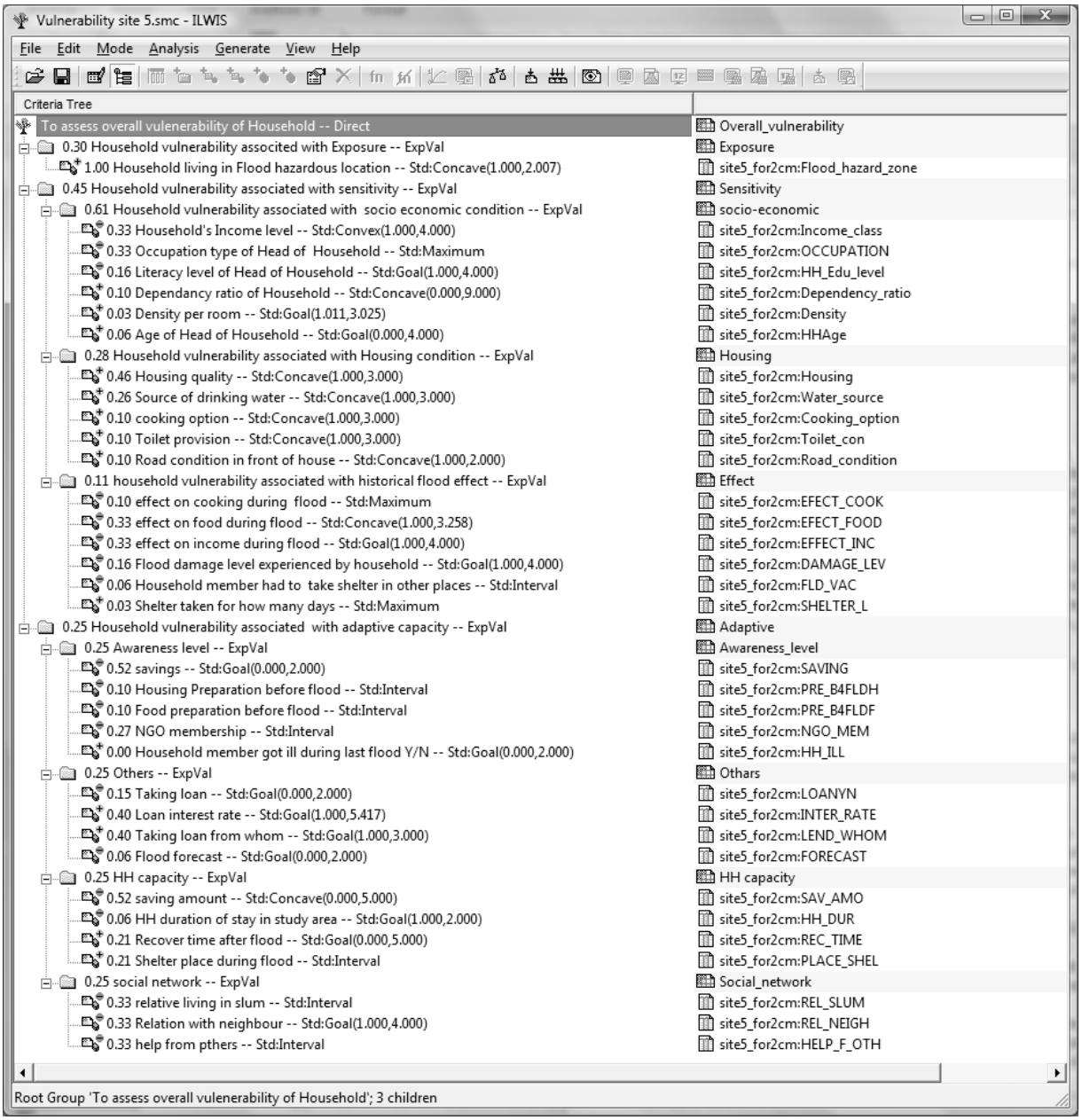


Figure 6-3: Criteria tree 1

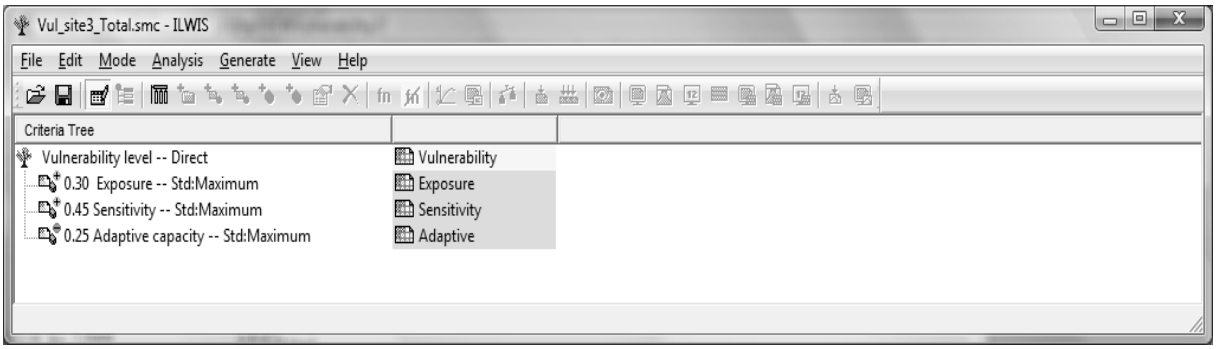


Figure 6-4: Criteria tree 2

6.5. Flood Vulnerability in Dhaka: Interpreting the Results of the Spatial multi criteria Model

The following graphs (Figure 6-5) illustrate the initial results obtained from SMCE. After having this result it is easy to understand the spatial distribution of vulnerability scores in the five study sites. In this chapter this result will explain the vulnerability level of households. As it is already explained in chapter 5 about all the components, factors and indicators of vulnerability, hence this chapter will only focus on selected indicators, (see Table 6-2) their contribution (weight) and result interpretation as well as discussion about vulnerability score.

In study site 1(Maghbazar) the vulnerability score is varying from 0.34 to 0.64 while, most of the scores are in between value .40 to .61 which is 80 % of the total household. However, highest frequency is observed in value .58 which is 19 % of the total household. The vulnerability value is varying in low range (.27) therefore it can be said the score distribution in this site is homogeneous.

In study site 2 (Dakhin Goran) highest frequencies, is observed in value .62 which is 20% of the total number of household. Consequently, second high frequency is observed in value .83 which is 14% of the total household and vulnerability score is varying from .28 to .90 in this site. Vulnerability scores has wide range of distribution in this site therefore this site is diverse in nature. On the other hand household living in close in one small group has almost same vulnerability score (see Map 6-2) though the score is varying within the different groups.

In the study site 3 (Goder Tek) the vulnerability value ranges is from .27 to .77, highest peak is observed in around score .67, which is only 18 % of the total number of household. While 14% of the households' vulnerability score is around .52. Simultaneously another 14 % of the households' vulnerability score is around .62 and another group (around 12.5%) of household has vulnerability score around .72 which is quite high score in this site and very few (around 5%) of them has vulnerability score from .32 to .37.

In study site 4 (Hazaribag) value range is within .32 to .93 when 25 % of the households are in value .8 while 38% of the household are in value .44 to .56. Only 5% household has low value (around .38) and very small percentage (around 1.5) has very high vulnerability score which is .93

In study site 5 (Khilkhet) the value ranges is .28 to .72. Highest peak is around value .54 which is 20% of the total household, second peak (high frequency) is observed in value .59 to .63 which is 30 % of the total household in this area.
Study site 2 and 3 has the highest variation in value range. On the other hand site 3 and 4 has similar distribution pattern of value range. Concurrently, site 1 has very short range of values therefore we can say this area is less diverse in nature.

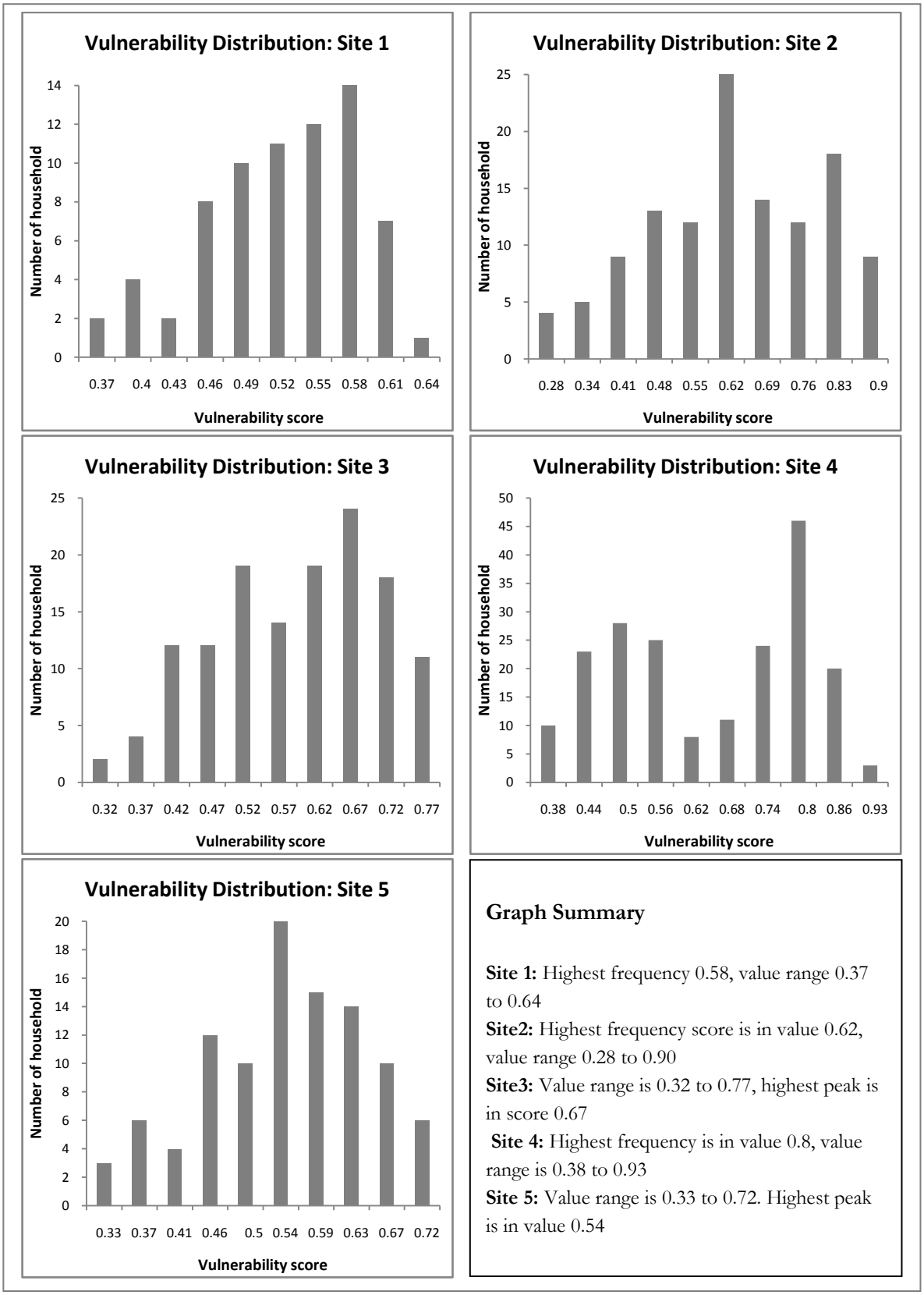


Figure 6-5: Spatial distribution of vulnerability in the five study site

After having the initial result of vulnerability score the final step was to classify the result meaningfully in order to make the result more interpretative to different stakeholders. In literature vulnerability score was standardized in between 0 and 1 where value close to 0 always refers low vulnerability and value close to 1 refer high vulnerability. According to the *Multi-hazard risk assessment, Guide Book*,(Westen & Kingma, 2010) the vulnerability scores have been classified between the range of 0 (low vulnerability) and 1 (high vulnerability). In this regard, the initial results above were categorised into five relative classes ranging from low (00-0.20) to extremely (0.81-1.0) vulnerability values, as shown in Table 6-3. This five intense classification were adapted from Peters Guarin, et al (2008) and applied based on local knowledge expertise author have.

Table 6-3: Initial Vulnerability score reclassified in the following table:

Vulnerability level	Index value
Low	0.00-0.20
Moderate	0.21-0.40
High	0.41-0.60
Very high	0.61-0.80
Extremely high	0.81-1.00

Study site 1

Most of the households in study site 1 are in high (.41 to .60) vulnerability level except very little variation in vulnerability level. In chapter 5, (Figure 5-1to Figure 5-8) it was described about the relevant characteristics of these households' related to vulnerability. During qualitative interviews household identified that housing condition and services are very important factor for them that increase their respective flood vulnerability. This site is in less flood hazard zone (see Flood Hazard Map 4-1). On average households having .41 to .60 vulnerability score however due to high sensitivity and less adaptive capacity they are vulnerable to face any kind of external shock. From the graph (Figure 5-4) it is observed that around 30 % of the household head in this site has no work, is very highly sensitive to flood. On the other hand around 70% of them are rickshaw puller and day labourers are particularly sensitive to flood due to high income uncertainties depending on weather condition. While

Around 60% people are in medium (only 58 to 110 US Dollar) income group, while 70% of the head of household has no educational background. On the other hand housing (45% Tin made, 25% straw or bamboo), drinking water source (70% shared tap water and 30% shared tube well), toilet system (100% public latrine), road condition (80% muddy) all this service is very poor quality. During last flood high 45% of the household faced decrease in income, 75% household faced difficulties in cooking and 60 % of them were not able to go to work during last flood and 70 5 of the household were in situation to eat less than normal time. Apart from these difficulties around 305 of the household were affected by diarrhoea during last flood.

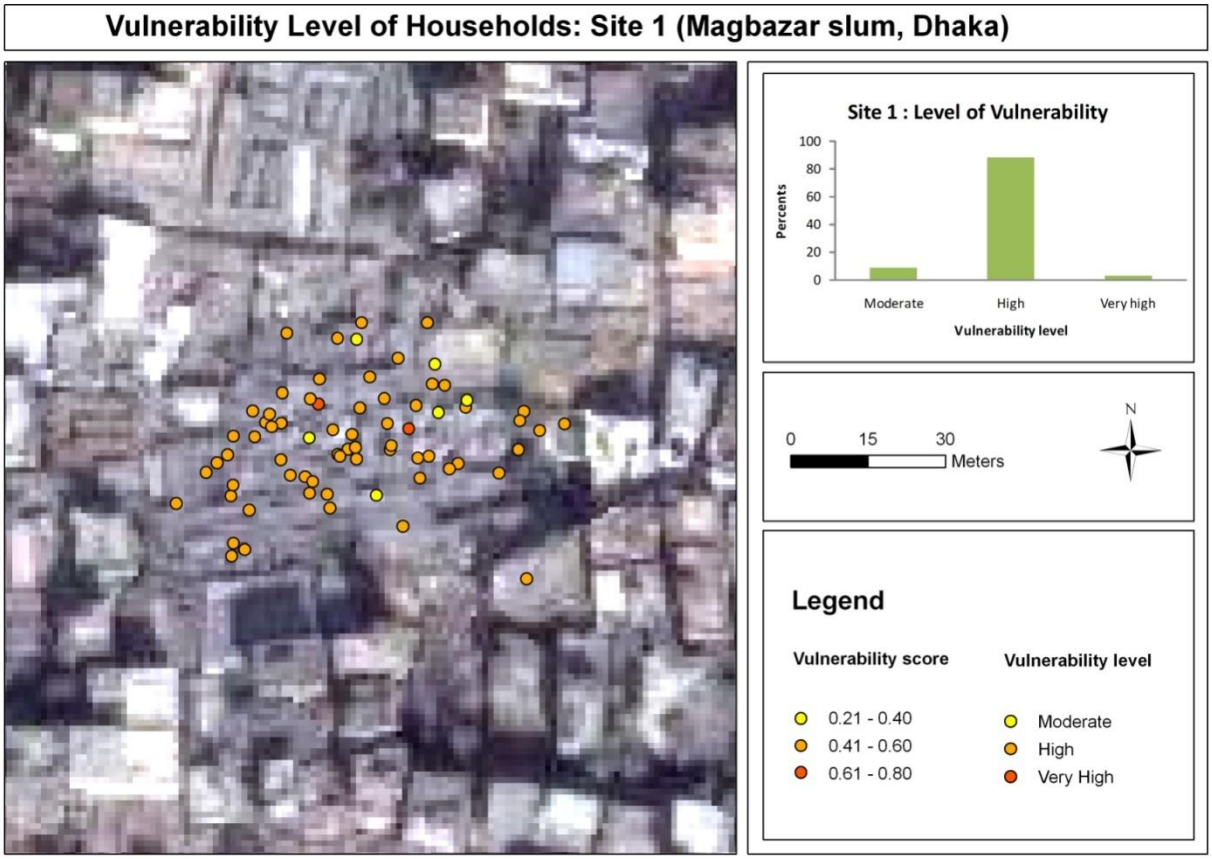
Study site 2

In study site 2 the percentage of moderately vulnerable households are 11.57. Most of the household in this study area are high to very high vulnerability level while the percentage is 38.01 to 35.53 respectively. This study area is highly exposed to flood except few household most (around 80%) of them are living in high flood hazard zone (exposure). A considerable percentage of households are extremely high vulnerable, 14.87 %. These households are exposed in same way as the others are in this study site, but due to their high sensitivity and little adaptive capacity they are extremely high vulnerable. Graph shows (Figure 5-4) a majority (35%) of the household are highly sensitive due to unemployment. Beside this 22% has low income (<40 US Dollar), that is not adequate to complete food demand another reason make them highly vulnerable. On the other hand weak housing structure make household highly vulnerable,

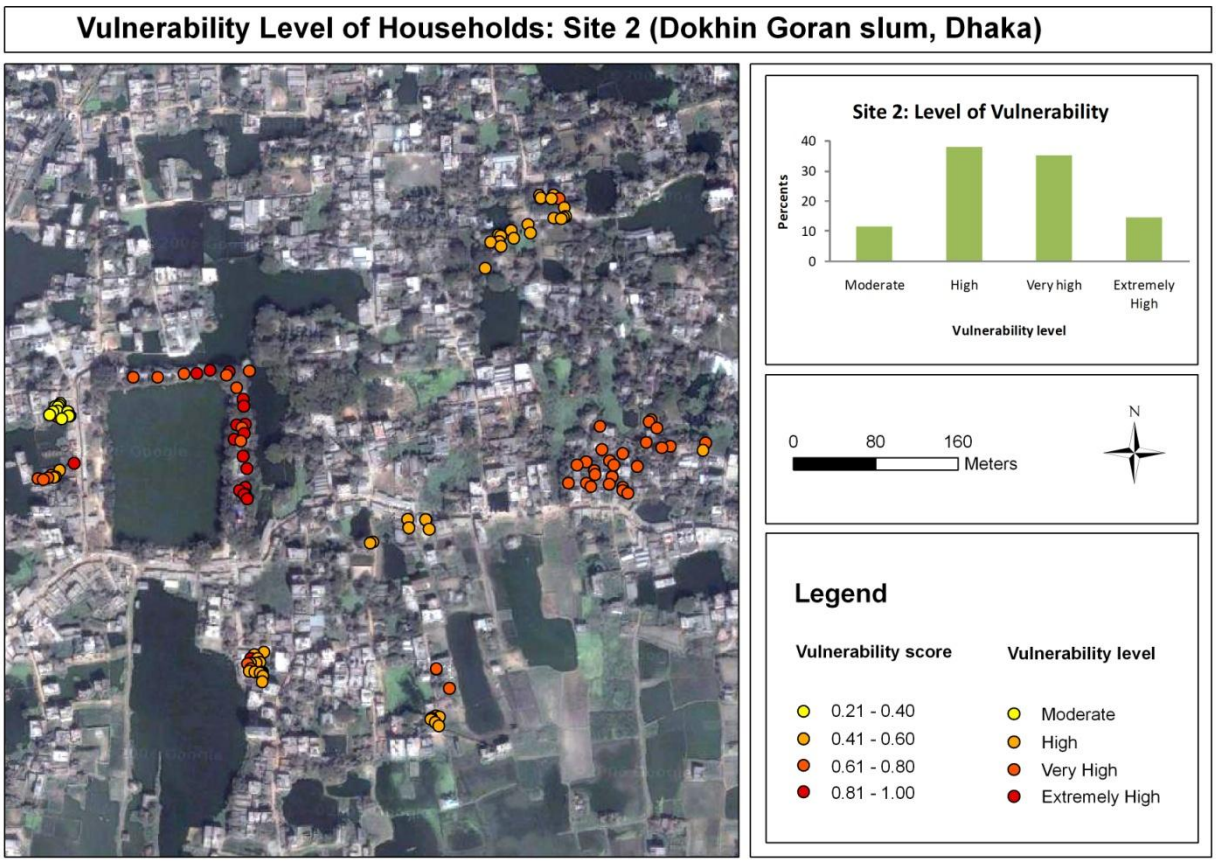
while other 20 % of the people have concrete housing are less vulnerable to flood. For 70% of the people in study area it becomes very difficult to cook during flood.

Study site 3

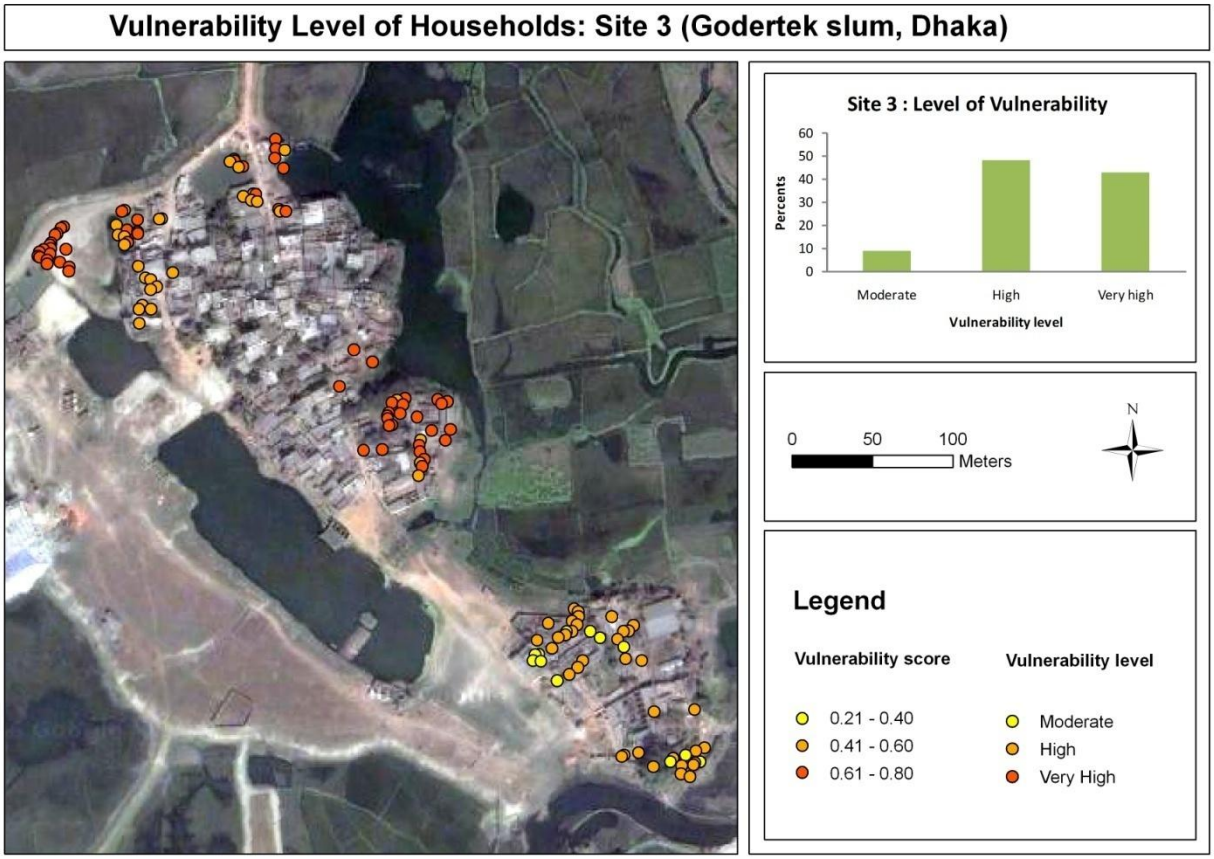
The result in this study site (Map 6-3) is showing three levels of vulnerability among the households. The north western part of the map is showing a vulnerability range varying from high to very high. On the other hand, south eastern part of the map is showing moderate to high level of vulnerability range of households. In the middle of the map households are highly vulnerable. Those households in the map showing moderate level of vulnerability, they have a higher adaptive capacity therefore their vulnerability level is varying. In this site around 70% of the household are living in high flood hazard zone, and 30% is living in moderate flood hazard zone. Frequent flood and water stagnation is common in this site for majority of the household. During last flood 20% of the household were affected by diarrhoea, 90% were forced to eat less due to high income decrease (see Figure 5-4, Figure 5-6, Figure 5-8).



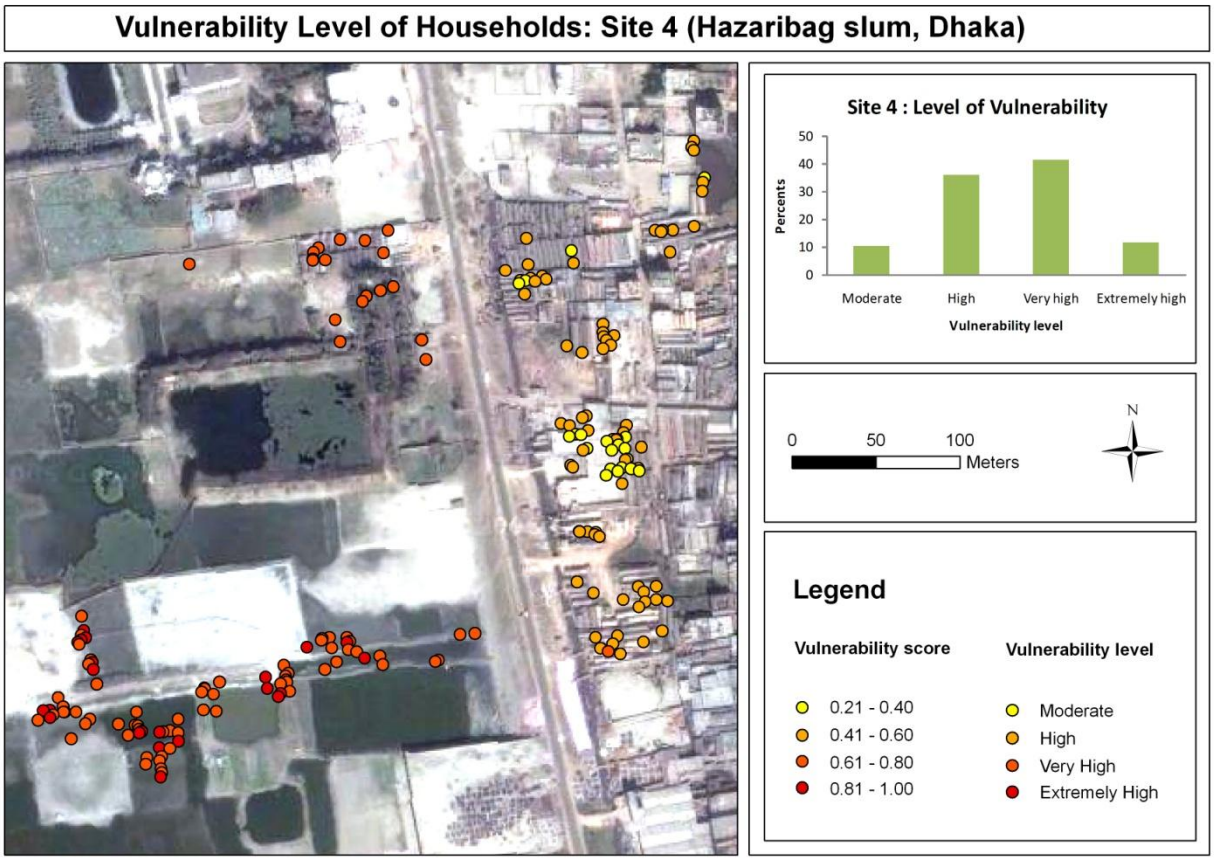
Map 6-1: Vulnerability level in study site 1



Map 6-2: : Vulnerability level in study site 2



Map 6-3: Vulnerability level in study site 3



Map 6-4: Vulnerability level in study site 4

Study site 4

Spatial Distribution of household points (site 4) according to the level of vulnerability has been represented in the above mentioned map. Above result (Map 6-2) is showing two types of variation in vulnerability score. First this map is showing there is a major variation in vulnerability score that can clearly distinguish the map into two parts. As western part of the study area is located in the non developed marshy land moreover it is outside of the embankment road therefore these households obtained very high and extremely high vulnerability score. On the other hand, as the eastern part of the study area mostly located in high dense urban settings but protected by flood embankment has less vulnerability score compare to western part of the map. In this site 45% household has medium income level, while 30% has low income are highly vulnerable to flood. Due to yearly flood high decrease in income is very common, 55% of the household faced high decrease in income. 35% of the household were affected by diarrhoea and 35% are forced to eat less, 35% household was not able to work due to inundation in working area.

Despite the fact that household living closer they have small variation in vulnerability score as observed. Western part of the map outside flood embankment their vulnerability is varying from very high to extremely high vulnerability level on the other hand eastern part of the map inside flood embankment their vulnerability score is varying in between moderate to high level.

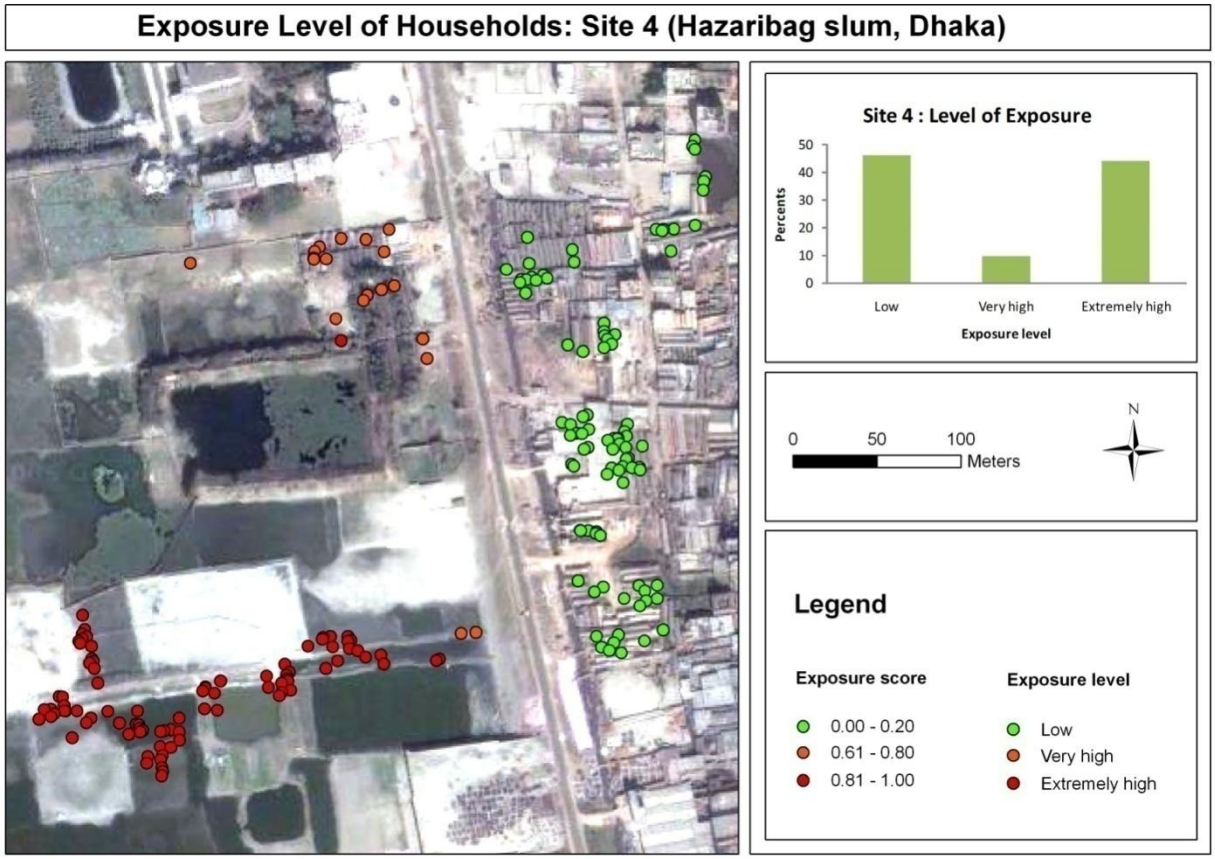
In this study site exposure has three levels moderate to extremely high, 45% are extremely high exposed while 45% and 10% are respectively moderate and low exposed to flood (see Map 6-5). In each flood zone household are exposed in same way but due to their sensitivity level and adaptive capacity level vulnerability score is varying inside the same level of exposed group. Map 6-6 is showing that 65% household has high sensitivity level (very low income, weak housing structure, bad service condition), 20% household are extremely high sensitive and 20% is moderately sensitive. In study site 4 around 80% of the household are living on bamboo pillar housing which very highly vulnerable to flood, while these houses are closely associated around water prone areas.

Box 6-1: Bad quality housing increase flood vulnerability of Household

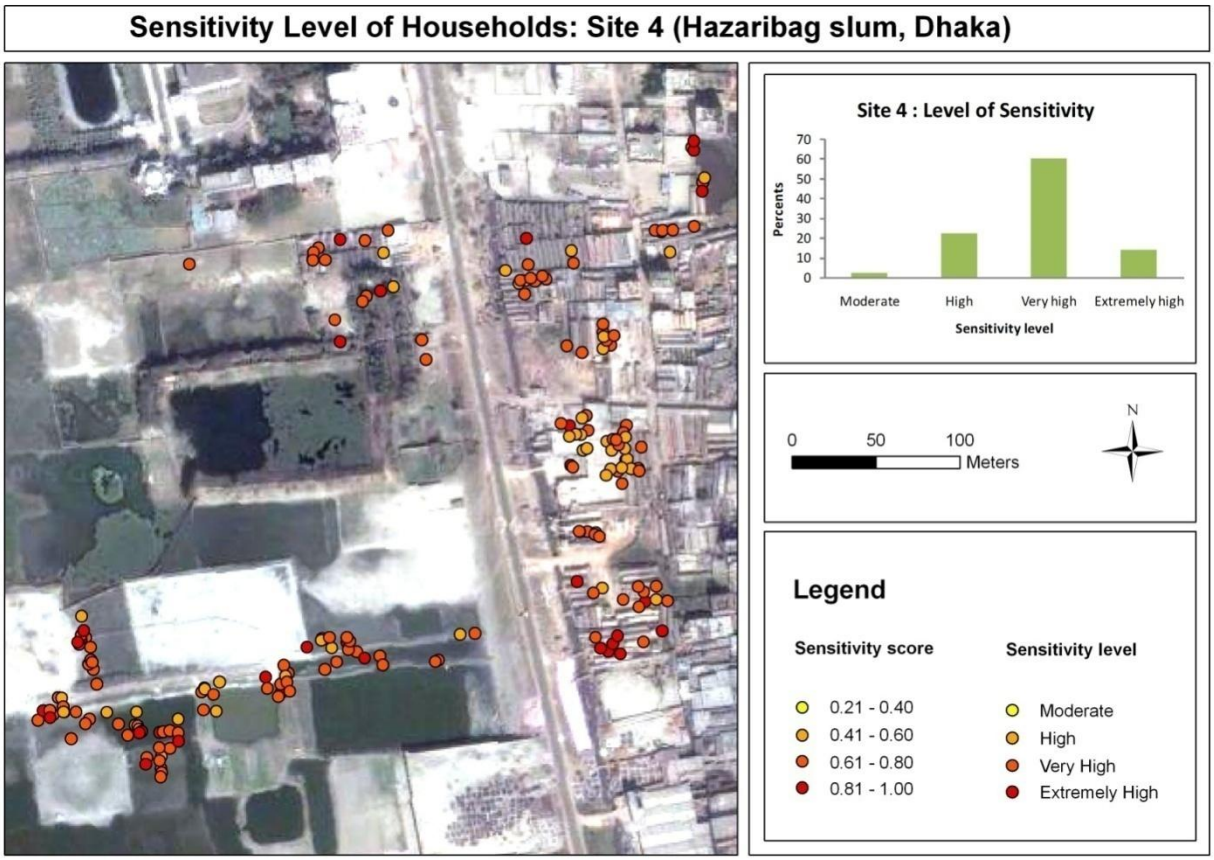
Bad quality housing increase flood vulnerability of Household
It was asked during what kind of problem do they face while living in this place?
The answer of Tahera was:
"How many problems should I tell you (koyda ashubidhar kata komu?). Water crisis, if it rains heavily water enter into house by licking the roof, water in front of house, mosquito, bad smell, water on yard."

Another interviewee replied from the same question: "*look what u can see underneath this bamboo floor (sewerage water). When monsoon comes water level increase then insects, snakes enter and walk on floor, for us we don't fear but my two year old kid whatever she see she put inside her mouth. How long I can keep my eyes on her. Last year my neighbour has lost her child in this water. That child was playing on bamboo pile suddenly she fall down into the water while her mother was cooking. It usually happens here."*

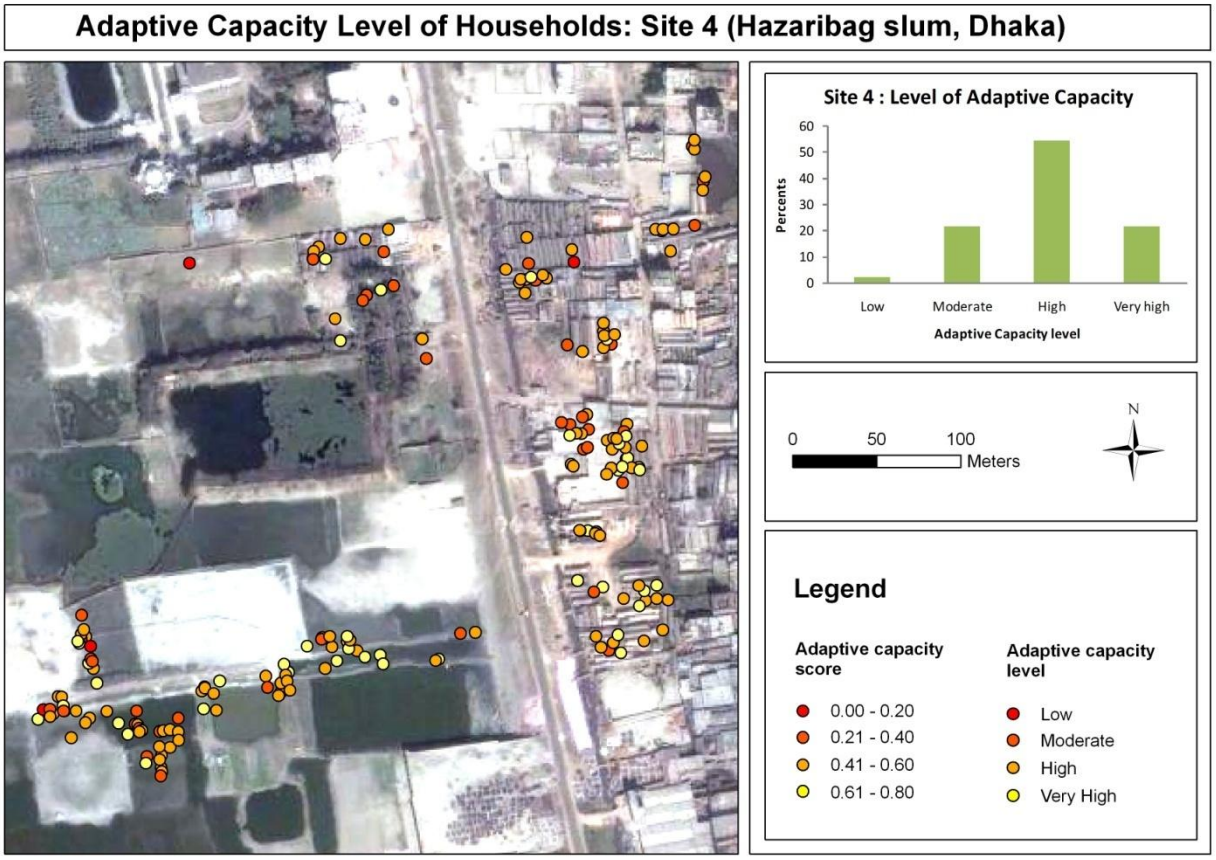
People living outside the embankment area are highly exposed but they have better adaptive capacity. Around 60% (Map 6-7) of the household in this area has high adaptive capacity (good social network, help from friends and relatives,) which reduces their vulnerability level to flood. After the flood damage taking loan from friend or relative is very common adaptive capacity in study area. This loan is very effective for households' immediate recovery during or after flood.



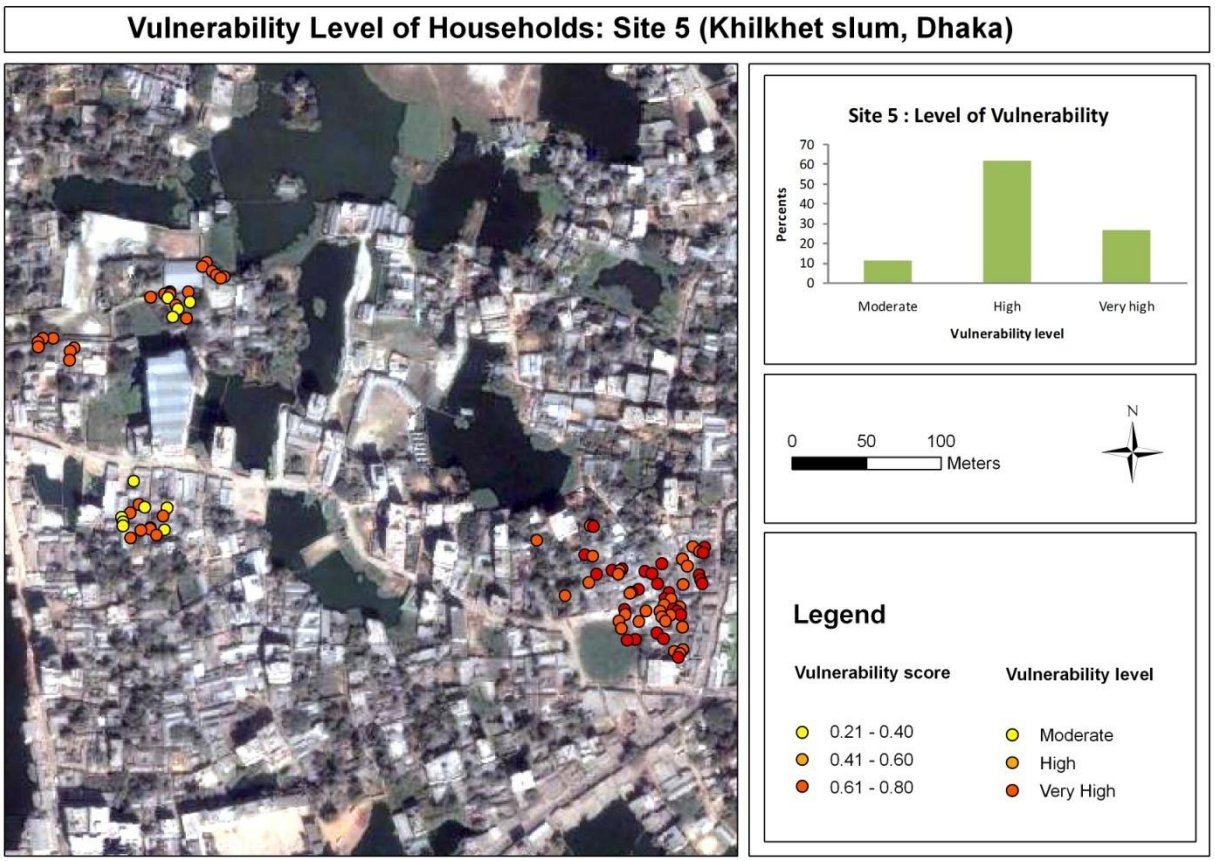
Map 6-5: Exposure level of households in site 4



Map 6-6: Sensitivity of households in site 4



Map 6-7: Adaptive capacity level in site 4



Map 6-8: Vulnerability level in study site 5

Study site 5

For study site 5 the map is showing that in the south-eastern part the vulnerability range of households is high to very high. The rest is moderate to high vulnerability level. After checking the score of adaptive capacity for those moderately vulnerable households it is found that they have a better adaptive capacity (savings as well as income, awareness level) than the others. Therefore their vulnerability level is varying.

In this site household are also very sensitive to flood. During last flood 40% severely affected by diarrhoea, 50% of the household were forced to eat less, 100 % household were not able to go to working area because of inundation took place, for 70% people it was very difficult to cook. Those who has good housing, better service option they are less vulnerable to flood.

Comparison in vulnerability level in different sites

Based on the overall vulnerability score (Table 6-4) obtained from the analysis performed in ILWIS SMCE, 54.53% of the households are highly vulnerable in the entire study area. On the other hand, 30.26% of the households are very highly vulnerable while a small portion of households are in moderately and extremely high vulnerability range the percentages are 9.85 and 5.36 respectively. In none of the study sites there is a household in low vulnerability range.

In study site 4 and 2 percentages of the extremely high vulnerable household are 11.86 and 14.87 respectively while in all other site there is no households in this category. For more information this two sites are located in very high flood hazard zone. In study site 3 and 4 a large portion of households are very highly vulnerable the percentages are 42.96 and 41.75 respectively. On the other hand, in study site 1 and 5 there is a large portion of household in high vulnerability range the percentages are 88.57 and 61.86 respectively.

Table 6-4: Household vulnerability level in all study sites (result obtained from spatial multi criteria analysis)

Vulnerability level	Index value	Percentage of Households					
		Site 1	Site 2	Site 3	Site 4	Site 5	All study sites
Low	0.00 - 0.20	0	0	0	0	0	0
Moderate	0.21 - 0.40	7.14	11.57	8.89	10.31	11.34	9.85
High	0.41 - 0.60	88.57	38.01	48.15	36.08	61.86	54.53
Very high	0.61 - 0.80	4.29	35.53	42.96	41.75	26.80	30.26
Extremely high	0.81 - 1.00	0	14.87	0	11.86	0	5.36
Total	**1.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Spatial Pattern of vulnerability

To see the spatial relationship of household vulnerability distribution a spatial analysis was carried out for study site 3 and 4 by using spatial autocorrelation technique in ArcGIS. To identify whether the households' vulnerability pattern are clustered or dispersed. Global Moran's I value was used to evaluate this pattern. Global Moran's index value expressed the pattern in between +1 and -1. When a Moran's I value near +1.0 indicates clustering while a value near –1.0 indicates dispersion (see chapter 3).

Table 6-5: Spatial Autocorrelation results of Site 3 and 4

Study site	Group ID	Moran's Index value	P-value	Sample size	Total sample size
3	1	0.56	0	59	**135**
	2	0.28	0.0009	29	
	3	0.12	0.05	47	
4	East	0.28	0	95	**198**
	West	0.22	0	103	

In study area 3, group 1 is highly clustered pattern. Here Moran's index value is 0.56 at 95% confidence level. On the other hand, group 2 also has clustered pattern but not so strong and 3 has almost randomly distributed pattern. In study site 4 both group has clustered pattern as not so strong relationship. This result is corresponds to the visual interpretation as shown in the above maps.

7. CONCLUSION AND RECOMMENDATION

This chapter gives the conclusion of this research and propose further research

7.1. Conclusion

This study has assessed the flood vulnerability in the local context of Dhaka. In doing so, it has analysed the existing vulnerability context, developed a contextual framework that has helped in assessing the flood vulnerability and applied in selected study areas in Dhaka.

In order to identify household stress and the social and bio-physical conditions of households in the slum of Dhaka qualitative interviews have been used. The vulnerability factors as well as the household stresses which contribute to an increase in household vulnerability were identified. To support this result, the households' characteristics were statistically analyzed. Findings from the qualitative interviews shows that human sensitivity and adaptive capacity plays important role to increase and decrease household vulnerability to flood. These are household income, occupation type, age, dependency ratio, savings and loan characteristics, household capacity (taking shelter, taking loan to recover, relative living in slum,) housing and service provision, living and working in hazardous location, past experience and behaviour during last flood etc. All these factors and indicators of vulnerability were encountered in the local context (housing type, means of recovery) of the study area.

Finally, three components of vulnerability (exposure, sensitivity, and adaptive capacity), seven factors and thirty four indicators were applied to assess the households flood vulnerability in the study areas. The result shows that a large number of households have high vulnerability level in all study area. Consequently, in study site 2 and 4, a considerable percentage of household are in extremely high vulnerability level. Only a small percentage of households are in a moderately vulnerable condition; no single household has a low vulnerability to flooding. In most of the cases, household vulnerability is varying from high to very high among all study sites. The results (positive Moran index value) obtained from the spatial pattern analysis revealed that households vulnerability has a clustered pattern. Finally, it can be said that households living closer to one another have almost the same vulnerability score, but the result vary little due to the individual household's sensitivity and adaptive capacity levels.

In general, the vulnerability level of households in all study sites is high while there is also some variation in between the community. This result shows that people living in the same community can have different levels of vulnerability although they are exposed in same way. As discussed before some have a lower sensitivity and a better adaptive capacity than the others; in that case they are less vulnerable than the others.

As slum dwellers are deprived from many aspects of livelihoods, they are highly susceptible to encounter many kinds of external stress. Slight increases in any kind of natural consequences will affect severely their livelihood means. Non-climatic stresses have also been found to increase vulnerability to climate change by reducing resilience and adaptive capacity. In the local context it has been found that in slums people share their daily services (water, cooking place, and toilet) with their neighbour. This and other non-climatic problems aggravate further their vulnerability situation during times of crisis. It can be assumed from here, that if there is an increase of natural calamities in the future and poor people's resources are

disrupted regularly, there is high probability that social problems in slums increase too, which would further decrease the slum dwellers' collective adaptive capacities.

In the context of climate change, the flood vulnerability of Dhaka city is very high, since many live in slums and are highly exposed and sensitive to floods yet they have little adaptive capacity in the present. On the way to building a safer and more resilient city, the city management authorities should take proper initiatives to minimize the hazards effect on a large number of the population.

As poverty and vulnerability are closely related, the policy measures have to include poverty reduction, capacity building, slum rehabilitation and a general increase in risk awareness in the population. Effective rules and regulations regarding housing in hazardous locations, and a proper management of the flood infrastructure can help to reduce the vulnerability of the slum population to floods.

7.2. Further research

Besides advancing further the vulnerability assessment future research should focus on how to reduce slum dwellers vulnerability level.

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ANNEXES

Annex 1: Unstructured questionnaire fro qualitative interview

Unstructured questionnaire for qualitative interview

Name:	Age:
Slum name:	Occupation:

Instruction before asking the questionnaire:

- Introduce your self to the case study(for the person who will go to collect interview)
- Explain the Purpose clearly
- Start to ask slowly about their daily life condition

Few general aspects about the people of study area and their Daily life

1. SOCIO- ECONOMIC

1.1. Occupation type?
1.2. How did you get this job?
1.3. Approximate how much your family income is in a month?
1.4. Is it sufficient for you (and your family)?
1.5. if not what do you do to supplement your family needs
1.6. How many children do you have?
1.7. Do they study?
1.8. Is it tough for you to manage their expenses?

2. FLOODING CONDITIONS

2.1. What kind of problem do you face in your everyday life (and in this slum)?
2.2. Are these problems related to flooding or weather conditions
2.3. In your opinion, do you think the weather condition is changing (rainfall or flood frequency)
2.4. If yes, has this change of weather condition has any effect on your daily life (income, occupation, health, housing, cost of basic needs)
2.5. What was major problem do you face during flooding time? (Explain about that?(housing, water, cooking, buying food or availability, toilet, to go to work, children's school)
2.6. Any other kind of problem if case study willing to speak about?

3. LIVING CONDITION

3.1. How long have you been living in Dhaka?... (And in this slum…….)?
3.2. What made you to move here?
3.3. Why you selected this area to live?
3.4. Which life you prefer most here in the slum or when you were living in the village? Why?

4. HOUSING CONDITION

4.1. What is your housing condition (is your house secure against flooding threats)?
4.2. What type of floor is your house built of (wooden, slab, mud)?
4.3. Is your house floor raised to protect you from the floods?
4.4. How is the condition of your floor (good, worn out)?
4.5. Do you own the house you stay or do you rent?
4.6. Relationship with the house owner?
4.7. Why you don't move to the other places? / Why do you prefer to live here?
4.8. If yes then what kind of problem do you face here?
4.9. What do you think about your future?
4.10. In your opinion how you will rank your problems? (Instruction: ask them to rank the problems)

Annex 2: Dhaka Hazard – Flood coping survey 2009

DhakaHazard - Flood coping survey 2009

id_1:	[number_interviewer][number_interview]]	id_1: e.g. 3005

Introduction

I am [name]. We come to your area for research on flood coping strategy. We are sorry that we only come for a research objective and cannot provide you any money or relief. We will be very happy if you help us in this survey. I want to ask you and your family questions about floods and related matters. We hope that this information helps for future planning and disaster management. It will take 40 to 50 minutes to complete this interview. Of course we keep all of your answers confident and we will not give them to any other person. It is up to your decision whether you participate in this interview and you may answer all or just some of the questions. But we hope that you participate in this survey and you help us with your answers. May I proceed with the questionnaire?

id_2	GPS waypoint	id_2: e.g. 004
id_lat	GPS coordinates – latitude	N: 23°.....`.....,..." e.g.: 23 46 54,2
id_long	GPS coordinates – longitude	E: 090°.....`.....,..." e.g.: 090 54 23,6

int	Interviewer	1. Tanzer, 2. Azad, 3. Moushumi, 4. Nila, 5. Daud, 6. Ratna, 7. Farhad, 8. Rocky	int e.g. 3
site	Exact id of study site	Bara Magh Bazar: 1_, Dokhin Goran: 2_, Godertek: 3_, Hazaribag: 4_, Khilket: 5_	site e.g. 28
date	Date of the interview	__ day __ month 2009	date e.g. 25.11.09
time	Starting time of the interview	_ am / pm __ min	time e.g. 2pm 50min
floodyr	relevant flood year[1]	2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009	floodyr

1

1. Specific information on interviewed person

1.01	Where is your home district?	_____ (district)	q1_01_t
1.02	What is your religion?	1. Muslim, 2. Hindu, 3. Christian, 4. Buddhist, 5. Other	q1_02
1.03	How long does the head of household live here in this house?	__ years	q1_03
1.04	Where did s/he live before?	1. In this area[2], 2. Other place in Dhaka, 3. Other (name of the district: _____)	q1_04

[1] We find the relevant flood year before we start the interview by asking for the longest and highest flood. This is part of the introduction.
[2] Within 1 km.

Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

2. Human Capital of the interviewed household

2.01	How many persons live with you for more than six months a year and eat with you from the same dish?	__ persons	q2_01

2.02	Position of the household member[3]	Age in years	Sex	Marital status	Highest educational qualification	Occupation
Legend	1. Head of household, 2. Wife/Husband, 3. Father/Mother, 4. Brother/Sister, 5. Child, 6. Grandchild, 7. Other relative, 8. Employee, 9. Other non-relative		1. Male, 2. Female	1. Married, 2. Divorced, 3. Widow, 4. Single	0. Illiterate, 1. Visited primary school, 2. Reading in primary school, 3. Visited high school, 4. Reading in high school, 5. S.S.C, 6. H.S.C, 7. reading university, 8. Completed university	0. No work, 1. Rickshaw Puller, 2. Hawker/Vender, 3. Day labor, 4. Domestic worker, 5. Service Hotel/Cleaning, 6. Waste collector, 7. CNG-Driver, 8. Car/Truck Driver, 9. Retailing/Small shops, 10. Security guards, 11. Factory worker, 12. Business, 13. Housewife, 14. Student, 15. Other
a.	[interviewed person] q2_02pos_a	q_2_02age_a	q2_02sex_a	q2_02mar_a	q2_02edu_a	q2_02occ_a
b.	q2_02pos_b	q2_02age_b	q2_02sex_b	q2_02mar_b	q2_02edu_b	q2_02occ_b
c.	q2_02pos_c	q2_02age_c	q2_02sex_c	q2_02mar_c	q2_02edu_c	q2_02occ_c
d.	q2_02pos_d	q2_02age_d	q2_02sex_d	q2_02mar_d	q2_02edu_d	q2_02occ_d
e.	q2_02pos_e	q2_02age_e	q2_02sex_e	q2_02mar_e	q2_02edu_e	q2_02occ_e
f.	q2_02	q2_02age_f	q2_02sex_f	q2_02mar_f	q2_02edu_f	q2_02occ_f
g.	q2_02	q2_02age_g	q2_02sex_g	q2_02mar_g	q2_02edu_g	q2_02occ_g
h.	q2_02	q2_02age_h	q2_02sex_h	q2_02mar_h	q2_02edu_h	q2_02occ_h

2

3. Experiences of last major flood event[4]

In the following chapter we want to ask you questions regarding your experiences with flood.

3.1. Dimensions of experienced floods

3.01	How many times did flood water enter your house since you live here?	__ times	q3_01
3.02	If 0 times: How many times did flood come in front of[5] your house and stay for more than two weeks?	__ times	q3_02

Now we want to ask you about the flood of the year ____

3.03	How high did the water reach in your house from the floor at that year?	___ feet	q3_03
3.04	How long did the flood water stay in your house at that year?	___ days	q3_04
3.05	How long did the water stay outside of the house in the yard?	___ days	q3_05

[3] In regard to the head of the household
[4] "Major flood event": When water stayed higher than two feet in the house of the interviewed person for more than one week or in front of the house for more than two weeks.
[5] In the meaning of: Common yard of the households – where people go to enter each room.
Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

3.2. Flood forecast

3.06	Did you get a flood forecast before that flood reached your area?	1. Yes, 2. No	q3_06

3.07	If yes: How many days did you hear of the flood before it reached your area?	__ days before	q3_07
3.08	How did you get the information that the flood will come?	1. Newspaper, 2. Radio, 3. TV, 4. Neighbours, 5. Friends, 6. Relatives, 7. Community leaders, 8. Other	q3_08
3.09	Was that information important for you?	1. Very important, 2. Important, 3. Little important, 4. Not important	q3_09

3.3. Effects of last event on household

Now we want to ask you how the flood of the year ____ affected your household.

3.3.1. Effects of last flood on human capital

3

3.10	Did a family member get severely ill during that flood, e.g. strong diarrhoea, cholera, snake bites?	1. Yes, 2. No	q3_10
3.11	If yes: How many family members got ill?	__ Persons	q3_11

3.12					
	Age of that family member	What kind of disease did s/he get? (diarrhoea, typhoid, cholera etc. [write disease])	How long was s/he ill (in days/555[6])?	Was that person able to continue working? (1. Yes, 2. No, 3. Partly)	How much money did you have to spend for medical treatment[7]? (Taka)
a.	q3_12age_a	q3_12dis_a	q3_12illdur_a	q3_12workcap_a	q3_12medtr_a
b.	q3_12age_b	q3_12dis_b	q3_12illdur_b	q3_12workcap_b	q3_12medtr_b
c.	q3_12age_c	q3_12dis_c	q3_12illdur_c	q3_12workcap_c	q3_12medtr_c

3.13	Compared to normal times, did you have to eat less during that flood event?	1. Far less, 2. Less, 3. Same, 4. Eating more	q3_13
3.14	Were you able to cook during the flood most of the time?	1. We did not cook, 2. It was very difficult to cook, 3. It was a bit difficult to cook, 4. We were able to cook normally	q3_14

[6] If person still did not recover from that illness, write 555.
[7] Consider expenditure for transportation to hospital, doctor fee and medicine.
Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

3.3.2. Effects of last flood on physical capital

3.15	Has the house / room been damaged during the flood?	1. Yes, 2. No	q3_15
3.16	If yes: How badly was it damaged?	1. Beyond liveability, 2. Repairment needed, 3. Minor damage	q3_16
3.17	Was the damage repaired?	1. Yes, 2. No, 3. Partly	q3_17
3.18	How expensive was it to repair the damage?	_____ Taka	q3_18
3.19	Who paid most of the money?	1. Household, 2. Landlord, 3. Government, 4. NGO, 5. Other	q3_19
3.20	Did anyone help you to repair it (e.g. working time or with money or advice)?	1. Yes, 2. No	q3_20
3.21	If yes: Who helped you to repair the damage? (three answers possible)	1. Neighbors, 2. Relatives, 3. Friends, 4. Government, 5. Landlord, 6. NGO	q_3_21_1 q_3_21_2 q_3_21_3
3.22	How long was the house damaged?	___ days[8]	q3_22

3.3.3. Effects of last flood on financial capital

3.23	Was the main earner of this household able to continue his / her job during that flood?	1. Yes, 2. No, 3. Yes, but less	q3_23
3.24	If Yes, but less / no: For how many days was s/he not able to work full time?	___ days	q3_24
3.25	What was the reason that s/he was not able to continue his / her job? (three answers possible)	1. Working area flooded, 2. No scope to get to working place, 3. Had to stay at home to take care of household, 4. Illness, 5. Other	q3_25_1 q3_25_2 q3_25_3

3.26	Did the head of household do any flood related job?	1. Yes, 2. No	q3_26
3.27	If Yes: What kind of job did he do?	1. Road repairment, 2. Embankment work, 3. Bamboo constructions, 4. House repairment, 5. Driving boat, 6. Relief distribution, 7. Other	q3_27

3.28	Did the income of your household decrease or increase during that flood time?	1. No income at all, 2. High decrease, 3. Some decrease, 4. No change, 5. Increase	q3_28
3.29	Did the head of household participate in any voluntary[9] work during the flood?	1. Yes, 2. No	q3_29
3.30	If Yes: What kind of voluntary work?	1. Relief distribution, 2. Medical treatment support, 3. Repairing of streets, 4. Bamboo constructions, 5. Enforce embankment,	q3_30

[8] If damaged up to recent date, write 555.
[9] Organized support by a group of people for others

Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

4

		6. Giving shelter, 7. Repair of houses, 8. Other	

Savings

3.31	Did your household have any savings before that flood?	1. Yes, 2. No	q3_31
3.32	If yes: How much Taka did you have?	_____ Taka	q3_32
3.33	How much money did you have to take from your savings to overcome that flood and the problems related to it?	_____ Taka	q3_33

3.34	Because of that flood did you lose any valuables or important things?	1. Yes, 2. No	q3_34

If yes: What? (Multiple answers possible)

3.35	What did you lose?	How did you lose it?	Did you replace that asset?	If Yes: How long did it take you to replace that asset?
	1. Clothes, 2. Food, 3. Furnitures, 4. Papers / documents, 5. Jewellery, 6. TV, 7. CD / DVD player, 8. Radio, 9. Mobile phone, 10. Sewing machine, 11. Rickshaw, 12. CNG, 13. Land, 14. Other	1. Stolen, 2. Had to sell, 3. Water damage, 4. Washed away	1. Yes, 2. No, 3. By something else [10], 4. Part of it	__ months
a.	q3_35val_a	q3_35how_a	q3_35repl_a	q3_35dur_a
b.	q3_35val_b	q3_35how_b	q3_35repl_b	q3_35dur_b
c.	q3_35val_c	q3_35how_c	q3_35repl_c	q3_35dur_c
d.	q3_35val_d	q3_35how_d	q3_35repl_d	q3_35dur_d
e.	q3_35val_e	q3_35how_e	q3_35repl_d	q3_35dur_e

5

(Do not ask!)

dead	If any person died, tick the reason.	1. Illness, 2. Snake, 3. Electrocuted, 4. Drown, 5. Accident	dead

3.36	Did you have any livestock before that flood?	1. Yes, 2. No	q3_36
3.37	If yes: Did you lose or did any of the following livestock die during that flood?	1. Yes, 2. No	q3_37

If livestock was lost during that flood:

3.38	How many did you lose?	How did you lose most of it?	Did you replace that livestock?	If Yes: How long did it take you to replace the livestock?
		1. Stolen, 2. Had to sell, 3. We ate it, 4. Died, 5. It ran away, 6. Other	1. Yes, 2, No, 3. By something else[10], 4. Part of it.	__ months
cow	q3_38losscow	q3_38how_cow	q3_38repl_cow	q3_38dur_cow

[10] In the sense of: Did you buy anything else because you lost that asset? If yes: What?
Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

goat	q3_38lossgoat	q3_38how_goat	q3_38repl_goat	q3_38dur_goat
poultry	q3_38losspoult	q3_38how_poult	q3_38repl_poult	q3_38dur_poult

3.4. Coping measures of households

Now we want to ask you some questions regarding the coping measures of your household with the flood.

3.4.1. External help / relief distribution[11]

3.39	Did you get any relief distributions during that flood event?	1. Yes, 2. No	q3_39
3.40	If yes: From whom did you get relief distribution? (three answers possible)	1. Government, 2. NGO, 3. Private person, 4. Private organizations, 5. Student groups	q3_40_1 q3_40_2 q3_40_3
3.41	What did you get? (three answers possible)	1. Pure drinking water, 2. Food, 3. Cloth, 4. Money, 5. Saline, 6. Medicine, 7. Water purifying tablets, 8. Full medical treatment, 9. Matches / candles, 10. Other	q3_41_1 q3_41_2 q3_41_3
3.42	Was that relief of great help for you?	1. Yes, it was great help, 2. It was helpful, but little, 3. It was far too small to be of any help	q3_42

3.43	If no: Why did you not get relief?	1. Nobody provided us, 2. We did not need it, 3. We did not ask / felt shy, 4. We could not reach there, 5. We were not eligible	q3_43

6

[11] Help from an organization / private group of people which distributes help for many people, not only for the interviewed household.

Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

3.4.2. Maintenance of livelihoods

3.4.2.1. Usage of social capital

3.44	Apart from relief distributions, did your household get any help from other persons during that flood?	1. Yes, 2. No	q3_44
3.45	If Yes: Who provided what?	(answer below)	
3.46	If no: Why did you not get any help?	1. Nobody provided us, 2. We did not need it, 3. We did not ask / felt shy	q3_46

3.45		Gave food? How often? 1. One time, 2. Sometimes, 3. Often, 4. All the time	Gave cloths? How often? 1. One time, 2. Sometimes, 3. Often, 4. All the time	Gave money (Taka)?	Working time (to repair house) (in days)	Took care of children (how many days)?	Gave shelter at their own house (how many days)?	Gave advice? 1. Yes, 2. No
a	Relatives in Dhaka	q3_45food_a	q3_45cloth_a	q3_45taka_a	q3_45reptim_a	q3_45care_a	q3_45shelt_a	q3_45advice_a
b	Relatives outside of Dhaka	q3_45food_b	q3_45cloth_b	q3_45taka_b	q3_45reptim_b	q3_45care_b	q3_45shelt_b	q3_45advice_b
c	Friends in Dhaka	q3_45food_c	q3_45cloth_c	q3_45taka_c	q3_45reptim_c	q3_45care_c	q3_45shelt_c	q3_45advice_c
d	Friends outside of Dhaka	q3_45food_d	q3_45cloth_d	q3_45taka_d	q3_45reptim_d	q3_45care_d	q3_45shelt_d	q3_45advice_d
e	Neighbors	q3_45food_e	q3_45cloth_e	q3_45taka_e	q3_45reptim_e	q3_45care_e	q3_45shelt_e	q3_45advice_e
f	Landlord / employer	q3_45food_f	q3_45cloth_f	q3_45taka_f	q3_45reptim_f	q3_45care_f	q3_45shelt_f	q3_45advice_f
g	Private people	q3_45food_g	q3_45cloth_g	q3_45taka_g	q3_45reptim_g	q3_45care_g	q3_45shelt_g	q3_45advice_g
h	Working colleagues	q3_45food_h	q3_45cloth_h	q3_45taka_h	q3_45reptim_h	q3_45care_h	q3_45shelt_h	q3_45advice_h
i	Other	q3_45food_i	q3_45cloth_i	q3_45taka_i	q3_45reptim_i	q3_45care_i	q3_45shelt_i	q3_45advice_i

7

3.47	Did you help other people during the flood or later?	1. Yes, 2. No	q3_47
3.48	If Yes: Whom did you help? (three answers possible)	1. Relatives in Dhaka, 2. Relatives outside of Dhaka, 3. Neighbours, 4. Friends in Dhaka, 5. Friends outside of Dhaka, 6. Landlord, 7. Others	q3_48_1 q3_48_2 q3_48_3
3.49	How many times did you help them during the flood or later?	1. One time, 2. Sometimes, 3. Often, 4. All the time	q3_49
3.50	What did you give to them during the flood? (three answers possible)	1. Food, 2. Clothes, 3. Gave money, 4. Help to repair, 5. Take care of children, 6. Shelter, 7. Advice, 8. Others	q3_50_1 q3_50_2 q3_50_3

Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

3.51	During the flood were you disappointed from anybody from whom you expected support, but did not get it?	1. Yes, 2. No	q3_51
3.52	If yes: Who was that? (three answers possible)	1. Relatives in Dhaka, 2. Relatives outside of Dhaka, 3. Neighbours, 4. Friends in Dhaka, 5. Friends outside of Dhaka, 6. Patron at working place, 7. Landlord, 8.NGO, 9. Government, 10. Other	q3_52_1 q3_52_2 q3_52_3

3.4.2.2. Usage of financial capital

3.53	Did your household take a loan during or after the flood?	1. Yes, 2. No	q3_53
3.54	If yes: From whom did you take the loan[12]? (three answers possible)	1. Relatives in Dhaka, 2. Relatives outside of Dhaka, 3. Neighbours, 4. Friends in Dhaka, 5. Friends outside of Dhaka, 6. Landlord, 7. Bank, 8. NGO, 9. Employer, 10. Local money-lender, 11. Other	q3_54_1 q3_54_2 q3_54_3
3.55	How much Taka did you borrow?	_____ Taka	q3_55
3.56	At what interest rate?	__ %	q3_56
3.57	What did you do with the loan? (three answers possible)	1. Repair house, 2. Buy food, 3. Buy medicine, 4. Went to doctor, 5. Pay rent, 6. Buy clothes, 7. Buy assets to work, 8. Start small business, 9. Other	q3_57_1 q3_57_2 q3_57_3
3.58	How much of the loan do you still have to repay?	_____ Taka	q3_58
3.59a	If "0 Taka": How long did it take you to repay the loan?	__ months	q3_59a
3.59	If not "0 Taka" to repay: How long will it take you to repay the rest of the loan?	__ months	q3_59

3.60	Did your household provide loan to anybody?	1. Yes, 2. No	q3_60
3.61	If yes: How much loan did you provide[13]?	_____ Taka	q3_61
3.62	To whom did you provide that loan? (three answers possible)	1. Relatives in Dhaka, 2. Relatives outside of Dhaka, 3. Neighbours, 4. Friends in Dhaka, 5. Friends outside of Dhaka, 6. Landlord, 7. Others	q3_62_1 q3_62_1 q3_62_1

[12] If more than one loan was taken, ask for the sum of all loans taken. To Question regarding „interest rate", write -7.
[13] If loan provided to more than one person, sum up the amount.
Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

8

3.63	Did you get any thing (other than relief distribution) which you had to repay some time later?	1. Yes, 2. No	q3_63
3.64	If yes: What did you get? (three answers possible)	1. Food, 2. Assets to work, 3. Medicine, 4. Material to repair the house, 5. Other	q3_64_1 q3_64_2 q3_64_3
3.65	From whom did you get it? (three answers possible)	1. Relatives in Dhaka, 2. Relatives outside of Dhaka, 3. Neighbours, 4. Friends in Dhaka, 5. Friends outside of Dhaka, 6. Landlord, 7. Shop keeper, 8. Other	q3_65_1 q3_65_2 q3_65_3

3.4.2.3. Usage of physical capital

3.66	Did any of your household members have to leave the building because of the flood water?	1. Yes, 2. No	q3_66
3.67	If yes: How many members of your household had to leave the house because of the flood?	___ persons	q3_67
3.68	Then, where did most of them go to?	1. Floodshelter / school, 2. Stayed on elevated road, 3. At relatives house, 4. On boat, 5. On the roof of own house, 6. Other	q3_68
3.69	How long did they stay there?	__ days	q3_69

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3.4.3. Preparations

3.70	Did you store any dry food before the flood came?	1. Yes, 2. No	q3_70
3.71	If yes: What kind of dry food did you store? (three anwers possible)	1. Puffed rice, 2. Molasses, 3. Chira, 4. Biscuits, 5. Medicine, 6. Others	q3_71_1 q3_71_2 q3_71_3

3.72	Did you organize material before the flood to protect your house from flood water?	1. Yes, 2. No	q3_72
3.73	If yes: What did you organize? (three anwers possible)	1. Bricks, 2. Sandbags, 3. Polythene, 4. Bamboo, 5. Rope, 6. Cement, 7. Mud, 8. Mud chula, 9. Fuel, 10. Other	q3_73_1 q3_73_2 q3_73_3

Conclusion on coping measures

3.74	Altogether, how long did it take your household to recover from the effects of that flood or to come back to normal after the	___ days	q3_74

Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

	water receded?		

10

Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

4. Present situation of the household

4.1. Access to livelihoods

4.1.1. Access to human capital

Now I want to ask you some questions about the present situation of your household. These questions are not related to any flood. The first question will be about the main occupation of the main earner:

4.01	For how many years does the main earner do his main job?	__ years	q4_01
4.02	Did the the main earner do other jobs during the last two years as well?	1. Yes, 2. No	q4_02
4.03	If Yes: How many other jobs did he do?	__ Number of jobs	q4_03

4.1.1.1. Health

4.04	In general, how do you rate your health?	1. Excellent, 2. Good, 3. So so, 4. Fair, 5. Poor	q4_04
4.05	Do you smoke cigarettes?	1. Yes, 2. No, 3. Previously yes	q4_05
4.06	If yes: How many times a day?	__	q4_06

4.07	Do you smoke bidis?	1. Yes, 2. No, 3. Previously yes	q4_07
4.08	If yes: How many times a day?	__	q4_08

4.09	Do you eat chewing tobacco?	1. Yes, 2. No, 3. Previously yes	q4_09

How often did you agree to the following statements during the last two weeks?

	Over the last two weeks	All of the time	Most of the time	More than half of the time	Less than half of the time	Some of the time	At no time	
4.10	I have felt cheerful and in good spirits	5	4	3	2	1	0	q4_10
4.11	I have felt calm and relaxed	5	4	3	2	1	0	q4_11
4.12	I have felt active and vigorous	5	4	3	2	1	0	q4_12
4.13	I woke up feeling fresh and rested	5	4	3	2	1	0	q4_13
4.14	My daily live has been filled with things that interest me	5	4	3	2	1	0	q4_14

Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

4.15	Is any of the member of the household currently affected by a severe disease e.g. cancer, tuberculosis, typhoid, disability?	1. Yes, 2. No	q4_15

4.16	If Yes: Who is ill (in relation to head of household)?	Age of that person	What kind of disease? (String Variable)	For how many months?	Ability to work affected?
	1. Head of household, 2. Wife / husband, 3. Father / mother, 4. Brother / sister, 5. Child, 6. Grandchild, 7. Other relative, 8. Employee, 9. Other non relative			__ months	1. Cannot work, 2. Can only partly work, 3. can fully work
a	q4_16pos_a	q4_16age_a	q4_16dis_a	q4_16dur_a	q4_16work_a
b	q4_16pos_b	q4_16age_b	q4_16dis_b	q4_16dur_b	q4_16work_b
c	q4_16pos_c	q4_16age_c	q4_16dis_c	q4_16dur_c	q4_16work_c

4.1.2. Access to social resources

4.17	If you need to borrow a substantial amount of money, say 2000 Taka, to whom would you turn to? (three answers possible)	1. Relatives in Dhaka, 2. Relatives outside of Dhaka, 3. Neighbours, 4. Friends in Dhaka, 5. Friends outside of Dhaka, 6. Landlord, 7. Bank, 8. NGO, 9. Employer, 10. Local moneylender, 11. Other, 12. Nobody	q4_17_1 q4_17_2 q4_17_3
4.18	If there is a problem in this neighborhood – struggle between two neighbors – who will intervene? (three answers possible)	1. Police / Ansar, 2. Landlord, 3. Local community group, 4. The neighbors, 5. Nobody	q4_18_1 q4_18_2 q4_18_3

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Membership in NGO

4.19	Does your household participate with any NGO at present in this area?	1. Yes, 2. No	q4_19
4.20	For how long is your household a member?	__ years	q4_20
4.21	In which activity is that member involved? (three answers possible)	1. Micro credit, 2. Health, 3. Education, 4. Others	q4_21_1 q4_21_2 q4_21_3

(If applicable!)

4.22	Is your household involved with the community organization: _____	1. Yes, 2. No	q4_22

4.23	How many relatives[14] of you live here in this slum?	___ relatives	q4_23

[14] We consider relatives up to Uncle/aunt, cousin.

Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

4.24	Where do most of your relatives live?	1. Here in this slum, 2. Other place in Dhaka, 3. Other place (district)	q4_24
4.25	Do you discuss your problems with your family?	1. Yes, always, 2. No., 3. Sometimes	q4_25
4.26	How do you interact with your neighbors? (three answers possible)	1. Dispute, 2. Not at all, 3. Gossip, 4. Discuss personal problems, 5. Work (wash / cook) together, 6. Help each other in difficult situations	q4_26_1 q4_26_2 q4_26_3
4.27	How do you describe the relation to your neighbors?	1. Very good, 2. Good, 3. Fair, 4. Bad / Mistrust	q4_27
4.28	Do you trust your neighbors in general in terms of lending and borrowing[15]?	1. Very much, 2. Some, 3. Not at all	q4_28
4.29	Do you lock the door during the day when nobody is at home for two hours?	1. Of course, 2. Sometimes, 3. No	q4_29
4.30	Do you have friends with whom you can share your joys and sorrows?	1. Yes, many, 2. Yes, some, 3. Yes, one, 4. Nobody	q4_30

Cognitive forms of social resources

4.31	Do you think that if you support another person, he also will support you as to his / her ability?	1. Yes, 2. No, 3. It depends	q4_31
4.32	Do you think that if you give anything to the community, you also will benefit in the long run from the community?	1. Yes, 2. No, 3. It depends	q4_32

13

4.1.3. Access to physical capital / infrastructure

4.33	Who is the owner of this house?	1. Private owner (mallik)[16], 2. Company, 3. Government, 4. Own house, 5. Nobody	q4_33
4.34	If not own house: How much is the monthly rent?	_____ Tk / month	q4_34

4.35	Who is the owner of this land?	1. Private owner (mallik), 2. Company, 3. Government, 4. Own house, 5. Nobody	q4_35
4.36	If not own land: How much rent do you have to pay to use this land altogether?	_____ TK/month	q4_36

4.37	If rent (either for house or for land) is paid: Did you have to pay the rent during the flood?	1. Yes, 2. No, 3. Some of it	q4_37

4.38	In how many rooms does your household stay?	_ rooms	q4_38

[15] e.g. Lending 100 Tk.
[16] Private person – other than interviewed household - owns the house/room.
Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

4.39	Is this neighborhood a safe place to live from criminal perspective?	1. Very safe, 2. Safe, 3. Quite unsafe, 4. Very unsafe	q4_39
4.40	Do you have electricity?	1. Yes, 2. No	q4_40
4.41	Do you think you move from this place within next one year?	1. Yes, 2. No	q4_41
4.42	If yes: Why are you going to move? (three answers possible)	1. Slum will be evicted by owner, 2. Slum will be evicted by government, 3. It is too expensive, 4. We do not like the house, 5. We do not get along with neighbors, 6. We move to a place with better house structure, 7. Place with better infrastructure, 8. We go back to our village, 9. Crime is too high, 10. Health situation is not good here, 11. We go to a place which is higher elevated, 12. Sanitation is too bad here, 13. Work, 14. Other	q4_42_1 q4_42_2 q4_42_3

4.43	Can you remember what were the reasons that your household came here to this area (and not to any other area in Dhaka)? (three answers possible)	1. Cheap, 2. We wanted to live in own house, 3. We were evicted, 4. We know people here, 5. We like this environment, 6. Because of work, 7. We had to leave homeplace beause of river erosion / poverty and did not know where else to go, 8. Other	q4_43_1 q4_43_2 q4_43_3

4.1.4. Access to financial capital

Socioeconomic background

4.44	What is the head of household's average monthly income?	_____ Taka/month	q4_44
4.45	What was your family income in the last month?	_____ Taka/month	q4_45
4.46	How much money do you send to your relatives per month?	_____ Taka/month	q4_46
4.47	Does your household have savings?	1. Yes, 2. No	q4_47
4.48	If yes: How much money savings do you have?	_____ Taka	q4_48

Statement of the family wealth – Do you have ...?

4.49	Electric fan	1. Yes, 2. No	q4_49
4.50	Radio	1. Yes, 2. No	q4_50
4.51	Television	1. Yes, 2. No	q4_51
4.52	CD/DVD Player	1. Yes, 2. No	q4_52
4.53	Mobile Phone	1. Yes, 2. No	q4_53
4.54	Sewing machine	1. Yes, 2. No	q4_54
4.55	Own gas stove	1. Yes, 2. No	q4_55
4.56	Refrigerator	1. Yes, 2. No	q4_56
4.57	Rickshaw	1. Yes, 2. No	q4_57

Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

4.58	CNG	1. Yes, 2. No	q4_58
4.59	Motorcycle	1. Yes, 2. No	q4_59
4.60	Car	1. Yes, 2. No	q4_60
4.61	Computer	1. Yes, 2. No	q4_61
4.62	Jewellry	1. Yes, 2. No	q4_62
4.63	Land	1. Yes, 2. No	q4_63
4.64	House at native village	1. Yes, 2. No	q4_64
4.65	How many chicken?	__ chicken	q4_65
4.66	How many ducks?	__ ducks	q4_66
4.67	How many goats?	__ goats	q4_67
4.68	How many cows?	__ cows	q4_68

5. End

Now we reached the end of the questionnaire.

q_dur	End of the interview: __ h __ min	Duration: ___ min	q_dur

Thank you very much for your answers. You helped us a lot for our research! We are sorry, that we cannot help you with relief or other help.

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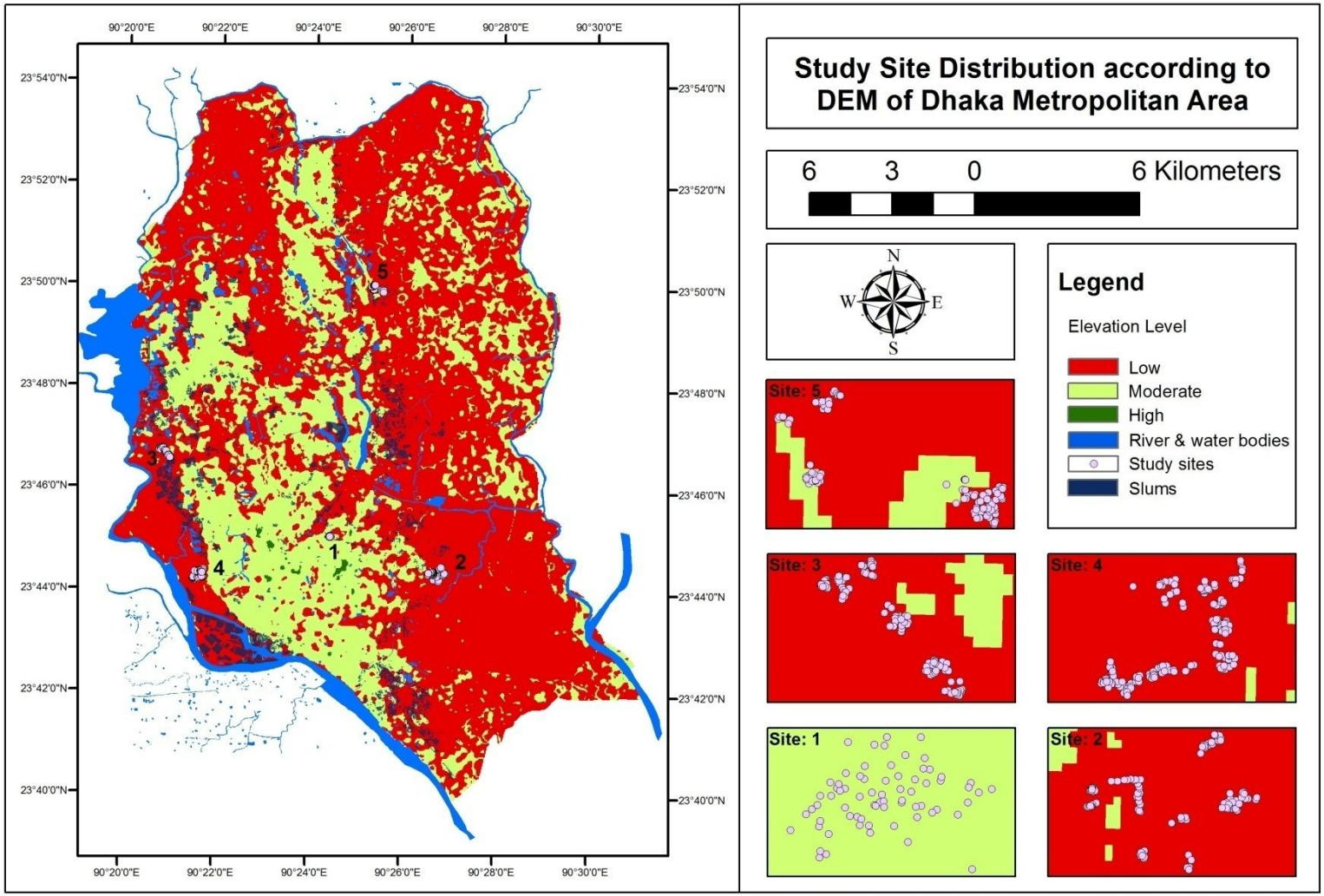
Do you want to add anything you think was not mentioned, but is important regarding your coping with floods? (no variable)
Do you want to make any remarks regarding this questionnaire? (no variable)
Most important resource for your household to overcome the flood of that year? (no variable)
What would you need to be better able to cope with strong flood events? (no variable)

If now you want to ask me any questions, please ask me.

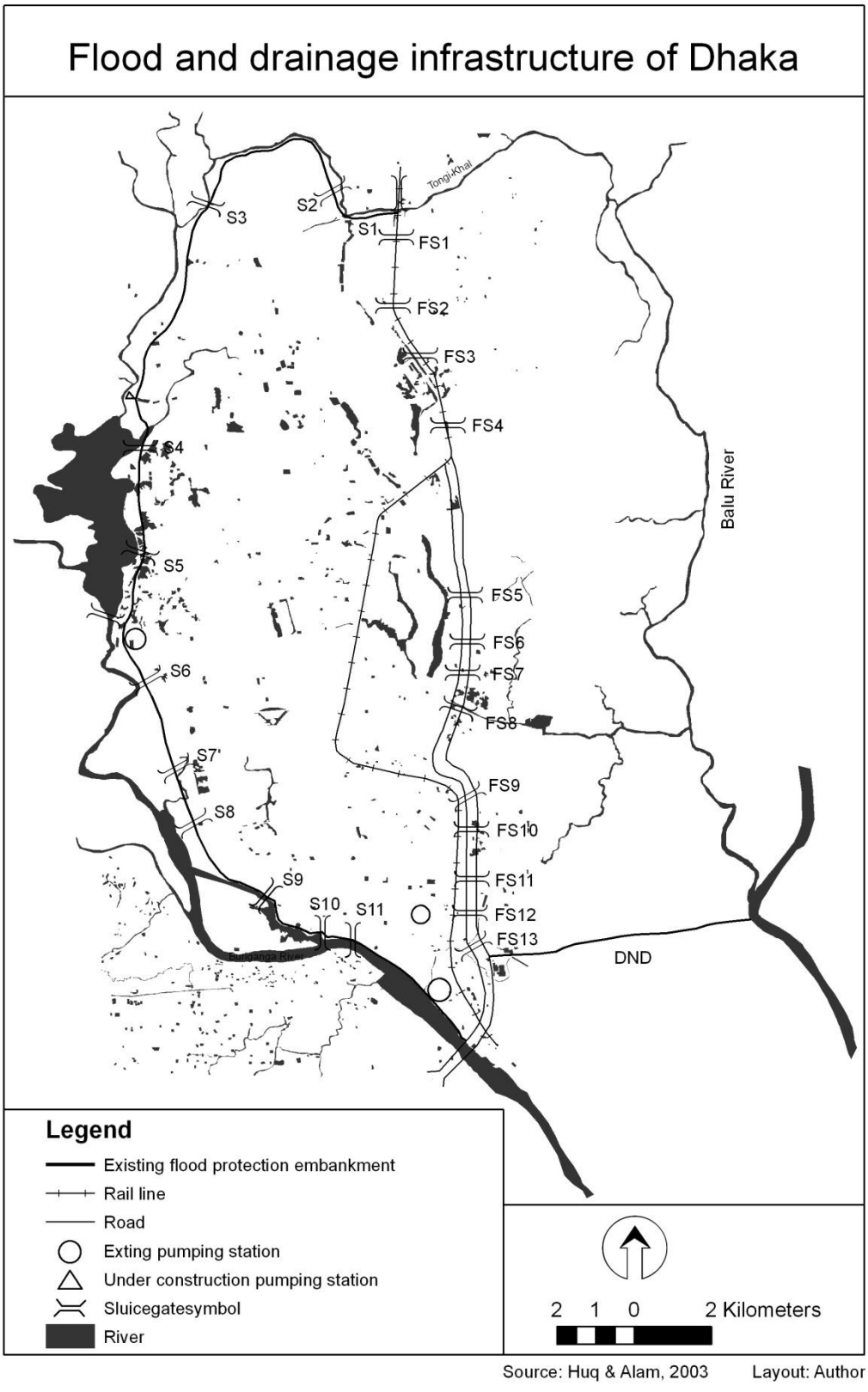
Not applicable: -7 *Answer refused: -88* *Answer not known: -99*

Annex 3: Map showing DEM of Dhaka City

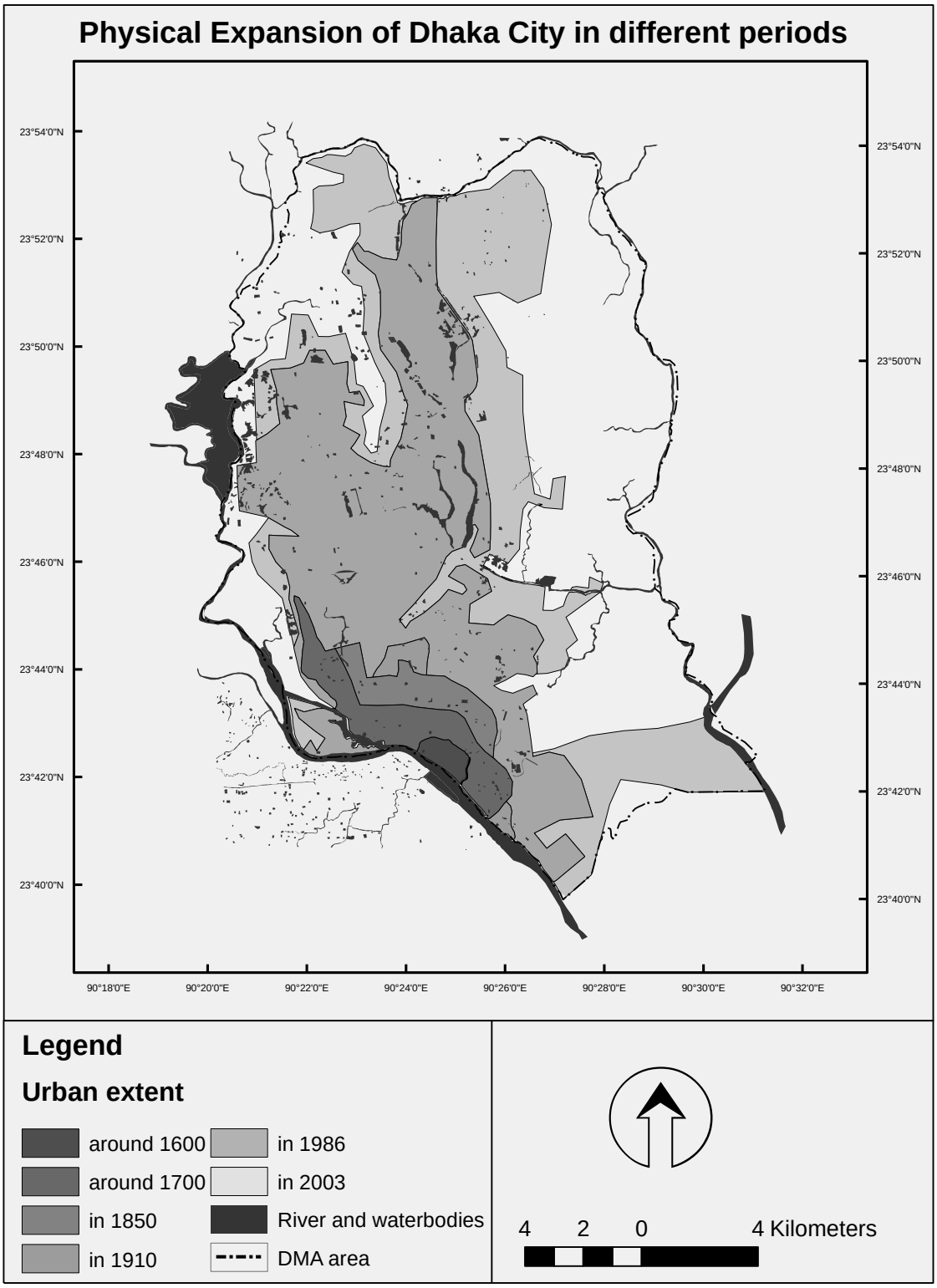


Source: SRTM 90m Digital Elevation Data, CGIAR-CSI GeoPortal, 2010

Annex 4: Map of Flood and drainage infrastructure of Dhaka

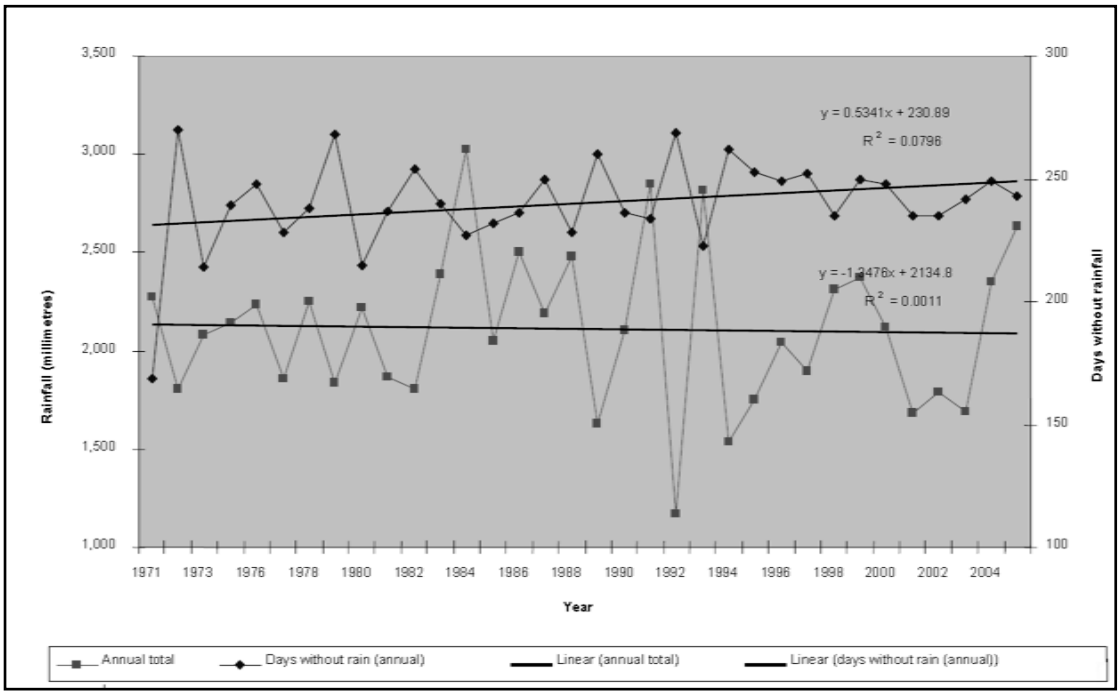


Annex 5: Map of Physical Expansion of Dhaka City



The Urban Livelihoods Project, University of Dortmund, Germany (2009), Layout: Author

Annex 6: Trend of Rainfall and Days without rainfall in Dhaka



Source: (Alam & Rabbani, 2007)

Annex 7: Terminologies used in risk management

Definitions

The following definitions are the result of a broad collection of different international sources, performed by the ISDR, responding to need expressed in several international venues of precise definitions to avoid confusion in the terms used in risk management (UN-ISDR, 2004)

"**Hazard:** A potentially damaging physical event, phenomenon and/or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydro-meteorological and biological) and/or induced by human processes (environmental degradation and technological hazards). Hazards can be combined, sequential or combined in their origin and effects. Each hazard is characterised by its location, intensity, frequency and probability."

"**Natural Hazard:** Natural processes or phenomena occurring in the biosphere, lithosphere, atmosphere, or hydrosphere that may constitute a damaging event. Natural hazards are classified by origin: geological, hydro-meteorological, or biological. Hazardous event can vary in magnitude or intensity, frequency, duration, area of extent, speed of onset , spatial dispersion and temporal spacing."

"**Risk:** Risk is equal to Hazard times potential worth of loss. Conventionally risk is expressed by the equation Risk = Hazards x Vulnerability / Capacity.

The probability of harmful consequences, or expected loss of lives, people injured, property, livelihoods, economic activity disrupted (or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable conditions."

Beyond expressing a probability of physical harm, it is crucial to appreciate that risks are always created or exist within social systems. It is important to consider the social contexts in which risks occur and that people therefore do not necessarily share the same perceptions of risk and their underlying causes.

"Disaster: A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources. A disaster results from the combination of hazards, vulnerability, and insufficient capacity or measures to reduce the negative consequences of risk."

"Disaster Risk: The probability of losses and damage which exceed the autonomous coping and response capabilities of the affected areas and populations and which lead to a serious disrupting of their routine functioning."

"Disaster Risk Management: A complex social process through which disaster risk is measured and evaluated, understood, reduced or predicted and controlled. It should be considered a dimension of sustainable development plans and actions and recognises different levels of intervention. These range from the global, integral, sectoral and macro-territorial levels through to the local, community and family levels. It also requires the existence of organizational and institutional structures which represent these levels and work as a coordinated and integrated whole."

"Resilience or Resilient
The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures."