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Vulnerability and Adaptation to Climate Change in Bangladesh

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Md Aboul Fazal Younus

Vulnerability and Adaptation to Climate Change in Bangladesh

Processes, Assessment and Effects

Doctoral Thesis accepted by
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My Dad Late Dr. S. A. K. Fazlul Haque

My Mum Late Zohura Fazlul

My Beloved Wife Dr. Raunak Rahat Konok, MBBS (Dhaka)

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My Doctoral Supervisor Professor Dr. Nick Harvey, Ph.D. (James Cook)

My Doctoral Co-Supervisor Emeritus Professor Dr. Martin Williams, Ph.D. (ANU)

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Supervisor's Foreword

Dr. Younus' book on Flood Vulnerability and Adaptation to Climate Change is topical. Younus has been working on the vulnerability and adaptation (V&A) issues to climate change since 1994. He graduated with thesis-based M.Sc. and B.Sc. degrees from the University of Dhaka, Bangladesh followed by an M.Phil. from the University of Waikato in New Zealand in 2001 on the topic of Coping with Flooding in Rural Bangladesh. I have known Younus since 2006 when he came to the University of Adelaide to take up a Ph.D. scholarship under my supervision, together with Prof. Martin Williams.

Dr. Younus was awarded his doctorate in Geography and Environmental Studies from the University of Adelaide in 2010. He then started working in the school of the Environment, Flinders University, South Australia, as a Sessional Lecturer where he taught Climate Change and Human Adaptation, Environmental Decision Making Tools and Research Project Design and Management. This further strengthened his knowledge on adaptation and climate change. Dr. Younus has published a significant number of research articles and conference papers on vulnerability and adaptation in refereed journals and conference proceedings in Australia, Finland, Norway, the UK, the USA, and Bangladesh. Dr. Younus has worked with Professors K. B. S. Rasheed, former Professor of Geography and Environment, Dhaka University; Q. K. Ahmad, former President of the Bangladesh Economic Association; and M. Morad, Anglia Ruskin University, UK. These collaborations, together with his work in Adelaide, have contributed to his success as a scientist in his own field: *Community-Based Vulnerability and Adaptation to Climate Change.*

The Intergovernmental Panel on Climate Change (IPCC) demonstrated the importance of adaptation to climate change and also warned that the Ganges Brahmaputra Meghna River Basin will be at greatest risk due to increased flooding and any adaptation capacity will be reduced by the region's poverty. The key concept of Dr. Younus' book is the notion of "autonomous adaptation" and its processes and impact on flood vulnerable communities in Bangladesh. This study is an example of a bottom-up case study for all academics and researchers concerned with vulnerability and assessment of climate change. One of the prime foci is the method Younus developed for assessing flood vulnerability and adaptation to climate change. He has used a multimethod technique which includes two participatory rapid appraisals (PRA) and a questionnaire survey of 140 participant analyses over 14 *mauzas* in the case study area, Islampur.

The book has four key points. First, it reviews flood literature including vulnerability and adaptation from 1980 to 2014; second, it examines farmers' crop adaptation processes in response to different types of extreme floods; third, it categorizes issues of vulnerability and adaptation on the basis of a weighted index matrix; and finally the book assesses the economic consequences of failure effects of autonomous adaptation. The book concludes that urgent action is needed to improve the sustainable crop adaptation capacity at a community level in the future to cope with floods under a regime of climate change.

This book is structured around eight chapters and appendices, including field questionnaires. The book is well-grounded with a review of the relevant literature on adaptation and vulnerability, flooding, food security, and human security related to climate change. I believe this book should be very useful to climate change researchers, those working on community-based adaptation, development and policy making. Younus is well-equipped to write this book. He has the knowledge on vulnerability and adaptation to climate change and I congratulate him on his timely and resourceful contribution.

Adelaide, June 2014 Prof. Nick Harvey

Preface

The Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (2007), especially chapter 17: *Assessment of Adaptation Practices, Options, Constraints and Capacity* demonstrates the importance of adaptation to climate change. The IPCC (2007, 2014) warned that the megadelta basins in South Asia, such as the Ganges Brahmaputra Meghna (GBM) will be at greatest risk due to increased flooding, and that the region's poverty would reduce its adaptation capacity. A key issue in assessing vulnerability and adaptation (V&A) in response to extreme flood events (EFEs) in the GBM river basin is the concept of autonomous adaptation.

This book investigates autonomous adaptation using a multimethod technique which includes two participatory rapid appraisals (PRA), a questionnaire survey of 140 participant analyses over 14 *mauzas* in the case study area, group and in-depth discussions and a literature review.

The study has four key approaches. First, it reviews the flood literature for Bangladesh from 1980 to 2009 and identifies a general description of flood hazard characteristics, history, and research trends, causes of floods and types of floods. Second, it examines farmers' crop adaptation processes in a case study area at Islampur, Bangladesh, in response to different types of EFEs (multipeak with longer duration flood, single-peak with shorter duration flood and single-peak at the period of harvesting) and describes how farmers have been adapting to the extreme floods over time. Third, it assesses the V&A in response to three EFEs in 1998, 1995, and 1988. V&A are categorized on the basis of a weighted matrix index. The book uses PRA methodology and makes an important methodological contribution for assessing V&A. Fourth; the book assesses the economic consequences of failure effects of autonomous adaptation in response to EFEs. The results show that Bangladeshi farmers are highly resilient to EFEs, but the economic consequences of failure effects of autonomous crop adaptation (FEACA) on marginal farmers are large. These failure effects are defined as total crop loss against potential production, plus total agricultural cost multiplied by the number of flood events in the studied area. Total agricultural cost includes cost of seedlings, fertilizer, pesticides, land preparation, human labor, and watering. The book estimates that the crop- related loss plus plants and houses damaged due to extreme flooding in 1998 in Bangladesh was US$14001.26 million.

The book contributes to current knowledge by filling three important research gaps as follows: (1) farmers' autonomous crop adaptation processes in response to various types of EFEs; (2) methodological contribution for assessing V&A through PRA; and (3) the economic consequences of the failure effects of autonomous crop adaptations. The findings of this study can act as a guide to policy decisions for effective allocation of adaptation funds at community level in Bangladesh. The book concludes that urgent action is needed to improve the sustainable crop adaptation capacity at community level in the foreseeable future to cope with extreme floods under a regime of climate change.

Acknowledgments

This has been a long journey for me. Completion of this research work and writing has been possible only with the vital support and guidance I have received from my chief supervisor Prof. Nick Harvey. The most important challenge was to find out the right way to express my views and shape the book. Nick's timely feedback and comments regarding my writing were of immense value and helped me to proceed in the right direction without which the study would not have been possible. I would admit that along the long journey I had moments of setback, but the inspiration and moral support from Nick kept me moving ahead.

I would also express my sincere gratitude to Emeritus Prof. Martin Williams. Taking valuable time from his own research, he reviewed my writing in great detail, and provided valuable feedback within a very short timeframe, which overwhelmed me.

The discipline of Geography and Environmental Studies helped me in many ways throughout the journey. I had the opportunity to participate in the ANZSEE conference in 2007 and the IAG conference in 2006 with financial support from the discipline. I also participated in a GECHS conference with a presentation of my study findings. These conferences gave me the chance to share ideas related to my study with many learned academics and researchers. I would like to thank Christine Crothers, the cartographer of the discipline who helped me by drawing few figures.

It is not easy to conduct survey work and undertake PRA in rural and remote areas of Bangladesh, particularly in isolated *char* land areas. I was given unconditional support from the local Government administration, *Upazila* Agricultural Officer, Block Supervisors, the local *Union Parishad* chairmen and members and community leaders and last but not the least, from the vulnerable farmers themselves. I am greatly indebted to them. Four field assistants, Mr. Ahmed, Mr. Iqbal, Mr. Shamim, and Mr. Rakib helped me during the questionnaire survey and conducting PRA sessions with sincerity and diligence. My heartfelt gratitude goes to them.

I would like to thank Dr. Q. K. Ahmad, Chairman, Dhaka School of Economics and Bangladesh *Unnayan Parishad* and former President, Bangladesh Economic Association; Dr. K. Sajjadur Rasheed, former Prof. of Geography and Environment, Dhaka University; Prof. Munir Morad, Deputy Dean of the Faculty of Science and Technology, Anglia Ruskin University, UK for their constant encouragement and inspiration. Late Prof. M. Aminul Islam former VC of the Open University, late Dr. S. M. H. Zaman and Dr. Z. Karim both as an agricultural expert, Prof. A. Q. M. Mahbub, former President of Bangladesh Geographical Society and Prof. Bhuiya of Jahangirnagar University, helped me with their valuable opinions in various forms, either by phone or face-to-face interview from time to time. Dr. Jan E. Carey and Chris Nance helped me with proofreading.

I cannot thank enough my sisters and brothers Dr. Asfia, Dr. Zakaria, Dr. Afia, Dr. Yousuf, and Ms. Irani for the encouragement they provided throughout this journey. I remember my mother who was the source of neverending encouragement for me, although unfortunately she could not see me completing it. My daughter Farah helped me with data entry, which was a very rewarding experience for me. I am also deeply indebted to my wife, Dr. Raunak Konok, who was there for me all through my journey, despite her busy work schedule in Hospital. Last but not the least, my gratitude to Almighty Allah for enabling me to complete this task.

Contents

Abbreviations

ACA	Autonomous Crop Adaptation
ADB	Asian Development Bank
AFDB	African Development Bank
BCCSAP	The Bangladesh Climate Change Strategy and Action Plan
BWDB	Bangladesh Water Development Board
BWFMS	Bangladesh Water and Flood Management Study
CBAC	Community-Based Adaptation Committee
COP	Conference of the Parties
DFID	The Department for International Development
EFEs	Extreme Flood Events
EIA	Environmental Impact Assessment
ENSO	El Nino-Southern Oscillation
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization
FAP	Flood Action Plan
FC	Fertilier Cost
FCDI	Flood Control and Drainage and Irrigation
FEACA	Failure Effect of Autonomous Crop Adaptation
FEACAs	Failure Effects of Autonomous Crop Adaptations
FPCO	Flood Plan Coordination Organization
GBM	Ganges, Brahmaputra and Meghna
GCMs	Global Circulation Models
GDP	Gross Domestic Product
GECHS	Global Environmental Change and Human Security
GOB	Government of Bangladesh
HYV	High Yielding Variety
IECO	International Engineering Company
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
IWRM	Integrated Water Resource Management
LC	Laboring Cost
LPC	Land Preparation Cost
MHL	Medium High Land

MLL	Medium Low Land
MoEF	The Ministry of Environment and Forest
MPO	Master Plan Organization
N	Number of Flood Strikes
NAPA	The National Adaptation Program of Action
NGOs	Non-Governmental Organizations
NWP	National Water Plan
OECD	Organization for Economic Co-operation and Development
PC	Pesticides Cost
PRA	Participatory Rapid Appraisal
PRRA	Participatory Rapid Rural Appraisal
RAP	Rapid Assessment Procedures
RRA	Rapid Rural Appraisal
SC	Seedling Cost
TECL	Total Expected Crop Loss
TERI	The Energy and Resources Institute
Tk	*Taka*
UNDP	United Nations Development Program
UNEP	United Nation Environment Program
UNFCCC	The United Nations Framework Convention and Climate Change
UNO	*Upazila Nirbahi* Officer
USAID	United States Agency for International Development
USCSP	United States Country Study Program
V&A	Vulnerability and Adaptation
VGF	Vulnerable Group Feeding
VLL	Very Low Land
WARPO	Water Resource Planning Organization
WC	Watering Cost

Author Biography

Md Aboul Fazal Younus, B.Sc. (Hons, First Class in Geography, Dhaka University), M.Sc. (First Class, Second, Dhaka University), M.Phil. (Waikato), Ph.D. (Adelaide), is a Visiting Research Fellow at the University of Adelaide, South Australia. He became a Lecturer from 2011 to 2013 in the School of the Environment at Flinders University, South Australia; and taught several courses: Environmental Studies: Climate Change and Human Adaptation, Environmental Decision Making Tools, Cities as Human Environments, and Research Project Design and Management. He worked in BUP. He has work experience with some world experts on climate change vulnerability and adaptation, they are: Nick Harvey, Martin Williams, Q. K. Ahmad, Munir Morad, Richard Warrick and K. B. Sajjadur Rasheed. He delivered special lectures in Dhaka University in Bangladesh; presented many papers in international conferences in the UK, the USA, Australia, Finland, Norway, and Bangladesh; and published many articles in international scientific journals. He is a member of the Institute of Australian Geographers, International Society for Ecological Economics (ISEE) and Australia New Zealand Society for Ecological Economics (ANZSEE), Bangladesh Geographical Society, Bangladesh National Geographical Association (BNGA) and Bangla Academy.

Chapter 1
Introductory Background and Statement of the Problems

Abstract This chapter of this book has focused on the problems in general, and reviews relevant literature on vulnerability and adaptation to climate change in general, focusing on riverine extreme floods in the context of Bangladesh. The literature review follows on three broad issues, namely, (1) V&A to climate change, (2) Bangladesh's agriculture, flooding, climate change and food security, and (3) Climate change impacts on agriculture. Flood research scenarios in Bangladesh have also been reviewed from 1980 to 2014. After reviewing these areas of the literature, research gaps, research questions and research objectives have been identified. The differences between the reviewed literature and the proposed research have been pointed out. The Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (2007) and the IPCC's [1] Fifth Assessment Report, especially chapters 14–17 which are based on adaptation, demonstrate the importance of adaptation to climate change which this book emphasizes. This chapter reviews recent literature on flood research in Bangladesh, focusing on that nation's vulnerability to climate change and its ability to adapt. The review reveals that none of the literature addresses community-based adaptation processes, and there is no assessment of the vulnerability of rural communities, their ability to adapt their farming methods, or the economic consequences of failure to adapt in response to extreme flood events. The structure of the book i.e. Chaps. 1–8 and their linkages with each other have been summarized in this chapter.

1.1 Introduction

> *… coastal areas, especially heavily-populated megadelta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers* [2, 3, p. 13].

The IPCC, 2007 working group II Fourth Assessment Report made this grave prediction in its summary for policy makers in the Asia section. This is an alarming forecast. The megadeltas in Asia, particularly the Ganges-Brahmaputra-

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Meghna (GBM) River Basin, would be 'at risk' due to increased flooding in the future. The IPCC also warned that "*Crop yields could increase up to 20 % in East and South–East Asia while they could decrease up to 30 % in Central and South Asia by the mid-21st century*" (IPCC 2007, p. 13). The report also predicted that by 2080, "*Many millions more people are projected to be flooded every year due to sea-level rise. . .*" and that ". . . *those densely-populated and low-lying areas where adaptive capacity is relatively low and which already face other challenges such as tropical storms or local coastal subsidence, are especially at risk. The numbers affected will be largest in the mega-deltas of Asia* …" (IPCC 2007, p. 12).

The above quotations indicate the following:

1. Hugely over-populated megadeltas, such as the GBM River Basin, will face increased flooding in the future.
2. Crop production could decrease up to 30 % in South Asia.
3. The adaptive capacity of these densely-populated areas is relatively low.

As a low-lying vulnerable country of South Asia, Bangladesh faces all three of the above challenges. The book 'Global Change and Integrated Coastal Management in the Asia-Pacific Region' [4], explored issues regarding the megadeltas, particularly the GBM River Basin. In Chapter 10, Woodroffe et al. [5, p. 277] stated: "*..megadeltas appear particularly vulnerable to impacts as a result of any change in sea level and other global change*", as also noted earlier by McLean and Tysban [6], and Kremer et al. [7]. Broadus [8] estimated that in Bangladesh a rise in sea level of one meter would cause inundation of 7 % of inhabitable land and affect 5 % of the population. Additionally, such a rise would lead to a 5 % fall in GDP. Another prediction by Brammer [9] emphasized that the impact of increased flood levels in mid-delta areas would have great adverse implications for the population of the GBM system. Hence, Bangladesh is identified as one of the most vulnerable countries to the effects of climate change. On one hand there will be increased frequency and severity of floods along with decreased crop production, and on the other hand farmers' adaptation capacity will be decreased with each event of extreme flood and its after-effects [10].

Assessment of vulnerability and adaptation (V&A) is an important part of the current study. The V&A guidelines, which have been formulated by the IPCC, UNEP and the United States Country Study Program (USCSP) for fulfilling the United Nations Framework Convention on Climate Change (UNFCCC), have highlighted the need to know the autonomous adaptation processes in various sectors under the present situation as well as under future climate change conditions. The consequences of failure of autonomous adaptation in various sectors, and particularly in the agricultural sector, might have great implications for future climate change research [11–16], IPCC (2007). The V&A assessment guidelines have been reviewed in this book and appropriate steps were adopted to conduct V&A assessment.

The agricultural adaptations in most developing countries are autonomous; that is, crop cultivation is automatically carried out by farmers and mostly depends on nature. Because flooding is part of the regular agricultural cycle in many parts of

Bangladesh, farmers with land prone to annual inundation have developed strategies for dealing with floods which exceed the tolerance levels of their crops. These strategies are termed autonomous adaptations, meaning the ways in which farmers cope with adversity. The research investigates three kinds of autonomous adaptations—in-built, routine and tactical—in the context of normal flood events, and more specifically with reference to the devastating floods in 1998, 1988 and 1995. This research sought to explore these three kinds of autonomous adaptation by measuring the adjustment capacity of Bangladeshi farming systems in response to EFEs. Stage [17] identified two types of adaptation: autonomous adaptation and planned adaptation. According to the author "*autonomous adaptation refers to adaptation decisions that are not made by government agencies; decisions that are made by private firms and households in order to adjust to the realities of climate change*" [17, p. 151]. In this research autonomous adaptation refers only household farmers' farming decisions in relation with the severity of flood characteristics: time, duration and depth.

The autonomous adaptation process ensures cropping patterns are in a sympathetic relationship with flooding characteristics. Different land types accommodate different flood depths and for different durations every year. Considering these types of flooding characteristics, farmers adjust their cropping systems to accommodate flooding. This cropping process then can be seen as an autonomous process. It comes automatically in response to flooding. Autonomous adaptations such as changes in crop varieties, soil management and irrigation systems, and changes in planting schedules and tillage practices are also important in limiting negative effects from severe climate-induced events such as flooding. The autonomous adaptation process is one of the fundamental determinants of the farmers' coping capacity under prevailing flood conditions. It is also a determinant of changes in cropping patterns and thus has implications for the potential change of agriculture land use in Bangladesh.

Four broad aspects of previous work were reviewed in order to identify and understand the research gaps. These are: (1) Agriculture, Flooding, and the Effects of Climate Change in Bangladesh; (2) Climate Change and Flooding in Bangladesh; (3) Agriculture and Food Security vis-a-vis Human Security in Bangladesh; (4) V&A to Climate Change.

1.2 Bangladesh: Agriculture, Flooding and Climate Change

Bangladesh is highly flood-prone, and under normal flooding 20–22 % of the country's area is usually inundated between June and October, even in years of normal rainfall [18]. However, as a consequence of climate change Bangladesh faces more frequent EFEs [19], IPCC (2007). In 1988 and 1998 floods were catastrophic and inundated 61 and 68 % of the land respectively [18]. The duration of extreme floods was long. For example, the 1998 flood continued for over 90 days

[20–22]. Ahmad et al. [23] have predicted that by the year 2030 Bangladesh would be 0.5–2 °C warmer if emissions continue at the present rate [24]. Moreover, climate models indicate that average monsoon rainfalls are likely to rise by 10–15 % by 2030, although the authors cited above emphasized that there is uncertainty in these predictions regarding magnitude, rates, and regional patterns [25].

The Bangladesh economy is mostly rural, though its contribution to total GDP is decreasing over time. In 1994, 35 % of GDP was derived from agriculture but by 2007 agriculture, including its sub sectors (livestock, fisheries and forestry) made up only 21.8 % of GDP [26]. Agriculture uses two-thirds of available land and employs about 75 % of the workforce, and in 1996 it comprised about 80 % of the nation's export earnings [27], especially the crop sector. Within the rural sector, crops account for about three quarters of the total production. Moreover, non-modernized agro-based industries of the country are dependent on the agriculture sector for raw materials.

In a research report on the 1998 floods in Bangladesh, Ninno et al. [28] examined how food security in Bangladesh was maintained following the 'flood of the century' and suggested measures for other developing countries in future natural disaster scenarios. It was proposed that these could comprise a timely and appropriate mix of public interventions, private market trade flows, and effective Government initiatives along with those of donors and NGOs. They recommended that continued investments in agricultural research and infrastructure development, along with the promotion of policies for more efficient markets and programs to provide targeted transfers and credits to those in need, would further improve food security.

Crop yields in Bangladesh are amongst the lowest in the world, although the soil in the river basin areas is quite fertile [23, 29]. This is because of the dependence on traditional methods in which the main technique is autonomous crop cultivation. There is no large-scale commercial farming in Bangladesh, all farming systems being based on subsistence methods. One of the major problems the country faces is its large population (estimated mid-2007 population was 143 million, expected to be near 180 million by 2025) with a high growth rate (1.54 % in 2001); the country's population rose by 54 million between 1974 and 2001. The population density is very high (969 person per km^2; by the year 2025 it could be over 1,200 km^2) [18]. Autonomous methods of cultivation and yearly flood hazards are factors which have a negative influence on food availability over time. Crop production and resultant availability of food depends entirely on environmental factors—particularly flooding and its nature, frequency, and severity. Farmers make their decisions based on traditional predictive factors related to flooding characteristics. If their decisions are in accord with natural phenomena (that is, if the predictions for the degree and nature of flooding prove to be correct) then there is usually sufficient production for their needs. This is a cyclical and continuous process in the agricultural system of Bangladesh.

However, in addition to concerns about the effects of population growth there is uncertainty about the effects on crop production of climate-induced natural and extreme flooding. In times of severe flooding Bangladesh faces shortages of food grains. In 1995, 813,000 metric tons of rice was imported, though total rice production in 1996 was 28, 008,000 metric tons [30: 141]. The country's yearly rice production increased from 7.7 million tons during the 1950s to about 20 million tons in 1992 (Karim [31]: 49), but this still failed to meet the demands of the ever-growing population. In the last 15 years total farm output has doubled. For example, in 1979–1980 rice production was 12,539,000 metric tons and the area under of cultivation was 25,105,000 acres. In 1992–1993 this increased to 18,340,000 metric tons though the amount of land under cultivation increased only to 25,151,000 acres [32: 132]. Despite this strong rise in productivity the very high population growth combined with other socio-economic and environmental factors increased food demand and caused an on-going food deficit of about 1.5 million tons annually [33]. Food shortages are already prevalent in rural areas, particularly in the *char* land areas which are sand bars formed within a river or estuary (Bengali terms are explained in the glossary). These lands are almost isolated from the mainland and are without any utilities. Most are low-lying areas which usually remain under water for at least three to four months during peak flooding periods in every year. Arable land, particularly floodplain fertile land, is limited; the population-land ratio is already very high, and the overall and seasonal rural rate of unemployment is also very high [34: 140, 35: 49–50]. An increasing food grain deficit has created a crisis situation in the agricultural sector, and improved land use management should be a major focus of government plans to minimize hunger and reduce food shortage.

Almost 74 % of the country is cultivated, and a significant proportion of the agricultural output comes from the fertile GBM River Basin [36]. The agricultural sector is attuned to seasonal rhythms and is dominated by wet and dry monsoons. Because of its geographical position at the confluence of the Ganges, Brahmaputra and Meghna rivers, and being a flat delta land Bangladesh experiences flooding every year. As noted previously, cultivation of rice is attuned to normal flooding which affects about 20 % of the land area each year. However, Bangladesh is prone to natural calamities, especially flooding. In 1988, 57–60 % of the country was flooded [37, 38, p. 189, 39]. In normal years, monsoon floods cover about 20 % of the territory every alternate year and 37 % of the territory one year out of ten [40: 07]. Other destructive floods of lesser magnitude occur quite frequently. According to a report by the Asian Development Bank (ADB), food-grain production fell by 1.8 % in 1994 and by 5.7 % in 1995 because of unpredictable weather [41: 115]. Hence, hostile and unpredictable weather, in association with the observed increase in frequency, extent, depth, and duration of flooding are threatening the already vulnerable agriculture sector of this poor country.

All these issues point to the Bangladeshi agricultural sector being mainly a 'deficit sector' with its production inextricably related to flooding. Farmers' adjustment mechanisms and their cropping decision behaviours in response to prevailing flooding characteristics are a determinant in identifying the risk to agriculture in the future in Bangladesh.

Ali [42] has discussed V&A to climate change in the context of Bangladesh with special focus on tropical cyclone frequency and intensity, storm surges, coastal erosion, and backwater effects. He suggested the following adaptation options in order to survive the climate change challenges: retreat, accommodation and protection.

Mirza et al. [19] examined the implication of climate change on floods in GBM rivers in Bangladesh. They predicted the likely change in magnitude, extent, and depth of flood of the GBM rivers by using empirical models and the MIKE11-GIS hydrodynamic model. Four general circulation models were used to construct climate change scenarios, namely CSIRO9, UKTR, GFDL and LLNL. They reached the conclusion that under climate change conditions peak discharge in all three rivers will rise, resulting in deeper and wider flooding. They predicted that a mean temperature rise of 6 °C will lead to an increase in the mean flooded area of 20–40 % and about 55 % of the flooded landscape will be under deeper water. More people, houses and infrastructure are likely to be affected by floods as an increased number of people will be living on the floodplains. All these changes will ultimately cause a significant fall in rice production in Bangladesh, though Mirza's paper has not focused on overall crop damage or the distribution pattern of average household crop damage. Nor has it explained the V&A assessments in response to EFEs in Bangladesh, or the failure effects of autonomous crop adaptation including losses incurred to households in terms of infrastructure and damage to plants.

Mirza [43] used climate change scenarios from four general circulation models as input into hydrological models which showed substantial increases in mean peak discharges in the GBM rivers. He predicted that the "*enhanced greenhouse effect is likely to have significant effects on the hydrology and water resources of the GBM basins and might ultimately lead to more serious floods in Bangladesh*" [43, p. 127]. He also predicted that severe flooding would ultimately cause damage to agriculture, flood control measures, and infrastructure across much of the country. According to his assessments, all three GBM rivers will experience a rise in peak flow, but the largest changes in flooding are expected in the Brahmaputra and Meghna rivers. In this paper Mirza also focused on crop damage, reporting that on average the yearly crop damage from flooding is around 0.5 million tons [44] while in 1998 it was estimated to be around 2.2–3.5 million tons. Crop damage during a monsoon was expressed as a function of flood volume in the GBM rivers. An empirical relationship was developed between combined peak discharge and the amount of crop damage. Using this relationship he estimated that the total 20-year crop damage from flooding has been around 1.5 million tons.

Yu et al. [45] have given a more thorough and recent review of potential climate change impacts and risk of food security in Bangladesh. In this book, using the GCMs, a trend towards a warmer and wetter future climate is projected on Bangladesh agricultural sector. They have demonstrated that there will be increased flow in the three major rivers (GBM basin) of up to 20 %, resulting in declining national crop production with a pronounced detrimental economic impact.

The direct annual cost to the national economy from damage and lost production over the last 10 years is estimated to be between 0.5 and 1 % of GDP [46].

Following is a summary of flood research scenarios and findings in Bangladesh, discussed in detail in Chap. 3 (Table 1.1).

Table 1.1 Flood research scenarios (1980–2014) in Bangladesh

Author and year of publication	Issues/findings
Islam [140]	Presented a preliminary appraisal of agricultural adjustment vis-à-vis flooding in three villages of Bangladesh. Agricultural adjustments evolved over the ages. Agricultural practices, particularly the cropping patterns, have adapted to the characteristics of flooding in general
Sen [141]	Argued that 'lack of entitlements to food due to loss of employment associated with lack of purchasing power not the food shortage', was the main cause of famine which followed the devastating 1974 flood [142]
Paul [143]	Studied post-flood impact on agriculture and adjustment processes and identified that normal floods are not harmful, but are beneficial to agricultural lands
Montgomery [144]	Examined crop losses due to floods, by analyzing deviations from trend
HIDD/ESCAP [145]	Assessed the distributional impact of flood damage and reached the conclusion that the poor are more vulnerable to floods
Haque [146]	Examined characteristics of human adjustment strategies to cope with riverbank erosion among inhabitants of the *Jamuna* floodplain
Zaman [147]	Explained human adjustments to riverbank erosion hazards in the Brahmaputra-Jamuna floodplain of Bangladesh
Hossain [148]	Analyzed fluctuations from estimated trends in food grain production at the regional and national levels to explain the production instability caused by natural hazards
Islam [129, 130]	Mentioned that the relationship between cropping practices and flooding of land accounts for much of the complex land use pattern that has evolved in Bangladesh
Thompson [149]	Reviewed existing appraisal and evaluation methods and recommended some improvements to these, particularly in relation to flood-control agricultural projects in Bangladesh
Brammer [150]	Mentioned that a UNDP-funded flood policy study recommended GBM rivers would be embanked to provide controlled flooding in adjoining floodplain areas
Brammer [151]	Reviewed the geographical background of 1987 and 1988 floods and argued that the 1987 flood was predominantly a rainwater flood
Khan [152]	Reported the impacts and severity of the 1987 and 1988 floods on the rural livelihood of two flood-prone villages
Brammer and Khan [36]	Described four aspects: disaster context, risk assessment, disaster management, and international assistance
Pearce [153]	Identified that floods in Bangladesh benefit agricultural lands, and the floodwaters usually renew the soil
Zaman and Wiest [154]	Mentioned population displacement due to river bank erosion
Rashid and Pramanik [37, 38]	Presented the methods and results of visual interpretation of satellite imagery for estimating areal extent of the 1988 flood

(continued)

Table 1.1 (continued)

Author and year of publication	Issues/findings
Haque [155]	A holistic approach—unlike the 'structural' strategy—to human aspects of water resource management
Paul and Rasid [44]	The average loss of rice production resulting from flooding in Bangladesh was approximately 4 % of the total country-wide rice production figure
Cobb [156]	'Rivers replenish, but they also resew the patchwork of paddies, villages, and roads—farmers must adapt'
Asaduzzaman [157]	Potential rise in rainfall in future is expected to increase surface run off causing severe flooding in the country
Khalequzzaman [158]	Discusses recent floods in Bangladesh and their possible causes and solutions
Rasid and Mallik [159]	Irrespective of significant spatial variations in preferences for specific ranges of flood levels, a majority of respondents preferred regulated levels that coincided with the overall range of the normal flood regimes to which rice crops were adjusted
Paul [160]	Farmers' level of awareness, responses to and possible positive and negative impacts of the proposed embankment projects
Thomson and Sultana [161]	There is little evidence that flood protection has stabilized the economic condition of households; embankment failure is a serious hazard
Paul [162]	Overall flood research in Bangladesh
Islam [163]	*Aman* crop damage due to 1998 floods
Chowdhury et al. [164]	Rapid economic appraisal which carried out a national estimate of flood loss to the economy
Ninno and Roy [165]	The impact of floods on food security and labour markets in rural areas
Islam [166]	The open approach to flood control as the way to the future.
Mirza et al. [167]	Flood damage adjustment research should receive more focus at the Government level
Ahmad and Ahmed [168]	Effective regional cooperation towards managing floods in Bangladesh
Dorosh, Ninno and Shahabuddin [169]	Analyzed the impact of 1998 floods and focused on comprehensive food security in Bangladesh
Benson and Clay [170]	How natural disasters affect financial system and how the financial institutions, both public and private cope with that
Younus et al. [21]	Investigated routine, tactical and in-built adaptation in the context of normal floods as well as the devastating 1998 flood.
Khandker [171]	The 1998 flood reduced both consumption and assets.
Ali [172]	Examined the nature and causes of the sudden 2004 flood
Younus et al. [173]	The autonomous adjustments are very resilient, and they can cope with a wide range of flood events

(continued)

Table 1.1 (continued)

Author and year of publication	Issues/findings
Brammer [174]	Temperature change and sea-level rise are unlikely to affect farmers' lives and livelihoods significantly during the next 20 years but climate change needs to be seen and addressed in the perspective of overall development needs
Brammer [138]	Severe floods are caused mainly by heavy rainfall within Bangladesh as well as the increased flood and cyclone risks associated with global warming. Alternative measures, such as flood-proofing' urban and rural settlements, development of improved crop varieties and more efficient use of irrigation and fertilizers, need to be implemented in order to provide security for lives, livelihoods and economic production
Banerjee [175]	Severe flooding may cause decline of agricultural production in disaster months, and open-access irrigational input leads to significant increases in post-flood productivity. New risks emerged, with unexpected changes in disaster archetypes and livelihood patterns of stakeholders
Cook and Lane [176]	Following the instigation and collapse of the Flood Action Plan, holistic or interdisciplinary knowledge management was needed (between natural and social science communities); there is isolation between the government and sciences
Cook and Wisner [177]	Integrated and interdisciplinary approaches are most likely to overcome flood vulnerability; researchers, experts and managers would learn from past efforts to inform future solutions, and there is little doubt their collaboration would play a critical role in future flood management
Paul et al. [178]	The majority of cyclone victims did not participate in evacuation initiatives though significant changes have been occurred in cyclone preparedness following the 1991 cyclone Gorky; 3,000 additional cyclone shelters with all public amenities should be built for coastal residents
Sultana and Thompson [179]	Local planning for floods revealed a gap in the activities of community institutions but the enhanced social capital could be a basis for adaptation to climate change; community resource management institutions could develop a more integrated approach that internalizes the interactions between water and resources
Yu et al. [45]	A warmer and wetter future climate is projected Bangladeshi agriculture; and resulting decline in national crop production and severe economic impact
Younus and Harvey [180]	The household failure effects of autonomous adaptation in response with the extreme floods in Bangladesh are large
Younus [139, 181]	Within the past 20 years the size of typical farms affected by extreme floods has been reduced by more than half

(continued)

Table 1.1 (continued)

Author and year of publication	Issues/findings
Younus [181]	Within the past 20 years the size of typical Bangladesh farms affected by extreme floods has been reduced by more than half
Younus [139]	How farmers adapt with flood characteristics: timing, frequency and duration
Younus [182]	A methodological contribution for assessment of vulnerability and adaptation
Younus and Harvey [183]	The economic consequences of failure effects of autonomous crop adaptation on marginal farmers are large

1.3 Climate Change and Flooding in Bangladesh

There has been much interest in climate-change research over the last 15 years or so. These studies suggest that global warming may significantly affect climate at regional levels, such as South Asia, including Bangladesh [47–53]. A change in rainfall pattern during the monsoon in Bangladesh would have significant impacts on flooding, resulting in increased vulnerability of agricultural land use, which will add to the increasing concern over food security.

The South Asian cropping calendar is determined by the monsoon because this brings the much-needed rain which is essential for rice production, particularly for high-yielding varieties of rice. Despite the very extensive research that has been done on climate change scenarios, it is still uncertain what sort of impacts increases in atmospheric concentrations of greenhouse gases will have on precipitation over South Asia [47, 50]. In the IPCC WG2 Third Assessment Report, Lal et al. [47: 3] noted from the currently available global climate models (GCMs) that: "*The GCMs show high uncertainty in future projections of both winter and summer precipitation over South Asia …..Since much of Tropical Asia is intrinsically linked with the annual monsoon cycle, research into a better understanding of the future behaviour of the monsoon and its variability is warranted*". They further noted with regard to the monsoon that: "*The monsoons of Tropical Asia could become more variable if ENSO (El Nino-Southern Oscillation) events become stronger and more frequent in a warmer atmosphere*" [47: 3]. Warrick et al. [50: 67] noted that though there is evidence to suggest that monsoon rainfall is weakly associated with the ENSO phenomenon, "*the specific relationships between ENSO and Bangladesh's climate have not yet been thoroughly investigated, so the question remains open*". Using the same global climate models Meehl et al. [48] concluded that the inter-annual variability of monsoon rainfall would be enhanced. Based on 20 years of observation the modelling shows a trend of increased inter-annual variability of Indian monsoon precipitation [48]. According to Lal, there is a strong possibility of more intense monsoon rainfall events over the central Indian plains in the future [52].

Douglas [54] concluded that food production will be disrupted by flooding—which is likely to be more severe and more frequent as a result of climate change. He forecasts that the situation will be much worse by 2080. A possible sea-level rise of 15–38 cm by 2050 [55] would ultimately displace around 35 million people around the Bay of Bengal. He described possible future changes as having four distinct implications. These are: (1) The timing and occurrence of flooding might be changed; (2) Monsoon precipitation in the GBM Basin will cause an increase in magnitude, depth, frequency, extent, and duration of flooding; (3) Likely changes in synchronization of flood peaks of the major rivers; and, (4) The above-mentioned changes will dramatically modify the land use pattern of all the major deltas of the subcontinent. All these changes are likely to make many people highly vulnerable to starvation or malnutrition.

Based on a range of global models, Ahmad et al. [51: 6], reporting on the IPCC's [24] 'business-as-usual' (BAU) emissions scenario, noted that Bangladesh is projected to be 0.5–2.0 °C warmer by the year 2030 compared to 1990. They stated that rainfall is more difficult to predict than temperature in these models, but go on to note that on the basis of 1990 forecasts: "*The best estimate is a 10 to 15 percent increase in average monsoon rainfall by the year 2030, although the uncertainties are very large*" [51: 6]. The significance of this projected increase in rainfall should be examined from the perspective of the natural year-to-year variation in rainfall in Bangladesh, which is large [49, 50: 68].

According to Lal et al. [47], recent studies have confirmed earlier predictions that an increase in the inter-annual as well as intra-seasonal variability of daily precipitation in the Asian summer monsoon will accompany increased greenhouse gas concentrations in the atmosphere. They observe that: *The intensity if extreme rainfall events is projected to be higher in warmer atmosphere suggesting thereby a decrease in return period for the extreme precipitation events and the possibility of more frequent flash floods in parts of India, Nepal and Bangladesh* [47: 14].

According to another study available at http://www.sdnbd.org, increased rainfall in the future will lead to increased surface run-off, with severe consequences for flooding in Bangladesh. Ahmed and Alam [53] stated that precipitation during the monsoon period would rise and the increased rainfall would lead to more flooding in summer. Mirza et al. [19: 315] also indicated that future peak discharges from the GBM rivers under climate change would be increased, and as a consequence Bangladesh would face more serious flooding in the future.

1.4 Agriculture and Food Security Vis-À-Vis Human Security in Bangladesh

Bangladesh is a poor country in the developing world, and it frequently experiences normal, severe, and extreme forms of flooding. Between 1988 and 1998 the country experienced three EFEs and as a consequence millions of marginal farmers in Bangladesh, as well as in the entire GBM Basin, suffered from acute food shortage, which threatened human security in this region (Ahmad et al. [56]). In his speech to the UN General Assembly on 14 July 2003 the Secretary-General stated that "*food insecurity remains a continued reality for millions of Bangladesh's extremely poor, including farmers and landless labourers. Half of the population, 65 million people, is too poor to afford enough food to sustain a healthy and productive life and malnutrition levels are amongst the highest in the world*" (quoted in http://www.righttofood.org/Bangladesh%20report.htm). It is clear that food insecurity precipitated by extreme flooding is a major challenge currently facing Bangladesh.

Bangladesh has an area of 147,570 km^2. The gross annual income for heads of households in rural areas was between 3,000 to 9,000 *taka* (app. 60 *taka* = US$1) [22, 57]. The present research updates this figure and is shown in Chap. 4, Sect. 4. 4. The overall scenario of food security in Bangladesh is grim and consists of inadequate diet, malnutrition, and hunger. In rural areas where household incomes are less than one US dollar per day, there are acute food shortages. The economic activities in rural areas are mainly concerned with various forms of primary production. Riverine flood-prone areas, *char* lands, areas prone to flash floods, and coastal flood plains are the regions where most severe food deficits occur. Even in good years farmers face food shortages, especially during the pre-harvesting/lean season. Karim et al. [33: 57] stated "*Bangladesh has a food deficit of around 1.5 million metric tons, varying from year to year. The deficit is met by importing food grains through both public and private sectors. Rice is the staple food which provides 68 % of the calorie and 54 % of the protein intake. The total food consumption is 868 g/day/person of which 57 % consists of cereals, 34 % vegetables and plant foods and 8 % animal food. More than 50 % of the total population suffer from malnutrition for lack of adequate diet and live below the poverty line*". Almost 50 % of households cannot meet their basic food requirements from their own resources, nor can they buy the required amount of food (USAID-Bangladesh). USAID, followed by the World Bank study, stated that approximately 32 million Bangladeshis cannot afford an average daily intake of more than 1,800 kilocalories. USAID also identified that for other developing countries the daily calorie intake average is 2,828 compared to only 2105 in Bangladesh. In comparison, developed countries have an average daily calorie intake of 3,377. This comparison indicates that most of the households in Bangladesh, particularly in rural areas, suffer from malnutrition, children and women being especially vulnerable.

It is to be noted that the issue of food security is inextricably related to the consequences of climate change for Bangladesh. USAID in 1992 issued a broad definition of food security which is "*when all people at all times have both physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life*" (http://www.usaid.gov/bd/food_sec.html; http://usinfo.state.gov/journals/ites/0502/ijee/bangla.htm). Food security is described as freedom from famine and chronic malnutrition and it entails three core factors: availability, access, and utilization.

In other words, food security means having the ability as an individual, family, community, region, or country to adequately meet nutritional needs on a daily and/or annual basis (http://habitat.igc.org/treaties/at-19.htm). Food security is best assured when food is locally produced, processed, stored and distributed and is available on a continuous basis regardless of climatic and other variations. The main cause of hunger is chronic poverty which is so absolute that its victims possess neither the resources to buy food nor control over the resources needed to produce it. Other causes of hunger include social and political breakdowns, crop failure, and ecological disaster. Bangladesh has 30 agro-ecological regions [58]. Because of recurrent flooding, the autonomous adaptation capacity of the farming system in Bangladesh is diminished, and as a result the agro-ecological regions fail to produce enough food locally to meet the needs of the people of that region. The consequence of crop failure is devastating. Subsistence farmers lose their buying capacity as they do not have any money or any other fixed assets which help them to survive into the next cropping season. Thus crop failure creates chronic poverty and food insecurity. If food insecurity persists then the question of human security comes into play.

Another study by USAID (http://www.usaid.gov/bd/food_sec.html; undated) revealed that 50 % of Bangladeshis live below the established food-based poverty line and one-third of them are in extreme poverty and severely undernourished despite the significant rise in food grain availability and production. In the years 1979 to 1981, 33.8 million people were identified as being undernourished, and for the period 1998–2000 the figure was 47 million—that is, 35 % of the population [59]. The total number of undernourished people has risen over the period from 1978 to 2000. Though rice production doubled (from 11.7 million metric tons in 1974 to 23.1 million tons in 2000), with an average annual increase of 3.6 % (USAID), it could not keep pace with the ever-growing demand from the high population growth rate—a situation which will almost certainly aggravate poverty. This issue is not further discussed in this book but could form the subject of a future study.

Gill et al. [59], provided an overview of food security issues from the perspective of the Millennium Development Goal (MDG) which aims to halve the number of people suffering from hunger by 2015. Seven Asian countries (Bangladesh, India, Nepal China, Indonesia, Cambodia and Vietnam) were considered for this study. The researchers explored the complexity that lies behind food security (dependent on supply, composition of supply, reliability of supply, and accessibility) and emphasized that though food is produced in rural areas, in many countries food security is higher in urban areas because of greater power to access.

1.5 Vulnerability and Adaptation to Climate Change

In accordance with the UNFCCC convention, different climate change literature [14, 15, 60–63], St. Petersburg Workshops (1995) focused on sectoral autonomous adjustments to climate change, especially in the agricultural sector. In this context, various international agencies have formulated V&A guidelines. The term 'vulnerability' is defined as 'susceptible to harm'. On the other hand "*Vulnerability refers to a condition of the vulnerable: it is their weakness, their exposure, their defenselessness or their instability*" [64: 2]. Chambers [65: 01] stated, "*Vulnerability here refers to exposure to contingencies and stress, and difficulty in coping with them. Vulnerability has two sides: an external side of risks, shocks, and stress to which an individual or household is subject; and an internal side which is defenselessness, meaning a lack of means to cope without damaging loss*". After reviewing relevant publications [63, 65–86] it was found that there is a research gap regarding the effects of autonomous adjustments in the agricultural sector in V&A analysis, specifically in considering dynamic socio-economic and demographic systems. Hazard literature [87–96] in relation to adaptation also suggests the above-mentioned shortcomings in research in this field.

Ahmed [97] addressed the rationale for integrating adaptation measures in the current policy regime, particularly in regard to water resources and other related sectors in Bangladesh. He argued that an appropriate policy regime must be developed to ensure sector-wide and inter-institutional integration for designing and implementing various adaptation measures. Ahmad et al. [98] published the first community-based flood management manuals in South Asia (Bangladesh, India, Nepal). They identified responses to floods and categorised them into two types: pre-flood responses, and responses during floods. There are a series of steps within each response. Also, they introduced the concept of the community-based flood management committee which is supposed to be in charge of the steps mentioned above.

The Institute for Social and Environmental Transition (ISET) International and ISET Nepal [99] organized a participant consultation in South Asia and identified that a clear differentiation between coping and autonomous adaptation will be necessary. Additionally, they emphasized that community adaptation activities are being undertaken but it is still necessary to consider how they can be scaled-up, and what their limitations might be.

Preston and Stafford-Smith [100] focused on some key concepts associated with climate change and V&A, as well as some of the commonly-used methodologies. They also examined frameworks for assessing vulnerability, adaptive capacity, and risk, though they did not develop any guidelines for assessing V&A in response to climate change. In this paper they highlighted the recent developments in the field of V&A. They commented that there is some confusion regarding how vulnerability is defined and framed. This term refers to biophysical vulnerability in some instances, but in others it emphasizes social, economic, cultural and political processes that are more aligned to the concepts of resilience, coping capacity, and adaptive capacity. Some authors define the issue of vulnerability as biophysical and socio-economic processes that collectively create the potential for harm. The paper also focused on barriers and limitations to adaptation. Preston and Stafford-Smith [100] identified the most critical challenges to adaptation research. These are concerned with scale, particularly with respect to spatial and temporal scale, that emerges from the complexity of social interactions involved in adaptation decision-making, and the identification of assessment approaches that reflect the nature of both V&A without complexity. Development of a novel framework and more thoughtful application of the existing toolkit are required to meet these challenges.

Adger et al. [80] argued that all societies are basically adaptive for in the past societies have adapted to climate changes and to similar scale risks. Yet some sectors and some groups in society are more vulnerable than others to the risks posed by climate change. They emphasized that in the face of present and future climate change risks, all societies need to enhance their adaptive capacity. In their opinion, the primary challenge is to promote adaptive capacity in the context of competing sustainable development objectives.

Adger [101] discussed social capital, collective action, and adaptation to climate change. He argued that adaptation is a dynamic social process and that the adaptation capacity of a society is determined by the ability to act collectively. He considered South East Asia and the Caribbean as two case study areas and illustrated, through analogy, the nature of adaptation processes and collective action in adjusting to future changes in climate.

Burton [102] explores the distinction between climate and climate change from the perspective of adaptation. He considers that improved adaptation to the current climate is a step towards coping with longer-term climatic change. Prior to 1997 there was no scientific consensus that extreme events had changed in frequency on a world-wide basis, although some regional changes were noted. Burton examined the relationship between climate and climatic change in terms of single and complex variables and phenomena, and he proposed that research communities studying adaptation to extreme events and adaptation to climate change should work in close collaboration.

Kahn [103] concluded that adaptation will play an important role in determining the economic and social costs of climate change.

Grothmann and Patt [104] addressed the importance of measurable and alterable psychological factors in determining adaptation. The model developed and used in their Model of Private Proactive Adaptation to Climate Change can describe and predict the process of adaptation and hence it has important implications for V&A assessment.

Smit and Wandel [105] reviewed the concept of adaptation of human communities to climate change in the context of V&A capacity. They argued that vulnerability indices provide relative vulnerability scores for countries, regions and communities and that participatory vulnerability assessment aims to identify feasible and practical adaptation strategies for the community. Vulnerability is related to differential exposure and sensitivity of communities to stimuli such as climate change and to the particular adaptive capacity of the community.

O'Brien et al. [106] presented and analyzed findings from recent studies on climate change V&A in Norway. Three major findings from their paper are: (1) the indirect effect can be more important than direct and sectoral effects; (2) highly sensitive sectors and communities combine with differential social vulnerability to create both losers and winners; and, (3) barriers to adaptation, particularly among the most vulnerable, are masked by high national levels of adaptive capacity. They emphasized that climate change is likely to have the greatest impact on the weak points of the ecological system or society, including communities which survive and operate under marginal conditions. They argued that the relationship between adaptive capacity and actual adaptation is complex and that there is little evidence of a direct, positive relationship. In the context of their study on Norway they concluded that many sectors and areas would fail to adapt without institutional and financial intervention.

Schroter et al. [85] proposed a method to guide vulnerability assessments to meet a common objective; that is, to inform the decision-making of specific stakeholders regarding available options to adapt to the effects of global change. They suggested five criteria for vulnerability assessment to achieve these objectives. These are: (1) various disciplines and stakeholders should participate to form the knowledge base, (2) the assessment should be place-based, (3) multiple interacting stresses should be considered, (4) examination of different adaptive capacities, and (5) assessment should be prospective as well as historical. On the basis of these criteria they proposed an eight-step guideline as follows:

Step 1: To define the study area;

Step 2: To obtain knowledge about the place, the ecosystem and the drivers of vulnerability;

Step 3: To hypothesize which stresses pose risk to which group of people;

Step 4: To develop a causal model of vulnerability;

Step 5: To find indicators for the elements of vulnerability that are place-based and relating to associated sensitivities and adaptive capacities of the human environmental system;

Step 6: To operationalize models;

Step 7: To project future vulnerability; and

Step 8: To communicate vulnerability creatively.

The authors hypothesize that with the use of this guide researchers will be able to prepare stakeholders for the effects of global change on a region-specific basis.

The ADB [107: 45–46] proposed that "*Within the context of the strategic approach to adaptation interventions mentioned, the South Asia Regional Department will help DMCs (developing member countries) adapt to the unavoidable impacts of climate change through risk management at the national, municipal, and community level, and improved physical planning, investments in defensive measures, support for insurance and other risk-sharing instruments, and climate-proofing of projects. Key sectors for adaptation intervention in South Asia will be water and agriculture. Risk management for possible disasters, such as floods and cyclones, will be a critical element in the process of adapting to climate change impact.*" By 2020 the ADB will focus on community-level adaptations to reduce vulnerability to climate change impacts. This report prioritizes the water and agriculture sectors for adaptation intervention in South Asia, and it also recognizes risk management as an integral part of that process.

O'Brien and Leichenko [108], in a human development report 2007/2008, have explored key points of climate change from the human-security perspective. Drawing examples from Southern Africa and rural Indian agriculture, they emphasized that vulnerability to climate change is not a static thing, rather it is dynamic and connected across both space and time. A human-security approach to climate change is focused on the management of threats to the environmental, social, and human rights of individuals and communities, and work on improving the capacity to respond to changes can thus be considered as a 'people oriented' approach.

Burton et al. [109] explain that a community's exposure to climate change and its ability to adapt to change are closely related to its development status. A strategic response to the increased risk of climate change must reach into economic, trade, agricultural and resource policies, among others. In their opinion, effective adaptation needs to operate at the intersection of policy areas and must be integrated in economic and developmental decision-making.

Olmos [110] emphasized that as a result of limited wealth, education, technology and access to resources, developing countries have less adaptive capacity and hence are more vulnerable to global changes. This implies that the poor would suffer disproportionately from the effects of climate change. He proposed that an eventual climate change knowledge network program on V&A should be focused on the developing countries most under threat.

Kelly and Adger [111] have defined 'social vulnerability' as the ability of individuals and social groupings to respond to, cope with, recover from, or adapt to any external stress placed on their livelihoods and well-being. This ability to respond is constrained by existing socio-economic and institutional facilities. They operationalised this definition in northern Vietnam and showed that complex interactions of dynamic socio-economic trends and associated institutional changes created a scenario of changing vulnerability to climatic extremes.

Adger [112] emphasized that social vulnerability to climate variability is the key dimension in the constitution of vulnerability. This parameter shifts importance on underlying causes of vulnerability from the biophysical to the human consequences. He also mentioned that vulnerability to climate change includes change in individual and collective vulnerability over time, associated with the changing incidence of extreme events.

Schipper [113] emphasized that climate change poses a big challenge, not only because of temperature rise or sea-level increase but because of the failure to alleviate poverty. That is why it is essential that the adaptation policies focus on both climate change and development planning. Adaptation has been an issue of interest, not only for the climate change community but also for the development assistance community [114–118] and the disasters assistance community who are working to explore the dynamics between risk and development. The paper also argues that work on adaptation so far has only highlighted the impacts of climate change but fails to address the underlying causes of vulnerability, and it reiterates that an adaptation process will be successful only when it adequately addresses the factors that are responsible for vulnerability.

Eriksen et al. (Global Environmental Change and Human Security (GECHS) Report 2007: 1) have explored the links between poverty reduction and adaptation to climate change. They emphasized that both adaptation and mitigation are absolutely necessary in meeting the challenge of climate change. They proposed three measures that can target the poverty/vulnerability interface, and their findings have important implications for adaptation to climate change in development aid activities. First, adaptation must be considered as a social development issue in addition to being an environmental and technological issue. Second, it entails adding consideration of climate change vulnerability to present activities. Thus 'responding to uncertainty' is an important ingredient of adaptation. Third, measures taken for sustainable development should be space specific. In this report they have also identified the institutional barriers to incorporating adaptation measures into poverty-reduction policies. Despite that, there are opportunities to enhance and include climate change adaptation in mainstream development policies. This will provide new kinds of development strategies at a local level that will enhance the achievement of basic needs for a decent life, reduce inequalities, and address environmental problems.

Henstra and McBean [119] focus primarily on local or community-based adaptation measures in extreme weather scenarios that might apply to Canada. They recommend that these should be part of broader public policies in order to enhance community resilience. They define adjustment as 'purposive changes to practices, processes, or structures undertaken to better cope with climatic stimuli and their impacts.' Every community has some innate ability to cope with climate changes—but only to a certain limit. This threshold is threatened in extreme weather, and autonomous actions then fail to resolve the crisis. Thus, state intervention through public policy is warranted in these cases. The authors refer to 'climate adaptation policy' as a course of action chosen by public authorities to facilitate adjustments to practices, processes or structures.

Kasperson and Kasperson [120] summarized some major findings developed from an assessment of the potential effects of current and future climate change. They emphasize that vulnerability assessment is essential for complete analysis of climate change impacts and should be addressed in any successful international climate change regime.

A 2003 monograph by the Energy and Resources Institute (TERI) of India considers the effects of climate change in the context of ongoing economic changes, and it examines its impact on the adaptive capacity of Indian farmers. The study draws attention to the need for strengthening institutions and for better integration of policies in order to enhance long-term adaptive capacity and resilience to ongoing and future climate changes.

Parry et al. [121] explained that the extent of any adaptations to climate change would depend on the 'tolerance' of the system, and the range of tolerance (delimited by critical levels) defining the range of climate forcing that can be accommodated. The paper describes a method for identifying dangerous climate change thresholds and its critical levels; and at the end they illustrate how these can assist the United Nations Framework Convention on Climate Change (UNFCCC) process.

Gregory et al. [122] emphasized that climate change may affect food systems in several ways, ranging from direct effects on crop production to changes in markets, food prices, and supply-chain infrastructure. The relative importance of climate change for food security differs between regions. As multiple socio-economic and bio-physical factors are affecting food systems and thus food security, the capacity to adapt food systems to climate change is not uniform. Improved systems of food production, food distribution, and economic access may all contribute to adaptation of food systems to cope with climate change.

1.6 Farmers' Crop Decisions

The ways in which farmers make decisions about what crops to grow in what land is a complex issue. There are several agricultural land-use theories and methods relating to farmers' crop decisions; for example, Von Thunen's Agriculture Land Use Model and Environmental Uncertainty [123: 404–410], the Multi-attribute Assessment of Alternative Cropping Systems [124: 408–420], Bayesian Decision Making Frameworks [125: 94], Behavioural Approach to Agriculture Location [126: 99–107, 127: 329–324], Point Score Analysis [128] and Repertory Grids and Agricultural Decision-Making [127]. All these theories and methods draw on behavioural concepts to deal with farmers' individual, group, or professional managers' responses to uncertain physical activities and hazards.

In the context of complex Bangladesh floodplain micro-environments, it will be difficult to scrutinize any fundamental base relationships between the specific flood characteristics and cropping decisions in a particular flood-land group (for example, depth of flooding and types of crops in very low lands). Consequently, it will be difficult to develop an agricultural model like those mentioned above. There is almost no literature relating to farmers' decisions on their use of Bangladeshi agricultural land [129, 130, 131: 87–94, 132]. It is therefore appropriate to seek a simple relationship as a first step research technique to explore the V&A issues associated with farmers' crop decisions and their relationship to flooding characteristics, rather than through any rule-based theory [133: 370]. These considerations led to the formulation of the objectives of this book.

1.7 Bangladesh Government's Climate Change Strategy and Action Plan

The Ministry of Environment and Forest [46] has published the Bangladesh Climate Change Strategy and Action Plan (BCCSAP). Bangladesh is one of the most vulnerable countries and is liable to be one of the worst affected by climate change. Developing the national adaptation program of action (NAPA) in 2005 was the first step in producing the BCCSAP which indicates that the Government is aware of the climate change issues and concerned about exploring ways to combat the challenges it poses for the country. The Government has already spent 10 billion US dollars over the last 35 years to reduce the country's vulnerability to natural disasters. These include flood management schemes, building coastal polders, cyclone and flood shelters, raising roads and highways above the reach of floods, developing well-equipped disaster warning systems, expanding community-based disaster preparedness, and breeding climate-resilient varieties of rice. The BCCSAP has focused on climate change impacts and adaptation and mitigation issues to cope with impacts, and at the same time it provides a ten-year program to upgrade the country's resilience to meet the climate change challenges over the next twenty to twenty five years.

In the BCCSAP, the Bangladesh government has emphasized the community-based approach to reduce vulnerability to climate change (Section IV, p. 20) but has not detailed any guidelines on how that would be achieved. There has been no explanation regarding how V&A issues would be identified and categorized to form the basis of a community-based approach to adaptation planning. It has also named the relevant ministries responsible for dealing with climate change issues, but has not outlined how they will activate and achieve the operational process of community-based adaptation planning. There has been no direction on how the community-based approach would be coordinated at inter-ministry, inter-institutional, or community levels.

1.8 The Problems

Recent studies on climate change suggest that it will affect the frequency and magnitude of flooding [19, 43, 52, 134, 135]; and the adaptation capacity would be reduced with the frequent adverse climatic hazards in this region [10, 136, 137]. Thus, climate change is expected to significantly influence the autonomous coping capacity of Bangladeshi farming systems.

The agricultural land-use potential in Bangladesh is inextricably related to two factors: bio-physical factors and farmers' behaviour. Therefore, while addressing future V&A issues using autonomous adjustment tactics, floods and land use patterns are considered inseparable. Land use patterns ultimately depend on flood characteristics in two ways: (1) bio-physically—the duration, length, frequency, and depth of flooding and the nature of precipitation influence the opportunities and limitations for crop types and cropping patterns in the season of *kharif* 2 and the transition period between *kharif* 2 and *rabi* (see glossary); (2) behaviourally—the ultimate decisions about land use are influenced by farmers' perceptions of micro-environment and environmental changes. Other factors also affect this decision-making, and they include market demands, prices, and individual competition.

However, adaptation has been the key to expansion of rice production in pace with population growth. In addition to farmers' responses, agricultural research institutes have made contributions of new crop varieties tolerant of problematic micro environments (e.g. flood, salt, drought, and arsenic tolerant or early maturing) [138]. Research is on-going to breed high-yielding rice varieties. Early maturing *boro* varieties are being developed to reduce loss by early floods; and *aman* varieties which can tolerate flood water up to 14 days during the peak period of flooding [138]. Nevertheless, the evidence in 1988 and 1998 flooding suggest that during the multi-peak and longer duration floods, farmers were unable to continue farming high yielding or local varieties (shorter maturation) of *aman* [139].

The climate change literature on the autonomous adaptation and V&A assessment guidelines provides little guidance on these bio-physical and behavioural matters in terms of assessing the failure effects of autonomous crop adaptation in Bangladesh.

1.8.1 Major Problems

To summarize this discussion, some major issues can be identified:

- The Bangladeshi agricultural sector will be 'at risk' in future if the present rate of rapid population growth is not contained and if autonomous cropping adjustments fail to fully regulate the potential of agricultural land use and the level of vulnerability.
- The failure effects of autonomous adjustments would be profound.
- Flooding characteristics also act as a regulatory force for cropping adjustments.

In order to address these issues, this book focuses on:

- An assessment of the likely changes in agricultural vulnerability and farmers' thresholds to flood vulnerability in Bangladesh as a consequence of climate change in particular.
- The processes of farmers' crop adjustment to EFEs.
- The process of failure effects of autonomous adjustments and their economic consequences upon household baseline data.
- Methodological contributions for evaluating V&A assessment in general.

1.9 Research Gaps

From the findings of the above literature and discussions it is clear there are some research gaps. These are:

- There has not been any comprehensive research regarding Bangladesh floods nor flood research trends.
- There is no substantial literature relating to adaptation and development in response to flooding in the context of Bangladesh.
- There is no significant literature relating to farmers' autonomous cropping adjustments to flooding over time.
- In the context of the GBM river Basin, there have not been any substantial studies relating to autonomous coping mechanisms to flooding and the controlling forces upon farmers' decision-making.
- There has been no attempt to assess V&A in response to EFEs where farmers' opinions have been prioritized and weighted.
- In accordance with the vulnerability and adaptation assessment categories mentioned above, there have not been any significant in-depth studies on 'community-based adaptation'.
- There is no substantial literature that applies the methodological contribution for assessing V&A.
- No attempt has been made to assess the failure effects of autonomous crop adaptation.
- No attempt has been made to assess the economic consequences of the failure effects of autonomous adaptation in response to EFEs in Bangladesh.

1.10 Research Questions

The above discussion raises a set of general questions. What is the relationship between adaptation and development within the literature of climate change? Are they reciprocal? What is the capacity of Bangladeshi farming systems to cope with autonomous adjustment processes in the event of extreme floods? How do millions of Bangladeshi subsistence farmers adjust to the great floods? What is the threshold at which autonomous adjustment processes become impossible? What are the V&A issues in response to EFEs? Is it important to understand these issues for future community-based adaptation planning? How large are the failure effects of autonomous crop adaptation? Within the crop failure situation and its resultant food insecurity due to EFEs in the case study area, what are the socio-economic factors affecting human security?

1.11 Proposed Research Objectives

In order to address these questions, this research has five main objectives as follows:

Objective 1: To examine the concept of 'adaptation' vis-a-vis 'autonomous adaptation' within the broad context of climate change in order to understand its importance in V&A assessment.

Objective 2: To review past and current literature on flooding in Bangladesh in order to understand the trend of flood research in Bangladesh.

Objective 3: To examine the autonomous cropping adjustment processes of farmers in response to bio-physical interactions with flooding in order to understand the impact and severity of EFEs on household.

Objective 4: To identify and weight the issues of V&A in response to EFEs, in order to make a methodological contribution for assessing future V&A in the light of climate change.

Objective 5: To evaluate at community level the economic consequences of the failure effects of autonomous adaptation in response to the EFEs on socio-economic-environmental base-level data in order to understand the future threat to human security in Bangladesh.

1.12 Structure of the Book

Chapter 1: Introductory background and statement of the problems

This chapter has focused on the problem in general and reviewed literature on three broad issues, namely, (1) V&A to climate change, (2) Bangladesh's agriculture, flooding, climate change and food security, (3) Climate change impacts on agriculture. After reviewing these areas of the literature, research gaps, research questions and research objectives have been identified. The differences between the reviewed literature and the proposed research have been pointed out.

Chapter 2: Research methodology

The multi-method research approach has been adopted in order to achieve the research objectives. Various kinds of research techniques are involved with the multi-method research approach of this book. These are: structured questionnaire survey, Participatory Rapid Appraisals (PRAs), in-depth case study, field observation, literature review, and professional judgment. A structured questionnaire survey has been conducted in the flood-prone case study area in Islampur *Upazila*, Bangladesh. One hundred and forty households have been chosen from seven *Unions* within fourteen *mauzas* (see Glossary). Two PRAs have been conducted. V&A issues have been identified, weighted, and categorized in accordance with vulnerable farmers' opinions through PRA sessions.

Chapter 3: Floods in Bangladesh: nature, history, research, causes and types

In this chapter, flood characteristics, flood history, causes of floods, and flood types along with flood research trends in Bangladesh have been reviewed. After reviewing existing literature from 1980 to 2007, this chapter identified the flood-research gaps which have been addressed in the subsequent chapters in this book and suggests some directions regarding future flood research in Bangladesh.

Chapter 4: Household information in the case study in Islampur

From the household information provided by the respondents, socio-economic, demographic, environmental and physical issues have been broadly identified. The effects of EFEs and the resulting failure of autonomous crop adaptation on these issues are examined. The research ultimately explores the ways human security is threatened and the consequence of that situation. V&A issues (to be reviewed in Chap. 6) and their degree and extent of importance are identified by household base-level information in this chapter.

Chapter 5: Crop adjustment processes to extreme floods

The chapter explores farmers' crop adaptation processes in response to different types of EFEs (multi-peak with longer duration flood, single-peak with shorter duration flood, and single-peak at the period of harvesting) in the case study area over time. It provides an understanding of how farmers have been adapting during the extreme floods. Farmers' crop decisions in relation to the nature of flooding are also taken into consideration in this section. Farmers' crop decision behaviour is important for understanding the processes of autonomous adjustments in response to EFEs in the case study area.

The findings of focus group discussions as well as the findings of questionnaire surveys and the documented observations of the case study area [57] contribute to the understanding of the farmers' flood crop-adjustment processes.

Chapter 6: Community-based vulnerability and adaptation assessment

IPCC, USCSP and UNEP-formulated V&A to climate change guidelines are reviewed and adapted in the V and A assessment steps in this chapter. A series of V&A issues in response to EFEs are identified, weighted and categorized. This weighted matrix index value is derived from two participatory rapid appraisals. The methodology used in this study through PRAs makes an important methodological contribution for assessing V&A assessment.

Chapter 7: The failure effects of autonomous adaptation

This chapter assesses the economic consequences of the failure effects of autonomous crop adaptation (FEACA) in response to EFEs. The FEACA are defined as potential crop loss plus total agricultural cost multiplied by the number of flood strikes in the studied area. Total agricultural cost includes cost of seedlings, fertilizer, pesticides, land preparation, total labouring, and watering. It is found that the FEACA are large in relation to marginal farmers' socio-economic and environmental base-level data.

Chapter 8: Conclusions and recommendations

Finally, Chap. 8 focuses on the outcomes of the above chapters. The major findings of the book are reviewed. Some recommendations are proposed, with the rationale for making them. The prioritization of V&A issues is discussed where V and A issues have been identified and categorized, and some recommendations are made in accordance with the importance of the categorized issues, which should prove useful in future community-based adaptation planning in Bangladesh. The conceptual contribution of this research is noted and recommendations are made for future research.

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Chapter 2
Research Methodology

Abstract In this chapter, the multi-method research approach is adopted in order to achieve the research objectives: (a) methodological contribution for assessing V&A in a riverine flood prone case study area; (b) failed effect of adaptation i.e. economic consequences on farmers' households. Various kinds of research techniques are involved with the multi-method research approach, these are: structured questionnaire survey for understanding farmers' economic consequences of flooding within the socio-economic, demographic and environmental characteristics of farmers at household level; Participatory Rapid Appraisals (PRAs) for evaluating V&A scenarios and their importance in V&A assessment. An in-depth case study, field observation, literature review and professional judgment contribute to the understanding of the autonomous cropping adjustment processes of farmers in response to bio-physical interactions with flooding and flood research scenarios in Bangladesh from 1980 to 2014. Some key methodological issues are discussed in this chapter. The issues are: reasons for choosing a case study approach for understanding V&A assessment, an overview of the epistemological debate about qualitative and quantitative paradigms, procedures of appropriate sampling in V&A assessment, how and why to conduct a structured questionnaire survey in the flood-prone case study area, appropriateness of uses of PRAs and their advantages and disadvantages, and recent advancements in V&A assessment. This chapter concludes by describing how V&A issues in a vulnerable case study area can be identified, weighted and categorized in accordance with vulnerable farmers' opinions through PRA sessions.

2.1 Introduction

In this book a multi-method research approach has been applied to a case study. This chapter deals with the advantages and disadvantages of a case study approach and at the same time explains why a case study has been chosen for this research. According to the literature, there are strong epistemological divisions between

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qualitative and quantitative approaches and their application in research work. In this research, a quantitative approach using a questionnaire survey and a qualitative approach using the Participatory Rapid Appraisal (PRA) method, in depth case study, and group discussions with farmers and block supervisors have been adopted. The PRA method is discussed in detail in Sect. 2.7 of this chapter.

The methodologist is concerned primarily with the logic of explanation, with ensuring that the arguments are rigorous, that the inferences are reasonable and that the method is internally coherent [1, p. 6]. The methodologist, therefore, is concerned with 'the logic of justification'. Hammersley [2] argues that rather than being derived from philosophical or methodological commitments, the choice of method should be based on the goals and circumstances of the research being pursued.

This chapter focuses on the field research methods used because the collection of information on vulnerable farmers and their responses to natural hazards (such as flooding in Bangladesh) in places where there is extensive illiteracy and poverty poses some significant difficulties. As this study is more concerned with human response to hazard (how farmers adapt with flooding over time) rather than the physical attributes of floods, a mix of qualitative and quantitative methods was considered to be appropriate. In this sense the research methodology has links with what has been termed 'multi-method' research in the literature [3–5]. As [3, 5] note, multi-method research allows for both in-depth inquiry into particular cases (usually employing qualitative methods) as well as an examination of trends and characteristics over large populations which are often established using quantitative methods. A critical criterion of multi-method research is a linking of the qualitative and quantitative approaches in order to capitalize on the complementary strength of different methods of enquiry. Teddlie and Tashakkori [6, p. 15] suggests "*Mixed method research involves the collection or analysis of quantitative and/or qualitative data in a single study in which the data are collected concurrently or sequentially and only the data is integrated at one or more stages in the process of the research*".

2.2 Research Design

Whatever the research approach, all applied research has two major phases, planning and execution and four stages embedded within them. These are definition, design/plan, implementation and reporting or follow up [7].

Figure 2.1 illustrates the research design for this book and linkages with the research objectives. There are two broad objectives: firstly, to assess the failure effects of autonomous crop adaptation, that is, the economic analysis and consequences of EFEs, which has been achieved by the questionnaire survey in the case study area. This questionnaire survey flow is shown in Fig. 2.1. It starts with a pilot (pre-test) survey followed by a questionnaire survey on vulnerable communities. The data analysis process is completed by coding, data validation,

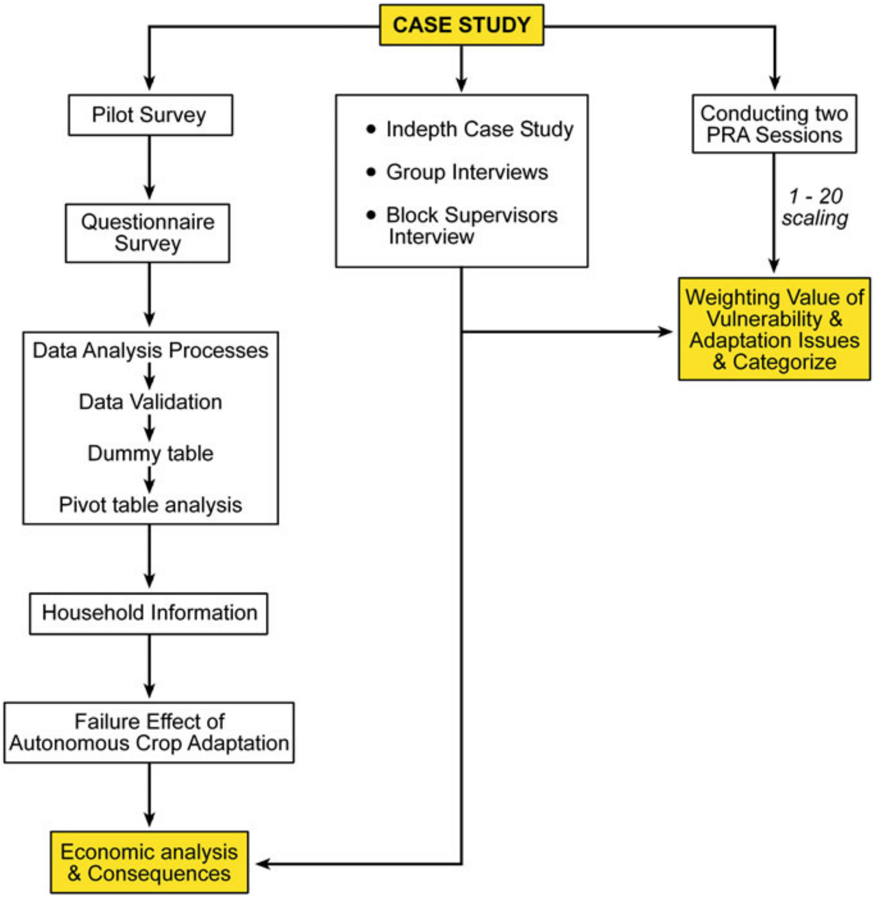

Fig. 2.1 Major findings and methodology used in the research

identifying the required dummy table, and manual analysis of the dummy table with the help of a pivot table analysis. The questionnaire survey provided two types of information, one is household information of vulnerable farmers and the other is the economic impact when the adaptation process fails. These two types of information determine the ultimate economic consequences.

Secondly, the research assesses V&A issues which are revealed by two PRAs. Both V&A issues are measured by a weighted index on a scale of 1–20 (Sect. 2.8).

Table 2.1 illustrates the broad objectives, methodology and respective category of research purpose for Chapters 3–7. The category of research purpose has been divided into three in accordance with research questions: exploratory, evaluative and interventional.

Table 2.1 Chapters with their broad objectives and respective methods used

Chapters	Broad objectives of the present research	Methodology used	Category of research purpose	Research questions		
				What	Why	How
Chapter 3	To understand and review about the flood research in the context of Bangladesh	Literature review	Exploratory: to develop an initial rough description or, possibly, an understanding of some little understood and complex social phenomena	√		
Chapter 4	To understand farmers' household information in order to understand the socio-economic and demographic characteristics of marginal vulnerable farmers	Household survey through structured questionnaire in the case study area	Exploratory: initial understanding of socio economic and demographic phenomenon	√		
Chapter 5	To examine the autonomous cropping adjustment processes of farmers in response to bio-physical interactions with flooding, in order to understand the impact and severity of EFEs	PRA, field observations, group interview, in-depth interview	Evaluative: to monitor social intervention programs, and to assist with problem solving and contributing to policy making	√	√	
Chapter 6	To identify the V&A issues in response to EFEs in order to understand its importance in V&A assessment	PRA through weighted value index	Evaluative: to evaluate V&A issues and to assist with problem solving and policy making	√	√	
Chapter 7	To evaluate the economic consequences of the failure effects of autonomous adaptation in order to understand the future threat of human security in Bangladesh	Structured questionnaire survey	Intervention: to intervene in a social situation by manipulating some aspects of it, or by assisting the participants to do so, preferably on the basis of established understanding or explanation			√

Adapted from Blaikie [8] and Yin [9]

2.3 Reasons for Choosing a Case Study Approach

The case study approach is being increasingly used in social science research. As described by Schramm [10], the essence of a case study is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented and with what result. Abercrombie et al. [11] discuss the case study approach in the *Dictionary of Sociology* as the detailed examination of a single example of a class of phenomena. A case study cannot provide reliable information about the broader class, but it may be useful in the preliminary stages of an investigation since it entails making a hypothesis, which may be tested systematically with a larger number of cases [12, p. 420]. Yin [9, p. 2] notes that the case study approach allows the investigators to retain the holistic and meaningful characteristic of real-life events. According to him the need to use a case study approach arises whenever an empirical inquiry must examine a contemporary phenomenon in its real life context, especially when the boundaries between the phenomenon and its context are not clearly evident [13]. Chetty [14] explains that the case study method of research is a rigorous methodology that allows decision making processes and causality to be studied. It is suitable when, why and how questions are asked about a set of events. McCutcheon and Meredith [15] argue that when properly conducted a case study is truly scientific despite being criticized as a weak form of research which lacks rigor and objectivity.

Benbasat et al. [16] defined case study research and noted that a case study examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities. He also identified eleven characteristics of a case study. Gable [17] presented an analysis of the benefits of integrating the case study and survey research methods. Flyvbjerg [18] described five misunderstandings about case study research and concluded that the case study is a necessary and sufficient method for certain important research tasks and it is a method that holds up well when compared to other methods in the gamut of social science research methodologies.

Platt [19] explained case study research in her historical American methodology thought as "*that which begins with a logic of design… a strategy to be preferred when circumstances and research problems are appropriate rather than an ideological commitment to be followed whatever the circumstances*" [19, p. 46]. The case study as a research strategy comprises an all-encompassing method, covering the logic of design, data collection techniques and specific approaches of data analysis. In this sense, the case study is neither a collection tactic nor merely a design feature alone [20] but a comprehensive research strategy [9, p. 14]. Majchrzac [21, p. 63] noted that case studies are advantageous in many respects as they 'are usually quick, cost efficient and allow room for impressionistic analysis of a situation'. Case studies are frequently used in policy research as they offer the opportunity to examine the process of policy implementation and at the same time outline recommendations for future policy development and implementation. Yin [22, p. 254] focused on 4 steps that seem to have been the most challenging in doing case study research: (step 1) defining and selecting the case(s) for a case study, (step 2) using multiple cases as part of the same case study, (step 3) strengthening the evidence used in a case study, (step 4) analyzing case study evidence.

In this study, one administrative unit, *Upazila*, Islampur, has been chosen as the case study area. This area is a riverine flood prone area which represents other riverine flood prone regions of Bangladesh. Two key objectives of this study are to assess V&A issues in response to EFEs and to assess the economic consequences of the failure effects of autonomous crop adaptation in the context of severe floods. To meet these objectives a case study area was required where farmers who are vulnerable to riverine floods and from whom household socioeconomic and demographic data can be obtained and compared with the failure effects of autonomous crop adaptation.

The author has chosen a case study approach for several reasons:

1. V&A issues which are being examined in this study can be easily explored by the case study approach.
2. Both qualitative and quantitative techniques can be used in the case study approach.
3. The case study approach is quick and explains realistic evidence in accordance with research questions.
4. The approach is cost effective and the required variables/information are easily obtainable.
5. Policy formulation and recommendations for development can easily be drawn from the obtained information.
6. It provides homogeneous information regarding flood vulnerability, adaptation and economic consequences.
7. It is an appropriate method to obtain and assess vulnerable farmers' opinions.
8. The case study approach represents phenomena likely to be found in other flood prone areas in this region.
9. The sampling and questionnaire survey method transforms primary information to secondary information.
10. The case study identifies holistic and meaningful characteristics of real-life events, for example, EFEs are the real life events that have been examined in this study.
11. The multi-method approach can be implemented in the case study method. For example, the questionnaire survey and the PRA methods have been effectively used in this case study.
12. The sampling was carried out in a broad case study area, for example, in Islampur *Upazila*, 14 *mauzas* from 7 *Unions* have been considered and compared. Two *Unions* were chosen for PRA sessions.

2.4 Overview of Qualitative and Quantitative Paradigms: An Epistemological Debate

The quantitative researcher isolates and defines variables and variable categories. These variables are linked together to frame hypotheses, often before the data are collected. In contrast, the qualitative researcher begins with defining very general concepts which, as the research progresses, change their definition. For the former, variables are the vehicles or means of the analysis while, for the latter, they may constitute the product or outcome. The qualitative researcher, searches for patterns of inter-relationships between a previously unspecified set of thoughts while looking through a wide lense, while on the contrary, the quantitative researcher seems to look through a narrow lens at a specified set of variables [23]. Crang [24, 25] explains how qualitative methods are now undergoing a period of more mature reflection and evaluation.

The second difference between qualitative and quantitative methods is the difference in data collection. In the qualitative method, researchers are involved as instruments, attending to their own cultural values and assumptions. It is important to achieve imaginative insights into the respondents' social worlds. To gain that, the investigator should be flexible and reflexive and at the same time maintain distance [26]. Participant observation is also an issue in this approach.

Qualitative techniques are usually applied where the research issue is less clear cut and the questions to the respondents are likely to result in complex and inconclusive answers. For example, participatory rapid appraisal (PRA) or in depth interviewing can be used as a qualitative technique. In this research PRA has been used in order to scrutinize the farmers' V&A assessment. By contrast, the quantitative method is much less flexible where the tool is predetermined and technologically tuned [23].

A quantitative method is appropriately applied where the research issue is clearly defined and the questions asked to respondents lead to concise answers. For example, a structured questionnaire survey has been used in this research in order to assess failure effects of autonomous crop adaptation. The method is developed based on the training and skill of researcher. Philip [27] has focused on the differences between qualitative and quantitative dualism and explained its subjectivity and objectivity. He also showed that there is both epistemological and methodological space for multiple method research.

Sale et al. [28] reached the conclusion that as the two paradigms do not study the same phenomena, qualitative and quantitative methods cannot be combined for cross validation purposes, but agreed that they can be combined for complementary purposes. Sandelowski [29] commented that the 'completeness' of any individual study, no matter what kind it is, must be judged without resorting to methodological fads or fetishes. Foss and Ellefsen [30] argued that the various methods used should be recognized as springing from different epistemological traditions which, when combined, add new perspective to the phenomenon under investigation. Winchester [31] emphasized that interviews need to be performed in a 'realistic framework'. He argued that if that is feasible, there would be no requirement of questionnaire methods to provide an illusion of 'academic respectability'. Firestone [32] argued that while rhetorically different, the results of the two methodologies can be complementary. Howe [33] spoke for a 'collaborative attitude' to research and emphasized that researchers need at least a rudimentary understanding of what alternative approaches can provide.

Brannen [23] has identified where qualitative and quantitative methods differ and overlap in logical terms, described below.

2.4.1 Analytic Induction Versus Enumerative Induction

Analytic induction is used in qualitative methods. In analytic induction, the researcher moves from the data to hypothesis formulation, testing and verification. It is theoretical in its aim rather than descriptive. Where a qualitative method is used in a case study, it is the testing of theory that is important rather than the issue of inference or generalizability [34, 35], cited by Brannen [23, p. 6]. Analytic hypotheses have been criticized as "unscientific", and at times fail to combine inductive logic of enquiry [23]. Moreover, a lot of qualitative research is mainly descriptive. It is mostly used in ethnographic work. The steps adopted in analytic induction are:

1. A research problem which is initially roughly defined.
2. A concrete case is then inspected by the investigator and its essential features are abstracted [36, 37].
3. A working hypothetical explanation is then formulated in the context of the case.
4. Determination, case by case, whether the facts fit the case.
5. Reformulation of explanation or redefinition of the phenomenon if a case does not fit the facts.
6. Explanation is confirmed after successions of cases are examined and the hypotheses seem to fit the case on every occasion.
7. The process is continued until no more negative cases are found. Unsuccessful cases generate negative feedback [1, p. 34], leading to the possibility of redefinition or reformulation which the researcher may carry on testing.

By contrast, in enumerative induction studies many cases with similar characters are abstracted conceptually due to their generality. In conclusion, enumerative induction abstracts by generalizing whereas analytic induction generalizes by abstracting [23, p. 7].

The quantitative researcher does not always test a hypothesis and its goal is often descriptive. In contrast qualitative researchers do have ideas about what they expect to find or intend to look for, albeit not necessary ideas to which they are heavily committed before the data collection phase begins [23, p. 8]. Another important criterion is that qualitative research is often criticized for being 'atheoretical' but sometimes it becomes theory-dependent.

2.4.2 *Generalization Versus Extrapolation*

If the quantitative researcher is interested in causal explanations, it is also necessary to go beyond statistical correlation and issues of representativeness and to resort to theoretical thinking about the linkages between the two characteristics [38]. In qualitative research, which is not based on statistical samples, the concern is mainly replication of the findings in other similar cases or sets of conditions.

In cases where quantitative methods are used such as surveys, there is a need to generalize, so samples are random or representative. On the contrary as qualitative methods are used in non-statistical samples, sampling may be done on the basis of theoretical criteria. The selection of cases cannot be planned beforehand as the researcher is expected to redefine the criteria governing the choice of comparison groups as the analysis proceeds on a case by case basis [23].

2.4.3 *Multi-method Research*

Some researchers such as Burgess [39] prefer the term multiple research strategy. It refers to the use of diverse methods to deal with one research problem. Burgess [40] argues that the researcher should be flexible and should select method/ methods warranted by the research problem under investigation.

Another term, 'triangulation', originally borrowed from psychological reporting [41] and further developed by Denzin [37], combines methods, data, theories and investigators. Many researchers worked on triangulation (e.g. [6, 42–54]; Mitchell [55]). The term in general means using more than one method of research, with the use of more than one type of data [56]. Triangulation represents varieties of data, investigators, theories and methods [57]. These four categories are as follows: (1) Data triangulation (2) Investigator triangulation (3) Theory triangulation (4) Methodological triangulation [57] (Table 2.2).

2.4.4 *Combining Approaches/Mixed Methods*

Different scholars have used different terms about integrating qualitative and quantitative approaches such as integrative, combined, blended, mixed methods, multi-method, and multi-strategy etc. The most accepted term across disciplines is mixed methods [58–63].

Sandelowski [64, p. 326] stated:

> In one kind of mixed methods study, qualitative and quantitative entities are in mixed company with each other, while in other kinds, they are actually blended. In the first kind of mixed methods study, entities are associated with or linked to each other but retain their essential characters, metaphorically, apple juice and orange juice both are used, but they are never mixed together to produce a new kind of fruit juice.

Table 2.2 Different types of triangulation [23, 37]

Triangulation types	Types of approach	Comments
Multiple methods	Within method approach	Same method is used on several occasions
	Between method approach	Uses different methods in relation to same object of study
Multiple investigators	Partnership approach Team approach	Multi-disciplinary research is done in partnership or by team, each bringing different view points
Multiple data sets	First approach	Can be derived from application of different methods
	Alternative approach	Can be derived by using same method in different/points/situations/settings/sources and or variety of contexts
Multiple theories		Uses multiple rather than simple perspectives in relation to the same set of objects

Tashakkori and Teddlie [65, p. 286] broadly defined the mixed method approach as research in which the investigator collects and analyses data, integrates the findings and draws inferences using both qualitative and quantitative approaches or methods in a single study or a program of enquiry. A key concept in this definition is integration. Teddlie and Tashakkori [61] differentiated mixed methods into two: quasi-mixed and mixed methods. The quasi-mixed method is a predominantly quantitative or qualitative approach, involving two types of data, but with no serious integration. On the other hand, the mixed method uses two types of data or analysis, integrated in all stages.

Rossman and Wilson [66] illustrated how qualitative and quantitative methods and the data they yield can be used together to enhance an understanding of complex social phenomena. Robins et al. [67] emphasized that a combination of methods provides more robust understanding of services but there has been little guidance on how to blend these methods to build on the strengths of their respective epistemologies. Bryman [68] distinguished between technical and epistemological levels of discussion in the literature dealing with the quantitative/qualitative distinction.

Darbyshire et al. [69] drew the conclusion that the multiple method approach is valuable and does not merely duplicate data but offers complementary insights and understanding that may be difficult to access through reliance on a single method of data collection. Johnson and Onwuegbuzie [59] described mixed method research as an eight step process and concluded that the key feature of mixed method research is its methodological pluralism which frequently results in superior research. Bryman [70] identified several barriers to the integration of qualitative and quantitative research and argued that there is still considerable uncertainty concerning what it means to integrate findings in mixed method research. Morgan [71] advocates a ‘pragmatic approach’ as a new guiding paradigm in social science research methods, both as a basis for supporting work that combines qualitative and quantitative methods and as a way to redirect our attention to methodological rather than metaphysical concerns. McEvoy and Richards [72] examined some of the issues that arise when methods are combined and concluded that using both qualitative and quantitative approaches gave the enquiry a greater sense of balance and perspective.

Bryman [73] suggests that there is considerable value in examining both the rationales that are given for combining quantitative and qualitative research and the ways in which they are combined in practice.

Previously triangulation was the most frequent purpose for conducting mixed methods. Today, it is being used more for other purposes. The main strength of the mixed methods approach is that researchers can attempt to reconcile diversity by using this method [65]. Both probability sampling and purposive sampling are used to maximize inference quality and transferability in mixed method sampling techniques.

The multi-method research approach depends on the purpose and research questions and ideas involved. Research questions lead to sampling type and data collection procedures, steps for data analysis and ultimately the research inferences and policy/practice/recommendation/decisions. In other words, research questions can lead to the defining of the research objectives. To meet the objectives, research methods are developed. Depending on the research objectives, qualitative or quantitative methods are applied. When research deals with an objective that needs both primary and secondary data, a multi-method research technique is usually required. Once a multi-method research is completed, policy recommendations are drawn in accordance with research aims and hypotheses.

Multi-method research was chosen for this study because the focal point of the research involves a cascade of multiple objectives. Three main objectives of this research are: (a) to examine the autonomous cropping adjustment processes of farmers in the case study are; (b) to make a methodological contribution for assessing V&A; and (c) to evaluate the economic consequences of failure effects of autonomous adaptation. Each of these key issues led to different research questions about bio-physical environments and the human response. To answer the many interrelated questions, the multi-method approach essentially is needed to deal with the complexities of the primary issues. The main methodological questions are:

1. How can I identify V&A issues?
2. What are the flood adjustments and who is obliged to adjust?
3. How can I assess failure effects of autonomous adaptation?

While searching for these answers, vulnerable farmers undoubtedly become the centre point. Only vulnerable farmers can fully describe the V&A issues as they are the group of people who have to adjust to extreme floods, and they can best explain what would be the effect of failure of autonomous adaptation processes. So, for this study, vulnerable farmers within the case study area were the main source of information. The author had to look for the best method to pose these questions to them in order to bring out the most credible responses.

The first method applied by the author was the questionnaire survey. Some questions called for open ended responses and others were closed. The questionnaire survey was designed to reveal that if adjustment fails, which issues would be affected as a consequence. Only vulnerable farmers, from their real life experience, are able to convert these losses to monetary terms. The socio-economic and demographic characteristics, and the adaptation techniques used by them can easily be identified by the structured questionnaire survey.

Similarly, adaptation and vulnerability issues can be assessed and weighted from the response of affected farmers by using the participatory research. The participatory rapid appraisal method (PRA) was adopted for this research because through the participation of the farmers and other local professional groups within the case study area, PRA explores the answers to the key research questions mentioned above. Field observations, in depth one on one interviews and group interviews have been chosen as additional methods in this study to obtain and clarify the required information. Therefore, all these methods applied in this study, comprise the multi-method research.

2.5 Sampling the Research Respondents

Sampling is a very important issue in research as the respondents chosen have a significant impact on the results. The sample is the subset of people to whom the questionnaire is administered [74]. Sampling means selecting units (e.g., events, people, groups, settings, artifacts) in a manner that maximizes the researcher's ability to answer research questions that are forthcoming in a study [65, p. 715]. A sample is selected to represent the group of people or institutions that are the subject of the research.

Sampling can be of five subtypes: (1) Random sampling, (2) Systematic sampling, (3) Stratified sampling, (4) Cluster sampling, (5) Multistage sampling.

In this research, survey work was performed in seven *Unions* of Islampur *Upazila*. Islampur *Upazila* was chosen as a case study area because of its unique characteristics, being an agrarian system located in a dynamic biophysical region. It is a highly flood prone area and experiences flooding every year under normal circumstances. It comprises *char* land area which is susceptible to riverine erosion and sand deposition. It is an ideal place to study main land characteristics and *char* land characteristics at the same time. Most importantly the farming system, is well adapted to the variability of the annual flooding. The farmers have been adapting to the flood situation every year and their crop planting decisions are determined by the prevailing flood characteristics.

From each *Union* two *mauzas* were selected according to severity of vulnerability to flooding. Information was collected regarding number of households in each *mauza* and number of members in each household. Each alternate household was selected as a sample for the questionnaire survey. Thus a systematic sampling approach was administered for this study. In systematic sampling, there is equal probability of sample selection when a random start that is less than or equal to the sampling interval is chosen, and every unit that falls at the start and at the interval from the start is selected [75]. The requirements for systematic sampling are lists of characteristics of the study population, for example, approximate count of study population (N), sample size (n), sampling interval, and random start. The advantage of systematic sampling is that it provides an even coverage of the population within the sampling frame [74, p. 93]. It is easy to administer in the field [75]. Another important issue is the sample size. Large sample size provides more representative estimates of population characteristics and yields more information to address the research problem [74]. At the same time a large sample means more time, effort and cost for conducting the survey work. It is to be noted that precision always increases with sample size, but the improvements in precision decrease at larger sample sizes [74]. The benefits of larger samples begin to level off at sample sizes of 150–200 [76]. For this study 140 households were chosen for questionnaire survey. Owing to time and budget constraints and because of the remote location of the study area, it was not feasible to increase the sample size.

2.5.1 Sampling for Chinaduli Union

A total of 125 household damage reports comprised of household structural damage and plant damage were considered in this study. Data were collected from an unpublished report compiled by the then local elected member of *Union Parishad* where random sampling had been used. The author calculated the failure effects of ACA including agricultural associated loss through the questionnaire survey. The numbers from the unpublished report (household damage plus plant damage related loss) were added to this (crop damage plus agriculture associated cost) to estimate the total flood related loss.

2.6 Structured Questionnaire Survey

In the questionnaire survey respondents filled out and returned to the researcher a self administered interview in which the questions and instructions were simple and complete so that the respondent could act as his or her own interviewer [77]. There are two key aspects to this. First, the researcher consciously controls the process of data collection with the goal of producing scientifically useful data. Second the researcher interacts with subjects to elicit their participation [78, p. 93].

The goal of survey research is to obtain information regarding the behaviour, attitude and characteristics of a population by using a standardized questionnaire or survey on a sample of individuals. This has been an important tool to address a wide range of issues including perception of risk from natural hazards. Survey research is particularly useful for eliciting people's attitudes and opinions about socio-political and environmental issues [74]. Before embarking on a survey research it is important to have a clear understanding of the research objective, the key questions to be addressed, the people or institution that make up the target population and the geographical area or time period of interest [74]. These issues underpin how the survey is designed and administered. When Fowler and Mangione [79] looked at strategies for reducing interviewer effects on data, they concluded that question design was one of the most important means of minimizing interview effects on data [80].

Survey research promises high generalizability. A theory built and tested with survey data has a better known range of applicability as to subjects than one based upon non survey data [78]. One of the main advantages of survey research is economy. It yields the maximum number of facts or bits of data per research dollar [77]. Another advantage is that the respondents can think, consult with others and review records before answering which is usually inappropriate in an interview setting. Some researchers argue that it is the most useful way to gather information on sensitive issues. If the respondent is convinced that the questionnaire is anonymous, then he or she can freely report attitudes or behaviour without fear of reprisal or embarrassment [81].

Surveys usually rely upon either questionnaires or fixed-choice interviews. As a result, there is little room for the investigator to probe areas about which the respondents are unable or unwilling to respond accurately. Due to the absence of experimental control over supposed independent variables and the fact that most surveys are cross sectoral, the task of distinguishing correlations between variables from truly causal relationships are complicated in survey research [78]. One of the limitations of this kind of study is that the questionnaire should be brief, otherwise respondents will not take time to complete them. Dillman [82] reviewed the effect of questionnaire length on respondents and concluded that 11 pages or 125 questions was the limit beyond which the response rate fell off. Another drawback is that the researcher cannot probe or follow up on interesting leads which is possible in interviewing and particularly of significance in exploratory research [77]. Some researchers argue that interviews produce better data and are more likely to generate extreme answers compared to a questionnaire survey. Another potential problem with questionnaire studies is the risk that someone other than the selected respondent can complete the questionnaire. In questionnaire surveys, there is scope for the respondent to come back later to change his/her answers once the real intent of the study becomes clear to him/her. Thus questionnaire surveys are not suitable for studies where some form of deception is practiced, according to Chadwick et al. [77].

2.6.1 Questionnaire Survey in the Study Area

A Pilot Questionnaire survey/pre-test questionnaire survey was conducted before the main questionnaire survey. Fourteen questionnaires were carried out in fourteen *mauzas* under seven *Unions*. This pilot survey was carried out to find out whether the questions in the structured questionnaire were realistic, acceptable and applicable to the vulnerable farmers. Minor changes were done to the questionnaire following the pilot questionnaire survey.

The questionnaire survey is a technique/method administered to collect primary data from the vulnerable case study area which in turn generates quantitative data through analysis. These quantitative data have been used as the main tool in this research.

To ascertain the failure effects of autonomous crop adaptation or economic damage, analysis in response to EFEs is derived from quantification of the responses from the structured questionnaires survey. V&A assessment issues have been categorized on the basis of the results of the questionnaire survey. Although the PRA method has been used widely in order to categorize and weight V&A issues, in the present research prime quantitative data/information were derived from the questionnaire survey. This questionnaire survey result has helped to determine the weighted value matrix in the light of professional judgment. So the structured questionnaire survey is used as the prime technique to clearly understand the following issues:

1. Vulnerable farmers' socio-economic and demographic status.
2. Flood severity.
3. Flood consequences.
4. Economic loss due to flooding.
5. Human responses to flood behaviour which can be cross checked with hydrological data/information.
6. Crop data and crop decisions.
7. Adaptation and vulnerability assessment issues.
8. Policy intervention related to V&A and also failure effects of flood crop adaptation.
9. Flood crop adjustment during 1988–1998 time periods.

Due to constraints of time, finance and funding of research assistants for surveying the questionnaires, the author selected seven *Union*s out of 12 *Union*s in Islampur *Upazila* (Fig. 2.2). The *Union*s along the Jamuna River, on the West of Islampur, were chosen because these are the most flood vulnerable areas within this region. The author selected 20 households from each of these seven *Union*s. Normally, each *Union* is divided into several *mauzas* and two *mauzas* per *Union* were selected in order to get a reasonable cross section of farmers. In each *mauzas* 10 systematic questionnaire surveys were done. As the homesteads were dispersed clustered (linear shapes beside *kacha* or unpaved roads) every alternate house was chosen for the survey work. The heads of the households were mostly selected as the respondent. Another criterion for selecting respondents was that they had to be farmers, whether cultivating owned land or leased landowners. The sample of 140 households from 7 *Union*s and 14 *mauzas* was considered adequate to represent the V&A scenario in this area given the above constraints. The *Unions* and *mauzas* selected were as in Table 2.3.

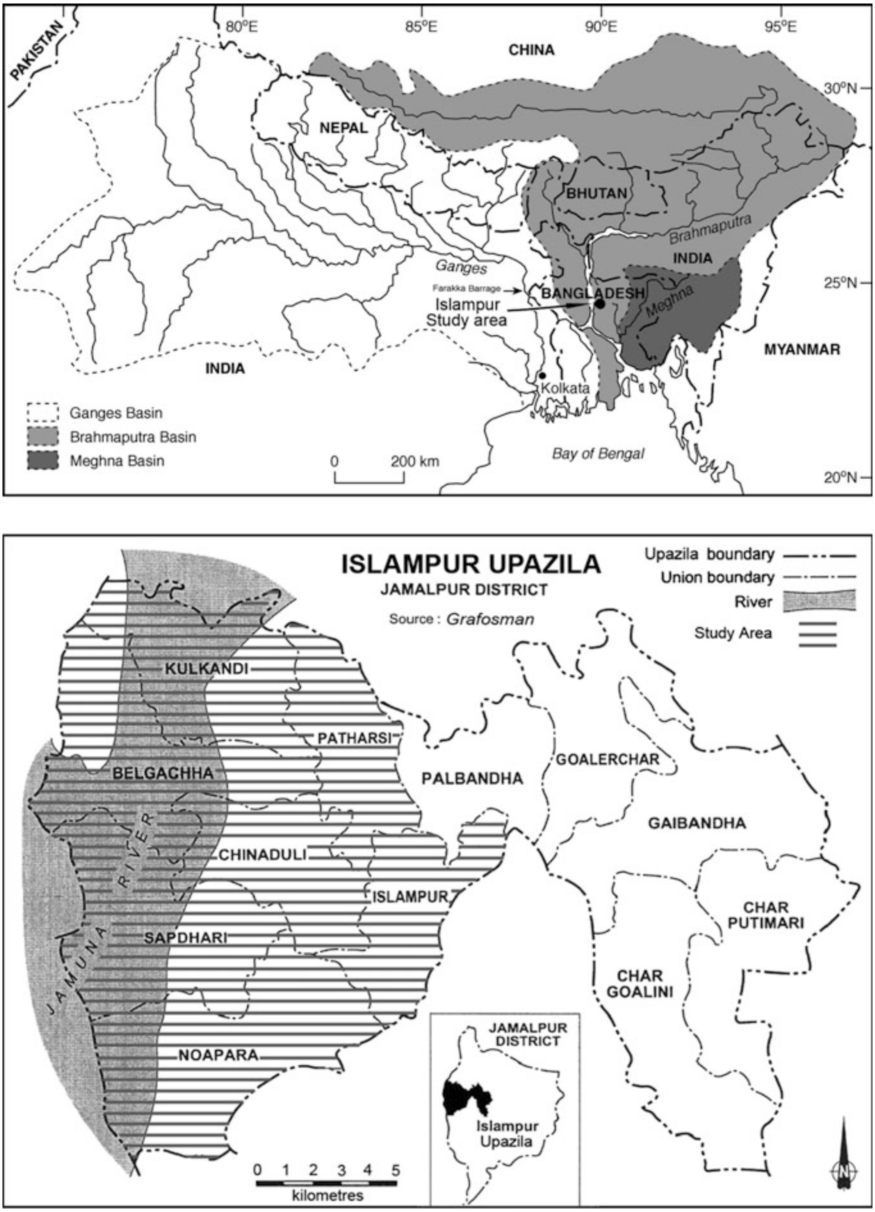

Fig. 2.2 The location of the Ganges, Brahmaputra and Meghna River Basin and the location of case study area (Islampur)

Table 2.3 Unions and selected Mauzas

Unions	Selected Mauzas
Kulkandi	Harindhara and Kulkandi
Sapdhari	Chengania and Shishua
Noapara	Maijbari and Kajla
Chinaduli	Gilabari and Bamna
Patharsi	Gamaria and Mukshimla
Islampur	Panchbaria and Pauchabahala
Belgacha	Dhantala and Belgacha

Four field assistants were employed to help with the survey work. All of them were interviewed before recruitment. They were from economics, geography, sociology and civil engineering backgrounds. The author chose them because of their background as this was meant to be a multidisciplinary study. Three of them were graduates of Dhaka University and the civil engineer a graduate from Bangladesh University of Engineering and Technology. They were all experienced with field survey study. They had to perform a field study while they submitted their thesis/project work during graduation. Among them the economist and the geographer were local, that is, from district Jamalpur, fluent in local dialect and jargon, which helped them to communicate appropriately with the local vulnerable farmers during the survey work. They were given instructions on the ethical rules and regulations about field questionnaire surveys. The field assistants had a good knowledge of social stratification in the context of rural areas in Bangladesh. In addition to helping the author with the questionnaire survey, they helped him with data coding.

2.6.2 Conducting a Questionnaire Survey in the Field

The author first trained the field assistants as to how to fill the questionnaire because the human response needed to be addressed and quantified systematically. They were first briefed about the characteristics of these three EFEs, since the author had previous experience of the flood characteristics: timing, duration, frequency, depth and areal extent and how farmers cope or adjust with the flood events. Local farmers were well experienced with these flood events and they know every detail of each flood event and its biophysical interaction on agricultural land. When they were asked about a past flood event they spontaneously responded regarding V&A issues. For the first 3/4 days the author himself filled the questionnaire in the field assistants' presence to teach them how to do this. After that they were sent to remote areas to work independently. They were advised to ask for initials from the respondents once the questionnaire is filled in. It was noticed that most of the respondents were skeptical about signing the papers as they were mostly illiterate and unable to read what is written in the paperwork.

This is a very sensitive issue, particularly when asked to give their initials in paperwork where their income has been stated. For this reason the field assistants were asked not to force someone to sign the paperwork if they were not willing to do so, but their address was meticulously noted in the questionnaire. Sometimes they tend to exaggerate in the hope of getting ‘relief’ but when it was explained that this is for the purpose of study and appropriate information is needed, they usually co-operated and came up with original information. Each day, after completion of the questionnaires, the author and the field assistants came back to the rest house (*dak* bungalow) and after dinner, used to sit together and edit and check each questionnaire properly. If any confusion was raised, it was solved by discussion. Once all questionnaires were filled in, the field assistants signed at the end of each questionnaire for which they were responsible. The author examined each of them and countersigned accordingly.

It needs to be mentioned that all seven *Unions* are located in remote area where rickshaw and van are the main mode of transport, and the connecting roads are all mostly *kacha* (not paved) particularly Sapdhari, Noapara, Patharsi, Chinaduli and Kulkandi. The team members used to set out for the whole day after breakfast, and usually returned before sunset. The local UNO (*Upazila Nirbahi* Officer) briefed the team that because of the poor law and order situation, it would not be wise to work after dark in these *char* land areas.

The assistants were advised repeatedly regarding how to deal with the farmers who had just suffered significant losses and were still trying their best to cope with that. Because the flood was an extreme one, the farmers were very eager to get some form of assistance or relief from different agencies. Before we resumed the interviewing process, respondents were informed about the purposes of the research and why they and their area had been chosen. In the end the consent form was not used because the farmers, mostly illiterate, became very apprehensive when they were asked to sign a printed sheet of paper.

We commenced field work on 25th of September in 2006. The author visited all the *Union*s in order to conduct the survey work and for over all supervision. Local influential people such as chairmen, reputed school teachers and *Union parishad* members were contacted and their help in conducting the survey work was requested.

The structured questionnaire was fourteen pages long (Appendix I), so it demanded reasonable time for completion. For that reason the author was careful to ensure respondents had enough time to respond. In general the co-operation was good and genuine. Some of the farmers invited the author to visit their home, although in rural Bangladesh society people are very conservative. It helped the author to collect further socio-economic information—information that would assist in developing the framework for examining crop adjustment processes, weighting issues of V&A, and assessment of failure effects of autonomous crop adaptation in response to flooding.

At the end of the day, the author used to go through all the completed questionnaires with the assistants. When the author felt confident about the assistant’s capability to fill in questionnaires independently, then they were allowed to move on to other sample areas separately. Once the survey work was completed in one *Union*, the field notes were taken from the assistants. The questionnaires were stored in a secure place.

2.7 Participatory Rapid Appraisal

2.7.1 Rationale for Choosing Participatory Rapid Appraisal

Before discussing PRA, we need to clarify what is participatory research. Breaking the linear mould of conventional research, participatory research focuses on a process of sequential reflection and action, carried out with and by local people rather than on them [83]. In recent years organizations ranging from small NGOs to UN agencies have been using participatory methods, and their use is on the rise [84]. Most participatory studies focus on knowledge for action, contrary to traditional research which usually generates knowledge for understanding [85, 86]. In conventional research, inappropriate recommendations have frequently followed from a failure to take account of local priorities, processes and perspectives [87, 88]. Participatory research focuses on a 'bottom-up' approach with emphasis on local priorities and perspective [89]. It is shown that involving local people as participants in research and planning enhances effectiveness and saves time and money [83, 90]. Pain [91] noted that some social geographers encourage students to experience participatory research.

Participatory rapid appraisal (PRA) is a form of rapid rural appraisal, a research technique developed in the late 1970s and early 1980s as an alternative or complement to conventional sample surveys. It ensures quick and systematic collection of information for general analysis, assessment, feasibility studies, identifying and prioritizing projects, project evaluation, participatory mapping and modeling, transect work, matrix scoring, weighted index and ranking, well-being grouping and ranking, seasonal calendars, trend and change analysis and analytical diagramming [92, 93]. Based on the work of Chambers [93] PRA flows from and owes much to the traditions and methods of participatory research [94], applied anthropology and field research on farming systems [95, 96] and has evolved most directly from a synthesis of agroecosystem analysis [97–99] and rapid rural appraisal [100–102]. In PRA most of the investigation, sharing and analysis is open-ended and often visual by groups of people and through comparison. Its purpose is more to gain an understanding of the complexities of a topic rather than to gather highly accurate statistics on a list of variables. The PRA method enquires about the population's attitude, beliefs and behaviours and is applied most effectively in relatively homogeneous rural communities which share common knowledge, values and beliefs. In other words PRA is an interesting, systematic but semi-structured learning experience carried out in a community by a multidisciplinary team which includes community members. It requires attitudes favouring: participation, respect for community members, interest in what they know, say, do and patience, not rushing or interrupting, listening, not lecturing, humility and methods which empower community members to express, share, enhance and analyze their knowledge [92].

In the last 10 years, rapid appraisal techniques have gained widespread recognition in development research and are being increasingly used as a complement to conventional research work [92]. In the last 5 years participatory research such as rapid rural appraisal (RRA), participatory rapid rural appraisal (PRRA), rapid assessment procedures (RAP), participatory learning methods (PALM), and participatory rural appraisal have gained huge momentum [92].

PRA has spread through field learning experience, through workshops by villagers and through dissemination material [93].

Features of PRA [92] include: (a) Triangulation: a form of cross-checking. Triangulation is done in relation to sources of information, composition of the team and mix of techniques; (b) Multidisciplinary team; (c) Mix of techniques; (d) Flexibility and Informality; (e) In the community; (f) Optimal ignorance and appropriate imprecision; (g) On-the-spot analysis; (h) Offsetting biases and being self critical.

2.7.2 Advantages of PRA

Some researchers proclaim that PRA is the universal solution to the problems faced by conventional practice [103, 104]. Some participatory methods like participatory rural appraisal offer strategies for generating both qualitative and quantitative information [105]. Participatory methodologies are often characterized as being reflexive, flexible, and iterative whereas the conventional methodology is rigid and linear. [84, 103, 106]

Commonly used survey methods often take too long for data to be collected, analyzed, and disseminated to be useful to development workers and community members [92]. Participatory research ensures the participation of community members and community development workers in the process of information collection rather than giving all key responsibilities to outsiders and thus is intended to serve as a tool for community development activities [92].

It is a short duration and low cost method which enables conducting a series of PRAs rather than having to rely on the results of one large survey [92]. If we want to learn about community member's attitudes, behaviour and opinions then the best method would be PRA (Theis and Grandy [92], p. 32). PRA also raises people's self-awareness, suggests viable solutions, and helps people analyze complex issues and problems.

PRA approaches and methods present a plurality of methods with triangulation and cross checking; and local analysts are usually committed to getting detail, complete and accurate information and can from their personal experience interpret change and causality [93].

PRA can be used as an alternative to conventional sample survey using questionnaires. It has been found to generate valid quantitative as well as qualitative data and also some good ratio estimates for some variables [93].

When well facilitated, PRAs are usually cheaper, quicker, more accurate and more insightful. For example in a 412 households study with a participatory wealth ranking approach in South India, the questionnaire cost seven times as much as PRA and took eight times as much staff time besides giving less valid results [107].

There is scope for local illiterate people to get involved as facilitator and trainers. It has been shown that they can map, model, rank, score, analyze and sketch a diagram, often better than the outsiders [93].

2.7.3 Disadvantages of PRA

Some have argued that a participatory approach is biased, impressionistic and unreliable [83]. There is the possibility that participatory research is being unnecessarily mixed up in the debate surrounding the qualitative-quantitative divide, with critics describing this method as soft [2], that is, insufficiently quantified.

The key element of participatory research lies not in the method but in the attitude of the researcher which in turn determines how, by whom and for whom research is conceptualized and conducted [83].

The practice of participatory research raises personal, political and professional challenges that go beyond the bounds of production of information [83].

Chambers [93] has identified four dangers associated with PRA:

1. Instant fashion: due to over rapid promotion and adoption followed by misuse, and because of sticking on labels without substance.
2. Rushing: Hurried rural visits, insensitivity to social context, and lack of commitment may mean that the poorest are neither seen, listened to nor learnt from. Pottier [108] found that hurried farmer interviews conducted in Zambia were erroneous. Similarly van Steijn [109] found that PRAs conducted in the Philippines were of low quality. So he came to the conclusion that rapid often means wrong.
3. Formalism: With any innovation, there is an urge to standardize and codify hence the rush to compose manuals. As the text lengthens, training is prolonged and more and more time spent in classroom and less and less in field practice which may lead to loss of spontaneity and learning may be slowed or even reversed.
4. Routinisation and ruts: practitioners in some organizations and regions have shown signs of slipping into unvarying standard practices, overlooking other options.

2.7.4 Summary: Spread and Characteristics of PRA

PRA is an internationally accepted qualitative survey technique which is widely used in different studies and international organizations such as World Bank, Action Aid, ILO, Aga Khan Foundation, Ford Foundation, GTZ, SIDA, UNICEF, UNDP and UNCHS (Habitat). Among many applications PRA has been used in natural resources management (community planning, fisheries, forestry, soil and water conservation), programs for women and the poor, agriculture, health and food security [93]. PRA has spread from Ethiopia to South Asia including Bangladesh, to at least forty Asian, African and Latin American countries. Hundreds of NGOs, Government departments, students and university staff have been using PRA methods for their research and action work [93] (Chambers [110]). It has some unique characteristics. Evidence of this was obtained by the author during his experience conducting two PRA sessions in the case study area; and other literature has supported this [83, 90, 93, 111–125] (Chambers [110]). These characteristics are listed below.

1. PRA is a short duration session which spreads knowledge and information rapidly among different people with varying occupations and economic groups.
2. Local information can be quickly collected by using this method.
3. It combines the knowledge of professionals/experts with the life experience of affected people.
4. Within the local/affected group of people, there are representatives from different social strata, religions, age groups and responsible local policy makers.
5. It has been developed for collaborating with local people in analysis and planning and has contributed to the development of action plans and participation strategies.
6. As a whole of community appraisal comes out of these sessions, country/national level policy makers attend these sessions as well.
7. It can transform qualitative data to quantitative data.
8. It helps in transferring the data to policy formation; the most important criterion of PRA is that it deals with qualitative information and transfers the knowledge into policy formation.
9. It emphasizes local knowledge, and enables local people to make their own appraisal, analysis, and plans.
10. The PRA technique uses group animation and facilitates information sharing with the stakeholders. Different strata of people: farmers, teachers, elected local public representatives, politicians, and students are involved as participants in this interviewing session.
11. It involves a bottom up research approach which transforms local information to national policy information.
12. It helps to assess scientific explanation routes, whether inductive or deductive. It enables information evaluation; if any confusion arises in the evaluation

process, it is possible to return to the initial planning process, such as problem identification and collect the information again and re-evaluate.

13. It enables the researchers to cross check information: the interlinked information can be cross checked as well.
14. It is a participatory approach, that is, it ensures the participation of local people in policy making without any third party involvement. If any controversy arises, information provided by a third party can be checked.
15. Semi structured questions are raised for consideration by the attending participants and they can respond to those.
16. As a consequence of discussion and debate between the participants the appropriate answers come out easily.
17. These answers can be ranked and weighted values can be given them in accordance with priority.
18. PRA evolved from a series of qualitative multidisciplinary approaches to learning about local-level conditions and local peoples' perspectives, including Rapid Rural Appraisal and Agrosystem Analysis.
19. PRA provides a "basket of techniques" from which those most appropriate for the project context can be selected. The techniques include interviews and discussions, mapping, ranking, and trend analysis.
20. PRA is cost and time effective compared with other methods used in social science such as structured questionnaire survey method.
21. The purpose of PRA is to enable development practitioners, government officials, and local people to work together to plan context appropriate programs. Within this session semi structured or specific questions are raised among the attending members; and they react to those. As a consequence the answers can easily come out; and later these can be ranked in order of the priority. No one among the participants can independently deliver wrong or misleading information. If someone wants to mislead then the majority react negatively and say that this information is wrong and at that time they also reveal the appropriate information along with the reasoning behind it. Through these processes we can get the right information and prioritize it.
22. It is an informal technique which helps to collect the local rural information quickly. The key tenets of PRA are: participation, questioning, teamwork, flexibility, 'optimal ignorance', and triangulation.

2.7.5 Differences Between RRA and PRA

Before we embark on a discussion about Participatory Rapid Appraisal (PRA) and Rapid Rural Appraisal (RRA) and their differences, it is important to know the differences between PRA and survey research, which are shown in Table 2.4. New research techniques such as RRA were developed in order to achieve a more comprehensive understanding of complex and highly uncertain and changing

Table 2.4 Differences between PRA and survey research

Issues	PRA	Survey research	Issues	PRA	Survey research
1. Duration	Short	Long	10. Major research tool	Semi-structured interview	Formal questionnaire
2. Cost	Low to medium	Medium to high	11. Sampling	Small size	Random, representative
3. Depth	Preliminary	Exhaustive	12. Statistical analysis	Little or none	Major part
4. Scope	Wide	limited	13. Individual case	important, weighted	Not important Not weighted
5. Integration	Multidisciplinary	Weak	14. Formal questionnaires	Avoided	Major part
6. Structure	Flexible, informal	Fixed, formal	15. Organization	Non-hierarchical	Hierarchical
7. Direction	Bottom-up	Top-down	16. Qualitative descriptions	Very important	Not as important as 'hard data'
8. Participation	High	Low	17. Measurements	Qualitative or indicators used	Detailed, accurate
9. Methods	Basket of tools	Standardized	18. Analysis	In the field and on the spot	At office

Source Theis and Grandy [92, p. 34]

Table 2.5 The comparison between PRA and RRA

Major issues	RRA	PRA
Period of major development	Late 1970s, 1980s	Late 1980s, 1990s
Major innovators based in	Universities	NGOs
Main users	Aid agencies Universities	NGOs, Government field organizations
Key resource earlier overlooked	Local people's knowledge	Local people's organizations
Main innovations	Methods	Behaviours
Predominant mode	Extractive-elicitive	Facilitating-participatory
Ideal objectives	Learning by outsiders	Empowerment by local people
Outcomes sought	Useful information, reports, plans, projects	Sustainable local action and institutions

Source Chambers [93]

societies and communities. RRA is the one of methods which deals with changing society and assesses vulnerability of environment. RRA is characterized by an applied, holistic, and flexible approach of progressive learning, conducted by multi-disciplinary teams which emphasizes community participation. RRA methods have been applied mainly in agricultural development, but now have widespread application in many different fields, for example, urban housing problems, health and medical geography and impact assessment of natural disasters [92].

Table 2.5 shows the differences between PRA and RRA. PRA and RRA share some of the same principles, such as direct learning from local people, offsetting biases, triangulating, seeking diversity and optimizing tradeoffs. One of the main differences between PRA and RRA is that RRA information is more easily elicited and extracted by outsiders, but in PRA it is more readily shared by local people [93].

The main differences between RRA and PRA are: in RRA the outsiders go to rural areas or case study areas, elicit and extract information from local people and then bring it back to analyze and process. The information collected is owned by the outsiders and usually not shared with the people from whom they obtained the information. On the other hand, in PRA, outsiders/professionals go to the rural/case study area in the same way but they facilitate rural people in collection, presentation and analysis of information by themselves. The information thus is owned by the local people but is often shared with the professionals/outsiders [123]. In other words, PRA empowers local people to assume an active role in analyzing their own living conditions, problems, and potentials in order to seek a change in their situation. These changes are supposed to be achieved by collective action and the local communities are invited to assume responsibility for implementing many, if not most of the actions.

PRA is a growing combination of approaches and methods that enable vulnerable people to share, enhance, and analyze their knowledge of life and conditions, to plan and act and to monitor and evaluate (http://participation.110mb.com/PCD/PRA_Training/pcdpra/How%20to%20carry%20out.pdf). The role of the outsider is that of a catalyst, a facilitator of processes within a community which is prepared to alter their situation.

PRA was first developed in India and Kenya during the 1980s (Chambers [110]); it has been mainly used by nongovernmental organizations (NGOs) working at the grass-roots level. However, the principles and many of the approaches and methods are increasingly being used by such organizations as The World Bank, UNDP, ILO, among others.

RRA is an extractive research methodology consisting of systematic, semi-structured activities conducted on-site by a multi-disciplinary team which enables quick and efficient acquiring of new information about rural life and rural resources.

RRA emerged in the late 1970s. The purpose of RRA is to quickly collect, analyze, and evaluate information on rural conditions and local knowledge. In most cases RRA is carried out by a small team of researchers or trained professionals in 1–3 days in a kind of workshop. The information is elicited and extracted in close cooperation with the local people. As the method developed, the research methods had to be adapted to the needs of local people. They especially had to meet the communication needs of people who could not read and/or write or people who were not used to communicating in scientific terms. Several tools like mapping, diagramming, weighting and ranking were developed and activated to collect information for decision makers. It is extremely important to develop and use locally understandable symbols to visualize the question so that the participants have no difficulty in understanding.

2.8 Conducting PRA Sessions in the Case Study Area

Two PRA sessions were conducted in order to assess V&A issues at community level in the case study area for this book. One was conducted in Sapdhari *Union* and the other in Noapara *Union*, Maijbari *mauza*. Sapdhari is *char* land area, very prone to river erosion. Maijbari is also an erosion prone area and at the same time is susceptible to severe sand deposition. Both these areas are remote; there is no connecting *pucca* (paved) road from Islampur *Sadar Upazila*.

Sapdhari is mainly *char* land, which means newly emerged alluvium and sand deposited in the middle of the river. It is two to three km from the main land, separated by the river Jamuna. The data collection team had to travel 2–2 1/2 h by small engine boat to reach the *char* land from the mainland. The only mode of transport is engine boat or manual boats which are locally called “*nau*” or “*nouka*”. As this is mainly alluvial sand and silt, onion, garlic, vegetables, chili, peanut, local variety of *aman* rice as well as some HYV *aman* rice are grown here. Irrigation is practiced in some areas but in most areas irrigation is not possible because of the nature of the soil. Farming land size is small and fragmented, as

Table 2.6 Participatory rapid appraisal (PRA) session 1

Participants particulars		
Number of persons	Age/s	Occupation
1	43	Teaching
10	36–68	Farming
1	40	Politics
3	40–62	Business
1	40	Agriculture Block Supervisor
2	40–55	*Union Parishad* Members
1	58	Present *Union Parishad* Chairman
1	56	Former *Union Parishad* Chairman

Place Shapdhari *Union* Parishad Chairman's temporary Office, located in Gothail Bazar, Islampur
Time 6–10 p.m.; *Date* 4/11/06

these farmers are mostly marginal and poor, so they own small pieces of land. *Khash jami* (newly emerged *char* land owned by government) is distributed among landless and poor farmers. Muscle power/political power/*matbar* sometimes plays a big role in the distribution of *khash jami* and thus many deserving people are being neglected or overlooked. While performing the survey work in *char* land, the author and his team gathered local knowledge, and got to know the local *matbar*, local chairmen (previous and present), school teachers and commissioners. They were asked to help the survey team to organize the PRA sessions. The existing chairman helped the team to choose a place for the session and helped with selection of participants. The author and his team did the final selection of participants with the help of the chairman. The participants were informed earlier of the time, place and purpose of the session. In this session, out of a total of 20 participants 50 % [10] were vulnerable farmers and 3 were businessmen, 2 were *Union parishad* members, and one each were teacher, politician, agricultural block supervisor, present and former *Union parishad* chairmen (Table 2.6). It was held in the temporary office of the *Union parishad* chairman in Gothail bazaar on the bank of the *Jamuna*. Refreshments, small remuneration and their travel costs were provided. The intensive session was 4 h in total from 6 p.m. to 10 p.m.

The second session was organized in Maijbari *mauza*. The total number of participants was 20 and again 50 % of them were farmers, 4 were businessmen, 3 local student political leaders, 2 teachers of local school and 1 agricultural block supervisor (Table 2.7). Team members hired a small engine boat to reach the study area, taking two and half hours to reach there from Gothail *bazaar*. During the survey work, the author and team members were familiarized with local farmers and people from other professions. The author chose knowledgeable people of different social levels and skilled farmers for the PRA session. The session was held in the residence of a local school teacher. The participants were aware of the time, place and purpose of the session beforehand. They were entertained by the team during this session and travel costs were paid for.

Table 2.7 Participatory rapid appraisal (PRA) session 2

Participants particulars		
Number of persons	Age/s	Occupation
2	33–55	Teaching
10	33–65	Farming
3	25–41	Politics
4	44–65	Business
1	40	Agriculture Block Supervisor

Place Maijbari, Noapara *Union*, Islampur
Time 10 a.m.–2 p.m.; *Date* 4/11/06

In both sessions, participants attended and answered the semi structured questions with much enthusiasm. As the sufferers of the flood events, they have first hand experience, very clear understanding of the calamity and its severity and practical knowledge of how to cope with the above mentioned EFEs. Even before the questions were asked, they gave brief overviews about each flood event, their nature, duration, frequency, peak, extent of damage done and how they reacted during and after the flood events.

The author adopted some concepts from the above mentioned general characteristics of PRA, and at the same time from the general characteristics of the two PRA sessions he conducted. These concepts are:

1. 20 respondents were considered for each session;
2. 50 % of them were farmers and the other 50 % were various professional people.
3. The answers were evaluated in a scale of 1–20 weighted value matrix.
4. In each session, 3 flood years, i.e. 1988, 1995 and 1998 were considered.
5. For each flood year, the respective V&A issues were weighted in a scale of weighted values;
6. Vulnerable issues were categorized as high, medium, low and very low;
7. Adaptation issues were also categorized as urgent, immediate and low in accordance with priority of need;
8. Degree of severity of each vulnerable issue was identified;
9. Similarly when the adaptation capability threshold was exceeded, some tactical interventions were identified and adopted;
10. These PRA sessions and the given evaluation process made an important methodological contribution for assessing V&A.

The number of respondents answering yes or no to one particular question was noted carefully in each session. With each question related to V&A issues they were asked to give a weighted value regarding severity and coping ability. For example, they were asked to measure the severity of each flood in terms of crop damage on a scale ranging 1–20. On the basis of their real world experience they came up with weighted values against each question which were unanimously accepted by all participants. Thus for each flood year two sets of weighted index value were obtained, one in each PRA session as shown in Figs. 6.2 and 6.4 thereby giving rise to six sets of weighted index data. This provides the opportunity to compare vulnerability and adaptation capacity of the marginal farmers against three recent extreme floods. The "agreed weighted value index" is neither a mean of the six scores (there were two sites/sessions and three flood years therefore six weighted numbers have been assessed in six rows) nor a mode. After the participants were asked to score each flood event separately, they were asked to give an overall score against each V and A issues irrespective of year.

The weighting matrix indices have been used in environmental impact assessment studies; though not so widely in V&A assessment in climate change literature. Weighting Scaling (ranking or rating) checklists can be used in such comparisons and evaluations [126]. Scaling refers to the use of algebraic scales for the impact of each alternative being evaluated on each identified environmental factor. Ranking checklists are where alternatives are ranked from best to worst in terms of their potential impact on identified environmental factors. Weighting ranking checklists involves importance, that is, weight assignments and the relative ranking of the alternatives from best to worse in terms of their impact on each environmental factor.

The weighting index is a complex scaled checklist; the weighting procedure was originally developed in 1972 in order to evaluate water resources development projects in Ohio in USA [127]. This technique is useful for comparing alternative development options but could miss impacts. It is seemingly a quantitative method but uses value judgments [128]. Weighting indexes have widely been used in hazard literature particularly in water resource evaluation projects, both in pre-project and post-project analyses. Through this technique the comparative evaluation between pre-project and post-project data can assess the overall advantages of water resources projects. For example, the Flood Action Plan (FAP 19 and FAP 3.1) (Environmental Impact Assessment Study) in Bangladesh has examined the environmental impact assessment through the weighted index method (e.g. [129]). In these studies, checklists have been identified; in accordance with the checklists, farmers responded about post-project impacts within a weighted index scale. By that means, after establishing embankments, the range of positive and negative changes recorded on these checklists were evaluated through a weighted index scale.

The weighting scaled checklist is one of the simplest and earliest methods in EIA. It indicates broad areas of concern and likely impacts, which is good for scoping and structuring the initial stages of an assessment. It is a criterion for evaluation which can be incorporated into the listing, usually in the form of ranking or ratings. The weight-scaled checklists indicate the relative significance of each impact and may indicate critical values such as the 'threshold of concern' for each factor [130].

The weighting index scale enables comparisons of different impacts (identified by an assessment), and it also facilitates these comparisons. This has encouraged the use of scaling, weighting, standardizing and aggregation of impacts to produce composite indices, which offer single, apparently objective, benchmarks

[128, 131]. Although the weighting index provides quantitative comparisons, in some cases it gives a false sense of scientific precision. In fact, it gives a representative environmental quality index. It has some disadvantages. Weighting (and some other transformations of data) may not be as objective as they seem. Often they are just 'value judgments of experts' and conceal the original raw data and their meaning. Undistorted qualitative data may be preferable to transformed quantitative data. Weighting should be applied only to interval and ratio-scale data. The evaluation procedure depends heavily on the weightings and impact scales assigned [132, p. 112]. The importance of weightings is determined by a panel of experts. It compares the relative importance of all impacts.

In this study, weighted matrix index values are measured in a scale of 1–20. This 1–20 scale is based on the response of 20 participants to specific semi structured questions. The scale (1–20) has been divided into 4 categories which are discussed in detail in the V&A assessment chapter.

2.9 Other Data/Information Collection Techniques

2.9.1 Literature Review

In order to identify the research gaps, a large amount of literature was reviewed. Bangladesh flood related research work conducted since 1950 was reviewed for this purpose. Works on adaptation to climate change, agriculture vulnerability to climate change and EFEs, weighted index and environmental impact assessment were extensively reviewed.

2.9.2 Group Discussion

Group discussions were held when some confusion arose regarding filling questionnaires. By that means any difficulty understanding any issue about V&A was solved instantly in the field.

2.9.2.1 Group Interviews and Interviews with Block Supervisors: Some Observations and Findings

Two other more formal structured group interviews were organized by the author. The first was with a group of farmers in Dhantala *mauza*, *in* Belgacha *Union* a long way from the site of the PRA sessions, and the second with the block supervisors. The first group interview included a few well-experienced old farmers who described their experience regarding coping with floods in the past and the sequencing of crops and types of crops that were grown at that time.

Interviews with block supervisors were held in *Upazila* agricultural office. Block supervisors are the representatives of the local agricultural office who work at field level and provide farmers with advice and assistance. They are responsible for collecting crop data in their respective areas. The author participated in a meeting where all block supervisors of that *Upazila* attended. It was focused on crop damage during flooding. For example, issues discussed included how many times farmers had tried to plant *aman,* both the local and high yielding varieties, as well as information on quantities of fertilizer and pesticides that are used on agricultural land during different cropping seasons. During the conversation the author found some discrepancy between his observations and the information provided by the block supervisors. Earlier farmers had mentioned to the author that block supervisors in general are very reluctant to do their duties. The author tried to get their records of crop damage information for their blocks. Although they said they have provided the local agricultural office with that information, they failed to show any copy of the paperwork.

At the community level, only these block supervisors work closely with farmers, this equips them with current knowledge of crop flood adaptation and the failure effects of autonomous crop adaptation. Information provided by the farmers (cost of agricultural input, cost of cultivation/land preparation, number of flood strikes, seedling cost, fertilizer cost, labouring cost, watering cost, pesticide cost) were cross checked with block supervisors. It was noted that information provided by the farmers was similar to that provided by the block supervisors regarding these issues. Block supervisors had made an important recommendation. They emphasized that in order to cope with multi peak floods, HYV flood resistant crop with short maturation time will prove invaluable.

The author also conducted an in-depth interview with Jahangir Alam, aged 35 years, from *mauza* Panchabahala, Village Panchabahala, *Upazila* Islampur. He is a marginal farmer who lost all his agricultural land due to river erosion in 1998. His observations helped the author to understand crop adjustment mechanisms and crop decision processes. His own experiences of the flooding were also very important in the author's data collection. For example, he mentioned that he had to sell his cow and personal belongings to buy food for his family and seeds for planting *Rabi.* He also mentioned that he did not get any return from cultivating *Gainja* in 1998. In his own words he described the flood events with their nature and severity which the author found very helpful in terms of understanding the recent and previous flood situations.

2.9.3 Media/Newspaper Information

News, editorials and post editorial on climate change and V&A from different newspapers such as the Daily Star, the New Nation, the Prothom Alo, the Jai Jai

Din, The Los Angeles Times, National Geographic, the New York Times, New Scientist and The New Age were consulted from time to time. Internet news regarding the GBM River Basin and the impact of climate change in this region was also considered.

2.9.4 Discussion with Professional People: Some Observations and Findings

Discussion with professional people was also used as a tool in this research, including policy makers at national level (agriculture expert, economist, geographer, environmentalist, and water resource experts) (Table 2.8). Late Dr S. M. H. Zaman, crop expert and former member of the Bangladesh Planning Commission was contacted as an agriculture expert in order to understand flood crop adjustment processes (described in Chap. 5). He gave some important hints about flood characteristics and community level crop adjustment processes. He agreed with the adjustment processes embraced by the farmers during these three major flood events as revealed by this study. He identified the flood crop adjustment differences between the 1970s and 1990s along with the likely cause of that.

As water resource and flood adjustment experts, late Professor M. Aminul Islam, former Vice Chancellor of the Open University and Professor K.B. Sajjadur Rasheed, former Professor of Geography and Environment, University of Dhaka, Bangladesh, were interviewed as main resource personnel. The structured questionnaire and identification of V&A issues were discussed with them. They agreed that it would be a methodological contribution to the research arena if V&A issues could be identified. In their opinion, vulnerable farmers' response to extreme flood had not previously been assessed in this way.

Dr A. Q. M. Mahbub, Professor and former President of Bangladesh Geographical Society was interviewed as a migration expert. He passed the opinion that the failure effect of autonomous adaptation is huge and as a consequence rural urban migration would rise alarmingly in Bangladesh.

Finally, the author discussed with Dr Q. K. Ahmad, former President of the Bangladesh Economic Association and IPCC lead author on sustainability, regarding economic consequences and its implication under climate change conditions on the Bangladesh economy in general.

2.9.5 Secondary Data

Some secondary data, both published and unpublished were considered. These data were used whenever needed. The resources used were as follows

Table 2.8 Key experts and issues highlighted

Name	Expertise	Subject	Issues highlighted
Dr S. M. H. Zaman former member of Bangladesh Planning Commission	Crop expert	Agriculture	Flood crop adjustment processes
Professor M. Aminul Islam, former VC of Open University	Flood adjustment expert	Geography and Environment	Assess V&A assessment
Professor K. B. Sajjadur Rasheed, former Professor of Geography and Environment, University of Dhaka	Water expert	Geography and Environment	Methodological contribution for assessing V&A issues
Dr A. Q. M. Mahbub, Professor and President of Bangladesh geographical society	Migration expert	Geography and Environment	Failure effect of autonomous adaptation is large and as a consequence rural urban migration would rise alarmingly in Bangladesh
Dr Q. K. Ahmad, President of Bangladesh Economic Association and IPCC lead author on sustainability	Climate change and Water expert	Economics and Environment	Economic analysis/impact and consequences and its implication under climate change conditions on agriculture in general

1. Small area atlas: *Mauzas* and *Mahallahs* of Jamalpur District, Bangladesh Bureau of Statistics.
2. BWDB: hydrology section-Hydrology data was collected.
3. Flood Forecast & Warning Centre, Motijheel, Dhaka, “Days when flood waters were above the danger level at the stations of Bahadurabath and Jamalpur” were collected.
4. Land and soil resources utilization manual, Islampur *Upazila*. Jamalpur (In Bengali) published by Ministry of Agriculture, Soil Resource Development Institute.

2.10 Recent Advancements in Vulnerability and Adaptation Assessment

Carter et al. [133, pp. 138–139] emphasized:

> Traditional knowledge of local communities represents an important, yet currently largely under-used resource for climate CCIAV (climate change impacts, adaptation and vulnerability) assessment. Empirical knowledge from past experience in dealing with climate-related natural disasters such as droughts and floods… can be particularly helpful in understanding the coping strategies and adaptive capacity of indigenous and other communities relying on oral traditions.

The author has developed a V&A assessment method where indigenous, empirical and traditional knowledge have been given immense importance. V&A issues from past experiences in response to EFEs have been identified and weighted through PRA sessions where vulnerable farmers' opinions were carefully considered. Farmers' empirical knowledge helped understanding of the V&A strategies and adaptive capacity.

Downing and Patwardhan [134] stated that vulnerability is highly dependent on context and scale and care should be taken to clearly describe its derivation and meaning. Patt et al. [135] also addressed the uncertainties inherent in vulnerability assessment. Ionescu et al. [136] and Metzger and Schroter [137] proposed formal methods of vulnerability assessment but those are very preliminary. In order to assess response or potential response of a system to climate variability, the methods and framework must deal with the determinants of adaptive capacity [138]. Some quantitative studies use indicators related to adaptive capacity while other studies consider indicators that promote or constrain adaptive capacity [139–141]. Community based approaches which identify adaptive capacity, also provides insight into the underlying causes and structures that shape vulnerability.

Carter et al. [133] describe several approaches to assessing adaptation, although they came to the conclusion that establishing a general methodology for adaptation assessment is very difficult. Some approaches identified, are:

- The scenario based approach
- Normative policy framework
- Employing models of specific hypothesized components of adaptive capacity
- Economic modeling
- Scenario and technology assessment
- Risk assessment

While describing key conclusions and future directions, the 2007 IPCC report describes a set of methodological, technical and information gaps. One of the gaps is a collection of empirical knowledge from past experience. It has been emphasized that experience gained in dealing with natural disasters, using both modern methods and empirical knowledge, contributes to understanding the adaptive capacity of vulnerable communities and its critical thresholds. This study has considered vulnerable farmers' empirical knowledge and has identified and categorized these factors accordingly.

2.11 Ethical Issues

The study was conducted following University regulations. Before the interview began, each of the respondents was informed of the objectives of the study and why it has been carried on in their locality. They were also briefed about the confidential nature of the study and were assured that the information collected will only be used for this research purpose. The respondent enjoyed the right to decide whether he would participate or not and also was free to withdraw at any stage of the interviewing process.

The consent form used for this purpose is attached in Appendix II.

2.12 Data Analysis and Data Presentation

After returning from the field in Bangladesh, coding and entry of data from the questionnaire survey were completed. The coded data were entered into an Excel spreadsheet with each row representing a household. In total, data for 140 households were entered and information relating to particular individuals in the household was included in sequence as the spreadsheet was developed. This system of data coding was very useful for examining household characteristics but it was somewhat problematic when it came to examining characteristics of individuals within the household or responses to questions that allowed for multiple answers.

In addition to the surveyed household data, the author also collected a significant amount of secondary information from different government offices. This was not always easy. Administrative procedures, lack of attention to requests and some quite obvious deliberate hiding of information made it difficult to get some critical data. For example, the author had great difficulty getting hydrological data. There were many official processes that needed to be followed in order to get approval to take information overseas.

The author produced a relevant and required dummy table, and in accordance with the excel spreadsheet data he categorized the information in different groups. Sometimes the author used the pivot table analysis technique. The pivot table analysis comprises functions included in Microsoft Excel under the heading ‘data’. The author has validated his Excel spreadsheet data in order to get pivot table results.

2.13 Research Limitation

Small sampling size is a limitation of this research. The seven most vulnerable *Union*s were selected for questionnaire survey and from each *Union* the two most vulnerable *mauzas* were chosen for this purpose. Ten households from each *mauza* were surveyed and every alternate household was chosen as a sample. Time limitations and budgetary constraints were two important limiting factors in considering the sample size. Most importantly the remote location of the case study area made it physically impossible to carry on further. Because of the remote location, the study became increasingly time consuming and expensive.

PRA sessions were very intensive and they lasted for about 4 h. Some literature describes PRA sessions of 1–3 day, but due to the team's previous experience in the region the sessions were efficiently and expeditiously conducted. The author was satisfied with the enthusiasm of the participants and the spontaneous outcome of the sessions.

2.14 Summary

The research techniques used in this study have been described in this methodology chapter. The main approach is multi-method research (mixed research methodology) which contains some research techniques: field survey questionnaire, group discussions, in-depth case study, field observation, two PRAs and some secondary data collection. It is also a mixed method where mainly qualitative data have been transformed to quantitative data through these research techniques as it is mainly a "human response" study. Through these research techniques some research issues were accumulated and operationalized in accordance with the research objectives, which will be described in the following chapters. The issues are:

1. Socioeconomic and environmental assessment through 140 household questionnaire surveys in the case study area (Chap. 4).
2. Comparison of flood crop adjustment in response to three EFEs in 1988, 1995 and 1998 through focus group discussion, group interview, in depth surveys and professional judgment (Chap. 5).
3. Methodological contribution for assessing V&A issues through PRAs and professional judgment (Chap. 6).
4. Assessment of failure effects of autonomous crop adaptation, that is, economic analysis of damage caused by the floods through 140 household questionnaire surveys (Chap. 7).

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Chapter 3
Floods in Bangladesh: Nature, History, Research, Causes and Types

Abstract This chapter reviews recent literature on flood research in Bangladesh: characteristics of riverine flood including Bangladesh's national water policy and the major components, activities and their importance and criticism of the Flood Action Plan, and causes and types of floods. The chapter concludes that community based prioritise vulnerability and adaptation issues need to be immediately addressed, and structural and non-structural flood management methods, which the Government is emphasising in recent policy, need to be implemented together in order to reduce future flood vulnerability under the probable climate change regimes.

3.1 Introduction

The purpose of this chapter is to provide an overview of the major findings of flood hazard history and research conducted so far in Bangladesh. In the light of the existing literature on flood history and research, this chapter outlines a general description of flood hazard characteristics, history and research trends as well as the causes of floods and types of floods. After reviewing existing literature from 1980 to 2007, the chapter identifies flood research gaps, which have been addressed in the subsequent chapters in this book, and suggests some directions about future flood research in Bangladesh.

It is found that none of the studies have focused on the failure effects of autonomous flood-crop adjustment, in other words the distribution pattern of household damages due to EFEs, nor the methodological contribution for assessing V&A in response to EFEs in Bangladesh. Environmental perception research on flood-plain areas has largely been neglected [1, p. 235], though FAP (Flood Action Plan) (especially FAP 19) explored some flood perception related studies which focus on both structural and non-structural measures in order to reduce flood vulnerability.

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3.2 Characteristics of Floods in Bangladesh

Flooding is a recurrent natural phenomenon occurring every year in Bangladesh. Destructive floods are one of the main barriers for economic development and planning in Bangladesh; in other words extreme floods, which appear frequently, are one of the most serious handicaps in this riverine country. Normal floods are beneficial for farmers and agriculture. Flooding usually commences in the beginning of the month of June, lasts until October to mid November and inundates about one-third of the area of Bangladesh. Farmers usually benefit from this normal annual flood event. It is called *borsha* which helps farmers to cultivate their farming lands within the flood waters, and the *aman* crops which need flood water in order to grow normally. Flooding is thus a productive resource for watering and fertilizing the agricultural lands.

On the other hand the catastrophic floods bring large scale destruction of agricultural lands, damage property and crops, homesteads and infrastructure, and even cause loss of life. They also disrupt economic activities and endangers the lives of people and their domestic animals and plants. This is called *bonna* which means it brings havoc and disaster. Sometimes, exceptionally severe floods, known as '*plabon*' occur and devastate the livelihoods of people and cause havoc to the national economy [2]. These floods are generally river-induced and often triggered by monsoon rainfall throughout the GBM region. Moreover, nearly 49,000 sq. km. of Bangladesh are influenced by storm surges associated with tropical cyclones of the Bay of Bengal with catastrophic loss of life

Some characteristics of floods in Bangladesh can be identified. These are:

1. 20–30 % of the land is inundated annually during the monsoon, even in a year of normal precipitation.
2. The 1988 flood inundated 61 % of the total land, and the 1998 flood inundated almost 68 % of the total land.
3. During April–May, the normal sequence of floods in Bangladesh starts with flash floods in the northern and eastern hills; in flash flood, rivers rise sharply and recess rapidly, usually within a few days or hours.
4. Bangladesh is on one of the largest deltas in the world. The delta is characterized by a flat terrain of alluvial soil criss-crossed by an intricate system of over 230 rivers, canals and streams [3]. The total drainage area of the GBM network is 1.75 million sq. km spreading over five countries: India (63 % catchment of the GBM Basin), China (19 %), Nepal (8 %), Bhutan (3 %) and Bangladesh (7 %). Out of that only 7 % falls within Bangladesh; but the area dominates the socio-economic life of the country as it constitutes 84 % of its land and is occupied by 93 % of its population [4, 5].
5. Bangladesh has to drain the runoff of an area which is 12 times larger than its size.
6. The amount of water that passes over the country would be able to create a pool having a depth of about 9 m over the country's entire geographical area [2].

7. Annually, some 1,360,000 million m^3 of water discharge in Bangladesh originate outside the country. Between 80 and 85 % of this discharge is generated during June–October.

Bangladesh consists mainly of low and flat land, except for the hilly regions in the southeast and northeast. The entire country is crisscrossed by GBM (Ganges–Brahmaputra–Meghna) river networks with their numerous distributaries and tributaries. Being fluvio-deltaic in origin, the relief in the major part of the country is low, varying between 1 and 2 m. Rasheed [5] stated "*Nearly 50 % of the country has an elevation of less than 10 m above sea level. Only in the southeastern parts of the country does the altitude exceed 300 m. At least 20 % of the land consists of low-lying tidal plains, with elevations of less than 3 m above sea level.*" The GBM River Basins have very low gradients—6–10 cm/km for the Brahmaputra, 4–5 cm/km for the Ganges and 3 cm/km for the Meghna (Rashid and Pramanik [6]). On the basis of age and process of formation, there are three major physiographic units which have been recognized in Bangladesh: Hills, Terraces and Floodplains.

Bangladeshi flood plains cover 80 % of the country which is formed by the deposition of alluvium by the network of GBM rivers. The alluvial plain slopes gradually southeastwards from an elevation of about 90 m at Tetulia in the far northwest to the coastal plain in the south of less than 3 m elevation [5]. The flood plain is essentially lowland. FAO [7] has defined 30 agro-ecological regions in Bangladesh ([8, 9]; Fig. 3.1). In this study Bangladesh has been divided into 20 physiographic units, of which 17 were in the floodplains. Rasheed [5] has divided the floodplain into nine physiographic subunits which were based on FAO's classification used in the Agro Ecological Zone (AEZ) study; the subunits are: Old Himalayan Piedmont Plain, Teesta Floodplain, Brahmaputra–Jamuna Floodplain, Ganges Floodplain, Meghna Floodplain, Surma–Kusiyara Floodplain, Ganges Tidal Floodplain, Meghna Estuarine Floodplain, Chittagong Coastal Plain. It is noted that the case study area Islampur is under the category of Brahmaputra–Jamuna floodplain. General physiographic units in Bangladesh and the location of Islampur case study area is shown in Fig. 3.2.

3.3 Flood History and Research in Bangladesh

Bangladesh has been experiencing floods throughout history. The earliest meteorological report on floods in this region was prepared by a well known meteorologist and statistician of that time, Professor Mahalanabis in 1927, which included a list of floods occurring between 1870 and 1922 [5, 10]. There are no authentic records of floods for the period of 1923–1953. Since 1954, flood events in this region have been relatively well recorded. Floods which inundate 33 % or more of the country are identified as catastrophic, and in the case of 25–33 % inundation, floods are called severe [5]. Severe and catastrophic floods affecting

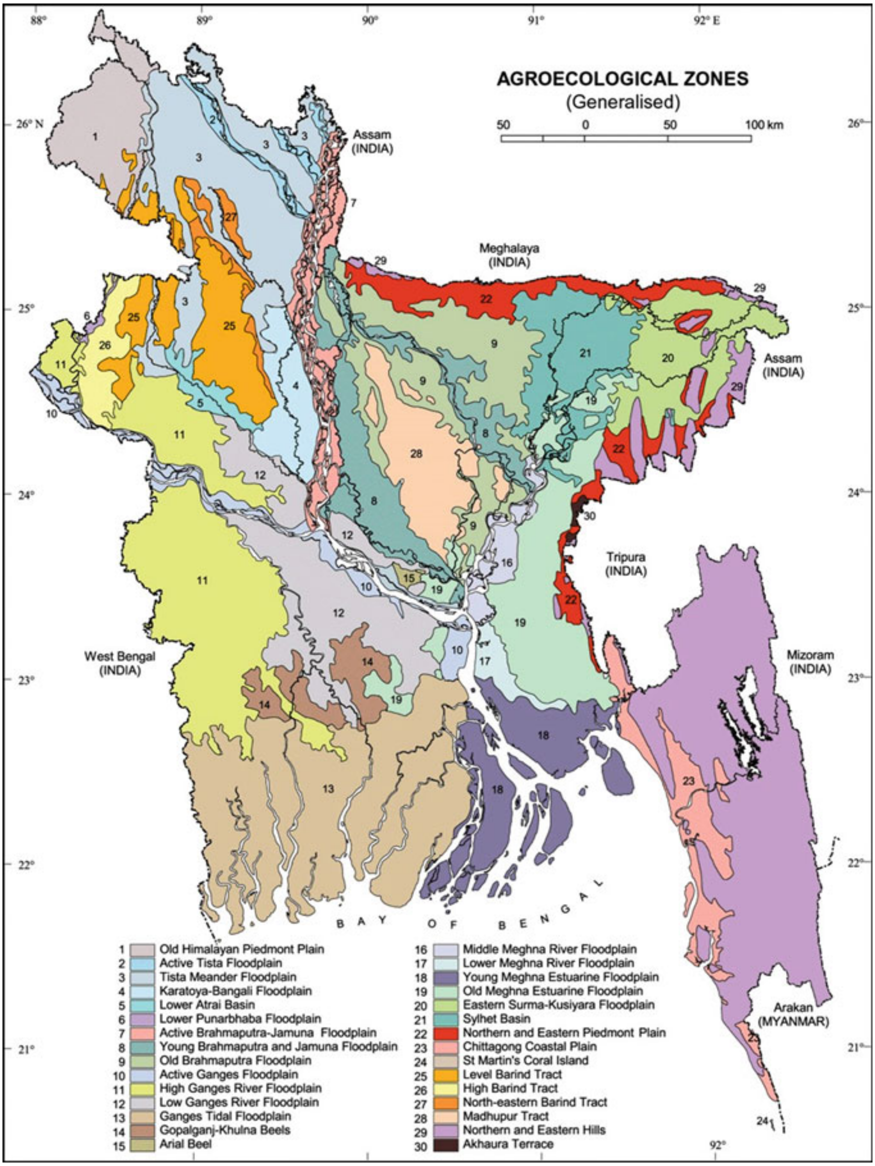

Fig. 3.1 Agro-ecological regions. *Source*http://www.banglapedia.org/httpdocs/HT/A_0079.HTM

this region during the period 1954–2007 and the percentage of area inundated by each flood event are shown in Fig. 3.3.

Since the mid-1960s, Bangladesh has been working on water resource planning. Initially the focus was on protecting crop lands from the severity of floods and thus

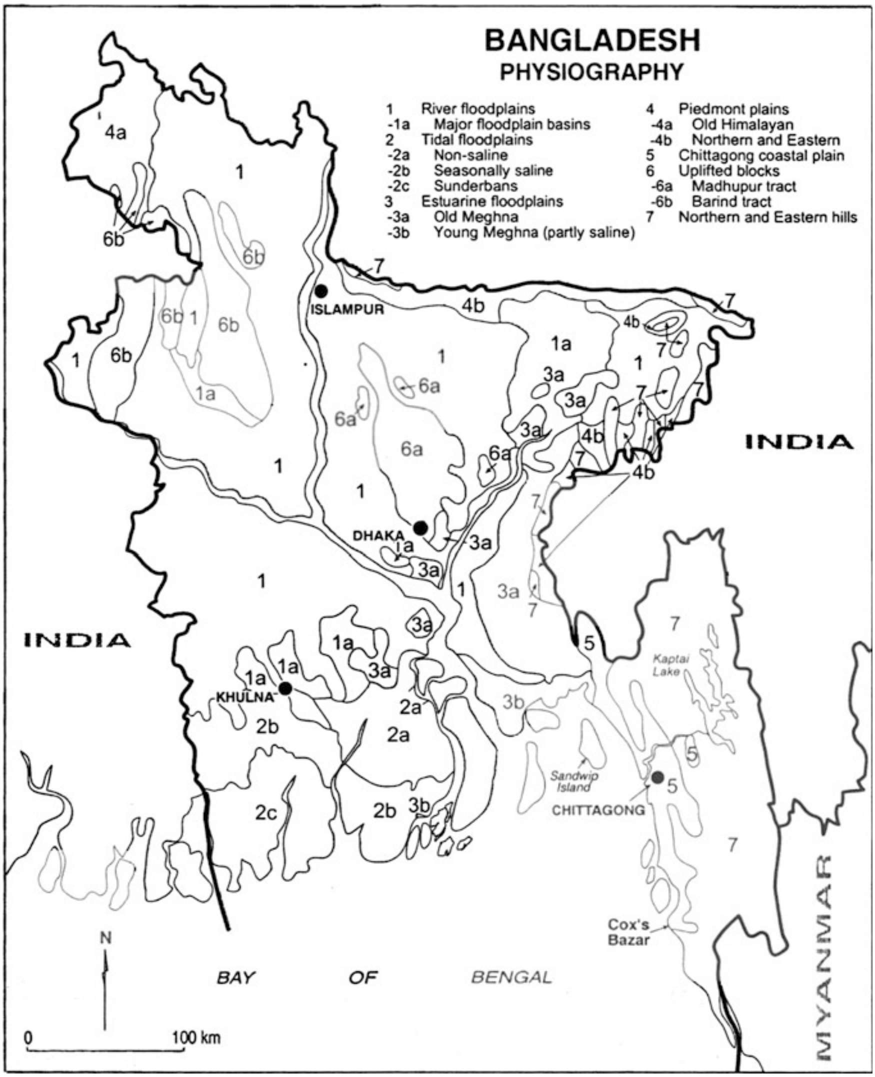

Fig. 3.2 Bangladesh physiographic units and the location of case study area (Islampur). *Source* [67]

prevent food shortage in the country. Since the mid 1990s the national outlook has changed towards a more holistic approach of flood management and integrated water resource management (IWRM). After the devastating floods in 1954 and 1955 in former East Pakistan (currently Bangladesh), global attention was focused on the need for and importance of flood management strategies in this region. As a consequence the "Krug mission" was formed to review the situation at the request of the government and with help from UNDP. The expert group of the mission

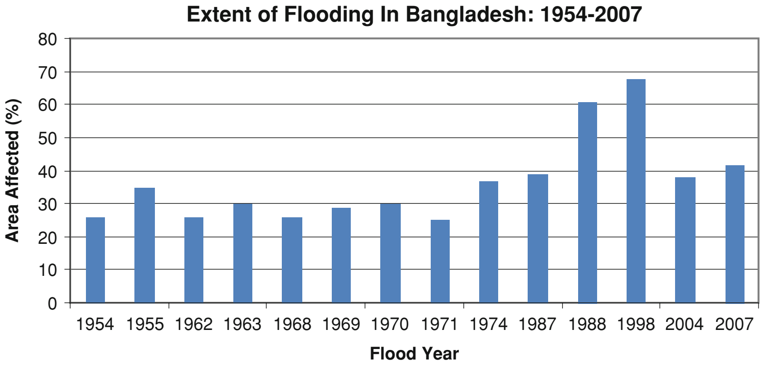

Fig. 3.3 Extent of flooding in Bangladesh: 1954–2007. *Source* [5, 68, 69]

recommended the creation of an autonomous organization to deal with flood management, and thus the East Pakistan Water and Power Development Authority was established in 1959. Accordingly a master plan was prepared by the US consulting firm IECO in 1964 with the primary focus on flood control. The master plan envisaged a set of 58 large scale projects, targeting flood protection and drainage of most of the country's flood prone area together with surface water irrigation by diverting water from the major rivers [11]. The master plan was actually a collection of individual projects rather than an integrated water resource development plan but it essentially formed the basis of all water sectors planning in Bangladesh for the next decade or so.

The international bank for reconstruction and development (IBRD) completed a 9 volume land and water sector study in 1972, in order to provide a basis for development programs in the water and agriculture sectors. The report recognized the potential problems associated with large scale flood control, drainage and irrigation schemes which were recommended in the 1964 master plan. However, this study did not entirely rule out the need for large scale projects in the long run and it was never endorsed by the Government or Bangladesh Water Development Board (BWDB) [11]. The Government, with assistance from the World Bank and UNDP, initiated a project to formulate the National Water Plan (NWP) in 1983. The Master Plan Organization (MPO), a separate organization, was set up by the Ministry of Irrigation, Water Resources and Flood Control to prepare the NWP for water resources development up to 2005. The NWP phase 1 was completed in 1986 with recommendations for emphasis on small scale private irrigation development rather than public sector projects for flood control and drainage. An updated version of the NWP completed as phase 2 in 1991, emphasized large scale flood control and drainage and irrigation (FCDI) projects and encouraged deep tube well schemes for irrigation. It also proposed full development of the main rivers by building barrages on the Ganges and the Brahmaputra [12]. Both MPO phase 1 and 2 were mostly not accepted by the Government, as inadequate attention was paid to surface water resources and non-agricultural water needs, leading to the subsequent launching of the Flood Action Plan (FAP).

3.3.1 Flood Action Plan

The severe flood in 1987 and the catastrophic one in 1988, revived concerns among the Government policy makers and major aid donors to seek measures for lasting solutions to the country's recurrent flood problems. As a result the flood action plan (FAP) was formulated by the International Donor Agencies in collaboration with the Bangladesh Government. The World Bank reviewed the findings from various studies and finalized a FAP in November 1989, comprising 26 components as an initial stage (1990–1995) in the development of a long term comprehensive system of flood control and drainage works in Bangladesh. A separate organization, the Flood Plan Coordination Organization, was established by the Government to coordinate the activities of the FAP. Eleven main components of the FAP covered four categories of study groups [5], namely,

1. Rehabilitation of present flood embankments,
2. Regional flood management planning,
3. Urban flood protection,
4. Flood warning and preparedness.

Fifteen other components were designed to provide the following types of studies: (1) reviews of past experience with floods and flood management projects, (2) environmental and fisheries impact assessment, (3) mapping support, (4) pilot projects with new concepts, (5) hydrological investigations, (6) assessment of institutional needs.

The most significant benefit from FAP implementation was the huge amount of new technical and socio-economic information, produced under different components of FAP. The large scale survey findings and database are a valuable asset for future planning in the water development sector of Bangladesh. Another important achievement was the preparation of a series of planning guidelines for

1. Project assessment,
2. Environmental impact assessment,
3. Social impact assessment,
4. People's participation [5].

The EIA prepared by the FAP was officially adopted by the Government and made mandatory for all future projects in the water sector which might have implications for environmental impact [5]. The FAP became a topic of public debate from the very beginning and any suggestion for structural measures for flood management met with severe criticisms and immense concerns. The conflict between the FAP authors and its critics was unfortunate because many engineers involved in planning were mostly absorbed in technical aspects, with little concern for social and environmental aspects, while the critics were overly preoccupied with the social and environmental aspects in a subjective and biased manner, and were least concerned and knowledgeable about economic benefits and technical aspects [5]. The major criticisms are [5]:

1. Technical feasibility of embankments: while there is no denying the effectiveness of a device like protective embankments and training of the reaches against flooding, what should be of particular concern is the cost, including the long-term cost not initially foreseen [1]. Embankments could raise the flood level outside the embankment and drainage from the land would be jeopardized.
2. Fisheries: embankments would prevent fish spawning and migration, diminishing fish production.
3. Agriculture: Embankments would prevent the supply of fertile silt to the agricultural lands.
4. Wetlands and biodiversity: general shrinkage of wetlands and loss of biodiversity.
5. Land acquisition and its consequences: would displace people, fisher and boat operators could lose employment.
6. Institutional capacities: suspicion of the strength and ability of BWDB as the implementing authority of the FAP.

The FAP management finally published the Bangladesh water and flood management study (BWFMS) in 1995 [13] and completed its program. The BWFMS was significant for identifying social, economic and environmental constraints of flood management and reviewing the options for more comprehensive development of water resources of Bangladesh. The FPCO (Flood Plan Coordination Organization) ceased to operate after the completion of FAP and from January 1996 all activities related to water planning and management came under the jurisdiction of the water resource planning organization (WARPO).

3.3.2 National Water Policy

Work on the National Water Policy was started in March 1997, approved by the Government in December 1998 and the national water policy (NWP) was published in January 1999. The goal of the NWP is "*to ensure progress towards fulfilling national goals of economic development, poverty alleviation, food security, public health and safety, a decent standard of living for the people and protection of the natural environment*" [14; cited in 5, p. 48]. The NWP defines six broad objectives [5]:

1. To address the issues related to harnessing and development of all forms of surface water and ground water and management of these resources in an efficient and equitable manner.
2. To ensure the availability of water to all elements of society.
3. To accelerate the development of sustainable public and private water delivery systems with appropriate legal and financial measures and incentives including delineation of water rights and water pricing.
4. To bring institutional changes to help decentralize the management of water resources.
5. To develop a legal and regulatory environment that will help the process of decentralization.
6. To develop a state of knowledge and capability that will enable the country to design future water resources management plans with economic efficiency, gender equity, social justice and environmental awareness [5].

NWP emphasized that management of water resources requires good co-ordination of existing institutions and to some extent reform and creation of new community based institutions. It was expected to provide guidance to all agencies and institutions related to the water sector in ensuring the achievement of the specific objectives of the policy.

3.3.2.1 Flood Management Methods

Flood management methods are techniques to avoid, prevent, minimize or reduce the impacts of flood disasters. They can be broadly divided into two groups: structural methods and non-structural methods. Structural methods include embankments, drainage and channel improvement and river training. Non structural methods are flood forecasting and warning, flood proofing, flood preparedness and flood plain zoning.

3.3.3 Flood Research in Bangladesh

There is no extensive and elaborate study related to agricultural adjustments in response to EFEs in Bangladesh though Brammer [8, 9, 15–17], Paul [18, 19] and Islam's [1, 20] literature on agricultural adjustments to flooding have focused on environmental perception associated with agricultural adjustments. Moreover there are large literature gaps in household flood damage data particularly associated with crop damage data. Some studies [21–23] mentioned crop damage data though these are mostly arbitrary and have not been systematically collected. With a few exceptions, flood research has been mainly limited to appraisals or evaluation studies in the form of reports which again focus mainly on agricultural loss. The failure effects of autonomous crop adaptation on marginal farmers' households have not been studied in current and past literature related to flood and agriculture in Bangladesh.

Islam [20] presented a preliminary appraisal of agricultural adjustment to floods in three villages of Bangladesh. Agricultural adjustments evolved over the ages. Agricultural practices, particularly the cropping patterns, had adapted to the characteristics of flooding in general.

Sen [24], in his well-known book entitled 'Poverty and Famine—an Essay on Entitlements and Deprivation' argued that 'lack of entitlements to food are due to loss of employment associated with lack of purchasing power, not the food shortage' and was the main cause of famine which followed the devastating 1974 flood [25]. It can be argued that the losses of employment and lack of purchasing power were indirect effects caused partly by the devastating flood in that year.

Paul [18] studied the post-flood impact on agriculture and adjustment processes and he concluded that normal floods are not harmful; they are rather beneficial to agricultural lands. It is when the floods are extreme that farmers fail to adjust and losses occur. He also mentioned that in cases of abnormal floods, the respondents practiced several adjustment techniques to reduce damages.

Montgomery [26] examined crop losses due to floods by analyzing deviations from trends. Murshid [27] studied the relative role of weather hazards and technology in affecting the instability of food grain output and concluded that weather related factors were the main determinants of agricultural output in Bangladesh.

HIDD/ESCAP conducted a study in 1988 which assessed the distributional impact of flood damage and reached the conclusion that the poor are more vulnerable to floods; the extent of distress is 2.5 times higher among the poor than in wealthier groups.

Haque [28] surveyed 547 randomly selected households in Jamuna floodplain in Bangladesh. The study examined characteristics of human adjustment strategies to cope with river bank erosion among inhabitants of Jamuna floodplain of Bangladesh. He concluded that the strategies taken at the community level fall in the preventative category while at the individual level they are more of corrective type.

Zaman [29] explained human adjustments to riverbank erosion hazards in the Brahmaputra–Jamuna floodplain of Bangladesh. His paper suggested that a unified approach integrating perceptual and behavioral variables with socio-political and structural factors is essential to a holistic understanding of the problem of adjustment.

Islam [30] mentioned that the relationship between cropping practices and flooding of land in particular accounts for the most part for the complex land use pattern that has evolved so far in Bangladesh. The agricultural decision making process is essentially complicated owing to differences in soils, flood incidences and cultural practices. He emphasized that further study of relations between the hydrologic events and the human use systems in the floodplain areas is necessary as a means of improving the effectiveness of development and protection programs.

Thompson [31] reviewed existing appraisal and evaluation methods and recommended some improvements to these, particularly in relation to flood control agricultural projects in Bangladesh. The study also recommended that standard databases be developed for improvement of project appraisals and understanding the benefits and limitations of flood mitigation choices of Bangladesh.

Brammer [15] reviewed the geographical background of the 1987 and 1988 floods and argued that the 1987 flood was predominantly a rainwater flood, caused by exceptionally heavy monsoon rainfall over the northern part of the country, whereas the 1988 flood was a river flood, caused by heavy monsoon rainfall over a wider area of GBM river catchments. In both years, breaching or cutting embankments aggravated flooding.

Brammer [16] reported that a UNDP funded flood policy study recommended GBM rivers would be embanked to provide controlled flooding in adjoining floodplain areas. As alternatives to embankments, the USAID funded team included upstream water storage in the Himalayas, basin storage on the floodplains, and draw-down of ground water beneath flood plains to absorb excess monsoon rainfall and run off. Brammer argued that there is no evidence that environmental degradation in the Himalayas or a greenhouse induced rise in sea-level aggravated floods in Bangladesh.

Khan [32] reported the impacts and severity of the 1987 and 1988 floods on the rural livelihood of two flood-prone villages, one in Jawar village and other in South Chamuria village, situated within the central region of Bangladesh. He found that in 1988, 71.43 % of households in Jawar village experienced 76–100 % of damage to *aman* rice. Similarly in South Chamuria village, 82.02 % households experienced 76–100 % *aman* crop damage.

Hossain [33] analyzed fluctuations from estimated trends in food grain production at the regional and national levels to explain the production instability caused by natural hazards.

Brammer and Khan [34], in their Bangladesh country study report, published by ADB, described four aspects: disaster context, risk assessment, disaster management and international assistance. In the vulnerability analysis section they estimated direct losses due to 1988 flooding as $1,300 million. This was an arbitrary estimate, and has only indicative value. In this report vulnerability issues have not been properly addressed, rather it is mainly based on a general description of flooding and hazards.

Pearce [35] contended that flooding in Bangladesh is a beneficiary agent for agricultural lands, because the flood waters usually renew the soil. As a consequence, during the 1980s, crop yields rose fastest on areas most prone to flooding. He also emphasized that both structural and non-structural measures are needed in order to prevent flood losses in Bangladesh.

Zaman and Wiest [36] discussed population displacement due to river bank erosion; they emphasized that the *char* land resettlement plan is a complex task and due to the changing nature of the riverine system, probably a continuous process. They argued that public policies should be developed both for short-term and long-term assistance of the displaced. The local *Upazila* Relief and Rehabilitation Office in the erosion prone areas should be better equipped to provide quickly the necessary services, skills, and logistics to cope with dislocation. They also emphasized that it is necessary to develop comprehensive *char* land policies for Bangladesh.

Paul and Rasid [21] found that the average loss of rice production resulting from flooding in Bangladesh was approximately 4 % of the total country's rice production. The magnitude of loss of agricultural production alone does not justify some of the proposed flood control measures. They also suggested that district-level patterns of crop damage may provide guidelines for planning infrastructural facilities for flood control.

Haque [37] proposed a sustainable floodplain development plan for Bangladesh. The paper concerned two broad areas of public policies regarding flood problems, namely, a holistic approach—unlike the 'structural' strategy—to human aspects of water resource management, and a sustainable floodplain development plan that will ensure benefits to its users. In his view, the current emphasis of the Bangladesh flood policies has been changed from flood prevention to flood adaptation. He argued that flood issues must be addressed both from sustainability and long-term development perspectives.

Rashid and Pramanik [38, 39] presented the methods and results of visual interpretation of satellite imagery for estimating the areal extent of the 1988 flood in Bangladesh. The satellite imagery showed that the 1988 flood inundated 31–42 % of the land, which differed from the Government of Bangladesh's statistic on inundation area (57 % of Bangladesh). An alternative method of mapping flood-affected areas by using newspaper—interpreted data was attempted, but the authors said the method has limited value because of reporting bias.

Cobb [40] drew a general picture of past floods and cyclones in Bangladesh and how villagers of Nishantapur adapted to the flood waters, saying 'Rivers re-plenish, but they also re-sew the patchwork of paddies, villages, and roads—farmers must adapt'.

Khalequzzaman [41] discussed recent floods in Bangladesh and their possible causes and solutions. He focused on change in the base level of rivers due to local sea-level rise and subsidence as possible contributors to recent floods together with inadequate sediment accumulation on flood plains, a possible increase in the watershed area due to seismic and neotectonic activities in the region, river bed aggradations due to siltation and damming of rivers, soil erosion due to unwise tilling practices, deforestation in the upstream region, and excessive development and population growth. He concluded that without regional cooperation among the co-riparian nations, any major inter-basin flood control measure is considered to be almost impossible. He also examined measures to reduce the severity of floods in this study.

A study by Asaduzzaman [42] found that a potential rise in rainfall is expected to increase surface run-off causing severe flooding in the future. They concluded that sea-level rise would be less than expected but about 11 % of the country and 5 % of the present population would be under threat of inundation and loss of land if a 45 cm sea-level rise occurs by the year 2070.

In 1995, Paul reported a study on farmers' level of awareness and their responses to and possible positive and negative impacts of the proposed embankment projects as outlined by FAP. The data collected from two rural areas of Bangladesh showed that the respondents overwhelmingly supported the embankment projects of the FAP and that they were also aware of both positive and negative impacts of the proposed embankment construction.

Rasid and Mallik in [43] surveyed 23 villages in five major floodplains in Bangladesh and found that irrespective of significant spatial variations in preferences for specific ranges of flood levels, an overwhelming majority of respondents preferred regulated levels that coincided with the overall range of the normal flood regimes, to which different varieties of monsoon season rice crops were adjusted.

Thomson and Sultana [44] found that there is little evidence that flood protection has stabilized the economic condition of households. In four out of five projects studied in detail, flood losses were higher in the 1988 flood inside the project areas compared with unprotected control areas. He also noted that embankment failure is a serious hazard, although embankments also act as refuges in peak floods.

Paul [45] reviewed overall flood research in Bangladesh and suggested that research into the impact of flooding on human settlement and other relevant aspects is much less developed in Bangladesh than the body of literature focusing on human adjustment to flood hazard.

Baqee [46] primarily studied the ability of *char* land people to cope with floods and erosion in *char lands* in Bangladesh. He had two case study samples, *Char* Wari and *Char* Hatighata and recommended that some simple changes in infrastructure (low cost columns/plastic poles to replace bamboo poles) will go a long way in softening the full brunt of flood havoc.

In a study in 1999, Ninno and Roy assessed the impact of flood on food security and labour markets in rural areas. The study concluded that as a result of flooding, economic activity slowed down but did not come to a complete halt. It drew the conclusion that the impact of floods is most severe on those who depend on agricultural activities for a living; at the same time floods reduce the access of households to food.

Islam [47] carried out another rapid appraisal on *aman* crop damage due to the 1998 floods and concluded that damage by floods has widened the food gap from 2 million metric tons to over 4 million metric tons.

The study by Chowdhury, Islam and Bhattacharya in 1999 was a rapid economic appraisal which carried out a national estimate of flood loss to the economy.

Mirza et al. [48] recommended six policy level implications for the Government agencies of the GBM River Basin countries. In the fifth point he suggested that flood damage adjustment research should receive stronger support at the Government level.

Islam [49] showed that the open approach to flood control is superior to the cordon approach, which involves building embankments and roads. He criticized the cordon approach to flood control in Bangladesh which has been pursued in Bangladesh for several decades and argued for the open approach. The main components of the open approach are: re-excavation of river beds and other surface water bodies, minimization of obstruction on floodplains, increasing the elevation of rural and urban dwellings, restoration of waterways, and promotion of rural settlement consolidation around permanent flood shelters.

Ahmad and Ahmed [50] found that the losses of lives and assets could be significantly minimized by implementing non-structural measures including the improvement of flood forecasting and warning systems. The existing flood forecasting capacity of Bangladesh could be more effective if real time data could be acquired from upstream areas within the GBM catchment where runoff is generated. They emphasized effective regional cooperation towards managing floods in Bangladesh.

Benson and Clay [51] documented case studies on Bangladesh, Dominica and Malawi, and assessed how natural disasters affect the financial system and how the financial institutions, both public and private cope with that.

Dorosh et al. [52] analyzed the impact of the 1998 floods and focused on comprehensive food security in Bangladesh.

Younus et al. [53] (**Appendix iii**) described autonomous adjustment to major flooding in Bangladesh and investigated three kinds of adjustment—routine, tactical and in-built—in the context of normal floods as well as the devastating flood in 1998. The article argued that the focus on farmers' adjustments will continue to provide an invaluable insight into how robust flood mitigation strategies could be successfully developed to anticipate future events.

Khandker [54] stated that the 1998 flood reduced both consumption and assets, and forced many households to adapt some coping mechanisms to mitigate the adverse effects. Consequently flooding increases households' vulnerability to poverty.

Younus et al. [55–57] (**Appendix iv**) observed that by the use of autonomous adjustments Bangladeshi farmers, when faced with floods, are very resilient, and they can cope with a wide range of flood events. However the multi-peak 1998 flood exceeded the capacity for these adjustments during the peak season for growing and harvesting wet rice.

Ali [58] examined the nature and causes of the 2004 sudden flood that affected the moribund delta lands in the dry and drought prone southwestern region of Bangladesh. He interviewed 453 flood victim families and found that this flood caused severe damage to the standing crops, fish ponds, permanent trees and homesteads and deterioration of human health and sanitation conditions. He mentioned high rainfall, unusual movement of a low pressure system into the affected area, cloudy weather and low evaporation, siltation of the regional river bed and rolling back of the Ganges river water by the Isamoti and Bhagiroti rivers as causes of this flood.

3.4 Causes of Floods

Floods in Bangladesh are caused by a combination of a complex set of factors [4, 5] summarized below.

1. Huge transboundary flows from the upstream catchments resulting in over spilling of the main rivers.
2. Runoff generated by heavy local precipitation that cannot drain out due to high stage in the outfall rivers.
3. High tides in the Bay of Bengal coupled with wind set-up caused by south-westerly monsoon winds that obstruct drainage of the upland discharge.
4. Synchronization of peak flows in the major rivers, causing drainage congestion at the mouth.
5. Excessive siltation of the river channels which have reduced their carrying capacity.
6. A low floodplain gradient that prevents quick recession of excess water.
7. Storm surges due to tropical cyclones in the Bay of Bengal.
8. Unplanned infrastructural development activities and inadequate drainage facilities leading to drainage congestion, together with excessive rainfall runoff, inducing high-magnitude flooding that inundates large areas.
9. Excessive destruction of natural vegetation and changing land use patterns in all the headwaters of the major rivers.

Some general characteristics of causes of floods are described below.

3.4.1 Unique Geographic Location of Bangladesh

The geographic location of Bangladesh in the downstream section of the GBM Basin along with the flat topographic nature of the terrain makes it extremely vulnerable to floods. Bangladesh is located at the lower part of the entire GBM River Basin and provides the outlet of the basin into the Bay of Bengal. Bangladesh is on the floodway of an immense area of the GBM Basins. The geographic location of Bangladesh with the Indian Ocean to the South, the Himalayas to the North and the prevailing monsoons, has made it one of the wettest countries of the world. Vast area of central India and the Southern Himalayas slope down towards Bangladesh. Three great rivers, the Ganges, the Brahmaputra and the Meghna, draining a total of nearly 16 million sq. km, join each other in this small country to reach the sea [59].

3.4.2 Flat Topography

Bangladesh is a flat delta with numerous abandoned channels inside the country, and many depressions known as *beels*, *baors* and *haors*. These natural depressions together have an area over 1,230 sq. km [59]. The flatness of the land surface gives a minimal gradient to the flood producing rivers. During flood time, the average slope of the Brahmaputra is of the order of 6 cm/km; and the Ganges and the Meghna have even smaller gradients [59]. Therefore the flood waters easily inundate the surrounding river catchment areas. The depressions, which are located in North-Eastern districts and Rajshahi and Pabna districts, hold much flood water and easily inundate huge areas along the periphery. *Haors* and *beels* of the flood prone region overflow to easily inundate the surrounding flat surface area and cause flooding havoc.

3.4.3 High Cross Boundary Flow

Flood water influx mainly comes from outside the vast GBM River Basin. The whole GBM river is under the influence of the monsoon. Heavy monsoonal rainfall, 80 % of which occurs in roughly 5 months, from June to October, coupled with snow melt water from the Himalayas, finds an outlet to the sea through the Bengal basin sharing approximately 7.5 % of the total basin area of the great river systems [1]. Monsoonal or orographic rainfall hits the entire GBM River Basin area especially in the Khasi-Jainta range of hills in Assam, India, and which extend towards the north of Bangladesh. Here lies Cherrapunjee, the place with the heaviest rainfall (12.7 m) in the world [59]. As a consequence rainfall run-off from this vast area coupled with Himalaya's snowmelt brings a huge inflow of water to Bangladesh during the summer monsoon.

3.4.4 Local Rainfall

The climate of Bangladesh is tropical monsoonal and as a consequence Bangladesh catches a huge rainfall which compounds the flooding. The average rainfall varies from 1,270 mm near the western border to about 5,600 mm in the bordering areas of the North-East. The mean annual rainfall is about 2,320 mm, but there are some places which receive mean annual rainfall of 6,000 mm or more [59]. A long duration of heavy rainfall associated with 'nor wester' thunderstorms is very common in Bangladesh, creating local floods in flood prone areas. An estimated 125 thousand cubic metres of runoff is generated by rainfall within Bangladesh [59]. The local rainfall runoff augments the incoming flood of the international GBM rivers. Due to unplanned drainage congestion, local rainfall runoff creates flood havoc in a comparatively small area. Another statistic, mentioned by Islam [1], is that the amount of rainfall occurring within Bangladesh and the combined flow of water draining into Bangladesh amount to an average of 960 MAF [1]. An average of 700 MAF of water is carried by the three major river systems of Bangladesh. If the remaining 260 MAF of water is distributed within 30 million acres of land, then approximately 2.74 m of water would be accumulating over the flood plain in the 5 months from June to October every year.

3.4.5 Human Intervention/Human Contribution to Drainage and Flood Problems

Constructions of barrages and protective works along of the banks of the rivers, particularly upstream (India, Nepal and Bhutan) have reduced the original floodplains thus the diverted water causes flooding in Bangladesh. The flood control projects in Bangladesh such as the Brahmaputra right bank embankment and *chalanbill* embankment project have protected the project area from floods, but it has increased the intensity of floods outside the protected area [59].

Deforestation in the upstream regions has intensified the flood events in Bangladesh in several ways. It causes acceleration of water flow from the upstream. It also causes soil erosion thus the sediment loads carried by the rivers are increasing. This reduces channel flow and consequent overflows on the floodplains occur [1].

Unplanned development with poor engineering workmanship causes obstructions of the natural flow of water. Construction of roads, railways and homesteads in the floodplains obstructs the flow of the flood. Sufficient openings for an undistributed flood flow are barely maintained, which intensifies the flows and causes drainage congestion, exacerbating flood problems.

3.4.6 Siltation

Rivers of Bangladesh are alluvial in type and erosion and siltation are a continuous process. Older literature refers to gradual siltation of many channels, reducing the water flow areas and at the same time decreasing the depth of the river beds, reducing their water containing capacity. Thus siltation can add to the severity of floods [1, 59].

3.4.7 Unstable and Migratory Rivers

The channel boundaries of alluvial rivers of Bangladesh are highly mobile and the rivers are subject to changing courses. Increased flood discharge, faulting of sediment deposits from previous flood years, or combinations of both, commonly cause shifts of the major flow, leaving behind abundant channels and low lying areas which tend to be affected again by floods [1, 59].

3.4.8 Tidal Effect

About one third of Bangladesh is under the influence of the tide. A moderately strong semi-diurnal tide with two high waters and two low waters over a period of 24 h affects the coast of Bangladesh. Backwater effects of tides, from the Bay of Bengal, particularly spring tides, prevent efficient drainage of flood waters causing flooding in the low-lying coastal areas. Flooding of the *haor* areas of Sylhet and Mymensingh is also affected by the tidal effect as it obstructs drainage of water of the river Meghna at Chandpur [1, 59].

3.4.9 Sea-Level Rise

The rise of the local mean sea-level by about 1 m during the monsoon due to the effect of south westerly wind adversely affects efficient drainage of flood water and raises water levels near the mouth of Meghna. Ultimately this affects all the interconnected channel network of the country [59].

3.4.10 Over: Land Storage

Water channels in Bangladesh are interconnected; the two main rivers Ganges and Brahmaputra unite at Gualanda and this combined flow unites with the Meghna, another main river, at Chandpur. The rise of water level at the confluence due to floods in either of the rivers slows down the flow in the other river due to the back water effect. If both of the rivers flow above danger level at the same time the subsequent flood would be more severe and long standing as seen in 1988 and 1998 [59].

3.4.11 Causes of 1988 and 1998 Floods

The devastating floods of 1987 and 1988 were due to excessive rainfall in the GBM catchment area, and synchronization of peak flow of the Ganges and the Brahmaputra–Jamuna rivers [60]. Effects of *El-Nino, La-Nina,* and synchronization of high tide were considered to be the causes of the devastating flood of 1998 which affected about two thirds of the area of the country [60, 61].

Heavy rainfall in the upper catchment area of the Brahmaputra significantly influenced the flood situation in Bangladesh in 1988. Within the time period of 1 June to 23 August approximately 50 % more water flowed into the country through the Brahmaputra compared to the flow during the same time period in 1987 [1, 62]. Moreover, synchronization of very high flow of all three major rivers in only 3 days aggravated the flood situation in 1988. Spring tides, due to the new moon coming in conjunction with the solar eclipse on early September 1988, delayed recession of flood waters particularly in the central and southern part of Bangladesh.

In 1998 there was also synchronization of peak flows in the three major rivers [5]. Of the three main rivers, the Ganges and Brahmaputra originate from the Himalayas and their flow comes from snow melting and rainfall. Because of all the factors Bangladesh can hardly avoid floods [63].

3.5 Flood Types in Bangladesh

Four major types of flood are experienced in Bangladesh

1. Flash flood
2. River/Monsoon flood
3. Rain water flood
4. Storm Surges

3.5.1 Flash Flood

Flash flood is characterized by a fast rise and fall of water levels in the rivers. It has the potential to cause extensive damage to crops and property including roads, railways and flood protection embankments. This type of flood generally occurs in the flood plains along the river course in the hilly areas as well as the foot hills. A 10 day maximum rainfall exceeding 300 mm is considered as an index for a flash flood in any given area [5, 10]. This type of flood is common along the northern, north eastern and south eastern parts of Bangladesh.

3.5.2 River Flood

River flood is characterized by a slow rise of water levels and gradual inundation of large areas through over bank spilling. This is caused by excessive rainfall in the river catchment outside Bangladesh. This is the most common flood occurring in Bangladesh. In normal years about 30 % of the land area is inundated; in the case of a devastating flood it is 50–70 %. When there is simultaneous rise of water level in the three main rivers, the flood becomes devastating, for example, the 1998 flood, and the most devastating flood in the last century. The Brahmaputra starts to rise in March due to snow melt causing its first peak in late May and early June, followed by subsequent peaks up to the end of August due to heavy monsoon rain over the catchment [5]. As the river flood usually affects large flood plain areas, it causes significant damage to crops, homesteads, livestock, plants, and infrastructure. It also causes extensive river bank erosion [5]. The determinants of the extent of devastation from river floods are timing, depth and duration of flooding.

3.5.2.1 Rain Water Flood

Rain water flood is most common in low-lying and drainage restricted areas of Bangladesh. These floods are caused by heavy rainfall occurring over the flood plains within Bangladesh, generating water volumes in excess of drainage capacity [5]. The amount and intensity of local rainfall and the water level of major rivers determines the extent, depth and duration of rain water flooding. Damage is particularly severe when rain water floods coincide with high river floods [5].

3.5.3 Storm Surges

These involve sudden but temporary flooding of coastal areas with brackish or saline sea water. In fact storm surges are raised sea-levels caused by a combination of low barometric pressure and strong onshore winds associated with tropical cyclones. The extent of storm surge floods depends on several factors [11]: the height of the storm surge at the coast, the relief of the adjoining land, whether or not a coastal embankment exists, the impedance of water flow by settlement, trees, crops and road embankments [5].

3.6 Summary

This chapter has reviewed some important issues including general characteristics of floods in Bangladesh, flood history and the concerned Government agency's activities since 1954, flood research in Bangladesh since 1980, causes of floods and types of floods. A review of relevant literature suggests that none of the studies.

1. Have dealt with community based autonomous adaptation processes in response to EFEs; and there are no indications about the cut-off points where crop–flood adjustment processes fail to continue;
2. Have assessed V&A using the proposed methodology;

3. Have assessed the failure effects of autonomous crop adaptation and its economic consequences/implications where the autonomous adjustments in response to extreme flooding fails; and
4. Have extrapolated the distribution pattern of household flood damage and plant damage;

These issues are necessary for future planning to reduce flood vulnerability at the community level in Bangladesh.

The chapter indicated that the flood issue is one of the most important issues, and has been highlighted since 1954 by the Government of Bangladesh (then East Pakistan) as it acts as a main development barrier. Currently the Government of Bangladesh is most concerned about natural calamities, particularly floods. It is predicted that Bangladesh will be affected by more frequent and severe floods due to climate change and sea-level rise and as a consequence millions of marginal farmers will be seriously affected. Therefore the Government of Bangladesh urged action at the World Climate Conference 3 in Geneva on September 3, 2009 by the international community for technological and financial support for upholding the community based adaptation mechanisms in order to reduce flood vulnerability.

For strengthening community based adaptation, it is necessary to focus on the above-mentioned issues (1–4). These issues are neglected as the existing literature on flood hazards indicates. Islam [1, 20, 30], Paul and Rasid [21], Paul [19], Chowdhury [64], as independent researchers, have worked on agricultural adjustments and flood damage to rice crops in Bangladesh, but apart from the FAP 19 studies the Government's research initiatives in this area are negligible. The studies already done at individual levels are not sufficiently comprehensive to understand the systematic assessment of flood damage including household damages due to EFEs, and V&A issues have never been adequately identified.

The Government has recently focused on both structural and non-structural flood management methods in order to reduce flood vulnerability [19]. The prudent approach is to have a combination of the two methods [5]. In addition to the structural and non-structural approach to flood management, it is important to upgrade the flood warning system and real time data exchange within the other upper riparian countries to address the flood management issue effectively [4, 50, 65, 66].

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Chapter 4
Household Information in the Case Study Area

Abstract Household base-level data of a riverine flood vulnerable area in Bangladesh were explored and identified by 140 households' questionnaire surveys in case study area Islampur upazila in 2006. The important findings were: high numbers of family members were in each surveyed household; numbers of dependent family members were very high in comparison with economically active family members where the main primary economic activity was farming; incomes were low i.e. poor economic conditions prevailed; house damage related loss was large in relation to respondent's annual income and socio-economic condition; occupational loss also was very large compared to overall economic condition of the respondents; within the past 20 years the size of typical farms affected by extreme floods has been reduced by more than half. This base-level household information is important in assessing any vulnerability and adaptation (V&A) scenario in relation with climatic shock such as extreme floods in Bangladesh. It is concluded that the explored household information indicates that the Government of Bangladesh needs to develop the base-level information data cell centrally, under the Ministry of Environment, where community based V&A information should be stored, in order to allocate adaptation funds to any specific hazard affected community. This information also helps government to establish nationwide adaptation to climate change policy, and its execution and implementation on community level. It is found that the affected farmers have been forced to become environmental refugees over time as they have been losing their agricultural lands significantly due to extreme floods; therefore, if this trend continues, resulting in a large scale illegal migration from Bangladesh into neighbouring countries, then the overall human security in the Asia Pacific Region would be severely threatened (further detail in Younus, J Bangladesh Natl Geogr Assoc 37(1):1–20, 2012 [1]).

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4.1 Introduction

V&A and failure effects of autonomous adaptation have been assessed against household socio-economic, demographic, environmental and physical data. To understand this household data is vital because:

1. The severity of V&A issues and their importance need to be understood in the appropriate context. The way V&A issues have been categorized and weighted (in Chap. 6), is linked to this background data. The household information provides the rational for the prioritization and categorization of V&A issues. It also gives a guideline to the actions needed to be adopted in the context of climate change in future, which is of immense value to policy makers.
2. The severity of failure effects of autonomous adaptation (Chap. 7) and its consequences are better understood in the context of the household information. The economic loss caused by the EFEs and its impact and consequence on marginal farmers make sense when the household information is taken into consideration.

Where a high value of loss is shown in the distribution pattern of household information for a particular issue, it is considered that this reflects the greater local severity of flooding. For example, in Fig. 4.14 the high value for the loss due to cattle death at Horindhora *mauza* is assumed to reflect greater severity of flooding than that at Gilabari where the loss due to cattle death is less. This assumption may be affected by other variables such as better husbandary or preparation by farmers but is considered a reasonable approximation in the absence of other data and was generally confirmed by the respondent farmers from those areas. Similarly, other factors may apply in the case of each issue analyzed in the following sections.

The socio-economic, demographic, physical and environmental characteristics of the 140 households surveyed for the case study were analyzed, as described below.

4.2 Demographic Characteristics of Households

One of the common aspects of the surveyed households was the high number of total family members. On average, the number of family members in each household was 5.44. Almost one quarter (23.57 %) of households had 7–11 family members. The majority (42 %) of households had 5–6 family members and about one third (34.28 %) had 3–4 family members (Fig. 4.1, Table 4.1).

The average of economically active family members was only 1.42 and the average of dependent family members was 4.15. The majority (71 %) of households had the highest dependent members, ranging from 6 to 9. Compared to dependent family members, the numbers of persons contributing to the family economically was quite low; on average, for one economically active member

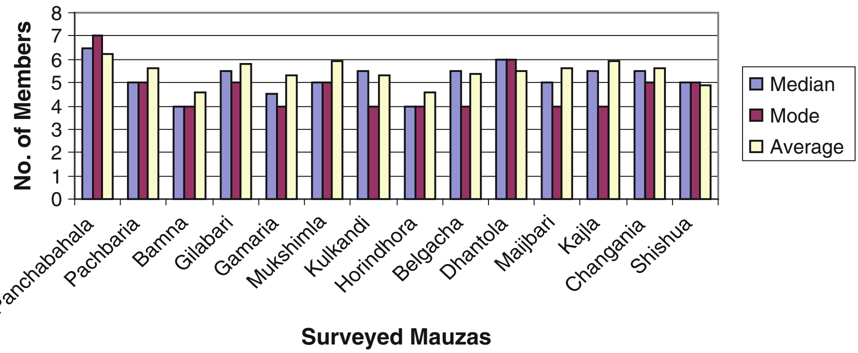

Fig. 4.1 Distribution pattern of household members

Table 4.1 Family members of the surveyed households

Members in household	Number of respondents	Percentage
Up to 3 members	8	5.71
Up to 4 members	40	28.57
Up to 5 members	32	22.85
Up to 6 members	27	19.28
Up to 7 members	19	13.57
Up to 8 members	07	05
Up to 9 members	04	2.85
Up to 10 members	02	1.42
Up to 11 members	01	0.71
Total	140	100

there were 2.81 dependent family members. About one third (33.57 %) of families had more than four dependent family members.

Most of the families had one earning member. Out of 140 households, only a few (17 %) had a second earning member and only a very small fraction (7 %) of households had three earning members.

The average number of male family members was 2.93 whereas the average of female family members was 2.49 (Fig. 4.2).

4.3 Economic Activities

The primary economic activity of the surveyed households is farming. The secondary economic activity is varied; in total 24 activities have been identified including business, day laboring, teaching, fishing, rickshaw pulling, mechanic, driving cattle/bull cart etc (Fig. 4.3).

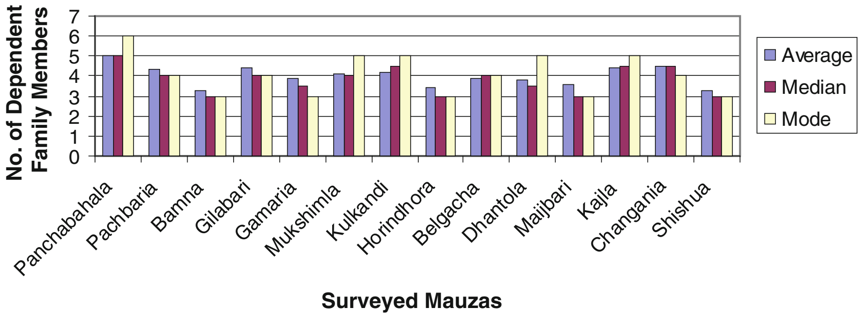

Fig. 4.2 Distribution pattern of total dependent family members of 140 households

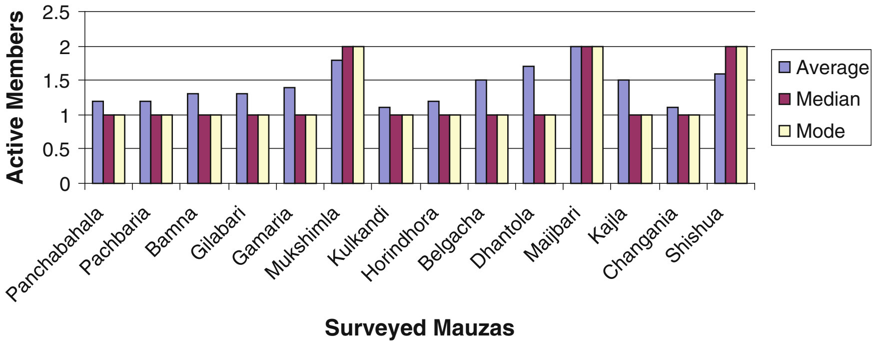

Fig. 4.3 Distribution pattern of economically active family members

4.4 Household Income

4.4.1 Primary Income

The average household primary income is 57,400 *taka* per annum. As shown in Table 4.2, the majority (64.28 %) of households had an average annual income of 0-50,000 *taka*. Just over one quarter (28.56 %) of households had an income ranging between 50,000 and 150,000 *taka*. Few (4.28 %) had income ranging between 150,000 and 250,000 *taka*, and even less (0.71 %) had an income between 250,000 *taka* to 350,000 *taka* and 350,000–450,000 *taka*. The majority of these

Table 4.2 Primary income distribution

Yearly income interval (taka)	Number of households	Percentage
0–50,000	90	64.28
50,000–100,000	27	19.28
100,000–150,000	13	9.28
150,000–200,000	03	2.14
200,000–250,000	03	2.14
250,000–300,000	01	0.71
350,000–400,000	01	0.71
No response	02	1.42
Total	140	100

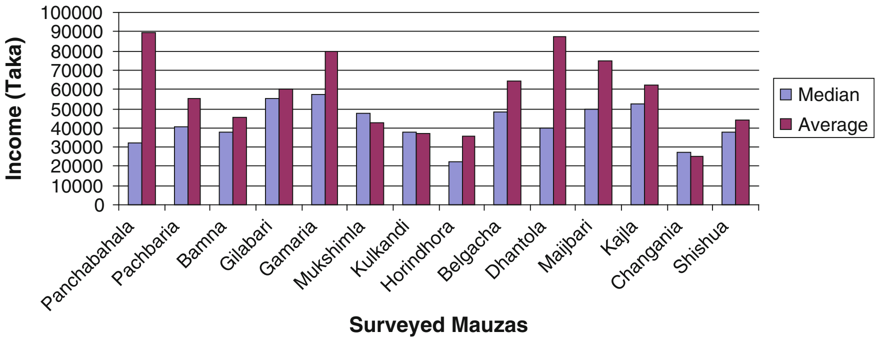

Fig. 4.4 Distribution pattern of primary income

families (64.28 %) thus had an annual income of 817.43 US dollars (1 US dollar = 70.22 *taka*, OANDA.com). In Kulkandi, Panchabahala, Changania, Shishua and Gamaria the income pattern is distributed mostly between 0 and 50,000 *taka*. In Maijbari, Belgacha and Mukshimla the income distribution pattern is mostly above 50,000–1500,00 *taka* (Fig. 4.4).

4.4.2 Secondary Income

Only one fifth of households had any secondary income (see Table 4.3). Only a few (7.14 %) had a secondary income worth 0–10,000 *taka* per annum. Very few (6.42 %) of the surveyed households had a secondary income of 10,000–20,000 *taka* and 20,000 to 40,000 *taka* per annum each. It is obvious from the data that not everyone had access to a secondary income and the contribution of secondary income to total annual income is insignificant (Fig. 4.5).

Table 4.3 Secondary income distribution

Yearly income interval (taka)	Number	Percentage
0–10,000	10	7.14
10,000–20,000	09	6.42
20,000–30,000	03	2.14
30,000–40,000	05	3.57
40,000–50,000	01	0.71
50,000–60,000	01	0.71
350,000–400,000	01	0.71
Total	29	20.71

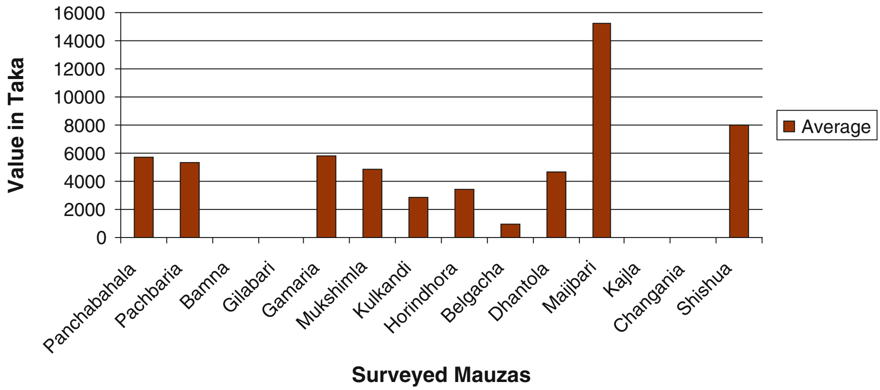

Fig. 4.5 Distribution pattern of secondary income of surveyed households

4.4.3 Tertiary Income

None of the households had any tertiary income.

4.5 Land Ownership Pattern

On average, the current (2006) owned land per household was 3.68 *bigha* (one *bigha* = 0.33 acre). The total land per household, that is, land including rent in, rent out, lease, *dokholi* (land in possession, not owned) averages 4.02 *bigha*. The distribution pattern of current owned land (see Chap. 7, Figs. 7.1, 7.2a) was mainly between 0–10 *bigha*. It is evident from the distribution pattern that in 1988 many more households used to own lands between 10 and 20 *bigha*. The trend shows that with successive flooding events the amount of land owned by households is decreasing over time (Chap. 7).

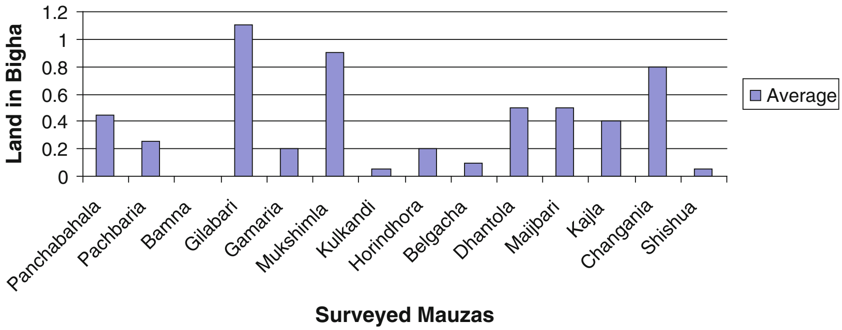

Fig. 4.6 Distribution pattern of rented in lands of 140 households

Less then one fifth (16.42 %), rented lands for farming. Usually those who do not possess any land 'rent in' land for farming from other owners. Of these, very few (4.28 %) rented 0–1 *bigha*, a few (5.71 %) rented 1–2 *bigha* and the rest (6.39 %) rented between 2 and 5 *bigha* (Fig. 4.6).

Only 3 households (2.14 %) 'rented out' lands. These households are from Belgacha, Gamaria and Dhantola, one each in each *mauza*. No lease or *dokholi* (illegal possession) was reported.

4.6 Types of Agricultural Lands and Exposure to Normal Flooding

Farming land has been divided into very low land, low land, medium low land and medium high land. This has been classified in accordance with the FAO classification, [2]. It is noted that every household had several different types of lands. None of the respondents had medium high land because in general the study area is a low lying area.

A small fraction (7.14 %) of respondents, reported that they owned very low land. Gilabari, Kajla, Gamaria, Kulkandi, Changunia and Shishua are the areas where respondents owned low lands. Very low lands are specially suitable for IRRI *boro*. More than half (71 households: 50.7 %) reported they owned low land. Of these, less than one third (31.42 %) owned 0–2 *bigha* of land, while a few (10.7 %) owned 2–4 *bigha*. Again just over half (71 households: 50.71 %) of the respondents reported that they had medium low lands. Of these, less than half (42.85 %) owned between 0 and 5 *bigha*, while a few (5.71 %) households had 5–10 *bigha* and very few (2.13 %) had 10–20 *bigha* (Figs. 4.7, 4.8).

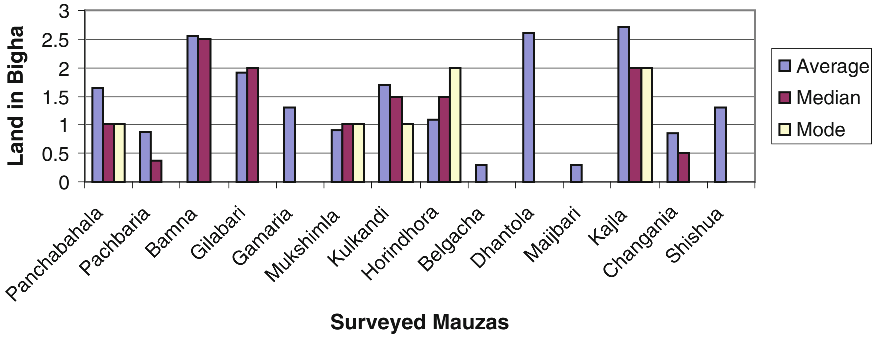

Fig. 4.7 Distribution pattern of low lands

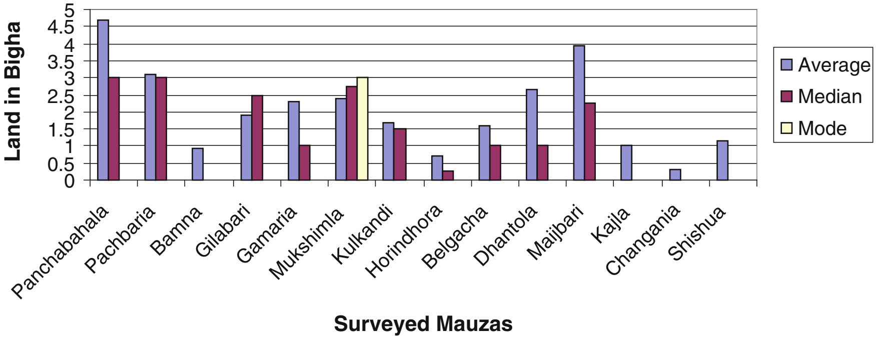

Fig. 4.8 Distribution pattern of medium low lands of 140 households

4.7 Respondents' House: Number, Types and Nature of Damage to Extreme Flooding

The majority (56.42 %) of respondents reported that they had 0–1 houses. House here refers to a single unit comprising more than one room. Less than one sixth (13.57 %) had 1–2 houses and even fewer (10.71 %) reported they had 2–3 houses. A negligible number of respondents (2.1 %) had 3–4 houses. Less than half (41.42 %) owned small houses with 1–2 rooms. A small number (10 %) of households had only 1 room and about one sixth (17.14 %) had 2–3 rooms. Only a negligible fraction (2.14 %) of respondents had 5–6 rooms.

About one sixth of the respondents (17.14 %) did not answer this question. It is assumed that they do not have their own house (living with relatives) or for some other reason were not willing to talk about this.

The vast majority (69.28 %) of houses were made of 'tin' (galvanized iron), whereas about one fifth (19.25 %) had houses made of hay. This leads to the impression that the majority of the population are poor and of low economic status.

4.7.1 House Damage Related Loss

Well below half (39.28 %) of the respondents reported that loss from house damage owing to flood was from 0 to 10,000 *taka* after the 1988 flood. Similarly, less than one fifth (18.57 %) reported house damage related loss of 10,000–20,000 *taka* while a few (10 %) suffered loss of 20,000–30,000 *taka* (Fig. 4.9).

Respondents from Panchbaria, Mukshimla, Kulkandi and Gilabari *mauzas* reported more extensive house damage which indicates that these *mauzas* were severely affected by flood. On the other hand, Maijbari, Changunia, Belgacha and Dhantola residents reported less extensive house damage which indicates low intensity of flood in these areas. In Horindhara and Belgacha *mauzas* loss up to 30,000–70,000 *taka* is noted.

In 1995, 21 households were damaged, which is about one sixth (15 %). House damage related loss of up to 6,000 taka was reported by one tenth of (10 %) respondents, up to 12,000 *taka* was reported by a negligible fraction (2.8 %) of respondents and very few (2.14 %) reported loss of more than 12,000 *taka*. It is noteworthy that the vast majority (85 %) of households said there was no house damage due to the 1995 flood. In Gilabari, Kulkandi, Mukshimla and Kajla no house related damage was reported (Figs. 4.10 and 4.11).

In 1998, less than half (61 respondents: 28.57 %) reported house damage related loss within 10,000 *taka*, Few (7.85 %) reported loss of 10,000–20,000 *taka*, very few (6.42 %) reported damage of 20,000–50,000 *taka* and reported losses of 60,000–70,000 *taka* were negligible. Compared to the annual household incomes however, these losses are very significant. Respondents in Gilabari, Mukshimla and Horindhara claimed bigger losses compared to other *mauzas*. Maijbari, Kajla, Changunia and Panchbaria residents claimed less house damage related loss.

4.8 Household Livestock Loss due to Extreme Flooding

In 1988, less than half (64 out of 140, 45 %) of the respondents reported that they had cattle deaths due to flooding. The largest number of cattle deaths occurred in Gilabari, Horindhara, Maijbari and Changunia; in Panchabahala, Dhantola, Panchbaria, and Kulkandi fewer cattle deaths occurred. About one third (32.85 %) of respondents had losses within the category of 0–10,000 *taka* because of cattle death. Average household loss because of cattle death was 4,192 *taka*. In 1995, very few (3.57 %) respondents reported deaths whereas in 1998, about one sixth of

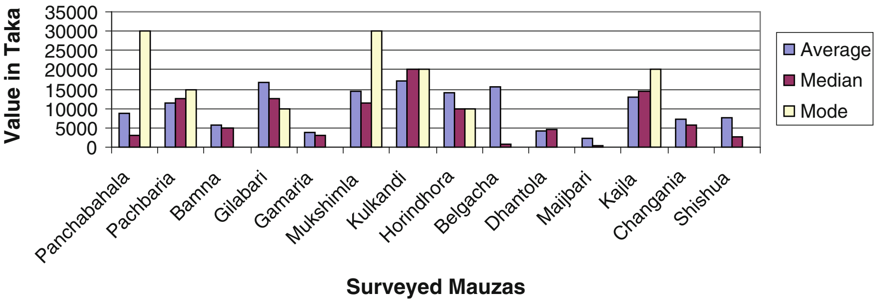

Fig. 4.9 Distribution pattern of hosue damage in 1988 flooding of 140 households

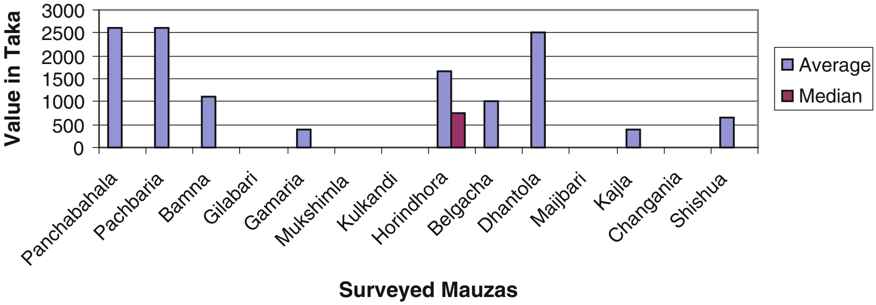

Fig. 4.10 Distribution pattern of house damage in 1995 flooding of 140 households

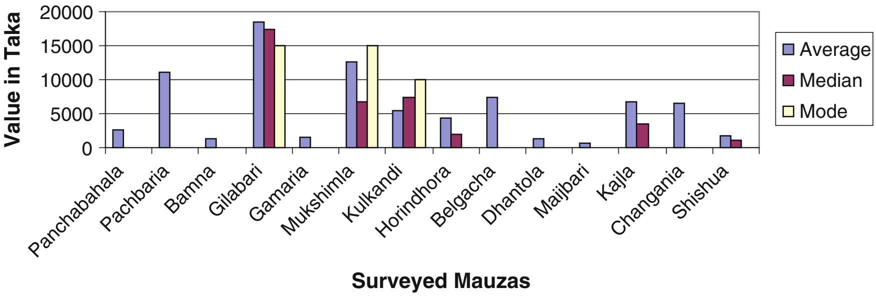

Fig. 4.11 Distribution pattern of house damage in 1998 flooding of 140 households

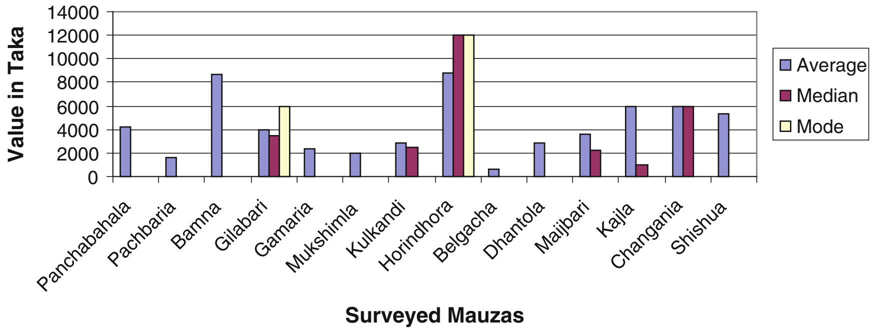

Fig. 4.12 Distribution pattern of loss due to cattle death in 1988 flood

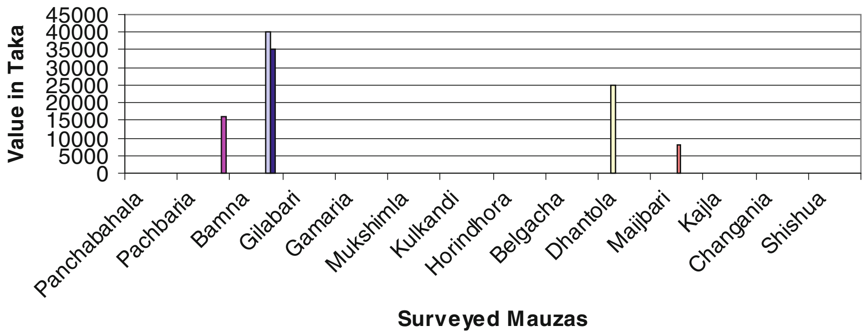

Fig. 4.13 Distribution pattern of loss due to cattle death in 1995 flooding

respondents (14.28 %) reported cattle deaths. Average household cattle deaths related loss was 843 *taka* in 1998 (Figs. 4.12, 4.13 and 4.14).

Less than half of the respondents (30 %) reported loss related to goat deaths in the 1988 flood. Out of these about a quarter (22.14 %) of respondents claimed a loss between 0 and 3,000 *taka*. Average household loss due to goat deaths was 783 *taka*. Higher numbers of losses are seen in Bamna, Gilabari, Horindhora and Changunia. Very few respondents reported cattle death related loss in 1995 (1.42 %) and 1998 (5.71 %).

Well above half of the respondents (63 %) reported loss related to chicken deaths in 1988. Of these, less than half (45 %) reported loss between 0 and 1000 *taka*. The average household loss related to chicken deaths was 716 *taka* in 1988. Only a few respondents reported chicken deaths in 1995 (10 %) and in 1998 (16.42 %). In 1995 the average loss due to chicken deaths was 76 *taka* and in 1998 it was 260 *taka*.

About one third of the respondents (31.42 %) reported that they were forced to sell cattle immediately after the 1988 flood for survival. The average household

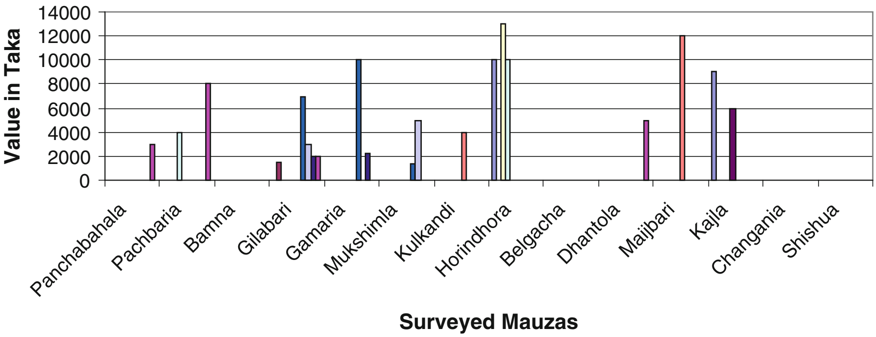

Fig. 4.14 Distribution pattern of loss due to cattle death in 1998 flood

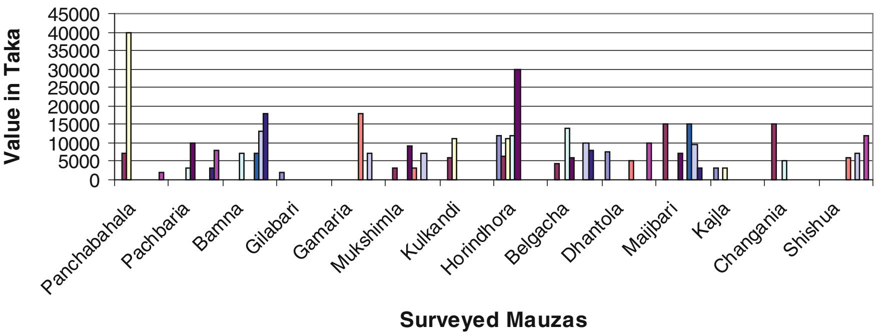

Fig. 4.15 Distribution pattern of cattle selling after 1988 flooding

loss due to this was 3190 *taka*. In 1995 few (6.42 %) respondents had to sell cattle following the flood. In 1998, about one fourth of the respondents (24 %) reported selling cattle with an average household loss of 1,550 *taka* (Fig. 4.15 and 4.16).

4.9 Occupational Loss at *Kharif* 2 due to Extreme Flooding in 1988, 1995, 1998 and 2005

4.9.1 Primary Occupational Loss

The average loss of each household due to primary occupational loss in 1988 was 44,172 *taka*. The majority (63.57 %) of households reported loss within the category of 0–5,000 *taka*. The vast majority (80.7 %) of respondents reported primary occupation related loss of 0–100,000 *taka*. In Panchabahala, Mukshimla, and

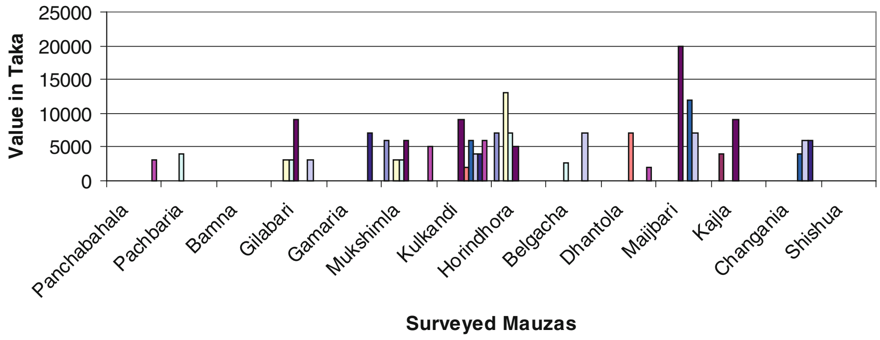

Fig. 4.16 Distribution pattern of cattle selling after 1998 flooding

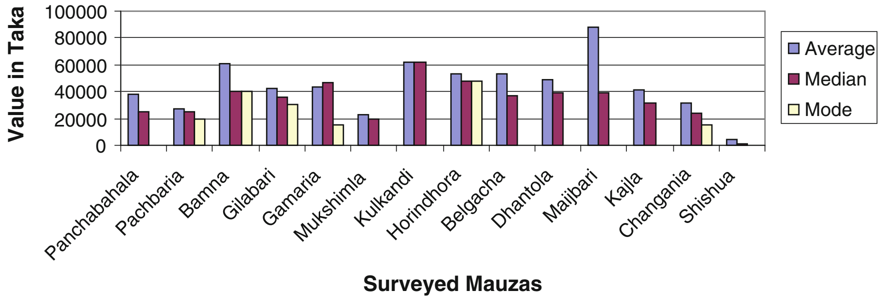

Fig. 4.17 Distribution pattern of primary occupational loss at kharif 2 in 1988 flooding

Shishua less primary occupational related losses were noted. On the other hand in Pachbaria, Gilabari, Bamna, Gamaria, Kulkandi, Belgacha, Maijbari and Changunia higher numbers of respondents reported primary occupational related loss. Households claiming loss above 50,000 *taka* were mainly located in Bamna, Kulkandi, Belgacha, Maijbari and Gilabari (Fig. 4.17).

In 1995, the average household loss due to primary occupational loss was 22,224 *taka*. Less than half (47 %) of the respondents reported loss between 0 and 20,000 *taka*, about two thirds of them (70 %) reported a loss between 0 and 40,000 *taka*. Less than one sixth (15 %) denied any loss or refrained from answering. In Shishua, Mukshimla and Gamaria primary occupational loss appears less.

The average loss incurred from primary occupational loss at *kharif* 2 in the 1998 flood was 32,388 *taka*. The majority (67.85 %) of respondents reported a loss of 0–50,000 *taka*. About one sixth (15.71 %) of them reported a loss between 50,000 and 100,000 taka. In Pachbaria, Gilabari, Mukshimla, Dhantola and Maijbari the distribution pattern of primary occupational loss was more

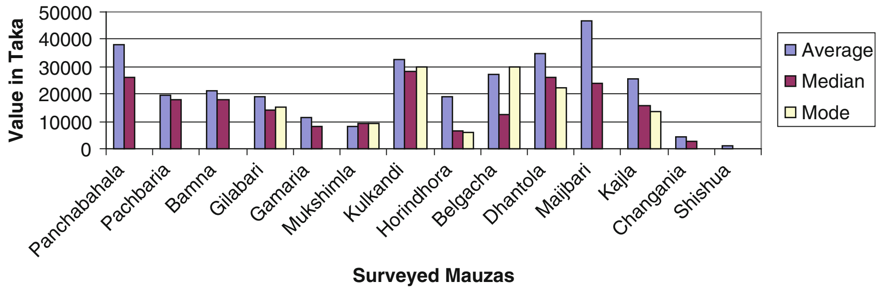

Fig. 4.18 Distribution pattern of primary occupational loss at kharif 2 in 1995 flooding

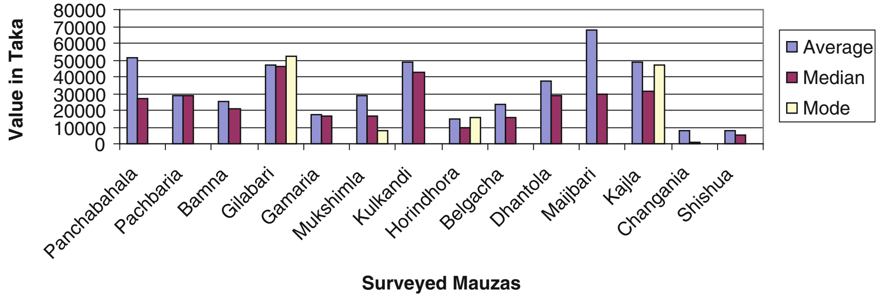

Fig. 4.19 Distribution pattern of primary occupational loss at kharif 2 in 1998 flooding

concentrated, that is, more respondents claimed a loss. On the other hand, in Changunia, Shishua and Gamaria, fewer respondents reported primary occupational loss (Figs. 4.18, 4.19 and 4.20).

4.9.2 Secondary Occupational Loss

Very small numbers of respondents had a secondary occupation. A small number of respondents (6.42 %) said that they had secondary occupational loss in kharif 2 in the 1988 flood. Secondary occupational loss is noted in Panchabahala, Gamaria, Horindhora, Kajla, Shishua and Mukshimla. The average loss per household was 534 taka. In 1995 the average loss per household was 669 taka, in 1998 it was 1409 taka and in 2005 it was 298 taka. In 1995, a few (8.5 %) reported secondary occupational loss and in 1998 the figure rose to 11.42 % whereas it was 7.85 % in 2005. This indicates that the 1998 flood was more severe and caused more damage compared to the other two flood events.

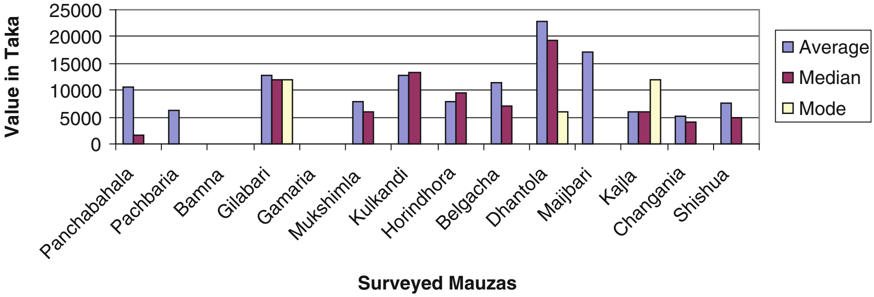

Fig. 4.20 Distribution pattern of primary occupational loss at kharif 2 in 2005 flooding

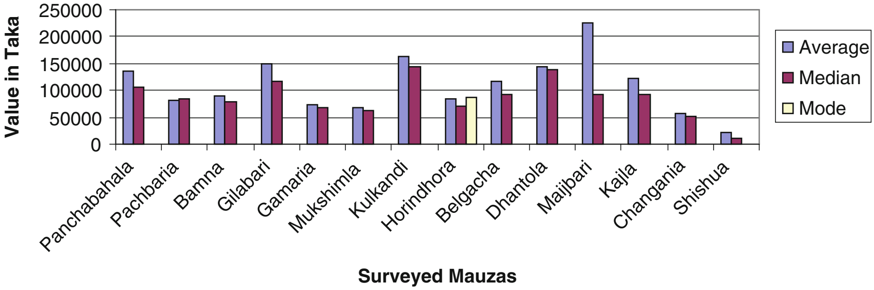

Fig. 4.21 Distribution pattern of total occupational loss at kharif 2 in 1988, 1995, 1998 and 2005 floods

4.9.3 Total Occupational Loss

Total occupational loss refers to primary occupational loss and secondary occupational loss combined. Total occupational losses of all four flood years (1988, 1995, 1998 and 2005) have been added and the distribution pattern is shown in Fig. 4.21.

The vast majority (91.42 %) of the respondents reported occupational loss. Among those more than half (58.57 %) suffered a loss of up to 100,000 taka. One quarter (25 %) of them incurred a loss between 100,000 and 200,000 taka, a few (7.85 %) reported a loss between 200,000 and 300,000 taka and very few (2.85 %) had a loss above 400,000 taka. Lower occupational loss was seen in Shishua, Belgacha, Mukshimla and higher total occupational loss was noted in Kulkandi, Gilabari, Maijbari, Kajla and Panchabahala.

4.10 Summary

Some important findings can be derived from the surveyed household base level data:

- High numbers of family members. On average, family members in each household numbered 5.44.
- Numbers of dependent family members were very high in comparison to economically active family members. There were 2.81 dependent family members for one earning member.
- Most of the families (87 %) have one earning member with a primary economic activity of farming. Only one fifth (20 %) of households had a second source of income. This gives a picture of a predominantly agricultural based economy.
- Most (64.28 %) of the respondents had an income between 0 and 50,000 taka, that is, 817.43 US dollars annually. This indicates a very poor economic condition overall.
- About one sixth (16.42 %) had to rent in land for farming and only very few (2.14 %) rented out land.
- Most lands owned are very low to low in topographic category which is highly to moderately vulnerable to flooding.
- More than half (56.42 %) respondents had one house, mostly made of tin (69.28 %) or hay (19.28 %).
- House damage related loss is large in relation to respondent's annual income and economic condition.
- Livestock death and sale related loss were significant in relation to the annual average household income in all three floods; but was generally noticed to be more common in the 1988 flood.
- Occupational loss also is very large compared to overall economic condition of the respondents. Well above half (58.57 %) of the respondents had total loss of 0–100,000 taka because of occupational loss.

These findings point to the acute poverty of the majority of the population in this case study. As mentioned earlier, V&A issues should be considered in the light of these findings. It is also important that the impacts of the floods, that is, the failure effect of autonomous adaptation, should be understood by taking into consideration the baseline household information.

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Chapter 5
Crop Adjustment Processes to Extreme Floods

Abstract This chapter investigates farmers' crop adaptation processes in response to three recent devastating floods in Islampur, chosen as a case-study area in rural Bangladesh. This chapter reports a multi-method research project which comprised a questionnaire survey, focus-group discussions, and interviews with agricultural block supervisors, the purpose of this chapter being to ascertain how farmers adapt and adjust in response to 'normal' floods which are almost annual events in the case-study area. The author analyses three recent severe floods in Bangladesh, occurring in 1988, 1995 and 1998, and reviews the adaptation techniques and strategies embraced by the same group of farmers in order to survive the more devastating inundations which occur from time to time. A riverine agricultural system in the flood-prone Jamuna river basin was the focus for this investigation. In this chapter the author compares the adaptation and adjustment processes employed by the farmers, and in particular the routine and tactical strategies applied by the farmers in normal flood events as well as in floods with different hydrological characteristics as experienced in 1988, 1995 and 1998. This chapter concludes that vulnerable farmers are highly resilient and, with appropriate support, their adjustments can be sustainable. This enquiry showed that in the face of climate change both the inclusion of autonomous adaptations into planning and policy-making and the enhancement and support of community-based adaptation can be effective in ensuring the survival of riverine farming systems. This case-study can be considered as a key reference case in regard to vulnerable locations in mega-delta basins, particularly in respect to Bangladesh.

5.1 Introduction

Significant background research on the Islampur farming system and farmers' autonomous adjustments was completed for a separate Masters study [1] but not published. For that reason this chapter provides a summary of those findings to provide a context for the current research conducted for this book. The survey

M. A. F. Younus, *Vulnerability and Adaptation to Climate Change in Bangladesh*, Springer Theses, DOI: 10.1007/978-94-007-5494-2_5,

results of the Masters thesis obtained through focus group discussion and questionnaire survey in 1998 differ only marginally from those of 2006 (obtained through PRA and questionnaire survey) because the farmers' responses to the ways they coped with EFEs were very similar. In the first section, a flood crop adjustment process under the normal flood situation is discussed. In the second section, flood crop adjustment processes under EFEs are described.

5.2 Normal Crop-Flood Adjustments in Islampur

Issues relating to normal flood adjustments in Islampur are:

1. The typical cropping pattern in a normal flooding situation.
2. The cropping pattern under normal flood conditions.
3. Autonomous adjustment strategies adopted by the farmers in normal flooding conditions.

Islampur's unique location on the right bank of the Jamuna, ensures that it is affected by floods every year. This area is also affected by the Old Brahmaputra River which flows on the other side (north east) of the region. The surveyed farmers occupy various types of land: very low land, low land, medium low land and medium high land. About 87 % of farmers possessing very low land identified that land as highly vulnerable to flooding under normal conditions. Sixty two percent of farmers who owned low land (74 %) said that their land is highly vulnerable to normal flooding. While 36 % noted that their land is moderately vulnerable. 55 % of owners of medium low land (75 %) identified their land as moderately vulnerable to floods in normal years, while 42 % noted their land is highly vulnerable. Most of those possessing medium high land (83 %) said their land was not vulnerable to flooding under normal situations [1].

The most significant determinant of crop damage is the timing of floods, as it regulates the patterns of crop damage on various flood land groups. Timing of harvesting, maturation of planted seedlings, and quality of grains all depend on the timing of flood. For instance, floods appearing at the end of June (middle of *ashar*), when farmers have already transplanted *aman*, will not allow farmers to replant HYV *aman* as there would not be enough time for maturation of the crop. In this situation they do not have much option other than planting the local variety. Usually, farmers stop planting HYV *aman* by the middle of *ashar* and harvesting is carried out in November to December, that is, at the end of *ograhoyon*. If flooding occurs later in the season, at the end of September when HYV *aman* starts to mature, farmers would not be able to replant any *aman* at all. Timing, along with depth and duration of flood are important regulatory factors in crop flood adjustment in the case study area.

Crop combinations in the *mauzas* and *Union*s differ depending on type of soil, land group, capacity of soil to store water, nature and distribution of alluvium, and land with or without embankments. In a specific time (June to mid of October) of the year, floods play a dominating role in farmers' crop selection and combination.

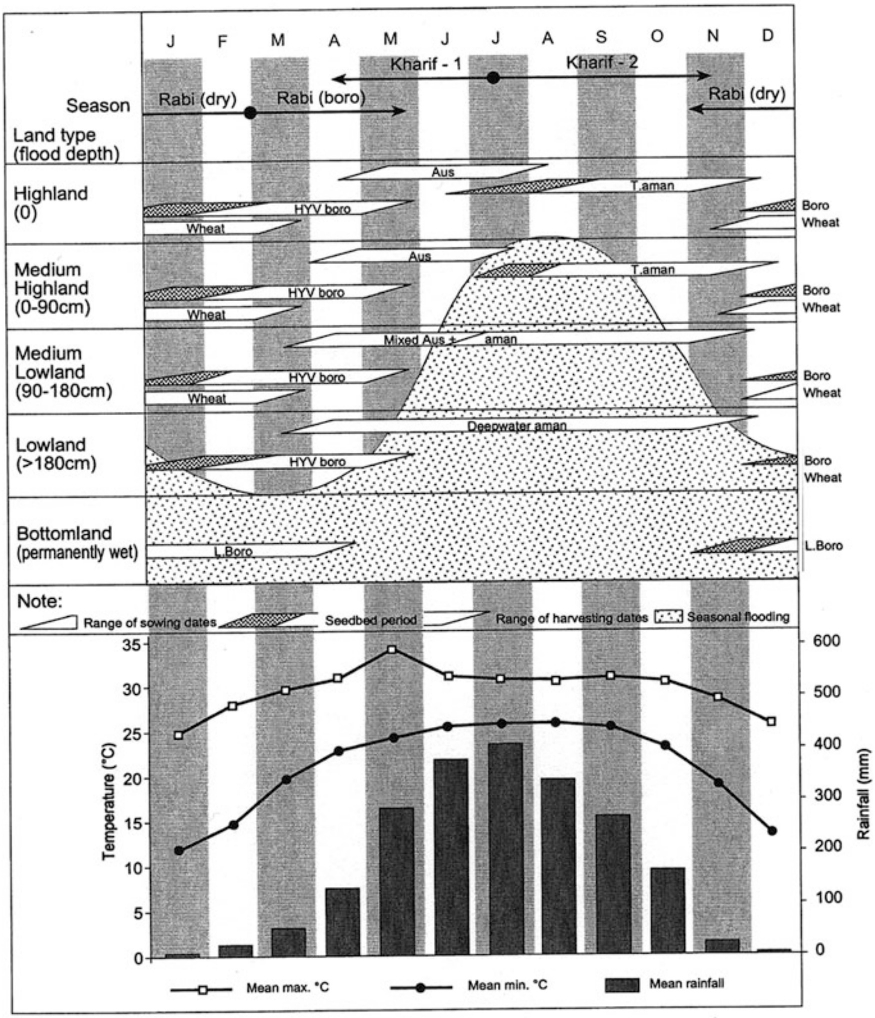

Fig. 5.1 Rice and wheat crop calendar in relation to seasonal flooding, rainfall and temperature. *Source* Ahmad et al. [2]

There are forty seven varieties of crops sensitive to floods either directly or indirectly in Islampur case study area.

As in the rest of the country, the crop calendar of Islampur consists of 3 broad categories and two transition periods. The crop calendar (Fig. 5.1) is as follows:

1. *Kharif* 1: Extends from early March to mid July, this includes the pre monsoon and early monsoon seasons. The main crops of this period are transplanted local *aman*, broadcast *aus* (local), mixed *aus* and local *aman*, jute, *kaun*.

2. *Kharif* 2: Extends from July to November (*Shraban* to *kartik*) and comprises most of the monsoon season. The main crops of this crop season are the transplanted HYV *aman*, transplanted local *aman*, broadcast local *aman*, mixed *aman* and *aus*.
3. Transition between *Kharif* 2 and *Rabi*: This is the period extending from the beginning of recession of flood water to the time before farmers start planting IRRI *boro*. The major crops of this season are potatoes, chili, oil seeds and onions.
4. *Rabi*: The period between November and February (*agrahaon* to *magh*), when the major crops of this season are HYV *boro*, local *boro*, wheat, peanut, mustard, sugarcane.

5.3 Crop Pattern and Crop Decisions in Islampur

In flood prone areas like Islampur, the selection of crops is largely regulated by flood timing, depth, duration and frequency. Other factors contributing to crop selection are, the water containing capacity of the soil, type of land (*char* land or mainland) and type of soil (sandy, loamy, alluvial). The crop selections of *kharif* 2 mostly depend on timing and duration of floods. Farmers tend to plant *aman* in combination with other crops in almost all crop seasons because *aman* is well adapted to flooding. Flood characteristics regulate whether farmers would plant HYV *aman*, transplant HYV *aman* or a local variety of *aman* in *kharif* 2 cropping season. Farmers prefer to plant wheat on the higher lands.

In the medium high land (*uchan jomi)*, farmers tend to plant HYV *aman*, which takes about 150 days to mature (planting seeds to harvesting). This period can be divided into five stages:

1. Planting and germination: 30 days required;
2. Early growth (*aroggo cal*): 10 days;
3. Growing period (*baronto cal)*: 45 days;
4. Emergence of rice ears (*kaitch thor*): 5 days;
5. Harvesting (*korton cal)*: the next 30 days when the rice ears start to mature, and the last 30 days when farmers try to harvest the plants.

Planting, growing, maturing and harvesting are the critical phases for *aman* production at the period of *kharif* 2 cropping season. *Aman* is one of the main crops which is well adapted to flooding, and meets farmers' food demands over the year. The production cost of *aman* is lower than IRRI *boro*. *Aman* can be planted in any land type except for very low land or the land with low water containing capacity. *Aman* cannot be cultivated in some of the *char* land areas and sand deposited lands. Therefore *aman* is the crop of choice for the farmers of Islampur.

The farmers know well how to maximize crop production from their small pieces of land. They have the knowledge and skill to get the maximum return from the land. Whatever type of land they possess, they aim for maximum production and economic return. One of their strategies to ensure maximum utilization of land is, after harvesting *aman*, to plant onions or chilli or potatoes; these cash crops are faster to mature and thus ideal in the transition period. They provide farmers with the money needed for IRRI *boro* crop production during *rabi*. If they plant oil seeds during the transition period, they miss planting IRRI *boro* in *rabi* as oil seeds take longer to harvest. They plant wheat instead, once the oil seeds are harvested. In that case farmers then prefer to plant jute or *aman* instead of *aus* in the next cropping season, *kharif* 2. During group discussions [1], it was noted that more than 4 days of rain on oil seed beds ruins the crop and farmers cannot plant anything else in that land in the transition period as there is not enough time to harvest any crop before *rabi*.

Islampur farmers plant IRRI *boro* in medium high land during *rabi*, after which they usually plant *aus*. Successful harvesting of 3 crops (*aman* local/HYV, IRRI *boro* and *aus*) in a year is difficult, because of erratic rainfall, uncertainty of flood occurrence, insect outbreaks etc. In very low lands (*naimla jomi*) *aman* and *aus* cannot be harvested as crop inundation occurs; farmers plant IRRI *boro* during *rabi* or use these lands for producing cash crops like sugar cane and chilli. The crop combination depends on the type of land and the particular crop desired. If farmers plant sugar cane the associated crops would be chilli and potatoes.

Different types of crop combination are found in *char* land areas. Farmers usually plant the lentils *mug kalai* or *kheshari kalai* in association with broadcast *aman* or planted (*buna*) *aman*. *Buna aman* is usually planted with *kheshari kalai* and broadcast *aman* with other seed crops like *mash-thakuri* or *shona-mug*. After planting the seed crops, farmers harvest the *buna aman* crop. When they plant *kalai* in association with *aman*, in some cases if they want to plant jute in the next season, they cannot harvest *kalai* because of the time constraint, so they use *kalai* leaves as green vegetables or fodder crops for livestock [1].

In some low lying areas *aus* and deep water *aman* are still planted together. Once *aman* is mature and harvested, *aus* grows, tolerating the rising height of regular flood waters. This practice is almost obsolete as farmers now tend to plant HYV *aman* and other cash crops in order to get higher cash returns.

Sand deposition usually occurs during flood recession. In these sandy lands farmers prefer to plant sugar cane instead of *aman* or *boro* as the water containing capacity of this land is poor and not suitable for *aman* or *boro*. The *char* lands are more dependent on transition crops such as onions, which are sometimes grown as a major crop if *aman* is ruined by flooding.

5.3.1 Crop Flood Adjustments in the 1988 Flood

The 1988 flood was a single peak high volume flood. This occurred in the middle of *kharif* 2 when *aman* was already planted and attaining maturity. It was evident from focus group discussion, interviews and responses of the local block supervisors [1] that the flood came suddenly and receded within a short period.

The agricultural land was flooded within 6–12 h and homesteads within 24 h. This is supported by hydrological data at the stations of Bahadurabad and Jamalpur and the rainfall data collected at Muktagacha and Sharishabari.

Characteristics of the1988 flood were:

1. High volume single peak flood.
2. Flood occurred when *aman* plant was in the middle of attaining maturity.
3. The depth of the flood was beyond the flood tolerance threshold of *aman* crop.
4. The duration of the flood was also beyond the flood tolerance capacity of *aman* crop.
5. Heavy local downpours resulted in significant river run-off which in turn caused massive havoc.
6. The flood water receded rather quickly.

As a consequence farmers were left with about 60 days of *kharif* 2 cropping season. In this situation they adopted an autonomous adjustment strategy that was different from the strategy they adopt during a normal flood in early *kharif* 2. Instead of planting HYV *aman* the majority planted local variety *aman.* Mostly farmers possessing medium high land opted for HYV as the floodwaters receded faster from these lands, providing more time for maturation of re-planted *aman*. It is noted that HYV *aman* takes longer for maturation compared to the local *aman* variety.

5.3.2 Crop Flood Adjustments in the 1995 Flood

Compared with the 1988 and 1998 floods, the 1995 flood was a moderate one. According to the information provided both by the hydrological data and the respondents, it occurred over a time period of June 29–July 20 but in some areas extending to early August [1]. This is the period of seedling phase of *kharif* 2 and in some places it overlapped with the end of the harvesting period of *kharif* 1.

The characteristics of the 1995 flood were:

1. It occurred when the seedlings (*aman*) were getting established-either HYV or a local variety.
2. The flood depth was lower than in 1988.
3. Flood depth exceeded the danger level for fewer days (evidenced by hydrological data from Bahadurabad *ghat* and respondents' information).
4. It was a moderate flood in comparison to the 1988 and the 1998 floods.

Farmers still had about 90 days of *kharif* 2 cropping season left after recession of the flood waters, which allowed a successful *aman* harvest. They re-planted *aman*, mainly the HYV, as the time was adequate for HYV *aman*. Thus they took a calculated risk in terms of crop production in 1995.

5.3.3 Crop Flood Adjustments in the 1998 Flood

According to the farmers, the 1998 flood was the most devastating flood they had ever witnessed [1]. It was a multi-peak flood and washed out planted crops three times, twice the HYV and once the local variety. It commenced during the harvesting of *kharif* 1 and continued, until the crop maturation period of *kharif* 2 (approximately June 11–September 30).

The characteristics of the 1998 flood were:

1. It was a deep multi-peak flood.
2. The flood caused the loss of a substantial period of the *kharif* 2 cropping season. In fact, farmers lost the period of seedling growth and maturation up to the mid period of phase 2 (Fig. 5.2).
3. Farmers attempted to re-plant *aman* at least three times in between the peaks.
4. Each time the re-planted *aman* was washed out by another peak.
5. Farmers were faced with an unprecedented challenge where all their ingenious adjustment strategies failed.

The autonomous adjustment threshold was exceeded in the 1998 floods thus resulting in almost total loss of the *kharif* 2 harvest. Some desperate farmers planted *aman* for the fourth time in the transition between *kharif* 2 and *rabi*, though they knew there was not enough time left in the cropping season for maturation of this crop.

Farmers of five *Union*s: Chinaduli, Noapara, Sapdhari, Belgacha and Kulkandi were asked how many times floods inundated their land. Most of the respondents answered that their crops had been washed out at least three times and their homesteads at least once (see Box 5.1). The depth of flood water ranged from 0.34 to 2.13 m depending on the type of land. The frequencies of peak flooding were erratic. Two *mauzas* of Islampur, Panchabahala and Panchbaria, were less affected by this flood and had relatively less frequent flood peaks. The local roads acted like embankments although they could not protect the lands from flooding as the agricultural lands were flooded at least 2–3 times.

Box 5.1: The Pain of Three Flood Peaks

'This was an unexpected flood and I had not seen this kind of devastating flood (*gojobi ban*) ever before in my entire life. The flood came three times and washed out the planted crops three times twice high yielding varieties and once the local one. You look at the last crop *gainja,* a local crop variety. Nothing will be returned from it'—Mr. Hossain, a farmer aged about 45 years, from Panchabahala village [1].

As revealed from focused group discussion, each peak of the flood in 1998 lasted for about 7 days and the depth of water was higher than the height of the standing crops during the peaks. Therefore, farmers lost their crops completely three times.

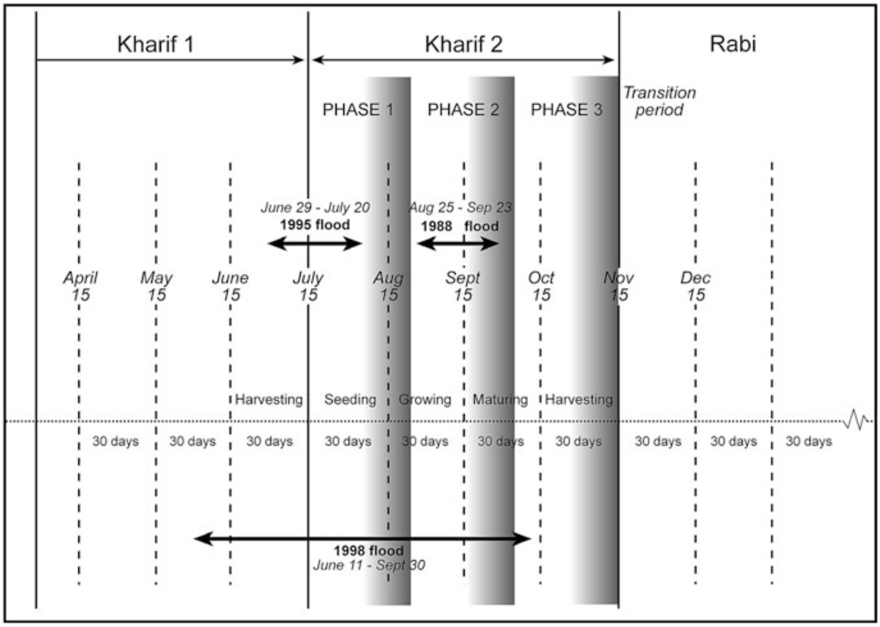

Fig. 5.2 Cropping seasons and the 1988, 1995 and 1998 floods in Islampur. *Source* Younus [1]

Some findings from farmers' responses to the 1998 flood can be summarized from [1]:

1. Farmers planted HYV aman twice, first time at the beginning of June, before the onset of flooding.
2. Floods caused damage to the crops three times.
3. HYV aman was planted the second time at the beginning of August, when floodwaters receded enabling them to plant the seedlings again.
4. As the planted crops were washed out again, they attempted planting *aman* for the third time in last week of August, this time mainly the local variety.
5. A fourth attempt was made to plant *aman* (the local variety named *gainja)* in some areas in mid September. Even though the maturation period in 1998 was severely shortened farmers did this as a desperate move to grow some rice.

It is important to understand why farmers opted for a local variety instead of HYV and how they managed to get the seeds. The first reason behind this was they thought they might get at least some crop production from planting a local variety of *aman* and secondly there were survival issues for themselves as well as for their cattle. This plant would at least serve as a source of straw for cattle even if there is crop failure.

Box 5.2: Post Flood Plantings: Seedling Cost

The farmers' comments during group discussions provide useful detail.
"My homestead (one v-shaped roof made of tin which is divided into three rooms) was flooded and I stayed on the *machang* (usually located under the roof, farmers use the *machang* as a storeroom) for at least 7 days. It also happened a second time. *Bhai* (brother), during the whole inundation period I had tried to plant crops. I had a small crop of *gainja*, which did not even cover what I paid for seedlings. Even in better land in Belgacha there was a very poor crop of *gainja* in 1998"—Mr. Ali of Belgacha in Islampur.
It was evident that the total return from the crops was not even equal to what farmers paid for the seedlings. For example, the total cost of planting *gainja* was approximately 900 *taka* per *bigha* including cost for pesticide and fertilizer whereas the crop production was 750 *taka* per *bigha* [1].

Seedling purchase proved a critical aspect in *kharif* 2:

1. There were not enough seedlings to meet the farmers' demand. They had to take the trouble of collecting the seedlings (*gainja*, *haloi* and *kater*) from distant places, mainly upstream areas.
2. This suggests the farmers were not prepared for a multi-peak flood at that time.
3. Farmers were unsure about the quality of collected seedlings and were confused as to whether they would have satisfactory production.
4. They were unsure whether they would get enough return from the crops to at least meet the cost of the seedlings.

According to the farmers three things ensure the quality of crop:

1. The quality of seedling plants
2. Seedlings of a reasonable height
3. Normal conditions associated with growth of seedlings.

For late planting, the seedling quality was not good enough and they were not mature enough. For that reason, individual plants were not able to stand without support of grasses. Farmers pointed out that when they tried to get rid of the grasses to facilitate better crop production, the seedlings fell over.

In the group discussions the farmers expressed their anguish, saying that they did not receive any assistance or subsidy from the government for collecting seedlings, not even the third time when they had already lost standing crops twice in the same season [1]. They had to purchase the seedlings using their own resources. They did not have any stored seeds of the local variety, and they were not prepared to plant the local variety either. Some had to borrow money from local businessmen with high interest, others borrowed from *matbars* (rich landlords) but had to promise half of their "to be produced" crop. Some had to borrow the money from their wives, who had saved that little amount over long periods of time.

The farmers said that in the case of severe floods, particularly floods with multi-peaks, they would expect help from the Government. Surprisingly they did not ask for monetary help, rather they spoke of the need for communal seed beds and proposed that the Government could help by providing government owned high lands for this purpose, such as land beside rail lines.

"In the old days we had other local kinds of *aman*, like *shobaraj, bagha, chonda, boro digha, hash kolom, ponkhiraj, kartic jhula, roga jhula, echa kuri* and so on, which used to survive within the uprising of flood water in a rhythmic way. They are all gone now" [1].

Box 5.3: Experiments in Adjustment in Late *Kharif* 2, 1998 Flood

Some farmers in Panchbaria village in Islampur planted HYV *aman* on an experimental basis once flood water receded. The crops showed very slow growth and poor maturation. In addition to that, the colour of the rice was reddish instead of green and there was infestation with unusual pests in spite of using fertilizer and pesticides. It was late in the *kharif* 2 cropping season, and farmers said that the colder environment with fluctuation of temperature, particularly in the mornings, was not suitable for optimum growth of the crop.

In 1998, due to the unprecedented nature of the flooding, farmers tried to plant some cash crops like chili, onion, oil seeds, eggplants, potatoes and *kalai* in the transition period between *kharif* 2 and *rabi* once the flood water receded. As they lost *kharif* 2 production, they did not have any significant amount of rice to ensure survival up to the next crop production. They were looking forward to some production from cash crops to meet the production cost including agricultural inputs of *boro* or wheat in the next season and at the same time to be able to purchase food for survival up to next harvest.

Though some of the farmers planted oil seeds as a cash crop in this transition period, due to erratic rainfall they were not successful, as oil seeds need favourable soil moisture balance for proper growth and maturation. Other cash crops like chili and onion need almost similar soil moisture so in this situation these crops were also difficult to grow. Farmers commented that this erratic rainfall made the soil unsuitable for cultivation of potatoes as well.

Similarly the *char* land farmers planted *kalai* after the recession of initial flood water. These crops were destroyed by either heavy silt deposition or sand deposition. Farmers in the silt deposited area prepared to plant onion and potatoes but the sand deposited land is not suitable for these crops. They said they would grow nuts in the sandy land later in the season. They had a bumper production of onions in *char* land areas after the 1998 floods [1].

Farmers' decisions about planting crops are influenced by community decisions. They usually meet one another either in *bazar*, tea stalls, outside *Matbar's* house, mosques or on their way to these places and exchange their views and take advice from older farmers. This plays a significant role in their crop decision making. They usually go for the same crops in the same kind of lands and share information regarding where good quality seeds or seedling are available, or where good quality fertilizer and pesticides are available at a cheaper price, what fertilizer to use and in what amount etc. Sometimes they get useful assistance from local Block Supervisors. There are many other reasons behind these community crop decisions, for example if someone grows a different type of crop, there is a possibility that it would be infested by pests or attacked by birds and rats. It is evident that community membership and interaction play a major role in crop decisions by individual farmers and at the same time their decisions are affected to some extent by advice from professional people like Block Supervisors, *Union Parishad* members and school teachers. For example during the post flood period, the cost of onion seeds was so high that only affluent farmers could afford it, and marginal farmers had no other option except to plant cheaper crops like oil seeds and *kalai*. In spite of that, most marginal farmers opted for onion growing as this is more profitable (see Box 5.3). They did not hesitate to borrow money at high interest to purchase onion seeds.

5.4 Summary

The flood crop adjustment processes in response to three EFEs (in the 1988, 1995 and 1998) were assessed by Younus [1]. Each flood event and its characteristics were identified. The flood crop adjustments under normal flood situation in Islampur were discussed. How farmers usually adapt with floods within the normal flood situation in Islampur, and what are the normal crop decisions for various flood land groups, were discussed through farmers' response and field observation. Some examples of the information obtained by consulting the farming community are given above.

Regarding the multiple and longer duration flood as evidenced in 1998, some key issues are:

1. The number of times farmers planted seedlings.
2. Types of seedlings used.
3. The reason farmers chose HYV seedlings instead of local varieties in the first two attempts.
4. The reason behind choosing local varieties of *aman* seedlings in third and fourth attempts.
5. How farmers gathered *gainja* and *kater* seedlings from the upstream and what were the quality of these seeds;

6. How farmers afforded to buy those expensive seedlings and where the money came from.
7. Whether farmers had any return from experimental plantings of BR 12 HYV at the late period of *kharif* 2 crop season.
8. The way farmers make their crop decision at the period of transition between the *kharif* 2 and *rabi*; and the types of crops planted in *char* land area.

The study of the 1998 floods and the way farmers responded with crop adaptation gives important background information about various types of adaptation. To concludes, farmers planted HYV *aman* after flood water receded the first time, that is, they responded with routine adaptation. In the face of further crop damage in the same cropping season, they planted a local variety of *aman* considering the shorter maturation period of the local variety, that is, they adopted a tactical adaptation process. As the standing crops were damaged for the third time and too short a period was left in the *kharif* 2 season, farmers were desperate for some production to ensure survival. Some of them planted *aman* for the fourth time in spite of knowing that there is no guarantee of crop maturation and successful harvest. This is a prime example of an in-built adaptation process.

The next chapter will focus on V&A assessment and V&A issues will be categorized through Participatory Rapid Appraisal.

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Chapter 6
Community-Based Vulnerability and Adaptation Assessment: Informing the Future by Understanding the Past

Abstract The Intergovernmental Panel on Climate Change (IPCC) (Climate change 2007: impacts, adaptation and vulnerability, contribution of working group 2 to the 4th assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, p. 976, 2007 [1]) warned that the mega deltas in South Asia (e.g. the Ganges Brahmaputra Meghna River Basin) will be at great risk due to increased flooding, and the region's poverty would reduce the capacity of the inhabitants to adapt to change. This chapter provides a 'bottom up' impact approach which focuses on a methodological contribution for assessment of vulnerability and adaptation (V&A) in a riverine flood-prone area, 'Islampur' in Bangladesh, where various impact assessment guidelines have been taken into consideration. In this chapter the evaluation of V&A assessments at community level has been accomplished mainly by a weighted matrix index value derived from two participatory rapid appraisals (PRAs). Based on the distribution pattern of various weighted value indices of V&A issues, the required adaptation techniques can be adopted for immediate policy-making, and appropriate actions should be undertaken through establishing community-based adaptation committees (CBAC) (further detail in Younus and Harvey (Local Econ [2]).

6.1 Introduction

The concepts of vulnerability (in terms of loss) and adaptation (how farmers adapt to extreme floods) (V&A) in climate-change science are crucial in understanding the past, present and future consequences of extreme floods. These terms have been widely used in natural hazard literature and social science research in the 1980s, and the V&A concepts are increasingly debated [3–8].

V&A are complex terms and vulnerability is being used differently depending on the multi-disciplinary context [8–12]. In the global environmental change literature, specifically climate change literature, vulnerability is most often described as having three attributes [13]: (1) the exposure of a particular population, place or system (exposure unit) to a threat, or suite of threats associated with global environmental

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change; (2) the sensitivity of the population, place or system to the threat(s); and (3) the capacity of the population, place or system to resist impacts, cope with losses and/or regain functions when exposed to global environmental change. It is noted that exposure and sensitivity increase vulnerability while capacity acts to decrease it.

The main objective of this chapter is to present a methodological contribution for assessing V&A in response to three EFEs in Bangladesh. The evaluation of V&A assessments is determined mainly by a weighted matrix index value; this weighted matrix index value is derived from two participatory rapid appraisals (PRAs) carried out in 2006, and a questionnaire survey of over 140 households in seven *Union*s in the case study area of Islampur.

The term vulnerability has been applied in two broad ways: in the hazard literature in human geography, and through political economic perspectives. Various definitions have been offered by other writers, and they include the following:

1. Vulnerability "*…is the degree to which a system, or part of a system, may react adversely to the occurrence of a hazardous event*" ([14], quoted in www.vulnerabilitynet.org/).
2. Vulnerability comprises "*the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impacts of natural hazards*" ([5], quoted in www.vulnerabilitynet.org/).
3. "*Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and the variation to which a system is exposed, its sensitivity and its adaptive capacity*" [1].
4. "*Vulnerability defines the extent to which climate change may damage or harm a system. It depends not only on system's sensitivity but also on its ability to adapt to new climatic conditions*" ([15], quoted in www.vulnerabilitynet.org/).
5. "*Broadly defined, vulnerability is the potential for loss of property or life from environmental hazards*" ([16]; quoted in www.vulnerabilitynet.org/).
6. "*Individual and collective vulnerability and public policy determine the social vulnerability to hazards and environmental risks, defined as the presence of lack of ability to withstand shocks and stresses to livelihood*" (Adger [17]; quoted in www.vulnerabilitynet.org/).
7. "*Vulnerability is the capacity to suffer harm and react adversely*" (Kates [18], quoted in www.vulnerabilitynet.org/).
8. "*Vulnerability is the potential of loss*" ([19], quoted in www.vulnerabilitynet.org/).
9. Vulnerability includes "*the presence of factors that place people at risk of becoming food insecure or malnourished*" [20].

The definition used in this study is "vulnerability is the potential for loss of life or property or assets and consequent food insecurity from the environmental hazards of extreme floods" (after [16, 19, 20]). This definition encompasses vulnerability issues analyzed in this book and includes crop and agriculture-related loss, farmers' household and agricultural assets, community infrastructure and other socio-economic activities in areas of Bangladesh devastated by extreme floods.

6.2 Vulnerability and Adaptation Guidelines

The United States Country Study Program (USCSP) has given V&A assessment process guidelines [21], described in six steps:

1. Define the scope of the problem(s) and assessment process. Factors to be included are: identify assessment goals, define sectors to be studied, select the study region, select the time frame, determine data needs, develop the context for assessment, and develop a schedule;
2. Choose scenarios: socio-economic, environmental and climate-change in which socio-economic and environmental impacts have been assessed.
3. Conduct bio-physical and economic impact assessments and evaluate adaptive adjustments. The bio-physical impacts are determined by examining the effects of baselines, climate, and environmental scenarios on each sector (agriculture, grassland, livestock, forest, water, and coastline) and other resources such as fisheries, health and wildlife.
4. Integrate impact results. This approach deals with different integration issues: (a) integration across sectors, (b) integration into common metrics, (c) integration with mitigation analysis, (d) integration with other government programs.
5. Analyze adaptation policies and programs. Through primary-approach adaptations policy options are evaluated. Some key steps taken into consideration are vulnerability assessment, defining the scope of policy assessment within the selection of sectors and regions, research on adaptation options, sensitivity evaluation of current policies, and analysis of adaptation options.
6. Document and present results. After arranging adaptation workshops and obtaining feedback, the final report is produced.

6.2.1 Seven Steps of Climate Impact Assessment

The IPCC [22] has also given a significant guideline for assessing climate impact assessment, with seven main steps for analysis:

1. Define problem
2. Select method
3. Test method/sensitivity
4. Select scenarios
5. Assess biophysical impacts, assess socio-economic impacts
6. Assess autonomous adjustments
7. Evaluate adaptation strategies

In regard to steps 6 and 7, the IPCC technical guidelines for assessing climate change impact and adaptation include a proposed process, the "seven steps adaptation development strategy" [22]. The steps defined in that document are as follows: (1) Define objectives, (2) Specify important climatic impacts, (3) Identify adaptation options, (4) Examine constraints, (5) Quantify measures/formulate alternative strategies, (6) Weight objectives/evaluate trade-offs, (7) Recommend adaptation measures.

6.2.2 Adopted Vulnerability and Adaptation Steps

Based on the above literature (IPCC and USCSP) the following steps have been adopted to assess V&A in the Islampur case-study area in regard to three recent EFEs. The steps are:

1. Identification of the problem regarding V&A in the context of the case study area through PRA.
2. Define the objective within the environmental barrier/constraints (e.g. extreme flood event).
3. In accordance with the problem, identify vulnerable and adaptation issues and options.
4. Quantify the V&A issues through a weighted index scale.
5. Classify and rank the V&A issues.
6. Measure vulnerability and define autonomous adaptation measures.
7. Recommend strengthening of the vulnerability and autonomous adaptation measures in the light of climate change.

The UNEP, IPCC and USCSP guidelines are based on the measurement of impact assessment where selected scenarios and assessments of impacts are essential elements. IPCC [22] has followed seven steps of climate impact assessment. Under the future scenarios, biophysical, socio-economic and autonomous adjustment/adaptation factors have all been assessed. Development of future scenarios is a hard task and these types of impact assessments sometimes raise various scientific questions which cannot be answered by the assessment itself. Therefore the approach in this study is to assess V&A where vulnerable farmers' experiences and responses were taken into careful account. Various factors and vulnerability issues have been identified in response to EFEs. In accordance with the severity of the vulnerability issues, the farmers' actual adaptation measures have also been taken into account.

The vulnerable farmers, including their various professional associates at the grass-root levels (school teachers, businessmen, *Union Parishad* chairmen and members, students, block supervisors at the local agricultural office, and local political leaders) expressed their opinions on V&A, especially crop-flood adaptation techniques, how they adapt to various types of normal and EFEs, and the consequences of failures in crop-flood adaptation. Their responses have been the basis for exploring and evaluating adaptation issues and for identifying interventions which might be needed in the future to support the sustainable development of V&A assessment processes under climate-change conditions.

The evaluation of V&A assessment processes and their prioritization is based on the outcomes of a questionnaire survey of over 140 households in seven *Union*s in the case study area, Islampur (located on the Jamuna River in north-central Bangladesh), and the unpublished household flood damage report of Chinaduli *Union* in Islampur.

6.3 The PRA Sessions

Two Participatory Rapid Appraisal (PRA) sessions were conducted. In each session 50 % of participants were farmers who owned their land and who had extensive experience of farming. The other half of the attendees were people who represented the professions and community groups, and they included teachers, businessmen, *Union Parishad* chairmen and members (former/existing), students, block supervisors from the agricultural office, and local political leaders. The purpose of the PRA meetings was to enable development practitioners, government officials, and local people to work together to plan and implement appropriate programs. Within each session either semi-structured or specific questions were put to the members, their answers later being ranked in terms of priority. By this means no individual among the participants could independently deliver wrong or misleading information. If an individual provided incorrect, misleading or unsuitable comments then others would react negatively and say that the information was incorrect and at the same time they revealed the appropriate information along with the reasoning behind it. Through this process it was possible to obtain credible information, and the participants were able to agree and prioritize that information. This was an informal technique which helped to collect local rural information quickly. The most important benefit of PRA is that it deals with qualitative information which can be transferred into policy formation.

The sessions were conducted in Sapdhari *Union* and Maijbari *mauza* in Noapara *Union*, two remote *mauzas* in Islampur *Upazila* within Jamalpur district, about 250 km north of Dhaka. Much of the mainland of Sapdhari *Union* was submerged by the river Jamuna. Alluvium and sand-deposited *char* land (newly emerged land in the middle of the river) is now known as the Sapdhari *Union*.

A second PRA session was conducted in Maijbari *mauza,* a very remote area which is best accessed by boat, the connecting roads being extremely poor. From the Gothail Bazar it takes about 2 h to reach the meeting place by motor boat. The participants in the second meeting were asked to attend the residence of a school teacher to participate in the PRA session. About half of the attendees were farmers, and the rest were in other occupations such as school teachers, local politicians, students, small businessmen, and the block supervisor. Having personally experienced flood events they had intimate knowledge of the issues, and participants answered the semi-structured questions with enthusiasm. They showed an understanding of the calamity and its severity, and the practical knowledge needed to cope with EFEs. Even before the questions were asked, they gave vivid accounts of each flood event, its nature, duration, frequency, peak, extent of damage, and how they coped during and after the flood events.

Table 6.1 Category of vulnerability, weighted index scale and number of vulnerability issues

Category of vulnerability	Category of vulnerability weighted index scale as per Table 6.2	No. of vulnerability issues as per Table 6.2
1. High vulnerability	16–20	36
2. Medium vulnerability	11–15	04
3. Low vulnerability	6–10	02
4. Very low vulnerability	0–5	03
Total no of vulnerability issues		45

6.4 Assessment of Vulnerability

In this study, the weighted matrix index value is measured on a scale of 1–20. Twenty respondents were taken into account in each PRA session, 2 of which were conducted, one in Sapdhari *Union* and the other in Maijbari *mauza* under Noapara *Union*. This 1–20 scale is based on the responses of 20 participants to specific semi-structured questions. The scale (1–20) has been divided into 4 categories.

About 45 vulnerability issues were identified during the PRA sessions (Tables 6.1 and 6.2). Weighted values of vulnerability were designated as either high, medium, low, or very low. Against each vulnerability issue, the respondents from each area answered differently for each flood year (1988, 1995, and 1998). For example, when queried about sand deposition on the agricultural land in the 1988 flood, 16 out of 20 respondents in Sapdhari *Union* answered yes and 19 out of 20 in the Maijbari *mauza* answered yes. For the 1995 floods, in answer to the same question, the number of respondents in Sapdhari who said yes was 14, and in Maijbari 16 gave the same response. In regard to the same question for the 1998 flood 17 in Sapdhari and 20 in Maijbari *Union*s replied yes.

6.4.1 Discussion of the Issues

6.4.1.1 High Vulnerability

Box 6.1 High vulnerability issues with highest scores (weighted index 20)

One-time entire standing crop loss	Household damage related loss
3-times entire standing crop loss	Latrine washed out
	Agricultural input loss (pesticide, fertilizer)
Seedlings drowned	Watering cost loss
Seedbed loss	
Primary occupation loss	Labouring cost loss
Plant loss	Land preparation loss

Table 6.2 Reported vulnerability issues, category of vulnerability, and weighted index scale

Reported vulnerable issues	1988		1995		1998		1–20 > agreed weighted index	16–20 > HV 11–15 > MV 06–10 > LV 00–05 > VLV
	A	B	A	B	A	B		
1. One time entire standing crop loss	20	20	20	20	0	0	20	HV
2. Three times entire standing crop loss	0	0	0	0	20	20	20	HV
3. Seedling drowned	20	20	20	20	20	20	20	HV
4. Seed-bed loss	20	20	20	20	20	20	20	HV
5. Loss of stored seeds	20	19	18	15	20	20	19	HV
6. Seed-bed erosion	18	18	15	15	18	18	16	HV
7. Sand deposition on seed-beds related loss	20	19	16	15	19	20	17	HV
8. Sand deposition on the agricultural lands	16	19	14	16	17	20	17	HV
Occupational loss								
9. A. primary	20	20	20	20	20	20	20	HV
10. B. secondary	18	17	17	16	18	17	18	HV
11. C. tertiary	17	17	12	11	17	16	10	LV
12. Cattle loss	20	18	15	12	20	19	18	HV
13. Chicken loss	20	19	13	11	20	18	18	HV
14. Goat loss	19	19	14	10	20	20	15	MV
15. Ponds fish loss	20	20	15	16	20	20	19	HV
16. Culture fish pond loss	1	1	1	1	1	1	05	VLV
17. Poultry loss	2	3	1	2	1	2	02	VLV
18. Plant loss	20	20	16	17	20	20	20	HV
19. Household damage related loss	20	20	18	17	20	20	20	HV
20. Livestock shed loss	18	19	15	16	19	20	18	HV
21. Storage place loss	17	18	15	15	19	19	18	HV
22. *Kachari ghar* (formal lounge) loss	19	18	16	16	19	19	18	HV
23. Latrine washed out/loss	20	20	18	19	20	20	20	HV
24. Tubewell washed out/loss/non-functional	12	11	10	10	13	12	10	LV
25. Crop land loss due to erosion	20	10	14	08	20	15	18	HV
26. Agriculture input (fertilizer, pesticides) loss	20	20	20	20	20	20	20	HV
27. Watering cost loss	20	20	20	20	20	20	20	HV
28. Labouring cost loss	20	20	20	20	20	20	20	HV
29. Land preparation cost loss	20	20	20	20	20	20	20	HV
30. Ploughing tools loss	20	20	12	14	20	20	18	HV

(continued)

Table 6.2 (continued)

Reported vulnerable issues	1988		1995		1998		1–20 > agreed weighted index	16–20 > HV 11–15 > MV 06–10 > LV 00–05 > VLV
	A	B	A	B	A	B		
31. Loss of land due to erosion	20	16	14	10	20	15	18	HV
32. Crop land loss due to sand deposition	18	19	12	16	18	20	18	HV
33. Homestead erosion related loss	18	19	16	16	18	19	16	HV
34. Diseases related loss (e.g. diarrhoea, dysentery, gastroenteritis)	14	13	12	11	15	14	14	MV
35. Injury related loss	05	04	02	02	05	05	05	VLV
36. Fuel wood loss	16	14	12	10	18	17	18	HV
37. Village link road erosion	18	18	14	12	19	18	18	HV
38. Main road erosion	16	16	11	11	16	16	16	HV
39. School damage related loss	16	16	11	11	16	16	16	HV
40. Mosque damage related loss	15	15	11	11	15	15	15	MV
41. Utensil loss	20	20	15	16	20	20	19	HV
42. Evacuation cost loss	16	16	13	14	16	16	15	MV
43. Bedding loss	18	18	15	15	18	18	18	HV
44. School books loss	18	18	15	15	18	18	18	HV
45. Clothing loss	18	18	15	15	19	18	18	HV

n = 20; 1–45: issue number (i/n); *A* Sapdhari session; *B* Maijbari session; *HV* Highly Vulnerability; *MV* Medium Vulnerability, *LV* Low Vulnerability and *VLV* Very Low Vulnerability; 1988, 1995 and 1998: extreme flood years

All 20 farmers (100 %) reported losing their entire standing crops at least once in both the 1988 and 1995 floods. The 1998 flood hit three times in succession with an overall prolonged duration of the flood period, and all farmers reported losing their crops three times. In the three flood events all respondents reported plant loss, seedlings drowned, and seed-bed loss. Plant loss and inundation of homesteads was slightly less in the 1995 flood because it was of shorter duration. The flood events were devastating because almost all homes and all agricultural lands were submerged. The loss of primary occupation (farming) was reported by all respondents. A serious health problem, indicated by latrines being washed out, was reported by all respondents in both *Union*s for the 1988 and 1998 floods, and was only marginally less in the 1995 flood. All respondents reported agricultural-input and associated losses, namely watering costs, labouring costs, land preparation costs, and fertilizer and pesticides costs.

Box 6.2 High vulnerability issues with weighted index 16–19

Loss of stored seeds	Fuel wood loss
Secondary occupation loss	Village link road erosion
Cattle loss	Utensil loss
Chicken loss	Bedding loss
Pond fish loss	School books loss
Livestock shed loss	Clothing loss
Storage place loss	Seedbed erosion
kachari ghar (formal lounge) loss	Sand deposition on seedbed related loss
Crop land loss due to erosion	Sand deposition on agricultural lands
Ploughing tools loss	Homestead erosion related loss
Losing land due to erosion	Main road erosion
Crop land loss due to sand deposition	and school-damage related loss

An index weighting of 18–19 was allocated to the land and household losses shown in the box above. Farmers usually store seeds for the next cropping season and try to save them at any cost. Seeds are stored in a *macha*, a storage area beneath the roof of each farmhouse, and so they are high above the ground and generally safe from rising water. However, the stored seeds were damaged in the severe 1988 and 1998 floods, so indicating the extremely high floods (sometimes above the rooftops) of those years. The result (issue 5) also indicates that the 1995 flood was more severe in Sapdhari (A) compared to Maijbari (B). Responding to secondary occupation loss, the survey results show that in Maijbari relatively few people had alternative or secondary forms of occupation, but on the *char* land people were more likely to have a secondary occupation such as day-labouring or rickshaw pulling on the mainland. For cattle loss (issue 12), the results show that flood severity was so extreme in 1988 and 1998 that even cattle could not be saved. Responding to household chicken loss (issue 13), goat loss and pond-fish loss, there was a large difference between the 1988 and 1998 floods and the 1995 flood. Similarly, livestock shed loss, *kachari ghar* (formal lounge) and storage-place losses were less severe in the 1995 flood (Table 6.2). It was noted that the number of households with *kachari ghar* was much less in *char* land Sapdhari *Union* (suggesting poor socio-economic conditions).

For crop-land loss due to erosion (issue 25), there was a marked difference between Sapdhari and Maijbari in all flood years (Table 6.2). This indicates that erosion is more severe in the *char* lands compared to the mainland, though normally the Maijbari (mainland) is highly prone to river erosion. For ploughing-tool loss (issue no. 30) the results suggest that the floods were so severe in 1998 and 1988 that even the heavy ploughing tools stored beside households were washed away.

Crop-land loss due to sand deposition (issue 32) was higher in all flood years in both Maijbari than Sapdhari; consequently, farmers in Maijbari usually plant sugarcane instead of rice. Fuel-wood loss in all flood years was slightly higher in Sapdhari than in Maijbari. Village link road loss was understandably higher in the two more severe flood years, 1988 and 1998. The losses of utensils, bedding, clothing and school books were clearly greater in the same high-flood years than in 1995. The loss of these household items indicates that the flood events were so severe that people were forced to evacuate at very short notice and were unable to carry bedding, clothing and utensils.

Six vulnerability issues related to erosion and sand deposition received a weighted value score of 16–17. They were seedbed erosion, sand deposition on seedbed related loss, sand deposition on agricultural lands, homestead-erosion related loss, main-road erosion, and school damage loss. Seedbed erosion was significant in both *Unions* but more severe in 1998 when it occurred three consecutive times in both places. The data for loss due to sand deposition on seed beds suggests that Maijbari was more prone to sand deposition than Sapdhari, and the sand deposition was extreme in the 1998 flood compared to the other two flood events. After the 1998 flood farmers started cultivation of sugarcane as the sandy land was then more suitable for that crop. Homestead-erosion loss was high in all flood years. The portion of Sapdhari *Union* connected to the mainland was almost totally eroded after the 1998 flood, and in 2006 it was noted that only a very small portion of mainland Sapdhari *Union* remains in existence. Main-road erosion and school damage losses were also very high in 1988 and 1998; these were repaired after floods under a food-for-work project executed by the *Union Parishad* concerned.

6.4.1.2 Medium Vulnerability

Four issues were identified as being of medium vulnerability, each being accorded a score between 11 and 15. These are: goat loss, disease-outbreak related loss, mosque-damage related loss, and evacuation cost loss. Goat loss was high in the 1988 and 1998 floods indicating that those floods were so severe that farmers could not save their livestock. Sapdhari respondents reported higher losses than Majbari in 1995, but both were less than in the high-flood years. Mosque damage was similarly less in the 1995 flood. Evacuation-cost loss was in the medium vulnerability range for all flood years, but a little higher in 1988 and 1998. People mainly evacuated to the main road where members of the community who had boats helped others, and those who could afford to vacate their homes did so early. In *char* land Sapdhari people were forced to evacuate when their roofs became submerged.

6.4.1.3 Low Vulnerability

Two issues were identified as low vulnerability, scoring 6–10. They are tertiary-occupation loss and tube-well washed out/non functional loss. Tertiary occupation loss was high in 1988 and 1998 but received a low weighted index because most farmers had no tertiary occupation. Tube-well loss was relatively low in all flood years and so received a low vulnerability value, all respondents agreeing on a low weighted index. Although some tube wells were non-functional after receding floods, the majority were not washed out, and because of their importance to farming activities and drinking water, community members collected money to repair them immediately.

6.4.1.4 Very Low Vulnerability

Three vulnerability issues were ranked very low (0–5), namely culture fish-pond loss, poultry loss, and injury related loss. For culture fish-pond loss, the response was 1 for both *Unions* for all three flood events; there were no large-scale fish culture ponds in the case study area. Similarly, poultry-loss received a low vulnerability index because there was no large-scale poultry farming in the case study area; only subsistence chicken raising is practiced in the area.

6.5 Assessment of Adaptation

6.5.1 Definition of Adaptation

As with vulnerability, numerous definitions of 'adaptation' are found in the literature, for example:

1. "*Adaptation is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities*" [1].
2. "*Adaptation to climate is the process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides*" ([3], quoted in [23]).
3. "*…the term adaptation means any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change*" ([24], quoted in [23]).
4. "*Adaptation involves adjustments to enhance the viability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events as well as longer term climate change*" ([25], quoted in [23]).
5. "*Adaptation is a key response to reduce vulnerability to climate change*" [26]

The definition of 'adaptation' adopted in this book is considered below. It reflects aspects of all of the above definitions.

6.5.2 Adaptation: Definition and Characteristics in the Context of the Case Study Area

Adaptation is a process which interacts with environmental extremes. Within the extremes people are capable of adjusting up to a threshold level, beyond which they cannot cope. Human beings try with all means available to deal with environmental extremes, but when conditions become too severe they reach a threshold where they cannot make any further meaningful adjustments. Crop-flood adaptation processes in response to different bio-physical characteristics of flooding in Islampur have been studied and it has been found that the multi-peaks and longer-duration floods, as evidenced in the 1998 flood, terminate the capacity of the normal threshold of autonomous crop-flood adaptation [27–29]. At this stage (when the adaptation capacity threshold is exceeded) some tactical interventions are needed. For example in the *kharif* 2 cropping season farmers plant a local variety of *aman* instead of HYV when the flood hits several times within a short period.

Adaptation is a process by which vulnerable people seek to cope with environmental extremes. Environmental extremes tend to disrupt adaptation capability but it is the nature of humans to try to adjust to the changed environment in order to survive. For example, after huge sand deposition in the agricultural land following the flood events, farmers plant crops such as sugar cane and peanuts, both of which grow well in sandy soil.

The type of land and the flood regime both control adaptation decision-making. For example, in flood prone areas farmers usually choose to plant wheat on higher ground.

Adaptation capacity is being reduced because of exposure to environmental extremes (particularly in developing countries) due to resource constraints, poor infrastructure, low household incomes, the small sizes of farms, high population growth rate, etc.

Adaptation is climate-sensitive. Global warming and sea-level rise might have serious implications by causing environmental extremes. Between 1988 and 1998, three major floods hit the study area. Between 1998 and 2006 more extreme floods occurred which significantly influenced farmers' adaptation capacity. With every extreme flood, some farmers are forced to sell their belongings and fixed assets such as land, stock, houses, trees, etc. Thus with every major flood the number of poor and landless increases, making them ever more vulnerable and unable to cope with even moderate or low-level floods in the following season.

Extreme environmental events increase landlessness as discussed in Chap. 7. From information provided by respondents in the PRA sessions for this research, the rate of land sales rose with each major flood. Farmers mainly sold their land to local people who were working in urban centres and who were earning good money.

Extreme environmental events, such as floods, force marginal farmers to migrate to urban centres, especially in cities. These flood victims lose their crops, sell land and other fixed assets, and finally, being unable to find job as labourers or as workers on other farms, have no choice but to migrate to cities for food and shelter. They ultimately become environmental refugees and live in slums, finding work as rickshaw pullers or day labourers.

Every extreme flood reduces farmers' coping ability to manage normal flooding for the following year. As they lose their crops and stored seeds they also lose their ability to afford seedlings, cultivation costs, watering costs, and agricultural input costs for the next cropping season, so becoming even more vulnerable.

Environmental events, such as floods, tend to erode local traditional resilience. Small flooding events and unplanned embankments encourage farmers to plant HYV or hybrid varieties as a part of the adaptation process. But extreme flood events do not permit them to do so. The PRA sessions indicated that traditional varieties of flood-resistant crops which were available 25–30 years ago are now extinct. The traditional deep-water *aman* grew slowly as water depth gradually increased with the rising of floodwaters. Government organizations protected the floodplains through establishing embankments and structures such as dams and sluice-gates, and as a consequence the rice-growing areas have been well protected from normal floods so that deep-water *aman* is now not grown at all and the seed is not available in the flood-prone areas. With increased frequency of severe flooding (as envisaged in climate change scenarios) when water rises very rapidly, breaches embankments, and destroys crops, it would not be feasible to practice deep water *aman* cropping in this situation.

6.5.3 Adaptation Measures

Adaptation measures are categorized into six forms (UNEP and IES Handbook, 1996, pp. 2-10–2-11):

a. Bearing the losses: this is the baseline response of 'doing nothing' but bearing any losses that may result. This occurs when those affected have no capacity to respond in any other way. For example, in extremely poor communities or when the costs of adaptation measures are very high compared to the risk or expected damages.
b. Share losses: this adaptation response means sharing the losses among the wider community. In traditional societies this happens when loss is shared with extended families, with the village, or the local community. In affluent societies losses are shared through public relief, rehabilitation, and reconstruction.
c. Modify the threat: when the risks are identified it is possible to exercise a degree of control over the environmental threat, for example by building dams and dikes in an attempt to control floods. Such measures are referred to as 'mitigation' of climate change and are considered to be in a different category of response from adaptation measures.

d. Prevent effect: this refers to adaptation measures to prevent or offset the effects of climate change and variability. For example, when an extreme flood damages the production of HYV *aman* crops then farmers select a local variety of *aman* as it has a shorter duration for maturation in the *kharif* 2 cropping season.
e. Change use: when threat of climate change or the consequences of a calamity make the continuation of an economic activity impossible or risky, changing the use can be considered. For example, after EFEs when sand has been deposited on the agriculture lands then farmers switch to planting sugarcane instead of rice.
f. Change location: this refers to change of location of economic activity. For example, following loss of agricultural lands and erosion of homes, flood victims are forced to migrate to the nearest cities and change their economic activity in order to survive.

Burton et al. [30] added two more adaptation categories; these are: (g) research and (h) education to inform and encourage behavioural change.

IPCC mentioned another category of adaptation, called restoration. It has been described as follows, "*Restoration, which aims to restore a system to its original condition following damage or modification due to climate (for example a historical monument susceptible to flood damage). This is not strictly an adaptation to climate as the system remains susceptible to subsequent comparable climatic events*" [31, pp 2–11].

6.5.4 Types of Adaptation

Adaptation has been grouped into several types [12, 22, 32]. These are

a. **Inbuilt adaptation** is an unconscious or automatic reaction to an exposure to a climatic perturbation. Sometimes inbuilt adjustments to climate that occur over a period of time, or adjustments initiated only under a particular combination of conditions, are difficult to assess.
b. **Routine adaptation** is the conscious response to variation in climate that is part of the routine functioning of a system. Such adaptation is often predictable and can be represented in models. For example, in regions where flood is a recurrent phenomenon farmers usually adapt to floods and plant their crops accordingly, and so these adaptations come about automatically.
c. **Tactical adaptation** represents responses to environmental factors such as floods that require behavioural change. It is not easy to separate autonomous tactical adjustments directly related to climate change from adjustments made in response to other factors influenced by climate change [32]. For example, when there is not enough time left for HYV crops due to prolonged or consecutive flood events farmers switch to local varieties of crops which need less time for maturation, as evidenced in the 1998 flooding.

d. **Autonomous adaptation** to climate change is essentially an unconscious process of system-wide coping, most commonly understood in terms of eco-system adjustments [32] and natural hazards. For example, farmers adjust to floods automatically over time and cultivate the right seedlings at the right time on the land. This kind of crop-flood adaptation is autonomous. Since 1996, the climate-change literature has started to focus on this issue [1, 32].
e. **Reactive adaptation** involves a deliberate response to a climatic shock or impact, in order to recover and prevent similar impacts in the future.
f. **Anticipatory adaptation** involves planned action, in advance of climate change, to prepare for and minimize its potential impacts. For example, enhancing the buffering capacities of natural systems in the face of climate extremes.

6.5.5 Adaptation Assessment by Weighted Index

The adaptation weighted matrix index assessment value introduced in this study is measured in the same way as vulnerability (on a scale of 1–20). In accordance with priority of the need, the adaptation assessment measurement scale has been divided into 3 categories (Table 6.3).

About 40 adaptation issues were identified during the PRA sessions (Tables 6.3 and 6.4). The number of respondents was 20, as before. For each adaptation issue the respondents answered differently for each flood year (1988, 1995, and 1998). For example, in seeking loans for seedlings from professional lenders, wealthy people, rich relatives, local landlords, banks, or NGOs in the 1988 and 1998 flood years, 20 respondents in both Sapdhari and Maijbari answered yes, whereas 15 in Sapdhari and 16 in Maijbari answered yes to the same question for the year 1995. Some of the adaptation issues were discussed with regard to cut off points (when farmers lose their ability to cope), while others were discussed in general with regard to during-flood and post-flood scenarios, which were taken into account.

6.5.5.1 Urgent Adaptation

Referring to Table 6.5, issues shown as urgent adaptations require high priority. Twenty of the 40 adaptation issues shown in Table 6.5 have been identified as urgent.

Discussion

After 1988 and 1998 all respondents sought loans for seedlings. During the crucial post-flood period farmers usually have no alternative but to borrow money from

Table 6.3 Category of adaptation, its weighted index and number of adaptations issues

Category of adaptation	Category of adaptation weighted index as per Table 6.4	No of adaptation issues as per Table 6.4
Urgent	16–20	20
Intermediate	06–15	13
Low	0–05	07
Total		40

local professional lenders who may charge high interest. At times, rich relatives or local wealthy persons/local landlords lend money with low interest or no interest. Not many people seek help from banks or NGOs as it is not easy to fulfill their requirements to be eligible for a loan. According to some participants, they had to bribe local bank or NGO officials to get a loan.

As the flood came three times in 1998 and its duration was longer, the *kharif* 2 planting season became shorter, therefore farmers needed a local variety of *aman* which has a shorter maturation time. The need for HYV *aman* was high in both *Unions* in the 1988 flood. This adaptation technique is urgently required during the post-flood period when there is enough time to grow HYV *aman* seedlings, as occurred in 1988. It was widely used in response to the 1988 and 1995 floods. In the severe flood of 1998 HYV was not needed because the flood came three times and was of longer duration, leaving no time for HYV maturation. All respondents needed to grow seedlings on flood-free high ground beside rail lines or roads immediately after the 1998 flood. Cropping and agricultural input, labouring, land preparation and watering costs are crippling to the marginal farmers; all respondents needed money for those purposes [33] (**Appendix v**) [27] (**Appendix vi**). Provision of finance as an adaptation technique—requiring access to loans—was identified as urgent during the post-flood period. All respondents mentioned the need for easy-access loans following all three extreme floods.

For the 1988 and 1998 floods, all respondents said they needed to establish flood shelters on flood-free high land for multipurpose use. Multipurpose shelters on higher ground can be used as schools, community centres, and as places for drying wet crops. Respondents also needed immediate shelter (mainly beside main roads, or in schools, colleges, mosques, *madrassas, or* government offices) after extreme floods. Participant responses indicate that these needs were felt very strongly during the 1998 flood period.

Most respondents spoke of the need for governments to provide production equipment, seeds, fertilizers, and other agricultural inputs through the local agricultural office. However, governments have no funds for this purpose even though farmers need this assistance after extreme floods. This is an urgently-needed adaptation technique and if governments could provide some farm aid through local agricultural offices the flood victims would be greatly helped. A majority of respondents said they needed immediate relief facilities. For relief and assistance, flood-stricken people mostly trust the armed forces rather than the local *Union Parishad*, where corruption is common. For food relief, vulnerable group feeding

Table 6.4 Adaptation issues, category of adaptation, and weighted index scale

Adaptation Reported adaptation factors/issues	1988		1995		1998		1–20 > agreed weighted Index	16–20 > urgent 06–15 > intermediate 00–05 > low
	A	B	A	B	A	B		
1. Look for loans for seedlings from professional lenders/wealthy persons/ rich relatives/local land lords/banks/NGOs	20	20	15	16	20	20	20	Urgent
2. Look for loans for immediate foods	15	15	08	07	16	16	15	Intermediate
3. Selling homes	15	14	08	07	16	16	15	Intermediate
4. Selling lands	16	17	14	15	16	18	16	Urgent
5. Selling trees	12	17	12	14	16	18	17	Urgent
6. Selling personal belongings	12	11	09	08	14	16	10	intermediate
7. Shifting house/s due to river erosion	10	10	9	8	12	11	11	Intermediate
8. To move temporarily to other cities/towns in search of works	16	15	13	12	17	16	17	Urgent
9. Change the occupation (*rickshaw* pulling, day labourer etc.)	11	11	9	9	13	12	12	Intermediate
10. Partial starvation (one meal per day instead of two or three)	17	16	13	13	17	17	16	Urgent
11. Change of food habits (looking for alternative/unconventional food)	11	12	10	9	12	12	12	Intermediate
12. Migration to other cities (Dhaka, Chittagong, Jamalpur, Mymenshing)	4	4	3	2	5	5	5	Low
13. Looking for fishing facilities	4	3	1	2	5	5	5	Low
14. Looking for small boats for transport	2	2	1	2	3	3	3	Low
15. Need for immediate food (*chira*, puffed rice, molasses etc.)	15	15	12	13	17	17	17	Urgent
16. Need for immediate shelter (school/college, mosque/*madrasa*, besides main roads, government offices)	17	17	13	14	18	18	18	Urgent
17. Need for materials for building temporary shelter/s (bamboo platforms on top of the roofs)	17	16	11	12	17	16	16	Urgent
18. Need to raise the boundary of the ponds or need to put net around the boundary of ponds in order to prevent fish being carried away by flood waters	1	1	0	0	1	1	1	Low

(continued)

Table 6.4 (continued)

Adaptation								
Reported adaptation factors/issues	1988		1995		1998		1–20 > agreed weighted Index	16–20 > urgent 06–15 > intermediate 00–05 > low
	A	B	A	B	A	B		
19. Need to make floating beds made by banana trees in order to grow vegetables/seedlings	1	1	0	0	1	1	1	Low
20. Need local variety *aman* seedlings	15	15	11	12	20	20	20	Urgent
21. Need HYV *aman* seedlings	20	20	18	18	12	12	20	Urgent
22. Need to grow seedlings on flood-free high lands immediately (beside rail-lines, besides roads)	18	18	15	16	20	20	20	Urgent
23. Relief through VGF cards within the supervision by *Union* Council	16	16	14	14	16	16	16	Urgent
24. Need immediate food for survival	15	15	13	13	16	16	16	Urgent
25. Need for money for next season's/transition period's cropping and agricultural inputs, labouring/land preparation and watering	16	16	15	16	20	20	20	Urgent
26. Need for immediate shelter B/A	15	16	13	14	16	16	16	Urgent
27. Need to regulate price of essentials in open markets	10	11	8	9	12	12	12	Intermediate
28. Need for work (as labourer in rich landowners' agriculture land preparation)	15	15	12	11	16	16	16	Urgent
29. Need for medicine/health care	13	13	11	10	14	14	14	Intermediate
30. Need to establish dams for river flow control to prevent river bank erosion/submerge	5	11	4	10	5	12	12	Intermediate
31. Need to do river dredging for quick drainage of river waters	04	05	02	03	05	05	05	Low
32. To provide production equipments/seeds/fertilizers/agricultural inputs through local agricultural office	18	18	15	16	18	18	18	Urgent
33. Need for veterinary help (medicine and expertise)	03	03	01	01	04	04	04	Low
34. Need to establish easy communication	10	10	06	06	10	10	10	Intermediate
35. No help needed/required	08	09	06	08	10	10	10	Intermediate

(continued)

Table 6.4 (continued)

Adaptation								
Reported adaptation factors/issues	1988		1995		1998		1–20 > agreed weighted Index	16–20 > urgent 06–15 > intermediate 00–05 > low
	A	B	A	B	A	B		
36. Easy access to bank/government/NGO's loans with low interest	20	20	15	16	20	20	20	Urgent
37. Need for immediate relief facilities (by the army)	17	17	15	16	18	18	18	Urgent
38. Need to ensure effective distribution of relief goods	14	14	10	11	15	15	15	Intermediate
39. Rebuilding homesteads after flood (*bhita uchu kora*)	13	14	08	09	14	14	14	Intermediate
40. Need to establish flood shelters in flood-free high lands; these should be multi-purpose (schools, drying wet crops)	20	20	15	16	20	20	20	Urgent

n = 20; *A* Sapdhari session; *B* Maijbari session; 1988, 1995 and 1998: extreme flood years

Table 6.5 Urgent adaptation issues grouped according to weighted index

Weighted values index	Adaptation issues	
20	Look for loan for seedlings	Need for easy access to loan from Banks, government, or NGOs, with low interest
	Need for local variety of *aman* seedling	
	Need for HYV *aman* seedling	Need to establish flood shelters in flood-free high land (multipurpose use)
	Need to grow seedlings in flood-free high land	
	Need for money for next season's	
	Cropping and agricultural inputs (fertilizer, pesticide) labouring/land preparation and watering	
18	Need for immediate shelter	
	Provide production equipment/seeds/fertilizer/agricultural inputs through local agricultural office	
	Need for immediate relief facilities	
17	Selling trees	
	To move temporarily to other cities/towns in search of work	
	Need for immediate food	
16	Selling lands	
	Partial starvation	
	Need for materials for building temporary shelters	
	Relief through vulnerable group feeding (VGF) card	
	Need for immediate food for survival	
	Need for shelter	
	Need for work	

(VGF) cards are distributed under supervision of the *Union* council. This technique is not widely used, particularly in the post-flood period, but is essential for landless and marginal farmers, and more such people need to be covered by this project. Respondents reported that the VGF card scheme is politically biased and severely mismanaged.

Materials for building temporary shelters (bamboo platforms above house roofs) while the floods rose were widely needed in the extreme flood years, and particularly in Sapdhari *char* land after floods recede. The government could help by providing plastic poles which would be more durable. The desperate adaptation response of selling land was seen after the extreme floods of 1988 and 1998. Partial starvation (one meal per day instead of two or three) was another adaptation technique born of desperation. Participants reported that this practice was significantly higher in Sapdhari *char* land as the *char*-land people are more vulnerable and poorer than mainland farmers. Adult women commonly go without food in order to feed their children.

Hunger was particularly evident during the 1998 flood, especially in the *char* lands. There was a need for immediate food for survival during the flood period in both *Union*s. Similarly, there was an urgent need for immediate shelter. People mostly took refuge (often without overhead covering) on both sides of main roads in whatever open spaces they could find. As there were no latrines the health issue was a constant risk and diarrhea was common.

Regarding the need for work (as a labourer for land preparation in the rich landowners' farms) three-quarters of the respondents answered in the affirmative for the 1988 and 1998 extreme flood years. This adaptation technique was strongly supported. Farmers want to remain independent of government help if they can, but if unable to find work or cope with extreme events they need other forms of immediate assistance.

6.5.5.2 Intermediate Adaptation Issues

Thirteen adaptation issues have been identified as intermediate, with a weighted index of 6–15 (Table 6.6).

Discussion

With respect to seeking a loan for immediate food, three-quarters of the farmers responded positively for the 1988 and the 1998 flood events in both areas; for the 1995 flood, positive responses were relatively low. Selling homes or parts of homes was an intermediate adaptation in both *Unions* for all flood years, especially in the 1998 and 1988 floods. This expediency was more prevalent in the *char* lands. There was a need to ensure an effective distribution of emergency supplies in both Sapdhari and Maijbari, for sometimes flood stricken-people are dependent on relief, and proper distribution of aid is crucial. During floods, and in the

Table 6.6 Intermediate adaptation issues grouped according to weighted index

Weighted values index	Adaptation issues	
6–15	Look for loans for immediate food	The need to regulate price of essentials in the open market
	Selling homes	The need to establish dams for river flow control to prevent river bank erosion
	The need to ensure effective distribution of relief goods	Shifting house due to river erosion
	The need for medicine/health care	Selling personal belongings
	Rebuilding homesteads after flood	The need to establish easy communication
	Change of occupation	
	Change of food habits	No help required

immediate post-flood periods, water-borne diseases are prevalent so the need for medicine and health care is an important adaptation technique. Local health care centres and NGO resource-distribution depots are usually inadequate at such times. Rebuilding homesteads after floods is another obvious need, but when money is unavailable farmers temporarily repair their houses with bamboo and jute straw in the hope that money will come in after the next harvest.

Regarding changes in occupation in both affected areas, about half of the respondents reported changing their occupations after the floods of 1988 and 1995. For 1998 the figures were higher in both *Unions*. Displaced farmers looked for temporary employment, such as day-labouring or rickshaw-pulling, in towns or in local areas, both occupations offering only minimal wages.

Questioned about changes in food habits (seeking alternative or unconventional foods), slightly over half of the respondents said that they had done so in all severe flood years. Regulating the prices of essentials in the open market is therefore an important adaptation issue which needs to be addressed by governments during post-flood periods. This is a serious concern because usually the prices of rice and other essentials soars beyond the reach of marginal farmers after floods.

About a quarter of respondents in Sapdhari and about half in Maijbari stated that there was a need to establish dams for river control to prevent river-bank erosion. The number of supporters was higher in Maijbari, which is erosion-prone mainland, compared to the *char* land of Sapdhari. The popular demand in Maijbari is for strong embankments and dams along the river Jamuna. Regarding the issue of moving houses away from eroding river-banks, the number of supporters was 10 for 1988 in both areas, whereas it was 9 and 12 for Sapdhari for 1995 and 1998, and 8 and 11 for Maijbari for those same years.

After devastating floods, people tend to sell whatever personal belongings they have, such as small ornaments and utensils. The need for better communications in the post-flood periods was supported by more than half of the respondents in regard to the severe flood years of 1988 and 1998. Better communications in the post-flood period is also considered to be important, an issue supported by about

Table 6.7 Low adaptation issues grouped according to weighted index

Weighted values index	Adaptation issues	
0–5	Migration to other cities	Looking for small boats for transport
	Looking for fishing facilities	The need to raise the boundaries of ponds
	The need for river dredging for quick drainage of river water	The need to make floating beds using banana trees in order to grow vegetables/seedlings
	The need for veterinary help (medicine and expertise)	

half of the respondents. If good communications exist between the *Unions* and Islampur *Upazila* headquarters, it is easier for flood victims to find out about the availability of temporary employment. Asked simply if they needed help after the three extreme flood years, less than half of the respondents in both Sapdhari and Maijbari said they did not need any help, an instance of farming communities asserting their independence. Some are apparently so accustomed to floods that they can cope without any help and so do not ask for any, as evidenced by the responses of such people in both PRA sessions.

6.5.5.3 Low Adaptation Issues

Seven adaptation issues have been grouped as low adaptation issues with a weighted index of 0–5 (Table 6.7).

Though the numbers are small, a certain percentage of people migrate after each extreme flood, as evidenced by the responses above. Regarding looking for fishing facilities, a small number of respondents said that they look for nets or small boats during and after floods so that they can sustain themselves by fishing. With respect to river dredging, again a small number asked for planned adaptation by dredging the river-bed. Addressing the need for veterinary help, only a few reported looking for veterinary help during and after floods. A small number of respondents stated that they had sought small boats for transport during and after the flood period. A few people mentioned other adaptation techniques such as raising boundaries of ponds, the need to encircle ponds with nets to prevent fish being washed away, and the need to make floating beds for growing vegetables or seedlings. Farmers wanted to embrace these forms of low-cost innovative adaptation ideas mainly after the extreme flood of 1998.

6.6 Summary

In this chapter, the definitions and characteristics of V&A issues have been reviewed in the context of the riverine case study area. Two Participatory Rapid Appraisal (PRA) sessions were conducted at community level (*mauza*). Twenty people attended each session, and of these 50 % were vulnerable farmers and the rest were from different local professional groups such as teachers, *Union Parishad* chairmen, small businessmen, students, block supervisors at local agricultural offices, and local politicians. Through these PRA sessions V&A issues were assessed at the grassroots level. The study dealt with the understanding of issues of V&A techniques in response to three EFEs. The issues were categorized on the basis of a weighted matrix index. Vulnerability issues were classified into four categories according to their respective degree of severity, and these together offered a genuine picture of vulnerability in their particular flood-prone area. This type of information can be of immense value if it is incorporated into policy-making and if it contributes to worthwhile action by authorities.

Adaptation issues were classified into three categories and this revealed that some inbuilt, routine and tactical adaptation techniques are already being implemented; but there are other high-priority adaptation techniques for which flood-affected people need support. When the adaptation capacity threshold is exceeded, tactical interventions (adaptation issues) can be rapidly identified and adopted.

The use of PRA sessions for collecting data makes an important methodological contribution for assessing V&A because the required adaptation techniques can be adopted immediately in policy-making, and appropriate actions can be undertaken promptly. If future climate-change and sea-level rise cause more frequent EFEs in such fragile environments as Bangladesh, some of the measures described above could reduce vulnerability and help to ensure sustainable development of this region.

It is increasingly recognized that climate change represents an unprecedented global challenge. Adaptation issues must be given priority in policy making, especially in those developing countries which will be most affected. In regard to EFEs that result from climate-change conditions, these findings from the past three EFEs will still be relevant in terms of understanding the V&A issues. If today's policy-making takes into account the findings it will help reduce vulnerability in the future. The study suggests that the community-based V&A assessment awareness programs, which are emphasized in the Initial National Communications to the UNFCCC and the National Adaptation Program of Action (NAPA), can deal at grassroots levels with helping farming communities adapt within a system nearing its threshold, and it also indicates what those communities can do to recover from future flood events under climate change conditions.

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Chapter 7
Failure Effects of Autonomous Adaptation

Abstract This chapter focuses on 'autonomous adaptation' and has one aim. It assesses the economic consequences of the failure effects of autonomous adaptation in response to extreme flood events. The chapter finds that Bangladeshi farmers are highly resilient to extreme flood events, but the economic consequences of failure effects of autonomous crop adaptation on marginal farmers are large. The failure effects are defined as total input costs plus the small profit (otherwise) made from selling the small surplus remaining from subsistence needs. The total input costs increase with the number of flood events in the studied area. Total agricultural cost includes cost of seedlings, fertilizer, pesticides, land preparation, human labour and watering. The chapter concludes that the economic loss accelerates food insecurity and could ultimately lead to human insecurity in Bangladesh, which could be exacerbated by the effects of climate change.

7.1 Introduction

'Autonomous crop adaptation' in relation to EFEs in mega-deltas in South Asia, particularly in Bangladesh, is a process which is commonly practiced by marginal farmers. Crops are grown successfully to maturity when farmers respond to floods by managing the effects of the floods in a natural way, and use it to their benefit. This is called 'autonomous flood-crop adaptation' (ACA) and is performed by farmers automatically, with no external interventions. The successful practice of ACA has been crucial to economic development in this region.

Farmers have readily adapted to normal floods, and to some extreme floods, which permit them to grow crops within the usual length of the cropping season (*kharif* 2), but multiple-peak and long-duration floods, which shorten the cropping season, cause economic loss and crop failure as farmers lose their ability to cope with such floods through the usual process of autonomous crop adaptation. Crop failure occurs when floods do not permit crops to reach maturity and the rice harvest fails. The economic impacts of failure of autonomous crop adaptation in

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relation to EFEs are large; flood-crop adaptation involves a significant economic investment (cost of seedlings, land preparation, agricultural input, labouring, and watering) in terms of farm incomes and in relation to their particular socio-economic and demographic settings. In this chapter the economic effects will be assessed as the 'failure effects of autonomous crop adaptation'.

The issue of autonomous crop adaptation and the failure effects of ACAs in response to EFEs in Bangladesh has not previously been explored in detail in academic literature [1–29]. Neither has climate-change literature associated with agriculture, adaptation, and natural hazards pin-pointed these issues [30–50]. The above literature has been reviewed in Chaps. 1, 3 and 6.

7.2 Autonomous Crop Adaptations in Response to Flooding

The crop adaptation process in Bangladesh is autonomous; that is, farmers adapt their lives and their practices quite automatically in response to flood conditions. There are no mechanical adaptations in the farming system, and farmers' adaptive capacity is low and climate-sensitive. Farmers build their ACA capacity in response to flooding. Timing, depth, duration, multiple-peaks, and single-peaks of floods are the determinants which regulate the ACA process. The nature of each flood controls the ACA process. If the flood comes in the late period of the cropping season then farmers decide to plant the local variety of *aman* crop (paddy) instead of planting HYV *aman* because the local variety of *aman* takes a shorter time to mature, which means farmers harvest the local variety crops within a shorter time. Normally, farmers plant the HYV *aman* which grows within tolerable flood waters, and it usually takes a longer time period for maturation. Farmers finally make the decision, considering the nature of each particular flood, as to whether they should plant the HYV variety *aman* crop or the local variety *aman* for the *kharif* 2 cropping season (one of the major cropping seasons in the monsoon in Bangladesh). The ACAs are categorized into in-built, routine and tactical adjustments.

The failure effects of ACA consists of the total crop damage per year in *taka* (*Tk*) (*taka* 70.22 = US$1) (OANDA.com 18/11/08) plus the total cost of crop production multiplied by the number of flood strikes on agricultural land. Total crop production cost (agriculture-associated costs) is defined as the cost of seedlings, land preparation, agricultural input (fertilizer cost, pesticides costs), labouring, and watering. Therefore the failure effect of ACA is large in an economic sense. If ACA fails then marginal farmers in the GBM River Basin face severe food shortages and the region's food security is threatened.

Bangladesh has been identified as the most disaster-prone of all countries [51: 433]. South Asia, including Bangladesh, is a multi-hazardous area which endures simultaneous normal floods, riverine floods, extreme floods, flash floods and coastal floods. Droughts, cyclones and storms are also common. It is notable that Bangladesh has suffered 170 large-scale disasters between 1970 and 1998. In particular, the EFEs in 1988, 1995 and 1998 were severe; the 1988 and 1998 floods submerged 57–60 % of the country [52: 189]. The flood in 1998 was one of the most destructive floods farmers in Bangladesh could recall for 50 or more years. Different simultaneous hazardous events affected the same communities and areas in the same year, and as a consequence the severity of hazards was acute, especially on rural households.

The primary economic activity is farming, which is the main income source for households where the average monthly income is only 3,000–5,000 *taka* (US$43–71). Some areas of the country face the risk of famine, while others have frequent floods and are often devastated by cyclones and storm surges [53]. More than 60 % of rural households are functionally landless and there are limited opportunities for income diversification in this mainly-agrarian economy [54]. For many Bangladeshis food availability falls short of basic requirements (scarcely 2,000 kcal per person per day). A total of 44 million (37 % of the population) were undernourished in 1997 [53: p. 560]. Primary occupation loss (cultivation) during extreme floods is common and the average loss of each household was 3,000–3,500 *taka* in 1998 and 1995, and 20,000–25,000 *taka* in the 1988 flood. Cultivation is usually the farmers only occupation. Crop labourers are also dependent on the nature of flooding, particularly on the timing of each flood. Within the flood period they do not have any other sources of income and most of the time they are unemployed. Farm labourers are usually very busy cultivating in the pre-flood and post-flood periods and can earn a reasonable amount of money which helps them survive for the rest of the lean season. During the flood period farmers, including the landless labourers, usually look for alternative economic activities such as pulling rickshaws, boating, and fishing. These are the common economic activities in Bangladesh's rural areas and are mostly climate sensitive. This is the scenario of rural households in Bangladesh, and the above characteristics are largely similar in other mega-delta regions in South Asia [55–58]. Considering these characteristics, the failure effect of ACAs on rural households in Bangladesh is very serious and its distribution patterns indicate that it is a question of survival for farmers of this region.

The failure effects of ACA due to EFEs are profound not only in relation to past EFEs, as this chapter indicates, but they could be accentuated with future EFEs under climate-change conditions if extreme floods become more frequent. Is climate change likely to exaggerate EFEs in this region in future? Some studies indicate that EFEs have already increased dramatically in the past 15 years in the GBM River Basin [59, 60, 53, 55–57, 61–66].

The Fourth Assessment of Working Group 2 of the United Nations Intergovernmental Panel on Climate Change (UN IPCC) argued in the Asia section in 'Summary for Policymakers' that heavily-populated mega-delta regions, such as the GBM Basin, will be at greatest risk due to increased flooding from the rivers [67: p. 13]. In its Third Assessment Report the IPCC concluded that extreme events, including floods, would be increased in temperate Asia. Bangladesh would be at risk of increasing flood disasters in the wet season, and researchers have pointed out that the intensity of extreme events may be higher in regions which have a warmer climate [68: 14]. These predictions suggest that the failure effects of ACAs would have significant impacts on South Asia including Bangladesh's economic development. Therefore it is essential to strengthen the capacity of ACA processes in order to ensure sustainable development in South Asia.

The Stern Report [51: 7] warned that '*Developing countries—and especially the low-income countries in tropical and sub-tropical regions—are expected to suffer most, and soonest, from climate change. They are especially vulnerable to the effects of climate change, because of their existing exposure to an already fragile environment and their economic and social sensitivity to climate change. And their poverty reduces their capacity to adapt'*. It is the tropical and subtropical regions, especially in South Asia, including the GBM Basin, which are expected to be the most vulnerable to climate change; and particularly to EFEs [69, 51]. This region is already experiencing multiple hazards including EFEs. Its environment is fragile and its economic and social activities are climate-sensitive. For example, the farming system in Bangladesh is highly dependent on rainwater and flood water, and the *aman* crop needs a specific depth of flood water for optimal growth. Farmers in India's Orissa state, where 10.34 % of the land is flood-prone, usually cultivate *champeswar* (a local variety of paddy rice), which is very tolerant to water stagnation [51: 431, 55]. Farmers in Assam, where 50.14 % of the land is flood-prone, and West Bengal of India, where 37.42 % is flood-prone, cultivate a fast-maturing variety of *aus* paddy rice which can be harvested before the flood season [55: 123, 196]. Thus farmers in the GBM Basin adopt autonomous adaptation techniques.

Based on the information provided in this chapter, a picture can be drawn of the severity of the EFEs and the resilience of farmers' crop-flood adjustments. This picture is important because it provides a guide to the events surrounding future EFEs and the measures which might be applied for dealing with them in this region.

If climate-change conditions lead to more frequent EFEs in this region, farmers' coping abilities will be severely threatened. The OECD declared '*That adaptation to climate change and its adverse effects is of high priority for all countries and those developing countries, especially the Least Developed Countries and Small Island Developing States are particularly vulnerable. The Least Developed Countries are among the most vulnerable to the adverse effects of climate change and in particular that widespread poverty limits their adaptive capacity*' [69: 5]. Bangladesh, as a 'Least Developed Country', would likely be more vulnerable to flooding, and its poverty would further reduce the ability of rural people to adapt. As evidenced in this chapter, with each EFE the marginal farmers become more marginal, landlessness becomes more common, poverty and unemployment increase; overall the adaptation capacity of the farmers is reduced and they become ever more vulnerable to extreme climatic events.

The IPCC predicted that *'poor countries are especially vulnerable, in particular those concentrated in high-risk areas. They tend to have more limited adaptive capacities, and are more dependent on climate-sensitive resources such as local water and food supplies* [67, 70: p. 7]. Bangladesh falls into the high-risk category, and farmers have limited adaptive capacity as they have very low incomes: about two-thirds of households have incomes between 3,001 and 9,000 *taka* (US$44.53–US$133.59) per annum [71]. IPCC [67, 70] also predicted that the most vulnerable societies are generally those in river flood plains, those whose economies are closely linked with climate-sensitive resources, and those in areas prone to extreme weather events.

The IPCC [67, 70] predicted that extreme weather events would become more intense and/or more frequent and as a consequence the economic and social costs of those events would increase. The evidence presented in this chapter examines those social and economic costs. To consider this issue it is relevant here to ask the following questions:

- To what extent have the failure effects of ACAs in response to extreme floods in the period 1988 to 1998 impacted on marginal farmers' households?
- What was the household distribution pattern of the failure effects of ACAs in response to EFEs during the period 1988 to 1998?
- Are these effects tipping points for survival?
- If these types of EFEs occur more frequently in future as a result of climate-change conditions then what would be the impacts on the marginal farmers' economy?
- Are they having impacts on the future development planning process?
- Would managing these impacts be beyond the capacity of farmers?
- Do these likely effects call for immediate emphasis in plans?

In order to address these questions this chapter assesses the economic consequences of the failure effects of autonomous adaptation in response to EFEs.

7.2.1 Hydrological Nature of Flooding and the Related Adjustments in Islampur

Table 7.1 describes the hydrological nature of normal and EFEs in the case study area. It also shows the autonomous adjustment processes which were implemented by farmers in response to the flood conditions. The question arises: if the adjustment processes fail then what would be the crop-related losses and damage in the households being studied?

Table 7.1 Hydrological Nature of flooding and their respective adjustments in Islampur

Flood condition	Hydrological nature of normal/EFEs	Autonomous adjustments by farmers
Normal flood condition	July 15 to August 15 is the normal flood period; single peak, short-duration, and reasonable depth of flood height is accepted for growing the seedlings	Either *aman-boro IRRI-aus* or *aman-wheat-jute* planted; farmers in general attempt to plant HYV variety *aman* at *kharif* 2 which is well adapted to normal flooding
1988 extreme flood year	Flood had single peak with high water level and volume, occurred quickly and receded quickly; the duration of flooding was short in comparison with the 1998 flood; heavy local downpours occurred	HYV *aman* was planted first but was entirely wiped out; the local variety of *aman* was then planted in the majority of cases, but some planted the HYV *aman*; this was *tactical adjustment*
1995 extreme flood year	Lower flood depths than in 1988 and 1998; flood depths exceeded the danger level for crops	Replanted their *aman* seedlings a second time (majority chose HYV); this was *routine adjustment*
1998 extreme flood year	Farmers experienced three flood peaks with high levels of flood waters (a multi-peak flood)	Farmers attempted to plant seedlings at least three times, but each time was wiped out by a new peak; many planted seedlings for a fourth time in the hope of getting some return; this was a new, *deliberate adjustment*

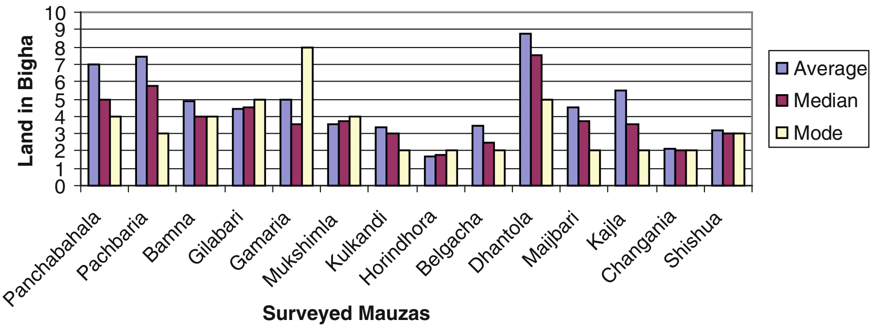

Fig. 7.1 Distribution pattern of total household lands in 2006

Table 7.2 Average household land in 1988, 1995 and 1998

Year	Average household land (*bigha*)
1988	8.95
1995	4.48
1998	4.02
2006	3.68

7.3 Land Distribution Pattern

Small farmers have up to 299 *shotok* (one *shotok* = 0.0104 acres); 63 % of informants in the study area were in the category of small farmers. Medium farmers have land totaling 300–699 *shotok*; 17 % of informants fell into this category. Large farmers have more than 700 *shotok*; 14 % of informants were in this category.

The distribution pattern of the farm-land held by the 140 participating households in 2006 is shown in Fig. 7.1. Most households had less than five *bighas* (1.65 acre) of land. Households in Shapdhari, Kulkandi and Noapara owned the smallest amounts of land, mostly falling below 5 *bighas* (one *bigha* = 0.33 acre). Of the households being surveyed, only eight out of the 140 had areas between 15 and 30 *bighas*.

7.3.1 Distribution Pattern of Household Current Owned Lands in 2006, 1998, 1995 and 1988

Table 7.2 indicates a rapid decrease in average household land-ownership by more than half during the years between 1988 and 2006. By 2006, 30 out of 140 households (21.42 %) had become landless. The majority of respondents had

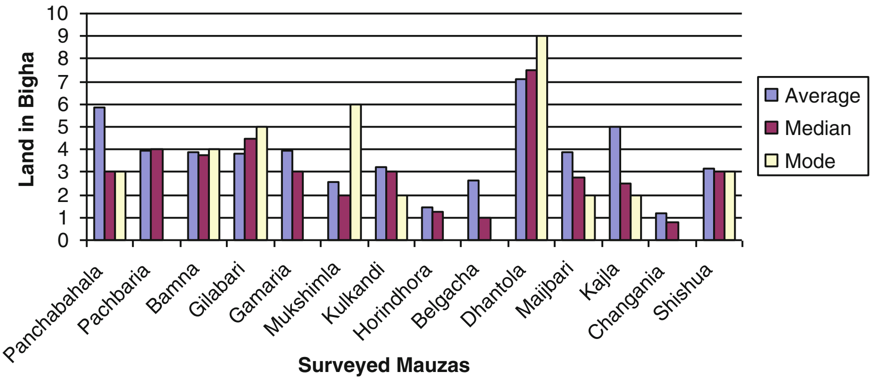

Fig. 7.2 Distribution pattern of household owned land in 2006

owned land in 1988. Questionnaire respondent no. 72 said that he had 20 *bigha* of land in 1988 but by 2006 he had become landless.

In order to explore the effects of floods the intention of the author was to conduct the study with those who owned at least some land. But as a result of the systematic sampling process it was found later that 30 (21.42 %) landless households had been included in the study. However, in 1988 only 10 of the participating households (7.14 %) had been landless. That is, between 1988 and 2006, 20 had lost all of the land they had formerly owned and farmed. None of the respondents reported any increase in the amount of land owned following the major flood events.

With every EFE, affected farmers tend to lose their fixed assets (and particularly their agricultural land); either farmers are forced to sell their land, or their land was eroded by rivers or degraded by sand deposition.

Figures 7.2, 7.3, 7.4 and 7.5 shows that in 2006 the land ownership pattern was mostly within range of 0–10 *bigha*. Land ownership was minimal in Panchabahala, Bamna, Gilabari, Panchbaria, Belgacha, Shishua and Gamaria. In Changania, Maijbari, Dhantola and Kulkandi holdings were less than 10 *bigha*. In 1988, most land holdings were between 10 and 20 *bigha,* especially in Kulkandi, Horindhora, Gilabari, Bamna, and Maijbari. In 1988 the size of landholdings was high in Maijbari, Horindhara, and Gilabari, but by 2006 average holdings had diminished as farmers were forced to sell their properties. A conclusion can be drawn that the last-mentioned *mauzas* suffered the worst of the flooding, and as a result the rate of loss of land was high and the number of landless increased with every EFE. Most farmers possess small and fragmented pieces of land, usually less than 5 *bighas* (Figs. 7.2, 7.3, 7.4 and 7.5).

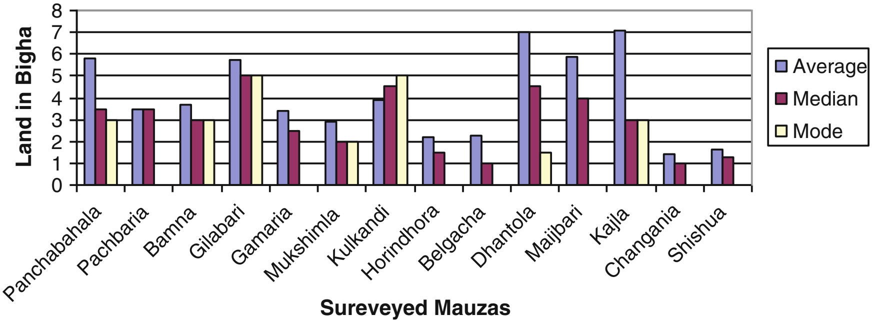

Fig. 7.3 Distribution pattern of household cultivated lands in 1998

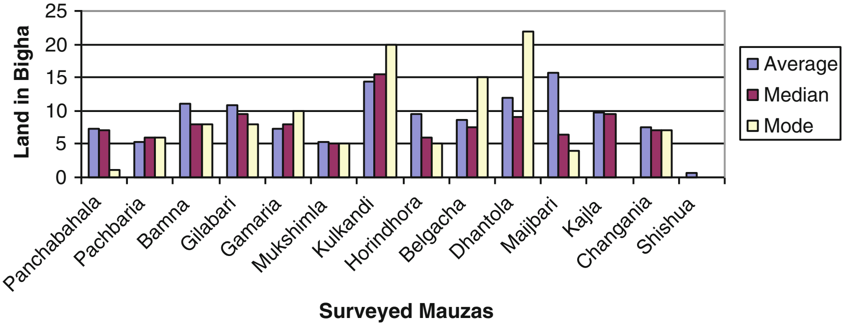

Fig. 7.4 Distribution pattern of household cultivated lands in 1988

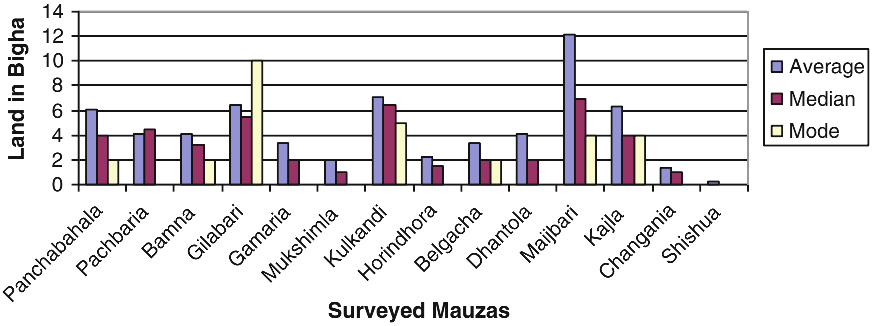

Fig. 7.5 Distribution pattern of household cultivated lands in 1995

7.4 The Failure Effects of Autonomous Crop Adaptation

This section assesses the failure effects of ACA in response to EFEs. The failure effects of ACAs are defined as total crop loss (that is, the quantity that might have been produced) plus related agricultural costs multiplied by the number of flood strikes in the studied area (further detail in Younus and Harvey [72]). Total agricultural cost includes cost of seedlings, fertilizer, pesticides, land preparation, total labouring, and watering.

$$\text{FEACAs} = \text{TECL} + \text{N}\,(\text{SC} + \text{FC} + \text{PC} + \text{LPC} + \text{LC} + \text{WC})$$

FEACAs	Failure Effects of Autonomous Crop Adaptations (ACAs)
TECL	Total Expected Crop Loss
N	Number of Flood Strikes
SC	Seedling Cost
FC	Fertilizer Cost
PC	Pesticides Cost
LPC	Land Preparation Cost
LC	Labouring Cost
WC	Watering Cost

During the survey farmers were consulted about their costs for these items. Prices reported by the farmers were the actual prices for 1988, 1995 and 1998. For example, the price of 20 kg of fertilizer in 1988 was 150 *taka*, in 1995 the price had increased to 175 *taka* and in 1998 it was 220 *taka.* Farmers recalled the actual prices for each year. Their responses therefore take into account the changes with inflation. In this study, inflation means a rise in the general level of prices of goods (SC, FC, PC and WC) and services (LPC and LC) in an economy over a period of time (1988–1998).

7.4.1 Seedling Cost

Seeding costs were highest in 1998 followed by 1988 (see Figs. 7.6, 7.7 and 7.8). Farmers planted seedlings at least twice in 1998, and in some places three times because they lost their crops three times with the three flood peaks. In 1988, the amount of land owned by each farmer was generally greater so their respective fertilizer costs were higher.

The other important finding here is that in 1998 farmers spent more for seedlings when they re-planted *aman* for the second time, and even more for the third time as the price went up and a crisis occurred as soon as flooding commenced.

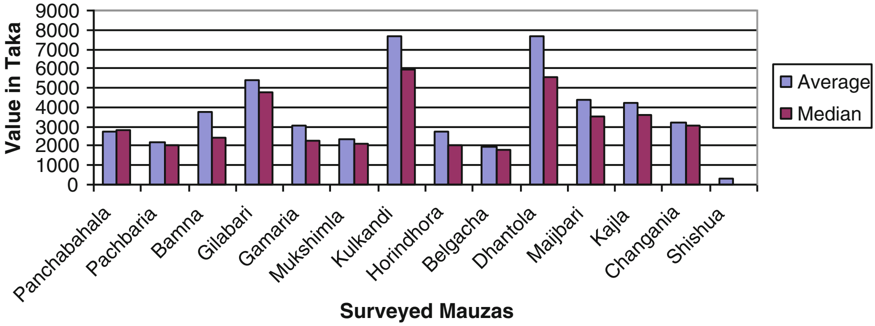

Fig. 7.6 Household distribution pattern of total seedling cost in 1988

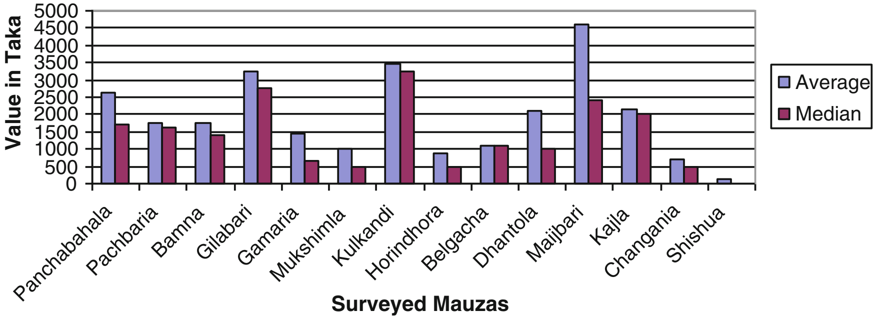

Fig. 7.7 Household distribution pattern of total seedling cost in 1995

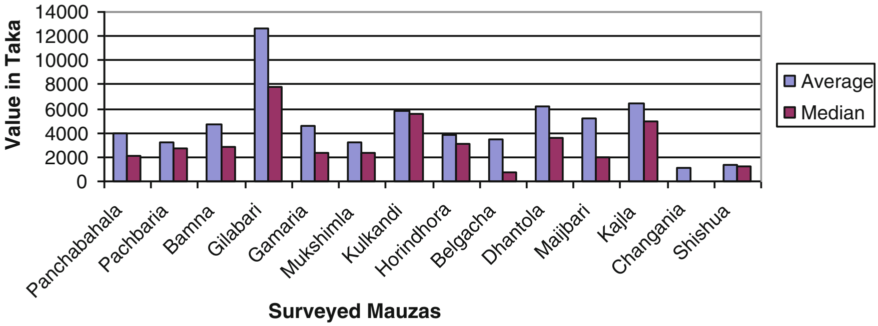

Fig. 7.8 Household distribution pattern of total seedling cost in 1998

Table 7.3 Average household agriculture associated costs in the 1988, 1995 and 1998 floods

Flood year	Average household agriculture associated costs (in *taka*)						
	Seedling	Fertilizer	Pesticides	Land preparation	Labouring	Watering	Total
1988	3,694.62	2825.50	611.57	3,224.03	4,562.09	327.35	15,243
1995	1,927.35	1806.97	357.19	1,623.25	2,389.30	252.23	8,354
1998	4,690.37	3041.68	714.89	2,534.42	4,503.10	370.00	15,852

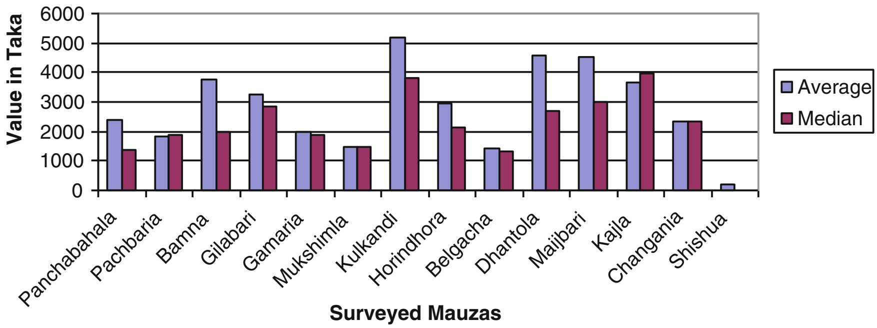

Fig. 7.9 Household distribution pattern of fertilizer cost in 1988

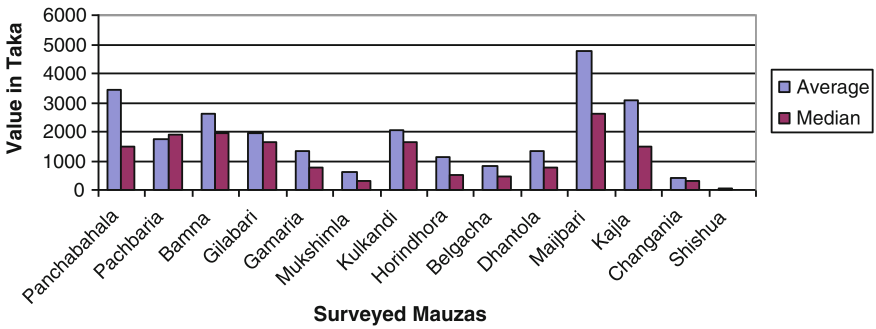

Fig. 7.10 Household distribution pattern of fertilizer cost in 1995

7.4.2 Fertilizer Cost

As shown in Table 7.3 fertilizer cost was highest in 1998. Again, this was because farmers planted *aman* at least twice, and in 17 % of cases three times in that season. Fertilizer use is part of land preparation and is used each time *aman* is planted. In 1988, fertilizer costs per household were up to 5,000 *taka* (Figs. 7.9, 7.10 and 7.11).

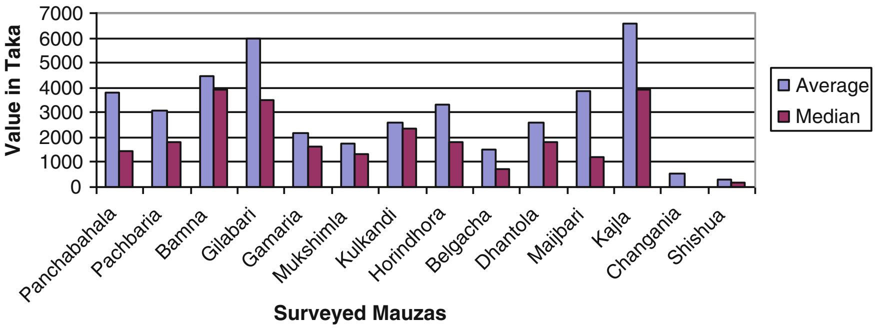

Fig. 7.11 Household distribution pattern of fertilizer cost in 1998

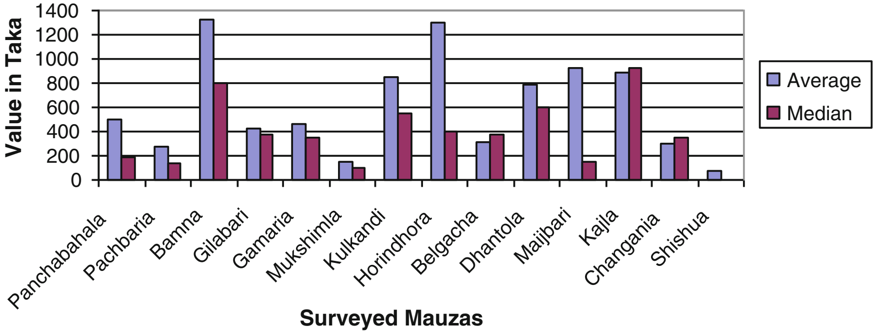

Fig. 7.12 Household distribution pattern of pesticide cost in 1988

7.4.3 Pesticides Costs

As shown in Table 7.3, pesticides cost less than seedlings and fertilizer and some respondents do not use pesticides. Some of them did not use pesticides for the first and second plantings but were compelled to use them when they planted *aman* for the third time, because it was late in the cropping season and the untimely crop was infested with different pests.

Pesticide cost was highest in 1998, although the amount of land owned was greater in 1988 (Figs. 7.12, 7.13 and 7.14). The 1988 floods arrived when the seedlings were not mature enough to require pesticides. Figures 7.12, 7.13 and 7.14 shows that the amount spent for this purpose was generally in the range 0–1,000 *taka*.

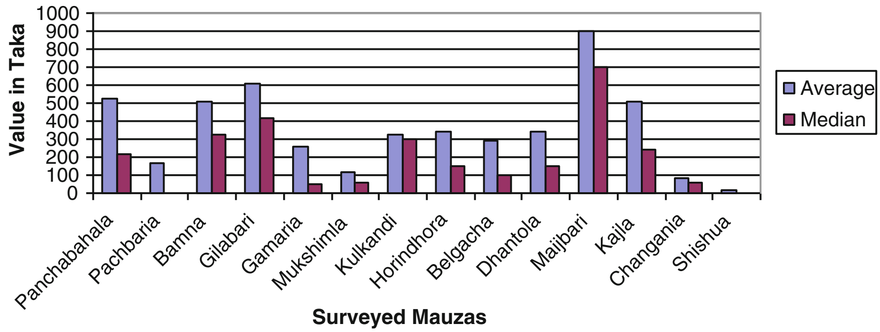

Fig. 7.13 Household distribution pattern of pesticide costs in 1995

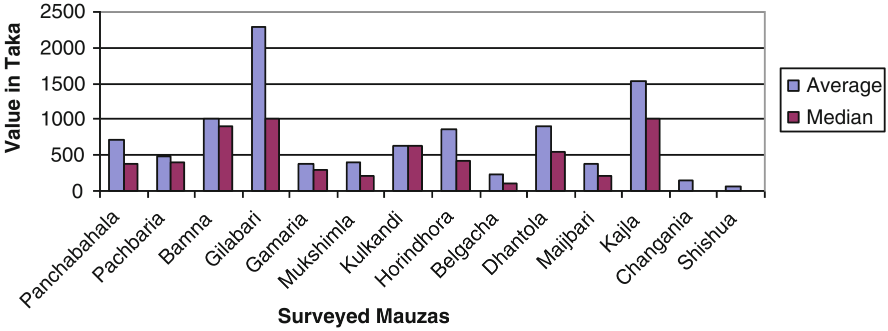

Fig. 7.14 Household distribution pattern of pesticide costs in 1998

7.4.4 Land Preparation Cost

Many farmers could, if necessary, employ day labourers to assist with the work of ploughing, aerating the soil, and weeding in preparation for rice planting. The average household land preparation cost was 3,224 *taka* in 1988, 2,534 *taka* in 1998, and 1,623 *taka* in 1995. Average household land preparation costs in 1988 were higher than in the 1998 and 1995 because the amount of land owned by households was generally higher in 1988. Average land preparation costs were in the range 0–5,000 *taka* (Figs. 7.15, 7.16 and 7.17). In 1988 land preparation costs in Maijbari, Kulkandi, Bamna and Dhantola *mauzas* were significantly higher, within the range of 2,500–10,000 *taka*. In contrast, in Shishua, Mukshimla and Panchabahala the average land preparation cost was lower (ranging between 0–2,500 *taka*). This is because the amounts of land possessed by the surveyed households were higher in those *mauzas* where land preparation costs were higher. For example, in Dhantola the total land possessed by 10 respondent households was 120 *bigha,* whereas in Shishua the total amount of land was seven *bigha* and in Mukshimla it was 52 *bigha*.

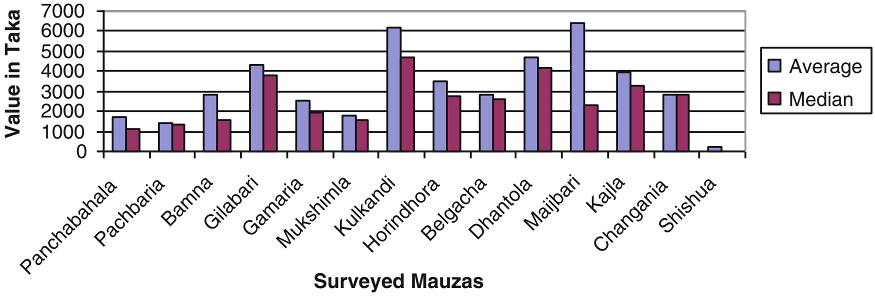

Fig. 7.15 Household distribution pattern of land preparation costs in 1988

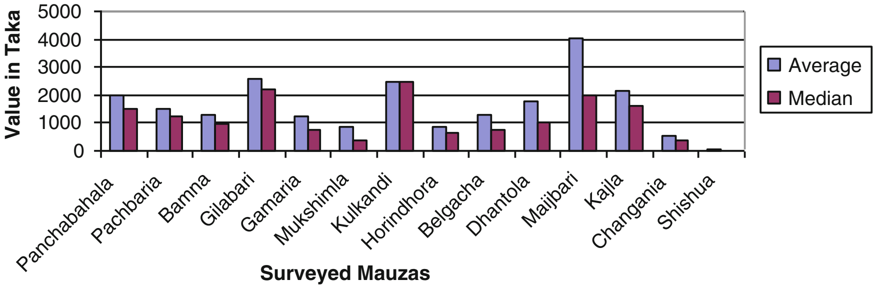

Fig. 7.16 Household distribution pattern of land preparation costs in 1995

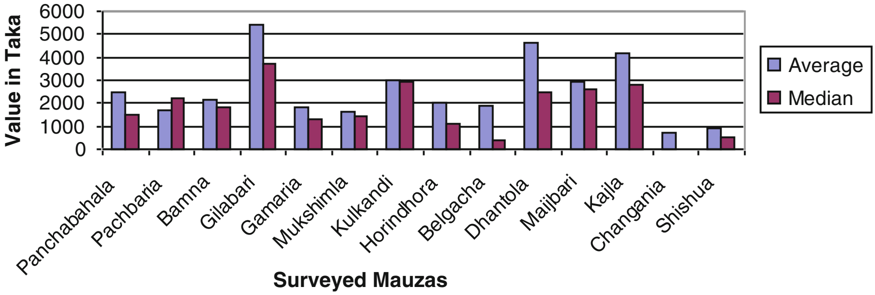

Fig. 7.17 Household distribution pattern of land preparation costs in 1998

In 1998 some farmers had to prepare their land twice or three times due to the multi-peak nature of the flood. The land preparation cost for the first planting was higher than the land preparation costs for the following two plantings because when the floods receded the farmers used the slightly-inundated land for re-planting the *aman*.

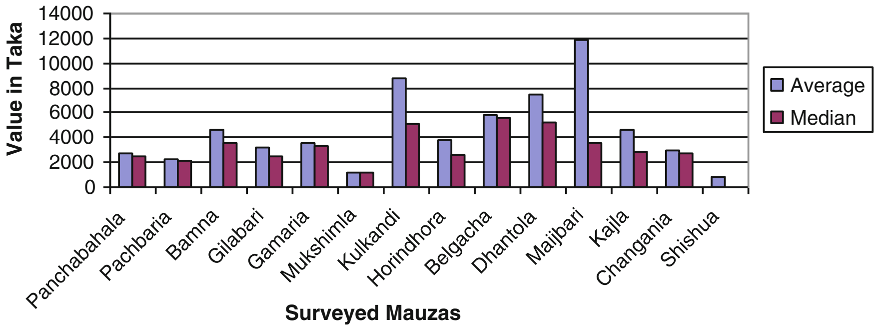

Fig. 7.18 Household distribution pattern of labouring costs in 1988

7.4.5 Total Labouring Cost

Labouring costs consist of the total effort exerted by male members of the households (invisible cost) and hired labourers for the period from land preparation to harvest (visible cost). The average labouring cost per household in 1988 was 4,562 *taka*, in 1998 the cost was 4,503 *taka,* and in 1995 it was 2,389 *taka*. Although the amount of owned land was higher in 1988 the labouring cost was very close to that of 1998 because in 1998 farmers had two or three attempts at re-planting *aman*.

Average total labouring costs ranged between 0–10,000 *taka*, but mostly they were within the range 0–5,000 *taka* (Figs. 7.18, 7.19 and 7.20). In 1988 labouring costs exceeding 10,000 *taka* were found in only 10 (7.14 %) households. In 1998, 15 out of 140 (10.71 %) spent more than 10,000 *taka* for labour. In Shishua, Kulkandi and Pachbaria the labouring costs were usually low, but in Maijbari, Kajla, Dhontola, Horindhora and Gilabari they were generally higher (exceeding 5,000 *taka*).

7.4.6 Watering Cost

In a normal crop year no irrigation is needed for *aman* cultivation because the yearly floods and rainfall are generally sufficient. Towards the end of the cropping season, if it is very dry irrigation may be required. The average watering cost for 1988 was 327 *taka*, in 1995 it was 252 *taka,* and in 1998, 372 *taka*. The watering cost was a little higher in 1998 than in 1988 though the amount of household land was greater in 1988. Again, this was because of multiple plantings of *aman* in 1998. In Shishua, Belgacha, Bamna and Maijbari watering cost was almost nil (Figs. 7.21, 7.22 and 7.23). In Changania, Kajla, Dhantola, Horindhora, Mukshimla and Gilabari the watering cost was higher. In 1998, six out of 140 households spent more than 1,000 *taka* for watering, and only two households

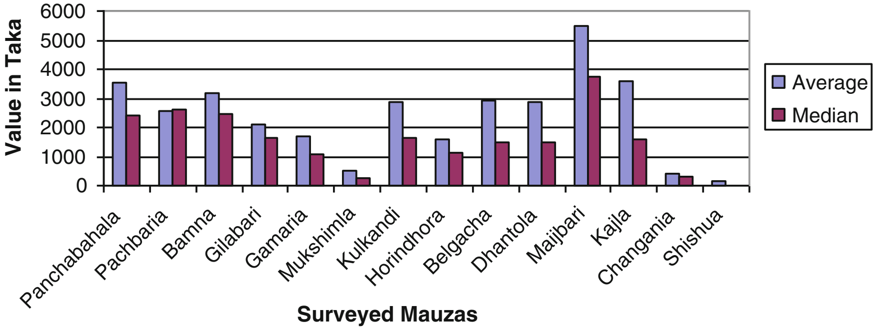

Fig. 7.19 Household distribution pattern of labouring costs in 1995

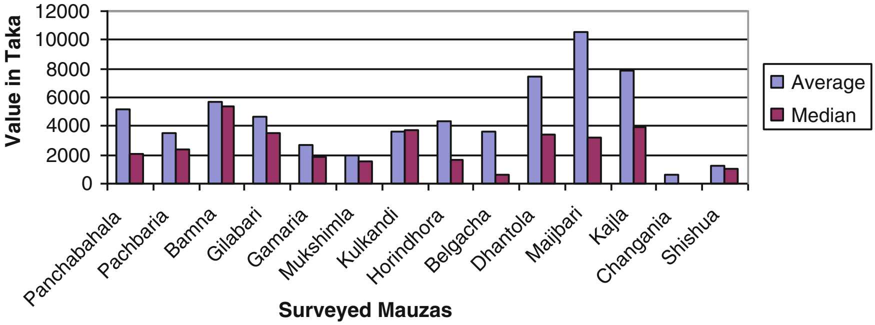

Fig. 7.20 Household distribution pattern of labouring costs in 1998

spent a significantly higher amount (6,000 *taka*). In comparison, in 1988 ten of the households had watering costs exceeding 1,000 *taka*.

7.5 Failure Effect of Autonomous Crop Adaptation

The failure effects of ACAs in each extreme flood year are very severe in relation to the low income, the high number of family members, the small amount of farming land, the few alternative sources of income, and the higher occupational loss of each household. The failure effects of ACAs were determined for 140 households in seven *Unions*. Farmers were asked for the crop losses of each flood event at the *kharif* 2 cropping season. In general, the 1988 crop losses per *bigha* were higher than the losses in 1998 and 1995. For example, one farmer reported a loss of 760 kg per *bigha* in 1988, which is equivalent to 5,000 *taka*. The same farmer reported a 684 kg per *bigha* loss in 1998, equivalent to 5,400 *taka,* and in 1995 his crop loss was 685 kg, equivalent to 5,400 *taka*. The actual price of rice in

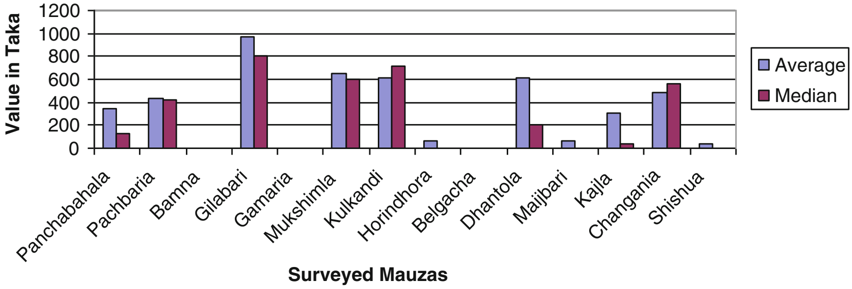

Fig. 7.21 Household distribution pattern of total watering cost in 1988

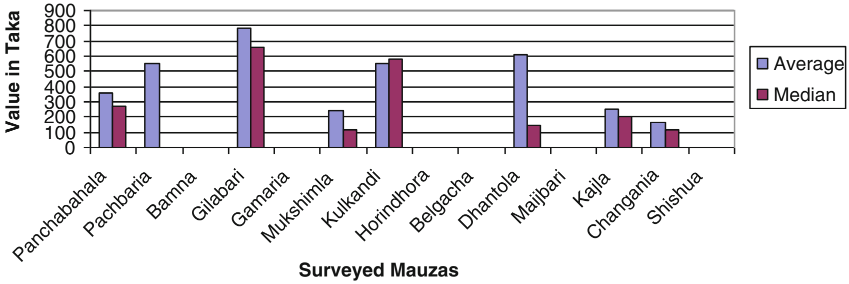

Fig. 7.22 Household distribution pattern of total watering cost in 1995

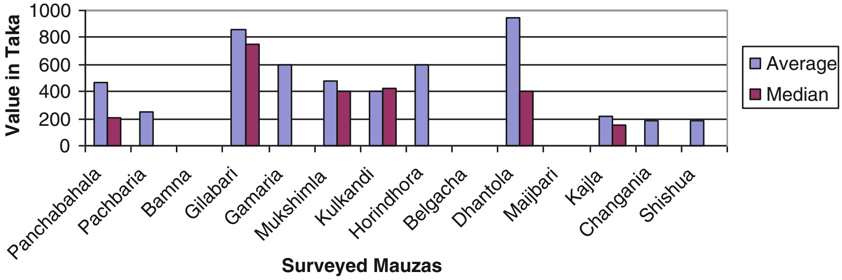

Fig. 7.23 Household distribution pattern of total watering cost in 1998

1998 was higher than in 1988 and 1995—this illustrates the variation in the price of rice over time. The crop losses in 1988 were clearly higher than the losses of 1995 and 1998 because in 1988 farmers held larger amounts of land than in 1995 and 1998. The time of the flood was the other significant reason for the crop losses recorded.

Farmers lose crops several times with the EFEs. This was particularly evident in years of multiple floods, such as 1998 when floods occurred three times, and the

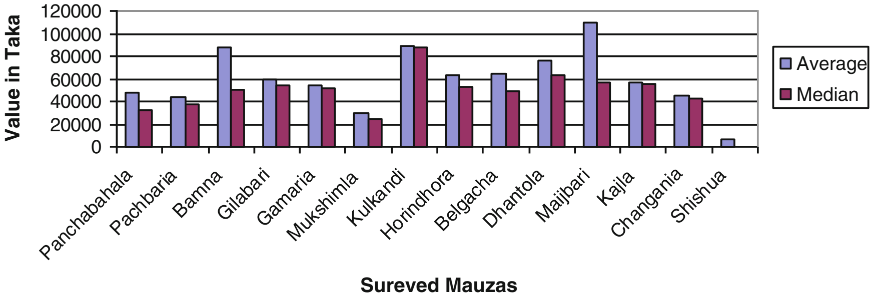

Fig. 7.24 Total household distribution pattern of the failure effects of autonomous crop adaptation in 1988

total cost of seedlings, fertilizer, pesticides, land preparation, labouring, and watering (together called 'agriculture associated cost') was therefore multiplied by three. As a consequence the distribution pattern of all these costs in 1998 appears higher in relation to the costs for 1988 and 1995. One respondent's first-time total agricultural cost was 2,326 *taka* per *bigha*; the second time it was 2,450 *taka,* and third time 1,950 *taka*; so all together it was 6,725 *taka* (US$99.83) per *bigha* (0.33 acre). This was a very significant loss in the light of that farmer's socio-economic, demographic and bio-physical setting.

The distribution pattern of the failure effects of autonomous crop adaptations is shown in Figs. 7.24, 7.25 and 7.26. These data are the sum of total expected crop losses plus the number of flood strikes multiplied by total agricultural associated costs. These effects are significant. The effects on households have been assessed in monetary terms in *taka*; most being within the range of 0–50,000 *taka* (US$0–US$742.21). Total losses in most *mauzas* were between 50,000–100,000 *taka* (US$742–US$1,484.42); a smaller number of households experienced losses of 100,000–200,000 *taka* (US$1,484–US$2,968.84); and only a few households had losses between 200,000–450,000 *taka* (US$1,484–US$6,679.89). Total household crop-related losses in 1998 were higher than the losses in 1988 and 1995; the majority of the losses in 1998 were between 0–150,000 *taka,* and only five households of the 140 which were surveyed had crop-related losses in 1998 between 150,000–300,000 *taka*. The pattern of crop-related losses in 1988 was severe: the majority experienced losses of 0–150,000 *taka* and only nine households out of 140 had crop-related losses between 150,000 and 450,000 *taka*. The losses for 1995 were mostly between 0 and 100,000 *taka*.

Considered overall, the failure effects of autonomous crop adaptations in 1988, 1995 and 1998 were profound. The total crop-related loss due to the failure effects of autonomous crop adaptations over 140 households in 1988 was 8,324,073 *taka,* in 1995 it was 5,371,228 *taka,* and in 1998 it was 6,830,887 *taka*. These indicate that each household's average crop-related loss in 1988 was 59,457 *taka,* in 1995 it was 38,641 *taka,* and for 1998 the figure was 49,143 *taka*. The total number of households in Islampur was 40,876 [73]. Therefore, in 1988 the total crop-related

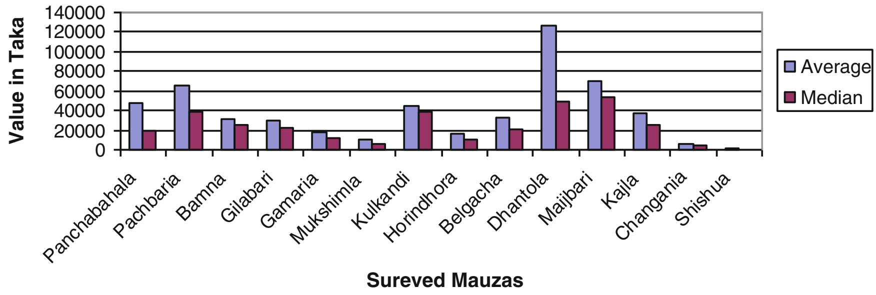

Fig. 7.25 Total household distribution pattern of the failure effects of autonomous crop adaptation in 1995

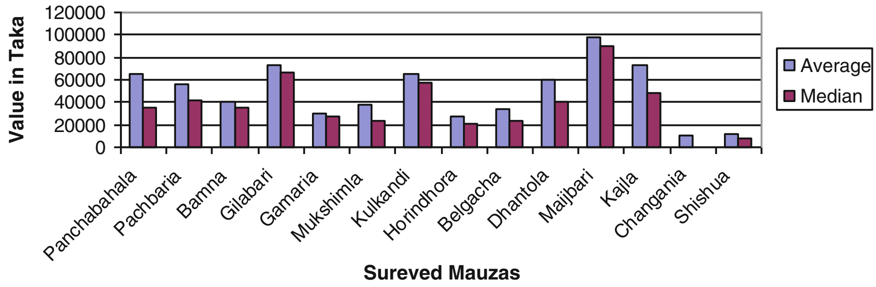

Fig. 7.26 Total household distribution pattern of the failure effects of autonomous crop adaptation in 1995

loss due to extreme flooding in Islampur was 2,430,364,332 *taka* (US$34.6 million), in 1995 the loss totaled 1,579,489,516 *taka* (US$22.49 million), and in 1998, 2,008,769,268 *taka* (US$28.6 million).

In the light of the losses in just one *Upazila,* Islampur, it is possible to generalize the results for the entire country. About 60–70 % of Bangladesh is flood-prone, and in 1998 68 % of the country was flooded, 314 *Upazilas* being affected [21, 56] (Rasheed [74]). Extrapolating the results listed above indicates that the failure of ACAs in 1998 led to crop-related losses across Bangladesh of at least US$8,982 million; in 1988 the total loss was approximately US$11,000 million, and in 1995 about US$7,000 million. Major uncertainties in these estimates rest on variations in the flood severity and its impact on the 314 *Upazilas* that are affected, on different flood depths over different land types (very low land, low land, medium/low land and medium/high land), on the hydrological cycles, local rainfall, and the number of households in each *Upazila*, etc. The estimate does not purport to be based on all the relevant biophysical and socioeconomic variables, but is presented to show the potential of the community-based survey data to contribute to policy-making.

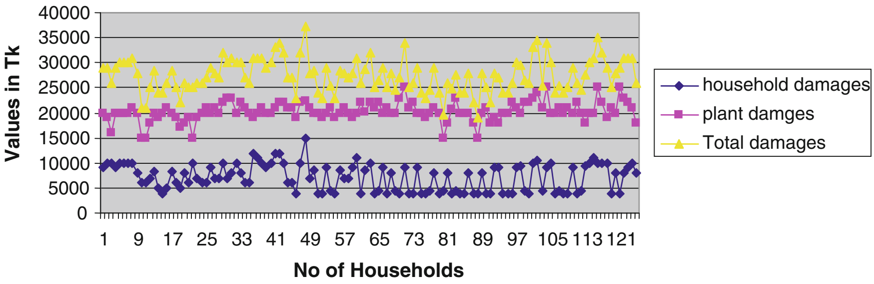

Fig. 7.27 Distribution pattern of total losses (house and plants) due to 1998 flooding in Chinaduli union

7.6 Household and Plant Damage in Chinaduli Union

Total losses from damage to plants and property in 125 households in *Chinaduli Union* in Islampur in the 1998 flood were also large (Fig. 7.27) (based on the [75]. The average loss for damaged plants in each household was 20,297 *taka,* for households the losses amounted to 7,171 *taka*; and so the total for plants and property in each household was *taka* 27,468. Extrapolating the *Chinaduli* data to the total number of households in Islampur (that is, multiplying the losses for Chinaduli by 40,876 households) it can be seen that for 1998 the losses in Islampur totaled 1122,781,968 *taka* (US$15.98 million). This included total plant-loss of 829,660,172 *taka* (US$11.8 million), and household/property loss of 293,121,796 *taka* (US$4.17 million).

In summary, the total average loss (49,143 *taka* for crop-related loss plus 20,297 *taka* for plants, and 7,173 *taka* for household loss) for each household in Islampur in 1998 was 76,611 *taka*. Total damage in Islampur was 3,131,551,236 *taka* (US$44.59 million). The total loss for the Bangladesh (that is, crops, plants, and houses) in 1998 was US$1,4001.26 million.

7.7 Consequences of the Failure Effects of Autonomous Adjustments

The consequences of the failure effects of autonomous crop adaptation are as follows:

1. A decrease in average household farm land. In 1988 the average landholding per household was 8.95 *bigha*, which was reduced to 4.48 *bigha* in 1995, to 4.02 *bigha* in 1998, and then to 3.68 *bigha* in 2006.

2. In 1988 each household, on average, incurred a seedling cost of 500 *taka* per *bigha*, a fertilizer cost of 667 *taka* per *bigha*, a pesticide cost of 300 *taka* per *bigha*, a land-preparation cost of 667 *taka* per *bigha*, and a watering cost of 333 *taka* per *bigha*; the total for 1988 being 2,467 *taka* per *bigha* (1988 assessment).
3. The average household agricultural cost in 1988 was 15,243 *taka*, in 1995 the cost was 8,354 *taka,* and in 1998 the figure was 15,852 *taka*.
4. In monetary terms, the failure effect of autonomous crop adaptation per household was 59,457 *taka* in 1988, 38,641 *taka* in 1995, and 49,143 *taka* in 1998.
5. Finally, in 1998 the average household loss from plant (orchard) damage was 20,297 *taka* and average household loss was 7,171 *taka*.

An important finding of this study is that farmers are losing the land they possessed at an alarming rate. On average, the area of land typically owned by farmers was reduced by more than half in the 18 years from 1988 to 2006. Thus, the marginal and poor farmers are becoming more marginal and being pushed to the edge of landlessness. In this way the vast majority of farmers are becoming more vulnerable economically and as a consequence their coping capacity and power to adapt to natural calamities, such as floods, is decreasing significantly. Food insecurity is a natural outcome of these calamities and if this continues for an extended time, human security could be affected. The impact of this is severe in the already-fragile socio-economic condition of Bangladesh. An increase in poverty and unemployment is likely, and such a situation would ultimately lead to mass migration from rural to urban areas, to a deterioration of law and order, and an increase in crime.

In relation to family incomes, rural households spend significant amounts of money on agricultural items (Chap. 4). These costs are on top of expected crop losses (synonymous with the failure effects of autonomous crop adaptation) and this is the estimate for one cropping season only (of the three cropping seasons in Bangladesh). If farmers cannot overcome their losses from one failed crop it is impossible for them to plant another, thus creating a vicious circle.

Typical households possess minimal cropping land, have high numbers of dependent family members, and low incomes. Their primary economic activity is farming. If floods become more frequent, higher, of longer duration, and multi-peak then the ‘adaptation capacity’ will be weakened. The failure effects are very important in the context of the above socio-economic, demographic and bio-physical factors. These comprise household expenses as well as the cost of seedlings, agricultural inputs, watering, and land preparation for the next cropping season. If each household loses this amount of money from the major cropping season (*Kharif* 2) then the head of the household is unable to pay for food and ancillary costs (clothing, education, medical, etc.) up to the next cropping season. As a consequence there is often acute food shortage and local food security is threatened. In this event, some heads of households try to obtain loans from local banks or money-lenders at high interest. Alternatively, some heads of households choose to become daily labourers involved with land preparation activities on the properties of more prosperous farmers. That is, the head of the household tries to survive up to at least the next cropping season by changing occupation. Others migrate to the city in order to survive, usually seeking work as rickshaw-pullers, garment workers, or performing odd jobs, all of which are very poorly paid.

Although farmers try to recover their losses and continue their cultivation, the normal floods (as well as extreme floods) destroy their autonomous adaptation capacity, leading to a vicious circle of poverty. Every extreme flood therefore reduces farmers' ability to cope with even normal flooding in the following year. The autonomous crop adaptation capacity of farmers in the study area has already been threatened due to frequent extreme flooding over the past couple of decades as shown by the distribution pattern of failure effects of autonomous crop adaptations in 1988, 1998 and 1995.

Since the number of dependent members of each household is large and the annual income is minimal, households face severe money shortages until the harvest. As the main family income is derived from farming they have no alternative sources of money for food or for agricultural activities until the next cropping season. Their other expenses are for clothing, medicine, crop land tax, children's education, cattle feed, house repairs and maintenance, transportation, electricity/kerosene, and livelihood and ancillary costs. Some farmers have to pay rent for the land they work; others have to pay mortgages. After experiencing each extreme flood some farmers have to give away the equity they may have in their land to meet their mortgage obligations or to obtain sufficient money to survive for the rest of the year. This leaves many landless, as they are not able to pay the money back.

With each EFE the marginal farmers suffer severe food crises, and the region is at risk of food insecurity. This situation highlights the issue of human security in the areas being studied, for household members do not have the ability to generate alternative economic resources in order to survive. They do not have access to other sources of food, have no fixed assets to ensure survival until the next harvest, and cannot meet family expenses such as education, health care, clothing, cattle fodder, utility expenses, and domestic energy. Moreover, they do not have access to adequate institutional arrangements or support from governments or NGOs. If these factors persist for a longer period and if the extreme floods occur more often in the future, then both food security and human security would be threatened. Increasingly, EFEs, which may or may not have a strong link with global climate-change, would accelerate food insecurity and ultimately human insecurity.

Bangladesh is particularly vulnerable to the effects of global warming and has very little socio-economic, demographic, bio-physical, or institutional capacity to cope with the impacts of climate change [68: 6, 51: 430, 67: 7]. Floods are a recurrent phenomenon in Bangladesh and are likely to become more intense and more frequent on account of ocean warming and intensified summer rainfall. This chapter has argued that a critical aspect of Bangladesh's agriculture, the capacity for autonomous adjustments by vulnerable farmers, will cease with increased frequency of EFEs associated with climate change, leading to food insecurity and human insecurity risk.

The GBM River Basin extends into five countries. Half of the length of the Brahamaputra River flows through Chinese territory, and 4 % of the Ganges is in China. India contains 79 % of the length of the Ganges, 34 % of the Brahamaputra, and 54 % of the Meghna. Bangladesh contains 4 % of the Ganges, 8 % of the Brahamaputra, and 46 % of the Meghna. Nepal contains 13 % of the Ganges. Bhutan contains several tributaries and also forms part of the GBM Basin [76]. The socio-economic, demographic and bio-physical settings of South Asia, particularly of the GBM River Basin have many similarities with the studied area. The autonomous crop adaptation processes among the various agro-ecological zones have many dissimilarities but the farming processes are mostly autonomous and reliant on the traditional knowledge and adaptive capacity of the farmers. It is also pertinent to note that farming methods are very traditional and labour-intensive, few farmers having access to mechanical forms of cultivation or harvesting. The farming systems are also entirely climate sensitive. The case study reported here leads to a review of conditions in the GBM River Basin as a whole. The IPCC has predicted that mega-deltas, such as the GBM River Basin, will experience more EFEs in the future, and this research shows that the diminishing adaptation capacity of farmers will very probably lead to reduced food security and reduced human security. This study suggests that the failure effects of autonomous crop adaptations of each household in the case study area are very high and that the sequence of serious floods has already diminished the ability of farmers to adapt their farming processes to extreme events which are likely in the near future. Therefore the issue of autonomous crop adaptations should be incorporated into future development planning in this region.

7.8 Summary

The chapter has examined the results of research into the ways in which farmers adapt to EFEs in Bangladesh, revealing some important facts about the failure effects of ACAs. The case study provides valuable findings which have implications for other mega-deltas in South Asia. The study shows that: (a) the intensity and frequency of EFEs have increased in this region over time; (b) farmers are very resilient in their responses to EFEs, but multi-peak and long-duration floods reduce, and terminate, their capacity for autonomous crop adaptations; (c) the failure effects of ACAs can be severe and far-reaching and must be considered within the context of the socio-economic, demographic and bio-physical settings of the farmers; (d) the longer the failure effects of ACAs persist, the worse the autonomous crop adaptation capacity becomes, meaning that farmers lose the ability to cope with EFEs; (e) with each flood event, the average amount of land owned by the farmers has decreased markedly, the study finding that in the past 20 years the size of typical farms has been reduced by more than half; (f) the cost of lost and damaged crops, equipment, and household effects has been very high;

(g) EFEs, which might be the result of global climate change, have accelerated food insecurity and, ultimately, human insecurity.

The purpose of this chapter was to examine the average losses incurred by each household from three EFEs. It calculated the monetary costs of all aspects of farming including crop losses and damage to land, equipment, plants, houses, utensils, and personal effects in order to determine the total losses from each flood. It demonstrated that the losses experienced by farmers have been very high indeed when compared to average household incomes. The fact that the majority of householders are small-scale and marginal farmers and that farming is their primary (sometimes only) source of income, highlights the significance of the losses. If their losses are not able to be recovered they cannot bear the expenses of the following cropping season. Even mere survival to the next cropping season becomes very difficult as most have large families with high numbers of dependent members. When the floods recede farmers desperately look for any source of cash and seedlings and are forced to act in ways that ultimately make them poorer and landless, such as selling land and fixed assets, taking loans at high interest, and mortgaging their land and homesteads. This situation can lead to food insecurity, and if prolonged could become an issue of human insecurity.

In order to prevent these consequences it is essential that marginal and vulnerable farmers receive some support in the post-flood period. This study provides reliable information regarding the help that is needed and in what capacity because it draws from the experiences of affected farming communities. From this analysis of the failure effects of autonomous crop adaptations in three major flood events, it provides a guide to the types of support and assistance needed in response to floods like those in 1988, 1995 and 1998.

The Government of Bangladesh is now trying to focus on community-based adaptation planning in response to climate change scenarios. As one of the countries mostly likely to be severely affected by climate change, Bangladesh will receive substantial funds for adaptation, and this study provides findings that may give direction as to how the funds could be used to maximum benefit. The findings of this chapter can act as a guideline for effective allocation of those funds at the community level.

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Chapter 8
Conclusion and Recommendations

Abstract This chapter summarizes the major findings of this book. These are: (1) since 1954 no study has focused comprehensively on community input to assessment of V&A; (2) the consequences of failed adaptation have been assessed in the light of vulnerable farmers' household information: socio-economic, demographic, and biophysical; (3) if these consequences prevail for a long time, and increase in frequency with each episode of flooding, it would eventually cause human insecurity; (4) the adaptation capacity of the agricultural community is generally very resilient, as evidenced in recent three EFEs; (5) V&A assessment guidelines outlined by the IPCC, UNEP, and USCSP have been reviewed, and new assessment steps have been adopted in order to assess, weight, rank and categorise V&A issues in the context of the case study area. This chapter has also drawn some realistic recommendations: formation of mauza-based farmers' data bank; formation of CBAC, which would act on the basis of prioritizing local vulnerability and adaptation needs; and would allocate adaptation funds (proposed in the Copenhagen Accord); including their rationale, policy implications, conceptual contributions and recommendations for future research. This chapter argues that an integrated assessment of rural vulnerability and community-based adaptation is needed in order to ensure sustainable changes in response to future climate change regimes in Bangladesh.

8.1 Introduction

The IPCC, UNEP, GECHS, IHDP and USCSP have focused on adaptation as a key strategy to tackle the impacts of climate change. 'Adaptation' has been recognized as an important issue in the current literature and is strongly emphasized in recent worldwide conferences, seminars and workshops. In addition, governments worldwide have been dealing with climate change and adaptation issues through establishing different departments, cells, or units. In Bangladesh, the Ministry of Environment and Forest has emphasized climate change issues and has published the 'Bangladesh Climate Change Strategy and Action Plan', in which Section Four

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focuses on adapting to climate change. In Australia, the government has established a Department of Climate Change, and the National Climate Change Adaptation Research Facility (NCCARF) has started work on adaptation to climate change in order to ensure sustainable development in future planning.

Climate change, sea-level rise, and global warming literature, in conjunction with various sectors such as the agricultural sector, have prioritized the adaptation concept. A country threatened by climate change impacts needs to adopt an effective climate-change regime for development to succeed. Without adapting to the changing climate, a country or a region cannot achieve sustainable development. In the face of climate change threats, vulnerability could increase, particularly in the agricultural sector. Adaptation to climate change is the forefront issue in the climate change literature which argues that adaptation techniques should be upheld and incorporated into development policies in order to ensure sustainable development.

Autonomous adaptation is particularly important in developing countries, which are more vulnerable to the risks associated with climate change and are dependent on autonomous adaptation in order to cope with climatic events. The autonomous adaptation issue has been identified in recent literature, but the processes and the assessment and failure impacts of autonomous adaptation have not previously been studied in detail. A recently-published book 'Adaptation to Climate Change', edited by Schipper and Burton [1], has highlighted adaptation to climate change, adaptation theory, vulnerability and resilience, disaster risk, development, and climate-change policy in relation to adaptation. None of the chapters of this book have articulated autonomous adaptation concepts, processes, assessment, or consequences and impacts of its failure. Nor did they focus on the sectoral (such as the agricultural) impacts of the failure of autonomous adaptation, how to assess V&A; and what would be the methodological contribution for assessing V&A—all issues explored in this book.

The objectives of this book are: (a) to understand 'autonomous adaptation' within the broad context of 'climate change', in order to understand its importance in V&A assessment; (b) to understand the trend of flood research in Bangladesh; (c) to examine autonomous cropping adjustment processes; (d) to identify and weight the issues of V&A in response to EFEs in order to make a methodological contribution for assessing future V&A in the light of climate change, and to develop a research technique for V&A assessment; and (e) to evaluate the economic consequences of failure effects of autonomous adaptation, and to identify its ultimate impact on human security.

8.2 Summary of Major Findings

In accordance with the objectives of the research (as specified in Chap. 1), some major findings have been drawn:

a. Islam [2–4], Paul and Rasid [5], Rasheed [6], Paul [7], Ahmad and Ahmed [8, 9] and Ahmad et al. [10, 11, 12], have all carried out independent research on agricultural adjustment and flood damage to rice crops and regional flood-management cooperation within the GBM River Basin. However, after extensive research into the history of flood research in Bangladesh since 1980 and related government activities since 1954, it was concluded that no study has focused comprehensively on community input to assessment of V&A.

b. Household information obtained in the case study (Chap. 4) revealed that the amount of farming land owned by each household was small and fragmented, that there was a high number of dependent family members, low annual incomes of earning members, and that farming is often the primary and only economic activity. The consequence of failure of autonomous adaptation has been assessed in the light of these parameters.

c. The adaptation capacity of the agricultural community in Islampur (case study area) is generally very resilient, as evidenced in farmers' adaptive responses to the hydrological profile of three EFEs. For example, after the 1988 floods farmers planted mainly the local variety of *aman* but some of them planted the HYV *aman* as they were left with a reasonable period of *kharif* 2 season. In contrast, following the 1995 floods farmers mostly opted for HYV *aman* as much of the *kharif* 2 season was available and HYV *aman* takes longer for maturation. The scenario was different in 1998 when the flood was multi-peaked. Farmers attempted to grow *aman* at least three times between the peaks. Practical applications of different types of adaptation techniques were also identified in this study.

d. V&A assessment guidelines outlined by the IPCC, UNEP, and USCSP have been reviewed, and new assessment steps (Chap. 6, Sect. 6.2.2) have been adopted in the present study. Both V&A issues were measured on a scale of 1–20 and ranked with a weighted value index. Subsequently, vulnerability assessment was categorized as high, medium, low, and very low. Similarly, adaptation assessment was categorized as urgent, intermediate, and low.

e. Failure effects of autonomous crop adaptation (FEACA) are large in relation to marginal farmers' socio-economic, demographic, and biophysical characteristics. The FEACAs are defined as total crop loss against potential production plus total agricultural cost multiplied by the number of flood strikes on the studied area. Total agricultural cost includes cost of seedlings, fertilizer, pesticides, land preparation, total labouring and watering. The distribution patterns of these variables (Sect. 7.4) indicate that there is a critical impact on the affected marginal farmers. The failure effects of autonomous crop adaptation determined using the above method of calculation amounted to US$28.6 million in 1998, US$34.6 million in 1988, and US$22.49 million in 1995 in the case study *Upazila*, Islampur. Using the same method of calculation, the total loss for Bangladesh was extrapolated as US$8,982.53 million in 1998, US$10,867 million in 1988, and US$7,062.9 million in 1995. The crop-related loss including plants and houses damaged due to extreme flooding in 1998 in Bangladesh was roughly US$14 billion. The total GDP of Bangladesh was US$79.6 billion in 2008 [13]. The agricultural sector contributes 23.50 % [14] which amounts to US$18.70 billion. In the 1998 flood, the total crop-related loss, including plants and houses damaged, was US$14 billion, which is 74. 86 % of the agricultural sector's contribution to GDP. This identifies the destructive nature of the floods and shows the extent of the failure effects of adaptation.

The amount attributed to flood-related total loss is very large in Bangladesh. From the perspective of marginal farmers' socio-economic conditions, the loss incurred at the individual level is also critical. The scale of loss leads to a situation where marginal farmers lose their adaptation capacity to survive until the next harvest and to bear the expenditure of the next cropping season. The calculated loss for each household refers to the minimum amount of monetary help they need to recover from this situation. The household loss calculations also provide information regarding the amount of financial and other help needed for different purposes and the prioritization of the various issues to which assistance should be applied. Such information can prove important for long-term development planning in Bangladesh.

The study also concluded that there was a decrease in average household land ownership by more than half during the period from 1988 to 2006. There is no evidence of any increase in the amount of land owned by the individual respondents in the study area during that time. Thus the marginal and poor farmers have become more marginal and are being pushed to the edge of landlessness. This leads to changes of occupation and rural-urban migration in a desperate attempt for survival.

f. Human security in Bangladesh.

The affected marginal or subsistence farmers are in a situation where they do not have access to any alternative income generation. As their land is under water, their primary economic activity is halted. Pursuing an alternative profession is also difficult under flood conditions. Rickshaw-pulling is not possible because of flooding. Day labouring is not available as all economic activities come to a standstill. They cannot rely on selling livestock because they have been washed out or there are no buyers. Marginal farmers do not have access to resources such as fishing nets or boats which they can use for income-generation. In rural areas, selling homestead trees is a source of income, however even this is not possible during and after the flood because most homestead trees/plants are damaged or inundated. They do not have access to natural resources, such as food grains, nor do they have access to sufficient cash to buy adequate food for survival. The access to social resources (that is, health-care, education, and availability of loans) breaks down as well. Institutional support from the government and NGOs also becomes unavailable and scarce during this period, mostly because the government lacks the financial capacity and ability to mobilize local manpower. If this condition prevails for a long time, and increases in frequency with each episode of flooding, it would ultimately result in food insecurity which would, in turn, lead to social unrest, crime, law and order breakdown, and political unrest. All these will eventually cause human insecurity.

8.3 Rationale for Recommendations

Based on the above major findings the rationales for the recommendations are as follows: The first recommendation is for a *mauza*-based databank which would readily provide information regarding each household and its respective flood-related losses. This could effectively guide rehabilitation work and post-flood planning. Besides, this databank would be useful for any long-term planning. For example, the Bangladesh Ministry of Agriculture is planning to offer subsidies of 25 % to assist farmers to purchase tractors, power tillers, and thrashers for rice and wheat. Before embarking on such decisions the *mauza*-based databank could provide important information about such relevant matters as the number of earning and dependent members, gross income of each household, amount of land owned, and access to other resources.

The second recommendation is for Community-Based Adaptation Committees (CBAC) which would provide a community-level platforms and centres of activity pre-floods, during floods, and post-floods in order to deal with V&A issues. The members of CBACs would comprise people of different social stratification. Community leaders and members of the locally-elected body could mobilize local resources. The block supervisor would act as the representative of the local agricultural office and could liaise with local government to convey the needs of the community. Teachers and *Imams* (local religious leaders) are included in the CBAC because of their influential position in society. The majority of the members of the CBACs would be farmers to ensure that the CBAC was aware of farmers' needs so that it could act in their best interests at all times. The CBAC would make decisions regarding adaptation strategies in accordance with different flood situations. Being community-based bodies, the CBACs would be familiar with the types of adaptation processes needed in response to different types of flood events.

8.4 Policy Implications and Recommendations

Based on the major findings of this book, the following recommendations are made for policy makers at local and national levels, for academics, and for researchers:

1. *Mauza*-based farmers' databanks should be established for the purpose of recording relevant information regarding each farmer. For example, details of land owned, types of land owned, number of landless farmers, rent, and household information (income, family members, family structure etc.). This should be operated as a nation-wide central databank under the Ministry of Agriculture.
2. A Community Based Adaptation Committee (CBAC) (Fig. 8.1) should be established on a *mauza* basis, each committee to include:

    a. Village leader/village community leader—2 persons
    b. Block supervisor—1 person

Fig. 8.1 Activities of community based adaptation committee

c. School teacher—1 person
d. Businessmen—2 persons
e. Farmers—5 persons
f. *Imam* (local religious leader)—1 person
g. Member of the local elected body—1 person.

Box 8.1: The Community Based Adaptation Committee (CBAC)

The CBAC would play an active role in disaster management at the community level, particularly dealing with floods. Areas of responsibility to include:

- Pre-flood (preparedness, warning system, etc.);
- During flood activities (relocation, facilitating availability of food/ drinking water, etc.);

- After-flood management activities (rehabilitation, advice re crops/loans, etc.);
- Liaison with *thana/upazila*-based government offices, e.g. water board, agricultural office, soil department, land office, TNO office, *Upazila* health centre, local banks;
- Mobilization and maintenance of resources, e.g. boat to be used for relocating people, fetching clean drinking water, emergency transport to hospital, etc.

The CBAC would ensure in-built routine and tactical adaptation requisites are met; for example, to facilitate routine adaptation post-flood, the CBAC would distribute HYV seeds or seedlings.

When adopting a tactical adaptation technique, farmers urgently need local variety *aman* seedlings so the CBAC could plan appropriate action. For instance it could arrange for the growing of seedlings on high land or on a floating base once the flood rises (e.g. *vela*—platform made of banana plants).

The CBAC could be authorized by government to use higher ground, such as land beside rail lines, district board roads/pucca roads.

The block supervisor (member of CBAC) could assess the needs of the *mauza* and act accordingly via the CBAC.

The CBAC could recommend to government to provide easy loans through the local agriculture bank or to provide seeds and seedlings at a subsidized price to support the post flood rehabilitation program.

3. Appropriate action by each level of the government should be adopted according to the level of vulnerability determined following assessment according to the methodology proposed in this research study.
4. Adaptation needs should be met in accordance with priorities as outlined in this study.
5. The study calculated the total loss incurred by each household due to floods, which is essentially the failure effect of autonomous crop adaptation. This will act as a guide to the amount of cash and other requisites that are needed in post flood periods to help them recover from the loss. The government and concerned NGOs should act immediately post-flood to compensate for these losses to prevent serious consequences such as food insecurity and human insecurity.
6. The government should prioritize and allocate funds to development projects if Bangladesh receives the adaptation funds proposed in the Copenhagen Accord. The present study has performed an economic analysis of the failure of ACA and explored the impact of major flood events at the household level. At the same time it prioritizes adaptation and vulnerability issues. Therefore it can act as a guide to policy decisions for the effective allocation of adaptation funds in Bangladesh.

The sixth recommendation refers to the UNFCCC's Conference of the Parties (COP 15) in Copenhagen on 18th December, 2009 (the Copenhagen Accord). Clause 3 of the Accord states that:

> Adaptation to the adverse effects of climate change and the potential impacts of response measures is a challenge faced by all countries. Enhanced action and international cooperation on adaptation is urgently required to ensure the implementation of the convention by enabling and supporting the implementation of adaptation actions aimed at reducing vulnerability and building resilience in developing countries, especially in those that are particularly vulnerable, especially least developed countries, small island developing States and Africa. We agree that developed countries shall provide adequate, predictable and sustainable financial resources, technology and capacity-building to support the implementation of adaptation action in developing countries.

This makes it clear that

- Adaptation to climate change is now considered the single most important issue, especially in the context of mega-delta regions such as the GBM River Basin;
- Implementation of adaptation actions has been recommended in order to reduce vulnerability and enhance resilience, particularly in developing countries;

It is unanimously agreed that developed countries will provide adequate financial resources, transfer technology, and capacity-building in order to support the implementation of adaptation actions in developing countries.

8.4.1 Prioritization of Vulnerability and Adaptation Issues

This study classified and ranked a series of V&A issues. In total, 45 vulnerability issues were identified and ranked with weighted index values through PRA sessions. In order to reduce vulnerability, action should be taken according to the degree of vulnerability. For example, 12 issues have been identified as having very high levels of vulnerability, and these should be given first priority in flood action planning. The government should propose effective measures to deal with them, such as subsidizing losses, or organizing easy loans or cash as needed on an emergency basis through the CBAC. Concerned agencies should be warned beforehand to take appropriate steps to mitigate the effects of floods. For example latrine wash-out has been identified as a priority vulnerability issue which may result in serious health hazards in the post-flood period. If this is predicted beforehand and if funds are allocated by the Government through the CBAC to deal with the damage as soon as flood water recedes, health-related consequences arising from this loss will be reduced.

Primary occupation loss is another highly vulnerable issue following a flood event. The after-effects can be mitigated by working towards restoring the primary occupation through providing cash, seeds, seedlings, boats, fishing nets, livestock, or ploughing equipment as needed, and as an interim measure organizing food and nutritional support.

Eighteen vulnerability issues were identified as highly vulnerable with a weighted value index of 18–19. One of these issues is stored seed loss. To reduce this loss a local body could be formed to collect and preserve the seeds from interested farmers or to encourage households to do so as a part of flood preparedness. Similarly, specific measures could be adopted through the CBAC to deal with the loss of cattle, poultry, pond fish, livestock-sheds, household goods, fuel wood, utensils, school books, crops and so on. Losses such as utensils, livestock sheds, and school books could be made up locally using local resources, with the CBAC acting as the central co-coordinator. Large landholders and well-off farmers could play an active role in this. For restoring roads, damaged households, or livestock sheds, the CBAC could effectively use local manpower for re-building work. Food for work and vulnerable-group feeding (VGF) schemes can be very effective in rehabilitation works such as these and could be organized through the CBAC. The CBAC could also play an active role in identifying the most vulnerable groups for inclusion in the VGF scheme. Thus, vulnerability issues should be dealt with according to the grading (high, medium, low, and very low) through the CBAC with active cooperation and help from all concerned local government offices.

Forty adaptation issues were identified and they were then classified into three categories according to priority based on weighted values adopted from participants of PRA sessions. The study reveals that vulnerable farmers have asked for some specific adaptation techniques in order to cope with losses. By enhancing the adaptation techniques already in place and pursuing those which vulnerable farmers need following floods, flood vulnerability can be reduced. Adaptation issues are described in chapter six in accordance with priority/level of urgency. The adaptation techniques labeled with highest priority are as follows: seeking loans for seedlings, a need for local and high-yield variety *aman* seedlings, a need for money for next season's cropping, a need for easy access to loans with low interest, a need for immediate shelter, a need for immediate relief facilities, a need for immediate/urgent relief, and a need for food. The adaptation techniques mentioned by the participants in PRA sessions should be addressed in order of priority. The CBAC could play an active central role in executing these techniques through liaising with various government authorities and concerned local NGOs.

8.4.2 The Failure Effects of Autonomous Crop Adaptation

A finding of this study, as detailed in chapter seven, is that average expenditure to cultivate one *bigha* land includes an average seedling cost of 500 *taka*, average fertilizer cost of 667 *taka*, pesticide cost of 300 *taka*, land preparation cost for cultivation of 667 *taka*, and watering cost of 333 *taka*; a total of 2,467 *taka*. Once floods wash away standing crops, when farmers are in a hurry to prepare land for replanting crops, they need to repeat the process and sometimes have to spend more than they had previously estimated because prices of seedlings, fertilizer, pesticides and all other essentials rise following a flood event. These costs are usually far beyond their means and either they take loans with high interest or try to survive by selling whatever fixed assets they have. Either way, they become poorer and more marginal. As this enquiry has shown, the amount of land typically owned by each household has decreased markedly during the period 1988–1998.

In these circumstances, the government and concerned NGOs should act immediately after floods to make up for the losses and provide farmers with essential requisites such as seedlings, fertilizer, pesticides, cash (for land preparation cost, labouring cost, watering cost), easy loans/incentives, and subsidized products. The losses calculated here per *bigha* land can be used as a guideline for the amount of money and other requisites that are needed by each farmer, taking into consideration the amount of land owned/cultivated. This could be effectively undertaken by the CBAC through active connection and support from *Upazila*-level government offices. For example, *Upazila* agricultural offices should supply seeds and seedlings on an urgent basis following a flood. The CBAC could request and distribute them as needed.

Organizing easy-access loans from banks is essential in post-flood rehabilitation. Usually this is a complicated process comprising multiple steps including applying and waiting for a period of time for the loan to be approved. The CBAC could liaise with local banks, help farmers prepare their paperwork, and make appropriate recommendations to the bank.

In order to prevent serious consequences arising from failure of autonomous adaptation, the government, NGOs, and the international community should respond immediately to uphold food security in affected communities. Bangladesh, as one of the most affected countries to bear the brunt of climate change, has asked for a share of the proposed international adaptation fund which will go a long way in supporting the causes of vulnerable people.

8.5 Conceptual Contribution of This Research

1. Within the climate change literature there has been a research gap regarding studies about autonomous adaptation processes. No other studies have been done so far to assess V&A and failure effects of autonomous adaptation. This book helps fill this research gap by:

   a. Assessing autonomous adjustment processes in response to EFEs in the past;
   b. Conducting V&A assessment and prioritization;
   c. Assessment of failure effects of autonomous adaptation.

This enquiry studied three recent EFEs occurring in Bangladesh. Recent climate change literature argues that flood frequency, intensity, and duration in the GBM River Basin would increase, suggesting that climate change would have a major impact on the flood regime in this region. From the findings of this study, an understanding can be drawn of autonomous adaptation processes, prioritization of adaptation and vulnerability issues, and failure effects of autonomous adaptation in regard to the frequency and magnitude of future flood events.

2. This study has shown that one of the major cropping seasons (*kharif* 2) is progressively being shortened due to recurrent multi-peak and long-duration flood events. As a consequence farmers have been losing one of their major crops—*aman*. This could be an important finding for the climate change research community and is a major result of this research.
3. A conceptual diagram (Fig. 8.2) shows that during the 1988, 1995 and 1998 floods farmers tried their best to adapt to the extreme conditions and as a result of their efforts the impacts of the floods were reduced. It is noted that due to the application of adaptation techniques the impact trend is forced downward. It also shows that because of the multi-peak and long duration of the flood in 1998 the farmers' adaptation capacity collapsed and as a consequence the impact trend shows a sharp rise. Repeated flood events that push farmers to the edge of the adaptation threshold and have impacts beyond the reach of their adaptation capacity, ultimately reducing their adaptation threshold and subsequently making them even more vulnerable. This book indicates that if this happens repeatedly, in the future farmers' adaptation thresholds will become very low and they will be unable to cope with even normal flooding.
4. The method adopted for assessment of V&A is based on the community-participation research technique. Two Participatory Rapid Appraisal sessions were conducted in the case study area and these facilitated completion of the assessment using data obtained from the responses of the participants. This enabled a measurement of the intensity of flooding and gave an overview of how the affected community was surviving floods by applying adaptation techniques. The information and findings were therefore extracted from the experiences of the affected community. The technique applied in this study can be considered as a 'participatory research technique' for assessing V&A. Utilizing PRA data in this way is a relatively easy and quick process whereby V&A issues and actions can be analyzed and evaluated through the direct participation of a subset of the vulnerable community. The method also serves as an educational tool to increase the understanding of flood risk management and possible responses by and for vulnerable communities. The technique applied in this study is unique and has not previously been used in V&A assessment in climate change and natural hazard literature though this technique has recently been using for understanding about the vulnerability and risk of natural hazards in developing countries such as Nepal, Cambodia and India (e.g. Bhandari [15]; Wikipedia [16]) (Sect. 2.7.4). The book thus presents a methodological contribution to research dealing with V&A.
5. The research technique mentioned above can be used for studying different natural hazards, particularly in developing countries in different regions. It can be applied in the context of other natural hazards such as coastal flooding, flash flooding, cyclones etc. It is more suitable for developing countries where illiteracy and poor infrastructure pose obstacles to other methods of

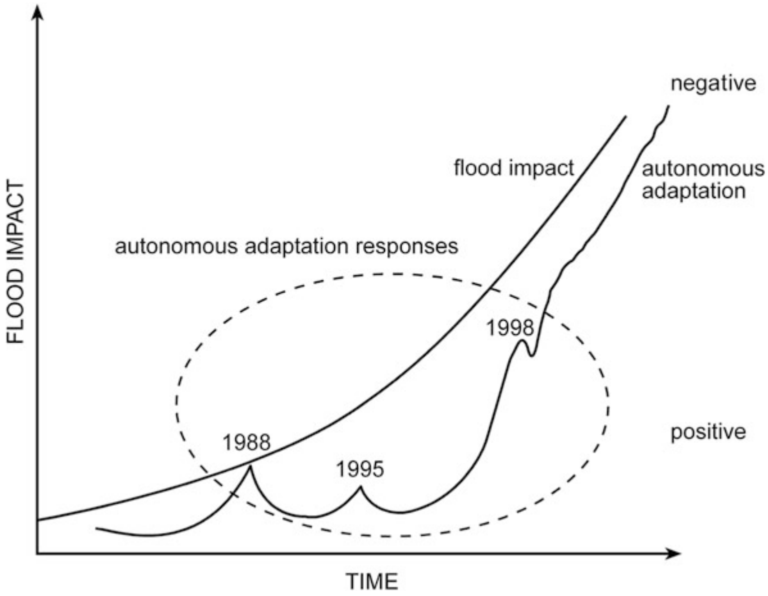

Fig. 8.2 Conceptual diagram of impact and adaptation in response to three floods

information collection (e.g. questionnaire survey by post and interviewing by telephone). Nonetheless, this research technique can easily be applied in developed communities as well.

6. This research technique can be used to forecast by analogy [17, 18]. The investigation of adaptation to current climate change variability, or to climatic events in the recent past, exposes assumptions and provides insights to raise the understanding of the likely impacts of similar events in the future. The picture drawn in this study from three recent major flood events in Bangladesh will enable the forecasting of V&A scenarios for future floods in the region.
7. Adaptation processes adopted by the vulnerable community have been explored in detail in this study (Chap. 5), providing important new data. The findings demonstrate the resilience of vulnerable people and their ability to cope with natural calamities at the cut-off point, as evidenced in the 1988, 1995 and 1998 EFEs. Their ability to use adaptation strategies at different levels of natural hazard should be incorporated in future development planning in order to ensure sustainable development.
8. The economic analysis of vulnerability in the case study communities was evaluated in the light of household information. It measures total crop loss against potential production, and it incorporates related agricultural costs (seedlings, fertilizers, pesticides, land preparation, total labouring and watering) and average household loss for each variable, in the three flood years. Through the case study and the questionnaire survey method an estimate of the total economic loss for Bangladesh was calculated. It was inferred that the

economic loss accelerates food insecurity and could ultimately lead to human insecurity in Bangladesh, which can be considered a model of the GBM River Basin.

8.6 Recommendations for Future Research

This study is an assessment of V&A in relation to three extreme riverine flood events in Bangladesh, and at the same time it has developed a research technique to assess V&A. It has also evaluated the failure effects of autonomous adaptation. Similar studies can be performed in relation to flash floods and coastal flooding, and both cumulative and integrated (combined effect of riverine, flash, urban and coastal flooding) effects can be investigated. The likely changes in V&A issues and the failure effect of autonomous crop adaptation in the context of possible climate change could also be studied using this research technique. The V&A issues and the intensity of their impact under a climate change scenario in the foreseeable future could be assessed and the impact of failure effects in the changed scenario could be investigated. At the same time such studies would serve an educational purpose, increasing the understanding of V&A issues and actions in the affected farming communities, and introducing a priority or risk-based approach to the management of outcomes from future extreme flooding events in Bangladesh.

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Appendix I

FIELD QUESTIONNAIRE

Community-Based Autonomous Adaptation and Vulnerability to Extreme Floods in Bangladesh: Processes, Assessment and Failure Effects

Md. Aboul Fazal Younus[1]

<u>Personal Information</u>:
1. Name of the respondent:
2. Address: Block:………………………; Mauza: ……………….
Village: …………………….; *Union*: ………………
Upazila: ………………………; *Zilla*:
3. a) Number of family members:
b) Number of family member (s) who is / are economically active:
c) Total number of dependent family members:

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4. Respondent's family profile

Person No.	Name	Relation to head of household	Age	Gender	Activities			General Income		
					P	S	T	P	S	T

P- Primary or major activity/occupation; S- Secondary occupation; T- Tertiary occupation

5. Land ownership pattern

Type of land	Amount of land in local unit	Total land (local unit or in acreage)
Owned		
Rent in		
Rent out		
Lease		
Dokoholi / Possession		

6. Respondent's type of land and its exposure to flood condition

Type of land	Size / Amount of Land	Exposure to normal flooding			
Very Low Land (VLL)		Highly Vulnerable	Moderately Vulnerable	Low Level Vulnerable	
Low Lands (LL)					
Medium Low Lands (MLL)					
Medium High Lands (MHL)					

6. Possessed things - Homesteads

Name of possessed	Number	Number of rooms	Made by	Approximal total value	Affected by flooding in		
things				of damage/s	1988 1995 1998		
Houses					P M T	P M T	P M T

P: Partially; M: Moderately; T: Totally

7. Possessed things – cattle, goats,

Name of Item	Number of cattle death due to flooding 1988	Number of cattle death due to flooding 1995	Number of cattle death due to flooding 1998	Number of cattle death due to flooding 2006
Cattle	N: V:	N: V:	N: V:	N: V:
Goat	N: V:	N: V:	N: V:	N: V:
Chicken / Duck	N: V:	N: V:	N: V:	N: V:
Others				

8. Number of cattle / goat affected due to flooding

	Number of cattle/goat sold due to flooding 1988	Number of cattle sold due to flooding 1995	Number of cattle sold due to flooding 1998	Number of cattle sold due to flooding 2006
Cattle	N: Value:	N: V:	N: V:	N: V:
Goat	N: Value:	N: V:	N: V:	N: V:
Chicken / Duck	N: V:	N: V:	N: V:	N: V:

9. Loss of storage seedlings for the next season as well as the current season

Flood years	Amount in kg for *kharif* 2 season	Market Value	Amount in kg for *Rabi* / transition period season	Market Value
1988				
1995				
1998				
Current				

10. Occupation loss in *kharif* 2

	What type of primary occupation was	Total losses (TL) in Tk*		TL	Tero ccu	TL
1988						
1995						
1998						
2006						

* in relation to number of flood days

11. Occupations loss in transition period (between *kharif 2* and *rabi*)

	What type of primary occupation was	Total losses (TL) in Tk*	secondary occupation	TL	Tero ccu	TL
1988						
1995						
1998						
2006						

* in relation to number of flood days

12. Occupations losses in *rabi* period

	What type of primary occupati on was	Total loss (TL) in Tk*	secondary occupation	TL	Tero ccu	TL
1988						
1995						
1998						
Current						

13. Total occupational loss in each flooding

	Loss from primary occupation	Loss from secondary occupation	Loss from tertiary occupation	Total occupation loss in Tk
1988				
1995				
1998				
2006				
Total	----			

14. Land loss due to flooding

	Loss of crop lands due to erosion	Loss of crop lands due to sand deposition	Loss of homestead lands	
1988				
1995				
1998				
2006				

15. How many times and when the floods appeared?

	1988	1995	1998	Normal flood period	2006
how many times floods appeared					
When it appeared					

16. Crop damaging pattern

	Damaging pattern in 1988	1995	1998	2006
Crop at *Kharif* 2	Entirely Partially	Entirely Partially	Entirely Partially	Entirely Partially None
Crop at transition period				

17. What type of crops and how many times were planted in various flood years

Situation in *kharif* 2	Practiced in 1988	In 1995	1998	Current year
1. First time Planted HYVs *aman* rice 2. second time again planted HYVs aman 3. third time planted local variety aman	1. 2. 3.	1. 2. 3.	1. 2. 3.	1. 2. 3.

18. Why did you choose normally HYVs aman crop instead of local variety at *kharif* 2 cropping season?

1. higher crop production ☐
2. easy access of seedlings ☐
3. the cost of seedlings are cheap ☐
4. appropriate / friendly for the season ☐
5. long crop growing period ☐

19. I chose local variety as

1. Due to short crop growth period
2. As the flood event/s took the substantial amount of cropping days from the *kharif* 2 cropping season
3. The seedlings are available in local areas and it is cheap

20. What type of crops you usually choose for your agriculture lands

For	*Kharif* 2	Transition period	Rabi	
Low land	Situation 1:			
Very low land				
Medium high land				

21. What type of crops were planted at the transition period in 1998?
----

22. Why these crops failed to harvest properly?
Answers:

1.
2.

23. Did you get crops at transition period in 1988 after being affected by the worse flood event?
Yes no
If no why
----

24. Total crop loss

	Crop loss in *kharif* 2 (in Kg and also in Tk)		Crop loss in transition period	
	Total crop loss / total crop lands	Crop loss/ acreage	Total crop loss / total crop lands	Crop loss/ acreage
1988	Kg Tk	Kg Tk	Kg Tk	Kg Tk
1995	Kg Tk	Kg Tk	Kg Tk	Kg Tk
1998	Kg Tk	Kg Tk	Kg Tk	Kg Tk
Normal year	Kg Tk	Kg Tk	Kg Tk	Kg Tk
2005	Kg Tk	Kg Tk	Kg Tk	Kg Tk

25. Production cost loss 1998

	Per household total lands		Per acreage	
First time flood				
Total cost of seedlings in Tk	--			
Fertilizer costs				
Pesticides costs				
Land preparation cost for cultivation (cow, ploughs etc hiring)				
Total labouring cost				
Watering cost				
Others				
Total cost				
2nd time flood				
Total cost of seedlings in Tk				

Fertilizer costs				
Pesticides costs				
Land preparation cost for cultivation (cow, ploughs etc hiring)				
Total labour cost				
Watering cost				
Others				
Total cost				
3rd time flood				
Total cost of seedlings in Tk				
Fertilizer costs				
Pesticides costs				
Land preparation cost for cultivation (cow, ploughs etc hiring)				
Total labour cost				
Watering cost				
Others				
Total cost				
Grand Total				

26. Total production cost and its loses in 1988

	Per household total lands		Per acreage	
First time flood				
Total cost of seedlings in Tk	--			
Fertilizer costs				
Pesticides costs				
Land preparation cost for cultivation (cow, ploughs etc. hiring)				
Total labour cost				

Watering cost				
Others				
Total cost				
2nd time flood				
Total cost of seedlings in Tk				
Fertilizer costs				
Pesticides costs				
Land preparation cost for cultivation (cow, ploughs etc. hiring)				
Total labour cost				
Watering cost				
Others				
Total cost				
3rd time flood				
Total cost of seedlings in Tk				
Fertilizer costs				
Pesticides costs				
Land preparation cost for cultivation (cow, ploughs etc. hiring)				
Total labour cost				
Watering cost				
Others				
Total cost				
Grand Total				

27. Total production cost and its loses in 1995

	Per household total lands		Per acreage	
First time flood				
Total cost of seedlings in Tk	--			
Fertilizer costs				
Pesticides costs				
Land preparation cost for				

cultivation (cow, ploughs etc hiring)				
Total labour cost				
Watering cost				
others				
Total cost				
2nd time flood				
Total cost of seedlings in Tk				
Fertilizer costs				
Pesticides costs				
Land preparation cost for cultivation (cow, ploughs etc hiring)				
Total labour cost				
Watering cost				
others				
Total cost				
3rd time flood				
Total cost of seedlings in Tk				
Fertilizer costs				
Pesticides costs				
Land preparation cost for cultivation (cow,				

ploughs etc hiring)				
Total labour cost				
Watering cost				
others				
Total cost				
Grand Total				

EFFECTS OF CROP FAILURE

28. What happened after failure of crops in *kharif* 2 and the transition period due to extreme flooding in 1998; how did you survive at that time?

	After 1988 flooding			
Sold lands	Amount of lands?	How much?		
Sold cows	How many	How much		
Took loans for seeds for the next cropping season	How much	From whom	How did you pay back?	
Got / took loans for cattle, fertilizer, pesticides etc	How much	From whom	How did you pay back?	
Sold the houses	How much	What did you do?		
Shifted houses due to river erosion	How much spent for that shifting	Where did you go?	Is the current homestead yours or relative's land?	Did you pay for that?
Moved to town or other cities for alternative work	What type of occupation: ------------	Monthly income-----	Did you move permanently along with family?	Usually come back two/one months interval
Worked as day labourer	Monthly income-----	What type of work?		
in the locality				
Started to pull Rickshaw	Monthly Income-----			
Loans for immediate foods	How much	From whom	How did you pay back them	How much interest it was

in the locality				
Started to pull Rickshaw	Monthly Income-----			
Loans for immediate foods	How much	From whom	How did you pay back them	How much interest it was
Used to eat once/twice meal instead of three times/ per day				
No ability to purchase foods mainly rice	How did you arrange/buy rice/ foods			
The price of rice was high	Was the price higher than normal ?	Cost per kilo(rice)		
Lose seedling buying capacity for next cropping season	How did you arrange the seedling cost for the next cropping season?			
Severe land erosion and displacement	Did you move your homesteads due to river erosion?	What was your previous place?	How did you arrange the relocation cost?	
Sand deposition on the agricultural lands	agricultural lands completely/partially deposited by sands?	How did you survive?		

29. What happened after failure of crops in *kharif* 2 and the transition period due to extreme flooding in 1988; how did you survive at that time?

	After 1988 flooding			
Sold lands	Amount of lands?	How much?		
rice				
Sold cows	How many	How much		
Took loans for seeds for the next cropping season	How much	From whom	How did you pay back?	

Got / took loans for cattle, fertilizer, pesticides etc	How much	From whom	How did you pay back?	
Sold the houses	How much	What did you do?		
Shifted houses due to river erosion	Shifting cost	Where did you go?	Is the current homestead yours or relative's land?	Did you pay for that?
Moved to town or other cities for alternative work	What type of occupation: ------------	Monthly income-----	Did you move permanently along with family?	Came back after two/one months interval
Worked as day labourer in the locality	Monthly income-----	Type of work?		
Started to pull Rickshaw	Monthly Income-----			
Loans for immediate foods	How much	From whom	How did you pay back them	How much interest it was
Used to eat once/twice meal instead of three times/ per day				
No ability to purchase foods mainly rice	How did you arrange/buy rice/ foods			
The price of rice was high	Was the price higher than normal	Cost per kilo(rice)		
Lose seedling buying capacity for next cropping season	How did you arrange the seedling cost for the next cropping season?			

Severe land erosion and displacement	Did you move your homesteads due to river erosion?	What was your previous place?	How did you arrange the relocation cost?	
Sand deposition on the agricultural lands	Agricultural lands completely/partially deposited by sands?	How did you survive?		

30. During the post flood period in 1998—did you get any help from the governmental agencies/NGOs?
    Yes No
    If yes what are the help?
31. During the post flood period in 1988—did you get any help from the governmental agencies/NGOs?
    Yes No
    If yes what are the help?
32. During the post flood period in 1995—did you get any help from the governmental agencies/NGOs?
    Yes No
    If yes what are the help?
33. Do you think VGF—Vulnerable Group Feeding system is adequate for survive from extreme flood events?
34. What kind of help do you need?
    During the extreme flood period:
    During the post flood period:

Appendix II

THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE
STANDARD CONSENT FORM FOR PARTICIPANTS

1. I, --- (please print name) consent to take part in the research project entitled "Autonomous Adaptation in Response to Extreme Flood Events in Bangladesh: Processes, Assessment and Failure Effect".
2. I acknowledge that I have read through the information sheet for participants in PhD research project: Autonomous Adaptation in Response to Extreme Flood Events in Bangladesh: Processes, Assessment and Failure Effect.
3. The principal researcher explained the purpose and importance of the research project. I am clearly convinced and willing to take part for filling the questionnaire. My consent is given freely.
4. I have been informed that I would not be recognised in person in the study and my personal information would not be disclosed in any form of research publications.
5. I understand that I am free to withdraw from the research project at any time.
6. If I wish then I can keep a copy of this consent form, when completed, along with the attached information sheet.

-- -------------------------

Signature Date

M. A. F. Younus, *Vulnerability and Adaptation to Climate Change in Bangladesh*, Springer Theses, DOI: 10.1007/978-94-007-5494-2,

WITNESS CERTIFICATION

I have explained to the participant the purpose and importance of the research project entitled “Community-Based Autonomous Adaptation and Vulnerability to Extreme Floods in Bangladesh: Processes, Assessment and Failure Effect”. In my opinion the interviewee clearly understood my explanation.

Status in Research Project:------------------

Name:-------------------------------------

Signature: Date:

Glossary

Agricultural Block Supervisor *Upazila* Agriculture Office has divided several blocks of agricultural lands. The block supervisors are responsible to collect agriculture related data from the concerned block/s and report to the agriculture office. They are responsible to discuss with the local farmers about their cropping decisions, and availability of agricultural needs

Aman It is a variety of rice which grows in *kharif* 2 cropping season (July to November). It has local as well as high yielding variety

Ashar, ograhoyon These are Bengali months

Bazar Small commercial place

Bigha Land measuring unit. One *bigha* = 0.33 acre

Bonna It is an abnormal flooding which brings havoc and disaster

Borsha It is a normal annual flood event. Farmers usually adapt with this normal annual flood event, and cultivate their required crops on the agricultural lands

Chalan bill One of the richest wetland areas of Bangladesh

Char Land areas which are sand bars formed within a river or estuary. It is a remote and isolated area from the mainland, and it has no utility services such as electricity, gas and water

Chinaduli *Union* It is located in the case study area

Gainja, Haloi* and *Kater Local variety of *aman* crop. These are short maturation crop

***Kharif* 2** It is a cropping season, and extends from July to November (*Shraban* to *Kartik*) and comprises most of the monsoon season

Machang Unusually located under the roof, farmers use the *machang* as a storeroom

Matbar Local community leader who is usually wealthy at grass-root level

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Mauza It is a root level land identification unit in Bangladesh. Sometimes it means a village. Several mauzas comprise a Union

Plabon Exceptionally severe floods. These devastate the livelihoods of people and cause havoc to the national economy

Rabi It is a cropping season, which is the period between November and February (*agrahaon* to *magh*)

Rickshaw Tri-cycle, pulled by man

shobaraj, bagha, chonda, boro digha, hash kolom, ponkhiraj, kartic jhula, roga jhula, echa kuri all are local varieties *aman*. These are called deep water aman, and grow with incoming flood water

Shotok It is a local land measuring unit. One *shotok* = 0.0104 acre

Taka currency of Bangladesh. 1 US dollar = 70.22 *taka* (OANDA.com)

Transition between *Kharif* 2 and *Rabi* This is the period extending from the beginning of recession of flood water to the time before farmers start planting IRRI *boro*

Union Parishad Every *Union* has elected committee, it is called *Union Parishad*. Every *Parishad* has an elected chairman and several elected members

Union It is a local administrative unit in Bangladesh. Several *Unions* comprise as an *Upazila*

***Upazila* (formerly it is called Thana)** It is an administrative unit in Bangladesh

***Upazila Nirbahi* Officer** *Upazila* administrative officer who represents the Government of Bangladesh