Impact of climate related shocks and stresses on nutrition and food security

in selected areas of rural Bangladesh

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IFAD Investing in rural people

A study conducted by:
Helen Keller International, the Bangladesh Centre for Advanced Studies, and the Institute of Development Studies, in partnership with the World Food Programme, and funding from the International Fund for Agricultural Development.

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BCAS
Helen Keller International
IDS Institute of Development Studies
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Foreword

The study - ‘Impact of climate related shocks and stresses on nutrition and food security in rural Bangladesh’ – was commissioned by the World Food Programme and conducted in collaboration with the Institute of Development Studies (IDS) at the University of Sussex, the Bangladesh Centre for Advanced Studies (BCAS) and Helen Keller International (HKI). It was jointly funded by the International Fund for Agricultural Development (IFAD) and WFP. The objectives of the study converge with two pillars of the Bangladesh Climate Change Strategy and Action Plan 2009: Pillar 1 food security, social protection and health; and Pillar 6 research and knowledge management. Since its inception, the study was guided by a technical committee headed by the Ministry of Environment and Forests and provided with feedback and suggestions at critical stages.

This study attempts to break down ‘climate change’ into ‘climate related shocks and stresses in the course of time’ and conceptualizes the food security and nutrition outcomes as combination of the adverse effects of shocks with the strategies that individuals/households develop in response to these shocks.

The study is unique in its breadth: it looked into six different types of climate-related shocks and stresses: drought, flood, flash flood, river bank erosion, cyclones and salinity intrusion; their occurrence and effects over a long time period. It is the first analysis of its kind, looking into single shock events, multiple events of the same types, and combined types of events.

The study includes both quantitative and qualitative approaches to steer the analysis on whether there are any associations between climate-related shocks and stresses with nutrition and food security outcomes. The HKI Nutrition Surveillance Project dataset from 1998 to 2006 used for the study allows to explore the possible lagged effects of the different events. The findings suggest where we would need to dig deeper and which kinds of data collections we would require to continue in order to enhance our knowledge and subsequent political and operational actions.

As such the study gives us a new perspective of viewing our conventional disaster response and rehabilitation approaches and offers a new window for addressing the prolonged effects on affected communities. This research substantially enhance our joint knowledge on climate change and climate related shocks and stresses, people’s lives and livelihood strategies and related nutrition and food security outcomes.

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Contents

Acronyms

AR	Assessment Report
BCAS	Bangladesh Centre for Advanced Studies
BCC	Behaviour Change Communication
BDHS	Bangladesh Demographic and Health Survey
BMI	Maternal body mass index
BWDB	Bangladesh Water Development Board
CED	Chronic Energy Deficiency
CEGIS	Center for Environmental and Geographic Information Services
Child dd	Child dietary diversity
CLP	Chars Livelihoods Programme
CMNS	Child and Mother Nutrition Survey
CRED (EM-DAT)	Centre for Research on the Epidemiology of Disasters Emergency Events Database
DDM	Department of Disaster Management
DFID	Department for International Development
DiD	Difference in difference
DiM	Difference in means
DL	Danger Level
DMIN	Disaster Management Information Network
EFSA	Emergency Food Security Assessment
FAO	Food and Agriculture Organization
FE	Food expenditure
FFWC	Flood Forecasting and Warning Centre
FGDs	Focus group discussions
FL	Flood Loan
FNSSP	Food Security and Nutrition Surveillance Project
GMB	Ganges-Brahmaputra-Meghna
GoB	Government of Bangladesh
HIES	Household Income and Expenditure Survey
HKI	Helen Keller International
IBTrACS	International Best Track Achieve for Climate Stewardship
IDIs	In-depth interviews
IDS	Institute of Development Studies
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
IPHN	Institute of Public Health Nutrition
IWM	Institute of Water Modelling
KIIS	Key Information Interviews
Maternal DD	Maternal dietary diversity
MDG	Millennium Development Goal
MoEF	Ministry of Environment and Forest
NAPA	National Adaptation Programme of Action
NDRI	Natural Disasters Risk Index
NOAA	National Ocean and Atmospheric Administration
NSP	Nutrition Surveillance Programme
PET	Potential Evapo-transpiration
PFB	Price of Food Basket
PIO	Project Implementation Officer
PO	Price of Oil
PR	Price of Rice
SPI	Standardized Precipitation Index
SRDI	Soil Resource Development Institute
SREX	Special Report on Extreme Events
UNICEF	United Nations Children's Fund
UNO	Upazila Nirbahi Officer
WFP	World Food Programme
WHO	World Health Organization
WMO	World Meteorological Organization
ZLEN	Length/Height for age z-score
ZWFL	weight for Length/Height z-score

Executive Summary

Executive Summary

80% people of the population over **156 million**, live in rural areas of Bangladesh

Background

With a population over 156 million people, 80 percent of whom live in rural areas, an average density of 940 persons per km^2 (the 9th most densely populated country in the world) and 70 percent of land area five meters or less above sea level, environmental hazards such as floods, cyclones, salt water intrusion and river erosion are expected to have massive destructive impacts in Bangladesh. In effect it is estimated that 30 to 50 percent of the country is affected by severe climatic shocks every year (WFP 2012a). These events have killed hundreds of people and injured thousands, ruined thousands of hectares of crops and washed away large areas of cultivable land, homes, and productive assets, amounting to huge human and economic losses.

In Bangladesh, undernutrition has long been recognized as a problem of significant magnitude, with 24% of women underweight and 13% of short stature, 41% of children under five years of age stunted in 2011, and 36% underweight (BDHS 2011). Undernutrition rates in Bangladesh are already among the highest in the world (NDRI 2010). In this context, a legitimate question is whether these described extreme events that are continuously affecting Bangladesh contribute significantly to the situation of undernutrition. One hypothesis is that the impact of climate related shocks and stresses on food security and nutrition in Bangladesh could be particularly severe given the reliance of a majority of poor rural households on agricultural livelihoods.

In March 2012, the World Food Programme (WFP) therefore conceptualized a study to "*develop an improved knowledge and understanding of the impacts of climate change on food security and nutrition*" in Bangladesh and more specifically to determine how climate-related shocks and stresses exacerbate the already high levels of food insecurity and undernutrition in the country.

The present report is the result of this study. It brings together the efforts of a multi-disciplinary team of researchers from Helen Keller International (HKI), the Bangladesh Centre for Advanced Studies (BCAS), and the Institute of Development Studies (IDS) to look at the impact of extreme events (what we refer to as climate-related shocks and stressors) on the food security and nutrition status of communities in rural Bangladesh. Funded by the International Fund for Agricultural Development (IFAD) and WFP, the study uses existing quantitative data and collected qualitative data, to attempt to address the current gap in knowledge related to these climate related shocks and stresses in relation to food security and nutrition in Bangladesh.

Methods

The quantitative analyses combine the Nutrition Surveillance Programme (NSP) dataset collected by HKI and a compilation of environmental and disaster-related data. The NSP provides data that are statistically representative of rural Bangladesh. Rounds of data collection take place every two months to capture seasonal changes in nutrition, health, household demography, socioeconomic status and distress, and local food prices. For nutrition, children's z-scores of length/height for age and weight for length/height were calculated. Children with z-scores more than -2 standard deviations below the reference median were classified as stunted or wasted.

Although other household-level datasets exist (e.g. the Household Income and Expenditure Survey (HIES) or the Child and Mother Nutrition Survey (CMNS)), the NSP is the only long-time series that provides data at a frequency (bi-monthly) that permits the capture of potential changes in nutrition and food security indicators following the impact of shocks.

Various data sets were used to identify the occurrence of shocks and stressors. Six different types of climate-related events were initially considered: flood and flash flood, drought, cyclone, river bank erosion, and salinity intrusion. For flood and flash flood, the daily water level recorded by the Bangladesh Water Development Board (BWDB) was used to identify flooding events. The daily rainfall data also recorded by the BWDB was used to identify drought events. Salinity intrusion was estimated through the Program Soil Salinity data collected by the Soil Resource Development Institute (SRDI). For cyclone the International Best Track Achieve for Climate Stewardship (IBTrACS) dataset was used to generate a map of the different cyclones and tropical storms that affected Bangladesh over the period 1995-2008. Finally for river bank erosion it was initially planned to use the River Cross Section dataset collected by BWDB. However this dataset was later discarded due to the absence of a clear methodology on how to correlate the data with the occurrence of specific river erosion events.

The conceptual framework used to structure the research derives from the UNICEF 1990 Strategy for improved nutrition of children and women in developing countries framework, the IDS/DFID sustainable livelihood framework, and incorporates some recent thinking around resilience to shocks in the context of food security. The analytical framework identifies a series of variables and interactions which are important to consider if one aims at assessing the food security and nutrition status of communities exposed to climate-related extreme events but also the specific resilience strategies that are adopted by households and communities as a response to these shocks.

In order to test as rigorously as possible the potential impact of specific events on household food security and child and maternal nutrition, a quasi-experimental approach was followed. Wherever possible, a difference-in-difference (DiD) protocol was adopted to compare the values of a particular indicator (nutrition or food security) obtained for two groups of communities: one group affected by a specific event (treatment), and one group not affected by the same event (control). The comparison was run with data collected before and after the period when that specific event occurs.

For salinity intrusion –for which the chronic nature of the event made the DiD approach non-applicable - a difference in means (DiM) approach was used instead. In addition, for salinity and for river bank erosion - for which it was not possible to match the NSP data with the river datasets - two qualitative investigations were implemented instead, one in Gaibandha in the north-west of the country where river bank erosion and floods are common and one in Satkhira in the southern coastal area where saline intrusion is now a recurrent problem. In both areas, key informant interviews, focus group discussions, and in-depth interviews were conducted.

For the quantitative analyses, three types of models were used: (i) individual-event models where specific shocks (e.g. the 1999 drought in Naogoan, or the 1996 flood in Manikganj) were tested individually using the DiD protocol; (ii) joint-event models where all the shocks of same type (e.g. all the cyclone events or all the droughts) were pooled together and tested using the DiD protocol; and (iii) combined-event models where drought and flood, and cyclone, flood and salinity events were pooled together and tested using the DiD protocol. This analysis allowed us to disentangle the impact of different types of event as many areas experience multiple events in the same year.

The analysis presents some limitations. First, not all the variables that were identified through the framework as potentially important in relation to the food security and nutrition status of the communities were available, or it was not possible to identify adequate proxies. This eventually limited our ability to explore some aspects related to resilience. Second, only households still living in the affected areas were surveyed and any individual or family that would have migrated somewhere else (e.g. neighboring town, provincial capital, or even Dhaka) as a consequence of past events were therefore not included in the analysis. Finally because it explores the potential interaction between different types of shocks and stressors and incorporates them into one single framework, the analysis is relatively complex and data intensive. Like any complex analysis it has to be considered with caution.

Main findings

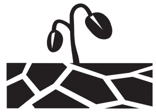
This study is the very first one that includes a comprehensive analysis of (initially) 6 different types of climate-related shocks and stresses: drought, flood and flash flood, river bank erosion, cyclones and salinity intrusion, and proposes to analyse the impact of these different types of events over a long period (1998-2006), relying on a rigorous, systematic and replicable approach that combines household-level food security and nutrition data with environmental time-series while controlling for household and community characteristics. It is also unique in that it is the first analysis of this type which, in addition to single types of events, also tested multiple events of the same types and combined types of events: drought and flood together; and cyclone, flood, and salinity together.

The very first conclusion that emerges is that working on identifying possible impacts of climate related shocks and stresses on household food security and child and maternal nutrition is both data-demanding and complex. A few of the results that emerged were challenging, counter-intuitive or even difficult to interpret. For others, coherent and more robust conclusions were reached only after comparing and combining the results of several individual tests or after triangulating the quantitative and qualitative analyses. The importance of combining several events in order to reach robust conclusions also means that one needs to resist the temptation of cherry-picking single cases in order to 'demonstrate' what we think are the 'coherent' findings.

Flood

A series of robust and coherent 'stories' emerge from this analysis. The first one relates to flood. Our analysis shows with strong statistical evidence that the prices of a food basket in communities affected by flood events are higher than in the control communities, and that this effect lasts for up to 9 months after the flood. This is consistent with the findings of the qualitative analysis which reveals that, while most food items are available in local markets, their prices are higher than in a normal period. The evidence that communities affected by flood take more food loans or have a higher share of their expenditure allocated to food than control communities is not clear. In terms of nutrition the analysis demonstrates with strong statistical evidence that the weight for height z score amongst children who live in communities affected by flood is lower (i.e. wasting rate is higher) than in the control communities, and that this 'peak' of acute undernutrition occurs around 5 months after the flood event. The analysis failed however to find any robust evidence that flood contributes to chronic undernutrition (stunting), or affect maternal body mass index. Finally the data suggests some strong positive impact on dietary diversity.

Drought



The second relatively solid story is about drought. Our analysis shows some relatively strong evidence that prices of food are higher after a drought and that this effect lasts for up to 9 months after the events. The analysis also suggests that as a response to the price peaks, communities increase the share of their total expenses allocated to food and that they do so (at least partially) by undertaking food loans. These strategies don't seem sufficient however to prevent chronic undernutrition amongst the children living in these communities. Our analysis found degree of evidence that drought events are associated with lower children's length/height-for-age z-score (higher stunting rate) around 5- and 9-months after the drought event started. On the other hand, no robust or consistent effects of drought on level of children's acute undernutrition (wasting) were found. Likewise the analysis did not find any robust evidence that drought events negatively affect the mother's body mass index, or the children and maternal dietary diversity indexes.

Cyclones

The third solid story relates to the impact of cyclones. First the analysis of food price indicators provides strong statistical evidence that communities hit by cyclones also have to face higher food prices. These price peaks can last up to 7 months for the most severe cyclone events but are generally less for lower intensity storms. Data also show that households take (statistically) higher food loans only for these more severe events. On the other hand data shows that affected households spend statistically less on food than households in control (i.e. not affected) communities. One possible explanation for this counter-intuitive finding could be that households affected by storms and cyclones spend a larger portion of their total expenses on covering the costs of rebuilding assets, and thus reduce their food expenses. Possibly this strategy explains also that cyclone events are statistically strongly associated with occurrence of lower weight for height z-score (suggesting high level of acute malnutrition); and that the impact seems to increases with the severity of the event. The analysis also indicates that cyclones may have some negative impacts on both the maternal and the child dietary diversify indexes with a lag of 5 to 7 months after the event. On the other hand the evidence of the potential impact on maternal body mass index is not clear.

Saline intrusion

The last main robust story relates to the impact of saline intrusion on the food security and nutrition status of the population living in the coastal belt. While the analysis is relatively inconclusive regarding the possible association of salinity with the price of food in these regions, the statistical models provide robust evidence that communities affected by high salinity are characterized by higher food loan rates and food expenditure levels than control communities in non-affected areas, thus suggesting some degree of food insecurity. In that context it is not surprising that the analysis also indicates that both child acute and chronic undernutrition levels are statistically higher in these saline-prone areas than in the rest of the country. More surprising is the correlation between saline intrusion and higher dietary diversity indexes Child dd and Maternal DD. The findings concerning the maternal body mass index of women is more inconclusive.

Some puzzling results

As part of these analyses, our research also reveals some more counter-intuitive results such as higher child and maternal dietary diversity indices in communities affected by floods and saline intrusions; and a lower stunting rate amongst children who live in cyclone-prone areas than in control areas.

Qualitative research results

In addition to these results which derive essentially from the quantitative analyses, other important information emerges from the qualitative research. First, the importance of rice and starchy foods. Given the emphasis on rice and potatoes in the diet, the absence of these two items would pose a challenge to local rural populations. Rice and potatoes are some of the cheapest and most filling items in the market, hence their ubiquity in the diet in normal times, but also just after a shock: these appear to be the most affordable following a disaster event.

Second, the key role of fish in both normal and disaster periods. While fish (along with eggs) is the only source of animal protein which is consumed with regularity during normal time, interviews indicate that its importance in the diet is even more pronounced during crisis. During flooding events, for instance, fish become a renewed source of nutrition and more fish are consumed during this time than in other times. This, combined with the fact that in the wake of disasters, sources of animal protein (other than fish) are not available for several months, makes fish an absolutely critical element in the food security and nutrition of populations affected by these shocks and stresses.

Third, saline intrusion makes everything worse. Salinity intrusion has been a recurrent and increasing issue in the southern coastal belt, affecting literally every aspect of people's life, livelihood, farming activities, human and livestock health, on a daily basis. Residents recognize shrimp farming as being the primary cause of high salinity levels, but they see the occurrence of climate-related events (cyclones, flood, drought) as aggravating the problems on a temporary or seasonal basis, adding hardships to an already very difficult life.

Observations on Nutrition

Children's nutrition is protected at the detriment of the mother. Coping strategies, such as eating fewer meals per day, eating less at each meal, skipping meals, eating less preferred foods, and decreasing dietary diversity were consistently listed as post-disaster coping strategies employed to bridge the household to better times. But the respondents also made clear that children are usually given preferential treatment to ensure their health and survival, being given the most nutritious food and being the last to make sacrifices in relation to meals. Women, on the other hand, make the biggest sacrifices, being the most likely to go hungry and not eat.

Nutrition was not considered a priority by the respondent after disaster. During an extreme event (cyclone, flood, river erosion) people experience significant hardship in terms of economic losses due to destruction of property, livestock, gardens, and other assets, and the absence of income. Our data indicates that diets are also significantly altered in the wake of a disaster and that nutrition is not identified by the respondents as a key-factor considered in consumption-related decision-making after a climate event. Because money and jobs are scarce, the primary concern is price of food, with quality and shelf-life being secondary concerns. Nutritious food is available in the market not long after, but access is hindered by lack of money to purchase nutritious food. In sum, optimal or even adequate nutrition is not regarded as a priority in the immediate period right after an event, but can be considered once economic and food security permits the luxury of making decisions around eating for nutrition instead of eating for hunger.

Recommendations

A series of recommendations emerge from these different findings.

Policy Recommendations

Integrating food security and nutrition into climate sensitive programmes

Although our analysis suggests that the pathways are shock specific and vary in nature and in intensity, the main finding of this research is that climate-related shocks (droughts, floods/flashflood, river erosion, cyclones) or induced stressors (salinity intrusion) have negative impacts on the food security and nutritional status of households living in affected areas.

Following these findings, a first recommendation for governments and international development agencies is to ensure that food security and nutrition interventions are better integrated into climate change focussed programmes. One way to ensure this stronger integration would be to make sure that nutrition indicators are part of the indicators included in the initial targeting mechanisms of climate change or resilience programmes and in their M&E systems.

The key role of markets in post-disaster recovery period

The major other result stressed by this research is the critical role that markets, and in particular food price dynamics, seem to play in the aftermath of disasters. While the exact impact pathway between high food prices and the final outcome measured in terms of nutritional indicators is still unclear (see recommendation below on the need for in-depth quantitative and qualitative studies) data suggests that there is a strong link between nutritional status of the communities affected by shocks and the peaks in the food prices which follow these shocks.

The ensuing recommendation that follows is that national governments and disaster relief agencies should prioritize market price stabilization mechanisms as a critical component to be established rapidly in the aftermath of (or perhaps in preparation to) shocks, in order to reduce as much as possible the possible lagged effect of these shocks on the food security and nutrition of affected communities.

Implications for disaster and rehabilitation programmes

The lagged effects observed in most of the models developed in this study open up new vista of phase-wise in-depth assessment of impacts at different stages of the disaster relief and rehabilitation process. In particular, the higher food prices after droughts, floods, and cyclones – and their prolongation up to 9 months after the event – urge us to review our conventional disaster response and rehabilitation approach.

As immediate response after a disaster, strategies like specific focus on available nutrient rich foods and communicating key messages about food sources that are plentiful could be very useful. Women's increased burden during disasters (see below) should also be made a center point in household level response. In addition, more research is needed on the cyclical effects of coping strategies and the impacts of repetitive events on households. This knowledge will allow programmes to encourage coping strategies that promote food and nutrition security in both the near and far terms.

Importance of fish and fishing activities in post-disaster recovery period

The analysis reveals that while fish (along with eggs) is the only source of animal protein which is consumed with regularity during normal times, its importance in the diet seems to be even more pronounced during and after disasters.

Recognizing the critical importance of fish in the food security and nutrition of populations affected by extreme events/shocks, a recommendation for the national government and its partners is to continue to foster the ecological sustainability of the inland fisheries resources of the country and to ensure that the governance and management mechanisms at both national and local levels recognize and protect the role of fish as an essential source of protein and micronutrient during both normal and recovery time.

Protecting both children and women

While direct accounts from respondents suggest that children are usually given preferential treatment to ensure that their health and nutrition are protected, women, on the other hand, consistently make the biggest sacrifices. Data suggests also that this altruist (but mal-adaptive) behaviour is for a large part dictated by social rules.

On the basis of these findings, interventions such as behaviour change communication (BCC) programmes need to be put in place by the government in collaboration with its international and local partners to protect children but also specifically women's food security and nutrition in the aftermath of shocks.

Strengthening the resilience of households to climate-related events

Although the household resilience mechanisms could not be explored thoroughly through this study, it is clear that strengthening the capacities of the local populations affected by climate-related events and help them respond more appropriately to the impacts of these events (in particular by reducing their propensity to adopt detrimental short-terms responses) would go a long way in reducing the negative effects of climate-related events on the nutrition and food security of the local populations.

The authorities in charge of disaster management (both at national and provincial/district levels), along with international organizations working on the same agenda, should invest in improving their understanding of the types of strategies that households and communities adopt in response to the various shocks and stressors that they face and identify ways to strengthen the capacities of the local population and local authorities in developing and adopting adequate responses which have long-term non-detrimental impact on the wellbeing of households members, in particular women and children.

Research recommendations

The critical importance of high frequency data surveys

Because it was collected every two months, the NSP data could capture and reflect the dynamics of sudden or progressive changes in food security and nutrition indicators following extreme events/shocks, thus providing essential information to understand the way shocks affect households, and how these households respond to those effects, just after and in the months following the event. Without these high-frequency surveys, such analysis would not be possible.

The related recommendation is that governments, international development agencies, and research organizations will need to support existing, or invest in new, high-frequency, comprehensive household surveys if they want to be able to integrate more appropriately the question of the impact of shocks in their planning and policy decision-processes.

The need for in-depth quantitative and qualitative studies

Identifying the potential impacts of climate change-related shocks and stresses on household food security and child and maternal nutritional status is complex and data demanding. We still know very little and many of the current findings remain working hypotheses which need to be explored/tested more thoroughly. What seems clear however, is that households' responses are shock specific. In that context, applying a blanket/generic post-disaster approach is likely to generate/trigger mal-adaptive responses, which could eventually slow down or even jeopardize the recovery process. Unfortunately too many interventions are still being based on a partial and incomplete (or even incorrect) understanding of the situation.

Following these remarks, a recommendation for governments, international development agencies, and research organizations is to continue supporting research and investigations around these issues. In Bangladesh more analyses should be conducted with the NSP data-sets. In all cases the use of mixed methods and combined models that incorporate different types of shocks should be prioritized over cherry-picking analyses based on an individual-event.

Introduction

Introduction

On November 15, 2007, Cyclone Sidr, a Category-5 equivalent tropical cyclone, made landfall in southern Bangladesh. Peak 1-minute sustained winds of 260 km/h were recorded during the event. The cyclone resulted in one of the worst natural disasters in Bangladesh. The Department of Disaster Management officially recorded a death toll of 3,363 persons, while some international NGOs estimated higher numbers (between 5,000 and 10,000). The disaster also led to the displacement of over three million people. Sidr was not, however, the first event of this type. The Great Bhola Cyclone of 1970, a Category-4 cyclone that brought a storm surge of up to 8 metre killed an estimated 350,000-550,000 people. In 1991 the Gorky cyclone killed at least 138,000 people and left as many as 10 million homeless (NOAA 2012). Overall, sixty percent of the worldwide deaths caused by cyclones in the last 20 years occurred in Bangladesh.

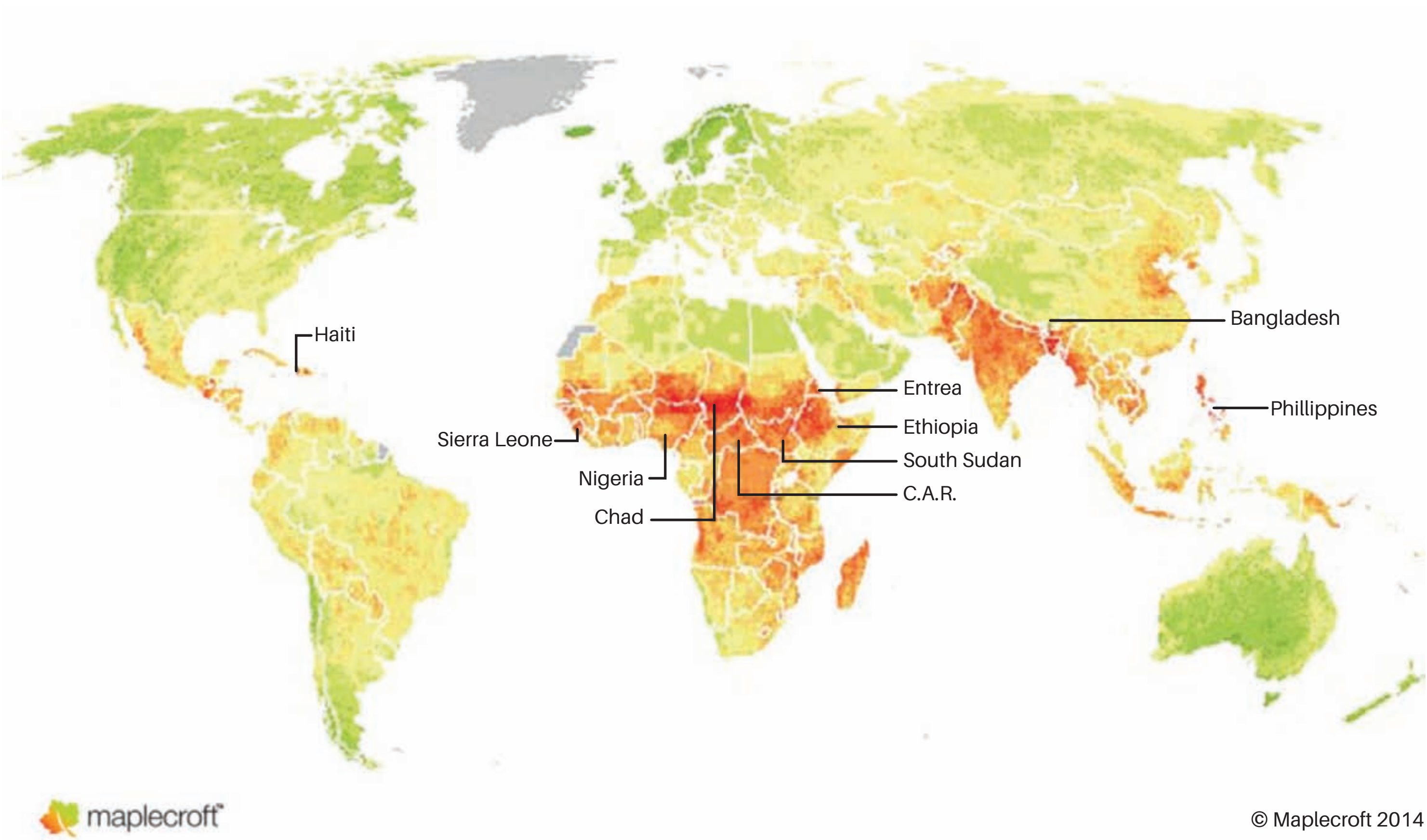
Cyclones and tropical storms are not the only extreme events that affect Bangladesh. The country has in fact a long history of natural disasters. Between 1980 and 2008, 219 natural disasters –cyclone, landslide, flood, or flash flood- were officially recorded, causing over US$16 billion in total damage (UNDP estimates). Over the same period Bangladesh has seen 191,637 deaths as a result of major natural disasters, with storms alone claiming 167,178 lives (NDRI 2010). Bangladesh is in effect ranked the first and most at risk country to climate change in the world (Fig.1).

With a population over 156 million (80 percent of whom live in rural areas), an average density of 940 persons per km2 (the 9th most dense country in the world) and 70 percent of land area five meters or less above sea level, environmental hazards such as floods, cyclones, salt water intrusion and river erosion are very common in this region of the world. As a consequence it is estimated that 30 to 50 percent of the country are affected by severe climatic shocks every year, with important negative consequences in terms of poverty reduction and agricultural production (WFP 2012a).

At a global scale, the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report (AR4) concluded that undernutrition linked to extreme climatic events is likely to become one of the most important impact of climate change due to the very large numbers of people that may be affected (Confalonieri et al, 2007). Calorie availability in 2050 is likely to decline throughout the developing world resulting in an additional 24 million undernourished children, 21% more relative to a world with no climate change (Nelson et al, 2009).

In Bangladesh, undernutrition has long been recognized as a problem of significant magnitude and 41% of children under five years of age were stunted and/or underweight in 2011. Undernutrition rates in Bangladesh are already among the highest in the world (BDHS 2011).

In this context, a legitimate question is whether the various extreme



Rank	Country	Category	Rank	Country	Category	Legend
1	Bangladesh	Extreme	6	Haiti	Extreme	Extreme Risk
2	Sierra Leone	Extreme	7	Ethiopia	Extreme	High Risk
3	South Sudan	Extreme	8	Phillippines	Extreme	Medium Risk
3	Nigeria	Extreme	9	C.A.R.	Extreme	Low Risk
5	Chad	Extreme	9	Entrea	Extreme	No Data

Fig. 1: The ten countries most vulnerable to climate change as estimated by the recent Global Risk Analytic group Maplecroft. It identifies 32 'extreme risk' countries in their Climate Change Vulnerability Index (CCVI), which evaluates the sensitivity of populations, the physical exposure of countries, and governmental capacity to adapt to climate change over the next 30 years. Bangladesh appears to be the first and most at risk. Source: Maplecroft 2014

events/shocks that continuously affect Bangladesh contribute significantly to this situation of undernutrition. One hypothesis is indeed that the impact of climate related shocks and stresses on food security and nutrition in Bangladesh could be particularly severe given the reliance of a majority of poor rural households on agricultural livelihoods.

In March 2012, the World Food Programme (WFP) conceptualized a study to "*develop an improved knowledge and understanding of the impacts of climate change on food security and nutrition*" in Bangladesh and more specifically to determine how climate related shocks and stresses are exacerbating the already high levels of food insecurity and undernutrition. The specific objectives of the proposed study were to:

1. Assess the current and future impacts of climate change on availability, access and utilisation of food as well as child and maternal nutrition, and assess which geographic areas, populations and livelihoods are most vulnerable to climate-related risks.
2. Assess and analyse the coping, adaptation and prevention strategies of poor and vulnerable households and individuals in the field of food security and nutrition, either implemented on their own initiative or externally supported by the Government and development partners.
3. Provide policy options and recommend food security and nutrition related climate change adaptation interventions to the Government and development partners, to prioritise interventions and target vulnerable groups, and ensure climate related aspects of food security and nutrition are more fully addressed.

The present report is the result of this study. It brings together the work of a multi-disciplinary team of researchers from Helen Keller International (HKI), the Bangladesh Centre for Advanced Studies (BCAS), and the Institute of Development Studies (IDS). Supported by the World Food Programme (WFP) and the International Fund for Agriculture Development (IFAD), and building on the work completed during a first inception phase with input from TANGO International, the study uses existing quantitative data and collected qualitative data, to attempt to address the current gap in knowledge related to the impacts of climate related shocks and stresses on food security and nutrition in Bangladesh.

In parallel an institutional mapping exercise was also conducted to complete this study (BCAS 2014). The main purpose of this mapping exercise was to identify and assess the work of relevant organizations in the fields of climate change adaptation and disaster risk reduction, and food security and nutrition issues.

The rest of this report is organized as follows: Chapter 1 reviews briefly the current evidence available in the literature on impact of climate change on nutrition and food security. Chapter 2 presents the general approach, conceptual framework and methodological protocol adopted for this analysis, along with the different sets of data that were used. Chapter 3 presents the details of the findings. This includes a series of quantitative (statistical) analyses as well as the presentation of two qualitative analyses. Chapter 4 discusses these different results and proposes a series of recommendations.

Chapter 1 2 3 4 5

Climate change, extreme events and food security and nutrition in Bangladesh

Climate change, extreme events and food security and nutrition in Bangladesh

1.1 Overview

In 2012 the Intergovernmental Panel on Climate Change (IPCC) report on extreme weather recognised that increases in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes "are virtually certain to be observed in the 21st century" leading to a very high probability of increase in natural disasters (IPCC 2012). Already the impacts of recent natural disasters have been increasing over the last decades, putting the humanitarian system under considerable pressure. In 2010 alone, natural disasters affected more than 217 million people, killed more than 297,000 people and caused $123.9 billion in economic damages (Guha-Sapir et al 2010). There have been an estimated 3.3 million deaths from natural hazards in the 40 years up to 2010 (82,500 per annum) with 95% of these happening in developing countries (World Bank 2010).

The challenges raised by these extreme events and their impacts on countries' development and populations are serious. Research -particularly from the 1990s onwards- on vulnerability, assets, poverty dynamics, coping mechanisms, malnutrition, and social safety nets has consistently demonstrated that inability to cope with shocks at local and/or national level is a major cause of the inability to escape poverty (i.e. chronic poverty), and of vulnerability to falling into poverty. The vulnerability of the poor to "hunger seasons", droughts, floods and other natural and man-made disasters has long been understood. But in recent years this perennial vulnerability has been compounded by the food and financial crises, by the threat of climate change, and by large scale humanitarian crises such as the recent ones in the Sahel and the Horn of Africa.

Evidence from regions affected by climate extremes demonstrates that they impact nutrition and long-term resilience. Studies from the Gambia reveal for instance that women who are pregnant during a hunger gap give birth to smaller babies (Rayco-Solon, et al. 2002). Longitudinal studies from Malawi have demonstrated a seasonal variation in height gain among young children linked to the annual hunger season (Maleta et al. 2003). In Ethiopia and Niger, children born during a drought are more likely to be chronically malnourished later in childhood than those who are not (Fuentes and Seck, 2007). Overall it is estimated that more than 20% of adult height variation in developing countries (the sign of chronic undernutrition in childhood) is determined by environmental factors, in particular drought (Silventoinen 2003).

Women are known to be more vulnerable to the effects of natural disasters than men. For example a study of 141 natural disasters from 1981 to 2002 found that when economic and social rights are equal for both sexes, death rates from diastases do not differ significantly for men and women. But when women and men's rights and socio-economic status are not equal, more women than men die in disasters (Neumayer and Plümper (2007). In Bangladesh, the focus of this report, of the 138,000 people who died from the flood-related effects of Cyclone Gorky in 1991, women outnumbered men by 14 to 1. Contributory factors limiting women's mobility and use of cyclone shelters were social norms and roles for women including primary responsibility for the care of children, the sick and elderly; social norms preventing women from leaving their homes or staying in cyclone shelters without a male relative; traditional dress codes such as wearing sarees that can easily become entangled; and concerns around privacy and safety in shelters. Women also represented an estimated 61% of fatalities in Myanmar after Cyclone Nargis in 2008, and 70% of those dying during the 2004 Indian Ocean tsunami in Banda Aceh, Indonesia (World Bank 2011).

Given the critical role that women play in relation to food security and nutrition especially for young children (Kennedy and Peters 1992; Quisumbing et al. 1995; Smith et al. 2003) one can hypothesize that food security and nutrition of children may also be jeopardized through the status of their mother after disasters hit.

1.2 Climate-related extreme events in Bangladesh

In Bangladesh people are exposed to a wide variety of climatic hazards, stressors and extreme events, which includes drought, river floods, cyclones and their associated tidal surges, river bank erosion, salinity intrusion. These disasters have killed hundreds of people and injured thousands, ruined thousands of hectares of crops and washed away large areas of cultivable land, and damaged infrastructure, homes, and productive assets, amounting to huge human and economic losses.

These extreme events and hazards however don't affect the entire country equally, and different areas are exposed to different types and magnitudes of climate change-induced natural hazards. Taking various climatic characteristics into account, a preliminary component of this research sought to identify climatic 'hotspots'. In the context of this work, the term climatic hotspots refers to the regions and ecosystems most responsive to climate change, and already climate-vulnerable and likely to suffer substantial impacts as a result of aggravated climate change.

Relying on existing documents and analyses the project team was able to identify 6 major types of climatic-related events that appear particularly relevant to the general context of Bangladesh. These are:

- Flood
- Flash flood
- Drought
- River bank erosion
- Salinity intrusion
- Cyclones

1.2.1 Flood

Most climate related hazards in Bangladesh are linked to water (Rabbani et al 2013); too much water or too little (but also wrong type –e.g. saline- or wrong timing) can lead to disasters. Amongst these four types of water issues, too much water (flooding), is the most common climate induced natural hazards and an annual phenomenon in Bangladesh. About 20 percent of the country is flooded in a 'normal' year, and up to 70 percent in extreme floods (Mirza 2002).

Flooding in Bangladesh is the result of a complex series of factors. These include a huge inflow of water from upstream catchment areas coinciding with heavy monsoon rainfall in the country, a low floodplain gradient, congested drainage channels and the major rivers converging inside Bangladesh (Mirza et al., 2002; Chowdhury et al., 1996). There is also high probability of inter-annual variability in distribution of flooded areas (Ahmed 2006). Depending on rainfall variability within the country and in the Ganges-Brahmaputra-Meghna (GBM) catchment area, the location and timing of flooding varies from one part of the country to another (FFWC 2012). Floods generally occur during monsoon. They particularly affect active river floodplains. The large catchment of the GBM system receives a huge amount of rainfall in each monsoon, about nine-tenths (Rahman 2010) of which flow through the major rivers in Bangladesh.

River floods extend beyond the active floodplains and damage agricultural crops in parts of the adjoining meander floodplains, mainly alongside distributary channels. The timing of the flood (whether early or late) and sometimes the duration of flooding are important determinants of agricultural crop damage (and success) as is the absolute height reached by a particular flood. Sediments deposited in channels also reduce the drainage capacity of minor rivers, roads and railway bridges and culverts, as well as irrigation and drainage canals. About three-quarters of Bangladesh's population remains exposed to severe flooding (Quirin Schiermeier 2014).

Keeping all this in perspective, flood-vulnerable Bangladesh has experienced an increased number of severe floods since the mid-90s (MoEF 2005). Recurring floods occurred in 2002, 2003, 2004, and twice in 2007 (July-August and September). Such frequency and intensity of floods is generally attributed to the aggravated changes in the climate.

1.2.2 Flash flood

In Bangladesh flash flooding usually begins in flashy rivers (that is, rivers which respond very quickly to rainfall with rapid rising and falling of water flow) typical in the northeastern and south-eastern hilly areas during the pre-monsoon months of April and May (Choudhury et al. 2004). These flash floods take place suddenly and from a few hours to a couple of days. Run-off during exceptionally heavy rainfall occurring in neighbouring upland areas is responsible for flash floods. Torrential rainfall causes streams to rise rapidly—often within hours. The sudden rise of water level in the upstream reaches of rivers ultimately causes flash flooding in their downstream branches and tributaries since these narrow meandering rivers fail to contain the billowing flow from upper reaches (Choudhury et al. 2004).

Flash flood can cause extensive damage to crops and property, particularly in the haor[1] areas. For crops, it is their timing which is usually most important. Flash floods in these areas generally cause severe damage to dry-season (boro) rice crop just before or at the time of harvesting virtually every year (Ahmad et al., 2001). Damages to property - especially road and railway embankments and bridges, and buildings alongside river channels - occur during exceptionally high flash floods. Flood embankments along some eastern rivers, especially the Khowai, are breached by floods almost every year. Cultivated land and land adjoining foothill streams sometimes get buried under sand.

[1] Haors are bowl-shaped depression of desirable aerial extent lying between the natural levees of rivers or high lands of the north-east region of Bangladesh. In most cases haors are formed as a result of peripheral faulting leading to the depression of the area. During the wet season, the haors are full of water, but during the dry season, they dry up.

Occasionally, areas adjacent to and within the region of the Madhupur Tract experience flash flooding, particularly in the pre-monsoon season before these areas are normally flooded by rivers or rainwater (Brammer, 1990). The north-western Piedmont plain as well as the Chittagong coastal plains can also experience flash floods (Choudhury et al. 2004). Flash flood occurring in the hilly terrain of eastern and north eastern part of Bangladesh has been increasing and also occurring a few days earlier in recent years than 40-50 years ago. Increased rainfall (from an average of 150mm to 250mm) in Meghalaya in March has increased in the last 30 years and is causing frequent occurrences of flash floods in Bangladesh (GoB 2010).

1.2.3 River bank erosion

River bank erosion is often presented as one of the foremost natural disasters responsible for poverty in Bangladesh because of the enormous destruction of resources and displacement of large numbers of the population (Khan and Islam, 2003). Most of the rivers of Bangladesh flow through unconsolidated sediments of the Ganges-Brahmaputra-Meghna floodplain and delta. The riverbanks are therefore susceptible to erosion by river current and wave action. River erosion includes channel shifting, the creation of new channels during floods, bank slumping due to undercutting, and local scour from turbulence caused by obstruction. The Brahmaputra, the Ganges, the Meghna, the Teesta, and the Surma-Kushiyara rivers flow within well-defined meander belts on extensive floodplains where erosion is heavy. Sudden changes are common during floods that cause rapid bank erosion (Sarker et al. 2006). In lower deltaic areas, river bank erosion is caused by tidal currents and storm surges from the sea. In the Jamuna River, bank erosion could lead to hundreds of meters of bank retreat annually (Mosselman, 2006).

BWDB estimated that 1,200 km of riverbank have been actively eroded and more than 500 km have been facing severe problems related to erosion, and every year despite some deposition of silt, a net area of 8,700 hectares of land is being lost (Ahmed, 2006). Christian Aid estimates that a million people are pushed off their land by river erosion each year and many of these end up permanently displaced (Christian Aid, 2006).

Higher volumes of water flowing down rivers due to climate related changes such as increased rainfall and summer glacier melt from the Himalayas will also increase the erosion of land beside Bangladesh's rivers (Ahmed, 2006). Increased river erosion due to climate change is therefore expected to displace an increasing number of people from their homes and farms.

1.2.4 Drought

Agro-ecologically speaking, drought is primarily a phenomenon that refers to conditions where plants are responsive to certain levels of moisture stress that affect both the vegetative growth and yield of crops. It occurs when supply of moisture stored in the soil is insufficient to meet the optimum need of a particular type of crop (Wilhite and Glantz 1985).

In Bangladesh, as a consequence of usual hydro-meteorological variability, drought occurs in pre-monsoon season when the potential evapo-transpiration (PET) is higher than the available moisture due to uncertainty in rainfall, while in post-monsoon season it is due to prolonged dry periods without appreciable rainfall (Karim et al., 1990).

In terms of magnitude drought also exhibits pronounced spatial variation in Bangladesh. The western parts of the country receive less rainfall averaging some 1400 mm as against the national average of about 2150 mm (Ahmed 2006). As a consequence, susceptibility and severity of drought in the western districts are much higher than elsewhere.

As a whole, Bangladesh is highly susceptible to droughts (Karim, 1996; Huq et al., 1996). Droughts cause damage to agricultural crops. Yield reductions due to drought vary from 45-70% in very severe drought situation (MoEF 2005)

1.2.5 Salinity intrusion

The coastal zone of Bangladesh has been under the constant threat of salinity as the topography of the coastal zone in Bangladesh is relatively low-lying. MoEF (2005) warned that the impact of saline water ingression in estuary and underground water is likely to be accelerated by sea level rise, land subsidence and low flow river condition. Less rain in the winter will mean less water in rivers in the dry season affecting river fed irrigation, industry, fisheries, travel by launch/ferries and increase salinity around the coast (Alam, 2004). In addition to these environmental 'external' processes, certain types of anthropogenic activities widely adopted in certain part of the coastal area (e.g. shrimp farming) seem to exacerbate the problem.

As a consequence of these different combined effects, the net-cropped area of coastal zone in Bangladesh has been decreasing over the years. In essence, fresh water reduction along with intrusion of saline water is perhaps the most severe consequence of climate change in coastal Bangladesh. Even though salinity intrusion is a slow process the impact is devastating. A study by IWM and CEGIS (2007) showed that under the IPCC's A2 emissions scenarios, high tide in the south-central region may increase by 30 cm and 80 cm for a 32 cm and 88 cm SLR, respectively. Seawater will continue to move further inland and freshwater river systems will be converted to brackish water systems – water with higher saline concentration – resulting in higher soil salinity (IWM and CEGIS, 2007).

Currently, about 6.0 million people are already exposed to high salinity (>5 ppt), but due to climate change this is expected to increase to 13.6 million in year 2050 and 14.8 million in 2080. The population in the areas of Khulna, Satkhira and Bagerhat will be most affected (Mohal and Hossain, 2007), the boundary to the area of high salinity ('the salinity front') moving gradually north by 40 km (Mohal et al, 2006) to 60 km (MoEF, 2005) by 2100. As well as making household water supply problematic, salinity negatively affects agricultural production. A study in Khulna, Bagerhat and Satkhira districts found that the suitable area for transplanted Aman rice cultivation will reduce from 88% to 60% with 32 cm rise in sea level and 12% with an 88 cm rise in sea level (CEGIS, 2005). Potentially increased salinity in coastal areas could mean that 659,000 metric tonnes of annual rice production could be lost due to climate change (Habibullah et al, 1999).

1.2.6 Cyclone

Tropical storms also known as cyclones are common along the 710 km coastline of Bangladesh (Tanner et al, 2007). But although only 1% of the world's total cyclones happen in Bangladesh it has sustained over half of the world's deaths from cyclones (Tanner et al, 2007). It is estimated that Bangladesh receives about two fifths of the total impacts of global storm surges (Dasgupta et al., 2010). Cyclones occur all along the coastal zone of the south and south-east of Bangladesh in two seasons one in

March through July and the second in September through December with greatest majority of storms arriving in May and October. Wind risk areas stretch far inland (Islam, 1994). Two studies – one by Sing et al. (2001) and another by Krishna (2009) - found that Bangladesh is becoming more prone to severe cyclones, particularly during November and May. A recent study (Chowdhury et al., 2012) showed that between 1985 and 2009 tropical cyclones have increased in annual frequency by 0.05 cyclones per year. As a result of climate change it is likely that future tropical cyclones will become stronger, with larger peak wind speeds and more heavy rainfall associated with ongoing increases of tropical sea surface temperatures (IPCC, 2007)[2]. Cyclones are expected to become 10 to 20% more powerful if sea-surface temperatures rise by 2 to 4°C in South Asia (Cruz et al, 2007). Recently Cyclone Sidr with 250 km/hr winds and a tidal surge of 5 metres killed over 5000 people on November 15th 2007 (Gentleman & Ahmed, 2007).

1.3 Climatic hotspots

The existing records and document from various sources[3] were used to produce an indicative list of the most affected districts in the country, based on the frequency of hazards' occurrence in each district (Table 1). The spatial distribution of these hotspots was then mapped (Figure 2). This broad map was then used to orient the initial geographical focus of the study, and in particular to help the geographical matching process between the nutrition data set and the variables and indicators that were used to identify the occurrence of climate-related events (see methodology section below).

The six different types of extreme events or shocks and stresses identified in this study are assumed to have direct and indirect consequences for the availability of, access to, and utilization of food at the household and individual levels. Exposure to risk of food insecurity and malnutrition is therefore expected to vary substantially across the different geographic regions, depending on the magnitude, frequency and duration of the climate-related disturbances considered.

Similarly, the livelihood strategies that communities and households pursue, the assets that they have at their disposal, and the institutional structures and processes they are involved in are thought to have a direct influence on their sensitivity and capacity to anticipate, prevent, respond, adapt and eventually bounce back from the different shocks and the on-going challenge of climate change. For instance, exposure to high levels of climate-related risks among poor households is often compounded by other factors such as poor access to markets, limited income-generating opportunities, and adoption of detrimental coping strategies (e.g. reduced food consumption, reduced expenditure on health care, engaging in environmentally harmful practices, and distress migration). Previous research focusing on Bangladesh has also demonstrated that food security and nutrition at the household level is influenced by women's empowerment

[2] The IPCC's Special Report on Extreme Events (SREX) (IPCC, 2012) found that it is likely that the frequency of cyclones is either staying the same or declining. However, wind speeds associated with cyclones were found to be on the increase. Cyclones are expected to have 3% to 12% faster wind speeds by the 2020s, rising to 4% to 20% faster by the 2050s (Tanner et al, 2007).

[3] Department of Disaster Management (DDM), CRED (EM-DAT) historical hazard datasets and secondary literature: Government of Bangladesh (GoB). 2005. National Adaptation Programme of Action (NAPA), Dhaka, Bangladesh; Asian Disaster Preparedness Center and BCAS. 2009. Report on Communication Mapping and Planning at Community Levels under the project "Support for a Disaster Management Information Network (DMIN)"; GoB. 2010. National Plan for Disaster Management 2010-2015, Ministry of Food and Disaster Management, Disaster Management and Relief Division, Disaster Management Bureau, Dhaka, Bangladesh; GoB. 2006. Bangladesh Climate Change Impacts and Vulnerability - A Synthesis, Ministry of Environment and Forests, Department of Environment, Climate Change Cell, Dhaka, Bangladesh.

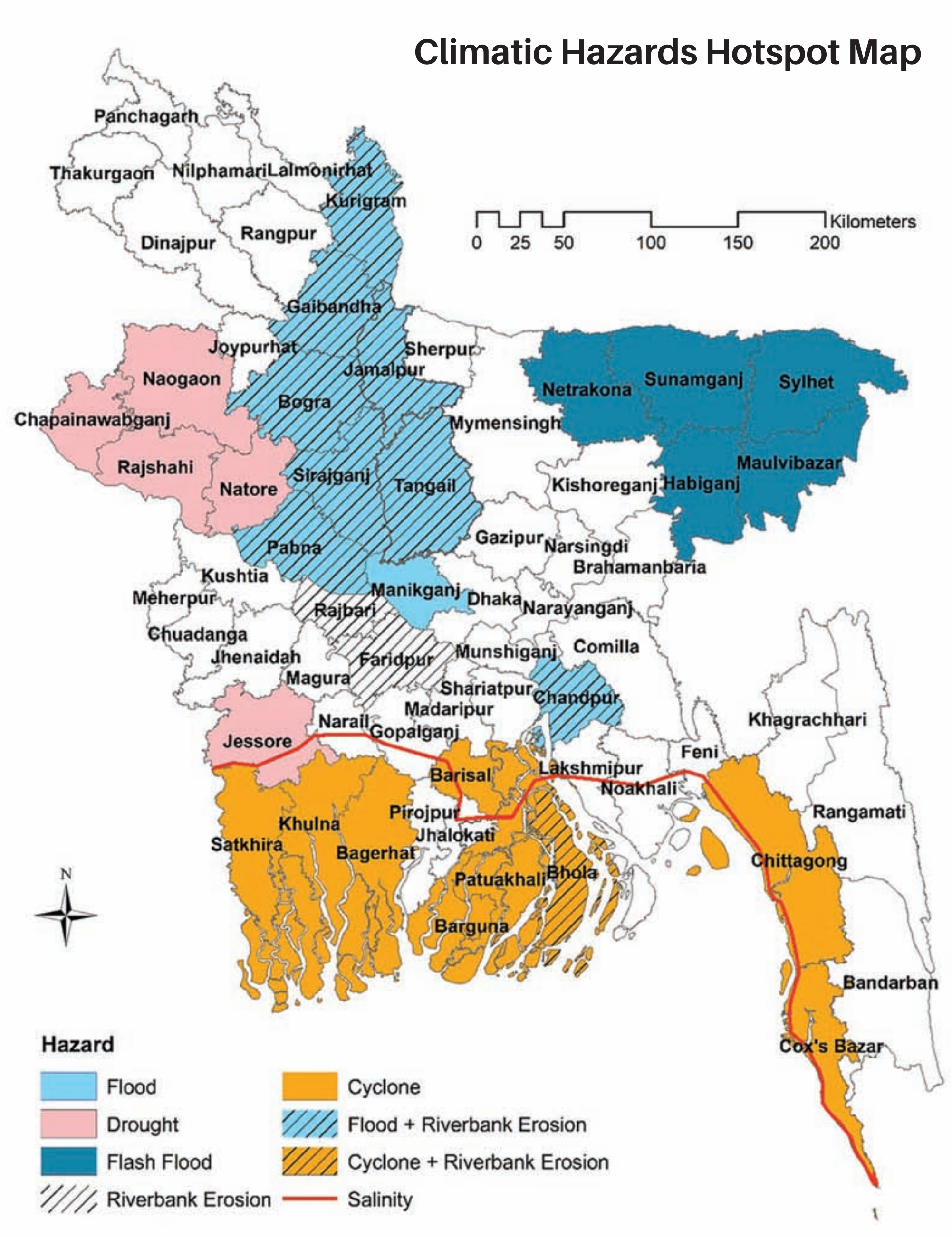


Fig.2. Climate hotspots for the major climate-related events included in this study: drought, flood, flash flood, cyclone, salinity intrusion, and river bank erosion

and access to effective governance at the local level (Roopa 2011; Smith et al. 2013). Highly sensitive households and communities with little adaptive capacity (due to limited livelihood options, few productive assets, and no institutional support) are more likely to suffer from food security and malnutrition in addition to other negative outcomes of climate change.

1.4 Food security and nutrition in Bangladesh

In the last 20 years, Bangladesh has made tremendous progress in relation to human development and poverty in both urban and rural areas declined by an impressive 19 percentage points in the last decade-and-a-half (BDHS 2011). Bangladesh also continues to make steady progress in reducing child undernutrition and household food security. Notably chronic child undernutrition (stunting) decreased by three percent between 2011 and 2012 (HKI-BRAC 2014). The government with the help and support of its partners has improved coverage and access to basic health, nutrition, and population services, which are reflected in encouraging improvements. Today, nearly 90% of Bangladeshi children receive Vitamin A supplements and over 80%

Table 1. Districts in Bangladesh most affected by the 6 major types of climatic-related events considered in this study

Climate Hazards	Districts
Drought	North-West region which includes Chapai Nawabganj, Jessore, Naogaon, Natore, and Rajshahi districts
Flood	Middle and North-Eastern part of Bangladesh which includes Bogra, Chandpur, Gaibandha, Jamalpur, Kurigram, Manikganj, Pabna, Sirajganj and Tangail districts
Cyclone	Coastal districts located in the southern area of the country. Frequently affected districts are Bagerhat, Khulna, Barguna, Barisal, Bhola, Chittagong, Cox's Bazar, Patuakhali and Satkhira districts
Flash Flood	Greater Sylhet division (Habiganj, Maulvibazar, Sunamganj, Sylhet districts) and Netrokona district
Riverbank Erosion	Kurigram, Gaibandha, Bogra, Sirajganj, Chandpur, Faridpur, Tangail, and Jamalpur districts
Salinity Intrusion	Coastal districts of Satkhira, Bagerhat, Khulna, Barguna, Pirojpur and Patuakhali

are vaccinated, contributing to an impressive reduction in infant and child mortality by more than two-thirds since 1990. This initiative resulted in a 40 percent reduction in maternal mortality between 2001 and 2010, and a 26 percent reduction in under-five child mortality between 2004 and 2010 (World Bank 2014). Bangladesh is on track to meet the Millennium Development Goal (MDG) targets in child health and maternal health, and the United Nations awarded its MDG Award 2010 for reducing child mortality to Bangladesh.

Yet, Bangladesh still faces considerable development challenges. The absolute number of poor people remains significant: around 64 million people still live below the international poverty line of $1.25 a day (World Bank 2014). Despite the tripling of rice production over the past 40 years, chronic malnutrition remains one of the greatest constraints to individual and household wellbeing in Bangladesh (in part due to the slow increases in levels of production of nutrient rich foods) (Beddington et al. 2012). Despite some improvement, the undernutrition situation remains serious with 41% of children under five years of age stunted in 2011, and 36% underweight and 24% of women underweight and 13% of short stature (BDHS 2011). More than a quarter of the population (26.8 percent) suffer from food inadequacy (FAO 2013). In rural areas for instance, per capita consumption of vegetables, fish, and tubers falls short of the minimum level recommended by the government for a healthy life, whereas an even larger deficit exists for pulses, fruits, oils, and animal-source foods (Hossain et al. 2005). Thorne-Lyman et al. (2010) showed that even prior to the 2008-2009 food price crisis and global economic downturn, there was relatively little variety in the diet of rural Bangladeshi households. When women's diets in Bangladesh were analyzed to develop guidelines for dietary diversity scores, less than 5% of women had even a 70% probability of obtaining the minimum level of required nutrients from their diets (Arimond et al. 2009).

In that context a growing number of experts are concerned that the recent progress made in relation to food

Box 1: key terms related to food and nutrition security

MALNUTRITION | a state in which the physical function of an individual is impaired to the point where he or she can no longer maintain adequate bodily performance processes such as growth, pregnancy, lactation, physical work and resisting and recovering from disease (WFP 2009).

UNDERNUTRITION | The consequence of an insufficient intake of energy, protein and/or micronutrients, poor absorption or rapid loss of nutrients due to illness or increased energy expenditure. Undernutrition encompasses low birth weight, stunting, wasting, underweight, and micronutrient deficiencies (WFP 2012b).

STUNTING | Low height/length for age for children over 2 years; a measure of chronic malnutrition characterized by a slowing in the growth of a foetus or child and resulting in a failure to achieve expected length in comparison to a healthy, well-nourished child of the same age (WFP 2009).

WASTING | Low weight for height; a measure of acute malnutrition characterized by considerable weight loss or failure to gain weight, which results in a child's weight being substantially below that expected in a healthy child of the same length or height (WFP 2009).

FOOD SECURITY | Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life; household food security is the application of this concept to the family level, with individuals within households as the focus of concern (World Food Summit 1996).

NUTRITION | Nutrition is the intake of food, considered in relation to the body's dietary needs. Good nutrition – an adequate, well balanced diet combined with regular physical activity – is a cornerstone of good health. Poor nutrition can lead to reduced immunity, increased susceptibility to disease, impaired physical and mental development, and reduced productivity (WHO 2014).

security and nutrition in Bangladesh may get cancelled out by the increasing frequency and severity of climate-related extreme events. Already some past analyses suggest that extreme events in Bangladesh have had detrimental impacts on people's nutritional status. Del Ninno and his colleagues for instance using a small 750 household panel data-set found that the prevalence of chronic undernutrition increases among children that had been affected by the 1998 flood (Del Ninno et al. 2003). Similarly Bloem and his colleagues, using the Nutrition Surveillance Programme data-set (the earlier sets of data which we are using in this analysis) found that child wasting was still extremely high in April 1992 (32%) i.e. 12 months after the 1991 cyclone Gorky and remained above 15% until October 1992 (Bloem et al. 2003). They also found that for up to one year after the 1998 flood, 46-50% of non-pregnant mothers in the affected areas were still displaying chronic energy deficiency (CED, body mass index <18.5 kg/m2). The prevalence of CED remained high during the 10 months following the flood (Aug 1998 – Jun 1999) suggesting that mothers' nutritional status deteriorated due to the flood. At the same time though, Bloem and his co-authors found that the 1998 flood did not seem to have a notable impact on child nutritional status, even though the prevalence of diarrhoea over the same period almost doubled between August and October 1998 in the flood-affected sub-districts and did not return to the pre-flood level until February 1999, six months after the flood waters receded.

Chapter 1 **2** 3 4 5

Methods

Methods

2.1 General approach

2.1.1 Combination of disasters, shocks and other (seasonal) stressors

Shocks and stressors are part of people's life, especially in developing countries[4]. However while there is no doubt that shocks and disasters are destructive and costly to those they affect, households in Bangladesh face a multitude of other problems. The poorest households, for example, face a daily struggle to find food to eat even in non-disaster periods, and the financial burden of a wedding can leave households in serious debt for years. Some of these problems affect more people more frequently than disasters but rarely capture national and international headlines even though they can be equally if not more damaging to the livelihoods and well-being of the poor. There are also seasonal patterns in many indicators of health, nutrition, and socioeconomic status caused by changes in the transmission of infectious diseases, food prices and the availability of employment.

Identifying the importance of disasters to livelihoods requires an understanding of how important disasters are relative to other household problems and seasonal effects that affect the lives of poor households and is important if resources are to be allocated where they will be most effective. Few surveys and studies of disasters allow the impact of a disaster to be distinguished from other problems because data are usually only collected during or after the onset of a disaster. If there are no data from non-disaster periods, it is difficult, if not impossible, to determine whether a high prevalence of an indicator such as child malnutrition is due to a disaster or is no different from 'normal' for a particular population at a specific time of the year.

2.1.2 Analytical framework

Prior to designing the study, it is essential to review relevant existing analytical frameworks that deal with climate change, food security and nutrition to inform the development of an appropriate framework for the proposed study. While there is no definitive and unique analytical framework that fully describes the relationships between climate-related shocks and stresses, food security and nutrition, WFP and others have proposed different frameworks that are useful. Of particular interest are the UNICEF 1990 Strategy for improved nutrition of children and women in developing countries framework (UNICEF 1990), the IDS/DFID sustainable livelihood framework (Scoones 1998), the WFP Emergency Food Security Assessment (EFSA) Framework (WFP 2009) and the Escaping the Hunger pathways to Resilience in the Sahel developed by the Sahel Working Group (Gubbles 2011). Representations of these four frameworks are presented in Appendix 1.

Our analytical framework is presented on Fig.3. The top part of the diagram

[4] In that context it is not surprising that shock, trends and seasonality were the three elements of the vulnerability context in the sustainable livelihood framework (Chambers 1989).

shows the different key elements that are considered important from a nutritional perspective. This draws closely on the UNICEF 1990 framework where child and mother health, food security, access to health centres and to water and sanitation, and dietary diversity, have all been recognised to be immediate and underlying factors affecting a child nutritional status. The central part of the diagram draws on the livelihood framework where livelihood outcomes (increased income, stable food self-production, good housing, etc.) result from the combination of (human, financial, natural, physical, social) assets, livelihood strategies, policies, institutions and processes, and a vulnerability context (shocks, trends, and seasonality). In our case the vulnerability context include the six types of events which we are testing (flood and flashflood, drought, cyclones, river bank erosion, and salinity intrusion), but also other (idiosyncratic/covariate) shocks or stresses such as high food prices, illness, or loss of assets.

We recognize that these different shocks, stressors and trends affect not only individuals and households but also communities, institutions, infrastructures and (agro-eco-) systems (see bottom of the diagram). In addition we distinguish what we call institutional outcomes (market efficiency, provision of education and health, social protection, governance and capacity building), which in combination with the livelihood outcomes, determine individual, household and community's food security and nutrition directly and indirectly through their effects on households livelihoods. Central to the dynamics is also the status of the natural environment (agro-ecological system). The various elements of the framework and the ways they are linked to each other do also reflect the WFP and the Sahel Working Group frameworks.

The new element, however, is the resilience component and how it relates to the other components of the framework. Following Béné et al (2012, 2014) resilience is conceptualised as resulting in three possible response strategies: persistence (the absorptive dimension of resilience); adjustment (the adaptive dimension of resilience), or change (the transformative dimension of resilience). In addition to these 3 dimensions, what is critical to understand is that the final outcome (food security and nutrition) is not simply the result of the impact of shocks (contrary to what is often stated in the literature), but instead the result of the combination of these shocks with the responses that individuals/households develop when affected by these shocks. Very concretely, when a drought affects a region, the degradation that is observed in food security and nutrition at the household level is not the result of that drought per se, but instead the result of how people/households responded to that drought –through e.g. coping strategies (such as reducing the number of meal, or selling productive assets). In the diagram this important point is captured by combining resilience strategies (e.g. coping strategy) with livelihood strategies (eventually all these are strategies, and a resilience strategy can be seen as a livelihood strategy at the time of a shock).

There are two important feedback loops that are included in our analytical framework. One on the left hand side shows that the institutional outcomes (e.g. level of access to health, presence/absence of social protection) will influence the impact of future shocks/stressors and the levels of infrastructure (e.g. through prevention, investment) and other key processes including norms and values. The other feedback loop on the right captures the fact that resilience outcomes will obviously impact on the level of assets and

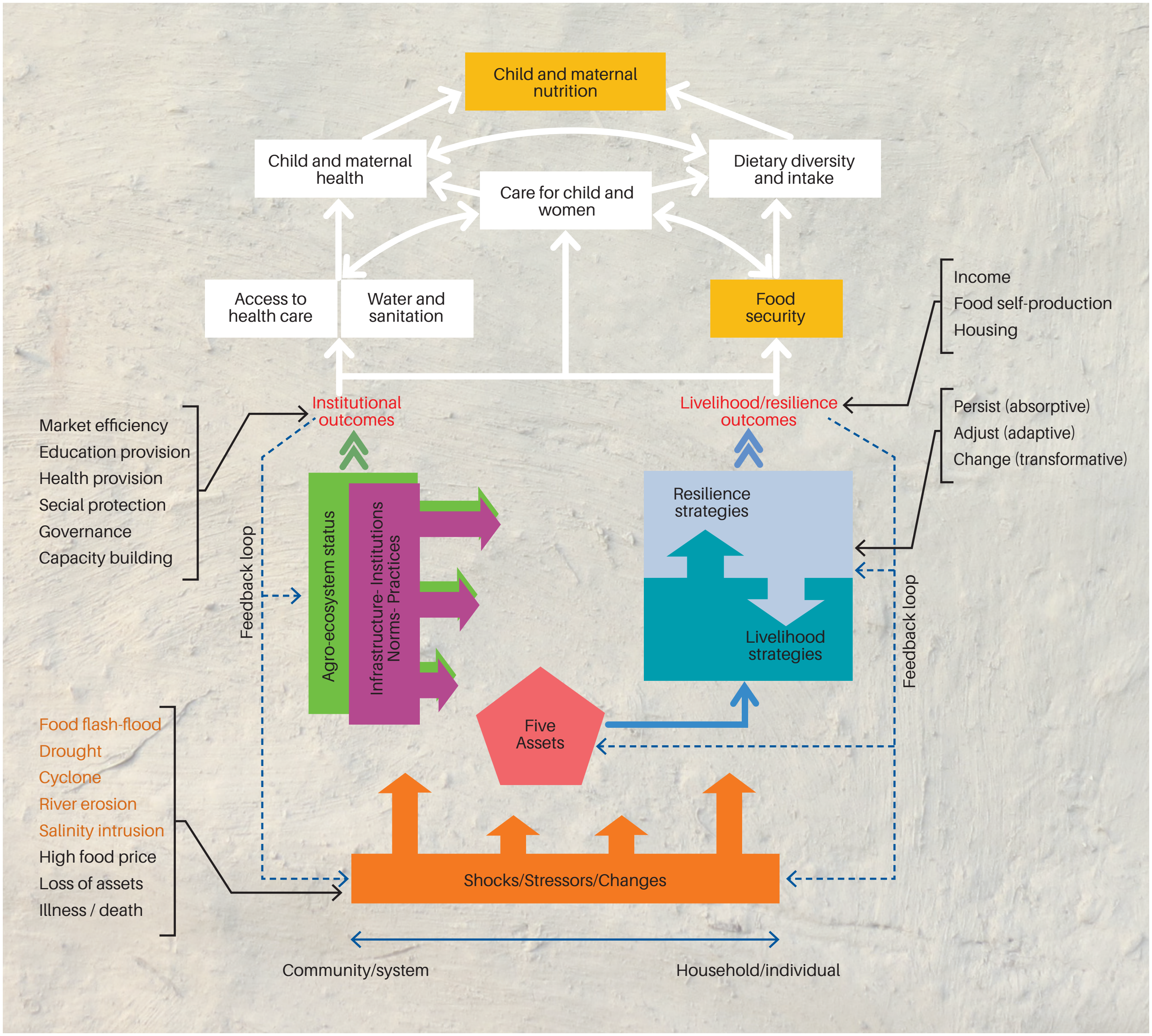


Fig.3. The analytical framework used to structure the research

livelihood strategies, and therefore on future effects of shock/stressors at the individual/household level.

2.2 The NSP data set

The Nutrition Surveillance Project (NSP) in Bangladesh was designed in 1990 in response to two major floods in the late 1980s, which brought the need for timely and accurate data to monitor the impact of disasters on child health and nutrition and the effectiveness of relief efforts to the attention of key stakeholders. The NSP originally collected data in disaster-prone sub-districts (*upazilas*) but in 1998 the sampling procedure was revised to provide data that are statistically representative of each division and of rural Bangladesh (Box 2). This study only utilizes the portion of NSP collected after this revision and the areas included are in annex 02. Rounds of data collection take place every two months to capture seasonal changes in nutrition and health, which allows the impact of disasters to be distinguished from seasonal effects. It also makes the NSP better prepared to assess the impact of a disaster or other crisis event because data are collected a maximum of two months before and after an event and therefore the magnitude of any change can be more accurately assessed (Bloem et al. 2003).

In theory because data are collected from many sites throughout the country, the NSP is able to compare data collected from areas affected by a particular disaster (treatment) with unaffected areas (control). In addition, the long series of cross-sectional rounds of data from 1998-2006 allows changes in indicators to be interpreted in the context of longer-term trends.

The NSP relies on different indicators to determine the underlying causes of a population's nutrition and health condition. As such the NSP is based on UNICEF's conceptual framework of the causes of malnutrition. Z-scores of height-for-age (stunting) and weight-for-height (wasting) were calculated from the NSP data.

An example of the two scores from one upazila is displayed in Fig.4. In addition to the stunting and wasting scores -and recognizing that one of the major causes of malnutrition is poverty-, NSP survey also collected socioeconomic data in the same sampling frame, in order to obtain a broader understanding of the extenuating circumstances that may account for inadequate nutrition (Bloem et al. 2003).

2.3 Shock/stressor data sets

2.3.1 Initial data sets

Various data sets were used to identify the occurrence of shocks and stressors. As indicated earlier in

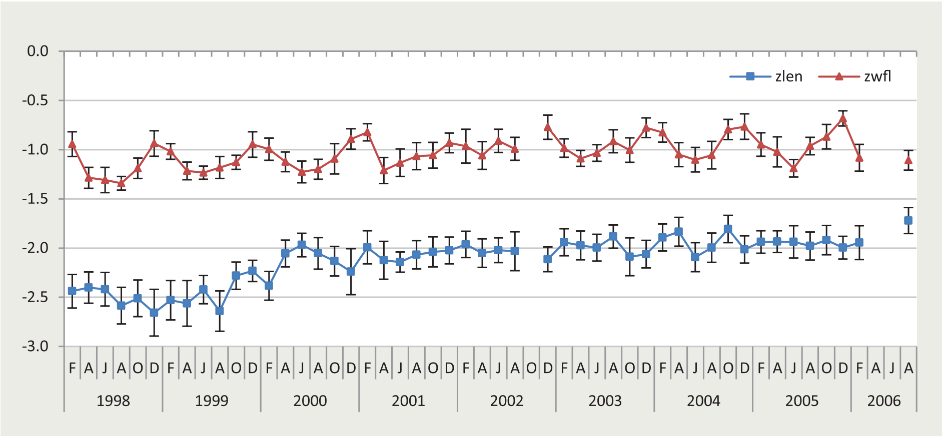


Fig.4. Example of zwfl (wasting) and zlen (stunting) score data as monitored by the NSP. These are from Hathazari upazila in Chittagong.

Box 2: The Nutrition Surveillance Project

The Nutrition Surveillance Project (NSP) was established in 1990 by HKI and the Institute of Public Health Nutrition (IPHN) of the Government of Bangladesh, and was implemented in collaboration with a total of 34 NGOs between 1990 and 2006. Data were collected every two months by the IPHN and NGOs, with training, field supervision, quality control, and data management and analyses conducted by HKI. These data include indicators of children's nutrition and health status, household demography, socioeconomic status and distress, and grain prices. The NSP was terminated in 2006.

Sampling

Over the course of nearly a decade, the NSP employed two different sampling schemes. Between June 1990 and June 1997, a multistage random cluster sampling design was used to select a new sample of 400-500 children every 2 months from purposively selected sub-districts (*upazilas*) in rural areas chosen because they were at higher than average risk of natural disasters. No data were collected between August 1997 and January 1998 because the NSP conducted a national vitamin A survey during this period.

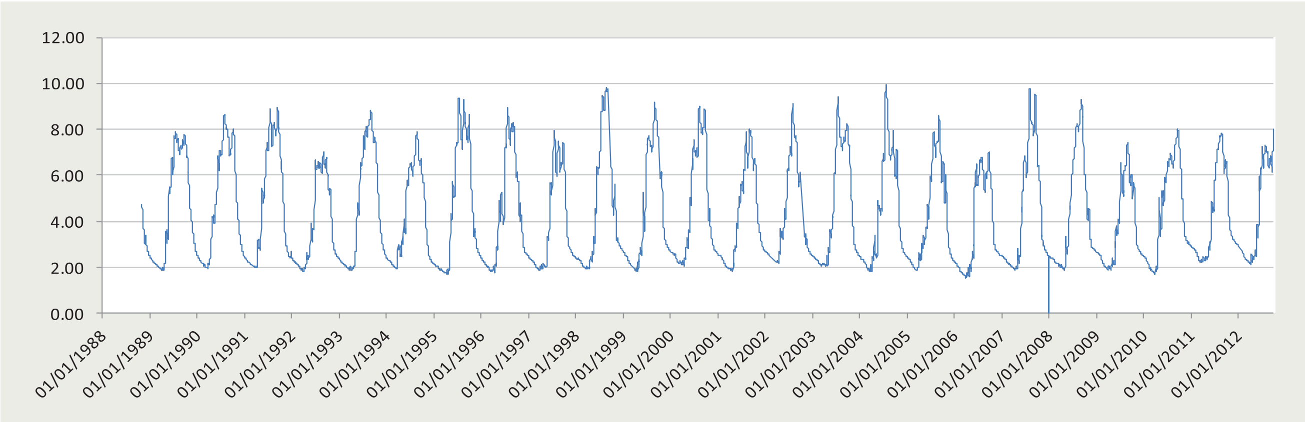
In February 1998, a stratified multistage cluster sampling design was introduced to make the rural sample representative at both the divisional as well as the national levels. In this revised sampling scheme, data were collected from 300 households in four geographically disbursed sub-districts in each of the six divisions of the country. These sub-districts were randomly selected in February 1998 and remained the same during each subsequent round of data collection. In each sub-district, 10 *mauza* (smaller administrative units) were randomly selected at each round, and within each *mauza*, 30 households were systematically sampled from one randomly selected village. In 2000, the sample size in each sub-district was increased to 375 households by increasing the number of *mauza* from 10 to 15 and reducing the number of households sampled from each *mauza* from 30 to 25. This method of sample selection limited NSP coverage to rural areas.

Data

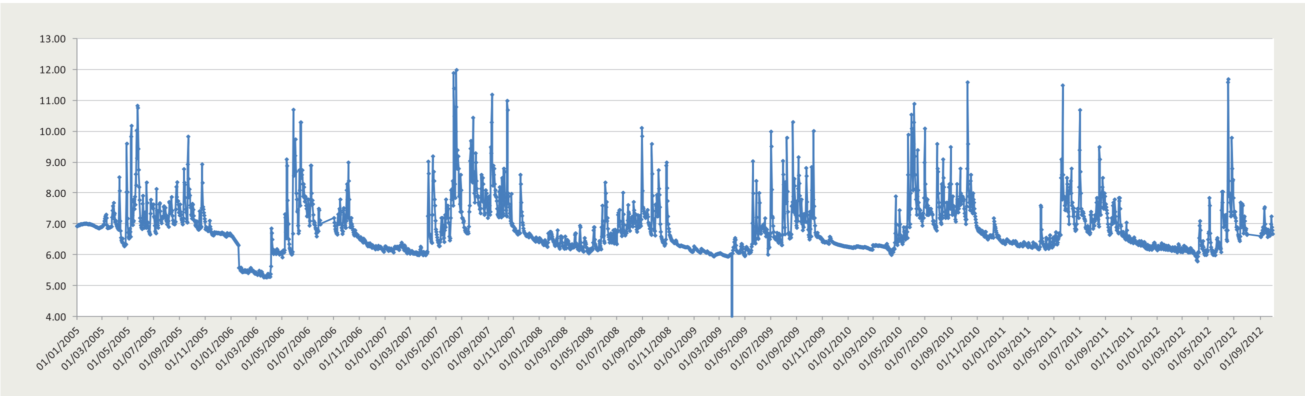
A structured coded questionnaire was used to record data on children aged 6-59 months, including anthropometric measurements, date of birth, sex, symptoms of night blindness, diarrhoea and acute respiratory tract infection, breastfeeding and child feeding practices, and receipt of vitamin A capsules. Household's composition, parental education, occupation of the main household earner, sanitary conditions, land ownership, food production and consumption, expenditure, exposure to natural disasters and domestic crises were also collected. Z-scores of the anthropometric measurements were calculated using the WHO 2006 growth reference.

Source: Bloem et al. (2003).

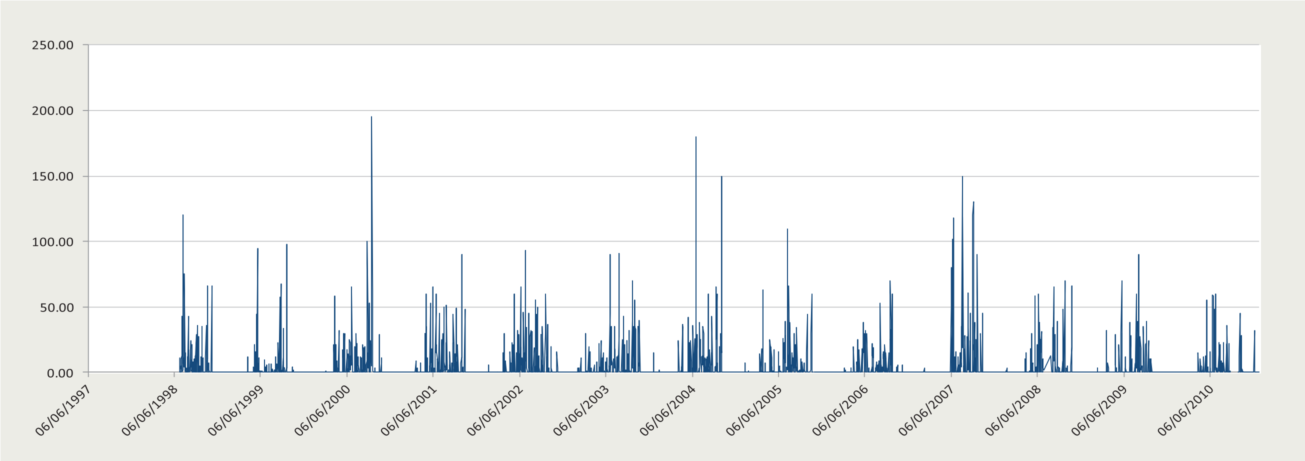
this report we investigated 6 different types of climate-related events: flood and flash flood, drought, cyclones, river bank erosion, and salinity intrusion (Table 2). For flood and flash flood, the daily water level recorded by BWDB was used. The data is recorded daily through a network of river flow stations. Examples are provided in Fig.5a and Fig.5b. For drought the daily rainfall data also recorded by BWDB was used (example displayed in Fig.5c). Salinity intrusion was estimated through the Program Soil Salinity data collected by the Soil Resource Development Institute (SRDI) (example displayed in Fig.5d). For cyclone the information was extracted from the International Best Track Achieve for Climate Stewardship (IBTrACS) dataset from the US National Ocean and Atmospheric Administration (NOAA) and used to generate a map of the different cyclones and tropical storms that affected Bangladesh over the period 1998-2006 (Fig.6). Finally for



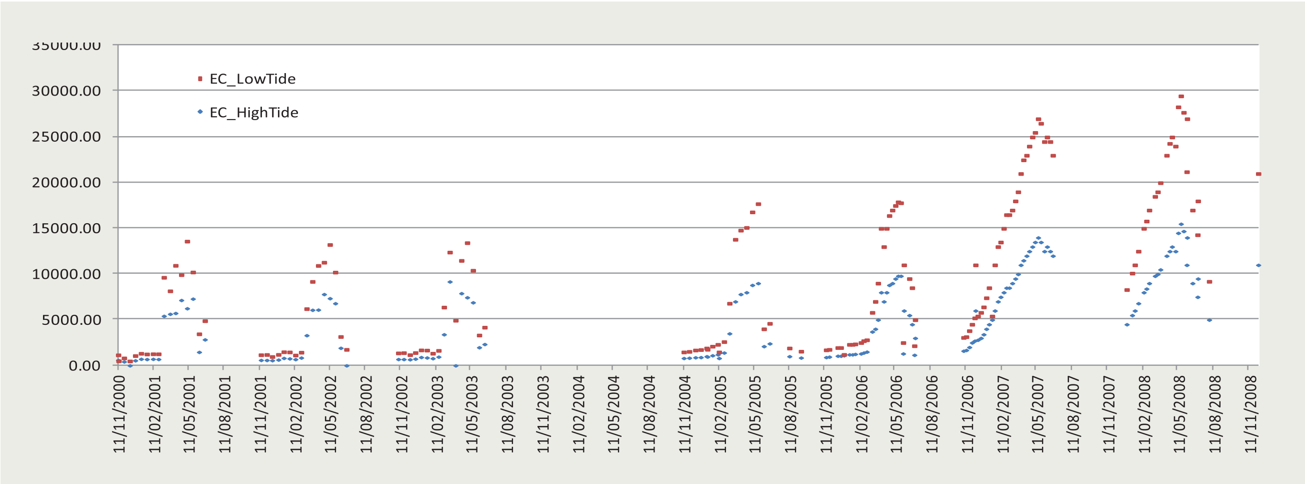
a. Flood. Monthly water level records (m) (Manikjganj station used here for illustration purpose)



b. Flash flood. Monthly water level (m) (Habiganj Station used here for illustration purpose)



c. Drought. Monthly rainfall records (mm/day) (Rajshahi station used here for illustration purpose)



d. Monthly salinity records (ChloridePPM) (Kuhlna Station used here for illustration purpose)

Fig.5. Illustrations of the data used for the shock/stressor (Source: see Table 2 for details).

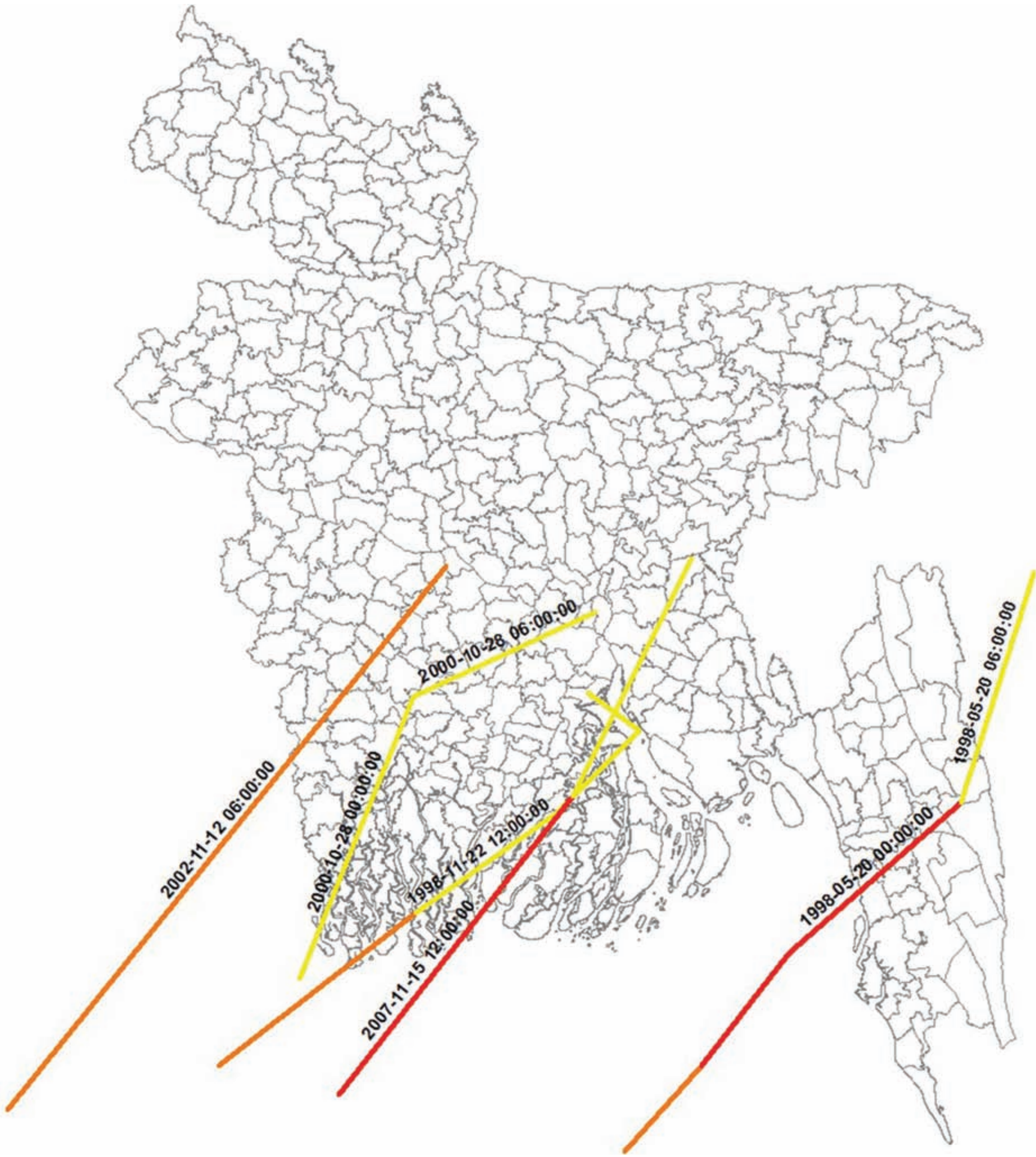


Fig.6. Paths of the cyclones and tropical storms that affected Bangladesh over the period 1998-2006. Source: IBTrACS-All data. The colour code indicates severity of the events -yellow: depression (0-62 m/s); orange: cyclonic storm (63-87 m/s); red: cyclone (87-118m/s). For information, the path of Sidr (15 Nov 2007) has also been indicated on the map.

Table 2. The sources of data bases used for the 6 different climate-related events considered in this study

Shocks	Name of Data Set	Sources	Web link	Report
Flood / flash food	BWDB Daily Water Level Data	Processing and Flood Forecasting Circle, BWDB	Not available	NA
Drought	BWDB Daily Rainfall Data	Processing and Flood Forecasting Circle, BWDB	Not available	NA
Cyclone	IBTrACS-All data	International Best Track Achieve for Climate Stewardship (IBTrACS), (NOAA)	http://www.ncdc.noaa.gov/ibtracs/index.php?name=ibtracs-data-access	NA
Salinity	SFSDP Program Soil Salinity Data	Soil Resource Development Institute (SRDI)	Not available	SRDI, 2012 Soil Salinity of Bangladesh - 2009
River Bank Erosion	River Cross Section Data	Processing and Flood Forecasting Circle, BWDB	Not available	NA

river bank erosion we initially planned to use the River Cross Section dataset collected by BWDB.

2.3.2 Identification of extreme events

Flood

For flood and flash flood the danger level (DL) as defined locally by BWDB was used to identify the period of flood using the water level data. Any period of the year during which the river flood data indicates a level of water above the DL is generally classified as flood or flash flood. For flood, we then used particular thresholds (10 days, 20 days, 30 days, 50 days above the DL) to categorize further the severity of the

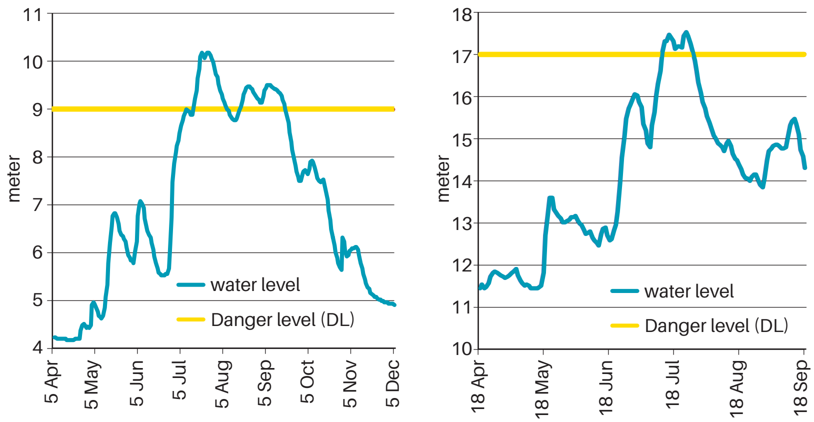


Fig.7. Two examples of flood events: 55-day flooding in Jul-Oct 1996 in Manikganj (left); and 15-day flooding in Jul 2004 in Jamalpur (right)

event. Fig.7 illustrates this with two examples: one of 55-day flood event in Jul-Oct 1996 in Manikganj and one 15-day flood event in Jul 2004 in Jamalpur.

Drought

Drought can be considered as a relatively slow-onset event. We use the Standardized Precipitation Index (SPI) (McKee et al. 1993) applied to the rainfall data to identify periods of local drought. SPI can be calculated for different timescales. We computed the 1, 2, 4 and 6-month SPIs. Six-month SPI is recognized to be especially relevant for agricultural drought (WMO 2012). Local drought was then assumed to correspond to events when the 6-month SPI remained below -1.2 for four consecutive months. Fig.8 shows the SPI calculation for three of these events. Colour codes were used to visualize the severity of the drought. In that example we see that the most severe drought occurred in Naogoan in 1999. Starting in April of that year, it lasted until January 2000. In comparison the event in Shahjadpur in 2003, which was still a

Naogaon Sadar 1999

Year	Month	SPI-1	SPI-2	SPI-4	SPI-6
1998	11	1.27	0.98	1.08	0.78
1998	12	1.26	1.28	0.92	1.02
1999	1	-0.54	1.19	1.23	0.91
1999	2	-1.15	-1.09	1.11	1.18
1999	3	-1.17	-1.15	-1.27	0.95
1999	4	-1.81	-1.83	-1.84	-1.68
1999	5	-1.83	-1.84	-1.85	-1.84
1999	6	-2.1	-2.13	-2.16	-2.16
1999	7	-2.55	-2.85	-2.86	-2.87
1999	8	-2.72	-3.09	-3.31	-3.3
1999	9	-3.03	-3.05	-3.33	-3.48
1999	10	-1.97	-2.72	-2.85	-3.1
1999	11	-1.04	-1.84	-2.59	-2.75
1999	12	-0.17	-1.16	-1.73	-2.49
2000	1	-0.68	-0.3	-1.38	-2.11
2000	2	0.25	0.13	-0.08	-1.2
2000	3	1.37	1.02	0.85	0.24
2000	4	2.47	2.37	2.29	2.37
2000	5	2.41	2.46	2.41	2.38
2000	6	1.85	1.9	1.92	1.86

Kaunia 1999

Year	Month	SPI-1	SPI-2	SPI-4	SPI-6
1998	11	0.89	1.41	1.25	1.1
1998	12	1.11	0.87	1.4	1.24
1999	1	-0.49	1.07	0.83	1.36
1999	2	-0.58	-0.78	1.03	0.82
1999	3	-0.6	-0.67	-0.78	0.87
1999	4	-1.13	-1.14	-1.12	-1.13
1999	5	-1.49	-1.48	-1.48	-1.47
1999	6	-2.09	-1.87	-1.87	-1.87
1999	7	-2.92	-2.93	-2.78	-2.79
1999	8	-1.8	-1.97	-2.06	-1.97
1999	9	-1.15	-1.93	-2.11	-2.21
1999	10	-0.4	-1.21	-1.93	-2.11
1999	11	-1.09	-0.38	-1.19	-1.9
1999	12	-0.15	-1.07	-0.38	-1.18
2000	1	-0.11	0.2	-1.12	-0.42
2000	2	-0.16	-0.11	-0.2	-1.11
2000	3	-0.6	-0.67	-0.78	-1.04

Shahjadpur 2003

Year	Month	SPI-1	SPI-2	SPI-4	SPI-6
2002	8	-0.5	-0.4	-0.22	-0.17
2002	9	-1.25	-0.56	-0.33	-0.22
2002	10	-0.34	-1.36	-0.73	-0.72
2002	11	-0.72	-0.37	-1.36	-0.74
2002	12	-1.17	-0.75	-0.38	-1.37
2003	1	-0.32	-1.32	-0.36	-0.45
2003	2	-0.58	-0.78	-1.53	-1.52
2003	3	-1.17	-1.32	-1.32	-1.53
2003	4	-1.55	-1.55	-1.53	-1.53
2003	5	-0.51	-1.27	-1.28	-1.26
2003	6	-0.31	-0.48	-0.91	-0.92
2003	7	-0.53	-0.59	-0.61	-0.94
2003	8	-0.61	-0.49	-0.52	-0.53
2003	9	-0.82	-0.83	-0.52	-0.56
2003	10	-0.6	-0.73	-0.77	-0.76
2003	11	-0.64	-0.63	-0.74	-0.78
2003	12	-0.16	-0.66	-0.65	-0.76

Pirganj 1998

Year	Month	SPI-1	SPI-2	SPI-4	SPI-6
1997	12	-0.8	-1.17	-1.17	-1.34
1998	1	-0.67	-0.89	1.15	-1.15
1998	2	-0.78	-0.78	-0.89	-1.15
1998	3	0.49	-0.89	-0.89	-1.01
1998	4	-1.03	-1.03	-1.01	-1.01
1998	5	-1.17	-1.17	-1.17	-1.15
1998	6	-1.34	-1.34	-1.34	-1.34
1998	7	-1.34	-1.34	-1.34	-1.34
1998	8	-1.17	-1.17	-1.34	-1.34
1998	9	-1.34	-1.34	-1.34	-1.55
1998	10	-1.17	-1.34	-1.34	-1.34
1998	11	-1.17	-1.17	-1.34	-1.34
1998	12	-0.8	-1.17	-1.17	-1.34
1999	1	-0.67	-0.89	-1.15	-1.15
1999	2	-0.78	-0.78	-0.89	-1.15
1999	3	-0.91	-0.89	-0.89	-1.01
1999	4	-1.03	-1.03	-1.01	-1.01
1999	5	0.53	-0.3	-0.98	-1.14
1999	6	1.18	0.67	0.23	-0.24
1999	7	1.5	1.99	1.75	1.57

Fig.8. Identification of the drought events using SPI calculation (1, 2, 4 and 6-mont SPI). Red colour indicates SPI below -2.0 (considered as "extremely dry" in the McKee et al. classification); orange colour indicate -2.0 < SPI < -1.5 ("severely dry"); and green indicate -1.5 < SPI < -1.2 ("moderately dry").

drought as per the definition, is more moderate.

Salinity intrusion

For salinity intrusion, no particular 'extreme events' per se were identified. Instead salinity intrusion was assumed to be a slow onset stressor that affects progressively a whole geographic area. Data indicate however that the increase in salinity did not occur in a linear manner. Instead the annual salinity over the period 2000-2012 remained relatively constant until the mid-2000s (although highly seasonal) and then started to increase rapidly from 2005-2006 onward[5] (see e.g. Fig.5d above for an illustration). For salinity, we therefore identified the upazilas that have been affected by these rapid increases in salinity post-2005 using the Soil Resource Development Institute's Survey, Mapping and Documentation of Saline Soils of Bangladesh (2009) dataset (Table 4). Upazilas were further categorized by the proportion of the area impacted by certain salinity levels (as measured in 2009) using five categories (s1=2.0-4.0 dS/m; s2=4.1-8.0 dS/m; s3=8.1-12.0 dS/m; s4=12.1-16.0 dS/m; and s5: >16.0 dS/m where

Table 4. Areas affected by salinity intrusion. Source: SRDI, 2012 Soil Salinity of Bangladesh - 2009

Area	Saline at or above the given level						
	20% or more of the land				40% or more of the land		
	s1+	s2+	s3+	s4+	s1+	s2+	s3+
Cox's Bazar Sadar, Cox's Bazar	Yes	Yes	Yes	Yes	No	No	No
Fakirhat, Bagerhat	Yes	Yes	Yes	No	Yes	Yes	No
Debhata, Satkhira	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Patharghata, Barguna	Yes	Yes	Yes	No	Yes	Yes	No
Lalmohan, Bhola	Yes	No	No	No	No	No	No
Rajapur, Jhalakathi	No	No	No	No	No	No	No
Patuakhali Sadar, Patuakhali	Yes	Yes	No	No	Yes	No	No

Areas included in the NSP system which did not have a salinity problem include: Sreepur, Gazipur; Jamalpur Sadar, Jamalpur; Serajdikhan, Munshiganj; Atpara, Netrokona; Nabinagar, Brahmanbaria; Hathazari, Chittagong; Chouddagram, Comilla; Naogaon Sadar, Naogaon; Kaunia, Rangpur; Shahjadpur, Sirajganj; Pirganj, Thakurgaon; Kaliganj, Jhenidah; Gangni, Meherpur; Habiganj Sadar, Habiganj; Sreemangal, Moulavi Bazar; Jamalganj, Sunamganj; Fenchuganj, Sylhet

dS/m (deciSiemens per metre) is a unit for measuring salinity.

Cyclones

For cyclone, the IBTrACS-All database provides the list of events to be considered. We used the severity of these event (estimated through the cyclone maximum wind speed) to distinguish four path widths[6] as detailed in Table 5: 50 km; 100 km; 150 km and 200 km. Based on this information we were able to identify the districts/upazilas affected by each event. Fig.8 shows two examples of cyclones (Nov 1998 and Oct 2000) and their respective paths.

[5] As if the buffer capacity (resilience) of the system has suddenly been reached.
[6] A 100 km width path would mean that 50 km on both side of the cyclone trajectory are assumed to be affected.

Table 5. Estimated path width of cyclone, based on their severity measured in wind-speed.

Severity (wind-speed (m/s)	Width (km)
[0-40[	50
[40-80[	100
+80	150
115	200

River bank erosion

For river erosion, the absence of available information and clear methodology on how to correlate the current existing river cross-section data with the occurrence of specific river erosion events forced us to abandon the idea of running quantitative analysis. Instead, qualitative analysis was used (see section 2.6).

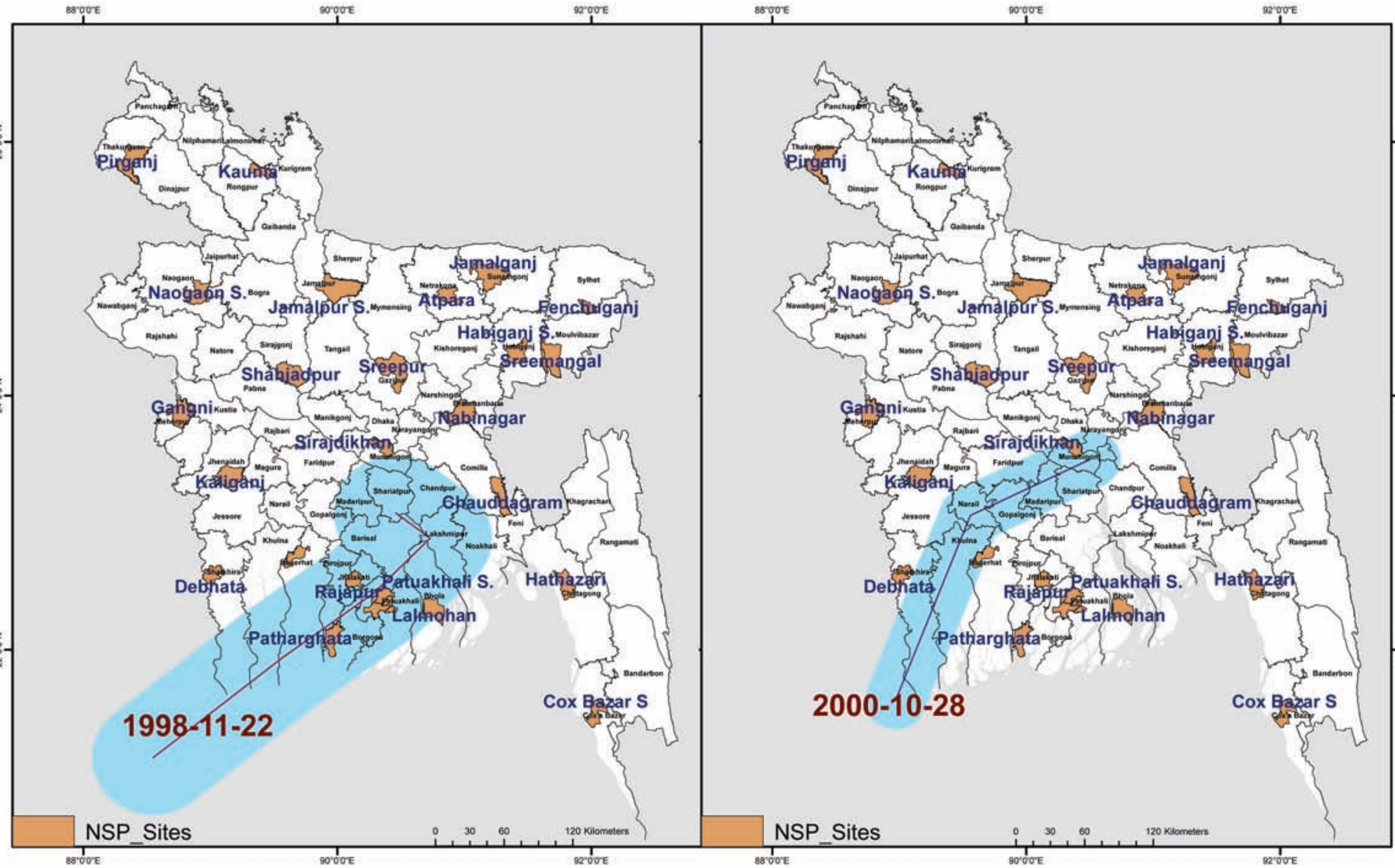


Fig.8.a (top) Path of the Nov 1998 cyclone; (b) (bottom) Path of the Oct 2000 cyclone.

Source: IBTrACS-All data. NSP-sampled areas are indicated in colour.

2.4 Test protocol

2.4.1 Difference in difference and identification of individual-events

On order to test as rigorously as possible the potential impact of specific events on the nutrition and food security of child/households, we followed a quasi-experimental approach. Wherever it was possible, we adopted a difference in difference (DiD) protocol (Zar 2010). In our case this DiD protocol means that we compare the value of a particular indicator (nutrition or food security) obtained for two groups of communities: one group affected by a specific event (treatment), and one group not affected by the same event (control), and that the comparison is run before and after the period when that specific event occurs.

The DiD protocol implies therefore a series of 4 stringent conditions:

(i) Treatment communities (i.e. communities that were affected by a particular event) can be identified amongst these that had been included in the NSP. This, in itself, implies that:

a. Shock/stressor data are available for the region/district that includes (or are sufficiently close to) these communities;
b. These affected communities were sampled at the appropriate time, i.e. both before and after the occurrence of that event;

(ii) We are able to identify control communities, amongst these that had been included in the NSP. This, in itself, implies that:

a. These control communities were not affected by the event -as was verifiable using the climate databases;
b. These non-affected communities were sampled by the NSP at the same time both before and after the event occurred in the affected communities

Clearly these conditions limited the number of testable cases for which the DiD protocol can be applied fully. This had some important implication for our work. In particular in the case of flash flood no single testable event was possible amongst the series of flash flood events that had been identified, essentially because flash floods –even if they occur relatively often- are very localized both geographically and temporarily, making the matching process impossible in our case for the period considered.[7] For salinity intrusion the slow onset nature of the process also implies that the DiD approach cannot be applied. Instead for salinity a simple difference in means (DiM) test was applied whereby the food security and nutritional indicators of communities living in the affected areas (treatment) were compared to the same indicators estimated for communities living outside the affected area (control).

For all the other shocks, applying the DiD was possible for the events that were satisfying the 6 conditions listed above. Thus, for flood, eight flood events were identified. Table 6 shows the full list of these flood events (location, date, duration). Amongst these the 1998 and 2004 events were major events (with the flood level remaining over the DL for more than 30 subsequent days in a large number of upazilas), while the other 6 events were less significant.

For drought, three drought events involving four *upazilas* (Naogoan, Kaunia, Shahjadpur, and Pirganj) were identified for which NSP data is available for both treatment and controlled communities. These are listed in Table 7.

[7] In addition, the river danger level data was missing for several stations in the areas where flashfloods were occurring, preventing us from being sure that the control communities were true control, i.e. effectively not affected by flashflood.

Table 6. List of flood events included in the DiD analysis

Year	Months	Areas affected, with the number of days flooded in brackets
1998	July - September	Shahjadpur, Sirajganj (74); Nabinagar, Brahmanbaria (64); Serajdikhan, Munshiganj (55); Sreepur, Gazipur (53); Jamalpur Sadar, Jamalpur (31); Naogaon Sadar, Naogaon (17)
1999	July - September	Shahjadpur, Sirajganj (60); Naogaon Sadar, Naogaon (15); Pirganj, Thakurgaon (5); Serajdikhan, Munshiganj (3)
2000	June - September	Shahjadpur, Sirajganj (52); Serajdikhan, Munshiganj (3)
2001	August - October	Shahjadpur, Sirajganj (25); Pirganj, Thakurgaon (14)
2002	June - August	Shahjadpur, Sirajganj (28); Nabinagar, Brahmanbaria (11); Jamalpur Sadar, Jamalpur (7); Serajdikhan, Munshiganj (6)
2003	July	Shahjadpur, Sirajganj (18); Nabinagar, Brahmanbaria (9); Naogaon Sadar, Naogaon (4); Serajdikhan, Munshiganj (11)
2004	July - October	Shahjadpur, Sirajganj (95); Nabinagar, Brahmanbaria (30); Naogaon Sadar, Naogaon (30); Serajdikhan, Munshiganj (17); Jamalpur Sadar, Jamalpur (15); Fenchuganj, Sylhet (15); Sreepur, Gazipur (15)
2005	October	Naogaon Sadar, Naogaon (12)

NSP-sampled areas which were not affected by flood between 1998 and 2006: Hathazari, Chittagong; Chouddagram, Comilla; Cox's Bazar Sadar, Cox's Bazar; Kaunia, Rangpur; Fakirhat, Bagerhat; Kaliganj, Jhenidah; Debhata, Satkhira; Patharghata, Barguna; Lalmohan, Bhola; Rajapur, Jhalakathi; Patuakhali Sadar, Patuakhali; Habiganj Sadar, Habiganj; Sreemangal, Moulavi Bazar; Jamalganj, Sunamganj.

Areas with river station data not available and thereby excluded from analysis are: Gangni, Meherpur; Atpara, Netrokona.

Table 7. List of drought events included in the DiD analysis

Year	Months	Type of event	Areas affected, with the number of months of drought in parentheses
1998	June	Moderate	Pirganj, Thakurgaon (7)
1999	April-May	Severe	Naogaon Sadar, Naogaon (10); Kaunia, Rangpur (7)
2003	February	Moderate	Shahjadpur, Sirajganj (4)

NSP-sampled areas in the drought zone with no periods of low rainfall from 1998-2006: Jamalpur Sadar, Jamalpur; Kaliganj, Jhenidah; Gangni, Meherpur.

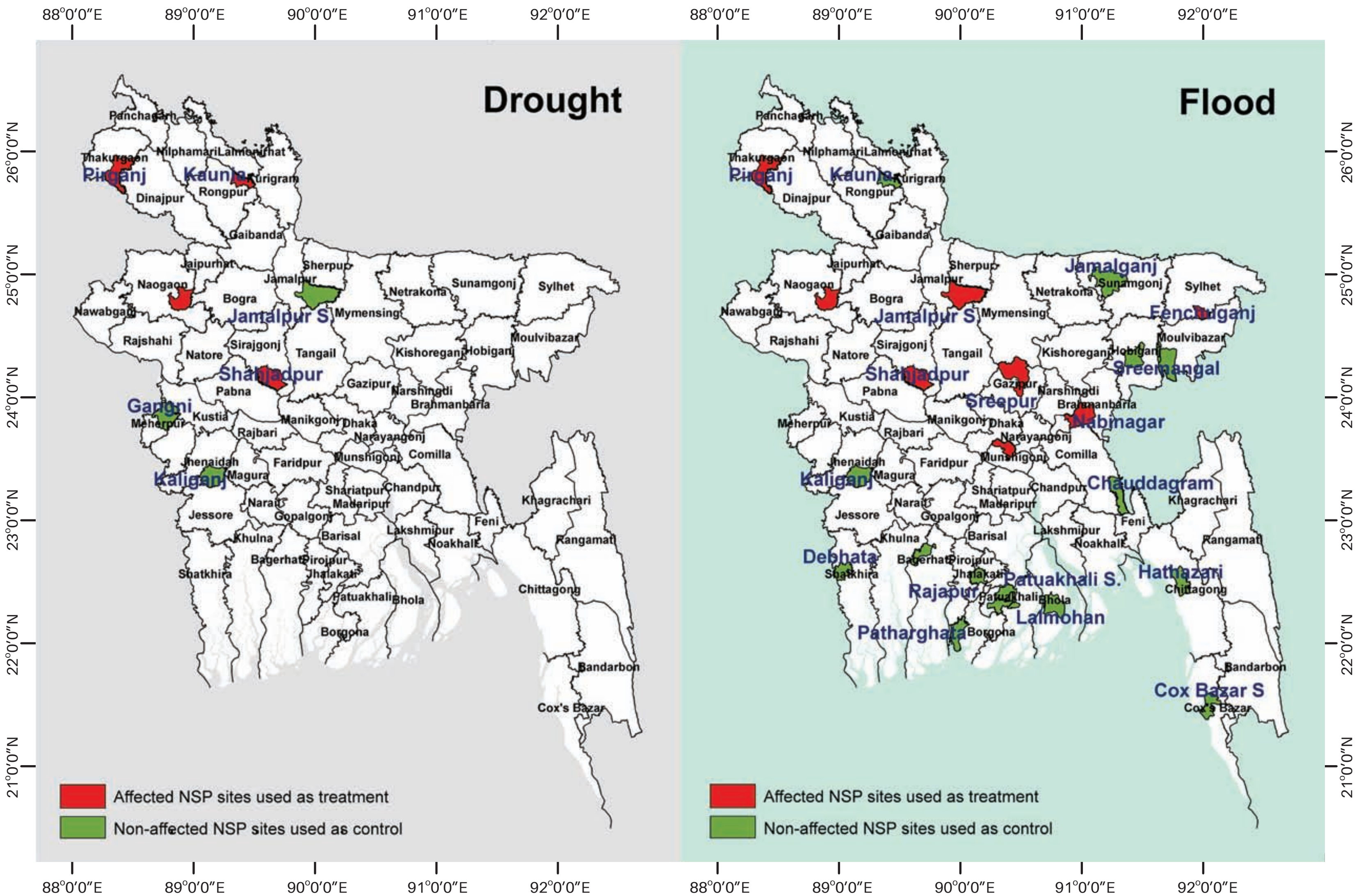
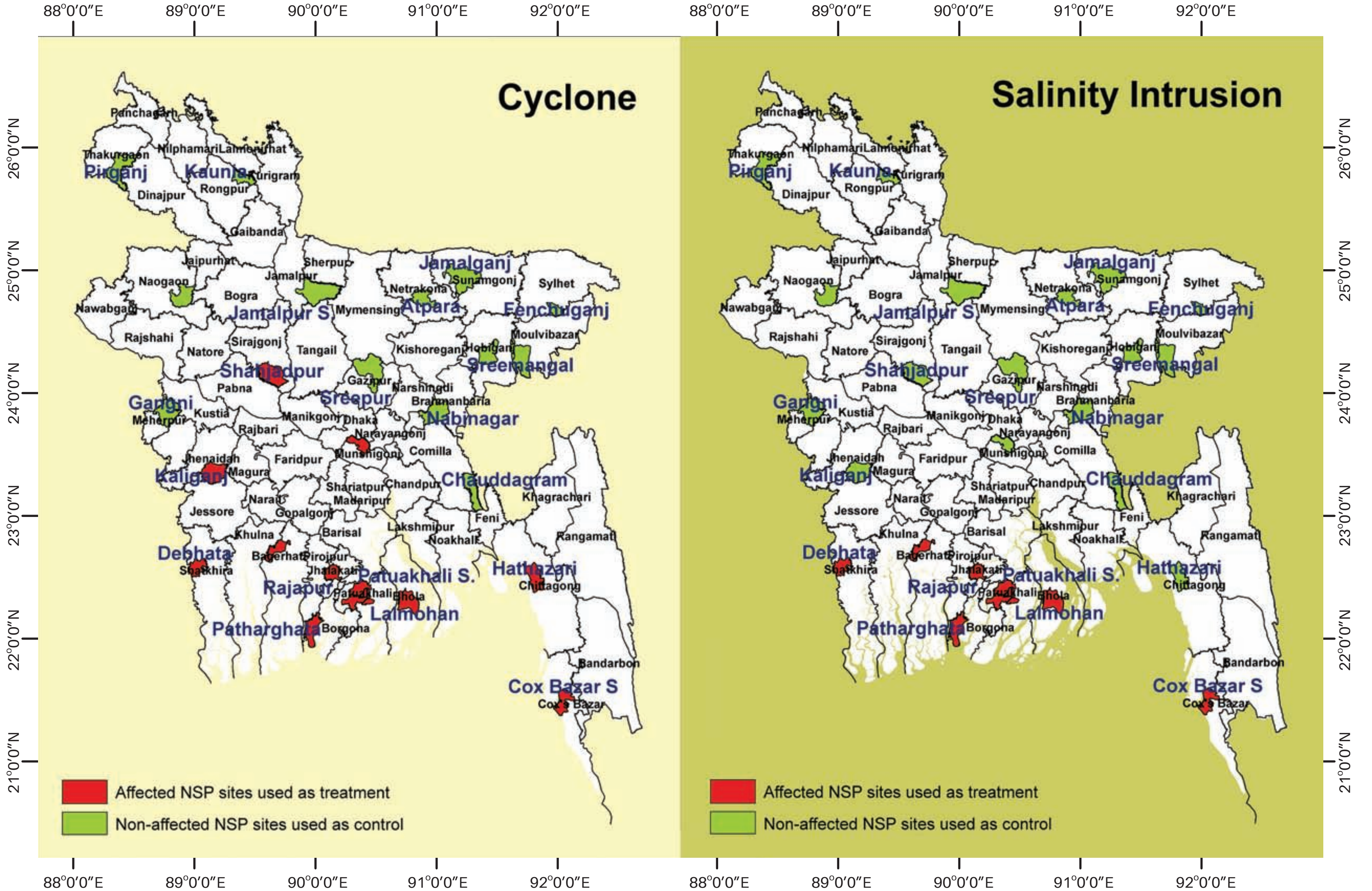


Fig.9. Maps of all the different affected (treatment) and non-affected (control) NSP sites included in the quantitative analysis



Cyclone
Salinity Intrusion
Affected NSP sites used as treatment
Non-affected NSP sites used as control
88°0'0"E
89°0'0"E
90°0'0"E
91°0'0"E
92°0'0"E
26°0'0"N
25°0'0"N
24°0'0"N
23°0'0"N
22°0'0"N
21°0'0"N
Pirganj
Kaunia
Jamalganj
Jamalpur S
Atpara
Fenchuganj
Shahjadpur
Sreemangal
Gangni
Sreepur
Nabinagar
Kaliganj
Chauddagram
Debhata
Hathazari
Patuakhali S.
Rajapur
Lalmohan
Patharghata
Cox Bazar S
Panchagarh
Thakurgaon
Nilphamari
Lalmonirhat
Kurigram
Dinajpur
Rongpur
Gaibanda
Jaipurhat
Sherpur
Naogaon
Jamalpur
Sunamgonj
Sylhet
Netrakona
Bogra
Nawabganj
Mymensing
Moulvibazar
Rajshahi
Sirajgonj
Tangail
Kishoreganj
Hobiganj
Natore
Pabna
Gazipur
Narshingdi
Brahmanbaria
Meherpur
Kustia
Manikgonj
Dhaka
Rajbari
Narayangonj
Munshigonj
Comilla
Jhenaidah
Faridpur
Magura
Shariatpur
Chandpur
Narail
Maderipur
Khagrachari
Jessore
Gopalgonj
Feni
Lakshmipur
Khulna
Barisal
Noakhali
Rangamati
Bagerhat
Pirojpur
Jhalakati
Satkhira
Chittagong
Patuakhali
Bhola
Borgona
Bandarbon
Cox's Bazar

Table 8. List of cyclone events included in the DiD analysis

Date	Wind-speed	Areas affected with the proportion of area impacted by the cyclone path in parenthesis
May 19, 1998	60	*Partially:* Hathazari, Chittagong (90%); Cox's Bazar Sadar, Cox's Bazar (10%)
November 22, 1998	55	*Completely:* Patharghata, Barguna; Rajapur, Jhalakathi; Patuakhali Sadar, Patuakhali *Partially:* Lalmohan, Bhola (80%)
October 28, 2000	35	*Partially:* Serajdikhan, Munshigonj (98%); Fakirhat, Bagerhat (70%)
November 12, 2002	55	*Completely:* Kaliganj, Jhenidah; Debhata, Satkhira *Partially:* Shahjadpur, Sirajganj (50%)

Areas with no cyclone events from 1998-2006: Sreepur, Gazipur; Jamalpur Sadar, Jamalpur; Atpara, Netrokona; Nabinagar, Brahmanbaria; Chouddagram, Comilla; Naogaon Sadar, Naogaon; Kaunia, Rangpur; Pirganj, Thakurgaon; Gagni, Meherpur; Habiganj Sadar, Habiganj; Sreemangal, Moulavi Bazar; Jamalganj, Sunamganj.

For cyclones, four events were identified. These are indicated in Table 8 along with the percentage of the upazilas that were affected by these cyclones. Note that because Sidr happened in 2007, that is after the NSP was terminated, it is not amongst the events which could be tested.

Fig.9 is a summarizing map that represents all the different upazilas which were included in the quantitative analysis. In red are the affected (treatment) areas, and in green the control areas for droughts, floods, cyclones and salinity.

2.4.2 Individual-event, joint models and combined models

Individual-event tests

For all the individual-events for which the conditions for the DiD protocol were fulfilled, the test was conducted with the 10 food security and nutrition indicators that were recorded in the NSP (see description of these indicators below). For each indicator, the test was run between the period before the event and the period just after (one half to two months after onset), as well as between the period before the event and 4 lagged periods each two months after the previous (1st lag: 2.5-4 months after onset, 2nd lag: 4.5-6 months after onset, 3rd lag: 6.5-8 months after onset, and 4th lag: 8.5-10 months after onset).[8] The idea of these additional lag tests was to explore the possible lagged effect of the

[8] In the rest of this report the 1st lag [2.5-4 months after the onset] will be referred to as the 3-month lagged period, the 2nd lag [4.5-6 months after the onset] as the 5-month lagged period; the 3rd as the 7-month lagged period; and the 4th as the 9-month lagged period.

event, considering two scenarios: (i) the impact of a particular shock may not appear immediately after the shock but only few months later, and (ii) the impact may last for more than just one period, e.g. start three months after the event but still be observed nine months later. Long term impacts are especially important with slow onset events, like floods and droughts, where the impact of the event would be expected only after some time.

The change observed in the indicator between the two periods (before-after) was then compared to the change observed for the same indicator and same periods for a non-affected group of communities (control). In addition, in all models, upazila level fixed-effects were used.

Joint models

In addition to these individual-events' DiD tests, joint-event tests were also conducted for which all the communities affected by one type of event (say droughts) were pooled together into one treatment group and compared to the remaining pool of non-affected (control) communities. For most event types, the level of severity of the event was captured (see further details below) and a variable was also introduced to control for time (years).

Note that for all tests (individual-events, joint models, and combined models -see details below) additional covariables were also included to control for other important factors influencing nutrition and food security (see section 2.5.2 below). In addition, in most models, upazila level fixed-effects were used.

Combined models

Finally two combined models were run that included two combinations of different events: (i) drought and flood together and (ii) cyclone, salinity and flood together. The reason for this was that certain parts of the countries are affected not by one single type of events, but by a combination of events which can even occur within the same year: the north west part where both drought and flood can be observed together in the same area, and the south coast where salinity, cyclones and flood are regular shocks. The underlying hypothesis was that as many communities experienced repeated events of different types the impacts seen on the individual results could be confounded by other events in the same area. By including all events we will be better able to disentangle the varying impacts of each type of event.

2.5 Indicators and variables

The analytical framework proposed earlier (cf. Fig.3) identified a whole series of different variables which are, in theory, important to consider in order to assess/quantify the impact of climate-related extreme events on food security and nutrition. Some of these variables are dependent variables (impact variables measuring the food security and nutritional status of households) while others are explanatory (shocks) or controlled covariables (household and/or community characteristics). Not all variables were available for measurement however, or were available but not in a form or a frequency that was optimal for this analysis. Below is the list of variables that were used.

2.5.1 Impact variables:

A series of 10 variables were used to assess the food security and nutrition levels of households: five for nutrition and five for food security and food prices.

Nutrition indicators

Length/Height for age z-score (ZLEN) - This indicator of chronic undernutrition measures the cumulative effects of growth retardation (stunting) through comparison of the length of children less than 2 years of age or height of children two to five years of age to the average growth attainment of children of the same age from a healthy, multinational and multiethnic cohort of children was collected on a bi-monthly basis by the NSP for the entire period from 1998 to 2006 (WHO Multicentre Growth Reference Study Group).

Weight for Length/Height z-score (ZWFL) - This indicator of acute undernutrition measures the thinness of the child (wasting) by comparing the weight of the child based on its length/height to the weight of children of the same length/height from a healthy, multinational and multiethnic cohort of children (WHO Multicentre Growth Reference Study Group). In line with WHO guidelines the recumbent length of children less than two years of age and the standing height of children two to five years of age were recorded. This indicator was collected on a bi-monthly basis by the NSP for the entire period from 1998 to 2006.

Maternal body mass index (BMI) - The nutritional status of the mothers of included children can be established using body mass index (BMI, $weight_{kg}$/ $height_{m}{}^{2}$). By normalising the weights of individuals over their heights, BMI gives an indication of the thinness or obesity of an individual and thereby information about the energy and nutrient composition of the diet consumed in relation to the energy requirements of the individual. Nutritional status indicators based on BMI are useful in determining if the individual is suffering from acute malnutrition. This indicator was collected on a bi-monthly basis by the NSP for the period 2000 to 2006.

Children’s dietary diversity (dd) - The diversity of the child’s diet (dd) is measured by adding the number of days in the week before the interview that the child has eaten foods of the following six types: rice, egg, green leafy vegetables, dal, fish, and fruit. As such the scale ranges from 0 for a child who is not yet eating any of these foods to 42 for children who have eaten every type of food everyday in the week before the interview. This variable was collected on a bi-monthly basis by the NSP for the period 1999 to 2001 and again from 2003 to 2006.

Maternal dietary diversity (DD) - The diversity of the mother’s diet DD is measured by adding the number of days in the week before the interview that the woman has eaten foods of the following six types: rice, egg, green leafy vegetables, dal, fish, and fruit. As such the scale ranges from 0 for a woman who has fasted during the week to 42 for women who have eaten every type of food everyday in the week before the interview. This variable was collected on a bi-monthly basis by the NSP for the period 1999 to 2001 and again 2003 to 2006.

Note that the way the DiD tests are designed means that in our case a statistically significant negative sign for any of these 5 nutrition indicators would indicate that the community affected by the event is significantly worse-off than the non-affected community (control), suggesting that the event had a substantially detrimental impact on the community nutrition status.

Food security and food price indicators

Food loan (FL) - The food loan (FL) is the proportion of households who have taken out a loan for food: NSP asked households the amount of loan they had taken for food consumption in the past month. This variable was dichotomized into households which had taken a loan and those that had not taken a loan. This variable was collected on a bi-monthly basis by the NSP for the entire period 1998 to 2006.

Food expenditure (FE) - The Food expenditure (FE) is the proportion of the household expenditure spent on food items of total household expenditure. With two exceptions, this variable was collected on a bi-monthly basis by the NSP for the entire period 1998 to 2006. There was no data on non-food expenditure in Dec 2001-Jan 2002 (sampling round 71), so this round is omitted from analysis, and information on food costs was missing for Shahjadpur during August-September 1998 (sampling round 51) so this was also excluded from analysis.

Price of rice (PR) - The Price of Rice (PR) is the average price of rice in a given upazila measured through a market survey in each village visited. As this commodity is produced locally in most of rural Bangladesh, an increase in price largely points to a negative impact of local market networks. This variable was collected on a bi-monthly basis by the NSP for the entire period 1998 to 2006 with one exception: no data from Shahjadpur during August-September 1998 (sampling round 51). This area during this round was thereby excluded from analysis.

Price of oil (PO) - The Price of oil (PO) is the average price of soybean oil in a given upazila as measured through a market survey in each village visited. As this commodity is not produced locally, an increase in price largely points to a negative impact of national or regional market networks. This variable was collected on a bi-monthly basis by the NSP for the entire period 1998 to 2006 with one exception: no data from Shahjadpur during August-September 1998 (sampling round 51). This area during this round was thereby excluded from analysis.

Price of food basket (PFB) - The price of food basket (PFB) is the average price of a given basket of goods that represents the average diet of a person in Bangladesh in 2005 (439.6 grams rice; 12.1 grams atta; 63.3 grams potato; 8.3 grams moshur dal; 3.8 grams mustard oil; 12.6 grams soybean oil; 7.8 grams beef; & 5.2 grams egg) as measured through a market survey. This variable was collected on a bi-monthly basis by the NSP for the entire period 1998 to 2006 with one exception: no data from Shahjadpur during August-September 1998 (sampling round 51). This area during this round was thereby excluded from analysis.

Given the nature of these five food security and price indicators and what they monitor, a statistically significant positive sign generated by a DiD test for any of these indicators would indicate that the affected community is substantially worse-off than the control community in terms of food security and food prices.

2.5.2 Covariates

Additional variables characterizing the household's main livelihood strategy, child and family characteristics, and housing characteristics have been collected by the NSP for each bi-monthly survey.

Livelihood strategies

Farmer - A dummy variable indicating if the main income earner in the household earned income primarily from farming (includes farmers, share croppers, and *jhum*[9] cultivators). This covariate was collected in all rounds from 1998 to 2006.

[9] Slash and burn technique.

Labour - A dummy variable indicating if the main income earner in the household earned income primarily from labour (includes agricultural day labour, contract agricultural labour, skilled, and unskilled labour). This covariate was collected in all rounds from 1998 to 2006.

Transport - A dummy variable indicating if the main income earner in the household earned income primarily from providing transport (includes rickshaw and rickshaw van pullers). This covariate was collected in all rounds from 1998 to 2006.

Salary - A dummy variable indicating if the main income earner in the household earned income primarily from a salaried job (includes professionals and other salaried workers such as factory jobs). This variable is used in all models except the price models. This covariate was collected in all rounds from 1998 to 2006.

Business - A dummy variable indicating if the main income earner in the household earned income primarily from business activities (includes both large and petty businesses). This covariate was collected in all rounds from 1998 to 2006.

Child and family characteristics

Child Age - The child's age was recorded in days by subtracting the recorded date of birth of the child from the date of survey visit. This covariate was collected in all rounds from 1998 to 2006.

Child Sex - The sex of the child included in measurements. This covariate was collected in all rounds from 1998 to 2006.

Child Birth order - The birth order of the child included in measurements. This covariate was collected in all rounds from 1998 to 2006.

Maternal lack of education - A dummy variable indicating if the mother in the household had not received any years of education. This covariate was collected in all rounds from 1998 to 2006.

Maternal age - The current age of the mother in the household. This covariate was collected in all rounds which also collected Maternal BMI (2000 to 2006).

Family size - The number of members of the household. This covariate was collected in all rounds from 1998 to 2006.

Housing

Improved water - A dummy variable indicating if the household used one of the following sources for drinking: a tap; shallow or deep tubewell/ handpump; purified water by boiling/ tablet; rainwater; or spring. This covariate was collected in all rounds from 1998 to 2006.

Improved latrine - A dummy variable indicating if the household had a closed latrine. This covariate was collected in all rounds from 1998 to 2006.

2.6 Qualitative analysis

A rigorous DiD protocol could not be applied for two types of events: (i) the salinity intrusion –for which the chronic nature of the event made the DiD approach non-applicable (there is no 'before' and 'after'), and (ii) the river bank erosion for which two technical issues were identified: first the absence of clear methodology on how to correlate the current existing River Cross Section data with the occurrence of specific river erosion; and secondly the very localized (both temporally and geographically) nature of the event, which made it impossible to match the NPS data with the river datasets[10].

[10] In addition the fact that a substantial number of households may migrate to other villages, neighbouring small towns, divisional or district capital or even Dhaka following these river bank erosion events affects the robustness of the test –as the population before and after is actually not the same any longer.

Instead, for these two types of events, two qualitative investigations were implemented, one in Gaibandha in the north-west part of the country where river bank erosion and floods are common, and one in Satkhira in the southern coastal area where saline intrusion is now a recurrent problem – see Fig.10[11]. The qualitative research involved Focus Group Discussions (FGDs), Key Informant Interviews (KIIs), and in-depth interviews (IDIs). The investigation in Satkhira further provided an opportunity to explore people's views and perceptions regarding recent cyclones (in particular Aila which happened after the NSP was terminated and for which quantitative data was therefore not available).

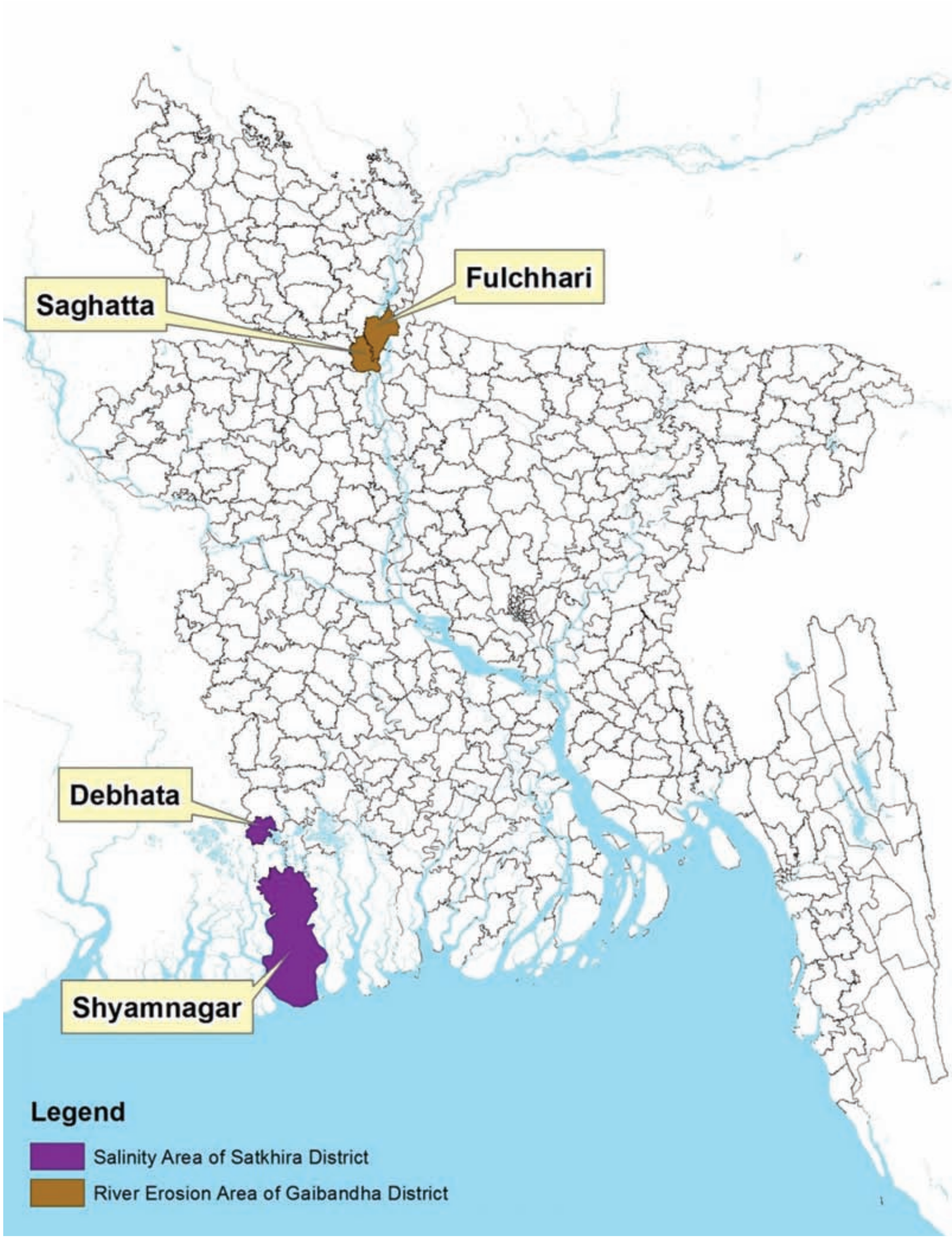


Fig.10. Areas where data collection for the qualitative analysis was conducted

[11] Two upazilas (sub-districts) were selected in each target district for qualitative data collection. Within each upazila, two unions were selected and two-three villages in those unions. This resulted in 12 villages of four unions of two upazilas. In Satkhira district, qualitative data were collected from Dhankhali, Shinghortoli and Jelekhali villages of Munshiganj union under Shyamnagar upazila; and, Nangla, Ghonapara, Aatshoto Bigha and Debi Shohor villages of Noapara union under Debhata upazila; In Gaibandha district, qualitative data were collected from Kumarpara, Goabari and Uttar Digholkandi villages of Haldia union under Saghata upazila; and, Deluabari and Jamira Char villages of Fulchari union under Fulchari upazila.

Data collection focused on perceptions of climate change and related climate events or occurrences, particularly river bank erosion and flooding in Gaibandha, and salinity and cyclone in Satkhira; food security and nutrition at the household and community level; immediate and long-term effects of a disaster; and ways in which individuals and households adapt to or cope with these effects or changes. Additionally, the in-depth interviews further explored access to, availability of, and consumption of various food groups in (i) normal times and (ii) following a disaster, specifically examining reported dietary changes and duration of these changes.

For the FGDs, respondents in selected areas were grouped into three age groups of 15-25 years, 25-50 years and 50-65 years, resulting in 12 FGDs. Three KIIs (n=12) were carried out in each of the four upazila with both male and female community leaders and representatives of an NGO working in the target area. In addition relevant government officials and representatives of the Local Government were also interviewed, including Upazila Nirbahi Officer (UNO) or Sub-district Executive Officer, Project Implementation Officer (PIO), Upazila Agriculture, Livestock and Fisheries Officers; Union Parishad (Council) members and Disaster Management Committee members.

To conduct IDIs four data collectors were trained for five days to ensure the interview objectives were understood by all and were appropriately translated for the local context in meaningful language. Prior to going to the field, the interview schedule was tested by the data collectors in Korail slum in Dhaka and in a flood-prone and riverbank-prone area of Bashkandi village in the district of Manikganj along the big river Jamuna.

In-depth interviews (n=27) were conducted over a 10 day period in March 2014 using a voice recorder and paper copies of the interview schedule. Interviews usually lasted 1½ to 2 hours and took place in the homes of respondents. Each evening the field teams met to discuss, review and clean the hand written responses. The data collected in Bengali were then typed, summarized and translated into English for the qualitative analysis.

Chapter 1 2 **3** 4 5

Findings

Findings

3.1 Quantitative analysis

3.1.1 Floods

■ *Individual event analysis*

The two major floods which took place during the period the NSP was implemented (1998 and 2004) were tested individually using the DiD protocol. The nutrition and food security indicators were computed before and after the events for communities that had been affected by the flood events, and the changes in these indicators were compared to the changes in the same indicators for control communities which had not been affected by the flood[12]. The analysis shows the following results:

Nutrition indicators

For the 1998 flood, only the child's zwfl and zlen could be used for the test as the mother BMI, the dd and DD had not been measured[13]. For the 2004 event, all five nutrition indicators (zwfl, zlen, BMI, dd and DD) had been measured and could be used for the test. Results for both events are shown in Table 9.

For the 1998 flood event, the DiD test shows that the zwfl (wasting) is negatively affected by the 1998 flood event: all zwfl indicators show negative coefficients for the period directly following the event and the five lagged periods (i.e. for three, five, seven, and nine months following the flood). This suggests that the flood had a negative impact on children's nutritional status. The difference is statistically significant ($p=0.004$; $p=0.006$; $p<0.0001$) for three, five, and seven-month lagged periods. The coefficient for zlen (stunting) was also negative, but the difference is only statistically significant ($p=0.035$) for the seven-month lagged period[14].

The 2004 event shows some degrees of consistency with this pattern. The coefficient for zwfl displays negative sign for zero, three, five, seven and nine-month lags, although none are statistically significant. The coefficient for zlen is also consistently negative for the three, five, and seven month lagged periods, but here again none of them are statistically significant.

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[12] There were two methods through which these comparisons were done due to data limitations. For the 1998 flood, as only a few rounds of data collection took place before event onset, this period was selected as the before period compared to the times after the event without controlling for seasonal variation. This method assumes that differences existing in the early part of 1998 were consistent with that experienced in other seasons. For the 2004 flood, since a full year of data collection was available before the event, the same season in the year prior to event onset was used as the before period enabling us to control for seasonal variation. This method implies that the seasonal variation experienced the year before onset was typical. This is a stronger assumption so whenever possible the second type of analysis will be presented though both methods were undertaken and largely consistent.

[13] Maternal BMI was not included in the NSP system until 2000. Dietary diversity was not included until 1999.

[14] It should be noted that a smaller sample of households were obtained from Shadjadpur (74 out of a usual 350) and Serajdikhan (180 out of a usual 350) during the first lagged period in 1998 (sampling round 51). These two areas were among the most severely affected by this flood. This it likely related to accessibility of this area at this time, and as such the estimates above may be an underestimate of the severity of the problem.

Table 9. 1998 and 2004 individual flood event models[a] – nutrition indicators

		zlen		zwfl		BMI		child dd		Maternal DD	
		coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
1998	event	-0.044		0.009		Not collected in 1998					
	+3m	-0.111		-0.136	0.004						
	+5m	-0.032		-0.125	0.006						
	+7m	-0.119	0.035	-0.164	0.000						
	+9m	-0.023		-0.079							
2004	event	0.033		-0.044		-0.190		-0.212		-0.327	
	+3m	-0.039		-0.061		0.107		-0.269		-0.663	0.013
	+5m	-0.014		-0.037		0.050		0.142		-0.587	
	+7m	-0.029		-0.058		-0.131		-0.776	0.012	-0.744	0.010
	+9m	0.001		-0.049		0.093		0.326		0.240	

Legend: Only statistically significant p-values are indicated (in bold), other non-significant p-values are omitted. Coefficient values highlighted in light red indicate cases for which the DiD test suggests a worsening situation in relation to nutrition, that is, a lower zlen, zwfl, BMI, child dd or maternal DD in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the nutritional situation is statistically significant.

zlen: Length/Height for age z-score; zwfl: weight for Length/Height z-score; BMI: Maternal body mass index; dd: Child dietary diversity; DD: Maternal dietary diversity. The notation +3m; +5m, +7m, and +9m indicate 3-month, 5-month, 7-month and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[a] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

For the 2004 event the three other nutrition indicators (BMI, dd, DD) were also monitored. The DiD test show that the mothers' BMI does not show any statistically significant change. The child dd shows negative correlations immediately after the event and for three and seven-month lagged periods, with the seven-month lagged period being statistically significant (p=0.012). This pattern is even more severe for the mother DD: negative correlation for the period straight after the flood and for the three, five and seven-month lagged periods. The three and seven-months lagged periods are statistically significant, with p=0.013 and p=0.01 respectively.

Food security and food price indicators

For both the 1998 and 2004 flood events, the five food security and food price indicators (FL, FE, PR, PO, PFB) were recorded and could be used for DiD[15]. Results for both events are shown in Table 10. No clear patterns emerge for most of these indicators. For FL (food loan) for instance, while the period following the 1998 event and the following five months were negative (with the three-month lag being statistically significant (p=0.024)), the same indicator over the same periods was positive following the 2004 flood, where the three month and five month periods were statistically highly significant (p=0.014 and p<0.001). Another example of lack of consistency in these indicators is the FE indicator (Food expenditure). While in 1998, the indicator was positive for the seven months following the flood event with the first three periods (i.e. for t=0, 3, 5) highly statistically significant (p=0.037; p<0.001, and p=0.018 respectively), suggesting a significant increase in household expenditures on food (usually a sign of degrading food security condition); the same indicator in 2004 was positive for the three month period and then negative for up to nine months after the flood event[16], with statistically significant negative values for the five month and nine-month lags (p=0.045 and p=0.001).

The only indicator which seems to show a consistent trend is the PFB (price of food basket). Both in 1998 and 2004 this indicator was consistently positive over the nine-month period following the flood events, with statistically significant values for the seven-month lagged period in 1998 and 2004 and for the 9-month lagged period in 1998 (p<0.001; p=0.001, and p=0.04).

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[15] It should be noted that the price indicators (PR, PO, & PFB), are missing from Shahjadpur, the most severely affected upazila in the 1998 flood for the first lagged period after the flood. This is in addition to the smaller sample of households obtained (see footnote 13). As such the estimates above are likely an underestimation of the severity of the impact.

[16] As the 2004 flood was shorter, one could hypothesize that household have moved cash away from just food, to other budget lines, such as replanting/etc. –thus explaining the progressive decrease in the FE coefficient observed after 2 months.

Table 10. 1994 and 2004 individual flood event models[(a)] – food security and food price indicators

		FL		FE		PR		PO		PFB	
		coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
1998	event	-0.203		0.036	0.037	0.561		0.443		0.261	
	+3m	-0.453	0.024	0.072	0.000	0.316		-1.628		0.143	
	+5m	-0.228		0.040	0.018	0.114		-0.574		0.053	
	+7m	0.289		0.002		1.428	0.001	0.916		0.800	0.000
	+9m	0.127		-0.019		0.911	0.004	1.943		0.521	0.001
2004	event	0.522		0.010		-0.050		0.694		0.076	
	+3m	0.526	0.014	0.007		-0.279		-1.143		-0.055	
	+5m	0.814	0.000	-0.024	0.045	0.223		-1.653		0.097	
	+7m	0.031		-0.025		0.453		-1.311		0.222	0.040
	+9m	-0.454	0.046	-0.047	0.001	0.467		0.040		0.222	

Legend: Only statistically significant p-values are indicated (in bold), other non-significant p-values are omitted. Coefficient values highlighted in light red indicate cases for which the test suggests a worsening situation in relation to food security, that is, a higher FL, FE, PR, PO, or PFB in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the food security or food price situation is statistically significant.

FL: food loan; FE: food expenditure; PR: rice price; PO: soybean oil price; PBF: price of food basket. The notation +3m; +5m, +7m, and +9m indicate 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[(a)] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

Table 11. Flood event joint models[(a)] – nutrition indicators

	zlen all		zlen 10 days		zlen 15 days		zlen 20 days		zlen 30 days		zlen 30 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	-0.014		-0.016		-0.001		0.005		0.019		0.030	
+3m	-0.013		-0.019		0.032		-0.005		-0.005		-0.004	
+5m	-0.027		-0.029		-0.013		-0.001		0.008		0.021	
+7m	0.013		-0.018		-0.024		-0.042		-0.055	0.039	-0.042	
+9m	0.001		-0.033		-0.032		-0.023		-0.035		-0.016	

	zwfl all		zwfl 10 days		zwfl 15 days		zwfl 20 days		zwfl 30 days		zwfl 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	-0.028	0.030	-0.044	0.002	-0.066	0.000	-0.042	0.031	-0.057	0.008	-0.061	0.035
+3m	-0.015		-0.018		-0.035		-0.021		-0.061	0.019	-0.057	0.044
+5m	-0.048	0.001	-0.084	0.000	-0.129	0.000	-0.110	0.000	-0.168	0.000	-0.186	0.000
+7m	-0.024		-0.026		-0.053	0.002	-0.014		-0.033		-0.029	
+9m	-0.024		-0.021		-0.011		0.006		-0.017		-0.024	
	BMI all		BMI 10 days		BMI 15 days		BMI 20 days		BMI 30 days		BMI 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	0.018		0.039		0.096		0.078		0.021		-0.004	
+3m	0.039		0.064		0.138	0.030	0.072		0.115		0.113	
+5m	0.000		-0.019		0.024		-0.002		0.032		0.030	
+7m	0.039		0.080		0.091		0.076		-0.020		-0.022	
+9m	-0.017		0.003		0.037		0.059		0.036		0.034	
	Child dd: all		dd: 10 days		dd: 15 days		dd: 20 days		dd: 30 days		dd: 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	-0.118		-0.420	0.000	-0.188		0.424	0.007	0.711	0.000	0.776	0.000
+3m	0.403	0.000	0.149		0.762	0.000	0.687	0.000	0.913	0.000	0.956	0.000
+5m	-0.120		-0.547	0.000	0.310		0.455	0.016	1.255	0.000	1.298	0.000
+7m	-0.042		-0.003		0.137		0.430	0.001	0.495	0.001	0.629	0.000
+9m	-0.119		-0.389	0.005	-0.232		-0.166		-0.284		-0.130	
	DD: all		DD: 10 days		DD: 15 days		DD: 20 days		DD: 30 days		DD: 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	-0.201	0.037	-0.475	0.000	-0.367	0.002	0.141		0.209		-0.043	
+3m	0.218	0.032	-0.014		0.471	0.001	0.288	0.034	0.496	0.008	0.478	0.011
+5m	-0.303	0.014	-0.710	0.000	0.042		0.167		1.075	0.000	1.056	0.000
+7m	-0.129		-0.062		-0.060		0.175		0.315	0.035	0.326	0.048
+9m	-0.066		-0.300	0.030	-0.308		-0.345	0.032	-0.408	0.045	-0.397	

Legend: Only statistically significant p-values are indicated (in bold), other non-statistically p-values are omitted. Coefficient values highlighted in light red indicate cases for which the DiD test suggests a worsening situation in relation to nutrition, that is, a lower zlen, zwfl, BMI, child dd or maternal DD in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the nutritional situation is statistically significant.

zlen: Length/Height for age z-score; zwfl: weight for Length/Height z-score; BMI: Maternal body mass index; dd: Child dietary diversity; DD: Maternal dietary diversity. The notation +2m; +4m, +6m, and +8m refer to 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[a] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

Multiple events models

In addition to the individual-event tests that were run for the two major floods (1998 and 2004), a joint model was also built where the eight flood events that had been identified (cf. Table 6) were pooled together[17] and a series of DiD tests were run involving the 10 food security and nutrition indicators over the four lagged periods. For these tests, flood events were categorized by the number of days the flood level was exceeded. Joint models were fit for floods at or longer than one day, 10 days, 15 days, 20 days, 30 days, and 50 days.

Nutrition indicators

Table 11 shows the results of the flood joint model for the nutrition indicators. Three main points emerge from these tests. First while a relatively large number –but not all- of zlen (stunting) coefficients are negative, none of these negative coefficients are statistically significant (with the exception of the seven-month lagged period under the >30-day flood event). This suggests that although flood could have a negative impact on the rate of stunting of children living in communities affected by flood events, this effect is not severe enough to be statistically significant.

In contrast, the zwfl indicator (wasting) consistently shows negative values for every level of flood severity and for every lag-period. In addition a relatively large number of these coefficients are statistically significant. This is the case in particular of the five-month lagged period which turns out to be highly statistically significant ($p<0.01$) throughout the entire series of test. It is important also to note that all coefficients increase linearly (in absolute value) with the severity of the events. This suggests that flooding has a significant impact on the wasting of children and that this impact increases with the severity of the flood event.

The third result is more surprising. Child dd and maternal DD indicators consistently show positive values for severe flood events (20 days and above) throughout the lagged periods and the vast majority of these values are highly statistically significant ($p<0.01$), suggesting that prolonged flood events are associated with higher dietary diversity for both children and mothers in affected areas. Below the 20-day thresholds (i.e. for less severe flood events) the pattern is more inconsistent with some positive and negative values.

Food security and food price indicators

Table 12 shows the results of the flood joint model for the food security and food price indicators. Several key-points emerge from these tests. First the FL (food loan) indicators systematically show positive signs irrespective of the flood severity and throughout the whole period (0 to 9 months) following the event; and the vast majority of these values are highly statistically significant ($p<0.01$). This suggests that flood has a statistically significant effect on the amount of money that household borrow for food following the event.

Second, the FE (food expenditure) indicator is consistently positive for the first few months following the flood events (up to five months) with most of these values being statistically significant ($p<0.05$), suggesting that the proportion of the household total expenditure spent on food items is higher for households affected by flood. In

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[17] For this model, all upazila were included except for the two upazila without available river station data (Gangni, Meherpur & Atpara, Netrokona).

contrast the value was negative (and statistically significant for a large number of these) for longer lagged periods, suggesting that in the longer-run (seven to nine months) households that had been affected by a flood event spend a lower proportion of their total income on food after the immediate period.

Third, the three food price indicators (PR, PO, and PFB) all demonstrate the same consistent story: they all had positive (and statistically significant p<0.001) values, which indicates that the prices of rice, oil and more generally food baskets are increased by flood, irrespective of the severity of the events, and that this effect lasts for more than nine months after the flood. The coefficient values also indicated an increasing trend from

Table 12. Flood event joint models[(a)] – food security and food price indicators

	FL all		FL10 days		FL15 days		FL20 days		FL30 days		FL50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	0.046		0.307	0.001	0.110		0.088		0.010		0.038	
+3m	0.282	0.000	0.517	0.000	0.344	0.000	0.323	0.000	0.359	0.000	0.375	0.000
+5m	0.209	0.008	0.534	0.000	0.456	0.000	0.361	0.000	0.526	0.000	0.604	0.000
+7m	0.193	0.009	0.296	0.000	0.052		0.097		0.117		0.092	
+9m	0.352	0.000	0.543	0.000	0.308	0.004	0.289	0.010	0.346	0.006	0.362	0.008
	FE all		**FE 10 days**		**FE 15 days**		**FE 20 days**		**FE 30 days**		**FE days**	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	0.037	0.000	0.052	0.000	0.059	0.000	0.035	0.000	0.058	0.000	0.092	0.000
+3m	0.015	0.012	0.030	0.000	0.020	0.036	-0.003		0.029	0.009	0.027	0.021
+5m	-0.001		0.021	0.002	0.017		-0.009		0.014		0.017	
+7m	-0.024	0.000	-0.021	0.000	-0.026	0.000	-0.039	0.000	-0.025	0.016	-0.019	
+9m	-0.006		-0.001		-0.013		-0.033	0.000	-0.022	0.046	-0.012	
	PR all		**PR 10 days**		**PR 15 days**		**PR 20 days**		**PR 30 days**		**PR 50 days**	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	0.032		0.075		0.249	0.023	0.304		0.530	0.006	0.928	0.000
+3m	0.647	0.000	0.968	0.000	1.497	0.000	1.487	0.000	1.613	0.000	1.468	0.000
+5m	1.073	0.000	1.541	0.000	1.979	0.000	1.990	0.000	2.567	0.000	2.351	0.000
+7m	0.588	0.000	1.242	0.000	1.755	0.000	1.675	0.000	1.904	0.000	1.719	0.000
+9m	0.226	0.003	0.597	0.000	1.033	0.000	1.009	0.000	1.266	0.000	1.284	0.000

	PO all		PO 10 days		PO 15 days		PO 20 days		PO 30 days		PO 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	1.897	0.000	3.460	0.000	5.630	0.000	4.906	0.000	7.137	0.000	7.219	0.000
+3m	2.419	0.000	3.752	0.000	7.911	0.000	6.893	0.000	10.059	0.000	9.159	0.000
+5m	2.869	0.000	3.478	0.000	6.638	0.000	5.056	0.000	7.934	0.000	6.985	0.000
+7m	2.498	0.000	3.272	0.000	5.844	0.000	4.057	0.000	5.716	0.000	4.818	0.000
+9m	1.755	0.000	2.129	0.000	3.882	0.000	1.930	0.000	2.443	0.000	2.002	0.000
	PFB all		PFB 10 days		PFB 15 days		PFB 20 days		PFB 30 days		PFB 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	-0.019		-0.023		0.144	0.009	0.157		0.338	0.000	0.533	0.000
+3m	0.383	0.000	0.522	0.000	0.898	0.000	0.888	0.000	1.038	0.000	0.949	0.000
+5m	0.575	0.000	0.753	0.000	1.075	0.000	1.069	0.000	1.550	0.000	1.437	0.000
+7m	0.306	0.000	0.602	0.000	0.891	0.000	0.847	0.000	1.054	0.000	0.955	0.000
+9m	0.161	0.000	0.322	0.000	0.568	0.000	0.532	0.000	0.730	0.000	0.726	0.000

Legend: Only statistically significant p-values are indicated (in bold), other non-statistically p-values are omitted. Coefficient values highlighted in light red indicate cases for which the test suggests a worsening situation in relation to food security, that is, a higher FL, FE, PR, PO, or PFB in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the food security or food price situation is statistically significant.

FL: food loan; FE: food expenditure; PR: rice price; PO: soybean oil price; PBF: price of food basket. The notation +3m; +5m, +7m, and 9m refer to 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[a] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

the less severe to the more severe flood events (for instance from 1.897 to 7.219 for the oil price PO indicator just after the events), suggesting that the more severe the flood, the higher the price peak. The coefficients also suggest that the prices of rice and food baskets are at their highest levels five months after the event, while the price of soybean oil is at its highest level three months after the flood.

3.1.2 Droughts

■ *Individual event analysis*

Three drought events had been identified as adequate for a rigorous DiD protocol: (June 1998, April-May 1999; and February 2003) in four upazilas (see Table 6 above). The food security and nutrition indicators were computed before and after the events for communities that had been affected by the drought events; and the changes in these indicators were compared to the changes in the same indicators for control communities which had not been affected by the droughts. The analysis shows the following results[18].

Table 13. 1998, 1999 and 2003 individual drought event models[(a)] – nutrition indicators

		zlen		zwfl		Maternal BMI		child dd		Maternal DD	
		coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
1998	event	-0.199	0.044	-0.067		Not collected in 1998					
	+3m	-0.261	0.000	0.076							
	+5m	-0.061		0.007							
	+7m	0.116		-0.062							
	+9m	-0.119		-0.146	0.044						
1999	event	-0.062		0.071		No DD data collected in 1998 for comparison no BMI collected in 1999					
	+3m	-0.031		0.177	0.027						
	+5m	-0.032		0.099							
	+7m	-0.101		-0.103							
	+9m	0.041		0.103							
2004	event	0.227	0.015	-0.144	0.047	-0.074		DD not collected in 2002 for comparison			
	+3m	0.232		0.070		0.016					
	+5m	-0.010		-0.132		-0.171					
	+7m	0.077		-0.063		-0.400					
	+9m	Round not completed									

Legend: Only statistically significant p-values are indicated (in bold), other non-statistically p-values are omitted. Coefficient values highlighted in light red indicate cases for which the DiD test suggests a worsening situation in relation to nutrition, that is, a lower zlen, zwfl, BMI, child dd or maternal DD in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the nutritional situation is statistically significant.

zlen: Length/Height for age z-score; zwfl: weight for Length/Height z-score; BMI: Maternal body mass index; dd: Child dietary diversity; DD: Maternal dietary diversity. The notation +3m; +5m, +7m, and +9m refer to 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[(a)] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

[18] Like for the 1998/2004 flood tests above (see footnote 11), there were two methods through which these comparisons were done due to data limitations. For the 1998 drought, as only a few rounds of data collection took place before event onset, this period was selected as the before period compared to the times after the event without controlling for seasonal variation. This method assumes that differences in the early part of 1998 were consistent with that experienced in other seasons. During the 1999 and 2003 events, full year of data collection was available before the event, the same season in the year prior to event onset was used as the before period enabling us to control for seasonal variation. This method implies that the seasonal variation experienced the year before onset was typical. This is a stronger assumption so whenever possible the second type of analysis will be presented though both methods were undertaken and largely consistent.

Nutrition indicators

For nutrition indicators child and maternal dietary diversity indicators (dd and DD) were only collected from 1999 to 2001 and again beginning in 2003. Maternal BMI was collected starting in 2000. DiD tests were therefore completed only for zlen and zwfl indicators for the three individual drought events (Table 13). The analysis does not show any consistent pattern. While zlen was negative in 1998 for almost all the nine months following the drought -two with statistically significant values (the one just during the event p=0.044 and the following one, two months later p<0.0001), these appear to be too soon after the drought to be attributable to the event (as zlen is typically slower to respond). The event in 1999 is also associated

Table 14. 1998, 1999 and 2003 individual drought event models[(a)] – food security and food price indicators

		FL		FE		PR		PO		PBF	
		coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
1998	event	-1.119	0.013	-0.076	0.014	-1.092	0.009	-3.467	0.005	-0.513	0.008
	+3m	-0.143		-0.041		-0.378		-0.550		-0.189	
	+5m	0.238		0.046		-0.892	0.047	4.467	0.000	-0.255	
	+7m	omit		-0.139	0.000	-1.108	0.010	8.467	0.000	-0.752	0.000
	+9m	-0.318		-0.062	0.043	-1.008	0.001	0.317		-0.606	0.000
1999	event	0.180		0.067	0.040	1.370		4.660		0.755	0.030
	+3m	-0.147		-0.015		-0.550		5.240	0.020	-0.093	
	+5m	0.044		0.049		1.025	0.017	-2.240		0.558	0.011
	+7m	0.964	0.000	0.026		0.850		-0.030		0.459	0.045
	+9m	0.780	0.007	-0.114	0.000	-0.140		1.230		-0.205	
2004	event	0.733		-0.025		0.785	0.000	0.301		0.324	0.029
	+3m	1.920	0.003	-0.041		0.733	0.002	1.039		0.266	0.000
	+5m	2.011	0.000	0.067	0.017	1.516	0.000	2.159	0.014	0.691	0.000
	+7m	-1.283	0.013	0.093	0.002	0.522		-0.427		0.193	
	+9m	missing round									

Legend: Only statistically significant p-values are indicated (in bold), other non-significant p-values are omitted. Coefficient values highlighted in light red indicate cases for which the test suggests a worsening situation in relation to food security, that is, a higher FL, FE, PR, PO, or PFB in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the food security or food price situation is statistically significant.

FL: food loan; FE: food expenditure; PR: rice price; PO: soybean oil price; PBF: price of food basket. The notation +3m; +5m, +7m, and +9m refer to 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[(a)] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

with negative values, but none of these were statistically significant. Even more inconsistent, the 2003 drought event generated positive values during the first two periods tested, with one of them being statistically significant (p=0.015).

Similar results are seen with the zwfl indicator. No consistent pattern emerges, with an equal number of statistically significant positive and negative values spread over the nine months period following the three different drought events.

Food security and food price indicators

In terms of food security and food price indicators, the analysis (Table 14) seems to initially confirm the observation made for the nutrition indicators: although some of the values appear to be statistically significant, no coherent 'story' emerges. For instance while the PR and the PBF indicators are consistently positive and significant in 2003 for all of the first three periods following the drought, the opposite is true for the 1998 drought event where the only significant differences are all related to negative values. The 1999 event, however, like the 2003 one, had significant positive differences for PR, PO, and PBF. A review of Fig.8 is useful at this stage, as it reminds us that these three drought events (1998, 1999, and 2003) are not similar in terms of intensity/severity. In particular the 1999 event was by far the most severe drought amongst these three events, followed by the

Table 15. Drought joint-event models[a] – nutrition indicators

	zlen		zwfl		BMI		child dd		Maternal DD	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	-0.047		0.000		-0.051		-0.551		-0.245	
+3m	-0.018		-0.004		-0.141		0.048		0.375	
+5m	-0.106	0.013	-0.047		-0.098		-0.199		0.490	
+7m	-0.005		-0.070	0.044	0.209		0.665	0.017	0.661	0.007
+9m	-0.102	0.013	0.095	0.011	0.072		0.284		0.412	0.020

Legend: Only statistically significant p-values are indicated (in bold), other non-significant p-values are omitted. Coefficient values highlighted in light red indicate cases for which the DiD test suggests a worsening situation in relation to nutrition, that is, a lower zlen, zwfl, BMI, child dd or maternal DD in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the nutritional situation is statistically significant.

zlen: Length/Height for age z-score; zwfl: weight for Length/Height z-score; BMI: Maternal body mass index; dd: Child dietary diversity; DD: Maternal dietary diversity. The notation +3m; +5m, +7m, and +9m refer to 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[a] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

2003 drought. In comparison 1998 was only a moderate drought. On this basis, acute drought events would logically be more likely to be associated with higher prices -as indicated by the positive statistical differences in the 1999 PR, PO, and PBF indicators. The 1999 food security indicators also suggest that severe drought events are likely to be associated with higher food loans seven, and nine months after the drought.

Joint model

For the joint model testing the effect of drought, only the seven upazilas for which we have reliable rainfall data were included in the analysis[19]. There were also too few events to categorize the drought by severity –in comparison to flood events where we were able to categorise the floods by their severity.

Nutrition indicators

The analysis (Table 15) shows that, as far as the nutritional indicators are concerned -similar to the individual-event analysis – no clear overall picture emerges. The zlen indicator seems to suggests that drought has a negative effect on child growth -all the values were negative and two are statistically significant: five and nine months after the event (p=0.013 for both); but the same relationship does not exist for zwfl. For zwfl the sign switched several times between the different lagged periods (positive,

Table 16. Drought event joint models[(a)] – food security and food price indicators

	FL		FE		PR		PO		PFB	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	0.390	0.008	0.009		0.808	0.000	8.595	0.000	0.599	0.000
+3m	0.824	0.000	0.097	0.000	0.749	0.000	4.630	0.000	0.622	0.000
+5m	0.101		0.044	0.000	0.492	0.044	4.462	0.002	0.396	0.005
+7m	-0.047		0.017		0.117		2.035	0.019	0.284	0.008
+9m	0.729	0.000	0.019		0.198		0.731		0.221	0.002

Legend: Only statistically significant p-values are indicated (in bold), other non-significant p-values are omitted. Coefficient values highlighted in light red indicate cases for which the test suggests a worsening situation in relation to food security, that is, a higher FL, FE, PR, PO, or PFB in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the food security or food price situation is statistically significant.

FL: food loan; FE: food expenditure; PR: rice price; PO: soybean oil price; PBF: price of food basket. The notation +3m; +5m, +7m, and +9m refer to 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[(a)] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

[19] These are: Pirganj, Thakurgaon; Naogaon Sadar, Naogaon; Kaunia, Rangpur; Shahjadpur, Sirajganj; Jamalpur Sadar, Jamalpur; Kaliganj, Jhenidah; & Gangni, Meherpur.

negative, and then positive again) with two significant values –one negative at the seven months and one positive at the nine month lag. The coefficients of the maternal BMI and the dietary diversity indexes dd and DD indicator had inconsistent and insignificant values Dietary diversity for mothers and children were negative just after the events, then positive (and even statistically significant) after seven months. This suggests that both children and mother diets were relatively more diversified in communities affected by drought than in the control communities after seven months.

Food security and food price indicators

Table 16 summarizes the results of the joint models for the food security and food price indicators. These indicators are more consistent than the nutrition indicators. They show in particular that communities affected by droughts are systematically facing (statistically) higher food prices (including oil PO, rice PR and generic food basket PFB) than communities non affected by drought, and that the effect lasts for at least 9 months after the event starts. As a consequence the share of the food expense (FE) and the food loan (FL) indicators are also positive and statistically higher for drought-affected communities than for non-affected communities just after the event ($p=0.008$) and in months three and nine for FL ($p<0.001$ for both) and in months three and five after the event for FE ($p<0.001$ for both).

3.1.3. Cyclones

■ *Individual-events*

Four cyclones had been identified for which the conditions for rigorous DiD tests were fulfilled. These are the May 19, 1998; Nov 22, 1998; Oct 28, 2000; and Nov 12, 2002 cyclones (cf. Table 8 above). Table 17 summarizes the results of the DiD tests on nutrition indicators run individually on each of these events[20].

Nutrition indicators

Like for the two other types of events analysed so far (flood and drought) the fact that maternal BMI and DD and child dd were not collected during all the rounds does limit the analysis to zlen and zwfl indicators[21]. None of these two indicators seems however to show any consistency in terms of statistical significant effects.

Food security and food price indicators

The analyses of the potential impact of individual cyclone events on food security and food price indicators are shown in Table 18. The picture that emerges is not necessarily clear. Some indicators behave as expected. For instance the FE indicator (food expenditure) is primarily positive for the cyclones of May 1999, Oct 2000 and Nov 2002, suggesting that households affected by cyclones spend a larger amount of their income on food. This however is not necessarily confirmed by the price indicators (PR, PO, and PFB):

[20] There were two methods through which these comparisons were done due to data limitations. For the May 1998 cyclone, as only a few rounds of data collection took place before event onset, this period was selected as the before period compared to the times after the event without controlling for seasonal variation. This method assumes that differences existing in the early part of 1998 were consistent with that experienced in other seasons. During the later 1998, 2000, and 2002 cyclones, full – or nearly full years- year of data collection was available before the event, the same season in the year prior to event onset was used as the before period enabling us to control for seasonal variation. This method implies that the seasonal variation experienced the year before onset was typical. This is a stronger assumption so whenever possible the second type of analysis will be presented though both methods were undertaken and were found to be largely consistent.

[21] The Oct 2000 cyclone does have data for maternal BMI and DD and child dd but the absence of these information for any of the 3 other cyclone events rules out any comparison, thus limiting greatly the reliability of conclusions that would be drawn from this particular event.

Table 17. Cyclones individual event models[(a)] – nutrition indicators

		zlen		zwfl		Maternal BMI		child dd		Maternal DD	
		coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
May 1998	event	-0.134		0.072		Not collected in 1998					
	+3m	-0.076		0.257	0.000						
	+5m	-0.010		0.081							
	+7m	0.009		0.122							
	+9m	-0.138		0.064							
Nov 1998	event	Round not completed				Not collected in 1998					
	+3m	0.055		-0.021							
	+5m	0.035		-0.016							
	+7m	0.007		0.063							
	+9m	0.153		0.123							
Oct 2000	event	0.155		0.087				1.487	0.002	0.138	
	+3m	-0.012		0.043		-0.058		-0.835	0.042	-0.784	0.012
	+5m	0.050		-0.118		0.191		-1.277	0.004	-1.248	0.002
	+7m	-0.034		-0.085		0.419		-0.441		0.055	
	+9m	0.094		-0.089		0.026		0.390		-0.150	
Nov 2002	event	-0.063		0.042		-0.053					
	+3m	0.139	0.030	-0.004		0.162					
	+5m	0.000		0.068		-0.053					
	+7m	-0.010		-0.054		-0.084					
	+9m	-0.011		0.056		-0.191					

Legend: Only statistically significant p-values are indicated (in bold), other non-significant p-values are omitted. Coefficient values highlighted in light red indicate cases for which the DiD test suggests a worsening situation in relation to nutrition, that is, a lower zlen, zwfl, BMI, child dd or maternal DD in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the nutritional situation is statistically significant.

zlen: Length/Height for age z-score; zwfl: weight for Length/Height z-score; BMI: Maternal body mass index; dd: Child dietary diversity; DD: Maternal dietary diversity. The notation +3m; +5m, +7m, and +9m refer to 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[(a)] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

none show any pattern corroborating that prices were higher following the cyclones events. As far as the FL (food loans) indicator is concerned, some positive and significant differences are observed during the May 1998 event and after the Nov 1998 event but a series of significant negative differences were also observed during and after the Oct 2000 event.

Table 18. Cyclone individual-event models[(a)] – food security and price indicators

		zlen		zwfl		Maternal BMI		child dd		Maternal DD	
		coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
May 1998	event	0.624	0.000	0.054	0.023	0.518	0.034	0.334		0.201	
	+3m	0.313		0.050	0.039	0.144		-0.478		0.031	
	+5m	0.111		0.027		-0.623	0.006	0.816		-0.227	
	+7m	0.090		0.074	0.001	-1.518	0.000	-2.666	0.000	-0.619	0.000
	+9m	0.077		0.099	0.001	-0.891	0.000	-1.825	0.007	-0.298	0.014
Nov 1998	event	Missing Round									
	+3m	-0.114		-0.102	0.000	-0.114		-0.098	0.020	-0.102	0.000
	+5m	0.192		-0.062	0.006	0.192		-0.037		-0.062	0.006
	+7m	0.107		-0.014		0.107		-0.069		-0.014	
	+9m	0.450	0.004	0.015		0.450	0.004	0.064		0.015	
Oct 2000	event	-0.517	0.031	0.030		0.814	0.019	0.605		0.357	0.011
	+3m	-0.687	0.000	0.055	0.003	-0.558		-0.375		-0.275	
	+5m	-0.764	0.000	0.057	0.001	-0.305		-4.564		-0.346	
	+7m	-0.115		0.078	0.000	0.632	0.003	-0.759		0.124	
	+9m	-0.514	0.019	0.078	0.000	-0.100		1.173		-0.117	
Nov 2002	event	-0.051		0.038	0.022	-0.495		-1.360		-0.276	
	+3m	0.163		-0.007		0.075		-1.190		-0.170	
	+5m	0.552	0.007	-0.009		0.429		-1.447		-0.066	
	+7m	0.209		0.034	0.039	-0.055		-2.207		-0.233	
	+9m	-0.726	0.001	0.035	0.033	0.024		-2.060		-0.212	

Legend: Only statistically significant p-values are indicated (in bold), other non-significant p-values are omitted. Coefficient values highlighted in light red indicate cases for which the test suggests a worsening situation in relation to food security, that is, a higher FL, FE, PR, PO, or PFB in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the food security or food price situation is statistically significant.

FL: food loan; FE: food expenditure; PR: rice price; PO: soybean oil price; PBF: price of food basket. The notation +3m; +5m, +7m, and +9m refer to 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[(a)] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

Multiple events model

In the joint model, cyclones were categorized by the portion of the upazilas that appear to be within the path of the storm, using three levels (not affected at all, 50% or more of the upazilas affected, 75% or more affected) and by the maximum wind speed of the event (upazilas affected by wind stronger than 40 m/s). For each of these categories, test were conducted for the five nutrition and the five food security and food price indicators and for the period directly following the event and four lagged time periods (i.e. up to nine months after the event).

Nutrition indicators

Table 19 displays the results of the joint model tests for the nutrition indicators. The zlen (stunting) indicators have a consistent pattern but not in the direction expected. Zlen is positive for all the lagged periods between three and nine months (irrespective of the severity of the events), most of the coefficients being statistically significant, thus suggesting that children living in communities affected by cyclones have lower levels of stunting than children living in non-affected communities.

Table 19. Cyclone event joint models[(a)] – nutrition indicators

	zlen all events		zlen 50%		zlen 75%		zlen wind 40+	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	-0.012		-0.026		-0.033		-0.002	
+3m	0.050	0.027	0.060	0.031	0.051		0.042	
+5m	0.052	0.024	0.036		0.049		0.059	0.027
+7m	0.062	0.007	0.058	0.027	0.078	0.005	0.064	0.008
+9m	0.015		0.063	0.030	0.071	0.023	0.002	
	zwfl all		**zwfl 50%**		**zwfl 75%**		**zwfl wind 40+**	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	-0.055	0.010	-0.036		-0.042		-0.067	0.005
+3m	0.025		0.017		0.000		-0.006	
+5m	-0.051	0.009	-0.063	0.007	-0.100	0.000	-0.089	0.000
+7m	-0.048	0.015	-0.055	0.022	-0.062	0.018	-0.045	0.043
+9m	-0.015		-0.029		-0.025		0.015	

	BMI all		BMI 50%		BMI 75%		BMI wind 40+	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	-0.063		-0.062		-0.080		-0.172	0.019
+3m	0.084		0.096		0.141		0.098	
+5m	-0.046		-0.054		-0.015		0.022	
+7m	-0.018		0.012		0.054		0.094	
+9m	-0.060		-0.030		0.018		0.010	

	Child dd all		Child dd 50%		Child dd 75%		Child dd wind 40+	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	0.791	0.008	0.790	0.007	1.664	0.000	Missing Rd	
+3m	0.824	0.000	1.073	0.000	1.157	0.000	0.674	0.000
+5m	-0.060		0.014		-0.018		0.078	
+7m	-0.294	0.035	-0.375	0.016	-0.337		-0.054	
+9m	0.427	0.012	0.605	0.004	0.694	0.003	0.662	0.000

	DD all		DD 50%		DD 75%		DD wind 40+	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	0.822	0.001	0.818	0.001	1.744	0.000	Missing Rd	
+3m	0.601	0.000	0.763	0.000	0.804	0.000	0.508	0.000
+5m	-0.129		-0.173		-0.259		-0.040	
+7m	-0.386	0.004	-0.556	0.000	-0.586	0.000	-0.249	
+9m	0.408	0.006	0.503	0.005	0.628	0.001	0.439	0.008

Legend: Only statistically significant p-values are indicated (in bold), other non-significant p-values are omitted. Coefficient values highlighted in light red indicate cases for which the DiD test suggests a worsening situation in relation to nutrition, that is, a lower zl, zw, BMI, child dd or maternal DD in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the nutritional situation is statistically significant.

zlen: Length/Height for age z-score; zwfl: weight for Length/Height z-score; BMI: Maternal body mass index; dd: Child dietary diversity; DD: Maternal dietary diversity. The notation +3m; +5m, +7m, and +9m refer to 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[a] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

In contrast the zwfl (wasting) indicators were consistently negative (most statistically significant) for lagged periods directly after the events until five and seven months afte[22]. It is also interesting to notice that for the five and seven-month lagged periods, the zwfl coefficients increase in absolute value progressively with the degree of severity of the events (from 'all events' to 'impact 75%'). For the severe events (wind > 40 m/s) the impact was negative and statistically significant just after the event and for five and seven months after periods. Overall the lowest coefficients are observed around the five-month lagged periods irrespective of the severity of the event.

Table 20. Cyclone event joint models[(a)] – food security and food price indicators

	FL all		FL 50%		FL 75%		FL wind 40+	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	0.040		0.059		0.138		0.251	0.000
+3m	0.111		0.080		0.005		0.205	0.005
+5m	-0.006		-0.052		-0.080		0.088	
+7m	0.149		0.150		0.169		0.302	0.001
+9m	0.073		0.134		0.082		0.160	0.043
	FE all		**FE 50%**		**FE 75%**		**FE wind 40+**	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	-0.045	0.000	-0.052	0.000	-0.039	0.000	-0.041	0.000
+3m	-0.031	0.000	-0.040	0.000	-0.040	0.000	-0.022	0.027
+5m	-0.026	0.004	-0.027	0.006	-0.032	0.002	-0.033	0.002
+7m	-0.001		-0.018		-0.020		0.002	
+9m	0.010		-0.010		-0.009		0.008	
	PR all		**PR 50%**		**PR 75%**		**PR wind 40+**	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	0.709	0.000	0.279	0.044	0.666	0.000	1.281	0.000
+3m	0.738	0.000	0.397	0.007	0.654	0.000	1.326	0.000
+5m	0.118		-0.154		0.072		0.920	0.000
+7m	-0.129		-0.249		-0.212		0.361	0.000
+9m	-0.309	0.000	-0.551	0.000	-0.461	0.000	-0.056	0.542

[22] Furthermore this relationship persists even after the zlen variable is added to the model (results not shown).

	PO all		PO 50%		PO 75%		PO wind 40+	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	5.247	0.000	3.761	0.000	6.753	0.000	9.434	0.000
+3m	3.690	0.000	2.356	0.006	4.431	0.000	7.441	0.000
+5m	2.267	0.001	0.949		2.264	0.012	5.525	0.000
+7m	0.111		-0.801		0.302		2.975	0.000
+9m	-1.443	0.004	-2.369	0.000	-0.952		1.111	0.008
	PFB all		**PFB 50%**		**PFB 75%**		**PFB wind 40+**	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value
event	0.433	0.000	0.193	0.014	0.419	0.000	0.748	0.000
+3m	0.372	0.000	0.183	0.017	0.323	0.000	0.682	0.000
+5m	0.122		-0.046		0.080		0.555	0.000
+7m	-0.016		-0.133		-0.081		0.313	0.000
+9m	-0.234	0.000	-0.411	0.000	-0.335	0.000	-0.027	

Legend: Only statistically significant p-values are indicated (in bold), other non-significant p-values are omitted. Coefficient values highlighted in light red indicate cases for which the test suggests a worsening situation in relation to food security, that is, a higher FL, FE, PR, PO, or PFB in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the food security or food price situation is statistically significant.

FL: food loan; FE: food expenditure; PR: rice price; PO: soybean oil price; PBF: price of food basket. The notation +3m; +5m, +7m, and +9m refer to 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'event' refers to the period during or just after the event.

[a] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

There is no statistically significant impact of cyclone on maternal BMI except for immediately after the most severe event. The maternal DD and child dd show very similar patterns: the period directly following the events and the three-month lagged period was positively related to the event, suggesting that the dietary diversity of both children and mothers in communities that have been affected by cyclones are higher than in communities that have not been affected by cyclones. After, it appears that mothers and children consume less diverse diets for two periods (statistically significant for 7 month lag), before finally settling back to more diverse again during the nine-month lagged period. The reason for this difference could be related to the seasons in which cyclones most often occur and possibly the variation in the seasonal accessibility/abundance of certain food items such as fish.

Food security and food price indicators

Table 20 displays the food security and food price indicators estimated for the cyclone joint models. All three price indicators (PR, PO, and PFB) were consistent: all signs are positive over the period directly following the cyclone and during the next two months and most of these values are statistically significant. Note also that the values of the coefficients tend to increase with the severity of cyclones. For very severe events (windspeed>40m/s) the food price coefficients remain all highly significant for more than seven months. For lower intensity events, however, the values of the coefficients tend to decrease relatively rapidly suggesting that for these lower intensity cyclones, prices return to more normal levels more rapidly.

The food loan (FL) indicator also had a consistent pattern suggesting that households did engage in loan taking for food. The coefficients increase with the severity of the event, to the extent that for severe events characterized by wind-speed greater than 40 m/s, all the coefficients are positive and statistically significant over all periods except the five-month lagged period.

The FE (food expenditure) is consistently negative and statistically significant for the first five months after the cyclones and this pattern is observed irrespective of the level of intensity, suggesting that households do not spend more of their budget on food after cyclones –instead it seems they spend even less than communities that are not-affected by these cyclones for the same period[23].

3.1.4. Salinity

Difference in Mean test

For salinity, because the slow onset nature of the process implies that the DiD approach cannot be applied, a difference in means (DiM) approach was applied whereby the food security and nutritional indicators of communities living in the affected areas were compared to the same indicators estimated for communities living outside the affected area. For this DiM test all upazilas were included, either as affected – treatment- or as control, depending on the location of the communities. For affected areas, upazilas were further categorized by their salinity levels as estimated in 2009 (SRDI 2012) using 5 categories (s1=2.0-4.0 dS/m; s2=4.1-8.0 dS/m; s3=8.1-12.0 dS/m; s4=12.1-16.0 dS/m; and s5: >16.0 dS/m)[24] and the proportion of the upazila area affected by a given salinity level (Table 21). The year was controlled for as a series of dichotomous variables[25]. In contrast to the DiD models above, DiM is not a causal model. Results, therefore, only show an association between salinity and the outcome variable, not an impact.

[23] Possible explanations for this pattern are provided later in this report.

[24] Because the number of communities where the salinity concentration was above 16.0 dS/m was too small to have any statistical power, these communities were merged with the S4 category.

[25] The model was also run to account for a potential interaction effect between year and salinity. The hypothesis was that the saline should have a larger detrimental effect as time went on (reflecting the observation made on Fig.5d). These results are largely not consistent with this hypothesis.

Table 21. List of areas affected by salinity intrusion – Source: SRDI 2012

Area	% of upazila area with salinity within the range s1 – s5 in 2009				
	s1	s2	s3	s4	s5
Cox's Bazar Sadar, Cox's Bazar;	0%	3%	8%	16%	5%
Fakirhat, Bagerhat;	20%	18%	13%	7%	2%
Debhata, Satkhira;	14%	17%	19%	16%	12%
Patharghata, Barguna;	17%	21%	10%	6%	4%
Lalmohan, Bhola;	24%	9%	1%	1%	1%
Rajapur, Jhalakathi;	2%	1%	0%	0%	0%
Patuakhali Sadar, Patuakhali;	33%	20%	8%	0%	0%

s1 = 2.0-4.0 dS/m; s2 = 4.1-8.0 dS/m; s3 = 8.1-12.0 dS/m; s4 = 12.1-16.0 dS/m; s5 >16.0 dS/m

Areas included in the NSP system which did not have a salinity problem include: Sreepur, Gazipur; Jamalpur Sadar, Jamalpur; Serajdikhan, Munshigonj; Atpara, Netrokona; Nabinagar, Brammonbaria; Hathazari, Chittagong; Chouddagram, Comilla; Naogaon Sadar, Naogaon; Kaunia, Rangpur; Shahjadpur, Sirajganj; Pirganj, Thakurgaon; Kaliganj, Jhenidah; Gangni, Meherpur; Habiganj Sadar, Habiganj; Sreemangal, Moulavi Bazar; Jamalganj, Sunamganj; Fenchuganj, Sylhet

Nutrition indicators

Table 22 displays the results of the DiM test for the nutrition indicators. Irrespective of the level of salinization s1, s2, s3 or s4, the zwfl (wasting) indicators were negative and statistically significant (all p<0.001), indicating that living in areas affected by saline intrusion is associated with higher levels of wasting among children. The zlen (stunting) had a similar pattern although the negative effect is not observed at the lowest salinity levels. The BMI results were not consistent: all the coefficients were significant but either positive or negative without clear trend or 'logic'.

The two dietary diversity indicators (for both child and mother) are also indicated strong statistically positive values[26] and most of them are significant for the child dd, suggesting that, for these children, living in a saline area is associated with greater dietary diversity than living in a non-saline area.

Food security and food price indicators

Table 23 displays the results of the DiM tests for the food security and food price indicators. Most of the indicators are consistent. All the FL (food loan) coefficients are positive and significant, suggesting that living in saline-affected areas was associated with taking more loans. Likewise the FE (food expenditure) indicator is also consistently positive and statistically significant across

[26] With the exception of maternal DD in the category saline_20_s1.

Table 22. Salinity tests[a] – nutrition indicators.

		zlen		zwfl		BMI		child dd		Maternal DD	
		coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
saline_all		-0.680	0.000	-0.237	0.000	-0.572	0.000	3.411	0.000	1.464	0.000
saline 20%	s1	-0.037		-0.219	0.000	0.324	0.000	3.345	0.000	-0.034	
	s2	0.278	0.000	-0.164	0.000	0.327	0.000	3.345	0.000	0.065	
	s3	-0.365	0.000	-0.158	0.000	0.327	0.000	3.300	0.000	0.065	
	s4	-0.369	0.000	-0.042		-0.570	0.000	0.230		1.563	0.000
saline 40%	s1	0.278	0.000	-0.116	0.000	0.327	0.000	3.300	0.000	0.065	
	s2	-0.365	0.000	-0.158	0.000	0.327	0.000	3.345	0.000	0.065	
	s3	N/A (only one upazila – Debhata had salinity levels above 40% in s3+ and no upazila were more than 40% s4+ saline)									
	s4										

Legend: Only statistically significant p-values are indicated (in bold), other non-statistically p-values are omitted. Coefficient values highlighted in light red indicate cases for which the DiM test suggests a worsening situation in relation to nutrition, that is, a lower zlen, zwfl, BMI, child dd or maternal DD in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the nutritional situation is statistically significant.

zlen: Length/Height for age z-score; zwfl: weight for Length/Height z-score; BMI: Maternal body mass index; dd: Child dietary diversity; DD: Maternal dietary diversity. saline_all include all the upazilas affected by saline intrusion, irrespective of the level of saline concentration. Saline 20% refers to upazilas where 20% or more of the area is affected. Saline 40% refers to upazilas where 40% or more of the area is affected. s1=2.0-4.0 dS/m; s2=4.1-8.0 dS/m; s3=8.1-12.0 dS/m; and s4>12.1.

[a] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

the whole range of salinity intensity, indicating an association between a higher proportion of income spent on food and living in a saline area. The pattern for the food price indicators is slightly more complex. First the PR indicator displays statistically positive coefficients across the whole range of salinity intensity, suggesting that the price of rice is positively associated with saline intrusion. Higher cooking oil prices (PO) were also associated with saline areas but only for the lower salinity conditions. Finally, the price of the food basket (PFB) is inconsistent. The only strongly significant values are positive and observed for saline_40_s1 and saline_40_s2, which would suggest that for the communities that are affected by high levels of salinity intrusion, food prices are actually lower than for non-affected communities.

Table 23. Salinity tests[(a)] – food security and food price indicators

		FL		FE		PR		PO		PFB	
		coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
saline_all		0.629	0.000	0.054	0.000	0.112	0.000	2.053	0.000	0.149	
saline 20%	s1	0.288	0.000	0.054	0.000	0.112	0.000	0.463	0.000	-0.541	
	s2	0.259	0.000	0.123	0.000	0.011	0.037	2.053	0.000	0.149	
	s3	0.305	0.000	0.158	0.000	0.011	0.037	-0.898	0.000	-0.627	
	s4	0.328	0.000	0.352	0.000	0.222	0.000	-0.587	0.000	-2.379	0.000
saline 40%	s1	0.603	0.000	0.123	0.000	0.011	0.037	0.397	0.000	-1.867	0.000
	s2	0.748	0.000	0.158	0.000	0.011	0.037	0.397	0.000	-1.867	0.000
	s3	N/A									
	s4										

Legend: Only statistically significant p-values are indicated (in bold), other non-statistically p-values are omitted. Coefficient values highlighted in light red indicate cases for which the DiM test suggests a worsening situation in relation to food security, that is, a higher FL, FE, PR, PO, or PFB in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the food security or food price situation is statistically significant.

FL: food loan; FE: food expenditure; PR: rice price; PO: soybean oil price; PBF: price of food basket. saline_all include all the upazilas affected by saline intrusion, irrespective of the level of saline concentration. Saline 20% refers to upazilas where 20% or more of the area is affected. Saline 40% refers to upazilas where 40% or more of the area is affected. s1=2.0-4.0 dS/m; s2=4.1-8.0 dS/m; s3=8.1-12.0 dS/m; and s4>12.1.

[(a)] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

3.1.5 Combined models

In addition to individual-event tests and joint-event models two combined models were run. These include two combinations of different events: (i) drought and flood together and (ii) cyclone, salinity and flood together. The rationale for these models is that differences in food security and nutrition of communities that are affected by repeated events of different types, are confounded by other events in the same area. By including all events we will be better able to disentangle the varying impacts of each type of event. In these models all the events that affected a particular upazila were pooled together. For drought and flood it means that only the six upazila for which we located reliable rainfall data and river data were included. These are indicated in Table 24. For cyclone, salinity and flood, all upazila were included except for the two upazila without available river station data (Table 24). These different sites and their locations are indicated on Fig.11.

Table 24. Upazilas included in the two types of combined models

	Events	Area
Drought-flood	Drought event & Flood event	Naogaon Sadar
	Drought event & Flood event	Shahjadpur
	Drought event & Flood event	Pirganj
	Drought event & No flood	Kaunia
	No drought & Flood event	Jamalpur Sadar
	No drought & No flood	Kaliganj
Salinity-cyclone-flood	Cyclone event, Flood event, & Not saline	Serajdikhan
	Cyclone event, Flood event, & Not saline	Shahjadpur
	Cyclone event, No flood, & Not saline	Hathazari
	Cyclone event, No flood, & Not saline	Kaliganj
	Cyclone event, No flood, & Saline areas	Cox's Bazar Sadar
	Cyclone event, No flood, & Saline areas	Fakirhat
	Cyclone event, No flood, & Saline areas	Debhata
	Cyclone event, No flood, & Saline areas	Patharghata
	Cyclone event, No flood, & Saline areas	Lalmohan
	Cyclone event, No flood, & Saline areas	Rajapur
	Cyclone event, No flood, & Saline areas	Patuakhali Sadar
	No cyclone, Flood event, & Not saline	Sreepur
	No cyclone, Flood event, & Not saline	Jamalpur Sadar
	No cyclone, Flood event, & Not saline	Nabinagar
	No cyclone, Flood event, & Not saline	Naogaon Sadar
	No cyclone, Flood event, & Not saline	Pirganj
	No cyclone, Flood event, & Not saline	Fenchuganj
	No cyclone, No flood, & Not saline	Chouddagram
	No cyclone, No flood, & Not saline	Kaunia
	No cyclone, No flood, & Not saline	Habiganj Sadar
	No cyclone, No flood, & Not saline	Sreemangal
	No cyclone, No flood, & Not saline	Jamalganj

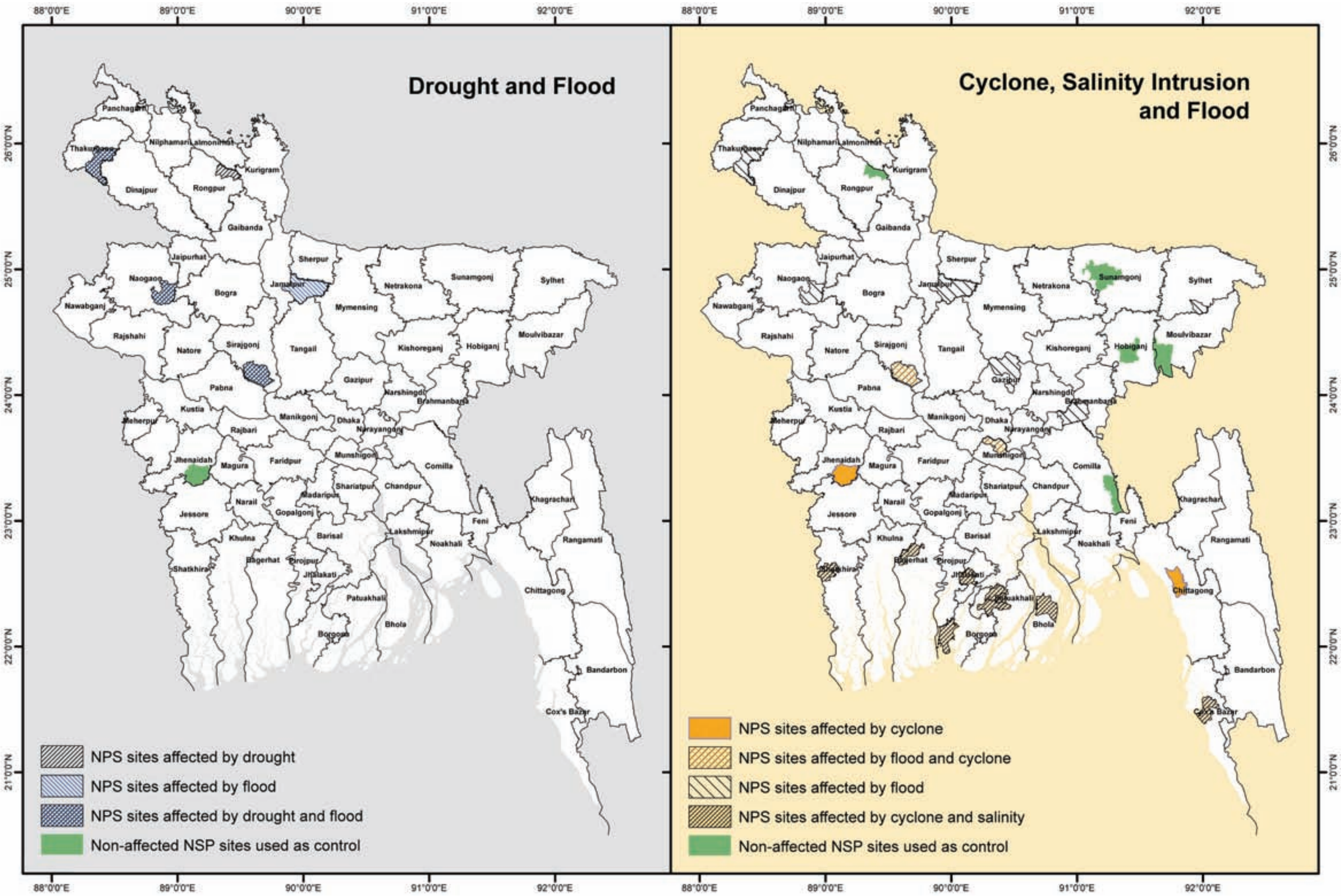

Fig.11. NSP sites used as treatment (affected) or control (non-affected) for combined models

■ *Drought and flood combined model*

As for the joint model, different flood severity were considered in this combined model (floods of or longer than one day, 10 days, 15 days, 20 days, 30 days, and 50 days).

Nutrition indicators

Table 25 displays the results of the DiD tests for the nutrition indicators. The effect of flood events on these nutrition indicators was mixed. In particular while the relationship in the months directly following the flood were by positive values in the zlen (stunting) indicator, the values of the coefficients decline rapidly over time and become negative around five to seven months –see for instance the coefficients of the zlen_30_days test, which passes from 0.074 at the period directly after the event down to -0.067 after nine-month-, suggesting a slow degradation of the stunting situation in these communities, compared to the non-affected communities. This degradation does not lead to any statistically significant level however.

The impact of flood events on the zwfl (wasting) indicators shows a clearer pattern: the difference was either negative or became negative after three to five months. In fact the five-month lagged period had the lowest coefficient values and these are all statistically significant ($p<0.001$ for the five tests: zlen_all to zlen_50 days). Values remained negative after this 5-month period and were statistically significant for the events of lower intensity. This pattern is in line with what had been observed with the joint models and the individual-events tests.

Drought events seem to have negative effects on both zwfl and zlen. For the zlen (stunting) indicators the effect appear to be lagged and was significant at five and nine month lags, while for the zwfl (wasting) indicator the drought effect begins immediately and lasts for up to seven months where it reaches a level of statistical significance for the events longer than 15 days. The strong positive effect of drought on zwfl at nine months is difficult to explain, but it could be due to a reduction in illness such as diarrhoea[27].

The results also indicate that drought seems to have little effect on maternal BMI. A negative trend starts just after the event, and lasts up to five months, but none of the values are statistically significant. There is in contrary some evidence of positive (and significant) effect for medium flood events (15 and 20 days) on BMI, but the statistical significance is not maintained across models and is therefore difficult to interpret.

Both child and maternal dd show statistically significant positive values with strong flood events (20 days and above) which start straight after the event and last up to 7 months. Here again these are quite difficult to interpret at first sight. They suggest that the level of dietary diversity for both children and mothers are statistically higher in communities that are affected by flood than in non-affected communities. This is in agreement with the results that were showed in the joint-events models.

For drought some initial negative values in both children and maternal dd can be observed just after the events but these are not significant. Instead some positive and significant values are recorded around seven to nine months, especially once only severe flood events are controlled for.

Food security and price food indicators

Table 26 displays the results of the DiD tests for the food security and food price indicators. The overall trend is relatively clear: for FL (food loan), and the three price indicators (rice, oil and food basket price indicators, PO, PR and PBF) the occurrence of drought or flood results in higher prices and a greater number of food loans, generally starting either just after the event or at the latest two months after. Most of these trends are statistically significant and remain so for up to the nine month-lag period. However, coefficients decrease as time passes

[27] Overall events the prevalence of diarhoea decreased in the period in which a drought began as well as in L1, L2, and L4. This held true in both the individual and combined drought models.

by. This trend is clear in particular in the case of the PO indicator (see e.g. the coefficient values decreasing from 6.224 to 1.052 or from 9.218 to 1.303 between the time of the event and the nine-month lagged period for PO 30 days under flood and drought respectively). For food loan (FL) the coefficient increases with the severity of the flood in particular around five month after the event (see for instance the coefficient values that increase from 0.139 to 1.037 for the five-month lag period), while for drought the overall trend is positive across the whole series of tests, with statistically significant values observed for all cases just after the event and at the three-month lagged period.

For FE (food expenditure), the trend is similar to the other indicators discussed just above (i.e. broadly positive coefficients) although not as strong especially in the case of flood where the effect stops to be significant after 5 months. It is however still possible to observe an increase in the coefficients for the period just after the event: the longer the flood the higher the FE coefficient, suggesting that after a flood event households' food expenditures not only increases but are also influenced by the severity (length) of the flood.

Table 25. Flood drought combined models[a] – nutrition indicators

	zlen all		zlen 10 days		zlen 15 days		zlen 20 days		zlen 30 days		zlen 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
flood event	0.019		0.016		0.021		0.045		0.074		0.074	
+3m	0.037		0.044		0.103	0.002	0.075	0.045	0.040		0.063	
+5m	0.008		0.013		0.000		0.000		-0.008		0.025	
+7m	0.028		0.011		-0.010		-0.003		-0.038		0.000	
+9m	0.013		-0.035		-0.032		-0.034		-0.067		-0.027	
drought event	-0.046		-0.037		-0.035		-0.034		-0.047		-0.044	
+3m	-0.015		-0.017		-0.014		-0.010		-0.014		-0.012	
+5m	-0.111	0.011	-0.114	0.010	-0.101	0.019	-0.097	0.024	-0.103	0.017	-0.100	0.020
+7m	-0.009		-0.015		-0.030		0.001		-0.005		0.000	
+9m	-0.103	0.012	-0.106	0.010	-0.102	0.014	-0.101	0.015	-0.105	0.011	-0.099	0.016

	zwfl all		zwfl 10 days		zwfl 15 days		zwfl 20 days		zwfl 30 days		zwfl 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
flood event	-0.009		-0.020		-0.010		0.042		0.023		0.040	
+3m	-0.024		-0.034		-0.010		0.012		-0.007		0.014	
+5m	-0.113	0.000	-0.138	0.000	-0.178	0.000	-0.104	0.000	-0.128	0.000	-0.140	0.000
+7m	-0.039	0.032	-0.039		-0.058	0.012	-0.012		-0.035		-0.027	
+9m	-0.047	0.012	-0.057	0.006	-0.031		-0.001		-0.029		-0.037	
drought event	0.002		0.004		-0.002		-0.001		-0.004		-0.004	
+3m	-0.012		-0.011		-0.013		-0.003		-0.007		-0.006	
+5m	-0.056		-0.053		-0.063		-0.051		-0.054		-0.052	
+7m	-0.061		-0.054		-0.093	0.008	-0.079	0.025	-0.080	0.022	-0.078	0.025
+9m	0.114	0.002	0.121	0.001	0.123	0.000	0.088	0.020	0.087	0.022	0.088	0.020

	BMI all		BMI 10 days		BMI 15 days		BMI 20 days		BMI 30 days		BMI 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
flood event	0.052		0.056		0.118		0.154	0.040	0.019		0.017	
+3m	0.080		0.087		0.212	0.008	0.223	0.005	0.142		0.141	
+5m	0.047		0.037		0.067		0.092		0.021		0.020	
+7m	0.044		0.067		0.084		0.091		-0.044		-0.044	
+9m	0.036		-0.005		0.035		0.112		-0.009		-0.009	
drought event	-0.054		-0.022		-0.027		-0.084		-0.046		-0.046	
+3m	-0.115		-0.117		-0.087		-0.076		-0.135		-0.135	
+5m	-0.117		-0.123		-0.146		-0.015		-0.092		-0.092	
+7m	0.170		0.162		0.077		0.302		0.223		0.223	
+9m	0.062		0.057		0.078		0.107		0.072		0.072	

	Child dd: all		dd: 10 days		dd: 15 days		dd: 20 days		dd: 30 days		dd: 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
flood event	0.439	0.001	0.063		0.294		0.935	0.000	1.240	0.000	1.215	0.000
+3m	0.270		-0.012		0.822	0.000	0.820	0.000	1.028	0.000	1.083	0.000
+5m	0.348	0.031	0.028		0.842	0.000	0.970	0.000	1.433	0.000	1.488	0.000
+7m	0.151		0.078		0.339	0.021	0.705	0.000	0.545	0.001	0.686	0.000
+9m	-0.102		-0.203		-0.040		0.445	0.012	0.278		0.540	0.005
drought event	-0.480		-0.496		-0.451		-0.538		-0.405		-0.387	
+3m	0.012		0.033		0.082		0.275		0.257		0.252	
+5m	-0.324		-0.217		-0.126		0.070		0.031		0.034	
+7m	0.616	0.031	0.668	0.016	0.591	0.031	0.898	0.001	0.860	0.002	0.873	0.002
+9m	0.225		0.255		0.171		0.490	0.014	0.441	0.026	0.455	0.023

	DD: all		DD: 10 days		DD: 15 days		DD: 20 days		DD: 30 days		DD: 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
flood event	0.153		-0.172		0.000		0.596	0.000	0.498	0.001	0.332	
+3m	0.145		-0.058		0.767	0.000	0.665	0.000	0.713	0.000	0.709	0.000
+5m	0.335	0.022	0.093		0.864	0.000	0.892	0.000	1.278	0.000	1.275	0.000
+7m	0.228		0.254	0.043	0.421	0.002	0.757	0.000	0.612	0.000	0.643	0.000
+9m	-0.087		-0.030		0.140		0.465	0.004	0.249		0.298	
drought event	-0.185		-0.227		-0.193		-0.260		-0.129		-0.133	
+3m	0.384		0.421		0.479		0.562		0.511		0.494	
+5m	0.456		0.565		0.660	0.043	0.715	0.025	0.647	0.043	0.634	0.048
+7m	0.628	0.013	0.676	0.007	0.595	0.012	0.874	0.001	0.820	0.001	0.814	0.001
+9m	0.334		0.357	0.046	0.305		0.611	0.001	0.549	0.003	0.541	0.003

Legend: Only statistically significant p-values are indicated (in bold), other non-significant p-values are omitted. Coefficient values highlighted in light red indicate cases for which the DiD test suggests a worsening situation in relation to nutrition, that is, a lower zlen, zwfl, BMI, child dd or maternal DD in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the nutritional situation is statistically significant.

zlen: Length/Height for age z-score; zwfl: weight for Length/Height z-score; BMI: Maternal body mass index; dd: Child dietary diversity; DD: Maternal dietary diversity. The notation +3m; +5m, +7m, and +9m refer to 3-month, 5-month, 7-month, and 9-month lagged periods respectively, while 'drought event' and 'flood event' refer to the period during or just after the event.

[(a)] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

Table 26. Flood drought combined models[(a)] – food security and food price indicators

	FL all		FL 10 days		FL 15 days		FL 20 days		FL 30 days		FL 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
flood event	-0.103		0.047		-0.108		0.167		0.068		0.250	
+3m	-0.158		-0.087		-0.312	0.017	0.055		0.358	0.016	0.362	0.038
+5m	0.139		0.268	0.022	0.169		0.456	0.002	0.895	0.000	1.037	0.000
+7m	-0.021		0.139		-0.305	0.015	-0.138		-0.007		-0.113	
+9m	0.021		0.175		-0.253		0.096		0.452	0.031	0.488	0.044
drought event	0.375	0.013	0.365	0.017	0.431	0.005	0.386	0.014	0.445	0.003	0.454	0.003
+3m	0.827	0.000	0.823	0.000	0.813	0.000	0.852	0.000	0.871	0.000	0.881	0.000
+5m	0.145		0.129		0.068		0.133		0.171		0.174	
+7m	-0.037		-0.051		0.024		0.015		0.069		0.076	
+9m	0.705	0.000	0.669	0.000	0.644	0.000	0.748	0.000	0.779	0.000	0.780	0.000

	FE all		FE 10 days		FE 15 days		FE 20 days		FE 30 days		FE 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
flood event	0.028	0.001	0.042	0.000	0.068	0.000	0.043	0.000	0.081	0.000	0.133	0.000
+3m	-0.016		-0.007		-0.022		-0.053	0.001	0.007		0.006	
+5m	0.006		0.017	0.043	0.023		-0.008		0.044	0.002	0.057	0.000
+7m	-0.012		-0.001		-0.009		-0.024	0.012	0.007		0.020	
+9m	-0.014		-0.002		-0.009		-0.031	0.002	-0.003		0.020	
drought event	0.014		0.013		0.016		0.017		0.013		0.016	
+3m	0.093	0.000	0.092	0.000	0.087	0.000	0.096	0.000	0.103	0.000	0.105	0.000
+5m	0.040	0.001	0.038	0.001	0.027	0.014	0.041	0.001	0.051	0.000	0.052	0.000
+7m	0.020		0.018		0.025	0.046	0.012		0.022		0.024	
+9m	0.019		0.017		0.014		0.015		0.023	0.037	0.025	0.023

	PR all		PR 10 days		PR 15 days		PR 20 days		PR 30 days		PR 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
flood event	-0.157		-0.366	0.004	-0.382	0.008	-0.444	0.009	0.000		-0.508	0.003
+3m	0.477	0.000	0.640	0.000	0.725	0.000	0.583	0.002	0.862	0.000	0.320	
+5m	0.680	0.000	0.906	0.000	1.073	0.000	1.024	0.000	1.641	0.000	0.954	0.004
+7m	0.281	0.011	0.554	0.000	0.608	0.000	0.584	0.001	1.132	0.000	0.567	0.026
+9m	0.231	0.026	0.384	0.001	0.591	0.000	0.530	0.002	1.205	0.000	1.072	0.000
drought event	0.802	0.000	0.774	0.000	0.722	0.001	0.712	0.002	0.953	0.000	0.883	0.000
+3m	0.857	0.000	0.907	0.000	0.933	0.000	0.817	0.000	0.884	0.000	0.803	0.000
+5m	0.573	0.016	0.618	0.007	0.789	0.001	0.612	0.012	0.669	0.005	0.565	0.019
+7m	-0.012		-0.078		0.099		0.286		0.322		0.213	
+9m	0.081		-0.009		0.081		0.337	0.012	0.372	0.005	0.286	0.040

	PO all		PO 10 days		PO 15 days		PO 20 days		PO 30 days		PO 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
flood event	0.801		2.007	0.000	4.009	0.000	2.636	0.000	6.224	0.000	3.703	0.000
+3m	0.905		1.782	0.005	6.418	0.000	3.893	0.000	7.417	0.000	4.706	0.000
+5m	1.088	0.047	0.922		4.959	0.000	1.281		4.403	0.000	1.494	
+7m	1.329	0.008	0.816		4.491	0.000	0.625		2.704	0.006	0.136	
+9m	-0.020		-0.494		2.407	0.000	-1.607	0.003	1.052		-0.479	
drought event	8.809	0.000	8.964	0.000	8.818	0.000	9.364	0.000	9.218	0.000	8.826	0.000
+3m	4.737	0.000	4.575	0.000	5.024	0.000	5.115	0.000	5.489	0.000	4.991	0.000
+5m	4.367	0.004	3.906	0.013	4.731	0.002	5.066	0.001	5.486	0.000	4.903	0.001
+7m	1.908	0.038	1.684		1.446		2.526	0.004	2.920	0.001	2.394	0.006
+9m	0.436		0.534		0.562		0.959		1.303		0.906	

	PFB all		PFB 10 days		PFB 15 days		PFB 20 days		PFB 30 days		PFB 50 days	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
flood event	-0.137	0.011	-0.263	0.000	-0.225	0.003	-0.253	0.006	0.082		-0.128	
+3m	0.267	0.000	0.337	0.000	0.473	0.000	0.407	0.000	0.686	0.000	0.394	0.007
+5m	0.392	0.000	0.455	0.000	0.629	0.000	0.527	0.000	1.034	0.000	0.666	0.000
+7m	0.170	0.003	0.261	0.000	0.351	0.000	0.267	0.005	0.619	0.000	0.314	0.015
+9m	0.156	0.002	0.193	0.001	0.306	0.000	0.190	0.025	0.619	0.000	0.523	0.000
drought event	0.586	0.000	0.576	0.000	0.560	0.000	0.572	0.000	0.687	0.000	0.650	0.000
+3m	0.689	0.000	0.712	0.000	0.733	0.000	0.659	0.000	0.712	0.000	0.668	0.000
+5m	0.455	0.001	0.476	0.000	0.574	0.000	0.463	0.001	0.515	0.000	0.458	0.001
+7m	0.211		0.178		0.260	0.033	0.374	0.000	0.416	0.000	0.355	0.000
+9m	0.153		0.118		0.151		0.288	0.000	0.325	0.000	0.279	0.000

Legend: Only statistically significant p-values are indicated (in bold), other non-statistically p-values are omitted. Coefficient values highlighted in light red indicate cases for which the test suggests a worsening situation in relation to food security, that is, a higher FL, FE, PR, PO, or PFB in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the food security or food price situation is statistically significant.

FL: food loan; FE: food expenditure; PR: rice price; PO: soybean oil price; PBF: price of food basket. The notation +2m; +4m, +6m, and +8m refer to 2-month, 4-month, 6-month, and 8-month lagged periods respectively, while 'drought event' and 'flood event' refer to the period during or just after the event.

[a] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2.

■ *Cyclone, salinity and flood combined model*

The cyclone-salinity-flood combined models were fit for floods longer than 30 days; cyclones with a wind speed greater than 40 m/s; and for areas with any salinity problem. For salinity, we also recall that a simple difference in means (DiM) approach was applied instead of a DiD due to the slow onset nature of the process. For the sake of space, we are reporting only the results of the models with flood events equal or longer than 30 days; cyclone events with wind speed greater than 40 m/s and for all areas affected by saline intrusion (including all categories s1 to s4).

Nutrition indicators

Table 27 shows the results of the tests for the nutrition indicators. The table suggests that for the communities that live in areas where saline intrusion, flood and cyclones are all common, saline intrusion is associated with increased malnutrition (as measured by zlen, zwfl, and maternal BMI indicators). The effect is highly statistically significant ($p<0.001$ for zlen and zwfl; and $p=0.012$ for BMI). The effect on child and maternal dietary diversity seems to be on the opposite side, however, with two strong positive values (p<0.001), suggesting that in these communities the dietary diversity of both child and mothers are higher than in the rest of the country.

Table 27. Combined salinity flood cyclone models[d] – nutrition indicators.

	zlen		zwfl		BMI		child dd		Maternal DD	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
saline_all [a]	-0.164	0.000	-0.236	0.000	-0.078	0.012	2.518	0.000	0.613	0.000
flood_d30 event [b]	0.014		-0.043	0.049	0.009		0.751	0.000	0.268	
+3m	-0.012		-0.025	0.334	0.140		0.838	0.000	0.485	0.010
+5m	0.004		-0.122	0.000	0.051		1.186	0.000	1.069	0.000
+7m	-0.013		-0.039	0.101	-0.012		0.486	0.002	0.406	0.009
+9m	0.008		-0.006	0.815	0.053		-0.272		-0.284	
cyc_w40 event [c]	-0.025		-0.029	0.199	-0.165	0.027	N/A			
+3m	0.060	0.016	0.004	0.873	0.064		0.518	0.001	0.383	0.007
+5m	0.080	0.003	-0.068	0.001	0.008		-0.057		-0.142	
+7m	0.086	0.000	-0.027	0.228	0.081		-0.260		-0.402	0.009
+9m	0.042		0.009	0.704	-0.024		0.551	0.004	0.373	0.031

Legend: Only statistically significant p-values are indicated (in bold), other non-statistically p-values are omitted. Coefficient values highlighted in light red indicate cases for which the DiD test suggests a worsening situation in relation to nutrition, that is, a lower zlen, zwfl, BMI, child dd or maternal DD in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the nutritional situation is statistically significant.

zlen: Length/Height for age z-score; zwfl: weight for Length/Height z-score; BMI: Maternal body mass index; dd: Child dietary diversity; DD: Maternal dietary diversity.

[a] all the upazilas affected by saline intrusion, irrespective of the level of saline concentration

[b] all upazila affected by flood events with water above the DL threshold (Danger level) for 30 days or more

[c] all upazilas affected by cyclone events with wind speed greater than 40 m/s

[d] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2. The notation +3m; +5m, +7m and +9m indicate 3-month, 5-month, 7-month and 9-month lagged periods respectively.

Flood seems to have a slightly stronger negative impact on zwfl (wasting) than on zlen (stunting). In particular the zwfl coefficient values are negative and statistically significant for the period just after the events and for the five and seven-month lagged periods. The impact of flood on zlen is less clear. The coefficient shows a succession of positive and negative values, none of which is statistically significant. Similar comment can be made for the BMI indicator, for which no clear story emerges. In contrast the dietary diversity indicators display some very clear pattern, with a continuous series of positive and statistically significant coefficients for both dd and DD across the lagged-periods. These different results regarding the impact of floods are in line with the results of the combined flood-drought model and these of the joint flood-only model.

As far as cyclones are concerned, these appear to have a negative effect on the wasting (zwfl), starting just after the event and continuing for 3 lagged periods, that is, up to 7 months after the event. The most severe effect seems to occur at the 5-month lagged period when the negative coefficient is statistically highly significant ($p=0.001$). In contrast, cyclone events were seen to decrease stunting, which is difficult to explain. All the values of the zlen coefficients become positive and statistically significant two months after the event and remain so until the seven-month lagged period. The results also shows a statistically significant negative effect of cyclone on maternal BMI just after the event ($p=0.027$). No clear pattern emerges between cyclone and dietary diversity. First data are missing for some of the rounds that followed the events, preventing us from conducting the test for that period. The three-month lagged period shows some strong positive values for both child and mother indicators ($p=0.001$ and $p=0.007$ respectively) but the next two rounds (five and seven-month lagged period) are negative with the value of the maternal DD indicator even showing some statistical significance ($p=0.009$) at 7-month lag. Both child and maternal indicators however become positive and significant at the nine-month lagged period.

Food security and food price indicators

Table 28 summarizes the results of the test for the food security and food price indicators. As far as the effect of saline intrusion is concerned, the tests indicate that communities affected by high salinity are associated with statistically higher FL (food loan) and FE (food expenditure) levels than communities in the rest of the country ($p<0.001$ for two tests). More counter-intuitive is the fact that PR (price of rice) and PO (soybean oil price) coefficients are negative in these communities (PR being actually statistically significant). Note that this last trend is however consistent with the results of the DiM presented above (Table 23).

The impact of flood on these communities is mixed. While the FE (food expenditure) appears statistically higher just after the flood the effect wanes away rapidly and becomes negative after 5 months. This contrasts with the three food price indicators (PR, PO, and PFB) which all display positive coefficients after 3 months and statistically significant positive values from 5 months until 9 months after the event, suggesting that flood events do lead to higher food prices in the affected regions. A closer look at the coefficient suggests that the price peak occurs around the seven-month lagged period.

Finally the lower part of Table 28 highlights the effects that cyclone events have on the food security and food price indicators. Food loan (FL) values are consistently higher in the affected communities than in non-affected communities (in fact statistically higher for all period except for the 5-month lag). The PR, PO, and PFB indicators indicate that the food prices in the aftermath of cyclones are higher than they are in non-affected communities, especially during the first 5 months following the events (during these periods the difference is actually statically highly significant for most of the tests). A look at the coefficients also suggests that the peak in these prices occurs around the three-month lag period.

Table 28. Combined salinity flood cyclone models[d] – food security and food price indicators

	FL		FE		PR		PO		PFB	
	coef	p-value	coef	p-value	coef	p-value	coef	p-value	coef	p-value
saline_all [a]	0.715	0.000	0.067	0.000	-0.670	0.000	-0.110	0.538	0.005	0.844
flood_d30 event [b]	-0.467	0.001	0.036	0.000	-0.201	0.035	0.677	0.016	-0.072	0.083
+3m	-0.027	0.802	0.012	0.282	0.057	0.489	2.143	0.000	0.158	0.000
+5m	0.088	0.457	-0.002	0.883	0.906	0.000	-1.069	0.001	0.592	0.000
+7m	-0.304	0.011	-0.017	0.074	1.575	0.000	4.990	0.000	0.846	0.000
+9m	-0.090	0.464	-0.014	0.184	0.824	0.000	1.596	0.000	0.401	0.000
cyc_w40 event [c]	0.309	0.013	-0.039	0.000	-0.272	0.000	2.515	0.000	-0.084	0.033
+3m	0.295	0.012	-0.029	0.002	0.913	0.000	3.158	0.000	0.349	0.000
+5m	0.155	0.154	-0.039	0.000	0.350	0.003	1.347	0.001	0.100	0.035
+7m	0.361	0.000	-0.007	0.485	-0.223	0.011	-1.384	0.000	-0.158	0.000
+9m	0.210	0.046	0.005	0.606	-0.047	0.532	-1.068	0.005	-0.161	0.000

Legend: Only statistically significant p-values are indicated (in bold), other non-statistically p-values are omitted. Coefficient values highlighted in light red indicate cases for which the test suggests a worsening situation in relation to food security, that is, a higher FL, FE, PR, PO, or PFB in the affected (treatment) communities, compared to the non-affected (control) communities. Dark red values indicate cases where the worsening of the food security or food price situation is statistically significant.

FL: food loan; FE: food expenditure; PR: rice price; PO: soybean oil price; PBF: price of food basket.

[a] all the upazilas affected by saline intrusion, irrespective of the level of saline concentration

[b] all upazila affected by flood events with water above the DL threshold (Danger level) for 30 days or more

[c] all upazilas affected by cyclone events with wind speed greater than 40 m/s

[d] The following variables were also included in the models (but not shown in the table) to control for individual and household effects: age and sex of child; mother age and education; livelihood strategies (farmer; labour; transport; salary; business); family size; birth order; source for drinking; use of latrine –see definitions in section 2.5.2. The notation +3m; +5m, +7m and +9m indicate 3-month, 5-month, 7-month and 9-month lagged periods respectively.

3.2 Qualitative analysis

In addition to the quantitative analyses described in the previous section, qualitative data was collected in two regions using multiple methods including focus group discussions (FGDs), key informant interviews (KIIS), in-depth interviews (IDIs); one region is Gaibandha in the north-west part of the country where river bank erosion and floods are common and one is Satkhira in the southern coastal area where the local population has to cope with saline intrusion and cyclones on a regular basis. Because the quantitative data reflects the time period from 1998-2006 and the qualitative data generally reflects the past decade, due to the tendency for respondents to recall more recent events, the findings from the qualitative data are useful for better understanding how people cope with disasters with regards to nutrition and food security, but do not speak specifically to the disaster events pinpointed by the quantitative analysis.

3.2.1 Salinity and cyclone-prone areas (example Satkhira)

In the cyclone-prone area of Satkhira, the local population deal with high salinity levels in the soil and water on a daily basis. Salinity levels are attributed to natural climate events, such as cyclones, drought, and heavy rainfall, but also to the development of shrimp farming. Respondents perceived shrimp farming to be the primary cause of high salinity levels and associated hardships, but climate events are viewed as exacerbating the problems on a temporary basis. In other words, the "usual" high levels of saline are even higher after an event, increasing the effects of high salinity, but also adding additional hardships. Therefore, the results in this section focus primarily on salinity because the responses to interview questions about climate events consistently centered around salinity, revealing it to be foremost in the minds of residents in the cyclone prone area of southwest Bangladesh.

■ *Nutrition Knowledge and Awareness*

Because this research aimed to better understand the strategies employed at the household level to acquire nutritious foods following a -climate event, it was necessary to look at how respondents define and think about nutrition. The most common response to "what is nutrition?" was: green leafy vegetables, fish, meat, and eggs - likely the result of nutrition education programmes that emphasize these foods. Respondents were, also, able to list specific fruits and vegetables when prompted. Some respondents attempted to repeat behavioural change communication messages to define nutrition, although not always correctly, such as [nutrition means a] "*lack of Vitamins A and D. Vitamin D deficiency generates goiter*" (20-year-old shrimp farmer in Nangla, Noapara, Debhata who passed class 11), while in actuality iodine deficiency is more commonly associated with goiter. Another women conflated nutrition with sprinkles or other supplementary nutritional products stating [nutrition is] "*nutrition powder, like husk, which is fed to children, and wheat flour, rice, sago*" (55-year-old housewife in Shinghortali, Monshiganj, Shyamnagar). There seemed to be a lack of clarity on what nutrition actually is, although, arguably, this question is difficult to answer. However, instead of listing food groups as most people did, one 25-year-old single female who completed class 12 was able to articulate that foods are nutritious if they "*meet the body's requirements*".

■ *Climate Change Knowledge and Awareness*

All but three respondents had heard of climate change. Like nutrition, most people used examples instead of a definition when asked what climate change is. Overall, climate change was described as causing drastic changes between seasons and temperatures, as well as an increase in illnesses such as cough, fever, and diarrhoea. A female day labourer (35 years old) in Nangla described how "*the duration of the rainy season decreases day by day and there's very hot weather. Due to these reasons, it creates different diseases like drowsiness, headache, weakness, etc*". Changes in crop patterns, such as decreased paddy growth and death of trees and other plants were also seen as an effect of climate change. One young female respondent in Ghonapara, Noapara, Debhata who graduated from secondary school (class 12) details the effects of climate change as "*dying trees, crops don't grow well, hampering production of paddy, wheat, jute etc. Houses are affected by saline and coating of houses or any construction becomes cracked and falls down slowly*". Climate events are thought to be increasing, "*Rainfall, storms, and drought are increasing day by day*" she says.

When defining climate change, Aila and the destruction caused by Aila were specifically mentioned by several respondents, demonstrating the perceived association between climate change and cyclones and the long-term effects this has on health, productivity, and food security. The 55-year-old housewife in Shinghortali recounts, "*Before, there were many types of trees, but after Aila the situation changed*" as well as other effects, "*After the cyclone, diarrhoea, cough, irritation, and other stuff increases, and vegetables, crops do not produce as much as before and we have to give more labour*".

■ *Soil and Water Salinity Changes*

Every respondent has noticed increased salinity in both soil and water. Most blame the increased salinity in the environment on shrimp culture, but almost half specifically noted that Aila increased salinity. This increased salinity is associated with steady decline in paddy and vegetable production. According to one shrimp farmer, crops need a lot of rain and since rainfall has decreased, crop production has decreased as well. Many people say they were able to drink water from the pond and tubewell before, but now "sweet" water is not available in the pond and in some of the tubewells. Changes in water availability and quality are causing a number of problems, such as increased incidence of disease due to less hygienic conditions and high saline levels in the water. "*Before, sweet water was available. Now water becomes saline, cannot bathe, cannot feed the livestock and, if feed the livestock, they suffer from diarrhoea*" (38-year-old male day labourer in Shinghortali). Also, the change in water salinity has caused some species of fish to disappear and fish populations to decrease. One man, a 33-year-old day labourer whose family has lived in Atshatobigha village in Noapara for 100 years, noted that "*before, the water seemed clear and clean, now it appears like blue*".

To unpack the perceived relationship between salinity levels, climate change, and man-made phenomena, participants were asked when the increase in salinity first began, probing for specific causes. Responses vary, but most participants attribute the start of salinity to the start of shrimp production and place that around 25 years ago, although one 60-year-old respondent says saline levels began to rise 45 years ago. A fisher (52-years-old) from Shinghortali says, "*They use saline water in shrimp business, and during dry season water in the shrimp farm becomes more saline*". One person, a 45-year-old woman in Ashtorbigha said that the embankment used to keep the saline water out. Others mentioned that when the barrage eroded they were forced to move to other villages. Climate events, such as drought, rainfall, and cyclones worsen the salinity levels that are already a problem. Another man (38-years-old), who has lived in Munshiganj, Shyamnagar almost his entire life talks about how, "*During Aila, saline water overflowed in the whole area and mixed with soil in such a way that salinity is increasing still now*". The water stayed in the area for 15-20 days after Aila before dissipating.

■ *Food Production*

Gardening

Almost all of the respondents grow a garden on their homestead. Vegetables and fruits that are grown during winter months differ between households, but about half of respondents grow red amaranth and spinach. Carrot, tomato, chili, cauliflower, arum, pumpkin, radish, and beans are other vegetables grown in winter by various participants. One respondent no longer grows a summer garden due to salinity. However, just over half grow a variety of produce, including Indian spinach, long beans, arum, lady fingers (okra), green amaranth, fingerling potatoes, pumpkin, and several gourds in the summer and red amaranth, spinach, beans, cauliflower, carrots , and several gourds in the winter.

All respondents who grow vegetables say production has decreased due to salinity, as much as one-third of what they produced in the past, especially since Aila. It was also reported that Aila damaged the garden so severely that plants were not able to grow for 1-2 years, an effect that lasted up to four years for some. Regional flooding has also had an impact[28]. "*My garden was affected by the flood in 2011 [due to heavy rainfall], for this reason, all plants were damaged because of the water overflow that mixed saline with sweet water*" says a 60-year-old housewife in Ashtobigha who lives with her elderly husband, two sons, and daughter. The sons work as day labourers. Her garden was severely impacted for a year and produces now, but not like before because of high salinity in the soil. Fruit trees have also been severely impacted. A 38-year-old man in Munshiganj village lost his fruit trees to Aila. "*No [I do not have fruit trees], we had guava and some other fruit trees, but after Aila, because of saline, the trees died*". Fruit trees are thought to be affected by high salinity in soil and water, specifically jackfruit and mango, and are not as abundant as in the past.

Market

Almost all respondents live near a market, with two-thirds living one kilometre or less from the nearest market, and another third within two kilometres. The farthest distance is 10 kilometres. Following a disaster, once flooding recedes, residents of this area are able to get to the market within a week or so. In response to low home production and high market prices, people cope by eating smaller portions of food for anywhere from two months to a year for an acute situation to resolve. For longer term adaptation, diets may be more reliant on shelf stable products, such as rice and dal.

[28] Satkhira district, particulatily the northern five upazila of Kalaroa, Tala, Satkhira Sadar, Debhata, and Assasuni, was affected by widespread flooding and subsequent waterlogging in 2011, starting from the mid-monsoon month of July. At least 20% of the households in the district were affected.

Crops

Few respondents produce their own rice or own land (three of 13). Everyone else buys from the market. However, only men go to market, although one woman sometimes accompanies her husband. Therefore, rice consumption is primarily dependent on access to the market and the availability of male members of the family to purchase. Of the few who produce rice or other crops, all say crops were destroyed during Aila and the paddy was not able to grow for several years. "*Now, paddy does not grow as well as before and production is reduced by as much as one-third*" says a 16-year-old female student in Jelekhali, Munshiganj, Shyamnagar who has lived in the same place her whole life and whose family is one of the few that produces their own rice. One farmer said that in previous times they would simultaneously produce garlic and rice, but now they can only produce one crop at a time and only during the rainy season. Crops do not grow well now, even with fertilizer. Saline water is understood to affect plants because "*the saline goes into the roots and then the plant slowly dies*" (20-year-old shrimp farmer in Nangla). Similarly gardens and crops were affected because "*saline mixed with the soil and crops did not produce the next season after Aila and, after the next season, they produced half than before Aila. Still now crops do not produce as like before. Before Aila, paddy got 21 mounds*[29] *each Bigha and now it gets 14 mounds*" (16-year-old female student in Jelekhali).

Livestock and Fish

Approximately half of the respondents declared that they have both large livestock (cow, goat, or both) and poultry (chicken, duck, swan, and/or pigeon) and the remainder have poultry only, except for one who has goats only and one who has no livestock at all. Goats are more common than large livestock, few people have cows and no one sells milk (except for one person). Everyone who owned livestock during Aila said the large livestock suffered greatly. "*Our household had 10 goats, but during Aila, five to six goats floated [away] with the water and the rest died after drinking saline water*" (52-year-old fisher from Shinghortali, father of two children whose wife fishes with him). Since livestock are accustomed to drinking from the pond, it is difficult to keep them from doing so and they end up becoming sick from the saline in the water. Livestock also suffer hair loss, which is attributed to increased salinity in the environment.

Since Aila, and because of the high levels of salinity in the soil and water, rice straw is not plentiful to feed livestock, grass is not growing, and the market price of rice straw is high. As a result, surviving livestock may have to be sold because the price of upkeep is inhibiting, "*grass does not grow well and straw is not available and high price. So we could not provide feed to livestock and sold them four or five years ago*" (60-year-old housewife in Ashtobigha who says she has seen the effects of salinity since she moved to the village 45 years ago).

Chickens and/or ducks are owned by nearly all and many both consume and sell eggs, mostly to buy rice and other food, or oil, pen, and paper. One respondent says they sell the eggs to buy the kids sweets and biscuits.

Like other livestock, poultry also floated away during Aila, one person lost their entire flock that way. Others lost their flocks within two months due to disease caused by flooding and saline water. In an effort

[29] One mound = 40 kg (kilograms) and one bigha = 0.1338 hectares.

to save their chickens, the family of an 18-year-old female student in Jelekhali kept them inside for a year to prevent them from drinking saline water and fed them cooked rice. "*Poultry could not be let out, had to close them in the room due to waterlogging. Some died from drinking saline water and we had to give [the remaining poultry] cooked rice instead of rice bran*". The negative effects of salinity on the poultry decreased a year after a cyclone, although they are still affected by high incidence of disease.

Fish ponds are found at almost every homestead with households consuming fish from the pond, while a number of them also catch fish from the river. Although meat is consumed from all animal sources, fish is the only one consumed with regularity. It is unclear if beef, goat, chicken, and duck consumption has decreased over time as the number of livestock has decreased due to rising salinity levels as a result of climate events and shrimp farming, or if eating these foods has always been infrequent.

During and after Aila, most or all of the fish in ponds died. Amongst those that survived, many died due to subsequent increases in salinity, even if the pond was flushed with fresh water. In addition according to respondents, fish that bred in "sweet water" [fresh water] in the past, do not survive in the water anymore and have to be replaced with other species that can grow in saline water. A 33-year-old day labourer from Ashtogigha (family is long-term village resident) who lives in a household with nine people described how "*the head of the fish grows large, but the body of the fish is smaller, taste is reduced, and [the fish are] infected with diseases and die*".

Even if fingerlings are introduced later to restock the pond, some survive, but some "*die due to salinity and disease*". Loans may be used to restock the pond, such as one respondent who did this after Aila and is still paying off that loan. It appears that fish ponds were able to begin producing fish about a year after the cyclone, although these are likely more saline-tolerant.

In addition to cyclones, drought was also mentioned as a reason that the ponds are more saline. "*Due to saline, the water and soil are polluted. Before, saline water was in the canal only, now saline water is in the farm, and due to heavy drought during the summer, saline increases in the water and the fish of sweet water die*" (35-year-old wife of a day labourer in Nangla with two sons, 18 and 13 years old). Fish in the rivers were also affected, and the respondents reported that river fish are not as numerous, especially indigenous varieties, or as big as before. Several people specifically mentioned fish and shrimp culture in saline water as inadvertently affecting freshwater river fish.

■ *Food Consumption*

Grains and Starchy Vegetables/ Tubers

In normal times, over half of the respondents consume starchy vegetables/tubers daily, many of them three times per day, and potatoes are, by far, the most consumed. Following a climate event, consumption drops to several times per week for some, while one-third of respondents do not have access within the first week following a disaster. After a month, almost all households responded that they are eating starchy vegetables/tubers at least once per week (range of 0-7 times per week). These starchy foods have never become available like "normal" for a few participants, and others say it can take up to two years before availability returns to normal. However, most respondents say the changes last 3-6 months.

Grain consumption varies considerably across the sample within the first week following a climate event, such as a cyclone. Although a small number of households are able to continue eating grains three times per day (the normal frequency reported), the majority of respondents describe a coping strategy in which they eat fewer times per day for the first half of the week, then increase the number of times per day over the remainder of the week. For most, this only lasts 1-2 weeks. Normal grain consumption usually resumes by a month later.

Legumes

Legumes are eaten several times a week by about half of the respondents. Bean consumption increases during the growing season. Legumes are available within a week following a climate event, however, for half of the respondents, consumption is reduced to little or no legumes for a week or more, but legume consumption actually decreases even more a month later. It is unclear from the data why this reduction in legume consumption occurs after a month, although it is likely a result of depletion of stores and increased market prices. Reportedly, these changes last for 2-6 months, although some people say it can be a year.

Vegetables

Vegetables are an integral part of the diet, being consumed anywhere from several times a week to every day in the absence of disaster. However, vegetables have limited availability in the first week following a climate event and few people have access to them. Even after one month, vegetable consumption remains less than normal, appearing to be around half of what is usually consumed, or not at all, with people eating fewer times a week or eating smaller amounts. As with many foods, respondents report varying time periods for resumed availability of vegetables, anywhere from right away to a year away.

Fruits

In the absence of disaster, people normally consume fruits several times per week during the various fruit seasons. Following a disaster such as a cyclone, fruit is not available in the market until a month later, and people's consumption is drastically reduced. Fruit does not become available again outside of the market for six months to a year. Purchasing fruit from the market does not appear to be common practice. Following a drought which increases salinity, fruit such as mango and jackfruit still produces in the months of May to July and can be consumed regularly. During a cyclone, the trees are inundated with saline water, which kills them, but in a drought, they manage to survive and produce the fruit.

Eggs and Dairy

Most respondents own poultry, however, the majority are not able to consume eggs within a week following a disaster. Eggs are available in the market, but not on the homestead. Although most are consuming eggs a month later, consumption is much lower for most people. For three respondents, egg availability is always the same, but for the rest, the poultry is not at normal production until six months to a year later.

Other Animal Source Foods

Just over half of respondents consume fish on a daily basis in normal times, while the other half consumes fish 2-6 times per week, supporting claims that fish is the single most important source of protein in the Bangladeshi diet (personal communication with Craig Meisner, World Fish Bangladesh Country Director). However, for all but two respondents, fish consumption reduces by about half for anywhere from 2 to 6 months following a climate event (this can even be a year for a few). Fish is reportedly available in the market, but prices are inhibitive.

In normal times (outside disaster period), red meat, poultry, or other flesh foods are not eaten with enough regularity to provide sufficient nutrient contribution. Consumption tends to be one to two times per month. In the wake of disaster, consumption decreases even more and animal sources of meat other than fish are not available for several months to a year. However, given the minimal contribution to the diet of flesh foods (apart from fish), the impact of disasters on livestock may not have significant immediate impact on the nutrition of households, whereas the impact on the fish population is likely to result in low protein consumption within the household.

Only few respondents drink milk regularly. No one else drinks milk more often than a couple of times a year. It is difficult to say whether milk and meat consumption was higher previously. It was noted however among some respondents that in the past they owned livestock, but now it is not feasible due to risk of loss and cost of care (see above).

Junk Food

Sugary and salty snacks are consumed from several times a week to daily in normal times. Unlike some other foods, these remain available following a disaster, but consumption decreases temporarily for a few weeks to a few months for about half of the respondents (the other half continue to consume junk food as normal). In fact according to the respondents junk food is the category of food that seems to be least affected in terms of disturbance of consumption patterns. In other words, whereas rice may continue to be consumed daily, the number of times per day or the amount consumed decreases, whereas, this is not the case with junk food for half of the respondents and the reduction in consumption for the other half is short-lived.

■ *Housing Effects*

Participants were asked about forced or necessary movement within and between communities, as well as their own observations and experiences of soil and water salinity related to climate events. Two-thirds of people interviewed have changed the location of their home for reasons related to a climate event, such as flooding or barrage or embankment erosion, which occurs when the structures built to regulate water flow erode, suddenly allowing fresh, brackish, or saline water to flow in. Residents from one village in particular, have been most affected, having moved multiple times (one person has moved six times) within their village, specifically. It also seems that moving to another community is not the chosen practice. Instead moving around within the community to find a more suitable location is preferred.

■ *Health, Water, Sanitation, and Hygiene*

Myriad health problems are attributed to climate-related disasters and increased salinity. Diarrhoea and skin diseases were identified as the most common health issues, followed by cough, fever, and pox (pus-filled rashes on the skin). There are various ways in which disaster affects people’s ability to address health issues. These include waterlogging reducing or preventing mobility, pharmacies being destroyed and no medicines able to be brought in, and no money held by households due to loss of resources and jobs. These effects can last for a few weeks or, as with the case of absence of cash-money, several months. Children can suffer from increased incidence of diarrhoea, fever, cold, and cough for a month or so following a disaster and may feel weak from not eating enough food. However, generally by a week after the event, access is open for doctors and pharmacies. In the interim, people may visit the local doctor or get aid, such as oral hydration therapy from the border guard. For pregnant women, decreased access to facilities could be an issue, as well as lack of clean water for bathing. Changing the source of drinking water is one strategy for preventing illness or reoccurrence.

Several people said the water usage had changed because of climate hazards. For example, [people] "*used to be able to drink pond water after separating it with a strainer but now the water is not potable because of high saline level*" (18-year-old female, daughter of a day labourer, Delekhali). When there is no access to safe water, most people go 1-4 kilometres to collect water from a trusted source, but many still treat it, usually with fitkari (aluminum sulfate product that causes impurities in the water to coagulate and sink to the bottom), or, to a lesser extent, by boiling it. However, a few people do not treat unsafe water. One respondent felt that they had no choice and no means to make water potable, "*we have to drink it although it is unsafe*". Alternate modes of obtaining clean water include drinking unboiled rainwater or treated pond water. One person says they drink their tubewell water with high saline levels anyway. As would be expected, water levels also fall during the dry months and "water goes underground".

Half of the respondents wash their hands with water only, while the other half uses soap or soap and ash. Given the clear connection between handwashing and diarrhoea, as well as handwashing and environmental enteropathy, unhygienic practices are contributing to poor nutrition outcomes and illness.

Latrines can be broken during a cyclone, and mud toilets crack from the saline water. After a cyclone, it can take 2-5 months to fix the latrine. While the latrine is not in use, people defecate in open fields or on the roadside and either leave the waste there, or throw it in the river.

■ *Other Impacts*

When asked how fuel sources were impacted by a climate event such as a cyclone, some people said the trees were waterlogged and could not be burned and rice straw was not available and expensive in the market. This situation lasted a few months after Aila for instance. Subsequently, trees and paddy have not grown well because of saline and cows have died, thus not producing dung for fuel, so fuel sources continue to be less abundant than they were before. "*There were many trees here, straws (dhaner khar), fuel made from cow dung (ghuta), were available and low cost. But now these are not available and costly if available*" (housewife in Nangla; she says fuel availability continues to become increasingly limited). In response to fuel shortages, respondents recount reducing the number of times per day food is cooked.

During flooding, cooking or the ability to cook is affected primarily because the cooking stove is usually located outside on the ground and gets covered in flood waters. Strategies for coping include moving cooking stoves to higher grounds, or putting in an open space where there is no water, although the stoves reportedly become dustier in the open than when they are located near the home. A couple of people mentioned that salinity in the soil causes the stoves, which are made of soil, to crack and break, needed to be repaired or rebuilt every year. Most people say their cooking is affected for 2-6 months following a climate event, although some people say they are now continuously affected by salinity (broken stoves).

Regarding effects on food storage, a majority of people reported that stored food spoils very quickly specifically because the rice is kept with water, which has high salinity and is attributed to be the cause of the spoilage. A young girl in Jelekhali who is partially responsible for cooking in the home describes how "*if food cooks with saline water, then it becomes spoiled and some foam is created on the food*". This effect persists today for some people but does not seem to be associated with specific location (village).

There is a perception that fertilizers are available to put on rice crops to keep them from spoiling and people have begun to apply fertilizers as a measure to cope with rapid spoilage of food in high saline conditions. However, one participant also noted that now crops do not grow well unless fertilizer is used. Other changes around the household and the community that were reported by participants include blackening of utensils from salinity, damage to equipment and tools from water, and overall fewer jobs following a disaster, than before a disaster event.

■ *Pre and post-event strategies*

Amongst the respondents, nutrition was not presented as a key-factor considered in consumption-related decision-making after a climate event. Because money and jobs are scarce in the wake of a disaster, the primary concern is price of food, with quantity and shelf-life being secondary concerns. Nutritious food is available in the market not long after, but access is hindered by lack of money to purchase nutritious food.

Dal, rice, pulses, fish, salt and chilis are the most frequent foods named as eaten in the wake of disaster (only one person mentioned vegetables). Most people eat less preferred foods for 2-6 months and less preferred foods for good nutrition for 1-3 months, although many do not eat less preferred foods just to get optimal nutrition intake. However, as noted above, after a week or so, people do begin to include vegetables in the diet depending on their cash/money situation.

Considerable variation exists in use of portion-size reduction as a coping strategy. For some, there is no need to reduce portion sizes, but for most this practice lasts from a week to six months. One-third of participants have not had to skip meals. For those who have, there is a split between a one day to a week and one month. This mirrors the responses for how long someone goes hungry, although a couple of people say they are hungry for six months.

Most respondents say they do not run out of stored food before the situation returns to normal. For a few, their stores last several days to several months. When asked about alternate means of obtaining food, less than a third of the group forage for wild foods and this strategy is utilized for a short period of a few weeks. However, half of the group borrows food, most for an extended period of time (six months to a year and a half) and also uses credit for approximately the same amount of time. Those foraging for food also borrow and use credit. A couple of people mentioned they wanted to borrow food or money, but no one wanted to lend it to them. Eventually they were able to take on short-term credit. The number one borrowed food is rice, followed closely by dal, salt, oil, and chilis, then vegetables for some. No one considers nutrition when asking for foods from others.

Family members who eat smaller portions or skip meals tend to be the women in the household, while a few reported that both the husband and wife engage in this strategy. When asked who gets the most nutritious food (after a disaster when the family may be employing various coping strategies), respondents overwhelmingly said children.

Multiple changes in crop production were noted, including new varieties of saline-resistant rice, new fertilizers for saline-resistant crops, limiting paddy production to the rainy season, switching from paddy to fish, and ceasing paddy production altogether.

Migration to earn money is not widely practiced, nor is the practice of selling assets for money to get by, although one person said their relative went to Chittagong to work and another said they sold their cow after the 2011 floods to have money for food. Some people do take on additional work as a day labourer to make ends meet in hard times. Due to loss of stock to disease, one fish farmer has shut down the family production and become a day labourer, although he still has a pond and stocks it with saline-tolerant fish for the family to consume. Another took out a loan after all of his fish died from saline water inundation and he is still paying back the loan. Several pond owners report having switched to saline-tolerant fish for their ponds.

3.2.2 Flooding and river bank erosion prone areas (example Gaibandha)

In Gaibandha in the north-west part of the country, river bank erosion and floods are common extreme-events. In this section the results generated through the FGDs, KIIs and IDIs, undertaken in this area are presented. Like for the southern coastal area presented above, the objective was to explore how these events affect lives and livelihoods, access to, availability of, and consumption of various food groups, with particular emphasis on nutrition; the immediate and long-term effects of a disaster; and ways in which the individuals and households adapt to or cope with these effects or changes, particularly if nutrition is a priority in developing strategies.

■ *Nutrition Knowledge and Awareness*

Nutrition is a difficult concept to define, but respondents in the northwest were able to give examples to illustrate what they meant. Nutrition was said to be what keeps you healthy, which means vegetables for most people in this flood prone area. Children were also recognized to have special nutritional needs. However, although special foods given to children may be considered nutritious by respondents, this is not always correct. For illustration, according to a 55-year-old woman in Char Kumar Para who lives with her daughter, daughter-in-law, and four grandchildren, "for child nutrition, you give rice mixed with oil, it makes them healthy". Others refer to multiple micronutrient supplements, such as this 40-year-old farmer's wife in Char Kumar Para notes, "Children eat nutrition packets, I see it at my younger daughter's house". Some respondents were able to provide a definition. One farmer's wife from Deluabari (55-years-old) states, "If you have nutrition, then no disease will come, it keeps your blood well". Relating types of food to nutrition, a 62-year-old farmer in Deluabari thinks, "Good food is nutrition, vegetables are nutrition". Nutritious, healthy, and energy foods are vegetables, fruits, pulses, eggs, meat, chicken, fish, bread/wheat, and rice. Specifically, people frequently mentioned banana and arum. However, when asked to name fruits and vegetables and discuss what grows in home gardens, the list was longer and more varied.

There is a perception among some people that eating well costs money, "Milk, egg, fish, meat [are nutrition]. We are poor, we eat more vegetables" reported an 18-year-old wife of a day labourer and mother of a 1-year-old daughter in Holdia with a class 5 education. Despite her perception that animal source foods are nutrition and vegetables are for the poor, her family sells their sheep for money and did not replace their poultry stock after losing them to a flood (note: it is not mentioned if the sheep are sold for money after a disaster or for festivals). Other respondents mentioned "*home vegetables*" as nutritious. Home production is an important source of food, as evidenced by this remark made by a 62-year-old widow in Deluabari, "*We can't buy. What we have in home, we eat that*" which was echoed by a number of respondents. People eat a variety of foods on a regular basis, including rice, ("*We can't live without rice*"- said by the same young housewife in Holdia who thinks nutrition is expensive), bread (ruti/paratha), many types of vegetables, fish, potatoes ("*Potatoes and corn have vitamins*" – 44-year-old farmer's wife in Deluabari), chicken, beef, pulses, and bananas.

■ *Climate Change Knowledge and Awareness*

In Gaibandha area, drought was the number-one meaning of climate change, followed by – in no particular order – tornadoes, flooding, river erosion, untimely rainfall, hail, fog, and sandy land. Because of drought in the past, crops have changed. "Previously, we saw kown (local grain) and jute. Now we see wheat and chili. Before, we didn't see irrigation machines, now we use machines, we make this changes by our hard work. In previous times, we didn't see nuts, corn, wheat, IRRI paddy, we only did china [peanuts], sweet potato" (note that this is the white-fleshed sweet potato, not orange-fleshed). Other effects of climate change were noted: "*Sandy land increases, temperature increases, now cold also increases, we need more warm clothes, now new diseases also come, like TB, cancer, gall bladder stone, appendicitis, etc*".

Communication links have contributed to an increasing awareness of climatic events in the area, helping people prepare for disaster. "*Now communication is better than before, we can hear about weather (rain or other) by radio or TV. We also have mobile phones now, we can hear news*". One person mentioned an NGO that has been working in the area to promote building higher houses and said this has helped avoid loss. Additionally, a few people noted that since their last move a few years ago, they have not been affected by flooding and erosion.

■ *General impacts of river erosion on people's livelihoods*

When asked about river erosion specifically, every single respondent has both seen and been affected by it. In fact flooding and river erosion has happened almost as long as people can remember. Some can put a time frame on it and say anywhere from 10-30 years ago, but there seems to be agreement that it just always happens several times a year. Likewise most of the respondents agreed that erosion is caused by increased water flow (strong current) and this happens every year, although some years are worse than others. Some participants claim, however, that river erosion has been increasing in recent years and that its trend has exacerbated hunger, while others believe the severity of the erosion has decreased, but the impacts from loss of land and assets, as well as changes in river morphology (e.g., changes in depth due to elevated river bottom causing water overflow from the river to spread over greater areas) continue to have a direct impact.

When asked what causes river erosion, respondents to the IDIs were able to clearly articulate the process, primarily citing both strong current and flooding as causes, as well as flood as a result of erosion. River erosion happens, "*when the river is deep and the current flow is more, it makes more river erosion and makes more flood*" according to a 35-year-old male farmer in Char Kumar Para who has not dealt with river erosion since relocating his home three years ago. Before that, he moved villages twice and faced erosion most years, usually three times a year, and lost his house, crops, and land to erosion.

Respondents are "*economically affected by house repairs*" which can happen yearly. "*Every year, we need to repair for flood and river erosion*". "*If we make a straw house, then it takes two to three months, and if we make a tin house, it takes 3-6 months*" to rebuild or make repairs. The economic effects can last six months. As mentioned earlier, some people have been taught how to build a new type of structure that is raised up off the ground and does not require repairs.

Participants were asked about forced or necessary movement within and between communities, as well as their own observations and experiences of river erosion. Almost all IDI respondents reported moving to another village in their lifetime because of river erosion, including moves within the past five years. Just over half of respondents also moved within their current village because of river erosion, many moving multiple times. The same 35-year-old farmer from Char Kumar Para laments *"the whole life I suffer for drought, flood, river erosion*". He has moved 15 times within his village because of river erosion. The household of another Char Kumar Para resident, a 40-year-old housewife, has relocated three times in the current village also due to river erosion. This respondent says river erosion destroys everything, including the house, bamboo wall, garden, and crops. Her family has lost their sheep and goats and arable land to river erosion, as well. This was a common scenario for most villagers. A 55-year-old illiterate and widowed female head of a household of six describes how, each time their house is destroyed, "*we make a small, temporary shelter while we search for a new house. Every time we go to higher elevation*". She has moved several times within Saghata in the past five years.

Houses and housing assets are not the only assets affected. In the last 15-20 years, according to the FGD respondents, 70 percent of the paddy fields in the area have gone under water and 40-50 percent of the agriculture labourers working in other people's land coming from poor and ultra poor families currently do not have a reliable source of income. Landless people either keep moving in their own village area in make-shift houses (either housing near a relative's place or in someone else's land/ property) relying on food aid support provided by local organizations working in the area. Alternatively they have been forced to migrate and move to other villages to settle down.

■ *Food Production*

Gardening

Most people have a home garden that produces a large variety of vegetables and fruits year-round, although a couple of people no longer have land to garden because they lost it due to erosion and to waters covering their land with sand. About half of the IDI respondents say they continue to produce the same vegetables they always have, such as this 38-year-old widow who works in an NGO office in West Deluabari, "*[we grow the] same thing like pumpkin, bottle gourd, bean, eggplant, green amaranth, cucumber, chili*". Due to the presence of the Chars Livelihood Programme (CLP), and possibly other programmes, in the area, the other half who garden say they now grow more vegetables than they did in the past. "*[We grow] mostly the same, but now we grow red amaranth, lady fingers, carrot, Indian spinach at home*". Change in the soil was cited as one reason for new cultivators and receiving seeds was another.

It is common for households to have several types of fruit trees, including jackfruit, mango, guava, papaya, blackberry, and jujube. A few people also reported how they had fruit trees in the past, but these were destroyed in recent years because they were swallowed by the river due to erosion. "*Now we have no fruit trees. Previously, we had mango and jackfruit trees, but last year they were destroyed by river erosion*" stated a 16-year-old female student (IDI) from Uttar Dighalkandi, Holdia, Saghata. Similarly, a 40-year-old female IDI respondent from Char Kumar Para, Holdia, Saghata said her family lost their mango, custard apple, and black berry trees to river erosion and no longer have fruit trees. The loss of these trees can have an immediate impact on access and availability of key micronutrients as households are suddenly in a situation where they have to purchase, forage, or receive fruit from others. Consequently, fruit consumption decreases for those who lose their trees to erosion. Note also that fruit trees take several years to grow to maturity. The loss of these trees is therefore likely to have impacts over several years.

The majority of people both consume and sell produce from their gardens. Produce is sold primarily for extras, such as betel leaf and nut, pen and paper, and cosmetics, or other foods not produced at home like rice, eggs, chicken or meat, and/or salt.

In addition to river erosion, floods and droughts are commons. However it seems that the ability to garden has not been affected over the long-term by flooding or drought in a significant negative way, (unlike in the areas with high salinity), but it is affected seasonally, or by sudden impact.

In addition given that flooding is a yearly occurrence, it is likely that seasonality and cropping techniques have been adapted to living with cyclical flooding. Indeed, residents in this area "*pull [the garden] up before the floods come*" according to a housewife (42 years old; IDI) in Char Kumar Para. Vegetables are grown after Chaitra season. The garden is destroyed by floods and the waiting time for the waters to recede and allow for planting anew can take anywhere from a few weeks to half a year.

Crops

When river erosion happens, crops in the affected area are destroyed and the land becomes sandy, which can have a permanent or long-term negative impact. The loss of land and property is especially severe for female-headed households. For one woman in Deluabari who lost her husband to illness and has become head of household, the loss of property was devastating, "*We lost four bigha land [0.53 ha] due to river erosion. Still we have not bought more land. Some sandy land rose up where our land was, but we can't cultivate it. Who will cultivate there?*" Another widow (62-years-old) in Deluabari completely lost her land to erosion. "*We have no land. Now, if we can bear the production costs, then we cultivate on another person's land*".

As for flooding, like with gardening, cropping adaptations have developed to maximize usage of non-flooding and post-flooding periods. For example, different varieties of paddy are planted in various times of the year, such as aman or IRRI varieties, that might be late varieties or more flood resistant. Also, different crops are planted to make use of the type of soil left. "*If it turns to sandy land then we do onion, nuts, kalai (black and grey pulse) if we get soil land, then can cultivate paddy there*". Respondents say it can take anywhere from one month to a year to be able to plant again after a flood or after erosion caused their land to be covered by sand, depending on what is being planted and the condition of the land. "*After flood in kartik month [approximately October 15 to November 15th] (after 3-4 months), we will again grow wheat, chili, and mustard on that land*".

Livestock and Fish
Half of respondents own large livestock. Most people in this area drink milk from their cows if they own a cow and a few also sell the milk. Goats and sheep are also sold for money, if owned. If the floods happen yearly, then they may lose livestock yearly. Whenever the land is disturbed by river erosion, livestock can also be affected. More often than losing livestock, the livestock pens/shelters are destroyed and have to be rebuilt. If livestock are lost, it is common to purchase more in the next year when money is available. To protect them during the flooding or if there is time to move them when the land is eroding, attempts are made to put them in a temporary shelter and/or at higher ground. "*They are kept in temporary place, sometimes the school house. If the school drowns, then we keep them in another house which is situated in high land*". Whatever livestock remain after others are swept into the river are moved to higher ground. Since cattle food is needed for up to three months following a disaster, if food cannot be found or purchased for them, then they are sold.

Chickens, or chickens and ducks, are owned by two-thirds of the respondents. A few others said they had chickens in the past, or larger flocks, but they no longer have chickens or the flock size has reduced due to disease. During river erosion and/or flooding, chickens are frequently swept away and drowned or, in the case of flooding, they may die later from disease. Sometimes, because of loss of other assets to erosion, they must be sold for money and hatchlings purchased at a later date. Occasionally, during prolonged flooding, chickens are kept inside until the flood waters recede or are safe. Ducks are more plentiful during the annual flooding season. If the river bank suddenly collapses, any animals not caught up in the river are salvaged. "*What poultry we can keep with us, we can take care of, the rest of them are lost in river water*" notes an 18-year-old housewife and mother of two in Char Kumar Para who has moved three times already in her lifetime because of river erosion. After the flock is devastated, it takes about two weeks to a couple of months for poultry to begin to replenish or for a household to acquire new stock.

No one owns a fish pond and less than half of the respondents catch fish in normal times. The main source therefore to access fish remains the local market. During flooding, however, fish actually become a renewed source of nutrition for residents in flood prone areas and more fish are consumed during this time than in other times. Likewise, fish are an easily accessible source of protein for residents who have lost poultry and other livestock to erosion.

Losing livestock, including poultry, can have both short-term and long-term economic consequences. Goats and sheep are a source of income when needed, as are eggs. In terms of nutritional impact, milk and eggs are commonly consumed, especially by children, and provide an important source of animal protein. These sources are somewhat diminished for a month or more after a flood or river erosion, but diets are supplemented with fish from the rivers.

Market
Since a large variety of products are produced at home, only certain foods are bought at the market, such as tomato, potato, rice, dal, oil, and salt. The markets are located 3-7 km from most people's homes, but other smaller stores and shops are located closer. Weekends are for the market and daily needs can be met locally. Only a few women (mostly widows) do the shopping at the market, as it is usually the men who go.

Impeded access to the market and the need to purchase food instead of eating from homestead production are the two main ways access to nutritious food is affected following river erosion and/or flooding. "We can't go to market, we request someone to do our regular market purchases. We do not buy many things, our income is poor, so we eat less". Getting to the market requires the boat, which can be unavailable or cost money and poses the risk of drowning. "*We have to wait a long time for the boat, sometimes one person does 10 people's daily market purchases*". Occasionally, the need to get to the market necessitates innovation, "*sometimes we make a temporary raft by tying banana trees together*". During the dry season, access to nutritious food is affected for lack of production at home and higher prices at the market.

Food Consumption

Overall, people's food stores appear to sustain them during flooding or other events, albeit frequency and quantity of consumed food may decrease. "*We cook a small amount food. What can we do except that? We need to live minimum one month with that*". Numerous strategies are used to prepare for the oncoming floods: saving money during the dry season, or store food. Other approaches to offsetting the need to buy food during flood times include working as a day labourer during the dry season for "*cheap labour at an advance rate*" to save money for the flood season. On the other hand since erosion "destroys everything" (numerous respondents) and comes suddenly, planning ahead is more difficult. Additionally, any food stores are swept away with the household, leaving families with total or near-total loss and no safety net to rely on.

Diets change following a disaster event, with less diversity and more reliance on prepared and accessible foods. [We eat] "*dry food like rice flakes, puffed rice, aurum roots, kanjal (inner white part of the banana tree). If we have money, then we bring food home, sometimes we bear the expenses from our savings, mostly we skip meals*". Dry rice flakes and puffed rice are prepared in advance of the coming floods. "*We buy paddy, then crush it in Saghata market and make rice for flood time*". Other measures must be taken when there are no food reserves, including purchasing rice flakes in the market. Some people make an effort to supplement micronutrient intake. "*Sometimes we bring a vitamin syrup from the doctor and also eat that*". During this time, nutritious food comes from the market, although a few people said they could also catch fish from the river for nutritious food. These changes last from one to three months after a disaster or even during the annual floods.

Grains and Starchy Vegetables/ Tubers

Almost all respondents report reducing the number of times per day they eat grains, including rice, in the week following a river erosion event, flooding, or other event. One person even reported that she does not eat grains daily during these crisis times, which is notable since rice is typically consumed two to three times per day. After one month, less than half are still not eating three times per day, however, rice continues to be eaten on a daily basis. Respondents do say that grains are available in the market. However, two primary reasons are cited for not consuming regularly: limited access to the market because it requires a boat and no income. Lower consumption of grains and starchy vegetables/tuber, like for many other foods, lasts for about two months.

Potatoes are so ubiquitous in the diet that they are what people spend money on at the market. As one person put it, "*vegetables means potatoes, there is nothing else without potatoes*". Except for a scant few, potatoes are still consumed on a daily basis following a disaster. Thus, for a diet already dominated by rice and potatoes, any food shortages are only going to mean less dietary diversity, with a heavier reliance on rice and potatoes.

Legumes/Pulses

There does not appear to be a shared pattern for eating legumes and pulses after river erosion, flooding or other event. It depends on whether the household produces their own and/or stores them (or loses their home to erosion), or buys from the market. "*If we can store it, then we can eat it, but we have to eat in less amount*". Some people eat more pulses following a climate event in the first week, some eat more pulses even a month later, indicating an increased reliance on food stores during that time. Others, who presumably do not store pulses or who lose their stores, eat less or none in the first week and some still have a pattern of less a month later. Regular consumption resumes "*after 2-3 months, when we can cultivate (usually after boishakh [approximately April 15 to May 15] month), but if we sell our own cultivated pulse, then we do not eat it anymore and we don't buy pulse*". Thus, food stores may also be less than normal if the household sells their crop for money to buy other products and does not store it.

Vegetables

Everyone reports reduced vegetable consumption for about three months after a disaster until they are able to cultivate or get money, but this reduction means that many people go from eating vegetables several times a day or week to once per day or fewer times per week. This reduction is directly related to loss of gardens. "*After 2-3 months we can buy [vegetables] and after Boishakh (after 6 months) we can eat our own vegetables*". Many people eat vegetables daily, but others eat two to three times a week normally. Vegetables are "*available all the time. In the dry season, we get less vegetable, in flood time we can get vegetables if we have money. Otherwise we eat dark green leafy vegetables*" which are foraged.

Although the garden may be under water, the market still has vegetables, but at high prices. Since this population is unaccustomed to spending money on vegetables, this is an added burden to the pocketbook and results in reduced consumption. Dark green leafy vegetables are foraged by some, but are also cheaper in the markets than other vegetables. There are a few households with minimal income or resources, however, which are particularly vulnerable during flooding. "*We do not buy vegetables in flood time, if we buy food, then we buy rice or rice flakes, otherwise we skip meals*". Again, when the home, garden, and crops are destroyed by river erosion, families employ each of these coping strategies, as well. However, they may be faced with an even higher burden to borrow money for food since they have lost everything.

Fruits

Fruit consumption varies by individual; some people eat more fruit than others, even when in season (1 per day to 1 per month). In regular flooding season, jackfruit and mango are available in the market and around the community. If people have to buy it, they eat less, but, generally, fruit consumption following a river erosion event (in normal flooding season) is only slightly less per individual. For some, there is no change. This is likely due to the fact that many fruits grow on trees and in shallow flooding, the fruit at the top of the trees would not be affected. For people who lose their fruit trees to erosion, however, fruit consumption decreases significantly.

Dairy and Eggs

Everyone who owns poultry eats the eggs, and many of them sell eggs as well, to buy items for school, clothes, cosmetics, or even bamboo to make repairs. Egg consumption varies according to availability in each individual household. They are eaten regularly only if available in the home or village, and less frequently if they have to be purchased at the market or gotten from somewhere else, although eggs are still eaten weekly. For those with chickens at home, chickens (and the eggs) usually disappear during the flood time, and the chickens don't start producing again for another two to three months. Duck eggs, however, are more available during flooding and after an erosion event.

If eggs are available, children are more likely to eat them than other family members. "*Children eat one time per day and adults eat 2-3 times per week*". For the few families who manage to keep their chickens and ducks, egg consumption continues at several times per week.

In the week following a climate event, it appears that most people do not consume milk, unless they have access to a cow that is producing". Milk is 60 taka a kilogram, with this money we can buy 2 kg of rice and can survive 4 days with that, how would we buy milk?". Like with eggs, consumption is higher if the family has livestock or access to livestock (e.g., a neighbour). Also, children are the first to get eggs and the first to get milk. In fact, many people said, in normal times, children regularly consume milk once per day and adults 2-3 times per week, although this is not true for all respondents and some people only consume milk a few times per month. If the family has to buy, they are less likely to provide milk on a regular basis, and likely not at all following a climatic event.

Other Animal Source Foods

Chicken, meat, eggs, and milk tend to be taken from the homestead when consumed, if available, however many participants do not regularly consume flesh foods in normal times. About a third of respondents say they only consume flesh foods on special occasions such as religious festivals or holidays, which usually means consuming meat two times per year. Others consume meat 2-3 times per month.

After river erosion or flooding, consumption patterns do not change for those respondents who do not consume meat except on special occasions. For those who normally consume meat 2-3 times per month, their consumption drops to zero until they are able to find work again (about three months later). Meat is not a significant component of the diet in this region. It appears that fish and eggs are the more common sources of protein.

Fish is consumed from the river and is usually eaten several times a week to daily. "*We can get fish more in flood time*". After river erosion and flooding, fish consumption increases to at least once per day for most respondents. Thus, although egg consumption, a valuable animal source food in non-disaster times, decreases, fish consumption increases, potentially offsetting any negative effects. One respondent said that they could catch fish for six months following a flooding, then they would start to buy from the market again and reduce consumption to 2-3 times per week.

Junk Food

Most people continue their usual consumption of sugary and salty snacks, which are only available at the market. These junk foods are eaten anywhere from 2-3 times per week to daily. Children get those more often than adults. One person even said, "*Children who do not get fed breastmilk, they mainly eat sweet and salty snacks*".

■ *Other Impacts and Coping Strategies*

There are some similarities here with what was observed in the southern areas. Trees, an important source of fuel, are lost when land erodes into the river or when the sand from erosion inundates the land through overflow. Likewise, cattle dung is a primary fuel source. The floods usually make all fuel sources wet and, after years of experience, most people prepare for the annual floods accordingly so they can continue to cook. "*We prepare and dry fuel before the flood and sometimes pull floating trees or branches from flood water and then dry to use it as fuel*". However despite efforts to stockpile fuel, it still becomes wet and damp if there are insufficient means to keep it away from the water and the number of times people cook reduces for that reason, as well as for less food.

In preparation for annual flooding, cooking stoves have to be moved to higher ground. "*We cook by using a movable stove made by mud, built in a higher place (macha)*". Since food cannot be stored in the water, people employ various methods to counter this problem. "*We cook food and then store it in a high place with a cover and tie a ladder to get to it. Usually we try to eat food when we cook it, this practice continues while the water stays here, nearly six months*". Rice is frequently kept with water and eaten with salt and chili since "*curry needs to be warmed sometimes*" and that requires fuel.

■ *Health, Water, Sanitation, and Hygiene*

Everyone suffers health problems during flood times, specifically diarrhoea, dysentery, fever, skin rashes, cold, and cough are the most common illnesses experienced. Cholera, typhoid, and hook-work are also attributed to flooding. Children appear to be the most susceptible because they want to play in the flood waters. Strategies to minimize exposure include trying to keep children away from flood waters, confining defecation (away from the house), and only drinking and bathing from the tubewell (if available) or drinking boiled flood water, as well as covering food (against flies). One person mentioned halogen tablets for purification. Additionally, respondents described illnesses such as cough and cold that could be attributed to living in temporary shelters.

Limited access to a doctor or hospital and to medicine is a problem for the sick and for pregnant women. Access is limited for the same reasons as for going to the market: they have to hire a boat. Some families try to feed pregnant women extra food, even if it means someone else skips meals. One family said they cannot allow the pregnant woman to have more food because there is not any and she is unable to rest either, because she must do house work. In contrast, another family keeps pregnant women on a high bed during the 2-3 months of flooding and accompanies her to a makeshift toilet of banana leaves.

For most people, medical care from a health care professional is not available until flood waters recede (2-3 months) and money can be made to hire a boat. A few do not have enough money for six months to see a doctor. Several respondents say they visit village doctors when they are unable to see real doctors.

Generally, safe drinking water is not available for 2-3 months following flooding or for groups of people living in temporary shelters after their homes have been swept away (respondents said they stay in these temporary camps for 2-3 months). Many people treat their water or they retrieve water from higher ground. Respondents use a variety of methods to treat unsafe water. Unsafe water is not perceived to be associated with nutrition by the IDI respondents, but, unbeknownst to them, they are decreasing their chances of developing or maintaining environmental enteropathy and, thereby, increasing their chances of absorbing nutrients when they treat it. All respondents report drinking tubewell water during normal times. In disaster times, most of the IDI respondents report drinking treated river water, if they are unable to find tubewell water, although many make an effort to find tubewell water above the flood waters. Water treatment methods reported by the IDI respondents include boiling and covering it, filtering it with a cloth or thin clothes after it has been allowed to settle, and using Fitkiri, though Fitkiri does not appear to be as common here as in Satkhira, with only two people mentioning it. Treatment methods and water sources are varied within this small study population.

To exacerbate the risk of illness from dirty water, handwashing with soap, as well as handwashing with clean water, is far from common, particularly after defecation. Given that waste ends up in the river and disposing of waste in the river is not only the norm, but is viewed as containing/disposing of the faeces, it is not surprising that diarrhoea, skin diseases, and other illnesses arrive with water inundation due to erosion and/or flooding

■ *Pre and Post-event Strategies*

The irregularity with which people experience annual flooding and river erosion has caused the development of a number of coping and adaptive strategies for dealing with the economic hardship that accompanies loss of home gardens and necessary repairs for destroyed property. As with disasters in southwest Bangladesh, thinking about nutrition is a less important factor than food costs for instance. "*We don't think about nutrition, we take what is cheap food*". Respondents say they are thinking about what is accessible and what is affordable.

Skipping meals was said to be practiced by all but one respondent. Several report not skipping meals after the first week of a flood event, but many continue to skip meals for 2-3 months. Almost everyone reported eating smaller portions and eating less preferred foods for up to three months. Most people are only hungry for about a week following a river erosion event. However, many people report going hungry during the dry season and running out of food stores during the dry season. In fact the dry season seems to be more of a problem than the periods following river erosion or flood events, in terms of food shortages.

Strategies for obtaining food are storing, borrowing, finding work to buy food, and getting aid from an NGO. Which strategies are employed is contingent upon whether or not there is time to plan. If the impact is sudden, such as an erosion event, there is no chance to store additional food beyond what is already stored in the home. In preparation for the annual flood, depending on how much food has been stored, this surplus can sustain a household for the entire flood period, or as little as a week. The stores seem to be the mainstay of diets following a disaster event. Borrowing is also a common strategy, including borrowing food, money, and taking credit. "*To minimize market food cost during flood time, we buy less amount of items like rice, wheat, kerosene oil, salt, and vegetables, if we can get vegetables from a high place house*". "*If we have own production [in storage] then use it, otherwise, we borrow food*". Almost everyone reports borrowing food for a week to several months, usually rice and at least one other item. The two most common other items are potatoes and/or pulses, followed by wheat and oil, salt and vegetables, and chilis.

Finally foraging is a strategy used to find food during a crisis period.

This involves essentially gathering fruit, fish, and plants, such as kanjal (the inner white part of the banana tree), and arum root, as well as leafy greens which may be growing wild near the home, This foraging strategy adds some variety and needed micronutrients to the diet.

3.2.3 Additional insights from the qualitative analysis

In addition to the direct findings generated in each of the two areas (cyclone and salinity prone area and flood and river bank erosion area) the qualitative analysis highlights some useful additional information.

■ *Discrepancy between the two zones*

Comparing the two areas suggests some potentially important differences. Protein intake, for instance, seems to be higher in Gaibandha (north) than in Satkhira (south), although both are reliant on fish. Children, especially, appear to consume more eggs and milk in the northwest than in the southwest. Similarly people of Gaibandha appear to have more diversity in their diets during non-disaster periods than people in Satkhira, largely due to the possibility of homestead food production, which is purportedly hampered by saline in Satkhira and has been promoted by the Chars Livelihood Programme in the sampling zone. Diets however are still largely reliant on rice, potatoes, and pulses (such as dal) in both locations. In Gaibandha, people are able to forage or purchase green leafy vegetables soon after floods and have access to fruits. In both areas, fish is a major animal source food, but in Satkhira, high salinity from flooding seems to have diminished the fish population, whereas in Gaibandha, fish become more available as flood waters impede the land. Overall, it seems, therefore, that the adaptive and coping strategies of the northwest, together with the environmental determinants for obtaining nutritious food appear to support better nutrition outcomes than in the southwest in the event of a climate-related disaster.

■ *The importance of the effect of prices and market dynamics*

In both areas local markets and food prices are undoubtedly critical elements affecting the food security of the populations, even in period of non-disaster. In the case of disaster however this impact is even more acute and includes both the question of physical and economic access. As was mentioned in the case of flooding for instance, physical access to markets may remain an issue for several weeks or even months until water recedes. For other types of disaster, this issue of physical access is not so prominent. The occurrence of a drought does not in itself affect people's ability to get to the local markets, but it does economically affect their access to food through prohibitive food prices at the market. In the case of salinity, physical access is also not an issue, but salinity does eventually negatively impact households' ability to access nutritious food because of inhibitive pricing, and at home because of contaminated soil and water: as commented a 25-year-old female who lives with her parents and siblings in Ghonapara "*If vegetables grew like before, then there would be no need to buy from outside. Now [due to salinity], we have to buy with high prices because we need vegetables*". However, in response to low home production and high market prices, people cope by eating smaller portions of food.

Chapter 1 2 3 **4** 5

Discussion

Discussion

The first section in the discussion will consist in comparing the results obtained for the different types of events for which quantitative analyses have been conducted (flood, drought, cyclone, and saline intrusion) across the three different models (individual, joint and combined models), in order to identify common emerging patterns/trends in these results. The next section will discuss, nuance, triangulate and put in perspective the consistency (or inconsistency) of these patterns, using information available through the literature and the qualitative analysis. Implications and subsequent recommendations will then be presented in the final chapter of this report.

4.1 Flood events

4.1.1 Nutrition indicators

The four types of models (individual-events (Table 9), joint models (Table 11) and combined flood-drought models (Table 25) and cyclone-flood-salinity models (Table 27)) were expected to show relatively consistent relationships with the nutritional and food security and food process indicators. The reality is a bit more complicated.

As far as the zlen (stunting) indicator is concerned no clear or consistent pattern emerges. There was a statistically significant negative coefficient at the seven-month lagged period under the 1998 individual test (Table 9) but it was not confirmed in any of the other models. It may be that the 1998 flood was particularly severe and with a slow recovery which had an impact on the stunting of children. In sum, the floods we examined did not impact child stunting levels. Conjointly the qualitative data reveals that residents of a flooded area may not engage in altered consumption patterns (e.g., eating less food and fewer meals) for more than a few months following a disaster, but they seek to protect child consumption.

In contrast to the zlen indicator, the zwfl indicator (wasting) had consistently negative (and mainly statistically significant) coefficients. This was the case for the 1998 individual test (Table 9) where three, five and seven-month lagged periods were associated with statistically significant negative coefficients [the 2004 flood event was also associated with negative coefficients for zero to nine months after the event but these were not statistically significant]. This trend is also observed for the joint model (Table 11) where every level of flood severity and every lag-period are associated with negative coefficients. The five-month lagged period was statistically significant ($p<0.01$) throughout the whole series of tests. This finding was confirmed in the case of the combined model with drought (Table 25) and in the case of the combined model with cyclones and salinity (Table 26). The results of the joint model also revealed that the coefficient values increased (in absolute values) with the severity of the events.

Based on these findings, it seems reasonable to conclude that these flood events in Bangladesh had a negative impact on wasting scores of children and that the effect was the strongest around five months after the event. Furthermore it seems that the impact increased with the severity of the flood event. The decrease in significant impact between five and seven months also fits with findings from the qualitative research that food availability and access begin to return to normal by seven months, although that varies by type of food. Additionally, illnesses like diarrhoea are reported to increase during flooding and respondents frequently reported disposing of human waste in flood waters.

Maternal BMI does not demonstrate any clear or consistent pattern in relation to flooding. It seems reasonable to conclude that these floods were not associated with altered BMI for women in Bangladesh. This should be qualified however by findings from the qualitative analysis which revealed that in approximately half of the households interviewed, women are expected to reduce (or are actually reducing) their consumption during crisis periods. Flood event included in this analysis might not have been severe enough.

The results for both maternal and child dietary diversity indexes are consistent with one another. While the individual 2004 flood event (Table 9), the lower level of flood severity in the joint model (Table 11) and the drought-flood combined model (Table 25) had negative coefficients, both dd and DD indicators demonstrate several statistically significant positive values across the models as well. This is especially true for the severe level of flood (20, 30, 50 days) for the joint model (Table 11), the drought-flood combined model (Table 25), and the flood-cyclones-salinity combined model (Table 27). This inconsistent pattern would suggest that while for the smaller flood events, child and maternal dietary diversity indices could have been negatively affected, for the larger flood events, was reversed and the dietary diversity indices seem to have been higher in flood-affected areas than in control areas. One possible explanation for this finding is suggested by the qualitative analysis where respondents reported that the availability of fruits and eggs are not severely affected by flood events; that rice, dal and vegetables are still consistently consumed (although often in lower amounts –especially for the mother[30]), and that fish is even more available and consumed more often during flooding than normally.

The overall picture in terms of nutrition for these households is therefore mixed. While we can confidently assert that these children in communities affected by flood events have a lower weight for height z-score than children in non-affected communities, the other nutrition indicators do not seems to show any negative impacts.

4.1.2 Food security and food price indicators

The food security and food price indicators were the next set of variables to be investigated and

[30] Technically, the dietary diversity index may not be sufficiently sensitive to detect the change in amount of consumption of these items. For instance while all respondents report reduced vegetable consumption for approximately three months after a disaster until they are able to cultivate crops or obtain money, this reduction means that many people go from eating vegetables several times a day to once per day or an equal number of times but in smaller quantities. These changes would not be detected by the dietary diversity indicator.

were defined through four types of models: (i) individual-events (Table 10), (ii) joint models (Table 12) and combined models with (iii) drought (Table 26) and (iv) cyclone and salinity (Table 28). As for the nutrition indicators above, some of these indicators appear to display some clear and consistent patterns, while others do not.

The three food price indicators show a relatively coherent story where the coefficients are for the most part positive and statistically significant across the models, and across the lagged periods and the different levels of flood severity. This trend was first observed with the individual-event model and the 1998 event (Table 10) where PR and PFB indicators displayed positive values over the whole series of lagged periods (particularly strong around the seven- and nine-month lagged periods). PO was also positive for these periods but not significant. This trend was confirmed by the joint model (Table 12) where the three food price indicators (PR, PO, and PFB) all show positive (and statistically very significant $p<0.001$ for all) values, and by the combined drought-flood (Table 26) and cyclone-flood-salinity (Table 28) models.

These various analyses indicate therefore that for the most part the prices of rice, oil and more generally food baskets are usually greatly affected by flood events, and that this effect lasts for up to nine months after the flood. This is also consistent with the finding from the qualitative analysis which reveals that while most food items are available at the local markets, their prices are higher than normal.

A closer look at the quantitative analyses also reveals other more nuanced patterns. The analysis shows in particular an increasing trend in the coefficients from the less severe to the more severe flood events, suggesting that the more severe the flood, the higher the price peak. The data also suggests that the prices of rice and food basket were at their highest levels five months after the event (which is when the wasting indicators are at their highest), while the price of soybean oil was at its highest level three months after the flood. This is especially clear in the joint model (Table 10) and the flood-drought combined model (Table 26).

The households' food security indicators are not associated to these high price shocks in a coherent or consistent manner. We would in particular expect the FE (food expenditure) indicator to show some strong positive values suggesting that households invest a larger share of their expenditure on food in order to cope with the increase in food price. It is the case for the 1998 event (Table 10) for the first 5 month periods following the event and to some extent for the joint model (Table 12) but in that case the positive coefficient is significant only during the period just following the flood and the three-month lagged period. For the combined drought-flood model (Table 26) the negative (statistically significant) coefficient seems to be more consistent as the severity of the events increase, but this is not observed for the cyclone-flood-salinity combined model.

On the basis of these results it is not clear that households affected by floods respond to the increase in price by reallocating a larger share of their income to food expenditures. They may alter or limit their market purchase behaviour to keep costs down (thus maintaining or reducing the relative proportion of expenditure allocated to food).

As far as the FL (food loan) indicator is concerned, results are clearer but still not completely consistent. The individual model (Table 10) suggests that households engaged in food loans only after seven months for the 1998 event but much earlier for the 2004 event (which seems counter-intuitive as the results for the other indicators showed that the 1998 event was more severe than the 2004 event). The results of the cyclone-flood-salinity combined model (Table 28) were also not as expected, demonstrating mainly (non-significant) negative values. In contrast the joint model (Table 12) displays a pattern that is more in line with what we could expect: the FL indicators were consistently positive throughout the whole period following the events (zero to nine months) and the majority of these positive values are statistically significant. The drought-flood model (Table 26) suggests a very similar pattern.

Overall the analysis tends to suggest that households affected by flood are likely to take more food loans than households that are not affected by flood events but the results of the different models are not totally consistent. Furthermore, the findings of the qualitative analysis do not necessarily provide clear answers to these inconsistencies. They indicate that a majority of households engage in food loans, which would tend to confirm the positive values observed for the joint-events and the drought-flood model. These differences could be due to differences in the relief activities which followed these events.

In sum, as with for the nutritional indicators, the overall picture in terms of food security of households affected by flood is mixed. They do certainly face some challenges and times during floods are associated with harsh conditions. People do report that they often have to skip meals or reduce portions up to two to three months after the events. But they also make clear that floods are 'expected' (seasonal) events and that they usually have prepared themselves for this harsh period. To recall one of the interviewees' responses: "*To minimize flood time suffering, we try to save some money in the dry season, we also store some food. We store wheat, prepare and store puffed rice, store dry fuel and make a movable stove*". In that context, perhaps it is not surprising that the food security indicators did not necessarily show any strong or consistent patterns as the change in individual household indicators may be contingent on the households' ability to prepare themselves as well as other households and possible community-level factors which have not been controlled for in the models.

4.2 Drought events

Individual-event models (Table 13), joint models (Table 15) and combined models with flood (Table 25) were also investigated for associations with drought events. Note that the combined cyclone-flood-salinity models are not included here as they did not cover drought events.

4.2.1 Nutrition indicators

No clear pattern seems to emerge from the analysis of the zwfl (wasting) indicator. From the individual models (Table 13) only two negative statistically significant coefficients were identified (one at the nine-month lagged period in relation to the 1998 drought event, and the second one immediately after the 2003 drought event), while the 1999 event had no significant coefficients. The joint model (Table 15) also had no significant measures. None of the coefficients of the combined flood-drought model (Table 25) -although negative for the vast majority of the cases over the lagged periods from 0 to seven months after the events- reached a level of statistical significance.

Overall it seems that drought did not have an impact on the wasting level of the children living in communities affected by drought events. Given the perception that diarrhoea may be linked to wasting, and drought conditions have been associated with reduced diarrhoea, this lack of association may not be surprising.

The zlen (stunting) indicator seems to display a clearer and more consistent pattern. First the individual-event models show negative values for the 1998 and 1999 events (Table 13) although the two statistically significant values are immediately after the 1998 event (zero and three-month lagged period) – which is not necessarily logical given that stunting is generally considered as a 'long-term, chronic' indicator of malnutrition. On the other hand the joint model also shows a consistent series of negative coefficients, two of which are statistically significant: one with a five-month lag and the second with an nine-month lag (Table 15). These two negative and significant coefficients at five- and nine-month lagged period are also observed in a very consistent way in the flood-drought combined model (Table 25).

This consistent pattern suggests that drought has a strong detrimental impact on the stunting rate of children living in communities affected by these events, and that this impact is observed between five and nine months after the drought occurs. This finding is corroborated by the qualitative analysis where a number of respondents recognized that drought is much harder to recover from in terms of food availability and market prices than floods.

As far as maternal BMI is concerned, a consistent pattern can be observed throughout the three models (Tables 12, 14, and 24) where BMI shows negative values straight after the drought and up to five to seven months after the event. None of these values –although consistent- are statistically significant. These results suggest that drought seems to have a minor effect on the BMI of women living in the areas where these events occur.

The analysis of the child and maternal dietary diversity indexes dd and DD relies only on the drought joint models (Table 15) and flood-drought combined models (Table 25) as no data was available for the individual model (Table 13)[31]. The data shows a consistent pattern: both child dd and maternal DD appear to be negative immediately after the drought events and the negative effect is observed up to five months for the child. None of these effects turn out to be statistically significant however. The coefficient then becomes significantly positive at the five, seven and nine-month lagged periods. The interpretation for such pattern is difficult but the conclusion is that except the slight (non significant) negative effect that is observed during the first couple of months after the events, drought does not seem to have detrimental impact on the child and maternal dietary diversity index in Bangladesh.

The overall picture in terms of nutrition for these households is one where the major effect of drought events seems to be a lagged impact on the stunting score of the children which become apparent after five months and remains so for a couple of months, and possibly on the BMI of their mothers. On the other hand, drought does not seem to have effect on the wasting score of the children. The results on the dietary diversity indexes are also inconclusive.

[31] Individual models could not be developed as there was an absence of data for the periods one year before or after the events. However, joint and combined models were possible because data were available the years before and years after the events, though not always in the period directly preceding or following.

4.2.2 Food security and food price indicators

As far as the food price indicators (PR, PO, and PBF) are concerned, the data appears to indicate a consistent pattern across the three types of models, suggesting that these drought events were associated with high prices. While the pattern is not totally clear in the individual-event models (Table 14) in particular with the 1998 drought, it becomes much more apparent with the joint-event models (Table 16) where the three indicators display consistent positive coefficients that are statistically significant from the period of the event up to the nine-month lagged period. This finding is confirmed in the combined models (Table 26).

The combined models provide further detail about these price dynamics. They show in particular that for the PO indicator the largest coefficients are observed immediately after the drought event begins and that these coefficient values then decrease gradually (but stay significant up to nine month after). This suggests that for soybean oil the peak in price occurs just after the drought event and then fades away progressively. The pattern for rice price (PR) and for the aggregated food basket (PFB) is slightly different. The coefficients are statistically significant just after the event (as with PO) but appear to be at their highest during the three-month lagged period, and then decline gradually, suggesting that for rice and food in general the peak of the prices occurs approximately three months after the drought event.

Overall the conclusion is that drought has a significant impact on the prices of food items in communities where these drought events occur and that the impact lasts up to 9 months at least.

What are the implications of these food price dynamics on the food security indicators of these communities?

As for the food price indicators, the analysis reveals a relatively consistent (but not necessarily coherent) pattern across the three types of models. While that pattern is not necessarily clear in the individual-event model (Table 14), it becomes much more apparent in the joint-event models (Table 16). There the data shows that both the food expenditure (FE) and food loan (FL) indicators are characterized by strong statistically significant positive values starting approximately three months after the drought event and lasting up to nine month after, suggesting that as a response to price peaks triggered by droughts, communities increase the share of their total expenses allocated to food and that they do that (at least partially) by undertaking food loans. This finding is logical and is confirmed by the combined model (Table 26).

The overall picture in terms of food security and food price indicators for these households is one where some strong effects of drought events are observed on the local economy through higher food prices, but where these higher local food prices don't necessary lead to significant impacts on food security indicators.

4.3 Cyclones

For cyclones, three series of models need to be included to draw conclusions: the individual-event models where four different cyclones were considered (Table 16), the joint models where these four different events are merged into one analysis (Table 19) and the cyclone-flood-salinity models (Table 27).

4.3.1 Nutrition indicators

As far as the zwfl (wasting) indicator is concerned, while none of the coefficients are statistically associated with wasting in the individual models

(Table 17), the joint-event models (Table 19) indicate that cyclone reduces zwfl consistently from the period of the event up to nine months after. This finding is confirmed in the combined models (Table 26). The same combined models also indicate that these negative effects are statistically significant for the five-month lagged period. For the most severe events (>40m/s), the statistical significance covers the whole period from 0 to seven months.

Based on these findings we can reasonably conclude that cyclones have a large negative impact on the wasting rate of children living in areas affected by these cyclones, and that the impact increases with the severity of the event.

The story of the zlen (stunting) indicator is different. First the individual-event models do not demonstrate any consistent pattern: none of the four individual-events are significantly related and two events (Nov 1999 and Nov 2002) have positive and statistically significant coefficients (Table 17). The inconsistency becomes even more obvious with the joint models (Table 19) where this time all the models are characterized by positive coefficients with a vast majority of them being statistically significant. This pattern is observed also in the salinity-flood-cyclone combined models (Table 26), suggesting the somewhat incoherent conclusion that the stunting scores of children living in cyclone affected areas are better than children in non-affected cyclones areas.

The results for the BMI are at best suggestive, but certainly not conclusive. The individual-event models (Table 17) don't show any clear pattern (partially because only two events could be tested: the Oct 2000 and the Nov 2002 events). These models show a series of positive and negative coefficients, none of which are significant. The joint-event model is also unclear, with again a series of positive and negative coefficients (Table 19). We note however that the coefficients just after the events are all negative (including the only statistically significant coefficient in these joint-event models, those associated with the severe (>40m/s) events). The combined cyclone-flood-salinity models confirmed this last observation (Table 27). Here again the only statistically significant coefficient in combined-event models is the negative one immediately after the events. Overall however, there is too little evidence to be able to conclude that cyclone events have a negative impact on maternal BMI.

Finally the results obtained for the child and maternal dietary diversity indexes dd and DD are coherent but should be interpreted with caution due to data missing at the time of these events. First only one event (Oct 2000 cyclone) was available for the individual test (Table 17). The results for this test suggest some severe negative impact on both dd and DD at the three and five-month lagged periods. The joint model (Table 19) also resulted in negative coefficients around the five and seven-month lagged periods, with a large number of these coefficients being statistically significant –all were significant at the seven-month lagged period but the relationship was positively and statistically significant at month zero, 3 and again at the nine-month lagged periods. Note also that this pattern is observed almost identically for both maternal and child indices. The results of the combined models show the same patterns: negative coefficients in five and seven-month lagged periods surrounded by positive ones (Table 27). Overall, it seems therefore reasonable to conclude that cyclones might have some negative impacts on both the maternal and the child dietary diversity indexes with a lag of five to seven months after the event but this conclusion is not necessarily very robust.

The overall picture in terms of nutrition is therefore unclear. On one hand strong evidence suggests that the wasting scores are significantly impacted by cyclones and that possibly the diet diversity indexes are also negatively impacted at five and seven months after the events. This is consistent with the information collected through the qualitative analysis. In normal times, the diet relies heavily on rice and potatoes with less than ideal dietary diversity from vegetables, fruits, and animal source foods to obtain a range of micronutrients. Those foods are almost systematically missing from the post-cyclone diet, which tends to consist of rice and dal, as well as potatoes (i.e., foods that can be easily stored) for several weeks to months.

But the other part of the story is less clear. In particular the fact that some strong statistical evidence were found that suggest that the stunting scores of children living in cyclone affected areas are better than those of children living in non-affected cyclones areas is difficult to explain.

4.3.2 Food security and food price indicators

The results for three food price indicators (PO, PR and PFB) offer a relatively robust story, although the initial individual models (Table 18) are not as clear. Indeed while the different events all display some positive coefficient and a fair number of them are statistically significant, an equal number of negative and statistically significant coefficients can also be observed. The results of the joint models are far more consistent (Table 20). The three indicators all show positive coefficients over the entire zero to seven month period after the cyclone; most of these coefficients are statistically significant and the values of the coefficients tend to increase with the severity of cyclones. The values of the coefficients also tend to decrease progressively with the time lag periods for a given level of intensity. The results of the combined models are not as robust or consistent (Table 28) but still confirm that the food prices in the aftermath of cyclones are higher than they are in non-affected communities, especially during the first five months following the events.

Based on these results, we can reasonably conclude that communities hit by cyclones have also to face higher food prices for up to seven months after the events, and that the severity of the cyclone seems to also influence the severity of the price peak.

As far as the food loan (FL) indicator is concerned, the pattern which emerges from the three types of models is relatively consistent and coherent. With the exception of the Oct 2000 events, all the other models in the individual-event models (Table 18), the joint (Table 20) and the combined models (Table 28) indicate that households affected by cyclone take a greater number or greater amount of food loans than communities that are not affected by these cyclones. The pattern seems stronger for severe events (>40 m/s). This finding is also in line with the results observed for the food prices indicators described above.

In contrast the results obtained for the food expenditure (FE) indicator are not clear. While the individual-event models (Table 18) tend to suggest that cyclones are associated with higher levels of food expenditure amongst the households that have been affected by cyclones, this finding does not hold for the specific event of Nov 1998, nor for the joint models (Table 20) or the combined models (Table 28). Instead for these models it would seem that affected households spend less than households in non-affected areas, a result which, given the pattern observed for the food prices and the food loan indicators remain difficult to explain.

The overall picture in terms of food security for these households is therefore relatively similar to that obtained for the flood and drought analyses proposed above. While the food prices indicators unambiguously suggest that the local economy of the communities where these events have stricken is affected by higher food prices, the impact of these higher food prices on the household food security indicators measured by the NSP is not clear and coherent.

4.4 Salinity intrusion

For salinity intrusion, two series of models were used: the DiM model in which the different nutrition indicators and food security and food price indicators (Table 22 and Table 23) were compared between regions affected and regions not affected by salinity intrusion, and the combined-event models (Table 27) where the same comparison was made but accounting also for flood and cyclone impacts. In this present section we pooled together the results of these two analyses with the objective to identify common emerging patterns/trends. As only two series of models were possible however (as opposed to three or four as in the case of the drought, cyclone and flood events analysed above) the robustness of the conclusion is reduced, in particular when the two types of models diverge in their findings.

4.4.1 Nutrition indicators

Both the DiM and the combined effect models show the same, consistent, pattern for the five nutrition indicators (Table 22 and 25). The two models show a strong, statistically significant negative association with the zlen and the zwfl scores and with the maternal BMI in the communities that are affected by saline intrusion. These results are in line with what we could have expected especially given the accounts that were also collected through the qualitative analysis. Salinity intrusion has been a recurrent and increasing issue in the southern belt, affecting literally every aspect of people's life, livelihood, farming activities, human and livestock health, on a daily basis. There is therefore no surprise that this situation has some severe repercussions on the nutritional status of the children but also the women living in the area.

What seems more surprising –at least at first sight- is that in these conditions the child and maternal dietary diversity indexes dd and DD turn out to be higher than in other (non-affected) parts of the country. This finding does not fit well with the numerous accounts collected during the interviews where people report how increased salinity intrusions (especially in the recent years) have affected their ability to grow vegetable, fruits and other food items. One possible explanation for this is that people in these areas have a more market oriented diet, due to the loss of subsistence agriculture to shrimp farming.

Irrespective of whether or not the communities managed to maintain or even to increase their dietary diversity, there is statistical evidence that the nutritional status of both children and women (in particular the short term (wasting) and longer term (stunting) scores of children, as well as their mothers' BMI) are negatively affected by the chronic exposure to high salinity. These findings were vividly illustrated (and corroborated) by the various accounts that were collected directly from respondents during the qualitative analysis.

4.4.2 Food security and food price indicators

Both the DiM and the combined models show some strong relationships but not necessarily in the same direction for all the indicators. The two analyses converge to conclude that as far as FL (food loan), FE (food expenditures), and PO (price of soybean oil) are concerned, there is strong statistical evidence that salinity intrusion has a negative association with these food security indicators for the communities living in affected areas.

When it comes to the other indicators however the lack of convergence in the findings between the two models is more difficult to summarize. While the simple DiM models (Table 23) suggest that price of rice (PR) and price of food basket (PFB) follow the trend suggested by the PO indicator, (that is, that salinity is affiliated with an increase in local prices), a closer look indicates that this is the case only for the lower level of salinity s1 and s2. For higher concentration the coefficients become negative, suggesting lower prices. Similarly the combined models (Table 28) indicate that the prices of rice and general food basket are lower in saline affected areas than in the rest of the country.

In sum, it is not clear whether the prices of food are effectively higher in the areas affected by salinity and whether this affects households' food budget. This lack of conclusive results is not necessary incoherent. Salinity is indeed a chronic issue and one could expect that the relatively efficient market mechanisms that operate in Bangladesh would have buffered and compensated for the lower local productivity by supplying food items coming from the rest of the country. On the other hand salinity also remains a seasonal problem the effect of which is far more acute and severe during the dry season. It is therefore possible that food prices do show some form of seasonal patterns, with some peak during the period when salinity is at its highest. The combination of both chronic but also seasonal association may be part of the reason why clear results were not obtained in this analysis regarding food price indicators.

4.5 Summarizing the findings

Table 29 is an attempt to summarize the different results that were generated across the various models for each type of event. Reducing these results in one table could be useful to comprehend the 'big picture' but should be considered with caution as the table does not necessarily reflect the nuances or the caveats that were highlighted in the individual sections above. The main feature that emerges from the table is the complexity and inconsistency in the results. (See table 29, in next page)

4.6 General discussion

Bangladesh has experienced an increased number of severe flood events in the last decade (MoEF 2005). Recurring floods occurred in 2002, 2003, 2004, and twice in 2007 (July-August and September). During the writing of the report (Aug. 2014), severe flooding hit the northwest of the country, in the area where the qualitative data was collected. Similarly Bangladesh -like many other south Asian countries- has been affected by more frequent and more severe tropical storms and cyclones (World Bank 2010). This increase in frequency and intensity of weather-related shocks is generally attributed to the aggravated changes in the climate (IPCC 2012). Yet in the last 40 years the number of deaths in Bangladesh related to these types of climate-related extreme events has been decreasing substantially (Fig.12), highlighting the impressive progress that the country has achieved in relation to disasters by investing in early warning systems, preparedness and capacity building at all levels.

The question in this context is: will Bangladesh still be able to continue its current progress in reducing the

Table 29. Summary of the quantitative analyses by events and types of models

Event	Single-event models	Joint-event models	Combined-event models
Flood	■ strong lagged negative effect on zwfl; negative but less strong impact on zlen ■ lagged negative impact on dd and DD but not clear pattern on BMI ■ no clear pattern observed for food insecurity but increase in the price of rice and the price of food basket with statistically significant values (especially for 1998 event	■ strong lagged negative effect on zwfl especially around 5 month lagged period; negative but less clear impact on zlen ■ positive impact on dd and DD for severe events but no clear pattern on BMI ■ strong positive and significant lagged impact on the food insecurity and food price indicators	**Flood-drought combined** ■ relatively strong negative lagged impact of zwfl (especially around 5 month lagged period) but no significant impact on zlen ■ no impact on BMI, strong positive impact on DD and dd for severe flood events ■ relatively clear positive impact on both food insecurity and food price indicators especially for severe flood events
			Salinity-cyclone-flood combined model ■ strong negative impact on zwfl and no clear pattern on zlen and maternal BMI ■ strong positive impact on DD and dd ■ positive lagged impact on the three food indicators but unclear pattern for loan and food expenses
Drought	■ no consistent or clear pattern for zwfl and zlen ■ BMI and dd and DD not available for a DiD analysis ■ some degree of positive impact on the food insecurity and food price indicators but not consistent	■ probable negative impact on zlen but no totally consistent or clear pattern on zwfl ■ no consistent or clear pattern on BMI, dd or DD ■ strong and consistent positive impact on food insecurity and food price indicators	**Flood-drought combined** ■ negative lagged impacts on both zwfl and zlen ■ not significant negative impact on BMI, but positive impact on dietary diversity DD and dd around 7 month lag ■ relatively clear positive immediate as well as lagged impact on both food insecurity and food price indicators

Event	Single-event models	Joint-event models	Combined-event models
Cyclone	▪ no clear pattern on zlen and zwfl ▪ BMI and dd and DD not available for the DiD analysis ▪ possible positive effect on FE, but unclear pattern for the other food insecurity and food price indicators	▪ strong lagged negative impact on zwfl but also some degree of positive impact on zlen ▪ unclear pattern for BMI, dd and DD ▪ consistent and strong positive impact on PR, PO, PFB immediately and for 3 months after the event; also some positive impact on FL, but strong and negative impact on FE	**Salinity-cyclone-flood combined model** ▪ negative impact on zwfl and on dietary diversity DD and dd, but strong lagged positive impact on zlen ▪ unclear pattern on maternal BMI ▪ positive impacts on FL, PR,PO and PFB immediately and for up to 5 months after the events, but strong negative impact on FE
Salinity	▪ negative and statistically significant association with zwfl, and negative and statistically significant association with zlen in the most affected areas ▪ strong positive impact on dd but no clear impact on DD ▪ possible strong positive impact on BMI ▪ consistent and robust positive trends for all the food insecurity and food price indicators except PFB		**Salinity-cyclone-flood combined model** ▪ strong and statistically significant negative impact on zlen, zwfl, and maternal BMI ▪ strong positive association with DD and dd ▪ positive effect on FL and FE but inconsistent negative association with food price indicators

impact of these climate-related extreme events, or will the increased intensity and severity of these disasters that is predicted in the future eventually overcome the resilience capacity of the country?

Our research contributes to answering this question. The impact of climate-related extreme events is not simply measured in number of deaths, affected people, or economic losses. The effect of these shocks also relates to indicators such as food security and nutrition which affect death, economic losses and other indicators. A vivid example in the Bangladesh context is the 1974 flood. While the flood per se only induced a relatively limited number of deaths, the devastation caused by the flood contributed to the failure of the rice harvest, leading to local shortage of food and price rocketing. The impact on the rural poor population has been catastrophic. Although figures vary, it is estimated that more than 1 million people died. The poor, labourers and landless were especially affected. Direct starvation was not the only factor though; a significant number of deaths was attributed to diseases, such as cholera, malaria and diarrhoeic diseases: as calorie consumption fell below survival thresholds, weakened disease-susceptible conditions resulted in high post-famine mortalities of over 450,000 (Sobhan 1979).

Our understanding of the impact of climate-related shocks and stresses on food security and nutrition however is still relatively limited. Overall, while some studies are available in the literature (e.g. Rayco-Solon et al. 2002; Maleta et al. 2003; Fuentes and Seck, 2007), these are mainly based on isolated, selected events. In Bangladesh Del Ninno et al (2003) focused on the 1998 flood. Bloem et al (2003) provide a more comprehensive picture by looking at the potential effect of floods, cyclones and droughts. Their work

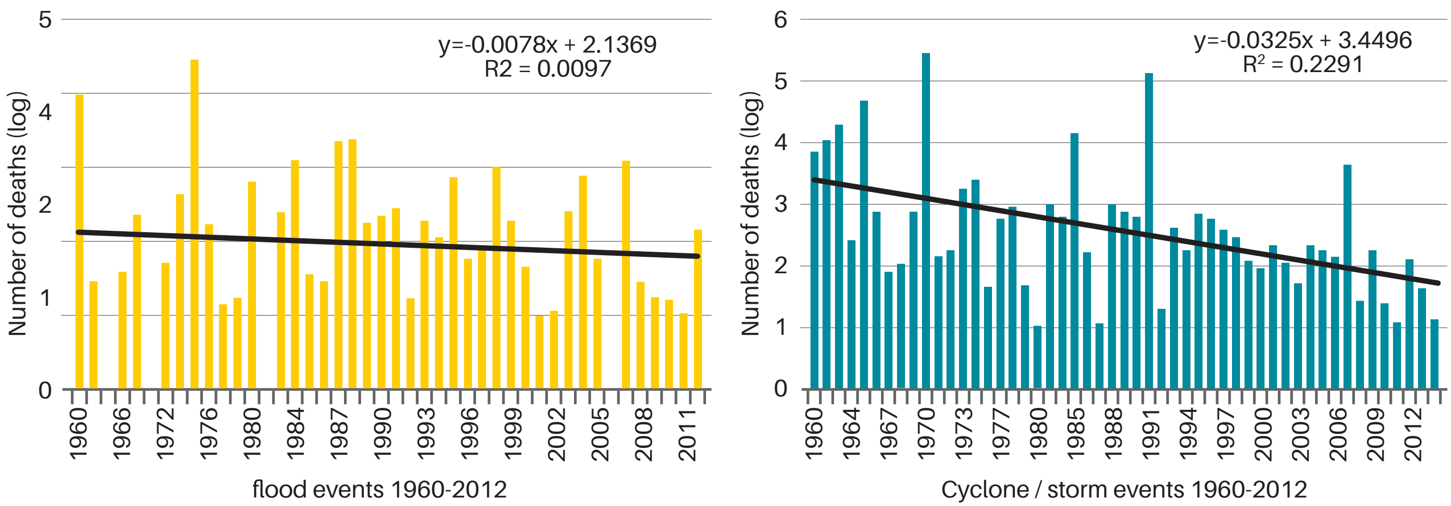

Fig.12. Recorded number of deaths for flood and cyclone/storm events in Bangladesh over the period 1960-2012 (source data: EM-DAT)

was useful in that it successfully highlighted the potential of high-frequency collection of nutritional data. But their analysis was primarily descriptive and only considered a single event at a time. More problematic is the fact that they did not provide any statistical evidence of their findings which remain based on visual analyses.

In this context this study is the very first of its kind. It includes a comprehensive analysis of (initially) 6 climate-related extreme events/ shocks and stresses: drought, flood and flash flood, river erosion, cyclones and salinity intrusion, and proposes to analyse the impact of these different types of events over a long period (1998-2006), relying on a rigorous, systematic and replicable approach that combines household-level nutritional and food security data with environmental time-series data while controlling for individual and household characteristics. It is also unique in that it is the first analysis that (in addition to single types of events) also combines multiple events of the same types (e.g. several successive drought events) in one single model, and different types of events: drought and flood together; and cyclone, flood, and salinity together –with the underlying assumption that communities that are affected simultaneously and/or consecutively by several different shocks are likely to face even harsher conditions than communities that are affected by only one type of event. Finally it further complements these quantitative analyses with a series of qualitative information derived from primary field data.

The conceptual framework we used to structure our research was also one which embraces the question from a comprehensive/holistic angle. It derives from the UNICEF 1990 Strategy for improved nutrition of children and women in developing countries framework (UNICEF 1990), the IDS/DFID sustainable livelihood framework (Scoones 1998) and builds on some recent thinking around resilience to shocks in the context of food security (WFP 2009; Gubbles 2011; Béné et al. 2012; 2014). The analytical framework helped us identify a whole series of variables and interactions which are, in theory, important if one aims to assess the food security and nutrition status of communities exposed to climate-related extreme events but also the specific resilience strategies that are adopted by households and communities as a response to these shocks. Not all of these variables (or their proxies) were available, however, or were available but not in a form or a frequency that was optimal for this analysis. While this situation did not affect our ability to address the main objective of the study –to analyse in a comprehensive manner the impact of climate-related extreme event/shocks and stresses on the food security and nutrition of households- it did limit our ability to explore some aspects related to the resilience dimension.

4.6.1 Strong and consistent 'stories'

Amongst the most robust results that emerge from this analysis, is the case of flood. Our analysis shows with strong statistical evidence that the prices of rice, soybean oil and more generally food basket are usually greatly affected by flood events and that this effect lasts for up to nine months after the flood. This is consistent with the findings of the qualitative analysis which reveals that while most food items are available at the local markets, their prices are higher than in a normal period. The analysis also shows –again with robust statistical evidence- that the amplitude of the price peaks reflects the severity (length) of the flood events.

In these circumstances we would expect the food expenditure indicator to have some strong positive values suggesting that households invest a larger share of their expenditure in food expenditure in order to smooth their consumption. The analysis however doesn't show such strong trend. Part of the explanation for this is perhaps the fact that –again, against our expectations- the analysis also fails to find strong evidence that households affected by flood take more food loans than households that are not affected by the same shock.

In terms of nutritional situation the analysis shows with strong statistical evidence that the weight-for-height z-score, which is an indicator of acute undernutritional status, is lower (i.e. worse) amongst children who live in communities affected by flood than in the control communities, and that this 'peak' of acute undernutrition occurs around five months after the flood event. Furthermore it seems that the impact increases with the severity of the flood. The analysis however did not find any evidence that flood contributes to chronic undernutrition, or to reduced maternal body mass index, or to lower dietary diversity in the areas affected by floods. However, the qualitative analyses showed that households report giving the most food to children while women tend to be the ones to sacrifice quantity and quality. This practice could be attributed, in part, to higher relative energy needs of children.

The overall picture for the flood-affected households is therefore mixed. While it appears that children in these communities suffer from acute undernutrition during several months after the event, the other nutrition indicators along with the food security indicators do not seem to show any significant negative impacts.

The second robust story is about drought. Our analysis shows some strong evidence that price of food after drought events is affecting households in the areas where these events occur. The three indicators of rice, soybean oil and aggregated food basket price display consistent and statistically significant positive coefficients from the period of the event up to nine months after the beginning of the drought. The analysis also suggests that for rice and aggregated food basket the price peaks occur around three months after the event. This also corresponds to the time when the households show the highest rate of food loans and food expenditure, suggesting that as a response to the price peaks triggered by droughts, communities increase the share of their total expenses allocated to food and that they do this (at least partially) by taking food loans.

These strategies, however, don't seem sufficient in preventing chronic undernutrition amongst the children living in these communities. Our analysis found strong statistical evidence that drought events are associated with lower children's length-for-age z-score (higher stunting rate) around five- and nine-months after the drought event started. On the other hand, no robust or consistent effects of drought on level of children's acute undernutrition were found. Likewise the analysis did not find any strong robust evidence that drought events affect statistically the mother's body mass index, or the children and maternal dietary diversity indexes.

The overall picture in terms of nutrition for these households is therefore one where the major effect of drought events seems to be a lagged impact on the chronic undernutrition level of the children.

The third robust story relates the impact of cyclones. First the analysis of the three food price indicators provides strong statistical evidence that communities hit by cyclones have also to face higher food prices. These price peaks can last up to seven months for the most severe cyclone events but are generally shorter for lower intensity storms. Data also show that households take (statistically) higher food loans only for these more severe events. On the other hand the impact of cyclone events on households' food expenditures was not what was hypothesized. Data shows that affected households spend statistically less on food than households in control (i.e. not affected) communities. One possible explanation for this counter-intuitive finding is that households affected by storms and cyclones spend a larger portion of their total expenses on covering the costs of rebuilding assets, and thus reduce their food expenses.

Perhaps as a consequence of this reduction in food expenditures, the data also shows that cyclone events are statistically strongly associated with lower weight-for-height z-scores (higher wasting) in the communities affected by these cyclones; and that the impact increases with the severity of the events. In fact for the most severe cyclones (>40m/s), the statistical significance covers the whole period from zero to seven months after the event. The analysis indicates that cyclones may have also negative impacts on both the maternal and the child dietary diversify indexes with a lag of five to seven months after the event. On the other hand the evidence of the impact on maternal body mass index is not strong.

Based on these findings we can reasonably conclude that cyclones contribute significantly to the level of acute undernutrition of the children living in cyclone-prone areas and affect equally the ability of the mother to maintain their dietary diversify and that of their children.

The last robust story relates to the association of saline intrusion with the food security and nutrition status of the population living in the coastal belt. While the analysis is relatively inconclusive regarding the possible association of salinity with the price of food in these regions, the statistical models also provide robust evidence that communities affected by high salinity are characterized by higher food loan rates and food expenditure levels than communities in the rest of the country, thus suggesting some degree of vulnerability in relation to food security.

In that context it is not surprising that the analysis also indicates that both child acute and chronic undernutrition levels are statistically higher in these saline-prone areas than in the rest of the country. Similar conclusions apply to the maternal body mass index of women in the same communities.

4.6.2 Less consistent results

In addition to the most robust findings summarized in the previous section, our research also reveals some less consistent and counter-intuitive results. Two of these emerge as particularly challenging. They both involve cases where the statistical models indicated a coefficient sign opposite to what the theory would expect.

The first one includes findings generated by models related to three types of events: flood, drought and salinity. In these three analyses the sign of the dietary diversity indexes dd and DD appears to be statistically positive. In the case of flood this finding was visible for the severe levels of flood (20; 30, 50 days) under three different models: the joint model, the drought-flood combined model, and the flood-cyclones-salinity combined model. In the case of drought, statistically significant positive coefficients for dd and DD indexes were also observed, with several lagged periods, in the joint-events models and the flood-drought combined models. And finally in the case of salinity, these positive coefficients were found in the DiM models and in the combined flood-cyclone-salinity models.

This pattern of positive coefficients would suggest that the child and maternal dietary diversity indexes are higher in communities affected by floods, droughts, or saline intrusions than in the control communities. This finding does not match the hypothesis tested, that these shocks have negative impacts on the child and maternal dd and DD indexes, but it also does not fit well with the accounts collected during the interviews in salinity-prone areas for example where respondents reported how increased salinity intrusions affect their ability to grow vegetables, fruits and other food items, or affect wild fish species.

No definitive explanation can be provided to this. Earlier in this report (see footnote 30) we discussed the possibility that the way the dd and DD indexes are calculated does not allow to reflect appropriately changes (and in particular degradation) in the diversity of the daily dietary intake (e.g. three times a day versus once a day). While this criticism is valid in general, it cannot be used to explain a positive difference. Alternatively, studies in Sub-Sahara Africa have shown that in areas characterised by initially low diet diversity due to strong mono-food preference, shocks affecting households can lead them to compensate for food scarcity by diversifying their source of food -thus leading to a higher diet diversity index. This hypothesis would have to be tested further.

The second counter-intuitive result that was observed across the different analyses is the positive (and statistically significant) series of coefficients that were found with the zlen (stunting) indicators under the joint cyclone models and the salinity-flood-cyclone models. The result suggests that children' length-for-age z-scores are consistently and statistically higher amongst children who live in cyclone-prone areas than in control areas. Here again we are not in a position to provide any robust explanation for this result.

4.6.3 Additional important insights

Beyond the results presented above which derive essentially from the quantitative analyses, other important information emerge from the research.

■ *The importance of rice and starch*

Given the emphasis on rice and potatoes in the diet (i.e., everyone eats rice three times per day in normal times and potatoes every, or almost every, day), the absence of these two items would pose a challenge to local rural populations. Rice and potatoes are some of the cheapest and most filling items in the market, hence their ubiquity in the diet; they are also the most affordable following a disaster event. In Satkhira for instance, where participants indicate that they already consumed leafy green and red, orange, and yellow vegetables with high frequency prior to a disaster and prior to the rise in salinity levels, the high cost at the market, coupled with low production at home, means their diets have now become even more reliant on starch through grains and starchy tubers on a regular basis.

Key role of fish in normal and disaster times

Interviews suggest that in normal times, consumption of red meat, poultry, or other flesh foods tends to be only one to two times per month, which means that these are not eaten with enough regularity to provide sufficient nutrient contribution. Along with eggs, fish in these circumstances is the only source of animal protein which is consumed with regularity. Fish, in particular the small freshwater species such as mola that are consumed whole in most parts of Bangladesh, are also a very important source of micronutrients (vitamin, calcium, phosphorus, iodine, zinc, iron and selenium). Not everyone however owns a fish pond or is involved in fishing. In our case less than half of the respondents catch fish in normal times. The main source therefore to access fish during normal times remains the local market.

During flooding, however, fish actually become a renewed source of nutrition for residents in flood prone areas and more fish are consumed during this time than in other times -our data indicate for instance that after flooding, fish consumption increases to at least once per day for most respondents. Likewise, fish are an easily accessible source of protein for residents who have lost poultry and other livestock through flood or other shocks and stresses. This, combined with the fact that in the wake of disasters, sources of animal protein (other than fish) are not available for several months and consequently that consumption of meat decreases even below the ordinary (already) low level, makes fish an absolutely critical element in the food security and nutrition of populations affected by these extreme events/shocks and stresses.

Saline intrusion makes everything worse

For residents in southwest Bangladesh, salinity in the soil and water is the one lasting effect from all climate-related disasters or events. Although it may be caused and continued by intense shrimp farming, all other negative associations seem to be related to the salinity problem in the minds of this population. For example, in a cyclone or flooding, whatever livestock survive the storm is then likely to die from drinking saline water or from disease somehow attributed to saline, or has to be sold because no fodder grows in saline soil and because food has then to be purchased and is expensive. In a drought situation, not only does the water table recede, but what is left or available usually turns out to be highly saline and unusable. The cyclone may wipe out gardens and crops, but salinity levels in soil and water remain too high for production to return to normal and people are, therefore, reliant on the market to get food for an extended period of time. Foods produced at home, both plant and animal, have changed over time in response to rising salinity levels, with fewer vegetables and fruits grown on the homestead. Water usage is altered out of necessity. More tubewells have been set, aluminum sulfate is used to clean water, and pond water is no longer a common source for drinking or bathing. Diarrhoea and skin diseases are common in humans, and disease has increased for fish and livestock.

Children's nutrition protected at the detriment of the mother?

Although families are reporting notable impacts that should be negatively affecting nutritional status (see above), behaviours such as giving the most nutritious foods to children may offset these effects, especially if the situation gradually improves from the time of the disaster to a normal state within a few months.

Coping strategies, such as eating fewer meals per day, eating less at each meal, skipping meals, eating less preferred foods, and decreasing dietary diversity were consistently listed as post-disaster coping strategies employed to bridge the household to better times. This is in line with other recent analyses (HKI-JPGSPH 2011; 2012; 2014). But the respondents also made clear that children are usually given preferential treatment to ensure their health and survival, being given the most nutritious food and the last to make sacrifices at the dinner table.

Women, on the other hand, make the biggest sacrifices, being the most likely to go hungry and not eat. This again is in line with the findings of the most recent Food Security and Nutritional Surveillance Project (FSNSP) report. Interviews indicate that in half of the households, only women eat smaller portions, while the dominant male-female pair, usually husband and wife, eats smaller portions in the other half of the households. With the male-female pairs, this behaviour seems to derive from a feeling of household responsibility, as evidenced by this quote from one mother-in-law and father-in-law, "we are the guardians of the family". For the households where only women eat smaller portions or skip meals (apart from one female-headed HH), there is a different sentiment. "Women should eat less". "Women always eat less". Children get the most nutritious food in the household, as well as the adult males if there is enough.

■ *Nutrition not a priority after a disaster*

During a disaster (cyclone, flood, river erosion) people experience significant hardship in terms of economic losses due to destruction of property, livestock, gardens, and other assets, and the absence of income. Our data indicates that diets are also significantly altered in the wake of a disaster. While in normal times, the diet relies heavily on rice and potatoes –with already less than ideal dietary diversity from vegetables, fruits, and animal source foods to obtain a range of micronutrients-, those foods are almost always missing from the post-disaster diet, which tends to consist of rice and dal, as well as potatoes (i.e., foods that can be easily stored) for several weeks to months. These findings suggest that nutrition is not a significant factor in decision-making around food choices during these times as most people are concerned with eating anything at all and making what little they have stretch until they can acquire more.

Both availability and accessibility of food can be an issue. Vegetables for instance have limited availability in the first week following a climate event and few people have access to them. Even after one month, vegetable consumption remains less than normal, appearing to be around half of what is usually consumed, or not at all, with people eating fewer times a week or eating smaller amounts. The data suggest in fact that, nutrition was not presented by the respondents as a key-factor considered in consumption-related decision-making after a climate event. Because money and jobs are scarce in the wake of a disaster, the primary concern is price of food, with quantity and shelf-life being secondary concerns. Nutritious food is available in the market not long after, but access is hindered by lack of money to purchase nutritious food. In sum, optimal or even adequate nutrition is not a priority in the immediate period right after an event, but can be considered once economic and food security allows for the luxury of making decisions around eating for nutrition instead of eating for hunger.

Chapter 1 2 3 4 **5**

Concluding remarks and Recommendations

Concluding remarks and Recommendations

Integrating food security and nutrition into climate sensitive programmes

The main conclusion of this research is certainly the confirmation that climate-related extreme events/ shocks (floods, droughts, cyclones, etc.) or induced stressors (salinity intrusion) have negative impact on the food security and nutritional indicators of households living in affected areas. Although the pathways are shock specific and vary in nature (acute and/or chronic undernutrition, reduced diet diversity, or high food prices, etc.) and in intensity, all the different types of climate-related event which we investigated show some form of impact on the food security and/ or nutrition status of the affected communities: drought events lead to periods of high food security distress and worsen children's chronic undernutrition; floods affect food prices and contribute to acute undernutrition; cyclones lead to periods of high price and aggravate acute undernutrition; and saline intrusion is associated with values of food insecurity and strong evidence of children's acute and chronic undernutrition.

Following these findings, the first recommendation of this report is for governments and international development agencies to ensure that food security and nutrition interventions are better integrated into climate change focussed programmes. In particular interventions aimed at strengthening people abilities to protect food security and nutrition at individual, household and community level should be more systematically included in climate change programmes and climate-related post-disaster or resilience interventions. While the link is often implicit (or even sometimes just rhetorical), it needs to be made more overt and direct in these climate change-focused programmes. One way to ensure this stronger integration would be to make sure that nutrition indicators are part of the indicators included in the initial targeting mechanisms of these Climate Change or Resilience programmes and in their M&E systems.

The key role of markets

Along with the impacts of climate-related events on nutrition and food security status, another major result stressed by the research is the critical role that markets and in particular food price dynamics seem to play in relation to these issues. Part of this finding is not necessarily new –accessibility/ affordability of food commodities has been recognized for long to be a key dimension of food security.

What the present analyses revealed however is the even more critical role that food accessibility seems to play in the aftermath of disasters. All the models we ran converge to highlight that the price of food commodities is consistently higher in the weeks and months following a disaster (irrespective of the types of shocks considered). While the exact impact pathway between these high food prices and the final outcome measured in terms of nutritional indicators seems to be shock specific and would deserve further research (see recommendation below on the need for in-depth quantitative and qualitative studies) it seems reasonable to assume that there is a strong link between the degradation in nutritional status as we observed in the communities affected by shocks and the peak in the prices which are occurring conjointly in the same communities.

The recommendation that follows is that national governments and disaster relief agencies should prioritize market price stabilization mechanisms as critical interventions to be put in place in the aftermath of (or perhaps in preparation to) shocks. Interestingly this rejoins the conclusion of Del Ninno et al. (2003) in the specific context of the 1998 floods where these authors highlighted the key role that the government played in stabilizing rice markets during and after the flood and claimed in particular that these market price stabilization interventions are what distinguish the 1998 flood event from the catastrophic famine that followed the 1974 flood.

From a research perspective, more insights into the mechanisms through which prices increase is required, as the relationship is not clear. For example, failed harvests and lost food stores would logically lead to an increase in rice prices and the cost of other local agricultural commodities, but the mechanism through which edible oil prices are increasing is not clear. Without knowledge of these mechanisms, design of maximally effective relief and recovery programmes is impossible.

Implications for disaster and rehabilitation programmes

The lagged effects on child and maternal nutrition which have been observed in most of the models open up new vista of phase-wise in-depth assessment of impacts at different stages of disaster relief and rehabilitation process. These findings clearly indicate that different types of climatic shocks and stresses affect child nutrition in different dimensions, pointing towards a need for more in-depth shock specific and context specific research on children and maternal nutrition. Moreover, the higher food prices after drought, flood, and cyclone – and its prolongation up to 9 months after the event – urges us to review our conventional disaster response and rehabilitation approach.

As immediate response, strategies like specific focus on nutrient rich foods that are available after a disaster; and communicating key messages about food sources that are plentiful after a disaster could be very useful. Women's increased burden during disasters (see below) should also be made a center point in household level response. In addition, more research is needed on the cyclical effects of coping strategies and the impacts of repetitive events on households. This knowledge will allow programmes to encourage coping strategies that promote food and nutrition security in both the near and far terms.

Strengthening the resilience of households to climate-related events

Although the household resilience mechanisms could not be explored thoroughly through this study, it is clear that strengthening the capacities of the local populations affected by climate-related events and help them respond more appropriately to the impacts of these events (in particular by reducing their propensity to adopt detrimental short-terms responses) would go a long way in reducing the negative effects of climate-related events on the nutrition and food security of the local populations.

The authorities in charge of disaster management (both at national and provincial/district levels), along with international organizations working on the same agenda, should invest in improving their understanding of the types of strategies that households and communities adopt in response to the various shocks and stressors that they face and identify ways to strengthen the capacities of the local population and local authorities in developing and adopting adequate responses which have long-term non-detrimental impact on the wellbeing of households members, in particular women and children.

The critical importance of high frequency data surveys

In the case of standard welfare measures such as poverty, occasional snapshots from household surveys (such as HIES) usually suffice to give a general pattern of ill-being across regions and countries, as well as basic trends. However, these standard household surveys are too infrequent to assess the consequences of shocks. In fact even in the fortunate but very rare case where a standard household survey is scheduled and effectively administrated just after a disaster –thus in a position to capture the short-term, direct effect of that shock- the next round of data collection usually doesn't occur soon enough (often only few years later), thus missing the opportunity to provide critical information on the post-disaster recovery process (a crucial phase for which we still have very little information).

In contrast, because of its high-frequency nature, the NSP allows us to observe the consequences of sudden shocks on the nutritional status of children and their mothers of a given community and to monitor these impacts over time. Rapid or progressive changes in indicators can therefore be identified, thus providing essential information to describe and understand the way shocks affect households and their most vulnerable members, and how households respond to these effects in the months following the event.

In addition to its high frequency the NSP presents another key advantage. Complementing the nutritional indicators (stunting and wasting scores, BMI, and diet diversity indicators), the NSP also collects in the same sampling frame socioeconomic information such as household demography, socioeconomic status (including main livelihood strategies, food expenditure share, etc.), local food prices, and –very importantly- coping strategies (e.g. food loan), which allows us to obtain a broader, more comprehensive and systemic understanding of the overall circumstances (including possible mal-adaptive household responses) that may account for inadequate nutritional outcomes.

The recommendation that follows from this is that governments, international development agencies, and research organizations will need to support existing, or invest in new, high-frequency, comprehensive household surveys if they want to be able to integrate more appropriately the question of the impact of shocks in their planning and policy decision-processes. The scaling up of routine high frequency surveillance systems through national institutions such as governmental structures would also stimulate and facilitate further research.

The need for in-depth quantitative and qualitative studies

Without high-frequency surveys it would be difficult to monitor the key variables that are critical to improve our understanding about how extreme weather-related and other types of shocks affect people's food security and nutrition. As this research has also demonstrated, quantitative analyses (even derived from high-frequency surveys) would however only provide a limited vision of the reality on the ground and it is essential to recognize that qualitative studies are also critical to ensure that the whole picture emerges. A mixed approach combining both qualitative and quantitative is therefore necessary.

What this study has also shown is that working on identifying possible impacts of climate change on household food security and child and maternal nutrition is complex and data demanding. More importantly none of the major, robust, conclusions were reached relying on the result of just one test. Instead these conclusions emerged after comparing and combining the results of tests or after triangulating the quantitative and qualitative analyses. The importance of combining several events in order to reach robust conclusions also means that one needs to resist the temptation of cherry-picking single cases in order to 'demonstrate' what we think are the 'coherent' findings. This is a difficult task as the pressure from the scientific and policy-makers' communities is strong and research studies are expected to generate findings that are in line with the main current narrative.

Yet we still know very little and many questions remain. For instance while the data suggests that communities hit by climate-related shocks such as flood, drought or cyclones are all likely to face subsequent periods of high food prices, the analysis also indicates that a given community may not necessarily respond the same way. For illustration, in the case of cyclones and despite the occurrence of high food prices, affected households spent statistically less on food than non affected households. If this behaviour is confirmed it would indicate a completely different response compared to the responses adopted by households affected by drought or flood events (where the analysis shows that households' food share on expenditures increases). While we provide a possible explanation for this counter-intuitive finding (namely the fact that households affected by cyclones may spend a larger portion of their total expenses on covering the costs of rebuilding assets, and thus reduce their food expenses) this hypothesis still needs to be explored/tested more thoroughly. More generally this result demonstrates that households' responses are shock specific and that assuming a household 'generic' response on which policy and post-disaster interventions can be designed is risky unless we are sure we have perfectly identified and understood the combined effect of the shock's impact and the households' responses.

A review of the literature indicates however that in many cases combined effect of the shock's impact and the households' responses is still poorly understood, if at all. This means that too many decisions/interventions are still being based on a partial and incomplete (or even incorrect) understanding of the situation.

Following these remarks, a recommendation would be for governments, international development agencies, and research organizations to continue supporting research and investigations around these issues. In Bangladesh more analyses should be conducted with the NSP data-sets, which would draw on, expand and deepen the main findings presented in this report. In all these cases the use of mixed methods and combined models that incorporate different types of shocks should be prioritized over cherry-picking analyses based on individual event.

Specific recommendations

In addition to the general recommendations a series of more focussed recommendations can be made, which derive directly from some of the specific findings of the study.

■ *Importance of fish and fishing activities in post-disaster*

The key role that fish (in particular the small freshwater species such as mola that are consumed whole in most parts of Bangladesh) play in the livelihood, food security and nutrition of people in Bangladesh is well recognized and documented (Thilsted et al. 1997; Thompson et al. 2002; Roos et al 2003). What this study reveals however is the key role that fish plays also in disaster and recovery times. While fish (along with eggs) is the only source of animal protein which is consumed with regularity during normal times, its importance in the diet seems to be even more pronounced during and after disasters. Our qualitative analysis reveals for instance that after river erosion and flooding, fish consumption increases to at least once per day for most respondents. This, combined with the fact that in the wake of disasters, sources of animal protein (other than fish) are less or not available for several months, makes fish an absolutely critical element in the food security and nutrition of the populations affected by these climate related shocks and stresses.

On these bases the recommendation would be for the national government and its partners to continue their current efforts to preserve or restore the ecological sustainability of the inland fisheries resources of the country and to ensure that the governance and management mechanisms at both national and local levels recognize and protect the role of fish as an essential source of protein and micronutrients both during normal and recovery times.

■ *Protecting both children and women*

While direct accounts from respondents suggest that children are usually given preferential treatment to ensure that their health and survival are protected, receiving in particular what is perceived as being the most nutritious food and being the last to have to make sacrifices in terms of food consumption, part of this protective strategy is implemented at the detriment of the household's adult female members. Our data reveal indeed that women are consistently those who make the biggest cut in their food consumption and that this altruist (but mal-adaptive) behaviour is for a large part dictated by social rules.

On the basis of these findings, interventions such as behaviour change communication (BCC) programmes need to be put in place by the government in collaboration with its international and local partners to protect children but also women's food security and nutrition in both normal times and in the aftermath of shocks.

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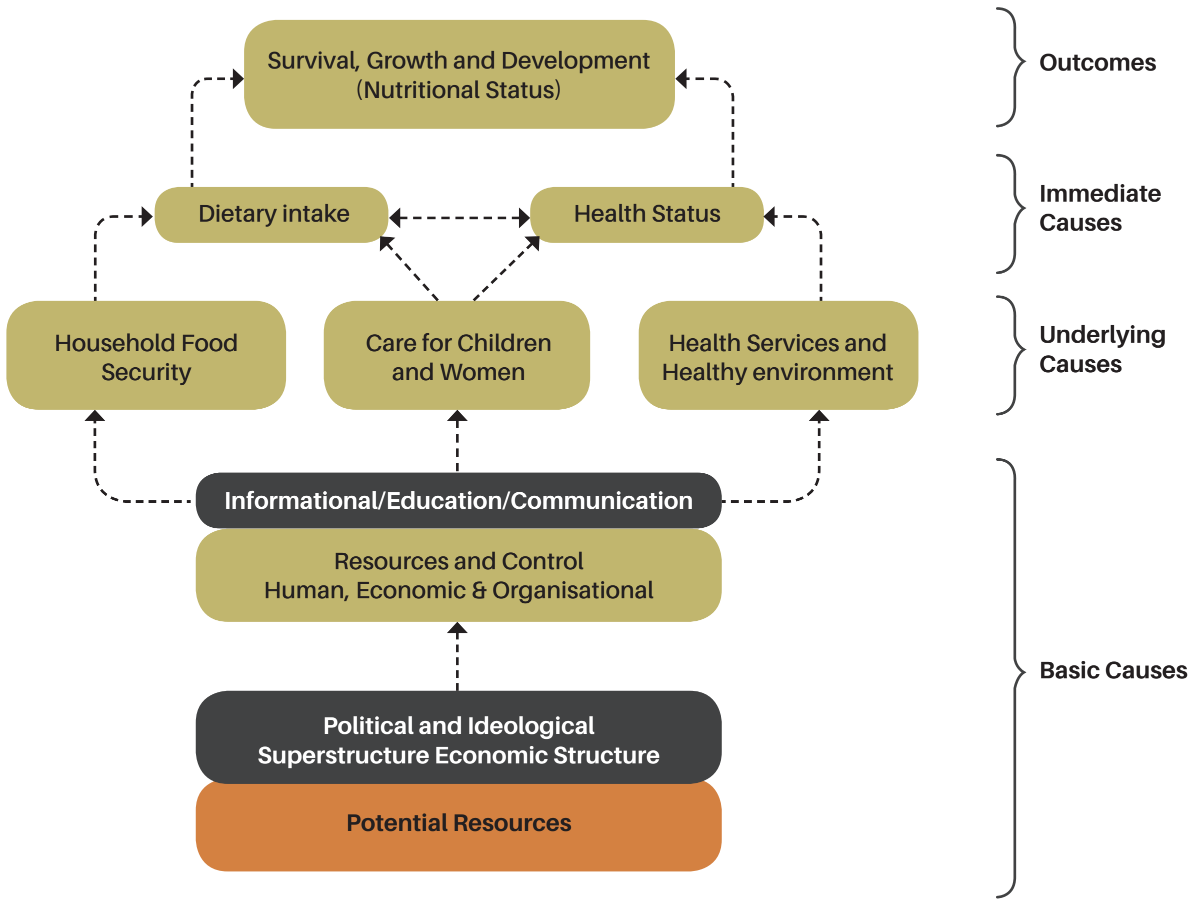
Appendix

Appendix 1

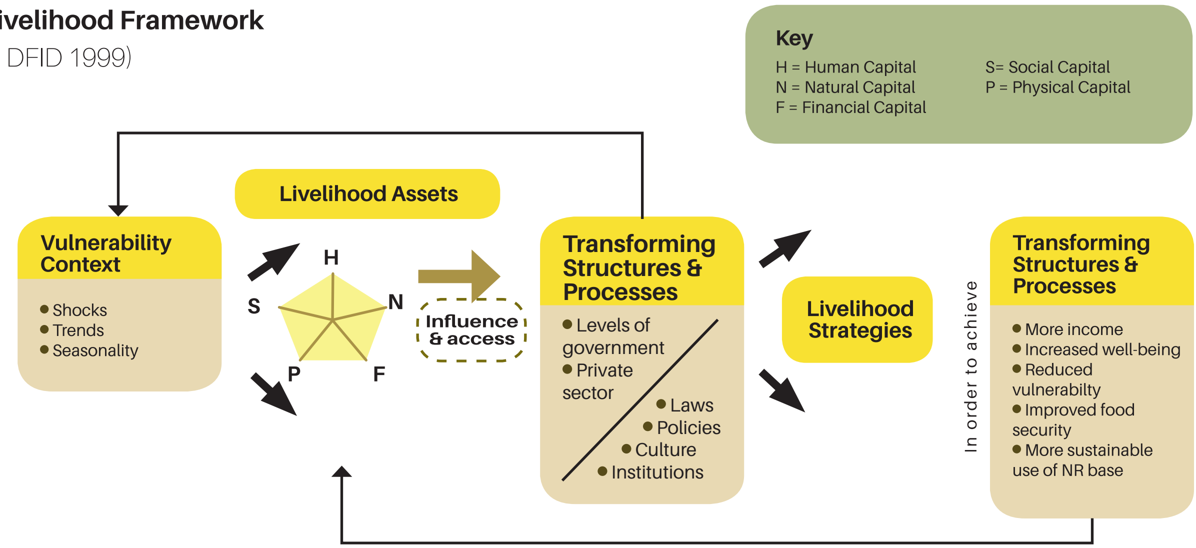
UNICEF 1990 Strategy for improved nutrition of children and women in developing countries framework

(Source UNICEF 1990)



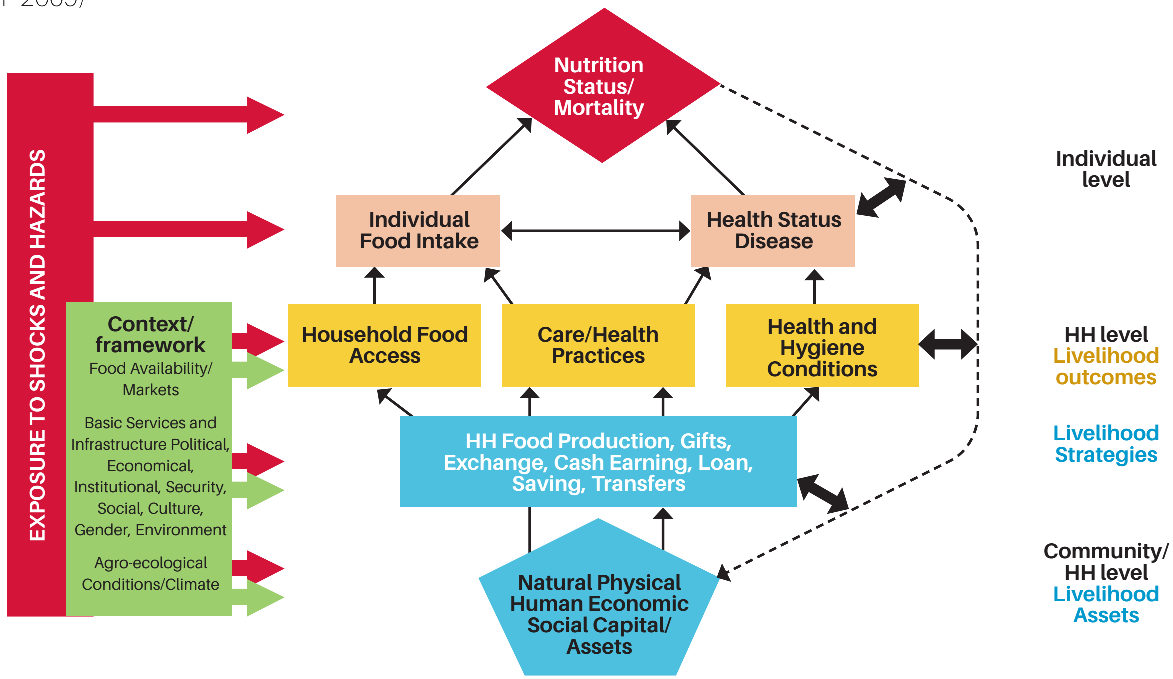
Sustainable Livelihood Framework

(Scoones 1998, DFID 1999)

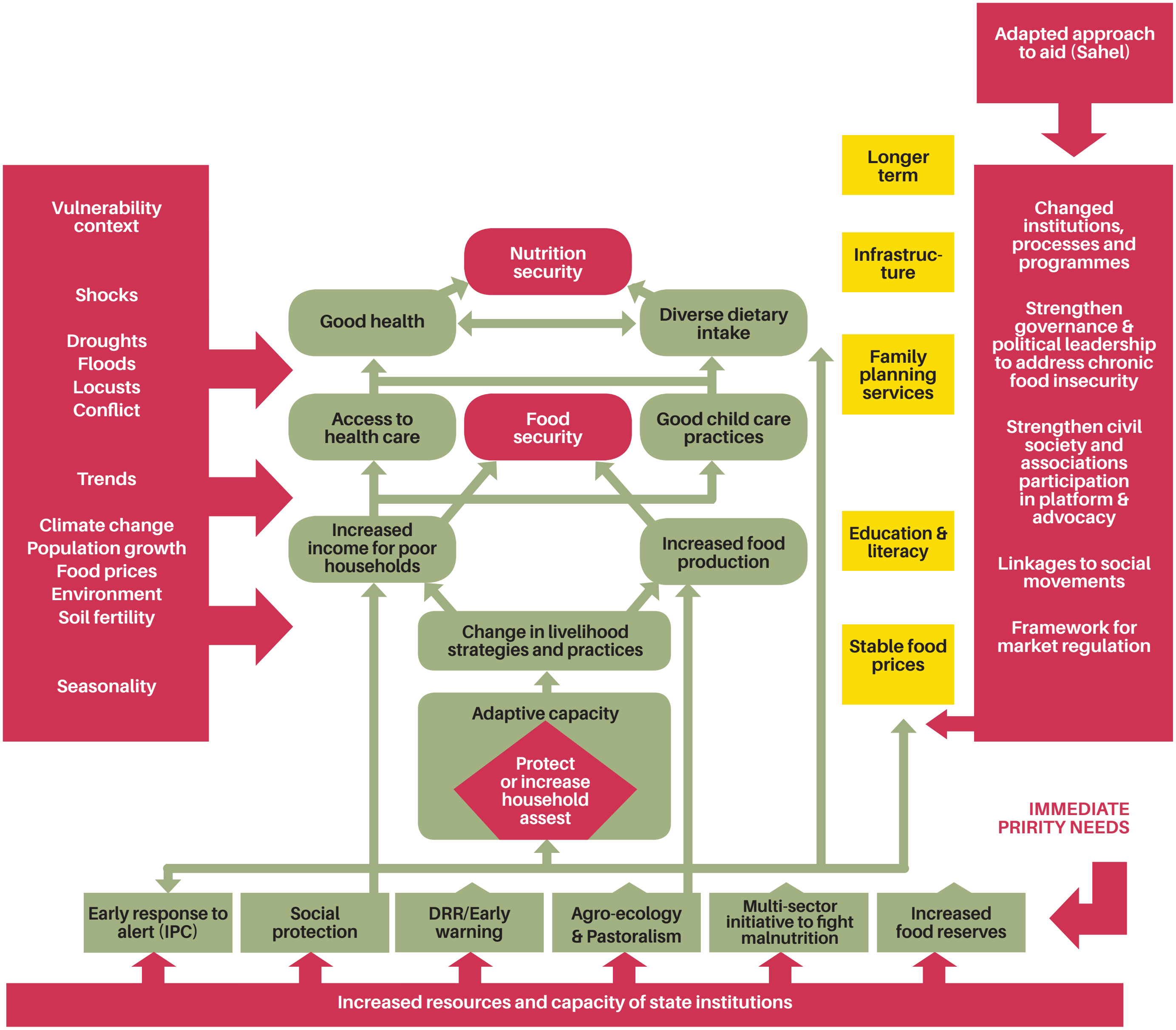


WFP Emergency Food Security Assessment (EFSA) Hand Book framework

(Source: WFP 2009)



Escaping the Hunger pathways to Resilience in the Sahel developed by the Sahel Working Group
(Source: Gubbles 2011)



Appendix 2

District Name	Upazila Name
Thakurgaon	Pirgonj
Kurigram	Chilmari
Sirajgonj	Kazipur
Sirajganj	Raigonj
Pabna	Santhia
Tangail	Mirzapur
Shariatpur	Shakhipur
Manikganj	Saturia
Madaripur	Rajoir
Gopalganj	Gopalganj Sadar
Bagerhat	Morrelganj
Patuakhali	Mirzagonj
Chandpur	Matlab
Comilla	Daudkhandi
Cox’s Bazar	Moheskhali
Cox’s Bazar	Teknaf
Rajshahi	Mohanpur
Naogaon	Manda

District Name	Upazila Name
Maulvibazar	Kamalganj
Kurigram	Fulbari
Jessore	Jhikargachha
Kushtia	Daulatpur
Sunamganj	Derai
Sylhet	Golapganj
Brahmanbaria	Sarail
Comilla	Chouddagram
Sherpur	Nakla
Chittagong	Rangunia
Netrokona	Kendua
Borguna	Patharghata
Bhola	Charfashion
Satkhira	Shyamnagar
Gaibandha	Palashbari
Dinajpur	Khanshama
Kishoreganj	Pakundia

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