The role of extreme events in reaching adaptation tipping points: a case study of flood risk management in Dhaka, Bangladesh

Farhana Ahmed, Berry Gersonius, William Veerbeek, M. Shah Alam Khan and Philippus Wester

ABSTRACT

Adaptation tipping points (ATPs) refer to the situation where a policy or management strategy is no longer sufficient, and adjustments or alternative policies/strategies have to be considered. In developed countries, the main focus of research has been on characterising the occurrence of ATPs in the face of slow variables like climate change. In developing countries, the system characteristics that lead to ATPs are more uncertain and typically comprise a combination of drivers. It is well recognised that policies and management strategies have often shifted in the wake of extreme events like floods. By focusing on flood risk management (FRM), this paper explores the role of sudden or extreme events and other drivers that trigger ATPs. It analyses the historical flooding pattern of Dhaka and policies relevant to FRM, and determines the tipping points for policy-making. A timeline has been established between the flood events, co-drivers, policy interventions and institutional reforms over the last 50 years. ATPs in a developing country context have been found to result from hydrological factors and uncontrolled urban growth as well as foreign intervention, non-implementation or untimely implementation of planned measures and fund constraints.

Key words | adaptation tipping point, flood, flood management, flood risk, urban growth

ABBREVIATIONS

ATP adaptation tipping point
BWDB Bangladesh Water Development Board
BCCSAP Bangladesh Climate Change Strategy and Action Plan
BWFMS Bangladesh Water and Flood Management Strategy
COP Conference of Parties
DAP Detail Area Plan
DWASA Dhaka Water Supply and Sewerage Authority
FAP Flood Action Plan
FPCO Flood Plan Coordination Organization
IPCC Intergovernmental Panel on Climate Change
NWP National Water Plan
NWMP National Water Management Plan

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INTRODUCTION

Extreme weather events like floods, cyclones and storms across the cities of Europe and Asia have often led to major changes in risk management strategies and subsequent measures. A major challenge in creating sustainable long-term strategies is coping with future uncertainties concerning the probability of occurrence, severity and consequences of such events. Several methods are available that incorporate such uncertainties including the adaptation tipping point (ATP) method that has been successfully applied in flood risk management (FRM) to cope with a range of future uncertainties. The method targets the situation where a policy or management strategy is no longer sufficient (i.e., acceptable risk levels are exceeded) and adjustments or alternative policies/strategies have to be considered. The ATP is that decisive moment (Werners 2013) when a new and essentially different policy, strategy or plan is introduced because a long-term driver or extreme event (Kwadijk et al. 2010) causes exceedance of a threshold (i.e., an evaluation criterion) on which the performance of the strategy is judged. The identification of ATPs requires an understanding of the point in time when thresholds may be reached and the possible responses developed to postpone those thresholds. Different characteristics of the drivers that cause ATPs have been identified by Werners (2013) and include (among others): whether the driver is a slow variable or a sudden/extreme event; whether change emerges from an exogenous mono-driver, or multi-driver and multi-scale (Kinzig et al. 2006), including endogenous drivers (Dawson et al. 2010); and whether the (sub-)system undergoes threshold-type behaviour or changes gradually.

A number of studies have characterised and/or simulated the occurrence of ATPs in the face of slow changing variables, such as climate change and land-use change (Kwadijk et al. 2010; Gersonius 2012). A study by Lavery & Donovan (2005) developed a long-term strategy for FRM of the Thames estuary in the UK in an approach similar to ATP. In a case study in the Netherlands, the effectiveness of the current water management strategies under different climate change scenarios was examined using the ATP method (Kwadijk et al. 2010). The outcomes of this case study have been used as the basis for the long-term strategy in the National Water Plan of 2009. The research results have also been a part of the investigation on future adaptation options by the second governmental Delta Committee. Since then, it has become an essential aspect of the Dutch water management strategies.

Currently, apart from the ATP method, several more elaborate frameworks and methodologies (Walker et al. 2006) have been developed that incorporate scenario development (e.g., robust decision-making), uncertainty management (e.g., adaptive policy-making) and comprehensive sets of alternative strategies and/or measures (e.g., adaptation policy pathways). While these methods provide more extensive facilities for adaptive risk management strategies under uncertain conditions, they primarily aim at the development of future strategies. For retrospective evaluation of major changes in risk mitigation strategies, the ATP method is well equipped, since it is limited to the identification of tipping points and subsequent policy changes instead of focusing on uncertainty handling, scenario development and other alternatives.

An important requirement for the identification of past ATPs is the occurrence of transformational changes in FRM strategies, policies and/or associated plans instead of merely the occurrence of incremental changes. In the Netherlands, for instance, the devastating flood of 1953 led to the development of the ‘Delta works’, a large-scale flood defence scheme that included the construction of extensive flood barriers closing off major parts of the Dutch delta. This was as opposed to merely adjusting the standards of existing flood defence works by raising dike levels to a lower exceedance probability of overtopping (e.g., Klijn et al. 2012). Another example of a policy transformation in the Netherlands is the introduction of the Room for the River Programme that was developed after the near catastrophic floods of 1993 and 1995. Instead of raising river dike levels along the Rhine and Meuse rivers, the programme focused on increasing the cross-section of rivers to increase the peak discharge capacity, thereby requiring less infrastructural investment (Kwadijk et al. 2010).

The role of sudden/extreme events in reaching ATPs has received relatively little attention in previous research. Studies have mainly focused on the occurrence of ATPs caused by gradual changes of long-term events such as climate change-induced sea level rise (Kwadijk et al. 2010),
rainfall flooding (Gersonius 2012) and drought (Keath & Brown 2008). Furthermore, the ATP method has been, until now, exclusively applied in developed countries where current management practices typically meet objectives and societal preferences. In developing countries, the rate of change in drivers that lead to ATPs is more uncertain. Furthermore, drivers often consist of both endogenous and exogenous factors, ranging from climate change to poor solid waste management blocking drainage inlets.

To make a first attempt at the identification of ATPs under such conditions, this study aims to explore the role of extreme events and changes in the associated flood management strategies in Dhaka, Bangladesh. This megacity has an extensive record of devastating floods, and rapid urban expansion combined with an underequipped flood protection and drainage system. With the increased risk of flooding due to climate change and unprecedented urban growth, the city’s limit for adapting to future threats is challenged. For successfully adapting to future flood risk it is not only essential to assess the risks of floods for the next 50–100 years, but also to look back into the past to learn about historical tipping points and assess the effectiveness of the FRM strategies. Therefore, an analysis has been made of the historical ATPs in Dhaka resulting from major flood events and the subsequent changes in FRM strategies, policies and plans.

This paper first covers the methodology by providing an in-depth review of assessing ATPs in the context of flood risk in retrospective studies. After introducing the case study of Dhaka, an overview is presented of all major flood events since 1950, major FRM plans and the subsequent ATPs that indicate transformative policy changes as a consequence of the flood events.

**METHOD**

The ATP method is similar to the pressures-state-impacts-responses (PSIR) framework (Evans et al. 2004), but it starts by specifying acceptable standards or societal expectations used to manage the impacts, and then assesses the specific boundary conditions (i.e., the state) under which these may be compromised. The boundary conditions can be related to the pressures in terms of corresponding slow changing variables (Kwadijk et al. 2010). This paper has modified these steps to incorporate the influence of sudden/extreme events on the occurrence of ATPs. Furthermore, it applies an ex-post analysis to establish historical ATPs rather than attempting to ‘predict’ future ATPs.

In this paper, ATPs are taken as the points of reference (i.e., the pressures exerted on the system) where the existing policies and/or plans are no longer sufficient and adjustments or alternative policies/plans have to be implemented. The pressures in this context comprise major floods that have occurred in the past, together with potential co-drivers such as food security. Therefore, the analysis of ATPs began with the identification of flood events and broader societal problems. Second, the flood patterns (e.g., extent and duration) and consequences in terms of damages and/or casualties were analysed, to obtain a better insight into the severity of the event. In the next step, the existing policies/plans and institutional arrangements were evaluated in terms of their ability to deal with these flood events and other relevant problems. We then analysed what major lessons have been learned after the flood about the effectiveness of these policies/plans and arrangements. This step was crucial to establish the linkage between the flood event (and co-drivers) and the need for alternative policies/plans and institutional arrangements. Finally, the responses, such as policy revisions, were identified and analysed in terms of the major shift that has occurred compared with existing policies/plans and arrangements. Here, only those responses have been included as an ATP that comprised a significant policy revision or institutional reform. It is of note, however, that the distinction between responses conceived as a ‘significant revision’ and as an ‘incremental adjustment’ can (in some cases) be fuzzy and subjective (Walker et al. 2001).

The following (simple) questions have been explored, using the modified ATP method, to establish historical ATPs as a consequence of sudden/extreme events:

- **Pressures:** what major flood events have occurred?
- **State:** what have been the extent, duration and consequences of flooding?
- **Impacts:** why have existing policies and plans been ineffective to deal with flooding?
- **Responses:** which alternative policies, plans and institutional arrangements have been implemented? What
have been the main shifts in policies, plans and institutional arrangements?

- (back to) Pressures: what flood events and co-drivers have caused a significant change of the strategy?

This research has conducted a review of secondary data (collected from different institutions) to determine the patterns and consequences of flood events in Dhaka in the past 50 years (e.g., Jahan 2000; Chadwick & Datta 2005; Huq & Alam 2003; Ahmed 2013). Furthermore, a content analysis of relevant policies and plans from the case study area has been executed. This analysis has addressed not only flood and water management, but also incorporated past and recent policies/plans on urban development and climate change – as these have been widely recognised as important co-drivers of change. Local experts in the fields of water resources management, climate change adaptation and water governance were consulted to validate the research findings on the adoption of alternative policies/plans, institutional reforms and their linkages with floods. A timeline has been constructed showing the linkages between the flood events, policy revisions and institutional reforms.

**RESULTS**

**Case study area: Dhaka city**

Dhaka is the capital of Bangladesh, located in the heart of the country (Figure 1). This 300-year-old city is surrounded by the rivers Buriganga, Balu and Turag. Its population doubled from the year 1991 to a total population of 14 million in 2010 and is projected to triple by 2015 (Rabbani et al. 2011). The way this city is growing is expected to play an important role in the growth of the urban population of Bangladesh, making it one of the 20 most populous countries in the world by 2050 (UN 2011). The administrative area of Dhaka is divided into Dhaka City Corporation at 153 km², Dhaka Metropolitan area at 360 km² and the area covered by the Detail Area Plan (DAP) at 1,528 km² in area (BBS 2011). The city has developed through the conversion of vegetation (grass, trees), bare soil, agricultural land (area with crops), water bodies and wetlands into built-up areas. This diminishing pattern of vegetation class with the growth of urbanisation is quite alarming for Dhaka as the reduction in permeable land because of the increase in built-up or paved area will generate more surface runoff due to reduced infiltration and natural drainage, resulting in more flooding, also due to congestion of the drainage system (Roo et al. 2001; Tingsanchali 2012).

**Major flood events and policy responses**

The identification and analysis of historical flood events, policy revisions and institutional reforms in Dhaka (and Bangladesh) have revealed a correlation between the major flood events and significant changes in policies and institutional arrangements. Figure 2 gives a timeline of the flood events, policy revisions and institutional reforms over the past 60 years. The relationships between the major flood events and significant policy or institutional changes are explained in Table 1. It includes only those events that have caused the occurrence of an ATP for FRM. The co-drivers in Table 1 are the factors that influenced the occurrence of the ATPs, along with the major flood(s).

**1955 flood and policy response**

During the floods of 1955, approximately 35% of Bangladesh was inundated (NWP 1991) and 80% of Dhaka was inundated (EPWAPDA 1964). The consecutive floods of 1954 and 1955 prompted the formulation of the Krug mission. The Krug mission prepared a report known as the Krug Report (UN 1957). Emphasis was mainly placed on embankments and channel improvements for flood control and on irrigation for agricultural development. This report also put forward the need for an institutional arrangement to support water resources development. As a result of the Krug Report, the Water and Power Development Authority (EPWAPDA) was created in 1959, which became the Bangladesh Water Development Board (BWDB) in 1971. EPWAPDA (in association with the International Engineering Company) prepared the first Master Plan of Water Resources in 1964 (Ali & Liakath 2002). This 20-year plan reiterated the recommendations given by the Krug Report with a special focus on flood control for the entire country. For Dhaka in particular, the plan proposed various flood
control and drainage projects in the Dhaka-Narayanganj-Demra area, the Dhaka-North area and the Dhaka-Southwest area. Only the Dhaka-Narayanganj-Demra project has subsequently been implemented.

Due to the extensive damage done to crops and settlements both the Krug Report and the Water Master Plan aimed at mainly controlling floods and ensuring food security. Implementation of the proposed projects caused adverse impacts on the environment (e.g., fisheries and forestry) and domestic and industrial water supply. Flood protection measures (e.g., embankments and polders) inhibited the natural water and sediment flows, being required to support agriculture,
aquatic resources and ecosystem health. Moreover, overuse of groundwater led to water scarcity (Ali & Liakath 2002).

1974 flood and policy response

The 1974 flood submerged approximately 37% of Bangladesh (NWP 1991). Analysis of a historical flood map shows that in Dhaka, 25% of the area was affected. This event emphasised the need for planned development of water resources and comprehensive assessment of on-going development projects. In 1979, the BWDB and the World Bank made the recommendation to prepare a comprehensive National Water Plan (Ahmed 2003). This recommendation led to the formation of the Master Plan Organization (MPO) in 1980 and the preparation of two consecutive National Water Plans (NWP-I) and (NWP-II) in 1986 and 1991 by the MPO. This concept of systematic planning and assessment was earlier proposed by a World Bank mission in 1970, but never considered for implementation prior to this flood. The national level plans included innovative tools and techniques for water resources assessment; criteria for user needs assessment; and a list of priority projects focused on water development and agriculture. The National Water Plans proposed the completion of the flood protection schemes of Dhaka. These, however, lacked a holistic approach for dealing with the other economic sectors.

Dhaka city experienced rapid urban growth, along with an increase of (local) flooding and drainage problems (Kabir & Parolin 2002). The Dhaka Metropolitan Area Integrated Urban Development Plan (DMAIUD) was formulated in 1981 with the aim of integrating flood protection and long-term urban development. This plan replaced the Dhaka Master Plan of 1959, which was the first urban development plan for Dhaka. The Dhaka Master Plan was a rigid plan, which was unsuited to accommodate the city’s growth and did not consider flood protection strategies. When the DMAIUDP was prepared, the existing master plan had already become redundant. However, despite being a well-defined strategic plan, the DMAIUD was not implemented due to a lack of formal institutional support.

1988 flood and policy response

Two-thirds of Bangladesh was submerged from August to September in the flood of 1988. About 50 million people were affected and 1,600 died. More than 50% of greater Dhaka (DAP in Figure 1) was inundated, which affected 1.9 million people (JICA 1990) and caused US$6–12 million
<table>
<thead>
<tr>
<th>Flood event</th>
<th>Co-drivers</th>
<th>Lessons learned</th>
<th>Policy revisions (ATPs)</th>
<th>Significant changes</th>
<th>Institutional reforms</th>
<th>Significant changes</th>
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<tbody>
<tr>
<td>1955</td>
<td>Food security</td>
<td>Extensive damage to crops and settlements substantiated the need for flood control and agricultural development</td>
<td>Krug report (1957)</td>
<td>Focus on flood control, drainage and irrigation</td>
<td>Bangladesh Water Development Board (1959)</td>
<td>Implement water development projects</td>
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<td>Water Master Plan (1964)</td>
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<td></td>
<td>Ecosystem health</td>
<td>Dhaka Master Plan was unsuited to accommodate the city's growth and did not consider flood control strategies</td>
<td>NWP-II (1988–1991)</td>
<td>Long-term strategic urban planning, including flood management</td>
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<td>Adverse impacts of water development projects on other sectors</td>
<td>DMAIUDP (1981)</td>
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<td>The Development plan DMAIUDP lacked institutional support</td>
<td>BWFMS (1995)</td>
<td></td>
<td>FPCO merged with WARPO (known as MPO) (1996)</td>
<td>Integrate water resources planning as well as coordination activity</td>
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<td>1998</td>
<td>Funding constraints</td>
<td>Lack of multi-sector focus</td>
<td>NWPo (1999)</td>
<td>Guidance for implementation of water resources development plans</td>
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<td></td>
<td>Need for public consultation</td>
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<td>NWMP (2001)</td>
<td>Holistic and participatory based approach</td>
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<td></td>
<td>Non-implementation of FAP due to high cost</td>
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(continued)
worth of damage (Jahan 2000). The floods of 1988 occurred while the National Water Plan was being prepared. The damage from this event and the worldwide attention compelled the Bangladesh government to take immediate action. A committee was assigned to investigate the causes of flooding and to prepare a Flood Action Plan (FAP) for the entire country. The FAP consisted of 26 study projects and 3 pilot projects. FAP represented a significant change from existing plans by introducing integrated FRM (protection, prevention and preparedness) through the incorporation of both structural measures (e.g., embankments, drainage networks, sluices, and pumps) and non-structural measures (e.g., natural canals, spatial planning, flood forecasting and warning). Yet the FAP lacked a multi-sector focus, and did not involve any public consultation.

FAP 8A and 8B covered the eastern and western part of Dhaka city. These reports recommended the construction of an eastern and a western embankment around Dhaka city, with the construction of other facilities such as drainage networks, sluices and pumps (Figure 3). The drainage proposals of FAP 8A and 8B were incorporated in the Dhaka Metropolitan Development Plan (DMDP), which provided urban growth strategies for the period 1995–2005. However, the associated high implementation cost made it impossible to fully execute the proposed flood control and drainage measures.

The Flood Plan Coordination Organization (FPCO) was formed in 1989 to coordinate and monitor the implementation of the FAP. FPCO formulated the Bangladesh Water and Flood Management Strategy (BWFMS), combining all strategic recommendations given in the FAP reports. The BWFMS stressed that a clear set of policies and plans was required for integrated development of water resources and managing the adverse environmental problems. With a view to integrate and institutionalise water resources planning and coordination within a single agency under the Ministry of Water Resources, the Water Resources Planning Organization (WARPO, previously known as the MPO) was created in 1992 and the FPCO was merged with WARPO in 1996. WARPO was created with the mandate to prepare and upgrade the national level water plans, policies and strategies for water resources use and conservation.

At the local level, the drainage services were transferred from the Dhaka Public Health Engineering Department and integrated with the sewerage services of the Dhaka Water Supply and Sewerage Authority to ensure adequate drainage and sewerage.

### 1998 flood and policy response

The major flood of 1998 inundated 52 districts, affecting 30 million people and causing US$3 billion worth of economic

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**Table 1 | continued**

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<thead>
<tr>
<th>Flood event</th>
<th>Co-drivers</th>
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<tr>
<td>2004 and 2007</td>
<td>Climate change</td>
<td>Non-completion of FAP and non-compliance with urban plans has enhanced flood problems</td>
<td>DAP (2010); NAPA (2005)</td>
<td>Detailed area specific plans</td>
<td>BCCSAP (2009)</td>
<td>Adaptation as an integral part of development</td>
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<td>2004 and 2007</td>
<td>Climate change</td>
<td>Need to enhance resilience to climate change</td>
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<td>2004 and 2007</td>
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<td>National level plans lack details required at local level</td>
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Figure 3 | Flood control and drainage map of Dhaka.
Construction of the eastern embankment, together with other and water pollution problems. The plan proposed the con-
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struction of the eastern embankment, together with other damages. The country remained under water for 65 days. Seventy out of 90 wards of Dhaka city were inundated for 2 months. The 1998 flood caused more damage than the 1988 flood, because of the intense development over this 10-year period and because many of the planned measures (proposed by FAP) were not, or only partly, implemented due to a shortage of funds. The eastern part of Dhaka remained unprotected from flooding due to the non-implementation of the eastern embankment (proposed in FAP 8A). The western embankment (proposed in FAP 8B) was able to protect the western part of Dhaka from river flooding, but its construction increased local rainfall flooding and led to other environmental changes, such as a conversion of agricultural land to residential use and a reduction in groundwater infiltration (Muhit 1993; Chowdhury 2003).

Following the 1998 flood, the Bangladesh government recognised that a national level framework was needed to guide planning and implementation of projects at a local level. Hence, a holistic approach in water resources planning was adopted, which represented a significant change from the existing policies and plans. Existing policies/plans were criticised for their sectoral approach (Wilde 2011) focusing solely on water resource development, neglecting the impact on other sectors and not involving public opinion. In this sense, the 1998 flood delayed and significantly influenced the outcome of the National Water Management Plan (NWMP). This plan was prepared with the intention to operationalise the directives given by the National Water Policy (NWPo). It provided the broader framework missing in earlier policies/plans under which line agencies can make regional or local water management plans and implement them in a coordinated manner. During the preparation of the NWMP, public participation was ensured at every stage of the process. The NWMP integrated multiple sectors, addressed sectoral and cross-sectoral issues, and proposed multi-agency projects.

The NWMP proposed regional plans and programmes for each of the eight hydrological regions of Bangladesh. The main water-related issues identified for Dhaka were the encroachment of the Buriganga River and other water bodies, flooding and drainage, supply of adequate water and water pollution problems. The plan proposed the construction of the eastern embankment, together with other additional works, appropriate urban planning and improved drainage systems.

2004 flood and policy response

Heavy rainfall beginning in June was the main reason for flooding in 2004. Approximately 38% of Bangladesh was inundated, which affected 36 million people (25% of the total population) and caused 800 deaths (ADB & WB 2004). The structural and agricultural damage amounted to US$2.2 billion. In September 2004, another flood occurred due to a localised monsoon depression, resulting in three times the normal rainfall and inundating Dhaka and the southwestern areas of the country.

In 2007, two major floods occurred in Bangladesh. The floods of 2007 inundated 32,000 km², resulting in 649 deaths. More than 85,000 houses were destroyed and almost one million were damaged. The agricultural damage was estimated to be over $1 billion (Bangladesh Climate Change Strategy and Action Plan (BCCSAP 2009)).

The extensive damage from the 2004 flood emphasised the need for an improved drainage management system in Dhaka. The government agency (Dhaka Water Supply and Sewerage Authority) therefore engaged in more projects on flood control and drainage, including a detailed study on the Drainage Master Plan. This study updated the drainage plan and recommendations given in the FAP 8A and 8B reports. The Drainage Master Plan recommended that, in light of the rapid urban growth taking place in eastern Dhaka, additional drainage structures and the conservation of water retention areas had to be ensured prior to the construction of the eastern embankment. This was particularly relevant, because ongoing urban development violated the guidelines of the DMDP. As the DMDP became outdated, the need arose for a DAP to stop haphazard development and the encroachment of waterbodies and wetlands. In the DAP of 2010 however, more importance was given to the construction of flood control structures than to setting aside adequate space for water retention ponds, parks and green areas.

Recognising that climate change will increase the frequency and severity of flooding, and in response to the call of the Conference of the Parties (COP7) on Climate Change, the Bangladesh government initiated the preparation of the National Adaptation Programme of Action
(NAPA) in 2005. The report of NAPA included a framework of adaptation, the key needs for adaptation, coping strategies and mechanisms, and a list of priority projects (MoEF 2005). This document stated that adaptation to climate change should be part of development projects. Therefore, the Bangladesh government formulated the BCCSAP to mainstream climate change adaptation within development projects. The BCCSAP proposed thematic projects on flood early warning and forecasting; hydrological modelling to assess future risk of climate change; developing a flood plain zoning and vulnerability map; rehabilitating existing embankments and appurtenant structures taking future forecasts into account; improving the drainage capacity of cities; and adopting non-structural flood-proofing measures. Furthermore, a Climate Change Cell was created in 2004 in the Department of Environment under the Ministry of Environment and Forests to prepare climate change mainstreaming guidelines and provide knowledge support to the ministry.

**DISCUSSION**

**The role of extreme/sudden events and co-drivers**

This retrospective study has focused on the relationship between major flood events and FRM policy revisions in Dhaka. While the occurrence of ATPs can be largely attributed to extreme/sudden events, a number of contributing co-drivers emerged from the case study. Socioeconomic constraints in the form of inadequate funding, untimely or non-implementation of projects and redundancy of plans played a significant role in reaching ATPs. Furthermore, cross-scale effects of incumbent policies/strategies constituted a major cause of ATPs. For example, a strictly sectoral approach as well as large-scale structural interventions has brought about adverse impacts on other sectors. The construction of embankments has led to internal waterlogging problems, drainage congestion and environmental problems.

Another driver for the adoption of alternative policies/strategies was the advancement of knowledge, either locally or nationally from lessons learned from flood events, or internationally from best practice policy examples. Ever since the inception of formal flood management in Bangladesh, be it the UN (1957), the Water Master Plan (1959), the action plan FAP (1991) or the recent climate change strategies and action plans, foreign knowledge or intervention has always played a major role. Yet although it seemed to be the best solution from an international perspective at that time, a number of these policies/strategies have later been found to be unsustainable for the environment. An example of this is the flood control and irrigation projects, which caused environmental problems such as internal flooding, groundwater recession and sedimentation. The concept of a participatory approach was introduced through the NWMP (2001) plan, so that local knowledge may be incorporated within the national planning framework.

Lastly, the interaction with slow variables such as urbanisation and climate change was a key factor influencing the occurrence of ATPs. There exist a number of well-formulated spatial plans that stress the need for maintaining water bodies and flood flow zones to ensure proper drainage, none of which have been fully implemented. Consequently, new urban developments constructed in floodplains were exposed to flooding and have increased runoff and subsequent waterlogging in adjacent areas. The potential effects of climate change, although acknowledged in the country’s national level programmes (e.g., MoEF 2005) and strategies (e.g., BCCSAP 2009) as an important issue, have not been incorporated in the latest urban development plan DAP 2010.

**Implications for FRM**

Over 10 major flood events have occurred in Bangladesh in the past 50 years of FRM, which have in five cases resulted in a revision of FRM at the national and/or local level. This insight suggests that extreme/sudden events could lead to the (potential) occurrence of ATPs. Furthermore, the case study findings demonstrated that ATPs are often caused by a combination of drivers. The identified co-drivers included socioeconomic constraints (paucity of funds, non-/untimely implementation), cross-scale effects, foreign intervention and knowledge, and future change. The implications of this set of co-drivers for FRM in Bangladesh (and beyond) are as follows:

- Paucity of funds: secure necessary funding from the outset for proper and timely implementation of the plan. This can be achieved with the involvement of donors...
prior to preparing any plans for development. In the Netherlands, the Delta fund was secured for short-term FRM measures under the Netherlands Delta Plan (until 2030). Other sources of funding, either public or private, can also be explored. Initiation of public–private partnership is a good option given the uncertainty in accruing investment from the development partners. The Hatirjheel multi-purpose lake development project in Dhaka is a good example where the project was completely funded by the Bangladesh government.

- Non-/untimely implementation: lack of funds, time-consuming or lengthy bureaucratic process and political turmoil are some of the reasons that lead to non-/untimely implementation of plans. Such was the case during the implementation of the FAP action plan. A monitoring system needs to be in place so that projects are implemented as originally conceived and, accordingly, corrective measures are taken. Timely implementation therefore necessitates ensuring adequate funds, preparing feasible plans, and setting aside alternative options in a situation where the plan is partially implemented so that the major objectives for FRM are achieved.

- Cross-scale effects: the need to adopt a holistic and integrated approach that considers all the relevant sectors and stakeholders. A focus on a single sector, ignoring others, causes environmental degradation. The Bangladesh Delta Plan (2100) is currently underway, which is going to address all the issues and challenges that persist in a dynamic delta country. Food security, disaster management, climate change adaptation, ecosystem sustainability, and massive population and economic growth are some of the major challenges that will be dealt with through this adaptive and eco-based plan. Participation will be ensured through stakeholders’ involvement in every phase to make the plan feasible and acceptable. For the plan to be successful in the middle of so many previous plans and for cross-sectoral effects to be reduced, integration should be ensured not only during plan preparation but also in the implementation phase.

- Foreign intervention and knowledge and future change: the need to adopt a flexible approach that allows for the incorporation of new knowledge in the future and allows the possibility to shift to a new strategy suitable for a local setting. Introduction of new knowledge or interventions from developed countries may not necessarily be productive for a country which is still in the process of development, as was evident in the case of the FAP, which was too ambitious given the technical and financial limitations of the country. Application of the ATP approach in conjunction with a more flexible approach like the Adaptation Policy Pathways can be very effective in incorporating new knowledge and suggesting possible adaptation strategies for reducing flood risks in Dhaka.

Reflection on the method

This paper represents a first attempt at identifying historical ATPs under sudden/extreme events. Previous applications have focused mainly on ATPs caused by slow variables, like climate change, and have adopted a forward-looking approach (as opposed to a retrospective approach). These have used a limited set of scenarios for one or two projection years (e.g., Gersonius et al. 2012). In the recent past, the concept of ATPs has been used in conjunction with the adaptation pathways approach. Adaptation pathways refer to a sequence of measures and potential options, which may be triggered before an ATP occurs. For example, Haasnoot et al. (2012) have applied the adaptation pathways approach to a semi-hypothetical case study, inspired by the Rhine delta of the Netherlands. It is of note that the adaptation pathways approach is able to incorporate extreme events (caused by climate variability) by using transient scenarios.

The original ATP method has been modified to enable the identification of historical ATPs under sudden/extreme events. This comprised the exploration of a number of simple questions related to the PSIR concept. The application of the modified ATP method has been demonstrated for a developing country context (Dhaka). Yet, it is to be expected that the sudden/extreme events as drivers for ATPs are not limited to developing countries. In the Netherlands, for example, the near-flood events in the Rhine and Meuse in 1993 and 1995 led to a shift in policy strategy from dike reinforcement to river relief.

The following lessons have been learned from the case study about the modified ATP method:

- As has already been stated, the distinction between responses conceived as a ‘significant revision’ and as an...
‘incremental adjustment’ can be fuzzy and subjective. This was particularly significant for the policies on a strategic level (e.g., the Krug Report, NWMP), because the adaptation actions have not always been clearly specified in the reviewed policy documents.

- It can be difficult to assign an ATP to a particular extreme event. The application for Dhaka has shown that ATPs are, in some cases, caused by a couple of events. It is also of note that strategies/policies generally change gradually, as it takes time to implement policy changes. This implies that in some cases policy change might already be underway when an extreme event occurs. This was the case for the mega floods of 1987 and 1988, which both occurred while the NWP national level plan was being prepared.

Given the importance of co-drivers, a recommendation for future research is to adopt a more integrated perspective by considering different sectors in conjunction. In this regard, it could be beneficial to construct time lines of ATPs for a range of sectors (e.g., flooding, food security and ecology) and to identify and explain the linkages across different sectors. For example, it has been found in Dhaka that actions taken to postpone the ATP for flooding have adversely affected the ecological conditions of major rivers in and around Dhaka. This consideration of cross-scale effects could contribute to an improved understanding of the role of co-drivers in reaching ATPs.

**CONCLUSIONS**

Through the application of the ATP method, extreme/sudden events and associated policy changes were analysed in a retrospective manner. This application differed from other methods such as adaptation pathways, which mostly rely on future scenarios in defining adaptation strategies (i.e., taking a forward-looking approach). The review of past floods in Dhaka, and the policy implications, has revealed that the continuation of FRM policies has been compromised under the influence of major floods. This finding could be explained by the fact that the recurrent floods have delayed the implementation of effective FRM, which, as a result, has achieved only partial reduction of flood damages and risks.

Moreover, the ATP method has shown benefit in demonstrating that significant policy or institutional changes have resulted not only from extreme events, but also from a set of co-drivers. Potential co-drivers included socioeconomic constraints (paucity of funds and non-/untimely implementation), cross-scale effects, foreign intervention and knowledge, and future change. This research outcome has important implications for FRM. While it is practically impossible to avoid major floods, there is significant room for improving the ability of policies to deal with co-drivers. As an example, it is possible to define corrective actions that should be triggered in the case of non-implementation or untimely implementation of existing plans. In this sense, the lesson learned from a retrospective analysis can be used to inform future policies by expanding the range of co-drivers being considered by policy-makers.

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