



**Autonomous adaptation to riverine  
flooding in Satkhira District, Bangladesh:  
insights for transformation**

**Adrian Fenton, Anne Tallontire,  
and Jouni Paavola**

October 2016

Sustainability Research Institute

Paper No. 99

Centre for Climate Change Economics and Policy

Working Paper No. 283

**SRI PAPERS**

SRI Papers (Online) ISSN 1753-1330

First published in 2016 by the Sustainability Research Institute (SRI)  
Sustainability Research Institute (SRI), School of Earth and Environment,  
The University of Leeds, Leeds, LS2 9JT, United Kingdom

Tel: +44 (0)113 3436461  
Fax: +44 (0)113 3436716

Email: SRI-papers@see.leeds.ac.uk  
Web-site: <http://www.see.leeds.ac.uk/sri>

### **About the Sustainability Research Institute**

The Sustainability Research Institute conducts internationally recognised, academically excellent and problem-oriented interdisciplinary research and teaching on environmental, social and economic aspects of sustainability. We draw on various social and natural science disciplines, including ecological economics, environmental economics, political science, policy studies, development studies, business and management, geography, sociology, science and technology studies, ecology, environmental science and soil science in our work.

**The Centre for Climate Change Economics and Policy (CCCEP)** brings together some of the world's leading researchers on climate change economics and policy, from many different disciplines. It was established in 2008 and its first phase ended on 30 September 2013. Its second phase commenced on 1 October 2013. The Centre is hosted jointly by the University of Leeds and the London School of Economics and Political Science (LSE) and is chaired by Professor Lord Stern of Brentford. It is funded by the Economic and Social Research Council (ESRC) with a mission to advance public and private action on climate change through rigorous, innovative research.

Its five inter-linked research themes are:

Theme 1: Understanding green growth and climate-compatible development

Theme 2: Advancing climate finance and investment

Theme 3: Evaluating the performance of climate policies

Theme 4: Managing climate risks and uncertainties and strengthening climate services

Theme 5: Enabling rapid transitions in mitigation and adaptation

More information about the Centre for Climate Change Economics and Policy can be found at: <http://www.cccep.ac.uk/>

### **Disclaimer**

The opinions presented are those of the author(s) and should not be regarded as the views of SRI, CCCEP or The University of Leeds.

## **TABLE OF CONTENTS**

<b>Abstract</b>	<b>4</b>
<b>About the Authors</b>	<b>5</b>
<b>1. Introduction</b>	<b>6</b>
<b>2. Conceptualising adaptation and transformation</b>	<b>7</b>
<b>3. Case study site, materials and methods</b>	<b>10</b>
<b>4. Results</b>	<b>11</b>
<b>5. Discussion</b>	<b>14</b>
<b>6. Conclusions</b>	<b>17</b>
<b>References</b>	<b>18</b>

## **ABSTRACT**

Systematic understanding of adaptation measures utilised by households in developing countries is needed to identify the constraints they face, and the external interventions or adaptation planning needed to overcome them. Ecological-resilience, political-ecology, and risk-hazard approaches have dominated research on climate change adaptation and they have mostly focused on incremental adaptation. This article examines to what extent these approaches can shed light on the less studied transformational adaptations. It tests their relative merits by analysing autonomous livelihood adaptations to riverine flooding in Satkhira District, Southwest Bangladesh, using semi-structured household interviews as primary material. Migration and adoption of aquaculture are the key transformational adaptations occurring in the case study. The risk-hazard approach appears most suitable for exploring transformational adaptations because of its capacity for understanding how households respond to livelihood risk, and what resources are required for it to be most effective. However, elements from political-ecology and ecological-resilience are needed to ensure that equity considerations and long-term implications are given sufficient emphasis.

## **ACKNOWLEDGEMENTS**

This research is part funded by the University Meets Microfinance initiative, the Sustainability Research Institute and the Centre for Climate Change Economics and Policy.

We would like to thank Dr Claire Quinn for helpful comments on the manuscript.

## **KEYWORDS**

Autonomous adaptation, transformation, livelihoods, Bangladesh, climate change

Submission date 15-08-2016

Publication date 14-10-2016

## **About the Authors**

**Adrian Fenton** is a PhD Researcher at the Sustainability Research Institute of the School of Earth & Environment. His research examines how rural finance institutions influence the livelihoods of households in Bangladesh. In particular, his research focuses on the role played by microfinance institutions in facilitating and inhibiting climate change adaptation.

Adrian is also a Visiting Researcher at the International Centre for Climate Change and Development (ICCCAD) and an Affiliate Researcher of the Centre for Climate Change Economics and Policy (CCCEP).

In addition to his academic research, Adrian has private consultancy experience working on assignments for the United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), and the International Institute for Environment and Development (IIED), as well as non-governmental organisations such as Oxfam and CARE international.

His research is part funded by the University Meets Microfinance initiative, the Sustainability Research Institute and the Centre for Climate Change Economics and Policy.

**Dr Anne M. Tallontire** is a senior lecturer in business, environment and sustainability in the Sustainability Research Institute at the University of Leeds. She has worked on voluntary sustainability standards for over fifteen years, exploring implications for small scale producers and workers, particularly in Africa. She wrote her PhD on fair trade and has conducted several research and consultancy projects on standards in agri-food chains, for ETI, HIVOS, Fairtrade International, Department for International Development, and Foreign Investment Advisory Service of the World Bank.

**Jouni Paavola** is Professor of Environmental Social Science and Director of the ESRC funded Centre for Climate Change Economics and Policy (CCCEP) in the School of Earth and Environment at the University of Leeds. His research examines environmental governance institutions and their environmental, economic and social justice implications, with a focus on climate change and biodiversity. He leads the CCCEP second phase research theme on enabling rapid transitions in mitigation and adaptation. He has published his research in journals such as *Science*, *Ecology and Society*, *Ecological Economics* and *Energy Policy*, and have co-edited books published by Blackwell, MIT Press and Routledge. He is member of editorial boards of *Ecological Economics* and *Environmental Policy and Governance*.

## 1. Introduction

Adaptation to climate change (henceforth 'adaptation') has become a critical issue for developing countries and the communities residing within them. It is generally accepted that external intervention or adaptation planning is required to help communities within developing countries meet adaptation challenges. This external support is predicated upon knowledge of what autonomous adaptation is taking place, by whom and how (Stern, 2006; Füssel, 2007; Smit et al., 2000; Smit et al., 2001). Autonomous adaptation consists of household responses to climate change. It is a continuous process occurring outside of top-down policy support, intervention and constraints, and it typically occurs in response to multiple stimuli rather than to climate stimuli alone (Smit et al., 2001).

Our understanding of autonomous adaptation remains weak (Thorn et al., 2015), with much of the local adaptation unnoticed, uncoordinated and unaided by development actors (Christoplos et al., 2009). It is also poorly understood to what extent adaptations remain incremental or are transformational, resulting in something fundamentally new. This distinction is important, as it is increasingly likely that transformational rather than incremental adaptations will be needed with regards to the changing climate (Smith et al., 2011).

This article examines autonomous adaptation in Satkhira District, Southwest Bangladesh. Bangladesh provides a good setting for examining household livelihood responses to climate change (Lewis, 2011). It is one of the least developed countries and one of the most vulnerable countries to climate change. A large proportion of its territory is comprised of flat alluvial plains, with 80 percent of land less than 10 meters above sea level (CCC, 2009). Bangladesh has one of the world's largest river systems, transporting the highest sediment load in the world. This contributes to its particularly high exposure to flooding. A quarter of the land is flooded annually with attendant livelihood and asset losses. Severe floods affect over half the country approximately every five years (MoEF, 2008). Floods destroy important household assets, such as agricultural land, and severely disrupt everyday lives (Tutu, 2005). In a changing climate, heavy precipitation events are projected to increase and flooding to become more intense and frequent (Kundzewicz et al., 2014).

Our study contributes to existing literature through the following. First it argues that the risk-hazard approach is most suitable for assessing autonomous adaptation for supporting adaptation planning. Using this approach, our study shows how households use a mixture of incremental and transformational measures to adapt to flooding. Additionally, it establishes that households do not have equitable access to adaptation measures, and that existing government extension programmes may inadvertently accentuate inequalities relating to adaptation. Furthermore, it demonstrates that the risk-hazard approach can lead to a static local-level analysis that struggles to shed light on the long-term implications of adaptation measures. Finally, it illustrates how elements of the political-ecology and ecological-resilience approaches are needed to ensure that adaptation planning results in equitable solutions that are viable over the long term.

## **2. Conceptualising adaptation and transformation**

Adaptation has different meanings in different areas of research (for an overview see Janssen and Ostrom, 2006). We use it to refer to the process through which households adjust to changing conditions, stresses, hazards, risks or opportunities (Smit and Wandel, 2006). Adaptation is distinct from 'coping' which refers to immediate responses to events: in contrast adaptation prepares households for expected future events (Berman et al., 2012). Adaptive capacity is a measure of the ability to adapt (for an overview see Smit and Wandel, 2006). Adaptations are often described by their function: adaptations which retreat from hazards can lead to the abandoning of vulnerable areas; others accommodate hazards enabling continued occupancy and use of vulnerable areas; lastly adaptations can seek to protect against hazards and thus defend vulnerable areas, economic activities and natural resources (Dronkers et al., 1990).

The need to adapt arises from vulnerability, which is understood differently in the three key strands of adaptation research. The ecological resilience approach originating from ecology (see Holling (1973) and Walker et al., (1981)) has focused on systems and thresholds, and the ability of a system to adjust and respond over the long term (Eakin et al., 2009; Eakin and Luers, 2006; Folke, 2006). The political ecology approach has its origins in the literature on poverty and geography (e.g. Sen (1981)) and has focused on power, equity, and capabilities. It is mainly concerned with immediate needs caused by vulnerability, causes of vulnerability, and how vulnerability differs across societal groups (Eakin and Luers, 2006; Eakin et al., 2009; Adger, 2006). The risk-hazard approach originates from the natural hazards literature (see White (1986) and Burton et al. (1993)), and is focused on exposure and sensitivity to hazards. It has been primarily concerned with practical implementation of adaptations at the sectoral and community levels (Eakin and Luers, 2006; Eakin et al., 2009; Smit and Wandel, 2006). It is increasingly focusing on enabling environments and creating decision-support tools to facilitate bottom-up adaptation by private sector, civil society and local government actors (Eakin and Lemos, 2006). Within this approach, adaptation measures that inadvertently increase vulnerability are considered as maladaptive (Barnett and O'Neill, 2010).

The different strands of research on vulnerability ask different questions, highlight different characteristics as central to vulnerability, and thus have their own strengths and weaknesses. For instance, the risk-hazard approach privileges efficiency and effectiveness over equity, whereas the reverse is true for the political ecology approach (Eakin et al., 2009). The approaches have also somewhat different scales of application. The political ecology and risk-hazard approaches are well suited to focus on household and community-scales, while the ecological resilience approach is more suited to study larger socio-ecological systems (Eakin and Luers, 2006). Despite these differences, there is some common ground between the approaches and there are possibilities for cross-fertilisation (Janssen et al., 2006; Adger, 2006; Gallopín, 2006).

The three approaches have also somewhat different takes on transformation as a form of adaptation. Their different insights are becoming increasingly important as worsening climate change impacts are likely to cause and demand more substantial responses. Small-island and other low-lying states threatened by sea level rise provide a vivid example: transformational changes such as loss of land and statehood may not only occur, but will likely result in subsequent transformative changes such as mass relocations of populations. In what follows we will examine how the three approaches address transformation.

For the ecological resilience approach transformation has long been a core issue, it is a vital component of the 'adaptive renewal cycle' (Holling, 1986) and the concept of 'panarchy' more generally (Gunderson and Holling, 2002). For this approach, transformation is fundamentally different from adaptation; the former refers to a regime change of a social-ecological system to a more desirable configuration once thresholds have been surpassed, while adaptation refers to changes within a regime which stays intact (Olsson et al., 2014; Folke, 2006). Transformation is associated with 'proactive ecological-resilience' and the acceptance of the inevitability of change and the need for systems to be capable of adapting to new conditions and needs (Dovers and Handmer, 1992; Gunderson and Holling, 2002). Transformation is needed when "ecological, economic, or social structures make the existing system untenable" (Walker et al., 2004:1). Transformation has occurred when a system is fundamentally new, although identifying something as 'untenable' or 'fundamentally new' is a matter of interpretation (Walker et al., 2004:2).

In contrast, the 'political-ecology' approach did not use the term transformation at all in the past. For instance, Amartya Sen's work (1982; 1981) does not mention transformation. The term has only emerged in more recent work (e.g. Dodman and Mitlin, 2011), in particular in that of Pelling (2011). Political-ecology looks at transformation normatively, focusing on observed inequalities in society (Pelling et al., 2015). Transformation for this approach 'refers to "structural or root causes of vulnerability", with an explicit reference to "social, cultural and economic relationships, and power hierarchies" (Pelling et al., 2015:114). Such is the focus on society that transformation does not need to occur in response to an environmental change (Manuel-Navarrete and Pelling, 2015).

The increasing focus on transformation within this approach results from perceived deficiencies with current efforts to tackle climate change which are argued to accept rather than contest change (Pelling, 2011). O'Brien (2012) argues that the existence of adaptation measures is insufficient for transformation to have occurred, suggesting that the risk-hazard approach (see below) could never alone lead to transformation. Political-ecology is often associated with the need to challenge the 'status quo' or wider structural causes of vulnerability (Pelling et al., 2015). Consequently, fundamental change often refers to emancipatory changes such as empowering women to have greater social, economic, and political freedoms (Manuel-Navarrete and Pelling, 2015; O'Brien, 2012). However, what level of change is sufficiently 'fundamental' is not made clear in the literature. In contrast to other approaches, the political-ecology approach

questions processes and outcomes, why people are vulnerable, and how different groups are subjected as 'vulnerable' (e.g. O'Brien, 2012; Eriksen et al., 2015).

The risk-hazard approach has also only recently started using the term transformation (Klein et al., 2014) but earlier statements such as the need for 'non-marginal change' already suggested it (Rickards and Howden, 2012 citing Stern, 2006). Transformation is emerging as an important topic particularly in research on agriculture (Rickards and Howden, 2012). Here transformation refers instrumentally to the depth or extent of change needed (Leclere et al., 2014; Klein et al., 2014). Actions adopted at greater scales or intensities, actions that are original to a particular region or resource system, and actions that transform places and shift locations are three observed types of transformation (Kates et al., 2012:1). But deeming what is transformational and what is not remains difficult in the risk-hazard approach as in other approaches. Rickards and Howden (2012) suggest that this is due to the multiple dimensions through which change can be assessed. Determining whether something is transformation is also subjective and relative. The risk-hazard approach is well placed to ask questions relating to cost, risk and uncertainty, and how much transformation is required (e.g. Leclere et al., 2014).

The risk-hazard approach has an instrumental take on transformation: it may be needed because of extreme vulnerability or severe climate change impacts, which threaten socially negotiated norms and inhibit the ability to fulfil objectives. Without transformation, losses would occur (Dow et al., 2013; Kates et al., 2012). Thus limits and barriers are central to transformation just like for the ecological resilience approach. In contrast, political-ecology does not put much emphasis on environmental limits to change as its emphasis is on reduction of societal inequalities (Pelling et al., 2015). 'Barriers' can frustrate adaptation but they can be overcome (Barnett et al., 2015). They are distinct from 'limits' that prevent objectives from being realised (Dow et al., 2013; Marshall et al., 2012). 'Hard limits' prevail when nothing can be done to avoid intolerable risk. Transformation can occur in the face of hard limits but they would entail drastic changes in objectives and associated values (Barnett et al., 2015). In the presence of 'soft limits' intolerable risks can be overcome with new strategies and measures (IPCC, 2013). Transformation can therefore be seen as a way of overcoming soft limits, for instance when efforts to tackle climate change are original to a new location (see Kates et al., 2012).

In light of the above discussion, the hallmarks of transformations are that a situation needs to be untenable, and the transformations must represent something new; although what this is in practice is not clear. In ecological resilience, transformation refers to a shift to a new system regime, while adaptations are incremental changes. Transformation is almost inevitable given the potential timespans and the system-scale focus. In political-ecology transformation refers to positive changes in social structures (e.g. equity and justice) as they are seen as the root causes of vulnerability, while incremental adaptation refers to actions that do not challenge current structures. Transformation appears difficult to achieve in this approach. In the risk-hazard approach, transformation refers to those responses which overcome intolerable risk. The approach is suited to household-level livelihood studies, with local-level responses

to climate change argued to be driven by how these changes impact on livelihoods and assets (Ayers and Forsyth, 2009) as opposed to broader societal structures.

We employ below the risk-hazard approach because of its household level focus. Consequently, transformative adaptations include those livelihood changes that enable households to overcome adaptation limits posed by hazards, and which are new to household livelihoods. Incremental adaptations in turn include those household livelihood changes that manage changing risks posed by hazards. We integrate the complementary insights of the other two approaches into our discussion of results. The political-ecology approach is used to highlight ethical concerns in the analysis. The ecological-resilience approach is used to consider long-term implications.

### **3. Case study site, materials and methods**

A single case study at the village level was adopted to enable an in-depth examination of the context specific nature of vulnerability and adaptation. This required the use of qualitative research methods as part of a wider mixed-methods approach, which in turn required a prolonged presence in the field in order to gain familiarity and trust of research participants. This approach is consistent with insights emerging from the adaptation literature (Janssen and Ostrom, 2006; Ford et al., 2010; Smit and Wandel, 2006).

Our research was carried out in the Satkhira District, Khulna Division; one of the poorest areas in Bangladesh where flooding is a common problem (Azam and Imai, 2009; Tutu, 2005). We selected this district in light of key informant interviews with national civil society organisations. Noapara village was selected after key informant interviews with local civil society, government, and community representatives. Both methodological and pragmatic considerations informed the selection process. Methodological concerns included the need for the village to be fairly typical for the district, exposed to a prominent hazard for a number of years, and with some indications of adaptation occurring. Pragmatic considerations included accessibility, safety, and no signs of research fatigue.

In March 2014, 30 participants (11% of the total households in Noapara village) engaged in focus group discussions involving tools such as seasonal calendars and Venn diagrams to explore village life, confirm the appropriateness of the village for the study, and to plan future research in more detail. Between May and June 2014, 266 households (99%) were surveyed on demography, assets, access to weather and climate information, support networks, innovations, access to improved seed varieties, and exposure and sensitivity to environmental hazards. Between March and April 2015, semi-structured interviews were conducted with heads of 38 households (14%) to explore household adaptation to environmental changes. Selection of households for interview was informed by livelihood profiles, constructed from survey data, purposefully sampled for socioeconomic status by considering land ownership, education, homestead status, and credit usage. Also, 13 short interviews were conducted with market stall owners. Personal observation and informal conversations complemented the above data collection methods.

Focus group findings were interpreted in situ with participants. Survey data was analysed using SPSS and interpreted in light of the literature. Semi-structured interviews were coded according to coping mechanisms and household adaptations. Analytical categorisation of was undertaken using an iterative process that builds on the initial descriptive coding, drawing themes from the literature to interpret the material.

## 4. Results

Noapara is surrounded by the Ganges Floodplain in the north and the Sundarban Mangrove tidal forest in the south. It is surrounded by agricultural land and dissected by a major road connecting Satkhira and Khulna and acts as a market village for other villages further away from the road. The nearby towns of Tala, Patkhelgata, and Paikgachha have larger markets and more economic activity. Noapara is home to 267 households, 74% of which have 3-5 members (median=4), and most are male-headed (94%). Agriculture is central to livelihoods, one respondent commenting that “no job means no farming”. Agriculture follows a pattern of cash crop cultivation during summer and high-yield rice cultivation in winter. Cash crops provide income, while rice provides food security. Summer cultivation of jute has been vital to livelihoods in recent years: one participant remarked “Oh jute, it had a huge impact on my livelihood, I paid [off land mortgage] with that money... I built this house using that money... I bought cattle and goats selling jute”. Small-scale livestock (cattle and goats) and poultry (chicken and ducks) rearing are also common, typically serving household consumption but also serving as investment. Aquaculture of fresh water prawn and fish is practised in ponds, with a few households engaged in larger-scale production for wider markets. Seasonal migration for agricultural labour to nearby Jessore, Khulna, and Satkhira is common. Less common livelihood activities include non-agricultural salaried work, international migration, and business in temporary or permanent premises.

In Noapara, socioeconomic status is defined by three key factors: farmland ownership, educational attainment, and homestead status. According to our survey, farmland ownership is highly positively skewed and most households are functionally landless. Land ownership is fragmented: households own small pockets of land in different locations. Land ownership patterns are broadly reflective of those in the Satkhira District as a whole (Government of Bangladesh, 2010). Education is held in high regard and is closely associated with reduction of poverty in recent times – for example, a teacher brought jute cultivation know-how to the village, which helped improve income. The survey suggests that over half of the people are illiterate. The elderly are mostly illiterate, whereas most children attend school. Only 6.7% of households have members with education above secondary level. Education is held in such regard that villagers have sold land and animals and obtained credit to pay for their children’s education. One villager stated “we need education... without education you cannot do anything”. Homestead type is also an important indicator of socioeconomic status. Households either live in traditional homesteads (constructed of earth), semi-improved homesteads (constructed of kiln-fired brick), or improved homesteads (constructed of

kiln-fired brick with plaster coating). According to the survey, many households live in semi-improved homesteads (56%), and most homesteads (82%) are on plinths of differing heights and reinforcement status.

Noapara households are exposed to multiple hazards but particularly to riverine flooding. Flooding typically occurs in July and August but it can have adverse impacts for much longer because of poor drainage from flat land of low elevation. Flooding occurs when water overflows the banks of the Kobadak River because of siltation, which has elevated the river above surrounding land. Flooding is a major concern in the area which is less than 3 meters above sea level (Ahmed, 2010). The main cause of siltation is the Coastal Embankment Project completed in the 1960s. Construction of polders and lack of dredging has restricted tidal flow and prevented sedimentation on surrounding floodplains, leading to sedimentation in rivers and reducing their drainage capacity (ADB, 2007; Tutu, 2005).

Participants indicated that the intensity of flooding has increased dramatically over the last ten years, with major events occurring in 2008 and 2011. Flooding lasts for 2-3 months but can continue longer. A local councillor commented that in 2011 flooding lasted for eight months. Surveys indicate that most households have been affected by flooding 3-5 times over the past 10 years and that exposure differs between households because land elevation differs in the village and across agricultural land. Traditional homesteads were not designed for extended flooding and plinths were too low to keep buildings dry: they collapse when unreinforced plinths and walls dissolve in flood-water. According to a local councillor, only semi-improved and improved homesteads survived flooding in 2011. Households coped by constructing temporary shelters on the main road and repaired damage after the flood. In 2011 “no one stayed in their homestead... [they all] took shelter on the roads”.

Many assets such as trees, livestock, and poultry have been lost, with one participant reporting that “Nothing is left, nothing is left, I have nothing left. There were big trees over there. There were coconut trees, mango trees and other fruit trees. Trees died because of the flood”. Households cope by selling affected assets at nearby markets, but they often obtain lower prices and returns on their investments. Participants also report higher incidences of disease and greater risk of snake-bites during floods. Summer cultivation of cash crops often fails during floods. Many households have now ceased summer cultivation because of the perceived likeliness of flooding which is too much for even flood-resistant seed varieties. As most agricultural inputs are purchased with credit, debt levels can increase when harvests fail. Demand for agricultural labourers also reduces when harvests fail or land is left uncultivated, reducing access to an important source of income for many households. Some households have to sell rice to repay debts, which reduces food security. Businesses are negatively affected by flood damage to premises and stock, but also due to low demand for goods and services with some of them closing for the summer.

Household interviews brought up numerous adaptations to flooding such as changing composition of poultry stocks, homestead and plinth improvements, domestic and international migration, conversion of agricultural land for aquaculture, halting of

summer cultivation, and salaried labour. These adaptations are all autonomous, despite the multitude of non-governmental organisations and government extension officers in the area. Some government extension services such as the provision of training and financial services have facilitated adaptation, but only serendipitously. Interviews with the local government representatives indicated a lack of formal support for household adaptation to flooding and that engineering solutions such as the dredging of the river were deemed the only solution to address the flooding.

Autonomous adaptations consisted of a mixture of incremental and transformative measures. Increasing duck rearing can be considered as an example of incremental adaptation which accommodates flooding. Chickens are considered vulnerable to snakes and diseases during flooding and need higher ground during floods. Rearing more ducks reduces the risk of asset losses and the need for animal housing investments. One interviewee said that “ducks float on water and become less infected by diseases, but chickens face problems as they stay on the ground.” Duck rearing is widespread in all socioeconomic groups. Survey results indicate that ducks now outnumber chickens, reversing the historical pattern.

Homestead and plinth improvements can be considered transformational adaptations which accommodate flooding. These improvements involve using bricks and mortar to construct homesteads and plinths instead of earth to prevent collapse during flooding. This adaptation attests the importance of a safe living place and has been made possible by the availability of credit. Interviews and survey data suggest that the proportion of households with semi-improved or improved homesteads has increased from 1% to 78% since flooding started. Homestead and plinth reconstruction is a transformational adaptation for households as it meets both the untenable and originality criteria. Most participants considered the risk of building collapse and costs of reconstruction untenable. Semi-improved and improved homesteads help overcome hard limits associated with basic homesteads and flooding. However, this also enables males to migrate without fear of homestead collapse. One participant living in a traditional homestead explained why he cannot migrate for extended periods: “My father is sick and anything can happen to him anytime. My brothers live [outside the village] and I feel anxiety about the house falling down. I feel afraid to stay outside [of the village]”. The originality criterion is met because for most households constructing buildings of bricks and mortar is a new technology. Previously only the wealthiest households had improved homesteads and plinths as they are much more costly and need the skills of hired labour.

Domestic migration can be considered transformational adaptation and represents a retreat from flooding. Male members of households typically migrate to elsewhere in Khulna Division to harness agricultural labour opportunities. Migration is increasing as summer cultivation of cash crops has decreased dramatically due to flooding, resulting in loss of income and lower demand for agricultural labourers. But it does not fully compensate for the loss of income. One interviewee complained that income earned while migrating was “not a handsome amount. Many people go to Jessore to get job and the daily wage decreases. I bring back a small amount of money”. Migration is particularly widespread among lower socioeconomic groups. It meets the untenable

criterion of transformation because households cannot withstand the loss of income and still fulfil livelihood needs. Domestic migration enables overcoming the hard limits imposed by flooding on crop cultivation. It also meets the originality criterion despite being a historical livelihood component, as planned migration to remote places as a substitute for summer crop cultivation and local agricultural wage labour is a new livelihood strategy.

International migration can be considered transformational adaptation and represents a retreat from flooding. Male members of some households migrate overseas to find non-agricultural labour opportunities. It is occurring because these households believe that flooding has suppressed the local economy to a level where livelihood diversification out of agriculture is not possible. One participant commented: "Yes, I can start a business. However, the interest charged would be more than the profit. If I go [abroad], that amount of money I would be able to make will be sufficient to repay loans." Another participant believed suitable jobs simply were not available for their son: "What he used to earn here was not enough. He has a master's degree. We thought that if he could go to abroad he would be able to earn more...it was absolutely the right decision". This adaptation only occurs among socioeconomically advantaged households. It passes the untenable criterion as the adaptation occurs in response to economic activity being suppressed to the point that socioeconomically advantaged households feel there are no appropriate livelihoods for them outside of agriculture in the area. International migration is thus a way to overcome the hard limits imposed on the economy by flooding. It passes the originality criterion, as it is a new livelihood activity for the households involved.

Conversion of agricultural land for aquaculture can be considered transformational adaptation accommodating flooding. It involves the cultivation of fresh-water prawn and fish on land previously used for agriculture. This land is usually particularly low-lying and located close to the nearby canal. Thus it often remains flooded for much of the year, which prevents agriculture. Wealthier households have seized the opportunity by renting adjacent plots of land from disadvantaged households, combining them and enclosing them with embankments. Consequently, aquaculture is mainly practised by wealthier households due to its resource requirements. It meets the untenable criterion because the height, duration, and consistency of flooding on associated land prevent agricultural activity. The hard limit flooding poses to crop production is overcome by using the land for aquaculture. Although a reliable source of fresh water is needed for aquaculture, flooding poses a risk for aquaculture as well. One interviewee noted that "during the flood the embankments get damages and the fish flows with the water... I am very worried [there will be a big flood]". Some households have ceased aquaculture due to the financial losses caused by the breaching of embankments. One over-indebted fish farmer said that: "for three years I tried to cultivate fish but I made loss... After that, I have never tried to do it anymore". Aquaculture also passes the originality criterion although it is not entirely new in the area. Small-scale aquaculture in household ponds for household consumption is common. Some households also operate fish farms in wetland areas. However, conversion of agricultural land for aquaculture is a new practice.

## 5. Discussion

The results demonstrate that households are autonomously implementing a mixture of incremental and transformational adaptations to flooding. They have made changes to livelihood assets, such as homesteads and poultry; and they have altered their income generating activities, such as transitioning from agriculture to aquaculture. This section proceeds by discussing each autonomous adaptation in turn focussing on its transformative potential.

The risk-hazard literature has typically adopted a sectoral approach and a developed country focus to the aims and possible ways to determine transformation (e.g. Rickards and Howden, 2012). This article contributes to this literature by adopting a household-level approach in a developing country context, focusing on the characteristics of transformational adaptations and their likely adopters. It provides evidence demonstrating that incremental adaptations accommodate hazards and require few resources. Transformational adaptations in turn often have higher investment and knowledge requirements and either accommodate or retreat from flooding. Low-cost transformations such as domestic migration are widely adopted, but transformations requiring greater resources such as international migration and adoption of aquaculture have limited uptake. The findings suggest that households cannot protect themselves against flooding. Additionally, households with limited resources to smooth consumption will partly retreat in the absence of protection measures.

The findings corroborate existing literature, which has suggested that the categorisation of transformation is subjective and relative from the researcher point-of-view (e.g. Rickards and Howden, 2012). The scale of assessment determines whether adaptation measures can be considered novel solutions or part of wider incremental change. For instance, the increasing number of households improving homesteads and plinths can be interpreted as an incremental increase in the uptake of an existing practice at the village and wider scales; although for the households it is a transformational change. Similarly, consideration of the wider livelihood context within which adaptations take place can determine whether they are complex transformations or simpler incremental changes. For instance, as an adaptation domestic migration can appear incremental when its driver is omitted. The findings of this study also contribute to the existing literature by highlighting how perceptions partly determine whether adaptations are incremental or transformational. For instance, household income aspirations determine whether the situation that gave rise to international migration was considered untenable.

The findings demonstrate the suitability of the risk-hazard approach for assessing autonomous household adaptations within a developing country context and how it could inform adaptation planning. More generally, the findings corroborate the findings in the existing literature that environmental hazards influence migration patterns, that environmental factors interact with socioeconomic and cultural processes to shape migration patterns, and that a variety of migration patterns exist because of the influence of adaptive capacity (McLeman and Hunter, 2010). The identified autonomous adaptations also demonstrate that households focus adaptation efforts on devising ways to reduce livelihood risk. This corroborates earlier arguments that

local responses to climate change are driven by how livelihoods and assets are impacted (Ayers and Forsyth, 2009).

Our study contributes to existing literature by demonstrating that the risk-hazard approach provides a good basis for investigating how households respond to climate change. Adaptation planning can use the risk-hazard approach to improve knowledge on existing autonomous adaptation, and in turn provide households with the required resources to reduce livelihood risk. In our case study, adaptation planning could provide flood forecasts, training for duck rearing or aquaculture and make available affordable long-term credit for homestead improvements. It could also decide to restrict certain adaptation measures, particularly if they are maladaptive for other households. For instance, salt-water shrimp farms found in coastal regions negatively affect agricultural farmers with adjacent lands (Paul and Vogl, 2011).

Despite the ability of the risk-hazard approach to inform adaptation planning, it does not give sufficient consideration and emphasis to ethical concerns because of its focus on risks and risk mitigation measures, and its inattention to the factors that shape the actors' ability to access and deploy them. This study contributes to the risk-hazard literature by highlighting how incorporation of elements of the political-ecology approach is vital to ensure that adaptation planning can deliver equitable outcomes. From that viewpoint, none of the adaptations observed in our case study were transformative, because they do not confront social inequities and power imbalances: the adaptation measures merely reflect pre-existing social inequities and structural causes of vulnerability faced by socioeconomically disadvantaged households. For instance, land converted for use by aquaculture is often owned by disadvantaged households. They were themselves unable to adopt aquaculture due to a lack of resources. Instead, they rented their land to wealthier households who had or could obtain the required resources. Unable to cultivate their land, socioeconomically disadvantaged households migrated to work as agricultural labourers for less than rice and jute cultivation provided earlier. One participant commented that "earlier I cultivated both rice and jute [and earned 12-13,000 BDT], now I have leased the land for fish culture. The rent is very small...6,000 BDT".

A political-ecology approach can also help highlight how government extension programmes can inadvertently contribute to unequal outcomes. For instance, households who transitioned into aquaculture did so in part because they accessed free training and larger amounts of cheaper credit from government extension programmes. According to the survey average loan size from banks was double than that from NGOs, and only 13.5% of village households accessed credit from banks. Socioeconomically disadvantaged households are less able to access these services, especially credit from government banks. This requires formal documentation that they do not have. Instead, they have to use more informal and expensive providers of credit; and cannot access the required volumes associated with transitioning into aquaculture. It is evident that making resources available to facilitate autonomous adaptation is necessary but not sufficient to ensure equitable outcomes. In addition, adaptation planning must recognise social inequalities that may be accentuated by external interventions to avoid maladaptive outcomes. It must also distribute resources and

devise interventions so that they are accessible to low-income and otherwise disadvantaged groups. Furthermore, it must be aware of the socioeconomic barriers that reduce adaptive capacity. For instance, education is a determinant of vulnerability. Participants associated education with desirable phenomena such as high agricultural productivity and its link with disempowerment. One participant when asked if they had any questions for me replied “You are educated person and I am not. How could I ask you a question?”

Another limitation of the risk-hazard approach is its tendency to result in static local-level analyses. We suggest it could benefit from incorporation of elements of the ecological-resilience approach such as its long-term perspective, attention to feedback loops, and use of socio-ecological systems ontology to improve the understanding of long term implications of interventions. Unfortunately, this is more difficult than integrating aspects of political-ecology. Our research design was somewhat incompatible with the ecological-resilience approach. Its structure was incompatible with socio-ecological system boundaries and was not longitudinal. However, it is still possible to tease out some valuable insights.

Flooding can be interpreted as the future unintended consequence of top-down flood management programmes such as the Coastal Embankment Project, a risk-hazard based intervention to reduce flooding and increase agricultural activity in southern Bangladesh. Flooding can be interpreted as the consequence of a feedback loop causing the elevation of the river above the surrounding landscape. This feedback loop results from concentrating siltation in distributary rivers rather than flood plains and inadequate river management. Two potential regime states have emerged: one where surrounding land is not flooded; and another where surrounding land is flooded. The threshold between them can be interpreted as the carrying capacity of the elevated river, the trigger being the amount of river flow. While changes caused by the feedback loops have been slow and gradual, crossing thresholds result in relatively sudden and dramatic changes (Folke et al., 2004) in terms of intensity and frequency of flooding. Thus adaptations that are locally successful in the short term may prove maladaptive over the longer-term. Ecological-resilience might even promote long-term management rather than short-term prevention of flooding. An example is the ‘Tidal River Management’ proposal to periodically flood areas to elevate floodplains over time (Tutu, 2005). Investigation at wider scales also highlights that localised problems can be caused by wider systemic changes. For instance, upstream deforestation and the Farakka Dam in India have contributed to siltation of rivers and thus flooding in southwest Bangladesh (Ali, 2007). Thus alleviation of local flooding problems may require wider considerations and even international cooperation (Ahmad and Ahmed, 2003).

## **6. Conclusions**

Our study contributes to autonomous and transformative adaptation debates by comparing the ways in which alternative approaches shed light on them, and by providing empirical evidence on incremental and transformational autonomous adaptation from southwest Bangladesh, as well as by drawing lessons for adaptation planning.

The three dominant approaches to adaptation were first highlighted. Considering local responses to climate change are driven by the impacts of those changes on livelihoods and assets, the risk-hazard approach is argued to be best suited for investigating how households autonomously respond to environmental change. Under this approach transformation refers to a depth of change: untenable situations call for novel solutions which overcome limits to adaptation.

Our study highlights that a considerable amount of autonomous adaptation to flooding is occurring and that it involves changes to livelihood assets and income generating activities. Observable adaptations included both incremental and transformative measures. Transformative adaptations accommodated or retreated from flooding and their uptake depended on resource requirements: high cost adaptation measures were only accessible to wealthier households, while low cost measures were widely adopted across socio-economic groups. The discussion demonstrates how the categorisation of adaptations as incremental or transformational is influenced the scale or unit of assessment and the wider context within which adaptation is seen to occur. It is also shown that perceptions within household-level analysis can partly determine this categorisation.

Households are shown to adopt adaptation measures which reduce livelihood risk, demonstrating the suitability of the risk-hazard approach for assessing autonomous adaptation within a developing country context. Adaptation planning can use the risk-hazard approach as a basis to improve understanding and facilitation of autonomous adaptation. However, it is unlikely to lead to equitable outcomes unless combined with elements from political ecology. This approach highlights how adaptation measures reflect social inequality, to which existing government extension programmes may inadvertently contribute. Additionally, it will likely result in static local-level analyses unless it adopts insights from ecological-resilience such as feedback loops which enable both longer term and broader scale analysis.

## References

- ADB. 2007. *Khulna-Jessore Drainage Rehabilitation Project* Department, O.E. Performance Evaluation Report
- Adger, W.N. 2006. Vulnerability. *Global Environmental Change-Human and Policy Dimensions*. **16**(3), pp.268-281.
- Ahmad, Q.K. and Ahmed, A.U. 2003. Regional Cooperation in Flood Management in the Ganges-Brahmaputra-Meghna Region: Bangladesh Perspective. *Natural Hazards*. **28**(1), pp.191-198.
- Ahmed, A.U. 2010. *Reducing Vulnerability to Climate Change: The Pioneering Example of Community Based Adaptation in Bangladesh*. Dhaka: Centre for Global Change (CGC) and Care Bangladesh.
- Ali, A.M.S. 2007. September 2004 Flood Event in Southwestern Bangladesh: A Study of its Nature, Causes, and Human Perception and Adjustments to a New Hazard. *Natural Hazards*. **40**(1), pp.89-111.
- Ayers, J. and Forsyth, T. 2009. Community-Based Adaptation to Climate Change: Strengthening Resilience through Development. *Environment*. **51**(4), pp.22-31.
- Azam, M.S. and Imai, K.S. 2009. *Vulnerability and Poverty in Bangladesh*. ASARC Working Paper 2009/02 Manchester, UK: University of Manchester.

- Barnett, J., Evans, L.S., Gross, C., Kiem, A.S., Kingsford, R.T., Palutikof, J.P., Pickering, C.M. and Smithers, S.G. 2015. From barriers to limits to climate change adaptation: path dependency and the speed of change. *Ecology and Society*. **20**(3).
- Barnett, J. and O'Neill, S. 2010. Maladaptation. *Global Environmental Change*. **20**(2), pp.211-213.
- Berman, R., Quinn, C. and Paavola, J. 2012. The role of institutions in the transformation of coping capacity to sustainable adaptive capacity. *Environmental Development*. **2**, pp.86-100.
- Burton, I., Kates, R.W. and White, G.F. 1993. *The Environment as Hazard*. New York: Guildford Press.
- CCC. 2009. *Environment Cost for Climate Change*. Climate Change Cell, DoE, MoEF; Component 4b, CDMP, MoFDM. .
- Christoplos, I., Anderson, S., Arnold, M., Galaz, V., Hedger, M., Klein, R.J.T. and Le Goulven, K. 2009. *The human dimension of climate adaptation: The importance of local and institutional issues*. Stockholm: Commission on Climate Change and Development.
- Dodman, D. and Mitlin, D. 2011. Challenges for community-based adaptation: discovering the potential for transformation. *Journal of International Development*. pp.n/a-n/a.
- Dovers, S.R. and Handmer, J.W. 1992. Uncertainty, sustainability and change. *Global Environmental Change*. **2**(4), pp.262-276.
- Dow, K., Berkhout, F. and Preston, B.L. 2013. Limits to adaptation to climate change: a risk approach. *Current Opinion in Environmental Sustainability*. **5**(3-4), pp.384-391.
- Dronkers, J., Gilbert, J.T.E., Butler, L.W., Carey, J.J., Campbell, J., James, E., McKenzie, R., Misdorp, R., Quin, N., Ries, K.L., Schroder, P.C., Spradley, J.R., Titus, J.G., Vallianos, L. and von Dadelszen, J. 1990. *Strategies for Adaptation to Sea Level Rise*. Report of the IPCC Coastal Zone Management Subgroup. Geneva: Intergovernmental Panel on Climate Change.
- Eakin, H. and Lemos, M.C. 2006. Adaptation and the state: Latin America and the challenge of capacity-building under globalization. *Global Environmental Change-Human and Policy Dimensions*. **16**(1), pp.7-18.
- Eakin, H. and Luers, A.L. 2006. Assessing the vulnerability of social-environmental systems. *Annual Review of Environment and Resources*. Palo Alto: Annual Reviews, pp.365-394.
- Eakin, H., Tompkins, E., Nelson, D. and Anderies, J. 2009. Hidden costs and disparate uncertainties: trade-offs involved in approaches to climate policy. In: Adger, W.N., Lorenzoni, Irene and O'Brien, Karen L. ed. *Adapting to Climate Change: Thresholds, Values, Governance*. Cambridge, UK: Cambridge University Press, pp.212-226.
- Eriksen, S.H., Nightingale, A.J. and Eakin, H. 2015. Reframing adaptation: The political nature of climate change adaptation. *Global Environmental Change-Human and Policy Dimensions*. **35**, pp.523-533.
- Folke, C. 2006. Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change-Human and Policy Dimensions*. **16**(3), pp.253-267.
- Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L. and Holling, C.S. 2004. Regime shifts, resilience, and biodiversity in ecosystem

- management. *Annual Review of Ecology Evolution and Systematics*. **35**, pp.557-581.
- Ford, J.D., Keskitalo, E.C.H., Smith, T., Pearce, T., Berrang-Ford, L., Duerden, F. and Smit, B. 2010. Case study and analogue methodologies in climate change vulnerability research. *Wiley Interdisciplinary Reviews: Climate Change*. **1**(3), pp.374-392.
- Füssel, H.M. 2007. Adaptation planning for climate change: concepts, assessment approaches, and key lessons. *Sustainability Science*. **2**(2), pp.265-275.
- Gallopín, G., C. 2006. Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change*. **16**(3), pp.293-303.
- Government of Bangladesh. 2010. *Agricultural Statistics of Bangladesh*.
- Gunderson, L.H. and Holling, C.S.E. 2002. *Panarchy: Understanding Transformations in Human and Natural Systems*. Washington DC: Island Press.
- Holling, C.S. 1973. Resilience and stability of ecological systems. *Annual review of ecology and systematics*, pp.1-23.
- Holling, C.S. 1986. The resilience of terrestrial ecosystems: local surprise and global change. In: Clark, W.C. and Munn, R.E. eds. *Sustainable Development of the Biosphere*. London: Cambridge University Press, pp.292-317.
- IPCC. 2013. Annex III: Glossary. In: Stocker, T.F., et al. eds. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, pp.1447–1466.
- Janssen, M.A. and Ostrom, E. 2006. Resilience, vulnerability, and adaptation: A cross-cutting theme of international human dimensions programme on global environmental change. *Global Environmental Change-Human and Policy Dimensions*. **16**(3), pp.237-239.
- Janssen, M.A., Schoon, M.L., Ke, W. and Börner, K. 2006. Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change. *Global Environmental Change*. **16**(3), pp.240-252.
- Kates, R.W., Travis, W.R. and Wilbanks, T.J. 2012. Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences*.
- Klein, R.J.T., Midgley, G.F., Preston, B.L., Alam, M., Berkhout, F.G.H., Dow, K. and Shaw, M.R. 2014. Adaptation opportunities, constraints, and limits. In: Field, C.B., et al. eds. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press,
- Kundzewicz, Z.W., Kanae, S., Seneviratne, S.I., Handmer, J., Nicholls, N., Peduzzi, P., Mechler, R., Bouwer, L.M., Arnell, N., Mach, K., Muir-Wood, R., Brakenridge, G.R., Kron, W., Benito, G., Honda, Y., Takahashi, K. and Sherstyukov, B. 2014. Flood risk and climate change: global and regional perspectives. *Hydrological Sciences Journal*. **59**(1), pp.1-28.
- Leclere, D., Havlik, P., Fuss, S., Schmid, E., Mosnier, A., Walsh, B., Valin, H., Herrero, M., Khabarov, N. and Obersteiner, M. 2014. Climate change induced transformations of agricultural systems: insights from a global model. *Environmental Research Letters*. **9**(12).

- Lewis, D. 2011. *Bangladesh: Politics, Economy and Civil Society*. Cambridge: Cambridge University Press.
- Manuel-Navarrete, D. and Pelling, M. 2015. Subjectivity and the politics of transformation in response to development and environmental change. *Global Environmental Change*. **35**, pp.558-569.
- Marshall, N.A., Park, S.E., Adger, W.N., Brown, K. and Howden, S.M. 2012. Transformational capacity and the influence of place and identity. *Environmental Research Letters*. **7**(3), p034022.
- McLeman, R.A. and Hunter, L.M. 2010. Migration in the context of vulnerability and adaptation to climate change: insights from analogues. *Wiley Interdisciplinary Reviews-Climate Change*. **1**(3), pp.450-461.
- MoEF. 2008. *Bangladesh Climate Change Strategy and Action Plan 2008*. Dhaka, Bangladesh: Ministry of Environment and Forests, Government of the People's Republic of Bangladesh.
- O'Brien, K. 2012. Global environmental change II: From adaptation to deliberate transformation. *Progress in Human Geography*. **36**(5), pp.667-676.
- Olsson, P., Galaz, V. and Boonstra, W.J. 2014. Sustainability transformations: a resilience perspective. *Ecology and Society*. **19**(4).
- Paul, B.G. and Vogl, C.R. 2011. Impacts of shrimp farming in Bangladesh: Challenges and alternatives. *Ocean & Coastal Management*. **54**(3), pp.201-211.
- Pelling, M. 2011. *Adaptation to Climate Change: From resilience to transformation*. London: Routledge.
- Pelling, M., O'Brien, K. and Matyas, D. 2015. Adaptation and transformation. *Climatic Change*. **133**(1), pp.113-127.
- Rickards, L. and Howden, S.M. 2012. Transformational adaptation: agriculture and climate change. *Crop & Pasture Science*. **63**(3), pp.240-250.
- Sen, A. 1981. *Famines and Poverty*. London: Oxford University Press.
- Sen, A. 1982. *Poverty and famines an essay on entitlement and deprivation*. Oxford: Oxford University Press,.
- Smit, B., Burton, I., Klein, R.J.T. and Wandel, J. 2000. An Anatomy of Adaptation to Climate Change and Variability. *Climatic Change*. **45**(1), pp.223-251.
- Smit, B., Pilifosova, O., Burton, I., Challenger, B., Huz, S., Klein, R., Yohe, G., McCarthy, J.J., Canziani, O. and Leary, N. 2001. *Adaption to Climate Change in the Context of Sustainable Development and Equity*. Geneva: IPCC.
- Smit, B. and Wandel, J. 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*. **16**(3), pp.282-292.
- Smith, M.S., Horrocks, L., Harvey, A. and Hamilton, C. 2011. Rethinking adaptation for a 4 degrees C world. *Philosophical Transactions of the Royal Society a-Mathematical Physical and Engineering Sciences*. **369**(1934), pp.196-216.
- Stern, N.H. 2006. *The economics of climate change: the Stern review*. Cambridge, UK: Cambridge University Press.
- Thorn, J., Thornton, T.F. and Helfgott, A. 2015. Autonomous adaptation to global environmental change in peri-urban settlements: Evidence of a growing culture of innovation and revitalisation in Mathare Valley Slums, Nairobi. *Global Environmental Change*. **31**, pp.121-131.
- Tutu, A.-U.-A. 2005. *River Management in Bangladesh: A People's Initiative to Solve Water Logging*. Participatory Learning and Action. International Institute for Environment and Development. 51.

- Walker, B., Hollin, C.S., Carpenter, S.R. and Kinzig, A. 2004. Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society*. **9**(2).
- Walker, B.H., Ludwig, D., Holling, C.S. and Peterman, R.M. 1981. Stability of semi-arid savanna grazing systems. *Journal of Ecology*. **69**(2), pp.473-498.
- White, G.F. 1986. Human adjustment to floods. In: Kates, R. and Burton, I. eds. *Geography Resources and Environment*. Chicago: University of Chicago Press, pp.11-25.