2016-05-01

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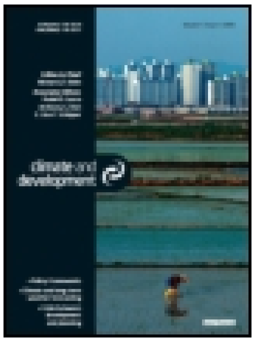
Climate and Development



Climate and Development

ISSN: 1756-5529 (Print) 1756-5537 (Online) Journal homepage: http://www.tandfonline.com/loi/tcld20

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To cite this article: Hannah Reid & Sarder Shafiqul Alam (2016): Ecosystem-based approaches to adaptation: evidence from two sites in Bangladesh, Climate and Development

To link to this article: http://dx.doi.org/10.1080/17565529.2016.1167663

Published online: 22 May 2016.

Climate and Development, 2016
http://dx.doi.org/10.1080/17565529.2016.1167663

climate and development

RESEARCH ARTICLE

Ecosystem-based approaches to adaptation: evidence from two sites in Bangladesh

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(*Received 18 June 2015; accepted 12 January 2016*)

Ecosystem-based approaches to adaptation (EbA) involve the use of biodiversity and ecosystem services to help people adapt to the adverse effects of climate change. This research looks at two components of effective EbA: ecosystem resilience and the maintenance of ecosystem services. It assesses EbA effectiveness in terms of how such approaches support community adaptive capacity and resilience at two sites in Bangladesh: Chanda Beel wetland and Balukhali Village in the Chittagong Hill Tracts. Research findings suggest that more attention should be paid to EbA as an important climate-change response. Results show that the many diverse natural resources available and utilized at each site have increased the number of different subsistence and livelihood options available in the community and hence local adaptive capacity, especially for poorer households. Major structural shifts in ecosystem functioning observed at each site to date can be attributed primarily to non-climate-change-related factors, although climate-change-related factors increasingly threaten to dramatically alter ecosystems, especially in Chanda Beel. Such shifts have important consequences for adaptive capacity and have led to a number of trade-offs. The lack of effective institutions, good governance and enabling policy at both sites has limited potential resilience gains from sound ecosystem management.

Keywords: climate change; adaptation; ecosystem-based approaches to adaptation; ecosystem-based adaptation; community-based adaptation; Bangladesh

1. Introduction

Ecosystem-based approaches to adaptation (EbA) are defined by the Convention on Biological Diversity (CBD) 2nd Ad Hoc Technical Expert Group on Biodiversity and Climate Change as "the use of biodiversity and ecosystem services to help people adapt to the adverse effects of climate change as part of an overall adaptation strategy" (CBD, 2009, p. 41). This definition was elaborated by the CBD decision X/33 on Climate Change and Biodiversity as including "sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits for local communities" (CBD, 2010, p. 3).

Many now acknowledge the importance of ecosystems and ecosystem services as a key component of adaptation (Colls, Ash, & Ikkala, 2009; Doswald et al., 2014; Girot et al., 2012; IPCC, 2014; Jeans, Oglethorpe, Phillips, & Reid, 2014; Munroe et al., 2012; Reid, 2011, 2014a; UNEP, 2012). This is because many of those who are most vulnerable to climate change are also highly reliant on ecosystems and ecosystem services for their lives and livelihoods. Ecosystems and the services they provide are already the foundation of many adaptation actions, especially for poor people, and many also deliver livelihood and climate-change mitigation co-benefits. There is also some evidence that EbA can be cost effective (Rao et al., 2013).

A study of the National Adaptation Programmes of Action (NAPAs) of the Least Developed Countries (LDCs) shows that many LDCs recognize and prioritize the role that biodiversity, ecosystems and natural habitats play in adaptation. The study found that some 56% of priority NAPA projects reviewed had significant natural resource components. In Bangladesh, 6 of 15 priority NAPA projects have a significant natural resources component (Reid, Phillips, & Heath, 2009).

Although anecdotal evidence of the benefits of EbA is strong, there is little rigorous evidence relating to EbA available in the scientific literature (Doswald et al., 2014; Reid, 2011). This research therefore seeks to assess evidence from specific Action Research for Community Adaptation in Bangladesh (ARCAB) sites to test the hypothesis that EbA can contribute to community adaptive capacity and resilience.

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2. Ecosystem-based adaptation principles

To assess the merits of EbA in the two selected ARCAB study sites, it is necessary to better understand how to define, measure and track EbA. The Nature Conservancy argues that effective EbA have two key components: the maintenance of ecosystem services and ecosystem resilience (Thomas, 2011). The Millennium Ecosystem Assessment (MEA, 2005) also uses these two components in its analysis of how changes to ecosystems and their services affect human well-being.

2.1. *Maintenance of ecosystem services*

Ecosystems provide a number of provisioning, regulating, cultural and supporting services (see Table 1). In the context of climate-change adaptation, these "natural assets" or "ecosystem services" include water provision, erosion protection, climate regulation, disaster risk reduction and genetic diversity.

The MEA (2005) found that approximately 60% of the ecosystem services examined had been degraded or used unsustainably, including fresh water, capture fisheries, air and water purification, and the regulation of regional and local climate, natural hazards and pests. This has worrying implications for the climate-vulnerable poor who are particularly reliant on these services and in some instances are in poverty because of a reduction in these services.

2.2. *Ecosystem resilience*

Resilience means different things to those working in disaster management, climate change and ecosystems. In ecology and the natural sciences, resilience was traditionally understood as a property that allows a system to recover its prior state after suffering a shock (Holling, 1973). The MEA (2005) defines resilience as "The capacity of a system to tolerate impacts of drivers without irreversible change in its outputs or structure". This article looks at ecosystem resilience, and how it contributes to human resilience in the context of climate change.

An exclusive focus on "natural resources" or "ecosystem services" in the context of adaptation ignores the fact that "An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the non-living environment interacting as a functional unit" (MEA, 2005). Central to the concept of EbA is the importance of adopting a holistic approach to maintaining ecosystem structure and functioning and ecosystem service provision.

Recognizing that ecosystems undergo change (due to climate change and other stressors) is key (Girot et al., 2012). Climate-change impacts such as changes in sea levels, temperature and rainfall will affect the functionality of ecosystems. Such changes can have significant social, cultural and economic consequences (Jeans et al., 2014). Observed changes in climate have already adversely impacted certain species and ecosystems, including causing changes in species distributions, population sizes, the timing of reproduction or migration events, and an increase in the frequency of pest and disease outbreaks. Further changes are inevitable (IPCC, 2014) and the MEA (2005) predicts that "By the end of the century, climate change and its impacts may be the dominant direct driver of biodiversity loss and changes in ecosystem services globally".

Ecosystems also have limits beyond which they cannot function. There is established but incomplete evidence that ecosystems are increasingly experiencing non-linear changes, including accelerating, abrupt and potentially irreversible shifts as a result of climate change and other pressures. When limits are breached, the ecosystem may no longer be able to provide the services on which human communities have come to depend (MEA, 2005; Scheufele & Bennett, 2012). Examples include disease emergence, rainforest dieback, the creation of "dead zones" in coastal waters and the collapse of fisheries (IPCC, 2014). Such dramatic changes affect people in

Table 1. Ecosystem services.

Provisioning services	Regulating services	Cultural services	Supporting services
• Food (capture fisheries, aquaculture, wild foods, livestock, forest products, crops) • Fresh water • Wood (for timber and fuel) and fibre • Genetic resources • Biochemicals, natural medicines, pharmaceuticals	• Climate regulation (global, regional and local) • Air quality regulation • Water regulation • Erosion regulation • Water purification and waste treatment • Disease regulation • Pest regulation • Pollination • Natural hazard regulation	• Spiritual and religious values • Aesthetic values • Recreation and ecotourism	• Nutrient cycling • Soil formation • Primary production (photosynthesis)

Source: MEA (2005).

different ways, but it is typically "groups such as the poor, women, and indigenous communities [who] have tended to be harmed" (MEA, 2005). Although there is uncertainty about the thresholds of climate change above which ecosystems are irreversibly changed (CBD, 2009), it is clear that ecosystems are more resilient to climate change if they are in good condition and non-climate stressors such as habitat destruction, over-harvesting of resources and pollution are minimized (Hansen, Biringer, & Hoffman, 2003; Morecroft, Crick, Duffield, & Macgregor, 2012).

To increase climate-change resilience, food, energy, water and waste management systems should be viewed as interconnected and mutually dependent components of natural systems rather than merely an array of unconnected and unlimited resources or services (Pimbert, 2010; Reid, Chambwera, & Murray, 2013). Reid and Schipper (2014) argued that if adaptation practitioners view adaptation threats and solutions in terms of natural resource silos as opposed to complex systems, maladaptation could occur.

3. Links between the maintenance of ecosystem services and resilient ecosystems, and human adaptive capacity and resilience

This research looks at how resilient ecosystems and the maintenance of ecosystem services can contribute to adaptation. It assesses how they can reduce the vulnerability – "The state that determines the ability of individuals or social groups to respond to, recover from, or adapt to, the external stresses placed on their livelihoods and well-being by (climate) hazards" (Wisner, Blakie, Cannon, & Davis, 2004) – of the climate-vulnerable poor; increase the adaptive capacity – "The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC, 2014) of the climate-vulnerable poor; and how they can enhance the resilience of the climate-vulnerable poor – that is, their ability to move beyond coping strategies towards achieving longer term development in spite of, or in light of, climate change (Dodman, Ayers, & Huq, 2009).

Resilient ecosystems and the provision of ecosystem services are likely to be important components of human adaptive capacity and resilience. The MEA (2005) does not refer explicitly to human adaptive capacity or resilience in the face of climate change, but it does refer to the importance of ecosystems and ecosystem services in terms of their contributions to "human well-being" – a concept that clearly emphasizes more than just access to natural assets and services.

Adaptation is a process rather than an outcome, so proxies for "reduced resilience" or "increased adaptive capacity" are required when it comes to adaptation monitoring and evaluation (Bours, McGinn, & Pringle, 2014). The Africa Climate Change Resilience Alliance (ACCRA) argues that asset-oriented approaches to defining, measuring and supporting adaptive capacity typically mask the role of processes and functions. It has therefore developed a local adaptive capacity framework (LAC) that tries to capture the intangible and dynamic dimensions of adaptive capacity, in addition to capital and resource-based components (Jones, Ludi, & Levine, 2010; Ludi et al., 2011). It describes five distinct yet inter-related characteristics that contribute towards adaptive capacity at the local level: (1) the asset base, (2) institutions and entitlements, (3) knowledge and information, (4) innovation and (5) flexible forward-looking decision-making and governance.

Clearly, "human well-being" as conceived by the MEA has much in common with "adaptive capacity" as defined above by the IPCC and ACCRA. Both contain not only elements of access to resources and assets, but also less tangible soft process-oriented elements, which are harder to quantify but address key issues such as the presence of a supportive social, institutional, policy and governance framework that can offer security and freedom of choice and action, and facilitate good decision-making. A key difference between human well-being and adaptive capacity is that the latter has much stronger emphasis on looking ahead, and creating an environment in which future changes can be accommodated.

4. Research sites

Bangladesh is particularly vulnerable to climate change not only because of its geographic location – more than half of the country is a floodplain – but also because of a number of social issues such as extreme poverty, which leaves the population extremely vulnerable to shocks and stresses (Hossain, Hein, Rip, & Dearing, 2013; Rai, Huq, & Huq, 2014; Rouillard, Benson, & Gain, 2014). To improve the understanding on whether and how ecosystem resilience and ecosystem service provision contribute to community adaptive capacity and resilience, two ARCAB sites with a strong ecosystem/natural resources focus were selected: Goalgram Village in the Chanda Beel wetland and Balukhali Village, Rangamati District, in the Chittagong hill tracts.

4.1. *Goalgram Village, Chanda Beel wetland*

Goalgram Village is located in Nanikhir Union, Muksodpur Upazila, Gopalganj District, Bangladesh. The low-lying Chanda Beel wetland (10,890 hectares) borders the village on its north, west and southern sides. The village covers about 610 hectares and lies about 40 km north of Gopalganj District town. It contains 2 primary schools, 13 temples and several small grocery shops, and is home to 661 families. During the monsoon flooding season, most of the village area (not homesteads) is inundated, including the three village roads, so people travel within the village and further afield using country boats. The village has three canals and many ditches (man-made ponds) around homesteads and also in crop fields. Large quantities of floating and rooted aquatic plants and weeds are present (Chakraborty, Adrika, & Hussain, 2005; Hussain & Chowdhury, 2005). The main occupation of villagers is agriculture. Borro paddy rice is the dominant village crop, cultivated in the dry season when farmers also grow crops such as vegetables. The Beel's natural resources have greatly declined over the years, but many varieties of fish, aquatic animals, aquatic weeds and plants and a large quantity of peat soils are still available and act as important sources of food and income (Ghosh & Mondal, 2013).

Chanda Beel is generally flat with low elevation above sea level. The area is prone to extensive monsoon flooding and water logging due to high tides and inundation by Ganges and Jamuna River water. During the monsoon, the Beel connects with other neighbouring wetlands (Chakraborty et al., 2005). Water levels are the lowest in February/March and highest in August/September. There are 44 villages in and around the Beel system, all on a relatively higher land.

4.2. *Balukhali Village, Rangamati District, Chittagong hill tracts*

Balukhali Village is located along the eastern side of Kaptai Lake in the south-east of Bangladesh, about 4 km away from Rangamati Sadar Upazila and Rangamati District town. Kaptai Lake was formed following the completion of the Kaptai hydroelectric dam in 1963, built to generate cheap energy to mitigate the power crisis in Dhaka and other cities. The initial environmental and social costs of the project were tremendous and these have multiplied over time. The lake submerged much of the Karnaphuli River valley and the lower reaches of other rivers (Rashid, 1991), including over 76,000 hectares of pristine forested valleys and cultivated land in the Chittagong Hill Tracts (Khan et al., 1994). It displaced 20–25% of the indigenous population and submerged nearly 22,000 hectares of fertile, flat, alluvial land. Kaptai Lake varies in area from 26,800 hectares in May up to a maximum of 74,200 hectares in October (BBS, 2004).

Balukhali contains roughly 194 households. Some 7% are very poor and 31% are poor. The village has no metal access road, and only a few paved village roads. The village has no market or secondary school, so people must travel by boat to Rangamati Sadar Upazila for their secondary or higher level education, and to sell their household or farm products, or buy household needs. Poor families struggle to pay for regular boat travel.

Agriculture is a driving force in the village economy and the main source of income for some 50% of households. Indigenous populations have practised traditional shifting "slash-and-burn" cultivation (known locally as "*jhum*") for thousands of years, and despite efforts by the authorities over the last century to encourage people to adopt more sedentary lifestyles, *jhum* remains the main livelihood source for many (Hassan & Van Lavieren, 2000). Borro paddy rice is the dominant village crop, cultivated during the dry season (January–May). Many farmers do agriculture-related activities for about six months of the year, spending the remaining six months fishing in the lake or working for daily wages in horticulture.

5. Methodology

This research asks whether and how changes to ecosystems and associated natural resources and ecosystem services affect human adaptive capacity and resilience in two ARCAB case study sites in Bangladesh. It is beyond the scope of this research to acquire quantitative measures of these parameters, so qualitative approaches and simple observations are used as proxies for these parameters. For example, this research does not measure specific ecosystem services, but rather details the different ecosystem services used by local communities.

Likewise, ecosystem resilience is not measured directly. Substantial uncertainties exist around the best way to define, measure, value and enhance human or ecosystem resilience (Morecroft et al., 2012; Scheufele & Bennett, 2012), and changes to ecological resilience are often only apparent after a change has occurred. This research therefore assessed whether the ecosystem selected had undergone or could undergo a major shift in its structure or function, as a result of human intervention and also climate change, which affected or could affect its ability to provide ecosystem services.

Assessments here about whether human adaptive capacity and resilience increase or decrease depending on changes to ecosystems and their services are largely qualitative and based on a combination of expert and community judgement.

This research also looks at what kinds of climate-change-related impacts ecosystems are experiencing or can expect to experience at each site, and how this affects or could potentially affect adaptive capacity. Results, however, are static and based on expert judgement in combination with community observations. They do not try to predict dramatic future changes/ecosystem shifts.

Research methods included interviews conducted with villagers at both sites. Past research, as well as data collected from recent published material and unpublished ARCAB surveys and focus group discussions (undertaken in 2012), was also collated. Much of this was unpublished and in local languages.

This research takes a broad definition of natural resources, in which cultivated crops and vegetables and non-indigenous species are included. At both sites, the environment has been heavily modified from its natural state, but it is what people use now. The MEA (2005) likewise treats agricultural land as an ecosystem in its assessment, despite the fact that it is intensely modified and managed by man.

6. Results

Tables 2 and 3 describe the natural resources and associated ecosystem services utilized by local communities at the two ARCAB sites. Their specific contribution to adaptive capacity or reduced vulnerability in the face of climate change is described, along with the climate-change- and non-climate-change-related impacts affecting (or potentially affecting) each resource/service.

Tables 4 and 5 describe the characteristics of the ecosystem as a whole at the two ARCAB sites, and which climate-change impacts and non-climate-change-related impacts affect (or potentially affect) ecosystem functioning. Resulting changes to adaptive capacity or vulnerability are then described.

7. Discussion

Much published literature on EbA emphasizes the importance of the multiple social, economic and cultural co-benefits ecosystems and the services they provide generate for local communities. For example, Colls et al. (2009) argued that healthy ecosystems provide drinking water, habitat, shelter, food, raw materials, genetic materials, a barrier against disasters, a source of natural resources and many other ecosystem services on which people depend. This research substantiates these claims, with natural resources and ecosystem services at both sites providing a multitude of household benefits and livelihood opportunities contributing to community adaptive capacity and resilience (see Tables 2 and 3). In many instances, these benefits would be difficult to quantify and thus ignored in standard economic assessments of value, although previous efforts to quantify non-use values at Chanda Beel suggest they are significant (Ghosh & Mondal, 2013). Most ecosystem services observed at the case study sites can be classified as provisioning, regulating and supporting services, with cultural services contributing less to adaptive capacity and resilience (Hossain et al., 2013).

The MEA (2005) describes how the benefit of sustainably managing ecosystems can exceed that of converting the ecosystem when both marketed and non-marketed ecosystem services are considered. This study does not quantify ecosystem services in the context of adaptive capacity, but it clearly shows that the wide range of services (or co-benefits) utilized by communities at both sites means that ecosystems and ecosystem services are central to adaptive capacity and resilience and need to be valued and supported accordingly.

7.1. *Resilience from diversity*

The Economics of Ecosystems and Biodiversity report (TEEB, 2008) argues that as with financial markets, a diverse portfolio of species stocks "can provide a buffer against fluctuations in the environment (or market) that cause declines in individual stocks" and that this stabilizing effect "is likely to be especially important as environmental change accelerates with global warming and other human impacts". Maintaining species and genetic diversity can also facilitate the emergence of species and genotypes that are better adapted to shifts in climatic conditions (TEEB, 2008).

Diversity in livelihood options open to a community can also buffer against environmental change and increase community resilience, especially if options encourage people to move away from unsustainable exploitation and degradation of natural resources (Colls et al., 2009).

Both case study sites clearly demonstrate the diversity of opportunities that ecosystems and ecosystem services provide for supporting subsistence and livelihood needs in each area at different times of the year. This has increased community resilience. In Chanda Beel, snails are collected when agricultural activities require less time, from September to November (Khan, Hussain, & Chakraborty, 2005), and in Balukhali Village, fishing occurs when agricultural activities require fewer inputs.

7.2. *Shifts and thresholds in ecosystems*

Although climate change-induced changes to ecosystems and ecosystem services have been noted throughout the world (IPCC, 2014), climate-change-related impacts on ecosystem resilience and service delivery are less well defined and understood (Pettorelli, 2012). Many agree, however, that restoring and alleviating other stresses on ecosystems can help them survive and adapt to climate change and thus continue supporting human adaptation (Colls et al., 2009; IPCC, 2014). Hossain et al. (2013) described how changing temperature and rainfall patterns could lead to dramatic shifts in the type and structure of wetland ecosystems in Bangladesh. This could dramatically affect livelihoods because roughly 80% of rural households depend heavily on wetland resources, and wetlands provide around 46% of all fish consumed in Bangladesh (Hossain et al., 2013).

Observed ecosystem changes at both study sites in Bangladesh can be attributed to a number of factors, some of which may be related to climate change, but most of which are due to other major stressors such as flooding due to dam construction by Balukhali Village, or road, culvert, bridge and sluice gate construction at Chanda

Table 2. The contribution of ecosystem services to adaptive capacity in Goalgram Village, Chanda Beel Wetland.

Natural resource and associated ecosystem service	Contribution to adaptive capacity or reduction in vulnerability	Non-climate-change-related impacts affecting resource/service	Climate-change impacts affecting (or potentially affecting) resource/service
Sparse indigenous and introduced tree coverage (timber and fruit trees).	– Reduced disaster risk (trees protect the houses during cyclones). – Local trees used to rebuild or repair houses damaged by disasters. – Local timber used for making "country boats" to collect water and travel around during floods. Women are responsible for collecting water, which is difficult during flooding as bridges and roads are damaged/underwater. – Rafts made from banana trunks used for moving around locally during floods. – Trees provide shade and help cool air locally during periods of high temperatures. – Trees are sold to increase family income. – Tree branches attract fish when placed in ponds.	Tree cover declining as trees are cut down for timber and fuel, for making furniture and to make space for infrastructure. Trees also replaced by smaller plants for cattle fodder.	Cyclones and floods can damage trees.
"doincha" (*Sesbania* sp.), which can be cultivated.	– Doincha is a member of *Leguminosae* family and plays a vital role in increasing soil fertility. Root nodules fix nitrogen through bacterial action, thereby increasing soil fertility, so most farmers cultivate doincha along with rice and vegetables. – Doincha checks soil erosion against wave action. – It can be used as a structure for growing pumpkins/gourds. – May be used as fuel or for making cattle shed fences. – Rotten doincha leaves are sometimes used as manure.	Reduced as destroyed by domestic livestock.	Damaged by drought and floods.
Grass and "dholkolmi"	– Grown to prevent homestead soil erosion during floods. – Used for fuel.	Decreasing as harvested regularly for fuel.	Decreasing due to dryer conditions.
Bamboo (not indigenous but grows naturally now and is common)	– Used to construct temporary platforms on boats during floods. – Used to rebuild houses damaged by disasters.		
Medicinal trees and plants (mostly cultivated on homesteads)	– Used during vulnerable periods such as floods or droughts when certain diseases are more prevalent.	People are planting more and conserving these species so their number is increasing.	
Large quantities of aquatic plants (floating and rooted). Water hyacinth (*Eichhornia crassipes*) is generally considered an invasive weed, but it grows naturally here and is not cultivated.	– Bed of water hyacinth used as a temporary floating "dhap" for housing during floods. – One type of dhap known locally as "baira" is used as a floating vegetable garden or for crop cultivation. This can reduce losses from flood damage to crops and vegetable beds. – Dhap used as a temporary shelter for livestock and their food during floods. – Rotten water hyacinth increases soil natural fertility (without chemicals), thus increasing crop and vegetable yields. – Dried water hyacinth and other aquatic weeds stored for use as cooking fuel, especially by very poor people. – Water hyacinth used as fodder for cattle. This is important during floods when there is a scarcity of fodder.	Siltation in the Beel (due to irrigation measures/sluice gate construction), pond emptying 2/3 times annually (to catch aquatic animals) and insecticide use has reduced plant resources.	Saline water can reduce availability, as can drought. Water hyacinth, lilies and "kalmi shak" increase during floods

(*Continued*)

Table 2. Continued.

Natural resource and associated ecosystem service	Contribution to adaptive capacity or reduction in vulnerability	Non-climate-change-related impacts affecting resource/service	Climate-change impacts affecting (or potentially affecting) resource/service
	– Used for making construction blocks and ropes. – Piles of water hyacinth around homesteads help prevent water erosion during floods. – People eat waterlilies and “kalmi shak” (a naturally occurring leafy vegetable) during floods. These grow naturally (they are not cultivated). – Local people feel water hyacinth cleans water bodies and reduces pollution. – Water hyacinths obstruct navigation of waterways, but this is not a major issue.		
Fish culture	– Some indigenous fish are cultured (mostly carp and tilapia) mostly for sale to increase household income.	Increasingly popular with local people.	Erratic weather and extreme weather events affect fish cultivation, for example, fish escape during floods.
Wild fish, molluscs and crustaceans (prawns and crabs)	– Caught from local beels/rivers during monsoon season. Especially valuable for most vulnerable people in this season. In the dry season wealthier people with their own ponds can benefit from these animals too.	Use of chemical fertilizers, pesticides and insecticides in paddy fields since the 1960s has degraded water quality and damaged aquatic resources. Fish migration routes have been severely affected by road and sluice gate construction.	Drought and salinity increases may be affecting resources.
Vegetable cultivation	– Grown on homesteads to meet subsistence needs and also sold.	People are growing more vegetables in recent years.	Erratic weather and extreme weather events affect homestead vegetable cultivation. Especially torrential rain and drought (and associated plant pest attacks).
Ducks (domesticated)	– Reared during monsoon floods. Chickens die but ducks are better in floods. They are especially important for women and the poorest.	Increasing.	Floods help.
Soils	– Used to raise homesteads during floods. – Soil-made containers safely store food grains and other family assets. – Clay soil used to make lightweight portable oven to cook during floods. – Used to raise fishery pond embankments to reduce the number of fish escaping from ponds during periods of inundation. – Peat soils used for fuel.	Heavy use of chemical fertilizers, pesticides and insecticides since 1960 has damaged soil fertility.	
Water	– Water for drinking from tube wells. – Flood water for washing and cleaning. – Ditches are built to conserve water for the dry season and provide a refuge for fish as well as for irrigation.	Highly modified waterways (canals, sluice gates, etc.) to manage water for irrigation.	Drought affects water quantity (not quality so much).

Table 3. The contribution of ecosystem services to adaptive capacity in Balukhali Village, Rangamati District, Chittagong hill tracts.

Natural resource and associated ecosystem service	Contribution to adaptive capacity or reduction in vulnerability	Non-climate-change-related impacts affecting resource/service	Climate-change impacts affecting (or potentially affecting) resource/service
Indigenous timber trees such as gamari (*Gmelina arborea*) and teak (*Tectona grandis*). Indigenous fruit trees such as mango (*Mangifera indica* Linn), jackfruit (*Artocapus heterophlla* Lmk), coconut (*Cocos nucifera)*, banana (*Musa paradisiaca* L.) and pineapple (*Ananas comosus*). Horticultural trees (mostly fruit). Imported timber trees such as mahogany (*Swietenia macrophylla* and *Swietenia mahagony*).	– Trees protect houses from storm and cyclone damage. – Timber used to build houses, cattle sheds and sanitary latrines strong enough to withstand storms/cyclones and torrential rain, and repair houses and structures damaged by disasters. Timber used to make "country boats" (to collect water and travel around during floods) and to make and repair furniture. – Timber sold to increase family income. – Rafts made from kala/banana trunks are used for moving around locally during floods. – Villagers are planting more fruit trees at their homesteads for shade and cooler air during high temperature days and droughts. – Timber and tree branches used as cooking fuel. Dry leaves too. – Cotton harvested from silk cotton trees and products from rubber trees are sold to enhance household income. – Fruits harvested for consumption and sale to enhance household income. – Horticulture can provide employment opportunities and income from the sale of fruits. Recently villagers have planted more horticultural trees. – Women grow tree saplings to sell at the market and generate income. – To prevent pest attacks on fruit trees (which are increasing because of drought), leaves are burnt under the trees to create ash. – Locals have been planting more trees to protect crops from the soil erosion and landslides associated with the increasing frequency of torrential rainfall episodes experienced in recent decades. – Locals have been planting more drought- and storm-resistant tree species. For example, drought-tolerant trees like acacia are planted on hills. – Farmers plant more teak trees instead of mango and jackfruit trees, which are susceptible to hailstorm damage. – Trees support a diversity of bird and animal life.	– Trees cut and sold to secure family income and repay loans. – Trees cut for construction purposes (houses, furniture, etc.) and for fuel. – Native trees cut down and replaced with fast-growing timber trees (teak, eucalyptus, acacia, etc.) – The forest department provides approval for cutting trees. – Imported timber trees and horticultural trees have increased as people have planted them following the cutting down of native species.	– Cyclones/storms uproot and damage trees such as banana trees. – Torrential rainfall creates landslides that uproot trees such as mango, jackfruit and banana. – Drought has damaged less resistant tree species such as banana. Pest attacks on fruit trees are increasing because of drought. – Tree flowers and fruits are damaged by drought and warm weather. For example, mango and litchi tree flowers and fruits are damaged by fog, drought and warm weather. – Mango and litchi trees are susceptible to hailstorm damage.
Medicinal trees and plants such as neem (*Azadirachta indica*).	– Leaves, seeds, fruits, skins and roots from medicinal trees and plants are used to help with diseases like malaria, ulcers, dysentery, skin diseases, tooth pain, coughs, arthritis, diabetes, heart disease, diarrhoea, metabolic disorders, rheumatic pain and rheumatic fever and pox. – Using natural medicines reduces modern treatment costs. – Tree/plant products can be sold to increase family income.	– Trees cut and sold to secure family income, make furniture, etc. – Trees cut due to a lack of knowledge about their medicinal value. Many people do not know which trees are good for which diseases.	– Cyclones, storms, torrential rainfall and landslides uproot/damage trees. – Prolonged drought kills/damages medicinal trees.

(*Continued*)

Table 3. Continued.

Natural resource and associated ecosystem service	Contribution to adaptive capacity or reduction in vulnerability	Non-climate-change-related impacts affecting resource/service	Climate-change impacts affecting (or potentially affecting) resource/service
		– "slash-and-burn" practices cut and burn grasses and bushes for crop cultivation.	
Smaller plants and grasses.	– Fuli gash and durba (*Cynodon dactylon*) are used as cattle fodder and also to prevent soil erosion. – Khagra and shon grass are used for thatching roofs, which help keep homes cool in hot months. – Khagra is used to make fish aggregating devices (like katha) for fishing. – Women make and sell mats from khagra to enhance family income.	– "slash-and-burn" practices cut and burn most grasses and bushes for crop cultivation. – They are also cut for fuel.	– Grasses, water hyacinths and other plants die during droughts.
Various bamboo species such as muli bamboo (*Melocanna baccifera*).	– Muli bamboo protects houses from storm/cyclone damage. – Bamboo helps prevent soil erosion. – Bamboo is used for making house frames and roofs, as well as fencing round the house. Strong houses built with bamboo help prevent storm damage. – Immediately after disaster events, such as torrential rain, bamboo is used for rebuilding and repairing houses. – Shon grass has recently become less available for house roofs so people use corrugated iron sheets fixed on to bamboo. This reduces warm temperatures in houses. – Bamboo is also used for winnowing and making split bamboo mats, water-pipes, boat masts, hand-fans, chairs, seats, cane furniture, baskets, platters/trays, sieves, etc. Women can generate income by making and selling these at the market. – Bamboo shoots are used as vegetables. – Bamboo and bamboo shoots are sold to enhance incomes. – Farmers attach banana plants and small horticultural trees to bamboo poles to prevent storm damage. – Farmers fix bamboo pools and fences on hillsides to prevent landslides.	– "slash-and-burn" practices cut and burn bamboo for crop cultivation. – Over-extraction or over-harvesting of bamboo shoots for sale. Some community members favour new laws to stop bamboo shoot cutting, or time restrictions on cutting imposed by the local administration.	– Bamboo plants are dying due to unknown natural causes.
Lake fish species.	– Household consumption**.** – Sources of livelihood/income.	– Numbers of fishermen are increasing. – Government releasing fish fingerlings into the lake, and banning fishing during breeding time and immediately after to protect fingerlings. – Illegal fishing practices. – Catching fish fry and fingerlings. – Use of smaller net meshes.	– High lake water temperatures cause fish death.

(*Continued*)

Table 3. Continued.

Natural resource and associated ecosystem service	Contribution to adaptive capacity or reduction in vulnerability	Non-climate-change-related impacts affecting resource/service	Climate-change impacts affecting (or potentially affecting) resource/service
		– Lake water pollution from diesel oil (from boats) and dumping waste and garbage.	
Freshwater sources: lake, stream, wells and rainfall.	– Stream water used for irrigating crop fields and drinking. Irrigation is particularly important during droughts. Collection pipes at highland sources are built, and water is conserved in tanks for use during droughts. – Well water is used for drinking by humans and cattle, washing utensils and taking showers. Some villagers also irrigate using well water. Stream water sometimes directed into wells dug to conserve water. – Rainwater is used for cooking, drinking and washing.	– Cutting down indigenous trees and plants and replacing them with imported trees like eucalyptus, acacia, etc., reduces water availability. – Kaptai Lake gates need to be closed to maintain lake water levels during droughts, but this does not always occur.	– Lake and well water levels fall during droughts. This hampers agricultural crop production and reduces the amount of water available for domestic and drinking purposes.
Agriculture/crop cultivation, for example, paddy rice, ginger (*Zingiber officinale* Roscoe), tumeric (*Curcuma longa*) and papaya (*Carica papaya*).	– Employment opportunities from agriculture, for women too. – Paddy rice for household consumption. – Watermelons and spices for family income and consumption. – Recently, cultivating certain types of paddy rice and pineapples has helped compensate families for losses from disaster events.	– Occasional damage due to poor knowledge about weeding. – Cultivation during unsuitable time periods.	– Torrential rainfall damages plants and their roots. – Drought and warm temperatures hamper plant growth and reduce crop production. – Hailstorms damage watermelons.
Vegetables (grown in *jhum* fields and on homesteads) such as bitter gourd (*Momordica charantia* L. Amaegoso), radish (*Raphsnus sativus* Linn), cabbage (*Brassica oleracea* Linn) and sesame (*Sesamum indicum*).	– Household consumption. – Sold for family income.	– Irrigation and use of chemical fertilizers and pesticides to increase production. – Poor crop care and irrigation techniques reduce outputs. – Poor training on crop cultivation techniques.	– Droughts reduce available water. – Torrential rainfall damages crops, which must then be re-planted. – Fog and insects damage vegetables during the early summer season.
Wild birds (such as crows and doves) and animals (such as tiger, deer, wild boar and monkeys).	– Some wild animals were killed and consumed in the past, when they were more common. Many are rare now.		
Domesticated animals: cattle and poultry (chickens and ducks).	– Household consumption. – Sold for family income. – Villagers use cow dung as organic fertilizer to retain soil moisture during drought periods and increase soil fertility.		
Mud/soil	– Villagers use mud plaster on house walls to keep their homes cool. – Farmers make water drainage systems using soil to save their crops from inundation during torrential rainfall. – Soil or mud is built up at the bottom of trees to prevent them becoming damaged during storms.		

Table 4. Ecosystem changes affecting adaptive capacity at Goalgram Village, Chanda Beel wetland.

Ecosystem	Non-climate-change-related impacts affecting ecosystem	Climate-change impacts affecting or potentially affecting ecosystem	Changes to adaptive capacity or vulnerability resulting from climate change and non-climate-change-related impacts
Chanda Beel wetland (which consists of rivers, lakes/ponds, canals and ditches and currently makes up 16% of the area of Chanda Beel).	– The wetland's natural resources have greatly declined over the years due to road, culvert and bridge construction, increases in irrigation structures to control water flow, settlement expansion, deposition of silt and decomposed water hyacinth, and the expansion of agricultural land. This rising of the Beel bed has facilitated agriculture, but at a cost to the natural ecological integrity of the wetland. The size of wetland areas with water throughout the year is now negligible (BCAS and CDI, 2006). Most of Chanda Beel is now under agricultural production, while in the past it was only used for aquatic resource services. Some of the fish, crustacean (prawn and crab) and mollusc species that were once found in Chanda Beel are no longer present. – Siltation has occurred due to the construction of sluice gates in the 1960s to control water flow for irrigation. Silting/drying up of canals connecting beels means that since 1980, launches, steamers and "country boats" can no longer navigate waters so easily, especially in the dry season. By the 1980s, the use of launches and steamers had almost entirely stopped. Smaller "country boats" with diesel engines became increasingly prevalent after 1975 and have gradually replaced manually operated country boats. – Roads have replaced waterways as the main transportation system for goods and passengers in recent years. – Sluice gates have also inhibited fish migration, and intensive use of agricultural chemicals has degraded water quality. – Traditional fishing practices, whereby	– Climate-change models predict that the south-central region in which Chanda Beel lies will be more prone to flooding and water logging due heavy rainfall and other adverse climate-change impacts. – A seasonal lack of rain (drought) and also salinization may be affecting animal and plant diversity in the beel, which have dropped. – Access to fresh water falls due to salinization during a couple of months each year. The local community has recently reported that the river water tasted salty, particularly in April and May. This can occur when seawater comes up the river due to sea-level increases or reduced water flows from upstream. – Larger floods help transport silt out of the area.	– Wetland destruction due to the construction of infrastructure such as embankments, roads, bridges and culverts has made commuting easier, created new jobs in the transport sector and allowed faster transport of goods to markets/towns. This has increased adaptive capacity for some (mostly men). – Women (the water fetchers) struggle to get fresh water at times during monsoon, as roads are impassable and boats cannot move through waterways. – Better infrastructure (e.g. transport infrastructure) has increased diversification into other income-earning opportunities such as carpentry, handicraft making and small businesses. This has increased adaptive capacity for those involved. – A significant proportion of people were fishermen in the past. Today the vast majority of people are farmers or wage labourers as wetland biodiversity is no longer rich enough to support the livelihoods and subsistence needs of fishers, who have therefore changed occupation or left the area (Chakraborty et al., 2005). Several fishers have become unemployed, many fishers leave the area on a seasonal basis and move to locations where they can use their skills. Most unemployed people, however, have found new unskilled occupations. – A large number of extremely poor people inhabit this locality. They live mainly on subsistence agriculture, fishing wage labour, small businesses and pulling rickshaws. The very poor have suffered more, despite other emerging opportunities such as growing vegetables and other livelihood opportunities that

(*Continued*)

Table 4. Continued.

Ecosystem	Non-climate-change-related impacts affecting ecosystem	Climate-change impacts affecting or potentially affecting ecosystem	Changes to adaptive capacity or vulnerability resulting from climate change and non-climate-change-related impacts
	fishers used sustainable fishing practices according to customary rights to the beel, have been replaced by more efficient but less sustainable fishing practices. Fishing used to be by subsistence fishers alone, but commercial operators are now present in the area and they use less sustainable practices. – Bird diversity decreasing for a number of reasons, likely related to the change from a wetland ecosystem and increased use of agricultural chemicals, and some hunting. People collect snails, which are sold to shrimp farmers and fed to reared ducks, and this leaves less food for birds. Snail collection also has a negative impact on wild fish production (wild fish eat snail eggs). People feel water is less clean so there are health impacts from the loss of snails. – Diversity of aquatic and terrestrial plants is also decreasing, and also animals, largely due to human intervention and changes to the ecosystem (BCAS and CDI, 2006).		have become available. – Traditional "safety nets" (such as employment in fishing or waterway transportation) have been reduced following the destruction of the wetland.
Agricultural land currently makes up 75% of Chanda Beel. This is up from 39% in the dry season, and 8% in the wet season before 1960. A further 7% is currently homestead land, and 2% lies fallow. Borro paddy is grown in the dry season and is the dominant village crop, and aman paddy crops are grown during monsoon. Farmers also grow chillies, vegetables and oil seed in the dry season mainly on higher land.	– Regular monsoon flooding and water logging occurs due to high tides and seasonal changes in river water flow. Monsoon floods prevent most crop production. – Changes from the use of indigenous technologies and knowledge such as ploughs, yokes, spades and hammers, to modern techniques such as tractors, irrigation pumps, harvesting machines, insecticides, chemical fertilizers, pesticides and high-yielding seed varieties has occurred since 1960. Coupled with sedimentation in the Beel, these have contributed to the expansion of agricultural activities in the area which has dramatically increased production.	– Enhanced flooding and water logging are predicted by climate-change models for the region, in part due to heavier rainfall. This will hamper crop production. – People have also reported that cyclones and increasingly erratic rainfall and temperature changes are hampering crop production and other livelihood activities. – Projected changes in the incidence, frequency, intensity and duration of climate extreme events (such as heat waves, heavy rainfall, floods, cyclones and drought) as well as more gradual changes in climate are expected. Cyclones, erratic weather/rainfall patterns and temperature changes are	– The economic condition of people overall has improved following the dramatic expansion and diversification of agriculture since the 1960s following siltation within the Beel. This has allowed communities to invest more in health and sanitation issues. More people now feel they are "middle class". The improvements in people's economic situation more than offsets the loss of safety nets/biodiversity/wetland ecosystem, in terms of adaptive capacity, for most. – Diversification of crop types on the silted Beel land has occurred, especially growing vegetables. This has nutritional benefits and helps increase household

(*Continued*)

Table 4. Continued.

Ecosystem	Non-climate-change-related impacts affecting ecosystem	Climate-change impacts affecting or potentially affecting ecosystem	Changes to adaptive capacity or vulnerability resulting from climate change and non-climate-change-related impacts
	These modern techniques have also reduced soil fertility in the long term and polluted water bodies, thus damaging wetland resources such as fish and aquatic vegetation.	already hampering crop production. – Potential salinization of river and irrigation water, particularly during the dry season, due to sea-level rise and/or reduced water flows from the upstream rivers (locals have observed recent salinization but scientific validation has not yet occurred). This could mean current agricultural practices are unsustainable and saline-tolerant rice varieties will be needed. Alternatively, changes to monsoon rain patterns could increase freshwater flows from the Ganges water catchment, thus decreasing salinity problems and sustaining monsoon-period agricultural practices for the long term. – Higher temperatures could increase pest attacks on crops.	income. – The expansion of agricultural activities since the 1960s means men can no longer handle the workload alone anymore. With more (and more diverse) income-earning opportunities available, many women (Hindu more than Muslim women) are now working alongside men in fields. This increases opportunities for women who like this change. – A large number of extremely poor people inhabit this locality. They live mainly on subsistence agriculture and fishing. Poor women and marginal sections of society suffer most from climate-change impacts, but the expansion of agriculture at the cost of the wetland ecosystem has not been bad for them.

Table 5. Ecosystem changes affecting adaptive capacity at Balukhali Village, Rangamati District, Chittagong hill tracts.

Ecosystem	Non-climate-change-related impacts affecting ecosystem	Climate-change impacts affecting or potentially affecting ecosystem	Changes to adaptive capacity or vulnerability resulting from climate change and non-climate-change-related impacts
Hills	– Deforestation and over-extraction of trees and plants in the hills damage the ecosystem. – Replacing indigenous trees with "thirstier" timber trees and fruit trees. – Cutting the hillside to sell soil, build new houses and create new crop fields. – "Slash-and-burn" (*jhum*) cultivation practices.	– Climate-change predictions suggest the number of rainless days will increase in future which could reduce stream water availability. – Villagers suffer from various water-related diseases due to the scarcity of safe water and lack of knowledge about proper hygiene. These could increase if temperatures increase. Diseases like malaria are also increasing, likely due to observed temperature increases. – Torrential rainfall causes erosion and landslides. – Cyclones and storms uproot and damage trees.	– Declining forest resources reduce available natural resources. This particularly affects the poorest families. – Tree and plant cover regulates water flow and reduces erosion/landslides. For example, farmers are planting more papaya, pineapple, lemon, guava and litchi trees, which reduce landslides. – Trees provide a multitude of household, nutritional and livelihood benefits. For example, fruit trees increase food security and supplement farming income.
Kaptai Lake	– Lake water pollution from dumping waste and household garbage and oil leakage from boats. – Building houses and shops besides the lake damages the lake environment. – Government releases fish fingerlings into the lake, and bans fishing during key times (May–July) to improve fish stocks, but the number of fishermen is increasing, and some use illegal/unsustainable practices. – Natural fish stocks are decreasing. Reliance on fishing has decreased.	– Torrential rainfall damages the lake environment. – Drought/reductions in seasonal rainfall significantly lower lake water levels and hamper fish production. – Mountain landslides cause siltation of the lake bed, reducing the water holding capacity of the lake. Government has built embankments around the lake to try and prevent this. – Data from the Bangladesh Meteorological Department (BMD) for the Chittagong Hill Tract areas show that over the last few decades, the annual maximum temperature has increased, whereas the minimum temperature has remained fairly stable. Higher water temperatures alter the lake ecosystem.	– Livelihood diversification into fishing occurs during months when agriculture does not occur. – Fisher families suffer during the annual fishing ban following fingerling release (many young men and women move to cities to look for work during this time), and from droughts which hamper fish production. – Poor fisher families are particularly affected by reductions in lake fish resources due to seasonal rainfall reductions and reduced lake water levels. – Lake formation has flooded much agricultural land and water level management has hampered crop production.
Agricultural land	– Use of non-scientific "slash-and-burn" cultivation practices. – Farmers use irrigation, high-yielding varieties of crops and vegetables, chemical fertilizers and pesticides to increase production, but improper use of chemical fertilizers and pesticides can also damage fields. – Wildlife sometimes damages crops in fields. – Lake formation flooded much fertile arable valley land. – The agreement to keep dam water levels below 27.5 m from April to August to allow farmers to grow one crop (boro rice) in the fringe valleys has not been respected in recent years, resulting in crop losses. Furthermore, maximum water levels	– The frequency of torrential rainfall episodes has increased in recent decades. These wash away top soil and soil nutrients, leaving the land barren and damaging crops. The erratic nature of rainfall makes it harder for farmers to plan appropriately. Torrential rain also increases lake levels, inundating paddy crops. – Sometimes torrential rainfall causes landslides, which deposit soil on crop fields, damaging the crops and reducing field fertility. Farmers must remove newly deposited soil from fields and start crop cultivation again. – Drought reduces soil moisture and crop production. It reduces lake water levels, increases irrigation costs and can make new crop cultivation	– During droughts crop production is hampered. Poor day labourers become unemployed. – Farmers and wage labourers suffer from lake level increases and resulting crop losses as there is less work for them. – New horticultural practices provide employment opportunities, especially for poor men and women. – Adaptive benefits from high-yielding crop varieties, horticulture and vegetable cultivation may not be sustained if rainfall decreases as predicted, reducing stream water availability for irrigation.

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Table 5. Continued.

Ecosystem	Non-climate-change-related impacts affecting ecosystem	Climate-change impacts affecting or potentially affecting ecosystem	Changes to adaptive capacity or vulnerability resulting from climate change and non-climate-change-related impacts
	in the rainy season have been exceeded, leading to the loss of yet more cultivable land. – Training from agricultural extension offices and NGOs on soil conservation practices has helped people grow lemons, pineapples and other vegetables.	impossible. – Hailstorms, fog, pest damage and warm temperatures can damage crops.	

Beel. As the impacts of climate-change intensify, however, they could magnify and intensify the pressures already experienced by these semi-natural ecosystems, and increase the likelihood of abrupt and potentially irreversible change.

There is established but incomplete evidence that climate and other environmental changes are increasing the likelihood of non-linear ecosystem changes (including accelerating, abrupt and potentially irreversible changes). This has important consequences for human well-being (MEA, 2005) and human resilience (Malik, 2014). For example, once a nutrient loading threshold is reached in freshwater ecosystems, an abrupt and extensive change known as eutrophication (whereby harmful algal blooms deplete oxygen levels to the extent that most animal life cannot survive) can occur.

At Chanda Beel it is possible that increases in soil and water salinity levels could hamper future agricultural practices, especially in the dry season. Intensive agricultural practices are increasing the demand for water, threatening the wetland (Ghosh & Mondal, 2013). Snails play a vital role in both ecosystem functioning and the local economy. They "clean" water by accumulating metals such as cadmium in their soft tissue, and they and their eggs provide a source of food for wild fish, snakes, ducks, rats and birds. Snails are used for feeding ducks reared by locals and also commercially as shrimp food. Snail catches are declining, however, due to harvesting before they reach maturity, increasing paddy cultivation and excessive pesticide use. If this trend continues, the loss of this keystone species could "affect the whole ecosystem on a massive scale" (Khan et al., 2005).

At Balukhali, the lake fish resources are already in rapid decline due to reductions in rainfall and lake water levels. The current Department of Fisheries programme releasing fingerlings into the lake may soon cease to be viable, with dramatic impacts on fisher livelihoods and income.

7.3. *Reaching the most vulnerable*

Both the MEA (2005) and the IPCC (2014) assert that changes to natural systems, climate change induced or otherwise, will disproportionately affect the poorest and the most vulnerable, in part because their livelihoods are so heavily reliant on natural resources such as fishing and agriculture. Women are particularly vulnerable to climate change (UNDP, 2010), as are children (Lawler, 2011; Plush, 2009). This appears to be the situation in Balukhali where poor families relying on fishing and day labour suffer most due to changes to the ecosystem and available natural resources from Kaptai Lake and the surrounding area, even though horticulture has provided some new employment and income-generating opportunities.

The situation at Chanda Beel, however, is more complicated. Here, wetland destruction has gone hand in hand with the dramatic expansion and diversification of agriculture and also improved market access, thus opening up a range of income-earning opportunities (such as carpentry and transport sector work) not only mostly for men, but also for women, many of whom are pleased to work alongside men in the fields. Fishers are amongst the poorest and most vulnerable societal groups in Bangladesh (Deb & Haque, 2011; Deb, Haque, & Thompson, 2014), and many have become unemployed or left Chanda Beel, but others have found new unskilled work. Those who are extremely poor (relying mainly on subsistence agriculture and fishing) are now a smaller minority than they were before the shift to agriculture. Dramatic ecosystem changes have not necessarily made their lives worse.

This study looks only at a snapshot in time, however. The overall perceived improvements in people's situations may or may not continue. The ACCRA LAC Framework stresses the importance of characteristics that can secure future as well as current adaptive capacity, but even this is weak on *long-term* adaptive capacity, which has not been assessed at either site.

7.4. *Trade-offs*

EbA are sometimes presented as a no regrets win–win–win scenario for poverty reduction, climate-change adaptation and biodiversity conservation (see for example Colls et al., 2009). The results described here, however, suggest that dramatically altering an ecosystem instead leads to a number of trade-offs. The MEA (2005) acknowledges this issue of trade-offs and describes how actions to increase one ecosystem service often cause the degradation of other services. Modification of floodplain environments in Bangladesh since the 1960s has come with many costs, such as wetland degradation and increased potential for large-scale disasters (crop failure due to drought, or extreme floods when embankments are breaching as in 1994) (Hossain et al., 2013; Rouillard et al., 2014). But wetland degradation in Chanda Beel has also stabilized farmers' incomes, fostered economic development and supported increases in LAC. Likewise, whilst the formation of Kaptai Lake flooded much fertile agricultural land near Balukhali Village, it facilitated livelihood diversification into fishing during fallow months.

Interestingly, many important ecosystem services are based on the use of non-native species at both sites. For example, water hyacinth has a multitude of uses in Chanda Beel, like making floating platforms known as "baira" on which vegetables/crops/seedlings are grown during the monsoon season when fewer jobs are available (Hussain & Chowdhury, 2005). In Balukhali Village, non-native horticultural tree cultivation is providing new employment and income-generating opportunities. Non-native species such as water hyacinth are largely detrimental to ecosystems in many ways, however, so the increases in adaptive capacity resulting from its use come with many trade-offs (Akter & Zuberi, 2009).

Temporal trade-offs may also occur. For example, in Chanda Beel, increases in adaptive capacity resulting from the use of more modern agricultural practices may not endure if wetland salinity levels increase making agriculture less viable at certain times of the year, and modern agricultural techniques further reduce soil fertility and pollute water bodies. Because of the substantial inertia that exists in ecological systems, and the resulting slow speed at which the implications of ecosystem change become apparent, it is difficult to assess the result of such changes on human well-being (MEA, 2005). At Balukhali too, the medium-term adaptive value of horticulture, high-yielding crop varieties and vegetable cultivation could diminish if the rainfall decreases predicted reduce water availability for irrigation. Likewise, the long-term adaptive value of fishing for local livelihoods could disappear if fishing in Lake Kaptai ceases to be viable.

Trade-offs occur between social groups or stakeholders. For example, in Chanda Beel, fishers have suffered from wetland degradation, but many of those employed in agricultural work have benefitted, notably women. Women have also been involved in new horticultural activities at Balukhali.

Spatial trade-offs may also be experienced, often some distance from the ecosystem under consideration. The flooding of fertile agricultural land near Balukhali Village, for example, is as a result of a demand for power from distant cities like Dhaka. Flooding in Chanda Beel may also result in part from decisions made about river basin water management far from the local area. Adaptive capacity can be affected where the boundaries of ecosystems do not correspond to social, political or administrative boundaries such as those under the integrated water resource management strategies in Bangladesh (Reid, 2014a; Rouillard et al., 2014). Ensuring synergies between scales is a key requirement for adaptive capacity, but very difficult to realize in practice.

7.5. *Institutions, policies and governance*

The availability of ecosystems and ecosystem services is just one component of resilience and adaptive capacity. Ownership, control over and access to these resources, and indeed over other non-ecosystem-related components of resilience, is another. Participation in decision-making is an essential component of good community-based adaptation (CBA) because it ensures that traditional/local knowledge informs adaptation planning (Ayers, Anderson, Pradhan, & Rossing, 2012; Reid, Alam, et al., 2009; Reid & Schipper, 2014). Dodman and Mitlin (2013) argue, however, that whilst CBA has emphasized the importance of participatory tools, it often does little to build up links with political structures above the level of the settlement. Reid (2014b) reiterates that CBA and EbA should do more to address the institutional, governance and policy context in which initiatives operate, as this will be pivotal to their success. This is as true for local institutions as for the higher level institutions and policies on which communities depend (Dixit, McGray, Gonzales, & Desmond, 2012; Rai et al., 2014).

Whilst little detail is provided, the case studies illustrate the importance of addressing the local institutional governance and policy context in order to improve LAC. In Chanda Beel, the institutional capacity of local government institutes and non-government organizations in the area to address climate change and climate-change-related problems needs enhancing (Chakraborty et al., 2005). "Baira" extension centres and committees have been established (Hussain & Chowdhury, 2005), but additional proposals include a wetland resource management plan, snail harvesting regulations and improved fish conservation and management practices (Ghosh & Mondal, 2013; Khan et al., 2005).

This reflects analysis by scholars working on wetlands elsewhere in Bangladesh, which clearly shows the importance of appropriate and strong institutions, governance mechanisms and policies for improving adaptive capacity. Deb and Haque (2011) criticize the system established by the Ministry of Land whereby waterbodies are leased out, and following the process of sub-leasing and several layers of powerful intermediaries, fishers are unable to eke out a living from fishing alone. Recommendations to improve adaptive capacity include strengthening institutional, legislative and management responses, for example by involving communities or local institutions in water management, establishing fish sanctuaries and prohibiting fishing during breeding months (Hossain et al., 2013; Khan & Haque, 2010; Rouillard et al., 2014).

In Balukhali Village, the government decision to invest in hydroelectric power led to the formation of Kaptai Lake, which flooded large amounts of important fertile arable land. Furthermore, decisions about managing dam water levels have made farming more difficult because commitments made to keep water at certain levels during different seasons have not always been met.

8. Conclusions

Reid (2014a) state that "well-managed, stable, diverse ecosystems can make a significant contribution to local adaptation efforts". This is particularly true for the world's poorest people who are worst hit by climate change and also disproportionately reliant on ecosystems and their services. This research supports those calling for more attention to be paid to EbA as a response to climate change. The default response to climate-change adaptation from many policy-makers, however, is engineered "hard" infrastructure. In Bangladesh in particular, little attention has historically been given to ecosystem-based flood management measures (Rouillard et al., 2014). Two-thirds of funding allocated from the Bangladesh Climate Change Trust Fund, for example, has been designated for water infrastructure projects in coastal areas, and Rai et al. (2014) argue that this overemphasis on infrastructure benefits those at the top of the income ladder while ignoring the rural communities at risk. Infrastructure-based approaches can adversely affect important ecological processes, potentially resulting in maladaptation (IPCC, 2014; Munroe et al., 2012). Dykes and dams, for example, can disrupt the annual flooding of floodplains. Combining or substituting such approaches with EbA can help avoid this. Jeans et al. (2014), Travers, Elrick, Kay, and Vestergaard (2012) and Reid and Schipper (2014) provide some practical guidance on how to integrate ecosystems into adaptation strategies and programmes.

Experiential field-based EbA activities are proliferating, but more objective rigorous analysis and learning are needed in order to assess what the social, ecological and economic costs and benefits of EbA are in different environments compared to other adaptation options, and what limitations, boundaries and trade-offs (temporal, geographic and social) are important (Colls et al., 2009; Doswald et al., 2014: Reid, 2014a). Much "grey literature" focuses on trying to advocate for the adoption of EbA without including obvious measures of effectiveness (Munroe et al., 2012). Better quantification of the multiplicity of co-benefits (disaster risk reduction, food security, water provisioning, etc.) and costs EbA deliver is needed, along with improved understanding of how different groups of people are affected by different interventions. This is crucial because the impacts of climate change often disproportionately affect the most vulnerable people (Reid, 2014a). Existing adaptation intervention monitoring and evaluation tools are generally weak on ecosystem components and need improving. Lastly, a better understanding of how to secure appropriate institutional and policy support for effective EbA mainstreaming into relevant national and local adaptation policies and broader national planning frameworks is required.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Akter, A., & Zuberi, M. I. (2009). Invasive species in Northern Bangladesh: Identification, inventory and impacts. *International Journal of Biodiversity and Conservation*, *1*(5), 129–134.

Ayers, J., Anderson, S., Pradhan, S., & Rossing, T. (2012). *Participatory monitoring, evaluation, reflection and learning for community-based adaptation: A manual for local practitioners*. London: CARE International.

BBS. (2004) cited in Khan, M. F. A., Mantel, S., & Choudhury, E. H. (Eds.). (2007). *The state of the environment of the Chittagong hill tracts*. Charm Project Report 2. Charm Project. Dhaka: Author.

BCAS and CDI. (2006). *Impact of development interventions on wetlands, its resources and livelihoods of people in Chalan Beel and Chanda Beel freshwater wetland*. Dhaka: Bangladesh Centre for Advanced Studies (BCAS) and Caritas Development Institute (CDI).

Bours, D., McGinn, C., & Pringle, P. (2014, January). *Guidance note 2: Selecting indicators for climate change adaptation programming*. Oxford: SEA Change and UKCIP.

CBD. (2009) *Connecting biodiversity and climate change mitigation and adaptation: Report of the second ad hoc technical expert group on biodiversity and climate change* (CBD Technical Series No. 41). Secretariat of the Convention on Biological Diversity, Montreal, Canada.

CBD. (2010) *Decision adopted by the conference of the parties to the convention on biological diversity at its 10th meeting* (X/33). Biodiversity and climate change. UNEP/CBD/COP/DEC/X/33. Retrieved from http://www.cbd.int/doc/decisions/cop-10/cop-10-dec-33-en.pdf

Chakraborty, T. R., Adrika, A., & Hussain, B. (2005). *Fish and wildlife of the Chanda Beel area*. Dhaka: IUCN Bangladesh Country Office.

Colls, A., Ash, N., & Ikkala, N. (2009). *Ecosystem-based adaptation: A natural response to climate change*. Gland: IUCN.

Deb, A. K., & Haque, C. E. (2011). 'Sufferings start from the mothers' womb': Vulnerabilities and livelihood war of the small-scale fishers of Bangladesh. *Sustainability*, *2011*(3), 2500–2527.

Deb, A. K., Haque, C. E., & Thompson, S. (2014). 'Man can't give birth, woman can't fish': Gender dynamics in the small-scale fisheries of Bangladesh. *Gender, Place & Culture: A Journal of Feminist Geography*, doi:10.1080/0966369X.2013.855626.

Dixit, A., McGray, H., Gonzales, J., & Desmond, M. (2012). *Ready or not: Assessing national institutional capacity for climate change adaptation*. Washington, DC: World Resources Institute.

Dodman, D., Ayers, J., & Huq, S. (2009). Building resilience. In S. Linda (Ed.), *State of the world 2009: Into a warming world* (pp. 151–168). Washington, DC: Worldwatch Institute.

Dodman, D., & Mitlin, D. (2013). Challenges for community-based adaptation: Discovering the potential for transformation. *Journal for International Development*, *25*(5), 640–659.

Doswald, N., Munroe, R., Roe, D., Giuliani, A., Castelli, I., Stephens, J., … Reid, H. (2014). Effectiveness of ecosystem-based approaches for adaptation: Review of the evidence-base. *Climate and Development*, doi:10.1080/17565529.2013.867247.

Ghosh, P. K., & Mondal, M. S. (2013). Economic valuation of the non-use attributes of a south-western coastal wetland in Bangladesh. *Journal of Environmental Planning and Management*, *56*(9), 1403–1418.

Girot, P., Ehrhart, C., Oglethorpe, J., Reid, H., Rossing, T., Gambarelli, G., … Phillips, J. (2012). *Integrating community and ecosystem-based approaches in climate change adaptation responses*. ELAN, unpublished. Retrieved from www.elanadapt.net

Hansen, L., Biringer, J. L., & Hoffman, J. (Eds.). (2003). *Buying time: A user's manual to building resistance and resilience to climate change in natural systems*. Washington, DC: World Wildlife Fund.

Hassan, D. M. M., & Van Lavieren, B. (2000). *Chittagong hill tracts region development plan* (ADB TA #3328 - BAN). Interim Report No. 3: Environment and Forestry. Rangamati, Asian Development Bank.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, *4*, 1–23.

Hossain, S., Hein, L., Rip, F. I., & Dearing, J. A. (2013). Integrating ecosystem services and climate change responses in coastal wetlands development plans for Bangladesh. *Mitigation and Adaptation Strategies for Global Change*. doi:10.1007/s11027-013-9489-4.

Hussain, B., & Chowdhury, T. I. (2005). *Baira: The floating vegetable gardens for sustainable livelihood.* Dhaka: IUCN Bangladesh Country Office.

IPCC. (2014) *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 on climate change. Cambridge: Cambridge University Press.

Jeans, H., Oglethorpe, J., Phillips, J., & Reid, H. (2014). The role of ecosystems in climate change adaptation: Lessons for scaling up. In E. L. F. Schipper, J. Ayers, H. Reid, S. Huq, & A. Rahman (Eds.), *Community based adaptation to climate change: Scaling it up* (pp. 253–265). London: Routledge.

Jones, L., Ludi, E., & Levine, S. (2010). *Towards a characterisation of adaptive capacity: A framework for analysing adaptive capacity at the local level*. London: Overseas Development Institute.

Khan, M. S., Haq, E., Huq, S., Rahman, A. A., Rashid, S. M. A., & Ahmed, H. (1994). *Wetlands of Bangladesh*. Dhaka: Bangladesh centre for Advanced Studies (BCAS).

Khan, S. I., Hussain, B., & Chakraborty, T. R. (2005). *Snails in the Chanda Beel area*. Dhaka: IUCN Bangladesh Country Office.

Khan, S. M. M. H., & Haque, C. E. (2010). Wetland resource management in Bangladesh: Implications for marginalization and vulnerability of local harvesters. *Environmental Hazards*, *9*(1), 54–73.

Lawler, J. (2011). *Children's vulnerability to climate change and disaster impacts in East Asia and the Pacific*. Bangkok: UNICEF East Asia and Pacific Regional Office.

Ludi, E., Getnet, M., Wilson, K., Tesfaye, K., Shimelis, B., Levine, S., & Jones, L. (2011). *Preparing for the future? Understanding the influence of development interventions on adaptive capacity at local level in Ethiopia*. Africa Climate Change Resilience Alliance (ACCRA) Ethiopia Synthesis Report. Overseas Development Institute, London.

Malik, K. (2014). *Human development report 2014. Sustaining human progress: Reducing vulnerabilities and building resilience*. New York: United Nations Development Programme.

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Synthesis*. Washington, DC: Island Press.

Morecroft, M. D., Crick, H. Q. P., Duffield, S. J., & Macgregor, N. A. (2012). Resilience to climate change: Translating principles into practice. *Journal of Applied Ecology*, *49*, 547–551.

Munroe, R., Roe, D., Doswald, N., Spencer, T., Möller, I., Vira, B., … Stephens, J. (2012). Review of the evidence base for ecosystem-based approaches for adaptation to climate change. *Environmental Evidence*, *1*, 13. doi:10.1186/2047-2382-1-13

Pettorelli, N. (2012). Climate change as a main driver of ecological research. *Journal of Applied Ecology*, *49*(3), 542–545.

Pimbert, M. (2010). *Towards food sovereignty: Reclaiming autonomous food systems*. London: IIED.

Plush, T. (2009). Amplifying children's voices on climate change: The role of participatory video' in community-based adaptation to climate change. *Participatory Learning and Action*, *60*, 119–128. London: IIED.
Rai, N., Huq, S., & Huq, M. J. (2014). Climate resilient planning in Bangladesh: A review of progress and early experiences of moving from planning to implementation. *Development in Practice*, *24*(4), 527–543.
Rao, N. S., Carruthers, T. J. B., Anderson, P., Sivo, L., Saxby, T., Durbin, T., … Chape, S. (2013). *An economic analysis of ecosystem-based adaptation and engineering options for climate change adaptation in Lami Town, Republic of the Fiji Islands*. Apia, Samoa: Secretariat of the Pacific Regional Environment Programme (SPREP).
Rashid, H. (1991). *Geography of Bangladesh* (2nd revised ed.). Dhaka: The University Press.
Reid, H. (2011, November). *Improving the evidence for ecosystem-based adaptation*. IIED opinion: Lessons from adaptation in practice series. London: IIED.
Reid, H. (2014a). A natural focus for community-based adaptation. In J. Ensor, R. Berger, & S. Huq (Eds.), *Community-based adaptation to climate change: Emerging lessons* (pp. 35–54). Rugby: Practical Action.
Reid, H. (2014b). *Ecosystem- and community-based adaptation: Learning from natural resource management*. London: IIED Briefing.
Reid, H., Alam, M., Berger, R., Cannon, T., Huq, S., & Milligan, A. (2009). Community-based adaptation to climate change: An overview' in community-based adaptation to climate change. *Participatory Learning and Action*, *60*, 11–33. London: IIED.
Reid, H., Chambwera, M., & Murray, L. (2013). *Tried and tested: Learning from farmers on adaptation to climate change*. London: IIED Gatekeeper Series No. 153.
Reid, H., Phillips, J., & Heath, M. (2009a). *Natural resilience: Healthy ecosystems as climate shock insurance*. London: IIED Briefing, December 2009.
Reid, H., & Schipper, E. L. F. (2014). Upscaling community-based adaptation: An introduction to the edited volume. In E. L. F. Schipper, J. Ayers, H. Reid, S. Huq, & A. Rahman (Eds.), *Community based adaptation to climate change: Scaling it up* (pp. 3–21). London: Routledge.
Rouillard, J. J., Benson, D., & Gain, A. K. (2014). Evaluating IWRM implementation success: Are water policies in Bangladesh enhancing adaptive capacity to climate change impacts? *International Journal of Water Resources Development*. doi:10.1080/07900627.2014.910756
Scheufele, G., & Bennett, J. (2012). Valuing ecosystem resilience. *Journal of Environmental Economics and Policy*, *1*(1), 18–31.
TEEB. (2008). *The economics of ecosystems and biodiversity: An interim report*. Bonn: TEEB.
Thomas, A. W. (2011). *Ecosystem-Based adaptation: Bridging science and real-world decision-making. Paper presented at the 2nd international workshop on biodiversity and climate change in China*. The Nature Conservancy Global Climate Change Adaptation Program.
Travers, A., Elrick, C., Kay, R., & Vestergaard, O. (2012). *Ecosystem-based adaptation guidance: Moving from principles to practice*. UNEP.
UNDP. (2010). *Gender, climate change and community-based adaptation: A guidebook for designing and implementing gender-sensitive community-based adaptation programmes and projects*. New York, NY: UNDP.
UNEP. (2012). *Making the case for ecosystem-based adaptation: Building resilience to climate change*. Nairobi: UNEP.
Wisner, B., Blakie, P., Cannon, T., & Davis, I. (2004). *At risk: Natural hazards, people's vulnerability and disasters* (2nd ed.). London: Routledge.