Ecosystem-based Approaches to Adaptation

Evidence from two sites in Bangladesh

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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. Those who are most vulnerable to climate change are often highly reliant on the natural environment for their lives and livelihoods, and ecosystems and the services they provide are already central to many adaptation strategies. This paper describes two components of effective EbA: ecosystem resilience and the maintenance of ecosystem services. Research assesses how effectively EbA supports community adaptive capacity and resilience at two Action Research for Community Adaptation in Bangladesh (ARCAB) sites. Findings suggest that more attention should be paid to EbA as an important response to climate change.

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Summary

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. Those who are most vulnerable to climate change are often highly reliant on ecosystems and ecosystem services for their lives and livelihoods, and ecosystems and the services they provide are already central to many successful adaptation strategies. 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 it supports community adaptive capacity and resilience at two Action Research for Community Adaptation in Bangladesh (ARCAB) study sites: 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 response to climate change. Results show that the many diverse natural resources available and utilised at each site have increased the number of different subsistence and livelihood options available the community and hence local adaptive capacity, especially for poorer households. Major structural shifts in ecosystem functioning observed at each site can be attributed primarily to non-climate change related factors, although climate change related factors increasingly threaten to dramatically change ecosystems, especially in Chanda Beel. Such shifts have important consequences for adaptive capacity and have led to a number of trade-offs. For example, wetland ecosystem degradation in Chanda Beel has provided opportunities (and consequent increases in wealth and resilience) from agriculture, interestingly for women and the poor too, who it is generally assumed suffer most from ecosystem degradation. Short-term adaptive benefits from agriculture-related ecosystem services could, however, be replaced by longer-term costs following the degradation of other services. For example, disaster risks could increase, salinity levels and unsustainable agricultural practices could reduce longer-term soil fertility and wetland resources, and social safety nets could decline. The lack of effective institutions, good governance and enabling policy at both sites has limited potential gains in resilience from sound ecosystem management.

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 (IPCC 2014; Colls *et al.* 2009; Reid 2011; 2014a; Girot *et al.* 2012; UNEP 2012; Munroe *et al.* 2011; 2012; Doswald *et al.* 2014). 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 successful adaptation strategies, 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 per cent of priority NAPA projects reviewed had significant natural resource components. In Bangladesh, six out of 15 priority NAPA projects have a significant natural resources component (Reid *et al.* 2009a).

Jeans *et al.* (2014) argue that although Community Based Adaptation (CBA) and EbA evolved separately (largely from development and environment groups respectively), and emphasise different adaptation strategies, both have the end goal of increasing the ability of vulnerable people to adapt to climate change. Further to this, just as a strong understanding of ecosystems and biodiversity can dramatically increase CBA effectiveness, a poor understanding of EbA can lead to maladaptation (Reid and Schipper 2014).

Central to the concept of EbA is the importance of seeing beyond the role of ecosystems as providers of a set of static 'natural resources' and instead seeing them as providers of a number of interconnected ecosystem services such as water provision, erosion protection, climate regulation, disaster risk reduction and genetic diversity. Proponents of EbA argue that a holistic approach to maintaining ecosystem structure and functioning and ecosystem service provision can support adaptation. Recognising that ecosystems have limits, undergo change (due to climate change and other stressors) and are interconnected is central to this approach (Girot *et al.* 2012). Reid and Schipper (2014) argue that CBA needs to take account of the complexity of ecosystems and ecosystem services to ensure initiatives are more successful. Equally, many EbA initiatives could account better for the social complexities that good CBA addresses.

Action Research for Community Adaptation in Bangladesh (ARCAB) is a long-term action research programme that aims to address knowledge gaps and provide evidence for the effectiveness of Community Based Adaptation (CBA). ARCAB Action Partners include ActionAid, CARE, Caritas Bangladesh, Christian Aid, Concern Worldwide, Oxfam GB, Islamic Relief Worldwide, Plan International, Practical Action and WaterAid, all of which work with poor communities in specific locations to address climate change. The ARCAB programme has a number of core action research themes, one of which is EbA. This paper describes research conducted under ARCAB that seeks to improve the evidence relating to EbA effectiveness from two ARCAB study sites.

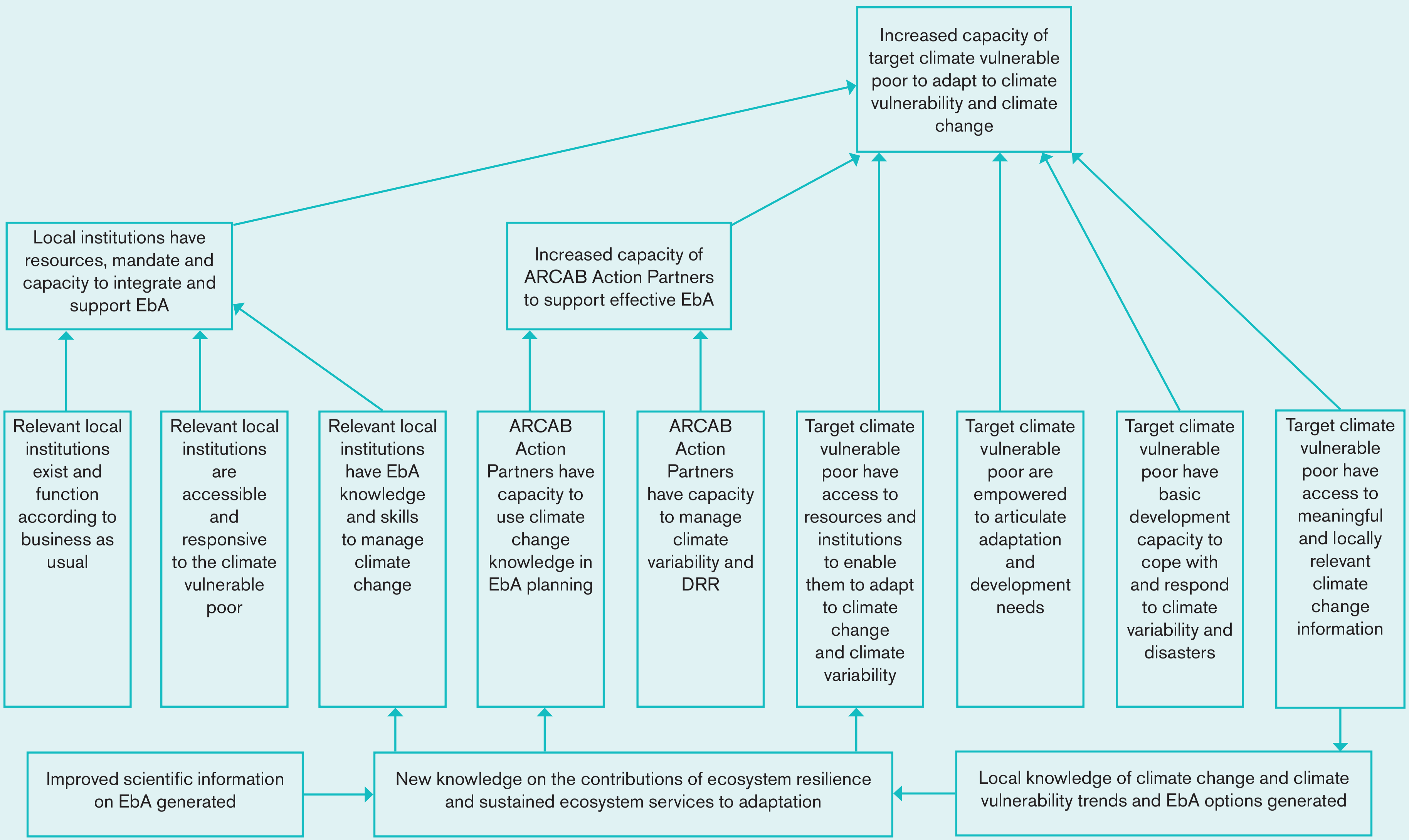
2

Using ARCAB to learn more about EbA Effectiveness

The ARCAB programme has a well-developed theory of change (ARCAB 2012). This encompasses broader issues relating to the scaling up and out of CBA that are central to ARCAB as a whole and its goal of achieving 'transformed resilience' for the climate vulnerable poor at scale. The theory of change proposed here (Figure 1) for the EbA theme focuses more specifically on the roles that ecosystems and ecosystem service provision can play in increasing the capacity of the climate vulnerable poor to adapt to climate vulnerability and climate change in specific ARCAB sites rather than at scale. Although anecdotal evidence of the benefits of EbA is strong, there is little rigorous evidence relating to EbA available in the scientific literature (Reid 2011; Doswald *et al*. 2014), so this research seeks to assess evidence from specific ARCAB sites to test the hypothesis that resilient ecosystems and continued ecosystem service provision can contribute to community adaptive capacity and resilience.

ARCAB uses a number of key climate change concepts, based on the Intergovernmental Panel on Climate Change (IPCC) definitions and other sources. See Box 1. Research described here is based on these definitions.

Figure 1: Theory of Change for the ARCAB EbA theme



Source: adapted from the ARCAB theory of change (ARCAB 2012)

BOX 1: ARCAB KEY CONCEPTS AND TERMS

Vulnerability: ARCAB uses the definition of vulnerability developed by Wisner *et al*. (2004): "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 wellbeing by (climate) hazards". Vulnerability is therefore determined by the climate change hazard that defines exposure to climate change impacts, and also the social, economic, cultural and political factors that determine resilience to climate change impacts.

Climate vulnerable poor: the poorest and most marginalised groups who are vulnerable to the impacts of climate variability and climate change. There are strong overlaps between the climate vulnerable poor, and poor and marginalised groups. This is because poverty, including a lack of access to assets, services and institutions that enable people to cope with or adapt to climate and other risks, is a key determinant of vulnerability.

Adaptive capacity: The Intergovernmental Panel on Climate Change (IPCC) defines adaptive capacity as "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". ARCAB Action Partners describe adaptive capacity in different ways, but common components used by all Action Partners include access to the necessary assets, livelihoods and institutional systems that enable people to adapt to climate and other stresses.

Resilience: ARCAB uses the definition proposed by Dodman *et al*. (2009) that sees resilience as moving beyond coping strategies towards achieving longer-term development in spite of, or in light of, climate change. Strengthening resilience involves building the securities of the climate vulnerable poor to enable them to respond positively to climate related shocks and stresses, and also address the myriad of challenges that constrain lives and livelihoods. Higher adaptive capacity leads to better climate resilience – this is true for individuals, households, enterprises and economies.

3

Ecosystem-Based Adaptation Principles

In order 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 has two key components: the maintenance of ecosystem services and ecosystem resilience (Table 1). The Millennium Ecosystem Assessment (2005) also uses these two components in its analysis of how changes to ecosystems and their services affect human well-being.

These two components reflect the understanding that good EbA, and hence good CBA, is not just about the provision of static 'natural resources' or ecosystem services, but about the stability and resilience of ecosystems as a whole, how they connect with each other, and the multiple roles that they can play in increasing community adaptive capacity and resilience as a result.

Table 1: Selected principles for effective ecosystem-based adaptation

PRINCIPLES	REQUIREMENTS	DETAILS
Maintenance of ecosystem services	• Valuation of ecosystem services • Determine climate change impact scenarios • Identify options for managing ecosystems or managing use • Involve user communities in adaptation action • Trade-off analysis	Maintaining ecosystem services is key, and conservation practitioners must improve their understanding of how to design and implement actions to do this, and their ability to effectively measure benefits provided.
Promotion of resilient ecosystems	• Modelling of projected climate change • Revise systematic planning • Revise protected area systems design • Involve local communities in restoration and management • Adjust management programmes and actions	EbA approaches cover a broad spectrum of land management, policy and project activities. Promoting ecosystem resilience for the benefit of communities is the first and most obvious set of actions.

Source: adapted from Travers *et al.* (2012) and Thomas (2011)

Maintenance of ecosystem services

Ecosystems provide a number of provisioning, regulating, cultural and supporting services (see Table 2). These can be seen as 'natural assets' in the context of climate change adaptation. The ARCAB definitions described in Box 1 make it clear that access to such assets can reduce the vulnerability, increase the adaptive capacity, and enhance the resilience of the climate vulnerable poor. The more access these people have to a range of such assets, the greater their resilience will be.

The Millennium Ecosystem Assessment (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. It argued that "The full costs of the loss and degradation of these ecosystem services are difficult to measure, but the available evidence demonstrates that they are substantial and growing." This has worrying implications for the climate vulnerable poor who are particularly reliant on these services. The Assessment acknowledges that "The degradation of ecosystem services is harming many of the world's poorest people and is sometimes the principal factor causing poverty".

Ecosystem resilience

Resilience is a topical yet 'slippery' concept, which to some creates more confusion than enlightenment (Morecroft *et al.* 2012), and to others brings a welcome emphasis on positive attributes rather than the more negative characteristics associated with vulnerability. 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 Millennium Ecosystem Assessment (2005) defines resilience as "The capacity of a system to tolerate impacts of drivers without irreversible change in its outputs or structure." A related concept, social resilience, is defined as the capacity of individuals or groups to secure favourable outcomes under new circumstances and, if need be, by new means (Hall and Lamont 2013). This paper looks at ecosystem resilience, and how it contributes to human resilience (see definition in Box 1) in the context of climate change.

Ecosystem services provide an important component of resilience. But an exclusive focus on such services 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" (Millennium Ecosystem Assessment 2005). While CBA projects often address the ecosystem services listed above, CBA practitioners tend to view adaptation threats and solutions in terms of natural resource silos as opposed to complex systems. This way of thinking can be problematic because it rarely considers crucial 'second-tier' ecosystem goods and services such as pollination, climate regulation, genetic diversity or the connections between different natural systems (Reid and Schipper 2013). It also doesn't acknowledge that ecosystems themselves can and will change due to climate variability, climate change and other stressors (Girot *et al.* 2012). Their functionality will be affected by changes in sea-levels,

Table 2: 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: Millennium Ecosystem Assessment (2005) temperature and rainfall. Such changes can have significant social, cultural and economic consequences (Jeans *et al*. 2013). Observed changes in climate have already adversely impacted certain species and ecosystems, and further changes are inevitable (IPCC 2014). The direct impacts of climate change on biodiversity include:

- changes in ecosystem processes, including changes in water catchment processes and natural fire regimes;
- changes in the timing of events in the natural world, which may lead to loss of synchrony between species, for example, with insect pollinators emerging at a different time to plants flowering, making it difficult for the plant species to survive – this may include crops;
- changes in species abundance and distribution, including the arrival of new (potentially invasive or pathogenic) species in a place if conditions become more favourable, and the loss of species that can no longer survive there. Some species may become extinct if they can't accommodate the changes occurring or move to more favourable conditions. This could include species that people directly or indirectly depend on;
- changes in the composition of plant or animal communities.

Ecosystems also have limits beyond which they cannot function and there is established but incomplete evidence that ecosystems are increasingly experiencing nonlinear changes, including accelerating, abrupt and potentially irreversible shifts. When limits are breached the ecosystem may no longer be able to provide the services on which human communities have come to depend (Millennium Ecosystem Assessment 2005; Scheufele and Bennett 2012). Examples include disease emergence, Amazon rainforest dieback, the creation of 'dead zones' in coastal waters, and the collapse of fisheries (IPCC 2014). Buddemeier (2004) describe how coral reefs in certain areas, have passed a tipping point and broken down to the extent that recovery is unlikely. Such dramatic changes affect people in different ways, but it is typically "groups such as the poor, women, and indigenous communities [who] have tended to be harmed by these changes" (Millennium Ecosystem Assessment 2005).

Climate change and a number of other pressures are pushing many ecosystems to the limits of their coping capacity. There is uncertainty about the thresholds of climate change above which ecosystems are irreversibly changed and will no longer function in their current form (CBD 2009). However, we do know that ecosystems are more resilient to climate change if they are in good condition and non-climate stressors such as habitat destruction, overharvesting of resources and pollution are minimised (Hansen *et al*. 2003). See Box 2.

BOX 2: GENERIC MEASURES PROPOSED TO INCREASE ECOSYSTEM RESILIENCE TO CLIMATE CHANGE

- Reduce other pressures on biodiversity
- Increase the number of protected sites
- Increase the size of individual protected sites
- Provide buffer areas around protected sites
- Improve the functional connectivity between sites
- Protect/create cool microclimates and potential refugia for species
- Maintain or increase the habitat heterogeneity at site and landscape scales
- Maintain species diversity within communities
- Protect natural processes
- Promote the potential for natural genetic exchange between populations
- Control invasive species

Source: Morecroft et al. (2012)

One of the key targets for the Convention on Biological Diversity (COP10 Decision X/2) for the coming decade is: "to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication." Building human resilience requires a good understanding of systems, the interaction between components of systems, and the feedback loops affecting system architecture (Malik 2014). Measures to increase climate change resilience must therefore not see the natural environment as merely the provider of an array of unconnected and unlimited resources or services coming from a number of linear or throughput systems. Rather, we should view natural food, energy, water and waste management systems as interconnected and mutually dependent components of a natural systems that together can support human resilience in a more holistic manner (Reid *et al*. 2013; Pimbert 2010).

4

Links between the Maintenance of Ecosystem Services and Resilient Ecosystems, and Human Adaptive Capacity and Resilience

Resilient ecosystems and the provision of ecosystem services are likely to be important components of human adaptive capacity and resilience. The Millennium Ecosystem Assessment (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' (see Table 3). The constituents of human well-being clearly emphasise more than just access to natural assets and services.

Similarly, the ARCAB definitions of adaptive capacity and resilience described in Box 1 acknowledge that assets – such as ecosystem services – are just one component of community resilience. 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 *et al*. 2014). The Africa Climate Change Resilience Alliance (ACCRA) argues that asset-oriented approaches to defining, measuring and

Table 3: Constituents of Human Well-being

Basic material for a good life	• adequate livelihoods • sufficient nutritious food • shelter • access to goods
Health	• strength • feeling well • access to clean air and water
Good social relations	• social cohesion • mutual respect • ability to help others
Security	• personal safety • secure resource access • security from disasters
Freedom of choice and action	• opportunity to be able to achieve what an individual values doing and being

Source: Millennium Ecosystem Assessment (2005)

Table 4: Characteristics of high adaptive capacity at the local level from the ACCRA Local Adaptive Capacity Framework

Asset base	Availability of key assets that allow the system to respond to evolving circumstances
Institutions and entitlements	Existence of an appropriate and evolving institutional environment that allows fair access and entitlement to key assets and capitals
Knowledge and information	The system has the ability to collect, analyse and disseminate knowledge and information in support of adaption activities
Innovation	The system creates an enabling environment to foster innovation, experimentation and the ability to explore niche solutions in order to take advantage of new opportunities
Flexible forward-looking decision-making and governance	The system is able to anticipate, incorporate and respond to changes with regards to its governance structures and future planning

Source: Jones *et al.* (2010)

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 *et al*. 2010; Ludi *et al*. 2011). The framework summarised in Table 4 describes five distinct yet interrelated characteristics that contribute towards adaptive capacity at the local level.

Clearly, 'human well-being' as conceived by the Millennium Ecosystem Assessment, has much in common with 'adaptive capacity' as defined by ARCAB (see Box 1) and ACCRA (see Table 4). Both contain elements of access to resources and assets, but also less tangible 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.[1] 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. Human well-being as defined by the Millennium Ecosystem Assessment, by contrast, is a more static measure.

[1] In a similar comparative exercise, Rouillard et al. (2014) note the synergies between Integrated Water Resources Management and adaptive capacity in the context of Bangladesh.

5

ARCAB Research Sites

Bangladesh is amongst those countries most vulnerable to climate change. This is because of its geographic location – more than half of the country is a floodplain – but also a number of social issues such as extreme poverty, which leaves the population extremely vulnerable to shocks and stresses (Hossain *et al*. 2013; Rouillard *et al*. 2014; Rai *et al*. 2014). To improve knowledge 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.

Goalgram Village, Chanda Beel Wetland

Goalgram Village is located in Nanikhir Union, Muksodpur Upazila, Gopalganj District, Bangladesh. It lies in the south-central Madhumati Floodplain, with the low lying Chanda Beel wetland bordering the village on its north, west and southern sides. A metal road borders its eastern side. The village covers about 610 hectares and lies about 40 km north of Gopalganj district town. It contains two primary schools, 13 temples and several small grocery shops, and is home to 661 families, 95% of whom are Hindu and the remainder Christian. The main occupations of villagers are agriculture (64%), agricultural wage labour (2%), non-agricultural wage labour (10%), sharecropping (3%), services (6%), business (3%), carpentry or masonry (10%) and other occupations (2%). The village has little tree coverage although some fruit trees, medicinal trees and other plants grow (mostly on homesteads).

Most of the village area (except homesteads and some parts of the road) is inundated during the monsoon flooding season. Most areas remain fallow during this time, with only a little aman paddy rice grown. Borro paddy rice is the dominant village crop, cultivated in the dry season when farmers also grow chillies, vegetables and oil seed, primarily on higher land. The three village roads are mostly submerged during the monsoon season, when people travel within the village and further afield using country boats. The village has three canals and large number of ditches (man-made ponds) around homesteads and also in crop fields. Large numbers of floating and rooted aquatic plants and weeds are present (Chakraborty *et al*. 2005; Hussain and Chowdhury 2005).

Many extremely poor people live here. They rely on subsistence agriculture, fishing, wage labour, small businesses and pulling rickshaws. Most are lower caste Hindus with little 'voice' and political power. Food insecurity is common.

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 water from the Ganges and Jamuna Rivers. 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. Of the 10,890 hectares covered by Chanda Beel, some 82% is used for agricultural purposes followed by 10% for settlement/homestead land, 4.5% for ponds (kua), 2% for canals (khal) and 1.5% for roads (kutcha/pucca). Human settlement in the Beel is very old. There are 44 villages in and around the Beel system, all on relatively higher land. Settlements are increasing rapidly in and around the Beel.

Many of the canals have silted/dried up in recent years due to the construction of sluice gates in the 1960s to control water for irrigation. Until 1980, larger launches and steamers in addition to smaller country boats were the primary means of communication throughout the year. Now only a limited number of country boats can function during the dry season. Manually-operated country boats have now been replaced by small boats with diesel engines, and transportation by road is now the main way to move goods and passengers. People use buses, rickshaws/vans and auto-rickshaws.

Although a significant proportion of people living near the Beel were fishermen in the past, today most people are farmers or wage labourers. Some fishers have left the locality, others have changed their occupation. Local fishers report that there used to be 57 fish species in the Beel, only 28 of which are now common and 7 are extinct. There were 16 species of prawn, 6 crab species and 16 mollusc species, but only a few of these are found in the Beel today. Fish used to be available all year round and there were enough to support fisher livelihoods and the subsistence needs of non-fishers, but this is no longer the case (Chakraborty *et al.* 2005).

These dramatic changes have occurred for a number of reasons: road, culvert, bridge and sluice gate construction have changed the Beel's physical features, reducing and controlling water flow for irrigation purposes, increasing siltation, and causing the Beel bed to rise. Waterlogging caused by siltation and decomposing water hyacinth has reduced water flow through the Beel still further. The result is that most wetlands have now been converted to agricultural land, and only a negligible proportion of the original wetland with water throughout the year remains (BCAS and CDI 2006). Sluice gates have also inhibited fish migration, and intensive use of agricultural chemicals has degraded water quality.

Fishers in Chanda Beel used to use indigenous technologies, mostly made of local materials like bamboo and rope. Fishers operated according to longstanding customary rights and regulations in the Beel. They would not harvest brood fishes, fingerlings and juvenile fishes in order to maintain fish abundance all year round. Fishing was for subsistence rather than commercial use. Today fishers use modern nets, which are more efficient but less sustainable.

Before 1960, only 39% of the total Beel area was under agricultural production in the dry season, and 9% in the wet season. By 2005 these figures were 72% and 20% respectively. Before 1960, the people of Chanda Beel used indigenous technologies and knowledge for cultivating their land, namely ploughs, yokes, spades etc. Natural sedimentation processes meant soils were very fertile and people relied on rainwater to grow crops. Modern irrigation techniques were almost unknown. After 1960 farmers started using tractors, irrigation pumps, harvesting machines and other inputs like insecticides, pesticides, chemical fertilizers and high yielding seeds varieties. Production has soared, but heavy use of pesticides and chemical fertilizers has also damaged land fertility, degraded wetland resources and reduced biodiversity. Prior to 1960, men used to work in the fields or as fishers and women would process agricultural products at home. Since the modernisation of agriculture in the area, however, men alone can no longer manage agricultural workloads alone and women are now working alongside with men during all stages of farming activities. This is truer for Hindu than Muslim women.

Biodiversity in the Beel area has fallen since 1960. Of 39 species of terrestrial birds recorded prior to 1960, only 15 are now common, and 5 are extinct. Of 20 species of migratory and aquatic birds, only 14 are fairly common today. Of 13 mammal species commonly found in the past, only 4 are now common. Similar reductions in number and diversity have also been recorded for amphibian and reptile species (BCAS and CDI, 2006). Terrestrial and aquatic floral diversity has also decreased for a number of reasons: deforestation and tree use for fuel and furniture construction; replacing timber and fruit trees with small plants for use as cattle fodder; shrub destruction by domestic animals; settlement and population growth; siltation in the Beel; emptying ponds to catch fish; and use of agricultural chemicals.

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. Recently, the local community has 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. People have also reported that cyclones and increasingly erratic rainfall and temperature changes are hampering crop production and other livelihood activities. Poor women and marginalized sectors of society suffer most.

A number of local non-government organizations (NGOs) and local government institutes work in the area but there is a lack of understanding of what climate change will bring and how best to address it. Participatory vulnerability assessments conducted by ARCAB in association with Christian Commission for Development in Bangladesh (CCDB), a local partner of Christian Aid, show that local people are using traditional knowledge and wetland resources to reduce their vulnerability and the impacts of climatic disasters. NGOs are also trying to promote CBA activities using locally available natural resources. For example, the Bangladesh Centre for Advanced Studies is educating teachers and students about fish conservation and it has established a Wetland Research and Training Centre (WRTC) in the Beel area. Although the Beel's natural resources have greatly declined over the years, 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 and Mondal 2012).

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. East of the village lies Maricha Beel. Kaptai Lake was formed following the completion of the Kaptai hydro-electric 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 flat, alluvial land, equating to roughly 40% of the most fertile arable valley land available, and also 24,000 hectares of sloping foothills.

The village is home to four different ethnic communities - 'Chakma', 'Marma', 'Tripura' and 'Bengali' - each of which lives in its own 'para' (segment of the village). All villagers have built their houses on hill slopes or hilltops. Balukhali has no metal access road, and only a few paved village roads. Villagers must therefore use boats to access Rangamati Sadar Upazila or the district town. There is no market in or near the village, so people must travel to the nearest market in Rangamati Sadar Upazila to sell their household or farm products, or buy household needs. The village has only two primary schools, and children must travel daily to Rangamati Sadar Upazila for their secondary or higher level education. Poor families cannot afford to pay for daily boat travel and other costs, so most children are not educated beyond primary level.

The village contains roughly 194 households. Some 7% are very poor and 31% are poor. No households identified themselves as rich. The main source of income for some 50% of households is agriculture, with agricultural wage labour at 8%, non-agricultural wage labour at 2%, sharecropping at 2%, services at 7%, fishing at 17% and business at 14%. 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. Many fish species can be caught in Kaptai Lake, but fishing is banned in May, June and July, during which time young men and women migrate to cities to look for work. In recent years, lake fish resources have been declining rapidly due to a reduction in seasonal rainfall affecting lake water levels. Reliance on fishing has thus decreased.

Hill tract land provides the villagers with many forest resources. Large numbers of indigenous timber trees grow in hills around Balukhali, and also a number of indigenous fruit trees. Naturally growing trees and plants are cleared for cultivation, homesteads and plantations. Villagers plant fruit trees for horticultural purposes, often in orchards, and also imported timber trees such as mahogany. These provide villagers with income and food. Villagers also use a number of medicinal trees and plants for health purposes.

Agriculture is a driving force in the village economy. Indigenous populations have practiced 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 source of livelihood for many, especially the Parahari people. Many of the local people displaced when the Kaptai Lake was formed took up jhum cultivation. Increased pressure on the land led to the shortening of the fallow period from 10-15 years down to 5-6 years (Hassan and Van Lavieren 2000), but Jhum still remains the most widespread form of agriculture. Annual and short 2 or 3 year lifecycle crops include rice, cotton, melon, cucumber and other vegetables. Perennial crops include fruit (such as mango, jackfruit, coconut and banana), rubber and tea. Farmers also practice intercropping.

Most of the village area (except homesteads and some parts of the road) floods during the monsoon period, during which time most land lies fallow and only aman paddy rice is grown. Borro paddy rice is the dominant village crop, cultivated during the dry season (January – May). Flooding from rainwater or Kaptai Lake usually inundates valley land between May and December. Kaptai Lake varies in area from 26,800 hectares in May up to a maximum of 74,200 hectares in October (BBS 2004). In addition to submerging much of the area's most fertile land during lake formation, crops have also been lost due to dam management practices. Dam water levels should remain below 27.5m from April to August to allow farmers to grow one crop (boro rice) in the fringe valleys, but this rule has not been respected in the last few years, resulting in crop losses. Furthermore, maximum water levels in the rainy season also seem to have increased significantly leading to the loss of yet more land that used to be used for monsoon season vegetable production. Overall, paddy cultivation and summer vegetable production has been severely affected.

People use water from different sources for irrigation, drinking, bathing, washing, sanitation and other domestic purposes. The main water sources are lake surface water, springs, and also rainwater when high enough. Collection pipes at highland water sources help villagers secure water. 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.

Villagers suffer from a number of climate-related disasters, most importantly droughts, torrential rainfall, cyclones and storms/strong winds. Dense fog, hailstorms and erosion also provide lesser challenges. Data from the Bangladesh Meteorological Department (BMD) for the Chittagong Hill Tract areas shows that over the last few decades, the annual maximum temperature has increased whereas the minimum temperature has remained fairly stable. Predications suggest the number of rainless days will increase in future which could reduce stream water availability. The frequency of torrential rainfall episodes has also increased in recent decades. These wash away soil nutrients, leaving the land barren and damaging crops. The erratic nature of rainfall makes it harder for farmers to plan appropriately.

As natural forest resources have declined, and dependence on these and also fishing has fallen, many poor families now undertake alternative income generating activities such as making handicrafts or clothes to supplement their income from agriculture. NGOs have provided training and support for this in recent years, particularly for poorer women, for example on horticultural and disaster risk reduction practices. Improved levels of education and available information on new agricultural technologies have helped with this.

6 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 a number of simple measures and qualitative approaches are used to provide a measure of these parameters and hence a broad overview of connections between them.

A number of techniques can be used to measure specific ecosystem services provision (de Groot *et al*. 2002) but this research doesn't seek to use these or quantify the particular ecosystem services observed. It rather details the number and diversity of different ecosystem services used by local communities.

Likewise, ecosystem resilience is not measured directly. The term 'resilience' is commonly used in the context of increasing both ecosystem and human resilience to climate change impacts, but it is not used consistently, and substantial uncertainties exist around the best way to measure it, place value on it and enhance it in either context (Morecroft *et al*. 2012; Scheufele and Bennett 2012). Changes to ecological resilience are often only apparent after a change has occurred. For the purposes of this research, a broad assessment of ecosystem resilience is made, looking at whether the ecosystem selected has undergone a major shift in its structure or function, as a result of human intervention and also climate change, which has affected its ability to provide ecosystem services.

Changes to human adaptive capacity and resilience in the face of climate change (as defined in Box 1) are also not quantified by this research. Assessments about whether these increase or decrease depending on changes to ecosystems and their services are largely qualitative and are based on a combination of expert and community judgement about how changes experienced to date have affected them.

This research also looks at what kind 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. Whilst EbA and CBA (and approaches that integrate both) have the potential to benefit the world's poorest people who are worst hit by climate change and also disproportionately reliant on ecosystems and their services, they must also look ahead and acknowledge that the environment is no longer static as climate change advances, and in many places people will have to adapt to conditions beyond anything experienced in living memory (Reid 2014b). The Millennium Ecosystem Assessment (2005) observes that "recent changes in climate, especially warmer regional temperatures, have already had significant impacts on biodiversity 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… 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." The assessment findings described here, 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 ARCAB surveys and focus group discussions (undertaken in 2012), was also collated.

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 Millennium Ecosystem Assessment (2005) likewise treats agricultural land as an ecosystem in its assessment, despite the fact that it is intensely modified and managed by man.

7

Results

Tables 5 and 6 describe the natural resources and associated ecosystem services utilised 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.

Ecosystem Services Provision

Table 5: 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 tree coverage: timber trees, fruit trees. Trees are both indigenous and introduced.	• Reduced disaster risk (trees protect the houses during cyclones). • Local trees used to re-build 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 the flooding period 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 they are cut down for timber and fuel, for making furniture and to make space for settlement and population growth. 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.

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
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)	• Bamboo used to construct temporary platforms on boats during floods. • Bamboo used to re-build houses damaged by disasters.		
Medicinal trees and plants (mostly cultivated on homesteads)	• Villagers use trees and plants as medicine during vulnerable periods such as floods or droughts, when a number of locally available plants provide medicinal uses for diseases that are more prevalent during these times. For example 'neem' 'tulsha' 'amloki' 'bashok' all have medicinal uses.	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 isn't 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. • 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 aren't cultivated). • Local people feel water hyacinth can clean water bodies and reduce pollution. • Water hyacinths obstruct navigation of waterways, but this not a major issue.	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
Fish culture	• Some indigenous fish are cultured (mostly carp, 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.

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
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 fertilisers, 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 fertilisers, 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 water ways (canals, sluice gates etc.) to manage water for irrigation.	Drought affects water quantity (not quality so much).

Table 6: 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
Trees: Indigenous timber trees (with local names) include: gamari (*Gmelina arborea*), teak (*Tectona grandis*), jarul, garjan (*Dipterocarpus alatus*), karoi, chil karoi, titia karoi, shimul (*Bombax ceiba*), kumbhoi, lalbadi, sada badi, goda (*Vitex peduncularis*), goya achol, ashoth, bot, meho agini, agaja gula, civit (*Swintonia floribunda*), shibarichi, chamashil, surosh, kadam (*Anthocephalus chinensis*), kom, daka karom, vogh, monchapa, kander, nakshafull, ma lakshmi, dom gula, varala, boa, agar (*Aquilaria agallocha*), ful summary, kurik, gud gudtha, tula, kurung, erja, chamely, fulchukni, champafull, konak, kanpoi and charuaful. Indigenous fruit trees (with local names) include: mango (*Mangifera indica Linn*), jackfruit (*Artocapus heterophlla Lmk*), coconut (*Cocos nucifera)*, jam (*Syzygium cumini)*, litchi, paina fall, kaju babdam, mialuchi, latkan (*Baccuria ramifolia*), dalim (*Punica granatum)*, kamola, kala/ banana (*Musa Paradisiaca L.*), anarosh/pineapple (*Ananas comosus*), jolpai, atashi, atha gula, sofeda, bel (*Aegle marmelos)*, plum, tamarind, supari/betelnut (*Areca catechu*), gab gula/deshi gab (*Diospyros peregrine*), jobna gula, sharbigula, khajur, jambura, guava, amlaki (*Phyllanthus emblica)*, lemon, kamranga, jamrul and baroi. Horticultural trees include: mango (*Mangifera indica Linn*), jackfruit (*Artocapus heterophlla Lmk*), litchi, banana, papaya (*Carica papaya)*, sofeda, guava (*Psidium guajva L.*), lemon, amloki and pineapple (*Ananas comosus*). Imported timber trees include: mahogany (*Swietenia macrophylla* and *S. mahagony*) acashmoni, belgium, eucalyptus, rubber, agor and belgium gas.	• House protection 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. • Rafts made from kala/banana trunks are used for moving around locally during floods. • Timber used to make and repair furniture. • 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. • Timber sold to increase family income. • Cotton harvested from silk cotton trees and sold to enhance household income. • Products from rubber trees are sold to increase family income. • Fruits harvested for consumption and sale to enhance household income. • Horticulture can provide employment opportunities and income from the sale of fruit. 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), ash (from burning dry leaves) is used, and leaves are burnt under the trees. • 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, banana and sofeda. • Drought has damaged less resistant tree species such as banana. • 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.

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
Medicinal trees and plants (with local names): neem (*Azadirachta indica)*, amloki (*Phyllanthus emblica)*, bohera (*Terminalia belerica)*, horitoki (*Terminalia chebula*), arjun (*Terminalia arjuna)*, udol, moa-ma, botta gula, shamol kasuri, bagraj, madon, lazzaboti, gritokumary, kaladaru, faziliti, shabarang and ashom pata.	• 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, diabetics, 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 don't know which trees are good for which diseases. • 'Slash and burn' practices cut and burn most grasses and bushes for crop cultivation.	• Cyclones/ storms uproot/ damage trees. • Torrential rainfall and landslides uproot/damage trees. • Prolonged drought kills/ damages medicinal trees.
Smaller plants and grasses (with local names): fuli gash, durba (*Cynodon dactylon)*, fuishkher, fuljharu, kutchipata, kanaia, polkher, kachuripana, khagra and shon grass.	• Fuli gash and durba are used as cattle fodder. • They also prevent soil erosion. • Khagra and shon grass are used for thatching roofs. Such roofs 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.
Bamboo (various species): baria, muli bamboo (*Melocanna baccifera*) mitingga, budung, ora and kalichari.	• 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 re-building 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.

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
Fish species: rui, katla, mrigel, boal, pangash, air, kali baos, sada baos, singi, baila, chapila, kaski, punti, tilapia, bacha, kala chanda, nag kata, baim, chotto chingri, banshkaitta, mola, poa, gozar, shol, taki, randalee, tengra, gulsha, samuk, jhinuk and kakra.	• 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 kaski net meshes. • Lake water pollution from diesel oil (from boats) and dumping waste and garbage.	• High lake water temperatures cause fish death.
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 doesn't always occur.	• Lake and well water levels fall during droughts, which hamper agricultural crop production and reduce the amount of water available for domestic and drinking purposes.
Agriculture/crop cultivation: IRRI paddy, BR-28 and BR-21 paddy, hira paddy, sangkar-3 paddy, local varieties of paddy (binni dhan), water melons, ada/ginger (*Zingiber officinale Roscoe*), halud/tumeric (*Curcuma longa*), silk cotton (tula), musur dal, papaya (*Carica papaya*), kala/banana and pineapple.	• Employment opportunities from agriculture, for women too. • Paddy rice for household consumption. • Water melons 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 water melons.

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
Vegetables (grown in jhum fields and on homesteads): shasa (cucumber), karolla/bitter gourd (*Momordica charantia L. Amaegoso*), bagun (eggplant), sheem (bean), misti kumra (suit pumpkin), lau (water gourd), derosh (ladies finger), borbati (bean), chal kumra (pumpkin), poi shak, lal shak (red spinach), plong shak (spinach), mula/radish (*Raphsnus sativus Linn*), full cafi (cauliflower), badha cofi/cabbage (*Brassica oleracea Linn*), goal alou (potato), shak alu, patol (pint gourd), jhinaga, sajina, teel/sesame (*Sesamum indicum*), shimul aloo, marfa/cucumber, brinjal (begun), chillies, bangee (chinal) and sweet pumpkin.	• 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 and animals: The following bird species are common in the village: kak (crow), doyel (magpie robin), ghugu (dove), babui, moina, payra, kakatua, tia, pakhi raja, ducks, pankouri, machranga (kingfisher), bok, tuntuni, shalik, charui, bulbuly, and lomba lesa pakhi. Animals include: tiger (bagh), deer (hrine), wild boar (bon sukar), erdaga (gui shap), ban morog, porcupine (shajaru) 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.		

Ecosystem Resilience

Tables 7 and 8 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.

Table 7: 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. 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.	• 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. • 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 can't move through waterways. • Better infrastructure (e.g. transport infrastructure) has led to more 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. 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 and fishing. The very poor have suffered more, despite other emerging opportunities such as growing vegetables and other livelihood opportunities that have become available.

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 (cont)	• Traditional fishing practices, whereby 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.		• Traditional 'safety nets' (such as employment in fishing or waterway transportation) have been reduced following the destruction of the 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
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 fertilisers, 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. 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.	• 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. • 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 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 hasn't 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.	• 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 also helps increase household 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 worst but the expansion of agriculture at the cost of the wetland ecosystem has not been bad for them.

Table 8: 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 damages 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.	• 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	• Dumping waste and household garbage pollutes lake water. • Mechanized boats pollute water through oil leakage. • Building houses and shops besides the lake damages the lake environment. • Natural fish stocks are decreasing. • Government releases fish fingerlings into the lake, and limits fishing during key times to improve fish stocks, but the number of fishermen is increasing, and some use illegal/unsustainable practices.	• Torrential rainfall damages the lake environment. • Drought significantly lowers lake water levels and hampers 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. • High 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, 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. • Lake water level management doesn't always suit farmers. • Training from agricultural extension offices and NGOs on soil conservation practices has helped people grow lemons, pineapples and other vegetables.	• Torrential rainfall and landslides remove the top soil from crop fields. 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 impossible. • Hailstorms, fog, pest damage and warm temperatures can damage crops.	• 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.

8 Discussion

Much published literature on EbA emphasises 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) argue 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 for their livelihoods. 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 5 and 6). In many instances these benefits would be difficult to quantify and thus ignored, although efforts to quantify non-use values at Chanda Beel suggest they are significant (Ghosh and Mondal 2012). Most ecosystem services observed at the case study sites can be classified as provisioning, regulating and supporting services, with cultural services perceived as playing a lesser role in terms of their contributions to adaptive capacity and resilience. Hossain *et al.* (2013) also found that provisioning services were most important for livelihoods and hence adaptive capacity in Bangladeshi wetlands.

The Millennium Ecosystem Assessment (2005) found that relatively few studies had compared the total economic value (including values of both marketed and non-marketed ecosystem services) of sustainable ecosystem management when compared with the conversion of ecosystems through farming, logging or other uses, but that some studies had "found that the benefit of managing the ecosystem more sustainably exceeded that of converting the ecosystem". This study does not quantify ecosystem services in the context of adaptive capacity, but it does clearly show that at both sites, the wide range of services (or co-benefits) utilised by communities means that ecosystems and ecosystem services are central to adaptive capacity and resilience and need to be valued and supported accordingly.

Resilience from Diversity

The Economics of Ecosystems and Biodiversity report (TEEB 2008) argues that "The security value of biodiversity can be compared with financial markets. A diverse portfolio of species stocks, as with business stocks, can provide a buffer against fluctuations in the environment (or market) that cause declines in individual stocks. This stabilizing effect of a 'biodiverse' portfolio is likely to be especially important as environmental change accelerates with global warming and other human impacts". Maintaining a wide diversity of species and genetic diversity can also facilitate the emergence of species and genotypes that are better adapted to shifts in climatic conditions and could well have important adaptation benefits in the future (TEEB 2008).

Just as species diversity can buffer against environmental change, so too can diversity in the livelihood options open to a community. Colls *et al.* (2009) take this one step further in the context of EbA and argue that such livelihood diversification can lead to positive feedback in terms of increasing resilience: "Livelihood enhancement and diversification can encourage people to move away from unsustainable exploitation and degradation of natural resources and thereby increase social and environmental resilience to climate change".

Evidence from both case study sites clearly demonstrates the diversity of opportunities that ecosystems and ecosystem services provide for supporting subsistence and livelihood needs in each area. In Chanda Beel, snails are collected when agricultural activities require less time from September to November (Khan *et al*. 2005), and vegetables/crops/seedlings are grown on floating platforms made from water hyacinth known as 'baira' during the monsoon season when fewer jobs are available (Hussain and Chowdhury 2005). In Balukhali Village, fishing occurs when agricultural activities require fewer inputs, and horticulture is providing new employment and income-generating opportunities. Diversity in the array of natural resources available and utilised at each site has thus increased the number of different subsistence and livelihood options available at different times and hence increased community resilience. Interestingly, many important ecosystem services are based on the use of non-native species such as water hyacinth or non-native horticultural tree cultivation.

Shifts and Thresholds in Ecosystems

Climate change induced changes to ecosystem services and also to ecosystems such as forests and wetlands due to climate change have been noted throughout the world (IPCC 2014). In most instances, however, a better ability to define ecosystem resilience, the parameters that affect it, and related impacts on ecosystem service delivery in the face of climate change is needed (Pettorelli 2012). Hossain *et al*. (2013) describe concerns about wetland ecosystems in Bangladesh, where changes to temperature and rainfall patterns could lead to dramatic shifts in the type and structure of such ecosystems. This will have consequences for 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 Beel. As the impacts of climate change intensify, however, it is likely that they will 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 changes (climate change related and otherwise) being made in ecosystems globally are increasing the likelihood of nonlinear changes in those ecosystems (including accelerating, abrupt, and potentially irreversible changes). This has important consequences for human well-being (Millennium Ecosystem Assessment 2005) and human resilience (Malik 2014). For example, once a nutrient loading threshold is reached in freshwater and coastal ecosystems, changes can be abrupt and extensive due to a condition known as eutrophication, where harmful algal blooms can deplete oxygen levels to the extent that most animal life cannot survive. Freshwater ecosystems are considered to be among the most threatened on the planet (IPCC 2014).

At Chanda Beel, for example, it is possible that increases to soil and water salinity levels could hamper future agricultural practices, especially in the dry season when freshwater flows from upstream are reduced. Intensive agricultural practices are increasing the demand for water, which threatens the wetland (Ghosh and Mondal 2012). Snails also 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 these keystone species from the wetland 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.

Reaching the Most Vulnerable

Both the Millennium Ecosystem Assessment and the Intergovernmental Panel on climate Change assert that changes to natural systems, climate change induced or otherwise, will affect the poorest and the most vulnerable worst. This is in part because their livelihoods are so heavily reliant on natural resources, such as fishing, agriculture and other forms of land or marine management. The Millennium Ecosystem Assessment (2005) argues that the harmful effects of ecosystem service degradation "are being borne disproportionately by the poor, are contributing to growing inequities and disparities across groups of people, and are sometimes the principal factor causing poverty and social conflict." 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 them with 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, transport sector work) mostly for men, but also for women, many of whom are pleased to be working alongside men in the fields. Fishers are known to be amongst the poorest and most vulnerable societal groups in Bangladesh (Deb and Haque 2011; Deb *et al*. 2014) and many have become unemployed or left Chanda Beel, but others have found new unskilled work, and those who are extremely poor (who rely mainly on subsistence agriculture and fishing) are now a smaller minority than they were before the shift to agriculture. The dramatic changes to the ecosystem have not necessarily made their lives worse.

It is important to note, however, that this study looks only at a snapshot in time. Whether the overall perceived improvements in people's situations continue has yet to be seen. The ACCRA Local Adaptive Capacity Framework (Table 4) 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 in this study.

Trade-offs

EbA is sometimes presented as a win-win-win for poverty reduction, climate change adaptation and biodiversity conservation. For example Colls *et al.* (2009) state "Reducing ecosystem degradation is a no regrets, win-win approach to adaptation." Results from study sites described here, however, make it clear that dramatically altering an ecosystem or replacing it with another leads instead to a number of trade-offs, rather than the all-round benefits or costs assumed by some advocates of EbA. Hossain *et al*. (2013) argue that a cost-benefit analysis of the modifications common to many floodplain environments in Bangladesh since the 1960s indicate that most of projects were unsuccessful because they did not consider the whole socio-ecological system. But degradation of the wetland ecosystem in Chanda Beel has led to opportunities (and consequent increases in wealth and local adaptive capacity) from agriculture. Rouillard *et al*. (2014) note, however, that whilst water management for the purposes irrigation has increased irrigated areas, stabilised farmers' income, and fostered economic development, it has increased the potential for large-scale disasters, such as crop failure due to drought, and extreme floods breaching the embankments as occurred in 1994. Whilst the formation of Kaptai Lake flooded much fertile agricultural land near Balukhali Village, it facilitated livelihood diversification into fishing during fallow months.

The Millennium Ecosystem Assessment (2005) acknowledges this issue of trade-offs and describes how actions to increase one ecosystem service often cause the degradation of other services, which in turn can cause significant harm to human well-being. For example, actions to increase food production typically involve increased use of water and fertilizers or expansion of the cultivated land area. This often degrades other ecosystem services such as water availability and quality or forest cover, which can have major impacts when non-linear change occurs or thresholds for ecosystem functioning are crossed.

Temporal trade-offs may occur over time. For example in Chanda Beel, adaptive capacity increases from current agricultural practices may only be short- or medium-term if wetland salinity levels increase making agriculture less viable at certain times of the year. The use of modern agricultural techniques has already reduced soil fertility and polluted water bodies. The longer-term impacts of this are also unknown, but if this trend continues and the ecosystem services on which future generations could rely on are substantially diminished, future adaptive capacity could be dramatically altered. The Millennium Ecosystem Assessment (2005) argues that 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 these changes on human well-being. For example, the accumulation of phosphorus in many agricultural soils threatens rivers, lakes and coastal oceans with eutrophication, but it may take decades for the full impact of this to become apparent. 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, if fishing in Lake Kaptai ceases to be viable, the long-term adaptive value of fishing for local livelihoods could disappear.

Trade-offs occur between social groups or stakeholders. For example, in Chanda Beel, fishers have suffered from degradation of the wetland, 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 in the costs and benefits of ecosystem changes may also be experienced between locations, often at some distance from where the ecosystem was changed. For example, changes in upstream catchments may affect water flow and water quality downstream. Problems can arise where the boundaries of ecosystems do not correspond to political or administrative boundaries (Reid 2014a). 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. Rouillard *et al.* (2014) comment on this in the context of integrated water resource management strategies to increase adaptive capacity in Bangladesh, where management at hydrologically relevant scales is often inconsistent with the social-political scales for decision making. Flooding in Chanda Beel may result in part from decisions made about river basin water management far from the local area. Ensuring synergies between scales is a key requirement for adaptive capacity, but very difficult to realise in practice.

Institutions, policies and governance

The availability of ecosystems and ecosystem services is just one component of resilience and adaptive capacity. Control over and access to these resources, and indeed over other non-ecosystem related components of resilience, is another. Ultimately, providing political and institutional structures – such as secure land and resources use rights – may be at least as important as maintaining a well-functioning ecosystem. Participation in decision making for good CBA is essential to capitalise on opportunities drawing upon traditional/local knowledge to inform adaptation options and ensure communities are framing the problem and not just the solution for initiatives implemented (Reid *et al.* 2009b; Reid and Schipper 2014; Ayers *et al.* 2012). Dodman and Mitlin (2013) argue, however, that whilst CBA has emphasised 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 ultimate success. This is as true for local institutions as for the higher level institutions and policies on which communities depend. Rai *et al.* (2014) argue that three 'building blocks' are needed for mainstreaming climate resilience into development planning: an enabling environment (including political will and information services), development planning (including institutional arrangements and policy and budgetary frameworks) and projects and programmes. Dixit *et al.* (2012) describe the five key functions for national institutions that are critical for local adaptation: assessment, prioritization, coordination, information management and climate risk management.

In Chanda Beel, for example, 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. The absence of a wetland resource management plan means the Beel faces the over-exploitation and loss of important resources (Ghosh and Mondal 2012). The lack of regulations imposed on snail harvesting, for example, could dramatically alter the wetland ecosystem because of the central role that snails play in ecosystem functioning (Khan *et al.* 2005). Likewise improved fish conservation practices and management would help enhance local long-term adaptive capacity. Chakraborty *et al.* (2005) note the absence of policy/legislative measures and institutional arrangements for Chanda Beel wetland management more generally, although 'baira' extension centres and committees have been established there (Hussain and Chowdhury 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) comment on the system established by the Ministry of Land whereby waterbodies are leased out, and through the process of sub-leasing and several layers of intermediaries, actual fishers are subject to 'rack renting' (a form of economic subjugation), and are ultimately unlikely to be able to eke out a decent living from fishing alone. Khan and Haque (2010) reiterate that these top-down management regimes involving the leasing of wetland property rights encourage exploitation by powerful elites and increased marginalization and vulnerability of fishers. They recommend adoption of a community-based or co-management approach to improve efficiency and minimise the marginalization and vulnerability of local resource users, and Rouillard *et al.* (2014) recommend the involvement of local institutions in water management projects to improve adaptive capacity. Hossain *et al.* (2013) call for stronger institutional and legislative and management responses to improve adaptive capacity in coastal wetlands in Bangladesh, including fair trade policies, support for renewable energy, fish sanctuary development and prohibition of fishing during breeding months.

In Balukhali Village, the government decision to invest in hydro-electric power led to the formation of Kaptai Lake, which flooded large amounts of important fertile arable land used by the community. 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.

ARCAB acknowledges the importance of local institutions having the resources, mandate and capacity to integrate and support adaptation (Figure 1), and whilst the case studies described here provide little detail on the local institutional context, they illustrate the importance of addressing the institutional, governance and policy context in which communities sit in order to improve local adaptive capacity.

9 Conclusions

These research findings support 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 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 be detrimental to important ecological processes (Munroe *et al.* 2011), for example sea walls affect the migration of mangroves as sea levels rise (Girot *et al.* 2011), and dykes and dams disrupt the annual flooding of floodplains. The IPCC reiterates that engineered defences such as dams, sea walls and levees adversely affect biodiversity, potentially resulting in maladaptation due to damage to ecosystem regulating services. It argues that EbA can be combined with, or even used as a substitute for, engineered infrastructure or other technological approaches (IPCC 2014). Reid (2014a) state that "well-managed, stable, diverse ecosystems can make a significant contribution to local adaptation efforts." Restoring and alleviating other stresses on ecosystems can help them survive and adapt to climate change and continue supporting human adaptation (IPCC 2014; Colls *et al.* 2009).

Jeans *et al.* (2014) and Reid and Schipper (2014) provide some practical guidance on how to integrate ecosystems into adaptation strategies and programmes, including those on CBA:

- As well as working the local community level, think and plan at the spatial scales that ecosystems operate at, and engage with institutions operating at these other scales (e.g. the watershed management scale) to create an enabling institutional environment that can address ecosystem functions.
- Maintain ecosystem services at multiple scales (e.g. replanting deforested slopes, managing water resources on a catchment-wide scale with multi-stakeholder participation, restoring and replanting mangroves).
- Increase ecosystem resilience by removing non-climate stresses and promoting ecosystem management and restoration. This is important for maintaining ecosystem functioning and service provision. For example, conserve and restore forests by preventing forest fragmentation, restoring corridors, avoiding over-use of resources and reducing risk of forest fires to increase their resilience to climate change. Adopting a precautionary approach in this way is important given the uncertainty about how climate change (and other stressors) will affect ecosystems.
- Facilitate ecosystem adaptation (recognising that ecosystems and natural resources will not remain stationary in the face of climate change). For example, providing forest corridors along gradients to help key species, such as pollinators, seed dispersers and medicinal plants, migrate as temperatures rise. Or providing space for mangroves to migrate inland when sea levels rise.
- Integrate local and traditional knowledge with scientific knowledge on natural resource/ecosystem management for livelihoods/human well-being.
- Promote partnerships that bring together local communities and decision-makers with development, conservation and disaster risk reduction communities of practice.

- Ensure the full extent of ecosystem services and values is included in any assessment of costs and benefits for adaptation planning.
- Monitor and manage ecosystem change to support ongoing human and ecosystem resilience and adaptation.

There are other components of adaptive capacity and resilience, such as new technologies and education, which have not emerged so strongly from this research. They may, however, be no less important. New technologies such as hydroponics and floating vegetable gardens could improve resilience in Chanda Beel. Hossain *et al*. (2013) suggest training and better awareness on environmental issues in addition to improving literacy would help increase adaptive capacity in the south western coastal district of Narail. Khan *et al*. (2005) describe efforts in Chanda Beel to educate communities about the ecological and economic importance of snails in the wetland. Chakraborty *et al*. (2005) emphasise the importance of raising community awareness about wetland resources in Chanda Beel. Porras *et al*. (2013) also emphasise the importance of characteristics such as landowner education levels on the outcomes of 'payments for environmental services' schemes in Costa Rica. Ensor and Berger (2009) stress the importance of engaging communities in discussions around the concepts that underpin climate change in a way that makes sense to them rather than through using abstract scientific concepts.

Experiential field-based EbA activities are proliferating, but more objective rigorous analysis and learning is needed in order to assess the conditions under which EbA works, and what the benefits, costs and limitations are compared to other adaptation options. A number of scholars and practitioners have noted the need for stronger evidence on EbA, which has a relatively short history of learning and practice (Reid 2014a: Colls *et al*. 2009). Much 'grey literature' focuses on trying to advocate for the adoption of EbA without including obvious measures of effectiveness (Munroe *et al*. 2012). This paper goes some way towards providing evidence on EbA effectiveness, particularly on the roles that ecosystems and ecosystem services play in increasing adaptive capacity and reducing vulnerability, but much more research and analysis is needed to fill the evidence gaps identified.

A greater understanding of the thresholds, boundaries and tipping points across a range of EbA in varying climatic zones is needed as these determine whether ecosystems can continue to fulfil their required functions under particular conditions, and what type of EbA approaches might best be applied in different situations. More detailed comparisons between EbA and alternative adaptation strategies are needed, taking into account the social, environmental and economic costs and trade-offs (at different temporal, geographic and social scales) as well as benefits and synergies. Better quantification of the multiplicity of co-benefits (disaster risk reduction, food security, water provisioning etc.) and costs EbA delivers is needed. The published evidence base is skewed towards particular climate change impacts and particular types of ecosystems and ecosystem services (for example disaster risk reduction from planting mangroves). In terms of sectors, a recent review of existing evidence (Doswald *et al*. 2014) found that most of the interventions using EbA addressed agriculture and the loss of biomass cover and productivity as their main target, with water, coastal protection, the provision of alternative livelihoods, forestry and urban areas also important targets. Evidence regarding the effectiveness of EbA in response to other climate impacts and in other sectors is weaker. A further gap in the evidence base for EbA is on social assessments, and how groups of people are differentially affected by different interventions or approaches. This is crucial because the impacts of climate change often disproportionately affect the most vulnerable communities and groups (Reid 2014a). Lastly, a better understanding of how to monitor and evaluate (M&E) EbA is needed, because existing CBA M&E tools are weak on ecosystem components, and how to secure appropriate institutional and policy support for effective EbA mainstreaming into relevant national and local adaptation policies and broader national planning frameworks.

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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. Those who are most vulnerable to climate change are often highly reliant on the natural environment for their lives and livelihoods, and ecosystems and the services they provide are already central to many adaptation strategies. This paper describes two components of effective EbA: ecosystem resilience and the maintenance of ecosystem services. Research assesses how effectively EbA supports community adaptive capacity and resilience at two Action Research for Community Adaptation in Bangladesh (ARCAB) sites. Findings suggest that more attention should be paid to EbA as an important response to climate change.

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