Ecosystem Services and Poverty Linkages in Bangladesh

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Summary

What is the relationship between ecosystem services and poverty alleviation? Finding answers to this question is vital if resources are to be used sustainably and to alleviate poverty. However, this is a question that has not received thorough attention in Bangladesh. In an attempt to understand and create linkages between ecosystem services and poverty alleviation, this Situation Analysis (SA) presents and analyses literature that has been published in academic books and journals that could help address this question.

In order to conceptualise the linkage between ecosystem services and poverty alleviation, emphasis has been placed on identifying ecosystems services. These services primarily include provisioning and regulating services. Additionally, it has also been important to identify the drivers of change that alter services. Drivers identified fall into two categories: direct and natural, and indirect and social. Keeping services and drivers in mind, the SA attempts to analyse various drivers change services that could affect poverty, which in the SA is defined through the concept of 'well-being'. This includes security, basic material for a good life, health, good social relations, and freedom of choice and action to influence decisions about services and well-being.

Five different ecosystems have been chosen to demonstrate the linkages between services, drivers, and poverty. In the mangrove swamp ecosystem section, focus is placed primarily on the impact of shrimp farming regulating and provisioning services, as well as women's economic well-being. Although women gain financially from shrimp fry collection, such activities have increased salinity and have affected agricultural land. The impact of drivers such as, floods and riverbank erosion, are explored in relation to inland water and floodplain ecosystem. Not only do these drivers destroy homes and livelihoods, but they also greatly affect human health. In an effort to control these drivers, the creation of embankments has had both negative and positive impacts, which are discussed. The SA also covers two types of wetland ecosystems, *haor* and *beel*. Such wetland areas provide vital provisioning and regulating services. These services are, however, under threat due to poor policies and overexploitation of natural resources. When analysing agro-ecosystems, the primary focus is placed on costs and opportunities that high yielding variety (HYV) crops bring. Case studies on HYV demonstrate the paradox of the need for Green Revolution

technologies to feed large numbers of people, yet at the same time how people must cope with soil and water degradation due to heavy use of chemical fertilizers and pesticides. Finally, an analysis of upland and lowland forest ecosystems highlight tensions between various actors and how poor policies have drastically changed ecosystems and the ability of ethnic minorities to access services.

The SA ends by identifying future areas of research taking account of the type of literature that has not been found through a bibliometric approach. It is anticipated that attempts will be made to fill in research gaps to create sound policies that both conserve services and help alleviate poverty.

1. Introduction

People are dependent upon the functioning of ecosystems to survive and improve their standards of living. The Millennium Ecosystem Assessment (MA 2005) defines ecosystems as 'a dynamic complex of plant, animal and microorganism communities and their nonliving environment interacting as a functional unit' (p.49). Ecosystem services provide provisioning services or goods, such as food, fuel, and fibre. People are also dependent upon regulating services such as climate regulation and disease control. There are also nonmaterial benefits that ecosystems provide, such as spiritual or aesthetic benefits. Alterations to the delivery of these goods and services can exacerbate poverty by degrading the level of well-being. The Millennium Ecosystem Assessment defines well-being in five ways: security (i.e. safety, secure access to resources, security from disaster), basic material for a good life (i.e. adequate livelihoods, sufficient nutritious food, shelter, access to goods), health (i.e. adequate food and nutrition, strength, feeling well, access to clean air and water), good social relations (i.e. social cohesion, mutual respect, ability to help others and express cultural value), and freedom of choice and action to influence decisions about services and well-being.

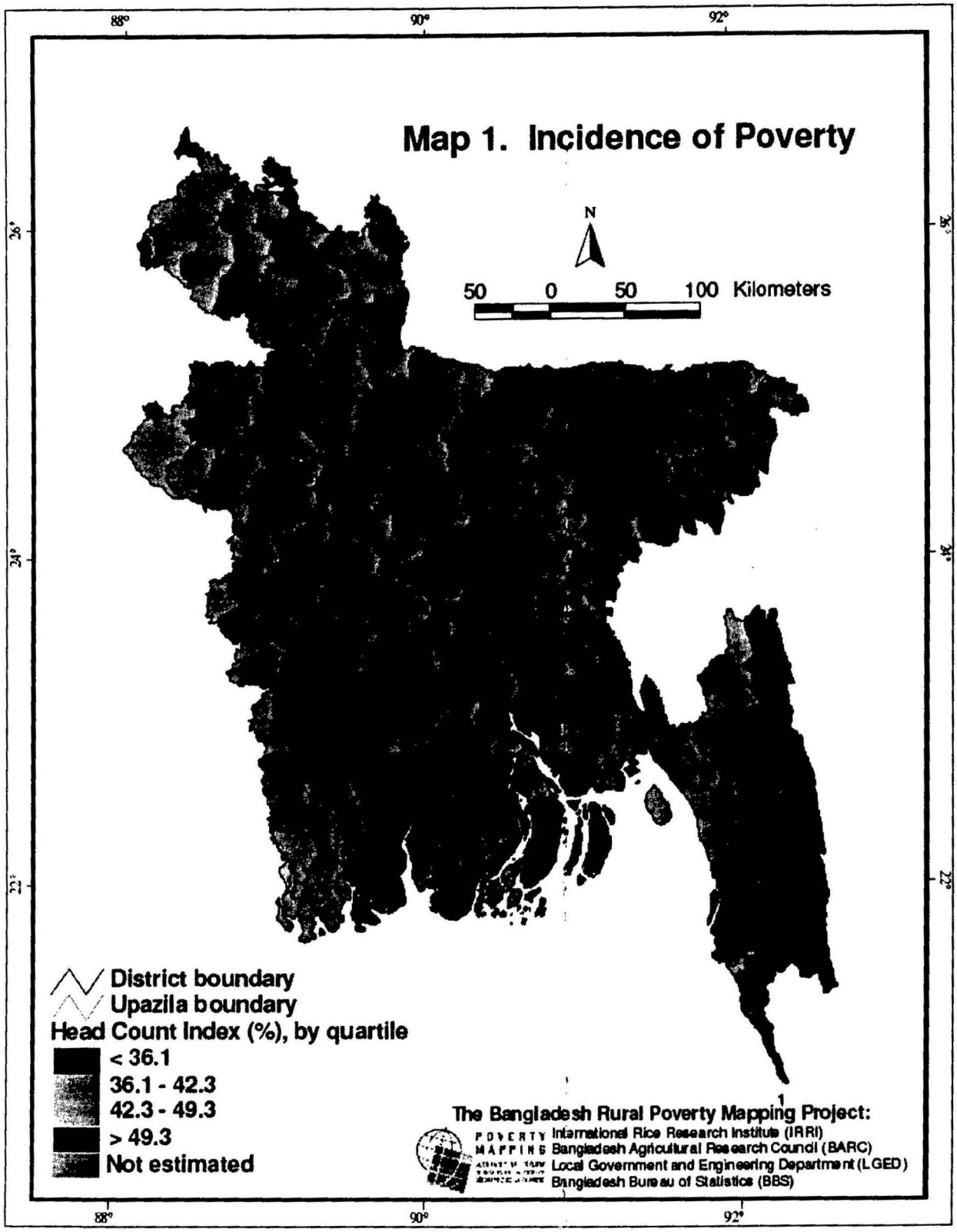
According to MA, globally 60% of all ecosystem services have been degraded or are used in an unsustainable manner affecting one or more components of well-being of many poor people. Degradation of ecosystem services is also taking place in South Asia where most poor people are dependent on a local resource base (Dasgupta 2007). The poor state of ecosystem services and its impact on poverty is major issue in South Asia. Although economic development is taking place in South Asia that can help alleviate poverty, natural resources are being used unsustainably. Degradation of services is due to several 'drivers' or factors that causes change to an aspect of an ecosystem. MA states that drivers can be natural and direct, which includes changes in local land use and cover; species introduction or removal; technology adaptation and use; external inputs; harvest and resource consumption; climate change; and natural, physical, and biological drivers. They can also be indirect and social, which includes demographic; economic; socio-political; science and technology; and cultural/religious aspects. Changes that these drivers bring not only altars ecosystems and their services, but can also worsen levels of poverty and human well-being.

This paper provides a conceptual framework in order to understand the linkages between ecosystem services and poverty alleviation, and how changes in ecosystems services affect poverty within the Bangladeshi context. This situation analysis focuses on landscapes, which can be defined as a land surface, including coastal and/or freshwater, that provide ecosystem services. Using MA's definition of ecosystem services and well-being, literature is reviewed about Bangladesh regarding these concepts. Due to time constraints, literature published primarily in the last 10 years has been reviewed. The situation analysis also includes information acquired from the Ecosystem Services and Poverty Alleviation Study in South Asia (ESPASSA) workshop that was held on 17 December 2007 at BRAC Centre in Dhaka, Bangladesh. Since most literature reviewed does not link ecosystem services with poverty in Bangladesh, an attempt is made to make this connection through analysis of the literature.

This paper is divided by ecosystems, which include mangrove swamps located on the coast, and terrestrial ecosystems, such as rivers, wetlands, agro-ecosystems, and upland and lowland forest ecosystems. This paper concludes with a section highlighting future areas of research to fill in gaps that could help better understand the linkage between ecosystems services and poverty alleviation.

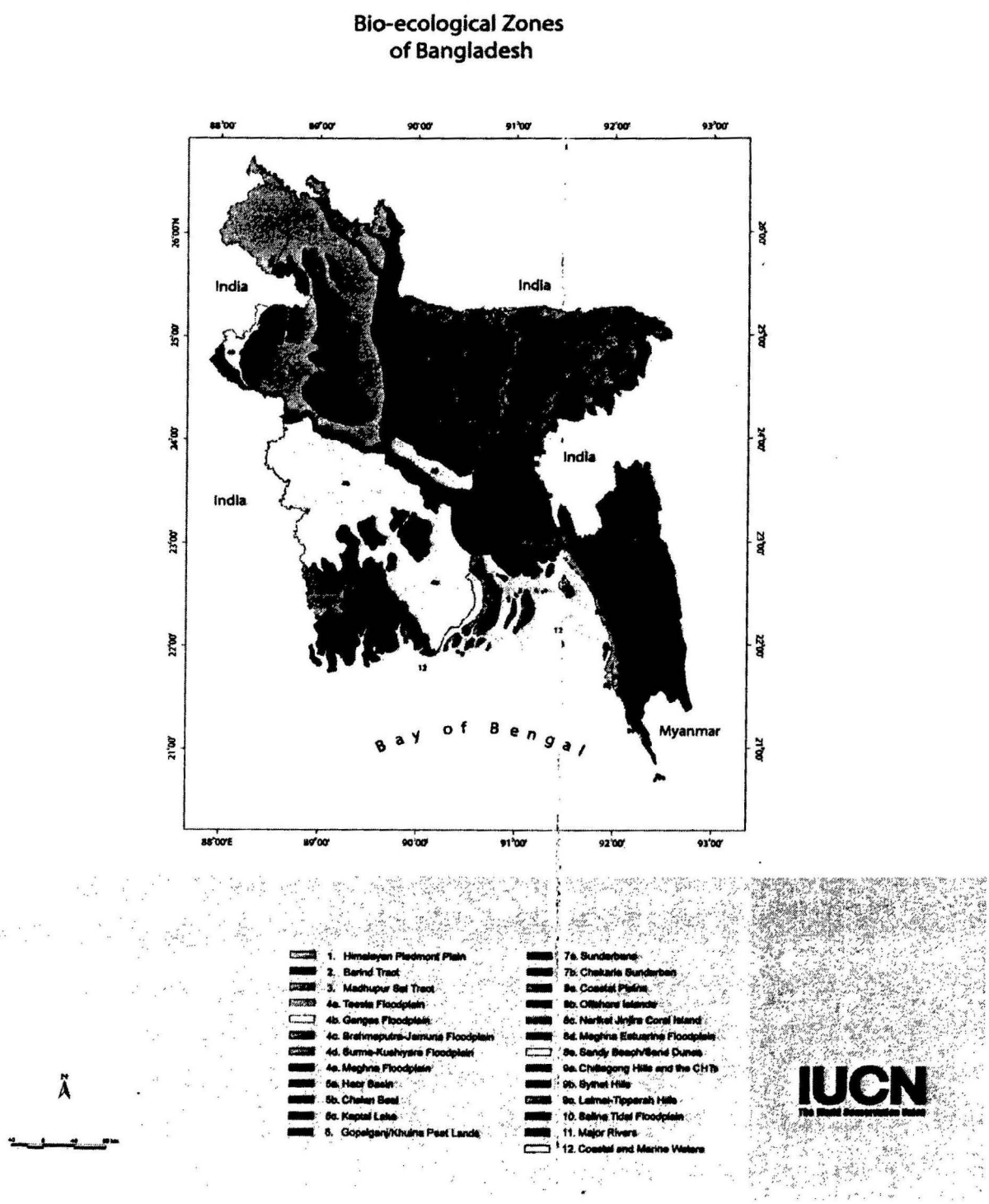
2. Conceptualising the Ecosystem Service-Poverty Linkages in Bangladesh

Ecosystem services play a critical role in Bangladesh with regards to human well-being. It has been estimated that in 2005, 153 million people in Bangladesh live within an area of 147,570 km^2 (UNDP 2007/2008). Almost 50% of people in Bangladesh live below the national poverty line (WRI 2005) and 75% of people live in rural areas (UNDP 2007/2008) that are directly dependent on various ecosystem services. Map 1 below demonstrates the various levels of poverty throughout Bangladesh. As this situation analysis will reveal, the ecosystem services that many poor people directly depend upon are being degraded in many parts of Bangladesh.


Map 1. Incidence of Poverty
88°
90°
92°
26°
24°
22°
N
50 0 50 100 Kilometers
District boundary
Upazila boundary
Head Count Index (%), by quartile
< 36.1
36.1 - 42.3
42.3 - 49.3
> 49.3
Not estimated
The Bangladesh Rural Poverty Mapping Project:
POVERTY MAPPING
International Rice Research Institute (IRRI)
Bangladesh Agricultural Research Council (BARC)
Local Government and Engineering Department (LGED)
Bangladesh Bureau of Statistics (BBS)

The drivers that can affect and worsen poverty levels will now be discussed based on particular ecosystems. Bangladesh is classified into 4 physiographic regions, which include eastern and northern frontier hilly regions; great table land; flood planes of the Ganges, the Brahmaputra and the Megna river system; and the delta (BBS 2005). These classifications are further divided into various bio-ecological zones as demonstrated in Map 2 below.

Map 2: Bio-ecological Zones of Bangladesh



Source: Nishat et al. 2002

In this situation analysis several bio-ecological zones will be covered, which are depicted in Map 2. These include Madhupur Sal Tract; Ganges, Brahmaputra-Jumuna Floodplains, Haor Basin, Chalan Beel, Sundarbans, Charkaria Sundabans, and Chittagong Hill Tracts. Table 1 below provides information on the type of ecosystems that will be discussed in the situation analysis and percentage of area it covers.

Table 1: Ecosystems and Area Covered

Location	Type of Landscape	Bio-Ecological Zone	% Area in Country	Land cover Categories
Coastal	Mangrove swamps	Sundarbans, Charkaria Sundabans	4%	4%
Terrestrial	Rivers: Permanent Rivers and Streams	Ganges, Brahmaputra-Jumuna Floodplains	4%	4%
	Wetlands	Haor Basin, Chalan Beel	30%	Estuaries and Swamps: 5% Shallow Lakes and Marshes: 1% Large Water storage reservoirs: 1% Small tanks and fish ponds: 1% Shrimp ponds: 1% Seasonally Flooded Floodplains: 21%
	Agro-ecosystems: Cropped		54%	Single cropped area = 19% Double cropped area = 28% Triple cropped area = 7%
	Upland Forest	Chittagong Hill Tracts	12%	11%
	Lowland Forests	Madhupur Sal Tract		1%

Source: BBS 2005

(a) Mangroves Swamps

The coastal areas of Bangladesh are one of the most populated areas. In 2001, it was reported that 35.1 million people live in coastal areas (Islam ed. 2004, a). The extent of poverty in coastal areas is relatively high compared to the rest of Bangladesh. It has been estimated that 25% are poor and 24% are extremely poor (Islam ed. 2004, a)[1]. Most people in coastal areas are agricultural labourers, small farmers, fishermen, and urban poor. One type of ecosystem in coastal areas is the mangrove swamp. Sundarban and Chakaria Sundarban are the largest mangrove swamps in Bangladesh that covers 4% land area. Sundarbans in southwest Bangladesh, offer various provisioning ecosystem services. These include wood, honey, bamboo, cane, herbs, and ornament plants. They also play a crucial role in maintaining the life cycle of economically important fish, shrimp, and crab species. They provide several regulating ecosystem services such as nutrient production, water purification, sediment trap, and shore stabilization. One estimate states that 1/3 of the country is dependent on the Sundarbans and 3.5 million people surrounding the area are directly or indirectly dependent on this ecosystem (Hoq 2007). Another study shows that 18% of Sundarban household depend on such resources (Islam ed 2004, a).

There are many people in the Sundarbans that depend on these resources as a source of income and economic well-being. There are 20,000 woodcutters (*bawalis*) and 7,000 seasonal honey collectors (*mouals*) who depend on the Sundarbans. The revenue generated from fuelwood, for instance, can be up to US$261,775 per year. Non-timber forest products (NTFP), such as food, fibres, resins, gum, and plant and animal products used for medicinal, cosmetic, and cultural purposes, are also extracted from the Sundarbans. In total, these products contribute Tk. 1.3 billion annually to the local economy (Billah 2003). NTFPs in particular not only help alleviate poverty, but they also contribute to food security and health of the poor who do not have alternative and easy access to food and health care.

The extent to which the ecosystem services the Sundarbans provide are, however, under threat. The Sundarbans, an area covering 601,700 hectares, have been described to be in an 'irreversible'

[1] This estimate suggests that 50% of poor people live in coastal areas of Bangladesh, which challenges WRI's estimate mentioned earlier that 50% of the *entire* country lives below the poverty line. Such differences in statistics are a major issue, which will be further discussed in this SA.

condition or 'sick' primarily due to over-extraction of resources (Islam ed. 2004). Demographic change has been a significant driver where over-harvesting beyond sustainable levels have occurred due to the combination of population pressure and the demand for resources. External inputs, such as development projects have also been key drivers in combination with poor resource management. For instance, timber needed for infrastructure purposes has led to the loss of forests as well as its value (Billah 2003; Islam ed. 2004) where the stumpage value for timber resources in the Sundarbans has fallen for all species. In-between 1991 and 1992, the stumpage value for Gewa in the Sundarbans, for instance, was Tk. 90,867,000. The reduction in stumpage value had fallen to Tk. 31,702,000 by 1995 and 1996 (Billah 2003). This has occurred due to a 'boom and bust' incidence where there was an initial high demand for poles required for rural electrification infrastructure, which then eventually led to fall in demand. The value placed on Gewa, is however, debatable. According to a participant from the government in the ESPASSA workshop, the value of Gewa is much higher. Nevertheless, the fall in value of provisioning services such as timber due to such development activities can negatively affect many poor people who use timber as house building material and for commercial purposes. This loss of timber stock and its stumpage value potentially diminishes their income earned and threatens their livelihoods.

The extent to which the southwest Sundarbans can economically benefit and provide food security is also dependent on natural drivers of change, such as cyclones, that change ecosystems. Cyclone Sidr that took place in November 2007 has not only destroyed 25% of the Sundarbans, which protects millions from tidal waves, but it has also completely destroyed 8-10% of mangrove forests. The cyclone also had devastating affects on people (Manik and Khan 2007). It killed thousands and ruined the shrimp-based economy that many poor people depended upon. It has been estimated that the shrimp farms in the cyclone-affected districts has suffered a loss of up to Tk 17.5 billion (Chowdhury 2007). Farmers will not be able to sell their shrimp because shrimp enclosures and hatcheries have been washed away. This incident demonstrates that cyclones as natural drivers can have drastic negative effects on economic well-being of people, and especially poor women who depend upon shrimp farming in coastal areas as their main source of income and nutrition.

Drivers, such as external factors in the form of infrastructure development have had a significant affect on regulating services the Sundarbans offer. Building of the Farakka Barrage has decreased the level of freshwater that reaches the Sundarbans from India and increased salinity in the coastal mangroves (Islam ed. 2004, a). Additionally, salinity is a result of illicit felling of trees and systematic over-exploitation of resources (Islam ed. 2004, a). Increased salinity can alter regulating services. This was especially evident in the Chakaria Sundarban in the Cox's Bazaar District, in southeast of the country where trees have disappeared due to high levels of salinity. In 1972, 19,390 acres were covered in forests and by 1995, the forest vanished (Gain 2002). Attempts were made to recreate the forest area through affc ion, however, this was not completely successful because people are more interested in shrimp farming. This land use change makes people in areas even more vulnerable to cyclones since coastal mangroves provided protection against storms. Although the ecosystem services provided by the coastal mangroves swamps were lost due to salinity, people took advantage of this ecosystem change and started to intensively farm shrimp in Chakaria Sundarban. This is just one example in the way in which people may adapt their livelihoods to accommodate changes in ecosystems.

The Chokoria Sundarbans is an area of 18,500 hectares and was declared a reserve forest in 1903 (BRAC 2008). Shrimp farming as an economic activity in the Chokoria Sundarbans has increased significantly. Between 1984 and 1985, the area under shrimp farming was 64,246ha. It rose to 203,071ha between 2003 and 2004 (BBS 2005). Shrimp export revenue has grown from US$ 4 million to US$ 360 million, making it 12 times more profitable than high yielding varieties of rice (Ali 2006). Shrimp farming can contribute between 8% and 10% of total export earning (Crow and Sultana 2002). Although 81.3% of non-poor are involved in shrimp farming, it is an activity that benefits 18% of poor people (Rahman and Hassan eds. 2006). Among those involved in aquaculture in mangrove swamps are women. Thirty percent of women in coastal areas are directly or indirectly involved in small-scale fisheries, which includes managing shrimp farms. Women also make up 50% of workers in shrimp processing centres (Karim et al. 2006). Among women, it is the poor who are primarily involved in shrimp fry collection. In addition to being a source of income, shrimp farming contributes to their food security and offers inexpensive source of protein required to maintain good health.

Shrimp farming has positive and negative impacts on coastal mangrove swamps ecosystems. In some cases, shrimp farming has changed to improve ecosystem services. For instance, shrimp farming can reduce insect attacks in rice fields, and fish faeces can contribute to organic mater that improves soil quality, which leads to increased rice production (Karim et al. 2006). In other cases, shrimp farming has had detrimental effects. Mass shrimp fry collection is a threat to the coastal ecosystem, causing damage to the nursery grounds of many species, newly planted mangroves, and reserve forests. Additionally, introduction of new species has also been detrimental to the mangrove forest ecosystem (Ali 2006; Hoq 2007). For instance many white fish are lost when collecting shrimp fry (BRAC 2008). Agro-ecosystems are being affected where coastal shrimp farming takes place in the same field/pond near a river where rice is also cultivated. Although shrimp farming and rice cultivation does not take place at the same time, encroachment of shrimp farming due to both demand for shrimp and population pressure has led to salt-water seepage, increasing salinity in soils and affecting soil fertility (Ali 2006). In some cases, influential shrimp entrepreneurs have forcibly rented land from small and marginal landowners to make fish ponds to cultivate shrimp. This has gradually led to salinisation of land, destruction of (social) forests, and depletion of livestock due to disappearance of grazing land and scarcity of fodder, such as rice straws (BRAC 2008). This has led to the fall in productivity of *aman* rice, for instance. Not only has productivity of this rice decreased between 1987 and 2000, but total unemployment in agriculture has also increased from 0% to 19% among males and from 46% to 55% among females in agriculture because of salinity caused by shrimp farming between 1975 and 1999 (Hoq 2007; Karim 2006). Therefore, changes in mangrove swamp ecosystems can make *aman* rice farmers vulnerable and threaten their income levels.

Changes in the ecosystem, such as increased salinity, especially affect poor women. Some poorer women cannot afford deep tube wells and have to travel up to 5km to collect drinking water since surface and groundwater become polluted due to salinity as a result of shrimp farming. They may also have to provide free labor in return for access to closer water sources (Crow and Sultana 2002). Such conditions affect their livelihoods because they are unable to find clean water for their homestead gardens and livestock (Karim 2006). Nutritional diversity also declines because saline water is unable to support vegetables and livestock for consumption. They may also be unable to gather livelihood resources from coastal forests, such as NTFPs as shrimp farms expand.

Therefore, changes in ecosystems greatly affect women's well-being through its impacts on their health, nutrition, workload, and livelihood strategies (Crow and Sultana 2002). Although formal and informal management mechanisms exist to sustain aquaculture in mangrove forests and minimize negative impacts, they have either been ignored or have collapsed over time (Crow and Sultana 2002).

(b) Inland Waters and Floodplains

Inland water bodies, such as rivers, are a source of freshwater upon which people and other biodiversity depend. Freshwater is essential for the functioning of many provisioning and regulating ecosystem services. Rivers provide water for production (irrigation, energy, fish[2]) and domestic use (drinking and sanitation). Freshwater is essential for human well-being. In Bangladesh there are in total 790 rivers that covers 1,094 million acres (BRAC 2008). Surface level freshwater is ample in Bangladesh as it is located at the confluence of Jamuna (Brahmaputra), Ganga, and Megna rivers. There are, however, several drivers of change such as poor quality of water, floods, river erosion, and waterlogging which negatively impacts agricultural production, creates disinvestments in land, loss of human settlement, lack of safe drinking water, and outbreak of water borne diseases (BRAC 2008). These drivers of change will be discussed in this section.

The quality of water in various parts of Bangladesh is degrading, which affects human well-being. Buriganga, Sitalakhya, and Naryanganj are the worst affected rivers of Bangladesh. Inland freshwater ecosystems are being changed due external inputs that include development activities, such as industrial production (Alauddin and Quiggin 2007). There are 6,000 large and medium industries and 24,000 small industries within various sectors such as chemicals, tanneries, paper and pulp mills, petrochemical and fertilizer complexes, and rubber factories (Islam ed. 2004; Zahid and Ahmed 2006 cited in Alauddin and Quiggin 2007). Run-offs from these industries, especially due to the lack of clean technologies contaminate inland water sources. It has been estimated that 85% of wastes are directed deposited into canals and rivers (BRAC 2008). For instance, in July 2007, Dhaka city produced 1.3 million cubic meters wastes per day but only disposed 0.12 mcm wastes per day through the Pagla waste treatment plant.

[2] Two million tons of fish are caught from rivers of Bangladesh per year (BRAC 2008)

The lack of sanitation technology is also a driver of change as it degrades water quality and changes ecosystem services when excessive human and animal waste enters rivers and lakes. Not only does this lower water quality that affects sources of income based on water resources, such as agriculture and fisheries, but it also affects the quality of health. Because the poor have limited access to health care services, their ability to recover from water borne diseases, due to poor water quality, is low. This significantly diminishes their health and well-being. Poor health in turn worsens economic poverty since the number of days one is able to work is reduced. This also leads the poor to purchase water, which sometimes costs more than in some developed countries. Since many cannot afford the high cost of water, they are forced to drink contaminated water (UNDP 2006). Therefore, the lack of appropriate technologies to minimize run offs and treat wastes, lowers both economic well-being and that related to health.

In addition to the indirect drivers mentioned above, there are several direct and natural drivers that change ecosystem services creating a negative impact on the poor in floodplain areas. Studies have shown, especially in Bangladesh, that drivers of change that alter water bodies and floodplain are seasonal flooding that takes place due to increase in rainfall, especially during the monsoon. The extent to which seasonal changes that create floods are the only significant driver that changes inland water and flood plains is, however, debatable. Many claim that the driver of change is deforestation in the Himalayas that loosens soil, which eventually creates sedimentation in rivers of Bangladesh as soil is washed down during the monsoon. Sedimentation then limits the ability of inland water bodies to absorb excess water. The correlation between deforestation in the Himalayas of Nepal and flooding in Bangladesh, however, has not been proven significant (Hofer and Messerli 2006). According to Hofer and Messerli, because deforestation has not occurred on a grand scale in Nepal, it is impossible to equate deforestation in Nepal to large scale flooding in Bangladesh. Flooding occurs due to various drivers that exacerbate the impact of flooding. These drivers include La Nina phenomenon, intense rainfall in Bangladesh, above danger flow of the three major rivers, and backwater effects in the Bay of Bengal, as was the case during the 1998 floods, which will be discussed shortly. Hofer and Messerli's work suggests that drivers of change that affect inland water and floodplain ecosystems are complex and debatable.

Although debates about drivers of change exist, the impact of the drivers can be catastrophic. As a flood-prone country, approximately 34% of land submerges under water between 5 and 7 months of the year. Flooding is an environmental issue that approximately 60% of households in Bangladesh face (Rahman and Hassan eds 2006). Although rivers that flood provide regulating ecosystem services, such as fertilization of fields, flushing out salts and toxins from soils and watercourses, and recharging reservoirs (Few 2003), floods as natural drivers can also be devastating. Floods as natural occurrence that alter ecosystem provisions, such as land availability and composition, tend to exacerbate poverty, and create land/homelessness through displacement, as it destroys natural resources the poor directly depend upon.

The flood in 1998 in Bangladesh, for example, is considered to be the worst in the 20th Century in terms of extent and duration. Approximately 50% of the country was submerged for 67 days (Hofer and Messerli 2006) due to flooding of Jamuna and Ganga rivers. It not only damaged 60% of the land and affected 30 million people (Hutton and Haque 2004), but it also caused 2.04 million metric tons of rice crop loss (Ninno et al. 2001). In a study by Ninno et al. (2001), a total of 24% of the anticipated agricultural production was lost. Even though the 1998 flood was devastating, markets were stable due to private sector imports of rice and wheat, as well as government supply. However, even though food was available, many poor people were unable to access them due to the loss of assets and income earning opportunities. It has been estimated that 55% of households lost assets worth Tk 6,936, which is equivalent to 16% of pre-flood total value of assets. Furthermore, day labourers were severely affected since their employment fell sharply from 19 days per month in 1997 to only 11 days per month from July to October 1998. This has also greatly affected human well-being in terms of increasing food insecurity. Ninno et al. state that 15.6% of flood-exposed households became food insecure. Many poor also do not have access to safety nets and resources to cope with natural calamities, which further leave them vulnerable after rivers have flooded (Few 2003). Additionally, human well-being was threatened as homes were damaged or destroyed. Therefore, floods, which are direct drivers of ecosystem change greatly challenges the poor whose well-being in terms of security and income become significantly worsened.

Floods also greatly affect health and people's well-being. The flood in 1998 had a significant toll on human health as access to safe water was reduced, and toilet facilities were destroyed or

damaged. In the 1998 flood, there were up to 400,000 cases of diarrhoea of which 500 ended in death (Hutton and Haque 2004). Another study states that 9.6% of individuals in the sample suffered from diarrhoea, and 4.7% were affected by respiratory illnesses (Ninno et al. 2001). Women and children were particularly affected. It has been estimated that 55% of children were stunted and 24% were wasted due to reduced access to food, the increased difficulties of providing proper care for children that came with disruptions in home life, and the greater exposure of children to contaminants. Women were also found to be energy deficient (Ninno et al. 2001). Most people whose health was affected by this epidemic were either 'poor' or 'very poor' with low levels of education. Floods as natural drivers of change can greatly affect the poor and deteriorate both their health and ability to recover because of their lack of assets (Kunii et al. 2002).

People have, however, developed sophisticated ways of coping and adjusting to life in floodplains that minimize the impact of their well-being. Hofer and Messeri identify that coping mechanisms can include raising their house courtyard to a certain height during the monsoon to prevent damage to their physical assets and loss of lives. People have also been planting flood-resistant plants, such as deep-water *aman* rice, jute, and sugarcane. Since flooding is part of life for many in rural Bangladesh, women, for instance, prepare portable stoves and keep firewood in stock during the wet season. Rafts from banana trees are also made for transport when roads are submerged.

River bank erosion is also a serious problem in Bangladesh. Interestingly, many rural people consider riverbank erosion a greater problem than floods, with high repercussion on well-being. Although floods may temporarily cause severe damages as discussed above, people are able to still use the land in flood plains after floods have receded. However, lateral riverbank erosion is a more constant threat to well-being because they erode living spaces and existence base of entire families (Hofer and Messerli 2006). It has been estimated that 2,000km to 3,000km of riverbanks annually experience erosion in Bangladesh (Hutton and Haque 2004) and 31% of households in Bangladesh are susceptible to riverbank erosion (Rahman and Hassan eds 2006). River bank erosion is due to extraction of sand from riverbanks to construct buildings (BRAC 2008). However, in most cases, riverbank erosion is a natural phenomenon.

River bank erosion primarily affects the poor, small landowners who live near the riverbank. It affects their well-being in terms of safety and shelter, as well as sources of livelihood (Brouwer et al. 2006). However, the impact is severest among the landless and impoverished farmers. Although some poor small landholders can rely on existing tenancy structures and resume their livelihoods, widespread erosion not only destroy their homes and land, but also their source of income and food on a large scale (Hutton and Haque 2004). Hutton and Haque demonstrates that 62% of displacees from river bank erosion, which include a large proportion of the poor who live along river banks and earn US$1-2 per day, do not have enough financial resource to buy food. Additionally, Hutton and Haque's work suggests that those who have been displaced due to river bank erosion are also affected by mental stress because of social fragmentation and difficulties in adjusting to urban areas where they migrate to, affecting their mental well-being. Women's well-being is particularly affected when they are displaced as they become more secluded, and subordinate as social pressures to wear purdha increases in their new place of refuge. Displacement in urban areas among women also causes purposelessness where in rural areas they play a critical role in household economics. Although it can be suggested that floods and river bank erosion leads to *char* formation, which is emerging land or islands in the middle of braided rivers creating land for re-settlement and agricultural production, these lands are not enough to improve peoples' well-being. Living and working conditions in *chars* are difficult since they are not connected to the mainland and are prone to acute erosion and flooding, hence leaving people vulnerable (BBS 2005).

In addition to natural drivers of change with regards to rivers, development projects as external drivers have also significantly contributed to changes in ecosystem services. For instance, the Farakka Barrage constructed by India in 1975 to divert water from the Ganges has led to droughts in lower Ganges channels within Bangladesh, as well as siltation and salinity. Such changes in regulating services have greatly affected the well-being of many people in Bangladesh due to significant losses in agriculture, fisheries, forestry, industry, navigation, and water supply amounting to US$3 billion (Rahman and Hassan eds 2006). Development planners have, however, tried to minimize the impact of floods and riverbank erosion on floodplains by creating the Flood Action Plan (FAP), 1989-1995. FAP was a consorted effort by various development organizations such as the World Bank, United Nations Development Programme, and USAID, along with the

government of Bangladesh (Government of Bangladesh 1995). The FAP suggested policies to promote physical solutions to flooding and riverbank erosion by promoting embankments. It also called for understanding the environmental impact that embankments could have, as well as ways in which to improve relief efforts, flood-proof villages, and share data. Policy documents such as FAP, however, are marked with controversy with regards to the feasibility of embankment projects. On the one hand, in some embankment areas they provide shelter during floods, and access to roads so that transportation and trade do not become disrupted during the monsoon. On the other hand, embankments can create a false sense of security since they can be breached and eroded leading to a sudden onrush of water that destroys infrastructure, homes and crops (Hofer and Messerli 2006). Because people feel secure with embankments, the costs of breached or eroded embankments are higher since people are not prepared for embankment failure. The question remains whether only technological feats, such as embankments, are adequate enough or whether a 'holistic' approach is the solution is still debatable.

(c) Wetlands: *Haor* and *Beel*

Wetlands are one of the most prevalent ecosystems in Bangladesh covering 30% of the country's land area. According to the first Ramsar Convention, a wetland consists of 'areas of marsh, fen, peatland, or wasteland, natural or artificial, permanent or topography, with water which is static or flowing, fresh, brackish or salt including areas of marine water' (Ramsar Convention Bureau cited in Billah 2004). This includes rivers, streams, lakes, rice fields, shrimp farms, inland flooded forests, swamps and coastal mangroves. Wetlands offer numerous regulating services. Some of the provisioning services that can be found in wetlands are water (for rice cultivation and aquaculture), grazing land, food, fiber, and medicines. Regulating functions include providing nutrients through floods, natural purification of water, and recharging of groundwater (Ratner et al. 2004). Additionally, wetlands help to store flood water, stabilize shoreline, reduce soil erosion, remove or retain nutrients, and provide food for plants and animals. They offer water transportation, preserve biodiversity, and stabilize micro-climates (Billah 2003). They are ecologically, economically, and culturally significant.

Within wetlands of Bangladesh are unique areas of backwater swamps that significantly contribute to people's well-being. One type of backwater swamp is known as *haor* or bowl-shaped depressions located between the natural levees of rivers. Hakaluki *haor*, which is one of the largest in Bangladesh, provides ecosystem services to 190,000 people. Using bio-economic models, the World Conservation Union (IUCN) has estimated that the economic value of Hakaluki Haor is Tk 585.75 per year (IUCN 2006). Similarly, USAID (2007) has also estimated the economic value of Hail Haor to amount to Tk 36,990/area and Tk 454,924,600 in total returns. The provisioning resources that can be found in such *haors* include plants, fish, birds and other wildlife. People have also practiced indigenous methods of floating cultivation or *dhap* (also referred to as hydroponics) in wetland areas for centuries, which have provided them resources such as vegetables (Islam and Atkins 2007). Cultivation on *dhap* can lead farmers to earn up to Tk. 16,000 in one season (Islam et al. 2000). Fish (260 species) and migratory birds especially contribute to well-being in relation to health as they provide nutrition and economic well-being since many people are involved in fisheries. It has been estimated that 80% of people in rural Bangladesh depend on wetlands areas, such as *haors*, for fish and other aquatic resources (USAID 2007).

Provisioning resources, such as fish, are, however, being depleted due to several reasons. The drivers of change include overharvesting of fish, loss of habitat and connectivity, paving of roads, and constructing flood embankment and water control structures that block fish migration and cause rivers to 'die'. These drivers of change also increases drainage congestion, reduces surface water due to irrigation of rice field during winter, increases water pollution due to dumping of industrial waste, while deforestation and poor land management that causes siltation and filling up of wetlands (USAID 2007). Regulating services, such as flood control and storm surge protection, have also degraded wetlands due to the building of transportation and communication infrastructure that cover up wetlands (Islam et al. 2000). Additionally, poor property rights prevent poor people who depend on common property resources from accessing natural resources from *haors* since the government controls many wetland areas. The government only provides short-term leases to people, which encourage maximum exploitation while excluding poor people from use of common pool resources (Islam et al. 2000). Due to the various reasons why fish stocks have been depleted, it has been estimated that consumption of fish has fallen by 11% in recent years where 40% of fish are threatened (USAID 2007). In order to sustain economic well-being of

people, some development interventions are helping to improve such situations. Development projects such as MACH funded by USAID have the potential to minimize overfishing by encouraging a community based natural resource management approach where a community is formed to address the negative impacts on ecosystems services while ensuring that their livelihood is sustained from fishing activities. This is being initiated by participatory planning process where rules and norms to manage aquatic resources through sanctuaries have been established (USAID 2007). There are also other non-governmental organization - led community based projects in various other *haor* areas (Rahman and Hassan eds. 2006).

Although development projects may have good intension, in some cases, they have degraded ecosystems due to development projects that act as negative drivers of change. This has taken place in Beel Dakatia affecting extremely poor people (Rahman 1995). A *beel* is defined as depressions and lakes that hold water permanently or seasonally in wetland areas. For instance, in order to prevent seawater during storms and floods from entering agricultural fields, which are adjacent to *beel* areas, development projects have constructed polders to drain the seawater. Such development projects have, however, been more harmful than helpful. Many polders blocked tidal flow of rivers and created siltation and waterlogging, which eventually did not allow seawater to be drained (Choudhury et al. 2004). Ecosystem changes due to salinisation and waterlooging include loss of trees with economic value, land productivity, livestock, kitchen gardening, fisheries, biodiversity, and clean drinking water, which are all provisioning services found in agro-ecosystems. This change has led to an 'ecological crisis' and loss in livelihoods for thousands of people (Rahman 1995). This has also forced many people to migrate away and/or take up various occupations to support their families affecting their financial and social well-being, especially with the loss of social networks. Additionally, people's health has also been affected where 87% of people in the area suffered from diarrhea (Rahman 1995).

(d) Agro-ecosystems

Agriculture contributes to 23.5% of the GDP in Bangladesh and 2/3 of the population depend on agriculture as a major source of income (BBS 2005). It is the largest (manmade) ecosystem in Bangladesh covering 54% of the land. Bangladesh has the highest percentage (70%) of land under agriculture in South Asia and highest degree of intensification of agriculture (Alauddin and Quiggin 2007). However, 50% of people are considered landless farmers and 80% have less than 2.5 acres of land. One of the key drivers of change in agro-ecosystems is population growth, which is growing at the rate of 2.2% per year (UNDP 2007/2008). Although the rate of population growth has declined from 3% per year at independence in 1971 to 1.4% per year at present, the absolute number is still increasing by 2.0 million every year. This requires the production of an additional 0.5 million tons of rice every year (BRAC 2008). This led to the adoption of Green Revolution technology in Bangladesh, which included cultivating modern high yielding variety (HYV) crops.

Currently 61% of rice production in Bangladesh is allocated to modern varieties (Baffes and Gautum 2001 cited in Rahman (b) 2003). HYV has significantly increased food production while minimizing the area of land required for agriculture. For instance, Bangladesh was able to increase its rice production from 15,043,000 tons in 1965 to 37,383,000 tons in 2003. High production level has ensured stable food grain prices, which has reduced the incidence of poverty. For example, incidence of poverty in Bangladesh fell from 41.5% in 1990 to 31.9% in 2000 due to production of HYV (Alauddin and Quiggin 2007).

Some studies consider the impact of HYV cultivation on levels of poverty. A study by Hossain (unpublished) examines the impact of HYV on various income groups and gender (i.e. very poor, poor, and non-poor men and women). His study demonstrates that, overall, yield and income have increased regardless of the various levels of poverty and gender. However, because HYV crops require a certain level of inputs such as fertilizers and pesticides, the price of agricultural inputs have also increased for most groups. On the one hand, this has lowered most farmers' economic vulnerability across all economic positions and increased food security in most cases except for one female and poor group. On the other hand, farmers will face greater expenses due to increases in agricultural inputs, which questions the benefits of HYV crops and the adoption of

Green Revolution in Bangladesh. Therefore, Hossain's study suggests that the benefits of the Green Revolution in Bangladesh are debatable.

National economic plans which act as drivers, has promoted the adoption of HYV technologies, which has led to significant decline in soil quality across all agro-ecological zones in Bangladesh. Cultivation of HYV crops resulted in constrained penetration of crop roots, reduced water infiltration, and increased surface runoff in many parts of Bangladesh (Rasul and Thapa 2004). Over time, production of HYV crops have fallen and this has primarily impacted economic well-being of farmers. Real income among modern rice farmers has decreased by 18% (Rahman 2003, b). Although Rahman (b) states that the reason behind this fall is the stagnant output price and rising costs of production coupled with declining productivity, it could be suggested that the fall in income is also related to the degradation of ecosystem services, that underpins agricultural production.

In addition to declines in soil quality, HYV technologies, which require fertilizers and pesticides, have also altered ecosystems services and human well-being. Policies that promoted subsidization of chemical fertilizers and pesticides have contributed to the deterioration of the agro-ecosystem. The government maintained the price of urea at a very low level, and as a result, the farmers use too much urea and too little other fertilizers (BRAC 2008). The high use of fertilizer as external inputs into the ecosystem and direct drivers of change has contributed to the deterioration of soil fertility. Small farmers especially use fertilizers for agricultural intensification since they do not have access to large agricultural land. Excessive use, however, contributes to soil degradation and water pollution. Between 2003 and 2004, 3,364,100 tons of chemical fertilizers were used in Bangladesh (BBS 2005). Even more pesticides were used in Bangladesh. In 2004, 22,116,000 ton/kl of pesticides were used (BBS 2005). According to Rahman and Parkinson (2007), more than 65% of the total agricultural land in Bangladesh is suffering from declining soil fertility and about 85% of net area suitable for cultivation has an organic matter below the minimum requirement due to excessive use of fertilizers. The loss of agricultural land and supporting services, such as soil formation, can directly affect the poor whose main source of income comes from agricultural activities (ODI 2006). Although intensified land use provides essential source of natural resources and income for poor or small farmers who do not have access to other income earning

opportunities, intense use of fertilizers and pesticides can lead to loss of vegetation, depletion of soil, and destruction of habitats (Dasmann 1988 cited in Niazi 2003) that all contribute to deterioration of regulating services, and thereby the reduction in economic well-being of farmers.

Hossain's study produces similar findings compared to the studies reviewed on the impact of HYV on the environment but disaggregates the information based on different levels of poverty and gender. His work suggests that all groups in the study, regardless of gender and economic status have experienced loss in soil fertility due to excessive use of pesticides and fertilizers. As a result of pesticide and fertilizer use, the level of biodiversity has also fallen in terms of quantity of aquatic and land plants and animals. With an increase in the use of HYV crops, pests and diseases have also increased. The detrimental effect on the environment has increased vulnerability to attacks by pests and diseases, affecting the health of farmers in all economic groups. Despite the negative consequences, farmers are not willing to stop producing through Green Revolution technologies because financial returns are higher from cultivating HYV crops, especially since existing policies do not require farmers to pay for external costs, such as health hazards and water pollution caused by Green Revolution technologies (Rasul and Thapa 2004).

Cultivation of HYV crops have negatively affected water tables due to the increase in groundwater use to cultivate HYV crops (and diversion of inland water as discussed in the previous section). No other country in the world depends on groundwater use to the extent that Bangladesh does. It is the most important source of water for domestic, industrial, and irrigation supplies (Islam ed. 2004). The decrease in the water table has not only reduced biodiversity due to drought, especially in the northern Rajshahi Division and western Khulna Division, but has also exacerbated impacts on the environment and livelihoods of people living in these areas. It has been reported that 30% of cultivable land has been affected by drought (Alauddin and Quiggin 2007). However, this finding does not apply in all cases. Hossain's study demonstrates that although cultivation of HYV increased vulnerability to drought, this was not the case for a very poor female ground and a non-poor female group because irrigation systems were installed.

Refreshing groundwater supply has been especially difficult because flood mitigation work and the use of levy banks to protect against flooding have reduced the spread of floodwater to replenish

groundwater sources. Although Bangladesh has more surface water than many countries in the world, farmers still rely on groundwater because it is easier to access and control for irrigation. However, depletion of groundwater has led to a major environmental health issue in Bangladesh, namely arsenic poisoning. Since 1993, when high arsenic concentration was discovered, 20 million people in Bangladesh have been affected by arsenic poisoning and 70 million are at risk. The poor are especially vulnerable to arsenic poisoning because they are not able to buy expensive tube wells that dig deep into the ground. It has been estimated that 74% of poor households use arsenic contaminated water (Rahman and Hassan eds 2006). Poor women in particular are more vulnerable than men to this public health crisis because they are nutrition-poor and unable to fight the poisoning. In addition to bodily harm, women who have been affected by arsenic poisoning face social repercussions since they become 'unmarriageable' (Crow and Sultana 2002). Additionally, chemical run-off from fertilizers has also contaminated groundwater by leaching nitrate, which causes methemoglobinemia or 'blue baby syndrome' (Rasul and Thapa 2004). Therefore, external inputs, such as excessive use of fertilizers and pesticides, not only alters groundwater quality, but seriously threatens the well-being of farmers and especially women with regards to their physical and mental well-being, in addition to threatening their source of income based on agriculture in agro-ecosystems.

There are examples, however, where farmers are adopting more environmentally sensitive farming methods compared to methods involved in HYV cultivation. Many farmers in villages, such as Pyraban, rely on compost for fertilizer, for instance, and not chemical fertilizers that can cause environmental damage. This practice is especially beneficial as it saves farmers money since price of chemical fertilizer has increased in recent years (BRAC 2008). However, the extent to which using more environmentally friendly cultivation practices provides more food and income security is unclear.

(e) Upland and Lowland Forest Ecosystems

Upland and lowland forests make up 12% of all forest areas in Bangladesh. The total land area under forests in Bangladesh according to government statistics is 2.52 million hectares (BRAC 2008). Most of the public forests in upland areas (600m to 1,052m) are in the Chittagong Hill

Tracks (CHT). Provisioning resources such as timber and bamboo are extremely important economic resources in CHT. The GDP from such forest resources between 2003 and 2004 amounted to Tk 56,202,000 (BBS 2005). External inputs such as development activities act as direct drivers of change in CHT. For instance, the Kaptai Dam in Rangamati District has created the Kaptai Lake, which is one of the largest man-made lakes in the world. Although Kaptai Lake has changed the local ecosystem to create a 'lake economy' and provide opportunities for aquaculture, irrigation, and generation of electricity, it has also had negative repercussions on the local population. It has displaced 10,000 tribal families, and 8,000 families that practiced slash and burn cultivation as well as other poor people (Rahman and Hassan eds 2006).

The establishment of plantations as development activities has also had negative repercussions. Plantations have created monocultures, which have degraded forest soils to a significant extent (Adnan 2004). Deforestation to create plantations has also been another reasons why 75% of upland forest areas are susceptible to soil erosion (BBS 2005). Although most literature on upland forest plantations does not directly reflect on poverty, some work implies that the creation of plantations has further marginalized ethnic minorities from the forests they depend upon, worsening their level of poverty and economic well-being (Gain 2002). The Khyang, for example, have been one of the most affected ethnic minority communities since expansion of government land has limited their access to ecosystem services (Rahman and Hassan eds 2006) and plantations have limited availability of forest resources (Adnan 2004). Women from such ethnic communities in particular are the worst victims of forest degradation and government expansion, especially because they are the ones who gather forest resources for their families for subsistence use and for commercial purposes. Because plantations have degraded soil quality, forest resources the Khyang depend upon are diminishing. This requires the Khyang women to travel further to collect resources, which increases their time and burden of work since access to forests has declined due to nationalization (Rahman and Hassan eds 2006). The Khyang example demonstrates how development activities can negatively impact economic well-being of marginalized groups who have few assets to begin with, to contribute to their well-being.

Local land use change is also a key driver of change in CHT. Studies have shown that conversion of forest land into agricultural fields due to decreasing availability of agriculture land, and increases

in population growth[3] and poverty have led to the loss of soil nutrients especially since soil conservation methods have not been used (Iftekhar and Hoque 2005; Islam and Weil 2000). Studies also demonstrate that *jhum* or slash and burn cultivation practiced by 'tribal' communities in CHT instead of agroforestry, is also a major reason why upland forests have degraded (Adnan 2004; Rasul and Thapa 2006; Rasul et al. 2004, Salam et al. 1999; Thapa and Rasul 2006). Although *jhum* cultivation is not an environmentally damaging practice per se because it allows for long fallow periods and regeneration of soil and vegetation, population pressures and demand for agriculture products has reduced the amount of time land lays fallow. Furthermore, because *jhum* cultivators, such as the ethnic Khyang, do not have secure land tenure due to state nationalization of land, they are unwilling to switch to more environmentally and economically better agro-forestry practices. Poor, small landholders also lack of access to credit to start up agroforestry production. Furthermore, the counter insurgency movement in CHT and conflict has left ethnic minorities landless since their land has been taken over by over by Bengalis. This has left many minorities devoid of assets on which they depend upon for economic well-being (Adnan 2004). Therefore, poor land policies, that leaves the Khyang land-insecure, in combination with poverty, create a land use system that degrades regulating services such as soil formation and regeneration. This in turn jeopardizes the livelihoods and economic well-being of 'tribal' communities who tend to be poor and with fewer assets.

Lowland forests, such as Modhupur Tracts, share many similarities with CHT. Madhupur Forests are *sal (Shorea Robusta)* forest that offers many provisioning services in addition to hardwood used for house-building. These provisioning services mostly include non-timber forests products, such as sungrass found in the undergrowth, which is used to make roofs. Root foods, wild fruits and berries offer supplementary food to local population living in and around the forests. Additionally, medicinal plants found in such forests offer immediate treatment to various health problems (Islam 2007, b). Although lowlands forests, such as Modhupur, offer several provisioning services, they have disappeared due to heavy deforestation. The disappearance of *sal* forests can also be attributed to the introduction of social forestry and plantations. The introduction of pineapple and rubber plantations and other foreign species in the name of 'social forestry' has

[3] Population growth includes both growth in the area and also land encroachers who enter CHT from other parts of the country to search for employment (Iftekhar and Hoque 2005).

depleted forest provisioning resources and forest areas to 10% (Gain 2002; Islam 2007). These social forestry schemes were advocated by the government, with the aid of major development organizations in order to take control from local people who are viewed as 'illegal encroachers' (Islam 2007). This is, however, debatable as government sources proclaim social forestry to have had positive economic effects due to large-scale production of crops while others state that social forestry has been a disaster because natural forests provide more ecosystem services, especially to the poor (BRAC 2008). This situation creates vulnerability among women and their families, as well as confrontation between ethnic minorities and plantation owners (Gain 2002; Islam 2007, b). Ethnic minorities, such as Mandis and Garos, have also not been able to access *sal* forest resources they depend upon because land conversion to plantations has reduced their access. They lost their rights to forests when Modhupur became a reserved forest in 1955 and national park in 1961 in the name of conservation (Islam 2007). This has especially affected the well-being of women since their access to forest resources have been minimized, which in turn increases their inability to access food and medicines for their families.

Thus far, this situational analysis has provided an overview of the drivers of change with regards to mangrove swamps, inland waters and floodplains, wetlands, agro-ecosystems, and upland and lowland forest ecosystems. Table 2 below demonstrates the linkages between ecosystem services, goods, and types of ecosystems. The check marks indicate linkages that have been discussed in this situation analysis in relation to poverty alleviation. The cells that are shaded in gray indicate a possible linkage although no evidence based on publications has been found.

Table 2: Goods, Services, and Ecosystems

Ecosystem Service Component	Goods or Services	Mangrove Swamps	Rivers	Wetlands	Agro-ecosystems	Upland and Lowland Forests
Sustaining Services	Oxygen Production					
	Nutrient Cycling	√	√	√		
	Primary Production					
	Habitat Provision	√	√	√	√	√
	Water Cycling		√	√		
	Carbon Sequestration					
	Pollination					
Goods	Food and Drink	√	√	√	√	√
	Fibre/Construction	√		√		√
	Medicinal/Cosmetic Resources	√		√		√
	Ornamental Products	√				
	Renewable Energy Products	√	√			
	Genetic Resources	√				
	Filtration of Air Pollution					
	Detoxification of water and sediment	√	√	√		
Regulating Services	Local Climate Regulation			√		
	Erosion Control			√		
	Flood Risk Mitigation	√				
	Storm Protection	√				
	Maintenance of surface water stores	√		√		
	Groundwater Replenishment		√	√		
	Crop Pest Regulation	√				
	Human Disease Regulation					
	Shore Stabilization			√		
	Sediment Trap	√				
Cultural Services	Paleo-environmental Records					
	Archaeological Preservation					
	Recreation and Ecotourism					
	Physical health and well being					
	Spiritual and religious values					

3. Areas of Future Research

In this literature review, an attempt has been made to link ecosystem services and poverty primarily based on publications between 1997 and 2007, within the Bangladeshi context. Considering this linkage is not made explicitly in most cases, it suggests that a greater emphasis needs to be placed on explicitly understanding not only how the two concepts link, but also how the various definitions and dimensions of poverty connect to the various components of an ecosystem in a much more direct manner. Table 2 above suggests that there is also room for research to examine how ecosystem services and goods link human needs as indicated by the grey cells. Using a basic bibliometric approach Table 3 below demonstrates additional research gaps with regards to understanding direct or natural drivers of change that affect ecosystem services and poverty.

Table 3 shows that major gaps exist on examining the introduction of species. This is based on the fact that only one publication has been cited on mangrove swamps, and one publication on upland and lowland forest ecosystems in this situation analysis review. Other areas where greater attention should be paid are external inputs (particularly in wetland areas) and impact of natural drivers on mangrove swamps. Table 4 below demonstrates gaps in research with regards to indirect or social drivers of change.

Table 4 shows that there are gaps in understanding indirect or social drivers in many cases. No publications were cited on cultural/religious and indirect science and technology drivers, and only 1 publication was cited under socio-political drivers. These are areas that deserve greater attention. Table 4 also reveals that great emphasis should be placed on understand upland and lowland forests ecosystems in relation to how demographic changes affects ecosystem services and human well-being considering only one article has been cited.

The ESPASSA workshop also identified several areas for future research, which are listed below in Table 5.

Table 3: Articles Relating to Direct / Natural Ecosystem Drivers

Direct / Natural Driver	Ecosystem	Author	Total Number of Publications
Local land use and cover and harvest and resource consumption (i.e. shrimp, NTFP, timber, agricultural products)	(a) Mangrove Swamps	Ali (2006), Billah (2003), Hoq (2007), Islam ed. (2004)	4
	(b) Upland and Lowland Forests	Adnan 2004, Gain (2002), Iftekhar and Hoque (2005), Islam and Weil (2000), Rasul and Thapa (2006), Rasul et al. (2004), Salem et al. (1999), Thapa and Rasul (2006)	8
Species introduction or removal	(a) Mangrove Swamps	Ali (2006)	1
	(b) Upland and Lowland Forests	Gain (2002)	1
Technology adaptation and use (i.e. Green Revolution)	Rivers	Alauddin and Quiggin (2007), Baffes and Gautum (2001), Dasmann (1988), Garcia and Altieri (2005), Hofer and Messerli (2006), Niazi (2003), Hossain (unpublished), Peterson (1987), Prescott-Allen (2001), Rahman (1995, b), Rahman (2003, c), Rahman and Parkinson (2007), Rasul and Thapa (2004)	13
External inputs (i.e. development projects, industries)	(a) Mangrove Swamps	Billah (2003), Islam ed. (2004)	2
	(b) Rivers	Choudhury et al. (2004), Hofer and Messerli (2006), Islam ed. (2004), Rahman (1995,a), Rahman and Hassan eds. (2006), Zahid and Ahmed (2006)	6
	(c) Wetlands	USAID (2007)	1
	(c) Upland and Lowland Forests	Adnan 2004, Gain (2002)	2
Natural, physical, or biological (i.e. cyclones, floods)	(a) Mangrove Swamps	Chowdhury (2007), Manik and Khan (2007)	2
	(b) Rivers	Few (2003), Hofer and Messerli (2006), Hutton and Haque (2004), Kunii et al. (2002) , Ninno et al. (2001), Rahman and Hassan eds. (2006)	5

Table 4: Articles Relating to Indirect / Social Ecosystem Drivers

Indirect / Social	Ecosystem	Author	Number of Publications
Demographic	(a) Upland and Lowland Forests	Iftekhar and Hoque (2005)	1
	(b) Mangrove Swamps	Ali (2006), Billah (2003), Islam ed. (2004)	3
Economic (general)		Billah (2003), Crow and Sultana (2002), Hoq (2007), Islam ed. (2004), Karim et al. (2004)	5
Socio-political	Wetlands	Islam et al. (2000)	1
Science and technology			0
Cultural / Religious			0

Table 5: Additional Knowledge Gaps

Ecosystem	Knowledge Gaps
Mangrove Swamps	Statistics about forest area and ecological accounting cannot be agreed upon. The type of statistics that should be used needs to be examined.
Agro-ecosystems	The potentials of using hydroponics to reduce impact on land for food production
	Potentials of crop diversification to enhance food security
	Impact of changing socio-economic conditions of marginal farmers who own 10 decimals of land and their natural resources over time its impact on the supply of food and how they indirectly affect poor people through prices
	Impact of rising prices on the supply of food and how they indirectly affect poor people
	How farmers' rights, and genetically modified organisms may reduce poverty.
Upland and Lowland Forests	The question of whether destruction of natural forests to implement social forestry and plantations (of foreign species) for larger production will alleviate poverty should be examined. It should also be investigated if natural forests provide greater ecosystem services compared to social forestry.
	There is a need to assess the political economy of Chittagong Hill Tracts
In General	Need scientific understanding of various ecosystem services, particularly focusing on changes in chemical composition, sediment loads, and microclimate information to know what should be conserved and used for poverty alleviation.
	Research is required on the political economy of natural resources to understand markets and potential for employment generation
	Impact of biofeuls on food prices and poverty as well as the state of energy reserves in relation to poverty alleviation.

In addition to research gaps identified based in Tables 4, 5, and 6, there are additional research gaps that should be emphasized. For instance, most of the literature reviewed depicts a doomsday

scenario where ecosystem degradation not only leads to poverty, but that the poor are trapped in a vicious cycle where they degrade the ecosystem services they depend upon because of the lack of alternatives. In general, the literature reviewed suggests that due to human activities, the carrying capacity of ecosystems is lost. This scenario is, however, too simplistic. The literature reviewed does not address issues of ecosystem resilience whereby certain ecosystems have the ability to regenerate. Placing an emphasis on understanding ecological resilience may help fill the gap on species introduction and removal. The doomsday scenario that the literature review depicts also suggests that people are incapable and powerless in terms of protecting the ecosystem services they depend upon. Therefore, research needs to be conducted that addresses how poor communities have developed (indigenous) mechanisms to protect ecosystem services and minimize risk and vulnerability when ecosystem services change. Although literature on *dhap* or hydroponics and flooding examine indigenous mechanisms (Hofer and Messerli 2006; Islam and Atkins 2007; Islam et al. 2000), no direct connection is made between protecting ecosystem services and poverty alleviation, and therefore, there is room for research in this area. Attempts should also be made to understand community-based institutions and governance to examine both cultural and socio-political aspects that can help protect ecosystems. Such work has only just begun in Tanguar Haor (Kabir and Amin 2007) and Hail Haor (USAID 2007). Understanding natural and human resilience offers positive stories that can be learned and possibly applied as policy solutions.

Attempts should also be made to further understand the relationship between actors and the politics of power between them that influences the types of social drivers that alter peoples' well-being. Although the example of the Khyang demonstrated changes in property rights and hinted at the power dynamics, between ethnic minorities and government officials (Gain 2002; Rahman and Hassen 2006), there is no in-depth analysis on social relationships and governance over ecosystem services that could explain why some social drivers have a bigger impact than others. Furthermore, the role of women and gender relationships are largely unexplored. Although women are mentioned with regards to their subsistence and commercial activities in forests and mangrove swamps (Karim et al 2006), how gender, power, and property rights relate to one another are not examined by any of the literature in any depth except for Crow and Sultana's work (2002) to understand how ecosystem services are managed between men and women to reduce poverty.

Filling these gaps would shed light on social well-being, which includes social cohesion, mutual respect, and ability to help others. Conducting such research will help assess the extent to which politics of power keep some people in poverty and alleviate poverty for others.

With regards to methodology, one that has been under-used in Bangladesh is environmental accounting or valuation. Although it is difficult to place value onto ecosystems because of the problems of defining and valuing ecosystem goods and services, placing monetary value on ecosystem services and the effects of human activity on the ability of the ecosystem to provide services, is one way to monetarily understand the relationship between ecosystem services and poverty. Valuation of ecosystem services in Bangladesh has hardly been conducted except for a few cases. In addition to Billah's work, the economic value of some *haors* has been estimated. For instance, Hakaluki *haor* provides ecosystem services to 190,000 people. Using bio-economic models, it has been estimated that the economic value of Hakaluki Haor is Tk 585.75 per year (IUCN 2006). Similarly, USAID (2007) has also estimated the economic value of Hail Haor, which amounts to Tk 36,990/area and Tk 454,924,600 in total returns. Although it is difficult to place an economic value on ecosystem services because they are complex public goods, valuation helps policy makers to make decisions with regards to ecosystem management (Duraiappah 2006). Therefore, attempts should be made to not only gather scientific data, but also translate it into helpful economic models so that planners are able to better control the impact of development activities. This is especially important since development activities are the most significant drivers of change as this situational analysis has demonstrated.

Last but not least, efforts need to be made to conduct research on policies made by governments, donor agencies, and other influential actors. Most ecosystem service degradation and impacts on human well-being have taken place due to non-existing or poor policy implementation that have failed to protect ecosystems and people who depend upon them. Understanding policy gaps through researching policies will help to not only identify areas where policies need to be made, but also where they need to be rectified. Work in this aspect has begun to take place in Bangladeshi. For instance, Islam and Khan (2007) have used remote sensing and policy analysis to highlight discrepancies in government policies regarding forests in lowland forests. Their work suggests that faulty policies are the major cause of deforestation in Bangladesh. If similar approach is used to

analyze policies in relation to mangrove swamps, rivers, wetlands, agro-ecosystems, and upland and lowland forests, it would minimize mismanagement of provision and regulating ecosystem services, which have direct links to human well-being as this situational analysis has demonstrated.

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