NORWEGIAN CHURCH AID

WHAT IS CLIMATE CHANGE? AND HOW IT WILL EFFECT BANGLADESH

By James S. Pender

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This paper is an attempt to summarise current international and national literature on climate change and put it into language which will be more easily understood by development practitioners in Bangladesh and elsewhere. It is to be expected that any summary may overlook some of the complexities involved so for more detailed information on any topic refer to the cited references. Comments and ideas for improvement of this paper will be welcomed by the author at: cbsdpconsultant-climatechange@yahoo.co.uk

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SUMMARY

The world's climate has always been changing between hotter and cooler periods due to various factors. However, for the first time in the earth's history it has now been firmly established that its human inhabitants are altering the climate through global warming as a result of greenhouse gas emissions. Although the basic science is now clear, the full range of effects due to human influenced climate change is still not fully understood.

However, it is known that climate change in the next hundred years will be significant and by the year 2100 best estimates predict between a 1.8˚ C and 4 ˚C rise in average global temperature, although it could possibly be as high as 6.4˚ C. Food production will be particularly sensitive to climate change, because crop yields depend directly on climatic conditions (temperature and rainfall patterns) and could lead to food yields being reduced by as much as a third in the tropics and subtropics. Meanwhile future tropical cyclones will become stronger, with faster wind speeds increasing the amount of damage they cause; floods will become more common due to changing rainfall patterns and glacier melt in the summer; sea-level rise could inundate large areas of low lying countries; and the changing climate may indirectly cause misery by increasing the incidence of disease and conflict. Furthermore biological diversity the source of enormous environmental, economic, and cultural value will be threatened by climate change.

'Climate change Mitigation' which refers to efforts to reduce greenhouse gas emissions or to capture greenhouse gases through certain kinds of land use, such as tree plantation is the main response that must be made to prevent future impacts of climate change. Greenhouse gases have mainly been emitted by developed Western countries and it is these countries that must act to prevent climate change becoming more serious. However, there are many measures that may be taken in developing countries that include reducing domestic emissions and deforestation, as well as advocating for mitigation in the developed world.

In terms of the impact of climate change few places in the world will experience the range of effects and the severity of changes that will occur in Bangladesh, which will include: Average weather temperatures rising; more extreme hot and cold spells; rainfall being less when it is most needed for agriculture, yet more in the monsoon when it already causes floods; melting of glaciers in the source areas of Bangladesh's rivers altering the hydrological cycle; more powerful tornados and cyclones; and sea level rise displacing communities, turning freshwater saline and facilitating more powerful storm surges. The impact will be intensified by the fact that Bangladesh is both one of the most populated and one of the poorest nations on earth.

'Climate Change Adaptation' which is the process through which people reduce the negative effects of climate on their health and well-being and adjust their lifestyles to the new situation around them is an essential and often overlooked part of the response to climate change; although it is not intended as a substitute for mitigation actions as adaptation has limitations. There are a number of basic strategies that can be taken in response to climate change that categorise various ways to adapt to the altered situation but a process that starts in and with the local community and its adaptive capabilities is vital; especially as climate change adaptation is context specific. Mainstreaming climate change adaptation into development thinking and practices has also been recommended as a priority and there are already many innovative projects in Bangladesh and around the world addressing the growing impacts of climate change on local communities.

Many more adaptation techniques need to be either transferred from other parts of the world or developed in the country. There is also a need for organisations to disseminate their ideas and experiences among likeminded NGOs in Bangladesh and develop their responses to climate change. Furthermore continued research is necessary to determine more accurately future and present effects of climate change on Bangladesh.

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INTRODUCTION

Bishop Michael S. Baroi, former Moderator of the Church of Bangladesh (2007), speaking of his fears about climate change says: "It would be a serious catastrophe for my country and for the whole region if much of the land in Bangladesh disappears under the sea. I become frightened to think that my grandchildren will have no place to live on this planet earth. I really want to be sure that they, and their children after them, will be able to enjoy the beauty of my country that I have enjoyed, and be able to have enough land to live and enough land for food".

Jesus prophesied in Luke 21.25: "On the earth, nations will be in anguish and perplexity at the roaring and tossing of the sea." Could this be a prediction of current worries over sea level rises because of climatic change? It just might be (Pender, 2007).

However, what is now certain is that changes in climate have already devastated the lives of poor people all over the world whether through disasters, disease, drought, famine or flood and that these apocalyptic forces will intensify over the coming decades if nothing is done to reduce the emission of greenhouse gases (Christian Aid, 2006).

Bishop George Browning, Convenor of the Anglican Communion Environment Network (2007), argues that 'the morality of global warming or climate change, or environmental degradation, is really quite simple. We now have sufficient information to know that environmental degradation is destructive; it steals from future generations, it penalises the poor, it is exaggerated by greed, it puts diversity at risk. Environmental pollution hurts all of life; it is in the interest of every living thing for human beings to do something about it'.

The Evangelical Environmental Network explains that as Christians we should 'care about what happens to the poor because God loves them. We care about these projected impacts of global warming because they are a profound challenge to Christian justice and Jesus' call to care for "the least of these" (Matthew. 25:40, 45). Pollution that causes the threat of global warming violates Jesus' Great Commandments to "Love the Lord your God with all your heart and with all your soul and with all your mind and with all your strength" and "Love your neighbor as yourself" (Mark. 12:30-31), and the Golden Rule to "Do to others as you would have them do to you" (Luke. 6:31). And Global Warming is a breach of our responsibility to care for God's other creatures (Genesis. 2:15). Failure to act to reduce the impacts of global warming denies Christ's Lordship. We are called to love and protect those with less power, such as the poor, children, the unborn, those yet to be born, and our fellow creatures. Global warming has profound implications for their welfare. Reducing this threat is part of what it must mean today to love God and our neighbor, as Jesus taught us to do' (EEN, 2005a).

Sir John Houghton Chair or Co-chair of the Scientific Working Group of the Intergovernmental Panel on Climate Change (IPCC) between 1988-2002 reminds us 'of words of Jesus spoken after he had told the parable contrasting the faithful and unfaithful stewards, "For unto whomsoever much is given, of him shall be

much required" (Luke 12:48). The challenge to our Christian churches and the opportunities with which they are presented are unmistakeable' (Houghton, 2005).

Former US Vice-President Al Gore (2006), stated: "If you believe in prayer, pray that people will find the strength to change (in response to climate change)" and then quoted an African proverb: 'When you pray move your feet'!

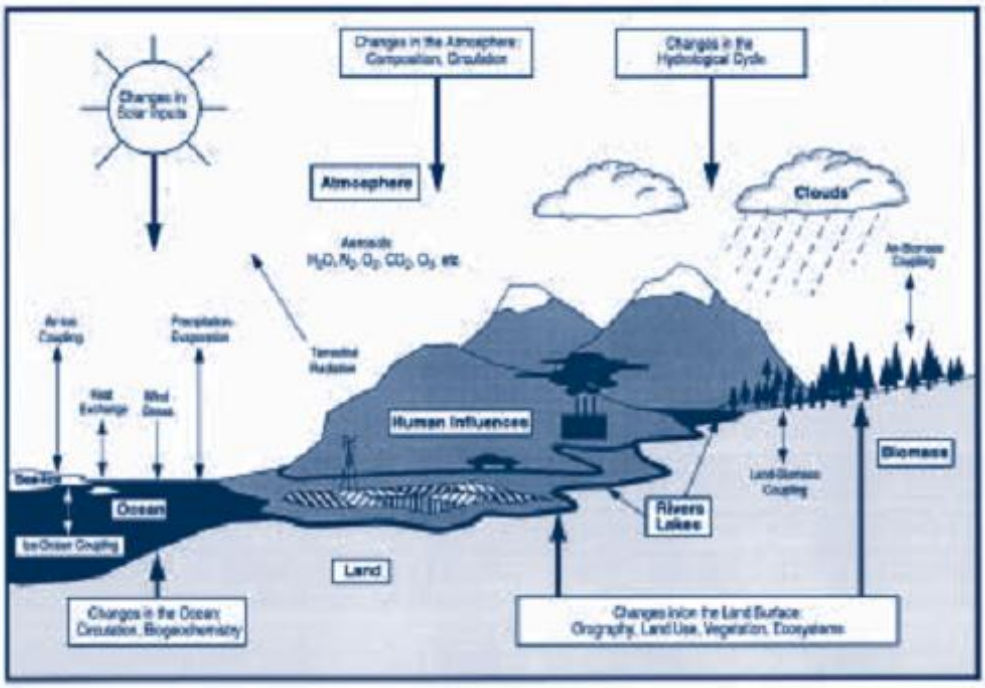
As a body of Christians in a country that will experience most of the adverse effects due to global warming predicted in the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) published in 2007, the Church of Bangladesh with its focus on serving the poor, has become committed to addressing the issue of Climate Change. The Church of Bangladesh will seek to do so by mitigating against greenhouse gas production through tree plantation; by calling for lifestyle changes in the countries that emit most greenhouse gases, especially through links to churches in the West; and by coming alongside poor communities which are already beginning to suffer from the effects of climate change in order to assist them to adapt to new weather conditions and to develop resilience in the face of increasingly common disasters.

SECTION 1: WHAT IS CLIMATE CHANGE?

1.4 Climate

1.1.1 Climate is simply the weather that is dominant or normal in a particular region; the term climate includes temperature, rainfall and wind patterns. Geography, global air and sea currents, tree cover, global temperatures and other factors influence the climate of an area, which causes the local weather. Figure 1 below is a schematic diagram of the climate system.

Figure 1. A schematic illustration of the climate system. (Williams, 2002).



1.1.2 The earth's climate has always varied naturally, in the past cooler cycles due to variations in the earths orbit round the sun, sunspot activity or volcanic eruptions, have altered the climate. However, large changes have been very gradual over huge time periods; nevertheless they are still blamed for the extinction of the dinosaurs.

1.1.3 What is new is that humans are now, due to pollution from industrial processes and wasteful lifestyles directly influencing the climate of the earth. Human influence is now believed to be changing the climate much faster than occurring in the past under natural processes.

1.1.4 Scientific evidence that humans were changing the climate first emerged in the international public arena in 1979 at the First World Climate Conference (Depledge & Lamb 2005). At this time when the first effects of human induced climate change were discovered, the changes were so small it didn't seem like a big issue. But by 1988 when the Intergovernmental Panel on Climate Change (IPCC) was formed the dangerous consequences of climate change became clearer (Houghton, 2007).

1.2 The Greenhouse Effect

1.2.1 The Greenhouse Effect is a natural process through which various gasses and water vapour in the atmosphere affects the earth's climate. It is so named because it acts like a glass greenhouse for plants by preventing the incoming heat from the sun from leaving causing warming of the earth just as the inside of a greenhouse warms. The Greenhouse Effect can also be likened to being under a blanket in the sunshine; the body under the blanket will heat up and the blanket will keep the heat from escaping causing warming.

1.2.2 The earth's climate is driven by this continuous flow of energy from the sun, mainly in the form of visible light. About 30% is immediately scattered back into space, but most of the remaining 70% passes down through the atmosphere to warm the earth's surface. Being much cooler than the sun, the earth does not give out energy as visible light. Instead, it emits heat in the form of infrared or thermal radiation. Greenhouse gases in the atmosphere block this infrared radiation from escaping directly from the surface to space (Williams 2002). This is illustrated in figure 2.

Figure 2. The Greenhouse Effect (Depledge & Lamb 2005).

1.2.3 Houghton, 2005 explains that 'by absorbing infra-red or 'heat' radiation from the earth's surface, "greenhouse gases" present in the atmosphere, such as water vapour and carbon dioxide, act as blankets over the earth's surface, keeping it warmer than it would otherwise be. The existence of this natural

"greenhouse effect" has been known for nearly two hundred years; it is essential to the provision of our current climate to which ecosystems and we humans have adapted'.

1.2.4 However, 'since the beginning of the industrial revolution around 1750, one of these greenhouse gases, carbon dioxide, has increased by over 30% and is now at a higher concentration in the atmosphere than it has been for many thousands of years. Chemical analysis of the carbon demonstrates that this increase is due largely to the burning of fossil fuels - coal, oil and gas' (Houghton, 2005). These are consumed mainly through industry and transportation and along with other greenhouse gases such as nitrous oxide and methane that are also produced by human activity are thickening the natural greenhouse layer. This therefore leads to a warming of the earth, commonly known as 'Global Warming' that may also cause more evaporation and a further increase in the greenhouse layer due to increased water vapour (Williams, 2002). This is illustrated in figure 2.

1.3 Evidence for Global Warming

1.3.1 It has been suspected for the last 40 years that human activity has been altering the earth's climate. To confirm whether this was true or not the Intergovernmental Panel on Climate Change (IPCC) was set up by the World Meteorological Organization and the United Nations Environment Programme, producing its first assessment report in 1990 (Depledge & Lamb 2005). Hundreds of scientists from many countries across the world review thousands of published scientific articles that include research using advanced mathematical modelling to predict future changes, as well as research monitoring historical and current changes in climate, in order to produce the IPCC assessments. Furthermore the work of the IPCC is backed by the worldwide scientific community, as well as being endorsed by all major world governments (Houghton, 2005).

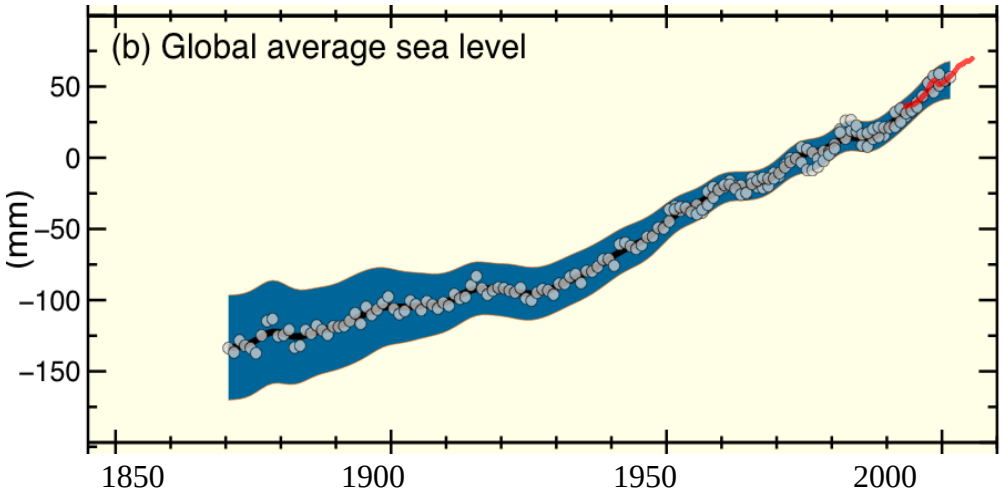
1.3.2 As research has accumulated on climate change, scientists have become more and more certain that global warming is happening and clearer as to its effects. The Fourth Assessment Report of the IPCC published in 2007 stated that: 'Most of the observed increase in global average temperatures since the mid-20th century is ***very likely*** due to the observed increase in anthropogenic (human caused) greenhouse gas concentrations', while 'the observed widespread warming of the atmosphere and ocean, together with ice mass loss, support the conclusion that it is *extremely unlikely* that global climate change of the past 50 years can be explained without external forcing (outside human influence), and ***very likely*** that it is not due to known natural causes alone'(Alley *et al*, 2007).

1.3.3 The strength of the evidence presented by the IPCC is such that very few policy makers or academics now deny the realities of global warming. As Sir John Houghton, states, "Although there is a lot of uncertainty concerning the detail, the basic science underlying global warming and climate change is well understood and is not in question" (La Trobe, 2002).

1.3.4 The foremost evidence for worldwide climate change has been global warming. For the Northern Hemisphere temperatures during the second half of the 20th century were higher than during any other 50-year period in the last 500 years and probably in the last 1,300 years. In addition eleven of the last twelve years (1995–2006) rank among the 12 warmest years in the instrumental record of global surface temperature began in 1850 (Alley *et al*, 2007).

1.3.5 The IPCC has also collected data that shows that global warming is affecting weather and the environment in a number of ways causing further problems: Sea level due to melting polar ice caps and seawater expansion (due to it being warmer) has been rising between 1993 and 2003 at a rate of 3.1 mm per year, as shown in figure 3. Furthermore rainfall patterns have been changing with increased droughts in some areas and heavier rain in others; glaciers and snow have been melting increasing water in rivers at certain times; winds are increasing in power; and ocean temperatures have been rising (Alley *et al*, 2007).

Figure 3. World Sea Level Rises (Alley *et al*, 2007).



SECTION 2: FUTURE CLIMATE CHANGE PREDICTIONS

2.1 Temperature

2.1.1 Latest IPCC predictions from their Fourth Assessment Report reveal that for the next twenty years warming at a rate of 0.2˚ C per decade is expected. While by the year 2100 best estimates predict between a 1.8˚ C and 4 ˚C rise in average global temperature, although it could possibly be as high as 6.4˚ C (Alley *et al*, 2007). How high exactly depends on whether tough action is taken to stop greenhouse gas pollution now or if very little action is taken as at present. However, if current trends are followed, it can be expected that average global temperatures will rise by 1 - 3°C within the next fifty years or so and the Earth will be committed to several degrees more warming if greenhouse gas emissions continue to grow (Stern, 2006).

2.1.2 According to Stern (2006), in higher latitude regions, such as Canada, Russia and Scandinavia, climate change may lead to net benefits for temperature increases of 2 or 3°C, through higher agricultural yields, lower winter mortality, lower heating requirements, and a possible boost to tourism. But these regions will also experience the most rapid rates of warming, damaging infrastructure, human health, local livelihoods and biodiversity. Furthermore the positive effects will be largely temporary as changes will become very damaging for activities such as agriculture under the much higher temperatures expected later this century.

2.1.3 However, most countries in the world will immediately find global warming a major problem with higher maximum temperatures, more hot days and heat waves, as well as higher minimum temperatures and fewer cold days over nearly all land areas. As well as indirect effects, hotter weather will increase the number of deaths and illness due to heat, particularly in older people and urban poor (Depledge & Lamb 2005). For example, 'moist tropical' conditions in Shanghai, China are associated with the highest average temperatures and humidity and lead to the greatest increase in daily average mortality which rises to 35-63 extra deaths per day. While the French heatwave in summer 2003, which was the hottest three-month period ever recorded in France, caused an estimated 15,000 extra deaths (Stern, 2006).

2.2 Agriculture

2.1.4 Food production will be particularly sensitive to climate change, because crop yields depend directly on climatic conditions (temperature and rainfall patterns). In tropical regions, even small amounts of warming will lead to declines in the amount of crops harvested. In cold areas, crop harvests may increase at first for moderate increases in temperature but then fall. Higher temperatures will lead to large declines in cereal (e.g. rice, wheat) production around the world (Stern, 2006).

2.1.5 Indirect effects on crops include increased amounts of Carbon dioxide (a greenhouse gas) in the air, this can help plants to grow (photosynthesise) and

to reduce the amount of moisture lost from leaves. But like warmth it will only benefit agriculture in the short term, as other indirect effects on crops such as drought, flooding, less moisture in soils and an increase in pests and diseases will soon lead to less food being produced from farmland (Stern, 2006). Added heat stress, changing monsoon patterns, and drier soils may reduce yields by as much as a third in the tropics and subtropics, where crops are already near their maximum heat tolerance. Further to these effects forestry due to drier and hotter conditions will face increased risk of fire damage (Williams, 2002).

2.1.6 Fisheries may be initially boosted by warmer waters, but again in the longer term it is bad news as increased Carbon-dioxide in the air will cause more carbon-dioxide to become dissolved in the oceans and seas which will make them more acidic, this will reduce the number of fish in them (Stern, 2006). Livestock farming will be threatened by increased animal diseases and the cost of straw or grain to feed them as crop harvests decrease (Williams, 2002).

2.1.7 So overall global warming is a big threat to human food supply. Around 12% of world's population is already at risk of hunger, but if temperature rises by only 2 to 3°C it will increase the people at risk of hunger, potentially by 30 - 200 million. Once temperatures increase by 3°C, 250 - 550 million additional people may be at risk most in Africa and Asia, where: The declines in harvest are greatest, dependence on agriculture highest, and spending power most limited (Stern, 2006).

2.3 Drought

2.3.1 Water is an essential resource for all life and a requirement for good health and sanitation. It is a critical input for industry and essential for sustainable growth and poverty reduction. Climate change will alter patterns of water availability by intensifying the water cycle. Droughts and floods will become more severe in many areas. There will be more rain at high latitudes, and less rain in the dry subtropics. Hotter land surface temperatures cause more powerful evaporation and hence more intense rainfall, with increased risk of flash flooding. Differences in water availability between regions will become increasingly pronounced and areas that are already relatively dry are likely to become drier (Stern, 2006).

2.3.2 Reduced water supplies would place additional stress on people, agriculture, and the environment. Already, some 1.7 billion people, a third of the world population live in water stressed countries, a figure expected to rise to 5 billion by 2025. Climate change will exacerbate the stresses on water supply caused by pollution and by growing populations and economies. The most vulnerable regions are arid and semi-arid areas, some low-lying coasts, deltas, and small islands (Williams, 2002).

2.4 Heavy Rainfall

2.4.1 Warming may induce sudden shifts in regional weather patterns such as the monsoon rains in South Asia or the El Niño phenomenon - changes that would have severe consequences for water availability and flooding in tropical regions and threaten the livelihoods of millions of people (Stern, 2006).

2.4.2 Heavy rainfall will become more common, and this is likely to damage farm incomes through increased soil erosion, and an inability to cultivate land due to the water logging of soils. It may also cause contamination of drinking water supply, exacerbating various water related illnesses (Adger *et al*, 2007).

2.4.3 Landslides and avalanche damage, loss of life and damage to buildings and property, and loss of livelihoods due to longer periods of flooding are additional effects of heavier rainfalls (Depledge & Lamb 2005).

2.5 Winds

2.5.1 According to the IPCC future tropical cyclones will become stronger, with faster wind speeds (Alley *et al*, 2007). Also known as hurricanes and typhoons, these massive storm systems combine the effects of heavy rainfall, high winds, and storm surge and sea-level rise. Warmer ocean temperatures will increase the frequency and intensity of such storms (Williams, 2002). Storm routes are also predicted to move poleward, which will mean changes in wind, precipitation and temperature patterns (Alley *et al*, 2007).

2.5.2 During the last 30 years total power released by storms in the Atlantic has more than doubled and so has the number of Category 4 and 5 hurricanes/typhoons worldwide and these are expected to increase due to warmer seas and oceans (EEN, 2005b). According to Stern (2006), 'infrastructure damage costs will increase substantially from even small increases in sea temperatures because: (1) peak wind speeds of tropical storms are a strongly exponential function of temperature, increasing by about 15 - 20% for a 3°C increase in tropical sea surface temperatures; and (2) damage costs typically scale as the cube of wind-speed or more. Storms and associated flooding are already the most costly natural disaster today, making up almost 90% of the total losses from natural catastrophes amounting to US$184 billion from windstorms alone, particularly from tropical cyclones during 2005.'

2.5.3 The effects of more often and more powerful storm and cyclones will include: Damage to crops; windthrow (uprooting) of trees; damage to coral reefs; electric current disturbance; increased risk of deaths, injuries, water- and foodborne diseases; post-traumatic stress disorders; disruption by flood and strong winds; potential for population migrations; loss of property (Adger *et al*, 2007); larger storm surges; heavier rainfall; damage to mangrove forests (WWF in Clime Asia, 2005); and coastal erosion (Depledge & Lamb 2005).

2.6 Glacier / snow melt

2.6.1 Snow cover and glaciers will continue to melt more rapidly, reducing in size. Widespread increases in thaw depth are projected over most permafrost (frozen ground) regions (Alley *et al*, 2007). Mountain regions are already under considerable stress from human activities. The declines in mountain glaciers, permafrost, and snow cover will reduce soil stability and damage hydrological (river) systems (Williams, 2002).

2.6.2 Stern (2006) explains that: 'Melting glaciers and loss of mountain snow will increase flood risk during the wet season and threaten dry-season water supplies to one-sixth of the world's population (over one billion people today). Climate change will have serious consequences for people who depend heavily on glacier meltwater to maintain supplies during the dry season, including large parts of the Indian sub-continent, over quarter of a billion people in China, and tens of millions in the Andes. Initially, water flows may increase in the spring as the glacier melts more rapidly. This may increase the risk of damaging glacial lake outburst floods, especially in the Himalayas, and also lead to shortages later in the year. In the long run dry season water will disappear permanently once the glacier has completely melted. Parts of the developed world that rely on mountain snowmelt (Western USA, Canadian prairies, Western Europe) will also have their summer water supply affected, unless storage capacity is increased to capture the "early water".'

2.7 Sea Level Rise

2.7.1 Global warming has raised and will continue to raise sea level due to thermal expansion (warmer water takes up more space) of the oceans and the melting of ice stored in glaciers or ice sheets (floating sea ice being lighter than water sits on the sea surface and when it melts it increases the seas volume causing sea level rise). The consequences of sea level rise include more frequent and more devastating flooding and loss of coastal land. For in coastal situations, a 50cm rise normally results in a 50m loss of land (Artic Climate Impact Assessment In: EEN, 2005b).

2.7.2 According to the latest information from the IPCC global sea levels will rise by at least 18 cm, but in the worst case scenario as much as 59 cm by the year 2100 (Alley *et al*, 2007). As half of the world's population is living in coastal regions, flooding due to storm surges already affects around 46 million people a year, mostly in developing countries. But with a 50 cm sea-level rise, this figure could double to 92 million. Indeed, it is estimated based on the IPCC reports, that by 2025 over half of all people living in developing countries will be highly vulnerable to floods and storms (La Trobe, 2002).

2.7.3 However, these predictions from the IPCC excluded the melting of ice caps as scientists have been finding it difficult to assess their impact on sea levels (Hodson & Hodson, 2008). Melting of the Greenland Ice Sheet is expected to continue to contribute to sea level rise beyond 2100, as melting ice adds water to the sea. If ice sheet melting continues as global warming increases, eventually that would lead to virtually complete elimination of the Greenland

Ice Sheet and a resulting contribution to sea level rise of about 7 m (Alley *et al*, 2007).

2.7.4 Rising sea levels will cause livelihoods to be lost and people displaced as land permanently goes under water, while the costs of sea defenses will rise. Coastal areas are amongst the most densely populated areas in the world and support several important ecosystems on which local communities depend. Critical infrastructure is often concentrated around coastlines, including oil refineries, nuclear power stations, port and industrial facilities. Currently, more than 200 million people live in coastal floodplains around the world, with 2 million Km^2 of land and $1 trillion worth of assets less than 1 m elevation above current sea level. Many of the world's major cities (22 of the top 50) are at risk of flooding from coastal surges, including Tokyo, Mumbai, Calcutta, New York, and London (Stern, 2006).

2.8 Oceans and Seas

2.8.1 Ocean and seas may be affected by climate change in a number of ways: In addition to higher sea levels, climate change will reduce sea-ice cover; decreases of up to 14% have been measured in the Arctic during the past two decades, and a decline of 25% has been recorded in the Antarctic from the mid-1950s to early 1970s. Climate change will also alter ocean circulation patterns, (the vertical mixing of waters, and wave patterns). These changes can be expected to affect biological productivity (such as fish populations), the availability of nutrients, and the ecological structure and functions of marine ecosystems. Changing ocean temperatures could also cause geographical shifts in biodiversity, particularly in high-latitude regions, where the growing period should increase (assuming light and nutrients remain constant). Any changes in plankton activity could affect the oceans ability to absorb and store carbon which could moderate or boost climate change (Williams, 2006).

2.8.2 The meridional overturning circulation (MOC) currents of the Atlantic Ocean will slow down during the 21st century, by about 25% but possibly by as high as 50% (Alley *et al*, 2007). Warm water brought to Europe's shores raises the temperature by as much as 10˚ C in some places and without it the continent would be much colder and drier. Worryingly during November 2004 a part of the Gulf Stream current, which is normally 60 times more powerful than the Amazon River, came to a temporary stop (Randerson, 2006). Circulating ocean currents have a huge impact on climate and fisheries, so if changes like this one become permanent in the Atlantic or elsewhere it would cause major problems for many countries.

2.9 Biodiversity

2.9.1 Biological diversity the source of enormous environmental, economic, and cultural value will be threatened by climate change. The composition and geographic distribution of ecosystems will change as individual species respond to new conditions created by climate change. At the same time, habitats will degrade and fragment in response to other human pressures.

Species that cannot adapt quickly enough will become extinct an irreversible loss (Williams, 2002)

2.9.2 The extinction of plant and animal species is getting faster with 11% of the world's species of birds, 25% of its species of mammal, and around 34% of its fish species are already vulnerable or in 'immediate danger of extinction' mainly due to human impacts (La Trobe, 2002). But 20-30% of plant and animal species assessed so far are will be at even more increased risk of extinction if increases in global average temperature exceed 1.5-2.5˚ C (Adger *et al*, 2007).

2.9.3 The warming of the 20th century has already directly affected ecosystems. Over the past 40 years, species have been moving polewards (towards cooler weather) by 6 Km on average per decade, and seasonal events, such as flowering or egg-laying dates for breeding birds, have been occurring several days earlier each decade. Arctic and mountain ecosystems are especially vulnerable and polar bears, and white spruce trees have all experienced recent declines. Climate change has already contributed to the extinction of over 1% of the world's amphibian species from tropical mountains. For many species, the rate of warming will be too rapid to withstand. Many species will have to migrate across fragmented landscapes to stay within their preferred "climate envelope" (at rates that many will not be able to achieve). While in some cases, the "climate envelope" of a species may move beyond reach, for example moving above the tops of mountains or beyond coastlines (Stern, 2006).

2.9.4 Environmental destruction also causes climate change for deforestation, slash-and-burn farming, soil loss or damage, road building and urban growth account for as much as 25% of greenhouse gas emissions (Evans, 2007).

2.10 Economic cost

2.10.1 The monetary cost of climate change is expected to be very high; this means it will reduce economic output measured in Gross Domestic Product (GDP). With 2˚ C to 3˚ C warming which is expected by 2100 there could be a loss of global GDP as high as 3%, but with 5-6 ˚ C of global warming into the next century global GDP could be reduced by 5-10%.

2.10.2 Furthermore developing countries will suffer more, with the highest impacts being in Africa, the Middle East, South Asia and South-East Asia. For example, the mean cost to India and South-East Asia is expected to be around 6% of regional GDP by 2100, compared with a global average of 2.6%. While after 2100 economic losses could be higher than 10% of GDP (Stern, 2006).

2.10.3 Global economic losses from climate related disasters are already rising fast. Reported economic losses have risen from $131 billion in the 1970s to $629 billion in the 1990s. It is estimated that the cost of disasters over the next 20 years will be from US$6 to $10 trillion - ten times the level of predicted aid flows. It has even been projected that the upward curve of economic damage

from global warming could overtake gross world product (GWP) by 2065, effectively bankrupting the global economy (La Trobe, 2002).

2.11 Conflict

2.11.1 Fields (2005) with reference to the Biblical book of Revelation stated: **'**When the apocalyptic horsemen of famine and pestilence appear, war can't be far behind'. He was highlighting the link between war and the reduction of resources in an area through disasters such as drought caused famines or pest attack on crops that can occur due to a changing climate.

2.11.2 Therefore Christian Aid (2006), declared: "Climate change fuels conflict. If temperatures are increasing in areas that are already hot, it will have a direct effect on the scarce resources required to sustain life, water, food, crops and livestock. In East Africa, a combination of drought and famine brought on by increasingly varied and generally warmer temperatures have already led to violent fighting among nomadic pastoralists".

2.11.3 On a larger scale countries may also find themselves in conflict over increasingly scarce food and water supplies. For environmental changes raise the risk of 'resource wars' as nations fight for rights to key resources. India and Pakistan, for example, have a treaty, which agrees the division of the waters of the River Indus, but if the river loses 40% of its water flow as predicted by 2100; will the agreement and peace be maintained? Climate change may also lead to instability within countries and across international boundaries as sea-level rise, deforestation and severe drought creates millions of environmental refugees. With a 50 cm sea-level rise, refugees could number 92 million, and up to 118 million with a one metre rise. These refugees will need to subsist somewhere, and this could create further tension and conflict over environmental resources (La Trobe, 2002).

2.12 Health & disease

2.12.1 Climate change is expected to have wide-ranging consequences for human health. For the health of communities depends on sufficient food, safe drinking water, comfortable homes, good social conditions, and a suitable environmental and social setting for controlling infectious diseases. All of these factors can be affected by climate (Williams, 2002).

2.12.2 The IPCC expects that climate change will affect the health status of millions of people, particularly those with low adaptive capacity (i.e. already poor and vulnerable), through: 'Increases in malnutrition, with implications for child growth and development; increased deaths, disease and injury due to heat waves, floods, storms, fires and droughts; and the increased burden of diarrhoeal disease. The increased frequency of cardio-respiratory diseases due to higher concentrations of ground level ozone related to climate change and, the altered spatial distribution of some infectious disease vectors such as mosquitoes will also impact upon health of communities' (Adger *et al*, 2007).

2.12.3 The World Health Organisation (WHO) estimates that climate change since the 1970s is already responsible for over 150,000 deaths each year through increasing incidence of diarrhoea, malaria and malnutrition, predominantly in Africa and other developing regions. Slum populations in urban areas are particularly exposed to disease, suffering from poor air quality and heat stress and with limited access to clean water. In some tropical areas, temperatures may already be at the limit of human tolerance such as in the Indo-Gangetic Plain where they can already exceed 45°C before the arrival of the monsoon. Just a 1°C increase in global temperature above pre-industrial (it is already 0.5˚ C higher) could double annual deaths from climate change to at least 300,000 (Stern, 2006).

2.12.4 Health will be further affected by changes in the water cycle. Droughts and floods bring disease, as well as causing death from dehydration or drowning. Prolonged droughts will fuel forest fires that release respiratory pollutants (causing asthma and allergies), while floods foster growth of infectious fungal infections, create new breeding sites for disease vectors such as mosquitoes, and trigger outbreaks of water-borne diseases like cholera (Stern, 2006).

SECTION 3: CLIMATE CHANGE MITIGATION

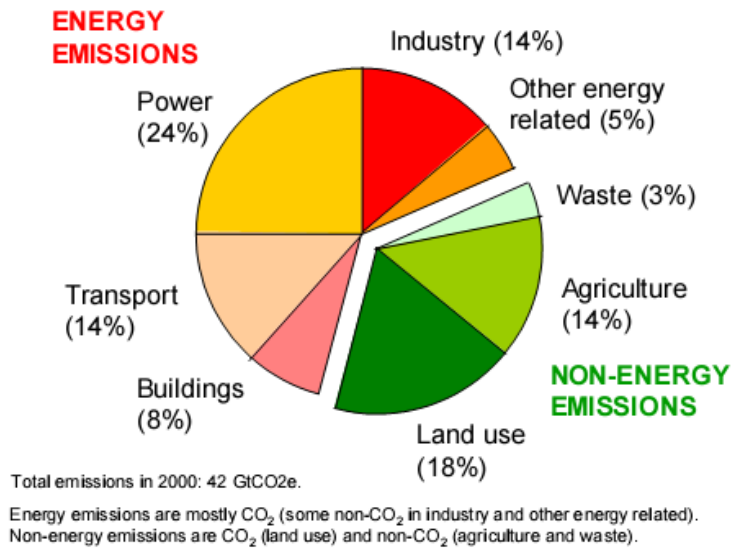
3.1 What is 'Mitigation'?

3.1.1 **'**Mitigation refers to efforts to reduce greenhouse gas emissions' (Huq, 2006). Mitigation may also refer to efforts to capture greenhouse gases through certain kinds of land use, such as tree plantation. This will reduce global warming, as the greenhouse layer in the atmosphere will not be so thick and its warming, blanket-like effect will be lessened.

3.1.2 Mitigation is the main response that must be made to prevent future impacts of climate change. It consists of measures such as switching from using coal, to petrol/oil, to natural gas, which are progressively better in terms of greenhouse gas emissions. Natural gas is the least polluting fossil fuel. Better still is the use of renewable sources of energy (Huq, 2006).

3.1.3 As can be seen from the graph below the majority of greenhouse gasses are contributed through energy emissions, while the remainder is related to land use.

Figure 4. Greenhouse Gasses emitted in 2000, by source (Stern, 2006).



3.2 Advocacy

3.2.1 In 1994 from which the latest available figures are available from, in Bangladesh 45.926 million tonnes CO_2 equivalent of greenhouse gases were emitted. This compares to 651.09 million tonnes CO_2 equivalent of greenhouse gases emitted from the UK, 4179.61 million tonnes CO_2 equivalent of greenhouse gases emitted from the European Union as a whole and 6893.81 million tonnes CO_2 equivalent of greenhouse gases emitted from the USA in 2003. These figures clearly show that Bangladesh's emissions are generally much, much lower than those of developed countries, though they exclude emissions from agriculture and land use (UNFCC, 2005).

3.2.2 If you consider that the population density of Bangladesh is probably the highest for any country in the world, now fast approaching 150 million, the per person emissions of greenhouse gasses are probably one of the lowest ratios in the world, at only 0.2 tons per year against an average of 6 tons per year in the industrial world (Zia, 2002). So Bangladesh's 'carbon footprint per person is extremely low.

3.2.3 In South Asia CO_2 emissions from passenger transport is also low at around 16 gm-passenger km, compared to 118 gm-passenger km for (15 countries of) the European Union and 193 for the USA (Sethi, 2005). So in other words the problem of climate change has been caused mainly by richer industrialised developed nations.

3.2.4 For example 80% of the human caused carbon dioxide emissions in the last 150 years that have built up in the atmosphere have come from Northern nations that have grown wealthy as they industrialised. Therefore the World Council of Churches see Climate Change as a 'justice' issue and call on

developed nations to reduce their emissions, as well as to assist through finance and technical resources, countries whose wellbeing they have threatened (Hallman, 2000).

3.2.5 As global warming will affect Bangladeshi people seriously they must get involved in advocacy with the USA and European countries, as well as new big polluters such as India and China on behalf of their children and poorest neighbours who will be most affected. Bangladeshi organisations can work in partnership with International NGOs, overseas churches and donors to highlight the effect of global warming and to lobby for action in developed countries to reduce greenhouse gas emissions.

3.2.6 Advocacy in this way is the most important way Bangladeshis can contribute to Climate change mitigation! It may do this through: Providing stories and photos to partner organisations abroad showing how global warming is hurting the poor; speaking directly on this issue when visiting developed countries, in churches, public meetings, to government representatives; organising petitions which can be sent by mail/through partners to overseas governments; by writing articles for websites and magazines circulated overseas so that the public there begins to put pressure on their governments and take action themselves on behalf of Bangladesh and other 'severely at risk' countries.

3.3 Mitigation Action in Bangladesh

3.3.1 It has been said that no single organisation or country can solve the problem of climate change. It would be foolish and arrogant to pretend otherwise. But we can make a difference by making a start and showing what is possible (Lord Browne, 2002). So while some of the issues may seem remote and organisations like the Church of Bangladesh unable to engage directly; for example in cutting US emissions, nobody is helpless there is always something to be done and examples to be set. Advocacy and lobbying others abroad is important but action is also necessary in Bangladesh.

3.3.2 Bishop Sarker (2007) has pointed out that although Bangladesh may not be the guiltiest in terms of climate change emissions; the country is now 'following blindly the Western ideology and technology for their development', just as India has. Orissa state's power stations in India, emitted 164 million tonnes of carbon dioxide in 2005, equal to the total emitted in the whole of India in 1996 and it will emit 3% of global emissions after new planned plants are opened (Das, 2006). China has also shown the negative impact a non-western country with a large population can have when it develops in the wrong way, as it recently become the world's largest emitter of greenhouse gasses, opening numerous coal fired power stations to provide energy for industry (Gore, 2006). China is now the second and India the fourth largest producers of greenhouse gases from their power generation sectors, emitting 2.7 billion and 583 million tonnes of greenhouse gasses per year (Vidal, 2007).

3.3.3 Bangladesh must not follow the same damaging route; it has too much to lose. In particular advocacy by civil society should call for a rethink in regards to the country exploiting its coal reserves in the face of energy shortages, for

alternative greener alternatives should be pursued instead. The necessary forced relocation of 40,000 of people in the area of the proposed Phulbari mine should also count against such a plan (Gain, 2007). So there is an important role for NGOs in influencing the development process in Bangladesh to follow an environmentally sustainable path in this and many other ways.

3.3.4 Bangladesh has about 30,000 industrial units: 24,000 small and cottage sized and 6,000 large and medium sized factories. These have a very poor environmental record (Gain, 2002a). These must be pressured by civil society directly and through government to improve their energy efficiency, dispose of waste properly and to reduce emissions.

3.3.5 Houghton (2007) quotes Edmund Burke, a British Member of Parliament 200 years ago who said: "No one made a greater mistake than he who did nothing because he could do so little". Bangladesh may be a small country, the Church of Bangladesh a small organisation, with beneficiaries and staff just individuals. But all have the opportunity to make an impact that will reduce the impact of global warming, however small; it is a moral choice for good everyone must take. If many people take action the combined impact becomes big.

3.3.6 It must never be said that a certain community is too poor or small to make a difference in terms of reducing global warming. For that would be to disempower them. In addition if you warn people of a great danger but tell them they can do nothing to stop it will make them feel helpless. This is not development. All must be encouraged that they can have an impact in terms of climate change mitigation.

3.4 Lifestyle changes

3.4.1 It was earlier mentioned how advocacy to influence businesses and governments in Bangladesh and overseas could help to mitigate global warming. But individuals and organisations in Bangladesh also have a responsibility to reduce their contribution to greenhouse gas build up in the atmosphere.

3.4.2 A major way to have an impact is in the area of transport which globally accounts for 14% of greenhouse gas emissions (Stern, 2006). Between 1986/7 and 1996/7 the amount of cars, trucks, and jeeps doubled in Bangladesh (Hossen, 2002). Most taxis and auto-rickshaws now run on compressed natural gas which when used as fuel, produces far less greenhouse gases than petrol, diesel or octane fuelled vehicles. All organisations concerned about climate change should use gas fuelled vehicles and individuals should seek to use buses, gas fuelled taxis or rickshaws that produce less greenhouse gases. Organisations and individuals should also seek to minimise air flights which result in huge emissions and to buy food and luxury items which have been made locally when out shopping, as less emissions will have been produced in the transport of locally made items than imported ones.

3.4.3 Buying recycled or second hand goods, or simply using them for longer, before discarding or recycling them additionally reduces greenhouse gas production. For industries will produce less emissions if less goods are being produced that cause emissions and it is easier to make something from recycled material requiring less emissions (Bogner *et al*, 2007). Bangladesh already has good recycling rates due to its impoverished 'rag pickers' but there is still room for improvement, and initiatives to improve the conditions and pay of those collecting rubbish and playing such an important role in society should be developed.

3.5 Energy Use

3.5.1 Energy use is another way greenhouse gas emissions can be reduced. Natural gas produces 24% of the country's fuel need and imported coal and mineral oil 19% (Moral, 2002). The latter is produces large quantities of greenhouse gases to produce electricity, while although very much less, gas still produces some carbon dioxide when burnt. Therefore every organisation should try and cut down on its use of electricity such as only using air conditioning on the very hottest days in offices, turning off lights, televisions, fans and computers when leaving rooms or at night.

3.5.2 Solar panels can also be installed on roofs to capture energy and have proved effective in Bangladesh (Moral, 2002) in fact solar lanterns have also been supplied for use in fishing boats. In remote Chalanbeel in Bangladesh, a fleet of boats fitted with solar panels even deliver a combination of services which include: Children's education, libraries, training in sustainable agriculture, and health advice. They also use solar power to recharge batteries to run solar home lighting systems, mobile phones and Internet access (Reid *et al*, 2007).

3.5.3 The use of energy efficient light bulbs; fluorescent or LED is one simple way to make a huge difference in electricity consumption. Church of Bangladesh Social Development Programme-Meherpur has already exchanged many of its light bulbs for low energy using small fluorescent bulbs.

3.5.4 Traditional fuels like wood, crop residue, and cow dung makes up 55% of total energy used in Bangladesh. So using energy efficient stoves or *chulas* to increase the amount of energy utilised from wood or dung from 5-15% to 50-70% when cooking and therefore reduce greenhouse gas emissions per family is good practise (Moral, 2002). The use of a *Chuli Water Purifier* (that is a coiled aluminium pipe through which water flows from one bucket to another) inserted into the clay stove when built can also make water safe to drink by pasteurising it at the same time of cooking. This reduces the amount of carbon-dioxide produced during boiling water, through wood burning, as well as deforestation, itself a cause of global warming. These are available in Bangladesh from IACD (Integrated Approach to Community Development) and Wagtech (suppliers of water testing equipment).

3.5.5 Biogas plants that use dung and vegetable matter to produce gas for cooking also reduce emissions of carbon-dioxide as they produce less than wood fuel. Removing 'wet/moist' dung from the ground surface into the below ground

biogas plant also reduces the greenhouse gas; methane naturally given off when it decomposes, going into that atmosphere, as the methane produced is burned (Smith *et al*, 2007). For methane (natural gas), is a more dangerous greenhouse gas than carbon-dioxide, in other words more effective in acting like a blanket over the earth (Houghton, 2004). Practical Action, Bangladesh has successfully installed biogas plants near Dhaka and Faridpur. Those near Dhaka use poultry manure that would otherwise emit methane into the air (Hasan, *pers com* 2007).

3.5.6 Solar ovens are yet another way to cut down on the emissions from cooking stoves. As they consist of a metal box and the heat from the sun simply heats food inside (Carter, 1994). Using the SODIS (solar disinfecting) method for purifying water, basically leaving a bottle of filtered water in the sun for a period of time (Burgess, 2005), using a similar principle and again saves on greenhouse gas producing fuel wood, as would other kinds of gravity (such as sand or ceramic) water filters.

3.5.7 It should be noted that all these methods of cooking are commendable for a number of reasons: They improve the health by reducing smoke inhaled from stoves; save time gathering wood or boiling water and save money spent on fuel by households. Saving electricity used from the national grid is also an important activity in itself, as the country is suffering from a shortage and it would reduce power cuts/load shedding.

3.6 Agriculture

3.6.1 Agriculture results in about 10-12% of total global human caused emissions of greenhouse gases including about 60% of nitrogen dioxide and 50% of methane, as well as significant amounts of carbon-dioxide. Emissions also increased by nearly 17% from 1990 to 2005. In contrast to industrial emissions of greenhouse gases emissions from agriculture are rising faster in developing countries than in developed ones (Smith *et al*, 2007).

3.6.2 In South Asia emissions are growing mostly because of the expanding use of nitrogen fertilizers and manure to meet demand for food, resulting from rapid population growth (Smith *et al*, 2007). Food production is essential for the well-being of the nation of Bangladesh however there are some realistic actions that may be taken to reduce greenhouse gas emissions from this source.

3.6.3 Firstly organisations should all have family planning on their agenda, as an increasing population will require more intensive agriculture leading to more emissions from this source, as well as leading to increases from other sources of greenhouse gases such as transport.

3.6.4 There are also ways to reduce greenhouse gases by the way land is farmed. One way to do this is to reduce the amount of artificial fertilisers, pesticides and other chemicals used. It is also important to apply chemical fertilisers, compost or manure directly into the soil, digging it in, as well as applying only the amount needed, as too much fertilising will lead to excess nutrients which

soil bacteria will release into the air as greenhouse gases (Smith *et al*, 2007). Organic techniques such as using compost instead of chemical fertiliser will result in less greenhouse gases being produced (Bogner *et al*, 2007).

3.6.5 Another way to reduce the reliance on chemical fertilisers as well as increasing fertility of the soil is by growing leguminous crops in rotation with other crops (Smith *et al*, 2007). They naturally absorb nitrogen from the air through their roots to add nutrients to the soil. A step further is to use improved strains of the nitrifying bacteria that live of the roots of these plants. These bacteria stored in peat as stuck to the seeds at time of planting with a natural adhesive such as 'rice water' and can increase yields by up to 200% without chemical fertiliser, manure or compost inputs. The Bangladesh Institute for Nuclear Agriculture has developed especially beneficial strains of nitrifying bacteria, also known as biofertiliser for groundnut, chick pea, soya beans, cow peas/*boroboti*, mussorie and kassurie lentils/*dals* (Sattar, 1997). Thus with this technique costs and greenhouse gas emissions can be reduced, while crop harvests are increased.

3.6.6 Although increasing rice production can be beneficial by increasing soil carbon stocks and taking carbon dioxide from the air. Rice production is also an area where different cultivation techniques could reduce greenhouse gas emissions. For cultivated wetland rice soils emit significant quantities of methane. In fact 82% of emissions of methane from rice production occurred in South and East Asia. Emissions during the growing season can be reduced by various practices: By draining wetland rice once or several times during the growing season; especially by keeping the soil as dry as possible and avoiding water logging outside the rice growing season; by adding compost, manure and other organic fertilisers in the dry season, not the wet season; and by using the rice straw for biogas (Smith *et al*, 2007). In southern Bangladesh where much rice cultivation relies on groundwater irrigation, there are concerns that as many of these water supplies are arsenic contaminated they are reducing yields (Sanyal & Naser, 2002), and accumulating in rice posing a threat to human health (Huq *et al*, 2006). So this strengthens the case for growing rice under 'aerobic' or moist rather than wet conditions. The former director of the Seventh Day Adventist Development Programme in Bangladesh (*pers com*, 2004) also claimed that by growing rice under dryer conditions harvests were increased.

3.6.7 Burning the stubble/stalks after rice or wheat harvesting contributes to climate change in several ways: Firstly, it releases greenhouse gases, notably methane, tropospheric ozone, nitrogen dioxide (the carbon dioxide released in this situation is reused by new plants so is not a problem) and aerosols; secondly fires reduce the reflectiveness or 'albedo' of the earth's surface for several weeks causing warming; Finally, burning can kill trees and bushes beside farms that takes the greenhouse gas carbon dioxide from the air during photosynthesis (Smith *et al*, 2007). In Bangladesh therefore the rice stalks would be better collected and composted or ploughed back into the soil. This management would additionally improve the quality of the soil for agriculture.

3.6.8 Agroforestry is the practise of combining forestry and farming on the same piece of land. As it includes shelter belts of trees or buffer strips, such as

besides roads and ponds with woody species. The standing stock of carbon above ground is usually higher than the same land use without trees, and planting trees may also increase soil carbon sequestration (Smith *et al*, 2007). So the added trees reduce global warming by absorbing carbon dioxide.

3.6.9 A further way to mitigate global warming is the cultivation of bamboo which is the fastest growing canopy for the re-greening of forest lands, but can also be grown in small plots or on field edges; with plants giving out 35% more oxygen then wood trees. Some bamboo can even absorb up to 12 tons of carbon dioxide per hectare from the air! Bamboo trees which are really a kind of giant grass send out extra shoots as they grow, so even after removing the weaker ones, eight more bamboos will be growing by the time the main plant is ready to be cut. As bamboos also enrich the soil increasing its fertility through their fallen leaves. In Bangladesh bamboo is used for building and other uses, but in Vietnam, bamboo has become a very valuable through processing into flooring material so further potential exists for its usage here (Doney & Wroe, 2006).

3.7 Trees and Forests

3.7.1 Forests play an important role in the climate system. They are a major reservoir of carbon, containing some 80% of all the carbon stored in land vegetation, and about 40% of the carbon residing in soils. Large quantities of carbon are emitted into the atmosphere when forest land is cleared. But regeneration and growth reabsorbs it. Forests also directly affect climate on the local, regional, and continental scales by influencing ground temperature, evapo-transpiration, surface roughness, albedo (or reflectivity), cloud formation, and precipitation (Williams, 2002).

3.7.2 However, during the 1990s forests were being cut down at a rate of 150,000 km² per year but only 50,000 km² per year was being planted leading to a total loss of 940,000 km² of forested land throughout the world, which means approximately 1,200,000,000 tonnes entered the atmosphere as carbon dioxide (Houghton, 2004). Tropical deforestation is estimated to contribute 20-25% of world global carbon dioxide emissions each year as forests in warmer regions contain more carbon containing trees and wildlife (Greig-Gran, 2006), so tropical and sub-tropical nations can play a major part in climate change mitigation by cutting emissions by preventing deforestation and planting more trees (AFP, 2007).

3.7.3 Bangladesh was once densely forested but this has been cleared for timber, converted to agriculture or cut for firewood. In recent times the speed deforestation has increased with forest cover shrinking from 18% in 1927 to a mere 6% today. In fact forest cover per person at around 0.022 hectares is one of the lowest ratios in the world (Gain, 2002b). So while Bangladesh's industrial contribution to global warming has been small its contribution through deforestation has been large.

3.7.4 A tropical or subtropical forest absorbs a lot more carbon dioxide into its leaves than a temperate one, typically from 100 to 600 tonnes per year, for

every square kilometre (Houghton, 2004). Therefore Bangladeshi NGOs can make a huge difference in preventing climate change by campaigning and taking other practical steps to preserve forests. Society for Environment and Human Development (SEHD) has been campaigning for the protection of Modhupur Forest to help prevent the loss of this severely threatened Sal Forest, but also for the benefit of the indigenous people such as Garos and Koch who depend on traditional medicine from it (Gain, 2005a). Other NGOs in the Chittagong Hilltracts and Sylhet should likewise be involved in advocacy to preserve forested land and the lives of the people who depend on it. Involvement could mean lobbying government, replanting areas or providing alternative livelihoods for those who threaten the forests through their activities.

3.7.5 There is huge potential for tree planting, forest protection and agroforestry in Bangladesh to mitigate climate change. Furthermore the presence of trees and forests benefits communities in many ways such as: Adapting to climate change impacts, maintaining natural resources and promoting sustainable development (Nabuurs *et al*, 2007). The Church of Bangladesh Social Development Programme has been distributing over 20,000 fruit, medicinal and timber trees to poor households per year in Meherpur District which will mitigate against global warming by absorbing carbon dioxide, but also improve nutrition, health and income respectively. Roadside plantation has also been one way to increase tree cover in a densely populated district where no natural woodland remains; as has promoting fruit orchards and tree nursery establishment have been other achievements. Even trees used for timber is good for the carbon is stored in buildings, and wood fuel reduces the use of greenhouse gas emitting fossil fuels, while gases from wood fuel are re-absorbed by new seedlings planted.

SECTION 4: CLIMATE CHANGE EFFECTS ON BANGLADESH

4.1 Overall Scenario

4.1.1 In terms of the impact of climate change few places in the world will experience the range of effects and the severity of changes that will occur in Bangladesh, which will include: Average weather temperatures rising; more extreme hot and cold spells; rainfall being less when it is most needed for agriculture, yet more in the monsoon when it already causes floods; melting of glaciers in the source areas of Bangladesh's rivers altering the hydrological cycle; more powerful tornados and cyclones; and sea level rise displacing communities, turning freshwater saline and facilitating more powerful storm surges.

4.1.2 As Bangladesh is one of the most densely populated countries on the planet at about 142.9 million people at a density of around 994 persons per km² (Habib, 2006), any climate induced change or disaster inevitably affects millions of people. Bangladesh is already one of the poorest places on earth with around half the population below the poverty line, yet according to McSmith (2006),

the cost to Bangladesh of changes in climate could be more than half the US$58 billion that the country has ever received in foreign aid!

4.1.3 Bangladesh is also among the most disaster prone countries in the world. It has suffered 170 large scale disasters between 1970 and 1998. The frequency of flooding episodes is growing, with catastrophic 'once in a generation' floods occurring more regularly. This includes eight major floods between 1974 and 2004, many of which are considered by hydrologists to be at a size expected only once in every 20 years. Increasingly severe disasters will play an important part in that calculation for even without serious climate change, between 1907 and 2004 a natural disaster survey group recorded 137 cyclones and 64 floods with the estimated loss to those affected was worth US$30 billion which is equivalent to four years national budget of Bangladesh (Ahammad & Baten, 2008) and disasters like these are predicted to increase in number and severity.

4.1.4 However, if people are to play a part in reducing the impact of climate change through climate change adaptation methods or through disaster mitigation measures, there must be a detailed up-to-date awareness of the predicted effects of climate change and where these will take place throughout the country.

4.2 Temperature

4.2.1 According to IPCC's Fourth Assessment Report all of Asia is likely to warm this century and warming in South Asia is likely to be above the global average at around 3.3ºC (Christensen *et al*, 2007).

4.2.2 Other studies have also predicted all seasons to get warmer within the Ganges-Brahmaputra-Megna Basins, with an increase in extreme temperatures. Temperatures are expected to warm slightly slower in Bangladesh than for other areas in the Ganges-Brahmaputra-Megna basin which is estimated to be 1.2 ºC warmer by the 2020s and up to 2.4 ºC by the 2050s. But warming is still predicted to be significant from 0.9 ºC to 1 ºC by the 2020s and 1.6 ºC to 2 ºC by the 2050s. This warming is predicted to be more pronounced from December to May, with for example average winters in the 2050s being around 1.9-2.4 ºC warmer compared to summers in the 2050s being 1.4-1.8 ºC warmer in Bangladesh (Tanner *et al*, 2007).

4.2.3 Extreme weather events have also been observed to be increasing in South Asia and can exacerbate mortality. In 2003 heat waves that killed 1539 Indians and cold waves that killed 1156 Indians are suspected to be linked to climate change (Akhtar, 2007). In the last 10 years severe cold waves have become common in Bangladesh (Roach, 2005), temperatures as low as 5ºC were recorded in January 2007 which were the lowest in 38 years in Bangladesh and also affected the north of India and Nepal killing over 130 people (Reid *et al*, 2007).

4.2.4 However, many more people could be affected by climate change's impact on disease, and a number of diseases in South Asia may become more common

due to hotter weather and changing rainfall patterns (Kovats & Alam, 2007). In Bangladesh a study of the Chittagong Hill Tracts has indicated that increased temperatures due to climate change in this already high rainfall area will increase the number of cases of malaria. This pattern is likely to be repeated in other areas of Bangladesh in the north and east. In 2002; 598 people died from malaria in Bangladesh, but yearly deaths will become much higher due to temperature rise as a result of climate change (Alam *et al*, 2007). Climate change is also likely to produce better conditions for Dengue Fever in Asia, which could lead to the disease spreading out to other areas of Bangladesh from its stronghold in Dhaka. While warmer sea-surface temperatures along coast of Bangladesh would support higher phytoplankton growth. These phytoplankton blooms provide excellent habitats for the survival and spread of infectious bacterial diseases such as Cholera (Cruz *et al*, 2007).

4.2.5 The effect of temperature on agriculture is complex due to a number of interplaying factors: However, while higher Carbon-dioxide levels and solar radiation theoretically can increase food production, heat stress, shorter growing seasons and higher evapo-transpiration resulting in soil moisture levels being lowered counteract the former influences leading to overall lower production of most foodstuffs such as most varieties of rice, wheat and potato. Reductions in yield could potentially be as high as a 17-28% decline for rice and 31-68% decline in wheat production (Karim *et al*, 1999). So 8% smaller rice harvests and a 32% smaller wheat harvests by 2050 now look likely (IPCC in Reid *et al*, 2007). Evapo-transpiration and moisture loss from soils as a result of hotter weather will be most severe during the post-monsoon and pre-monsoon seasons especially considering already diminishing rainfall in winter and erratic rainfall patterns, particularly in the north-west of Bangladesh (Ahmed, 2006). Most affected of all will be the *Rabi/Pre-Karif* growing season from December-March where evaporation already exceeds the unpredictable rainfall at this time, where soil moisture is stored from previous seasons' rainfall and water stress is already severe (BCAS *et al*, 1994).

4.2.6 Increased temperatures in the water bodies of Bangladesh may also impact on fisheries, such as by advancing the sexual maturation process of *Hilsa ilisha* fish and the timing of their spawning leading to a decline (Ali, 1999). In terms of impact on livelihoods and the economy most affected by a rise in surface water temperatures would be Bangladesh's coastal shrimp farming industry, for if the temperature goes above 32ºC, the small shrimp fries would have high death rates. Warmer water would also encourage algal bloom which reduces shrimp growth (Ahmed, 2006). Increased ocean temperature and thus changing ocean currents as well as increased water acidity due to more dissolved carbon dioxide, may additionally affect the marine fishing industry of Bangladesh by reducing catch size: For greater ocean acidity makes it harder for fish and other ocean creatures to develop skeletons and shells and may stop the growth of corals which provide nurseries for commercial fish, as well as reducing numbers of important fish foods such as plankton and snails (Stern, 2006).

4.3 Rainfall

4.3.1 Over South Asia, the summer is dominated by the southwest monsoon, which occurs from June to September and influences the seasonal cycles. However, according to the IPCC's Fourth Assessment Report, climate change is likely to weaken the monsoonal flows and the large scale tropical circulation; this could affect rainfall patterns, such as the time it occurs each year. Furthermore a warmer, moister atmosphere is also likely to lead to heavier rainfall during the monsoon (Christensen *et al*, 2007). According to the IPCC Distribution Centre rainfall in South Asia is predicted to increase by 5-7 per cent in the 2020s, 10-13 per cent in the 2050s and 15-26 per cent in the 2080s (Tanner *et al*, 2007).

4.3.2 A variety of different studies all point to average rainfall increasing in Bangladesh during the summer monsoon by around 1-4% by the 2020s, and 2-7% by the 2050s (Tanner *et al*, 2007). As can be seen from the range of estimated percentage increases predicted, experts are not sure on the amount of extra rainfall expected but all agree that a wetter Bangladesh is likely in the monsoon due to more rain.

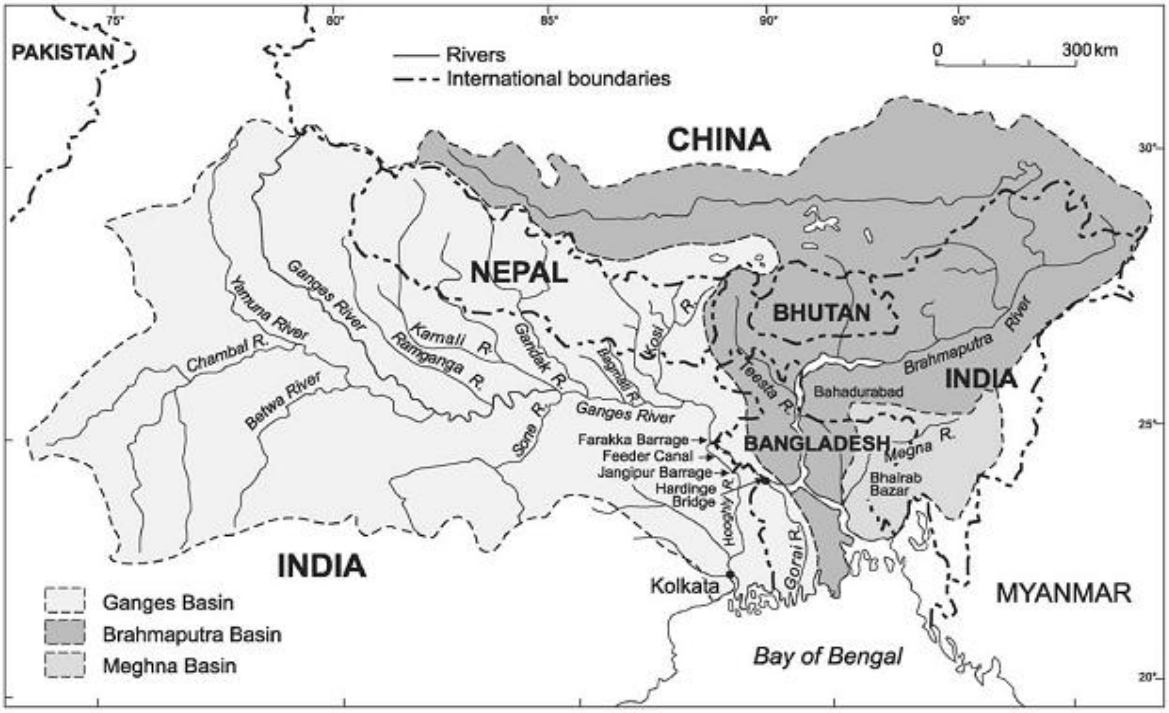
4.3.3 Likewise the studies also agree in predicting slightly less rainfall in winter months though it could slightly increase initially with estimate averages indicating that rainfall will increase slightly by around 3% in the 2020s, but decrease by around 3-4% by the 2050s. The winter drying trend is less certain than that for increasing rainfall in the monsoon (Tanner *et al*, 2007).

4.3.4 In the Ganges-Brahmaputra-Meghna basin as a whole the increase in rainfall in the monsoon is predicted to be larger from around 4-8% by the 2020s and 9-10% by the 2050s, while winter rainfall is expected to reduce by 4-5% by 2050 (Tanner *et al*, 2007). The combined total catchments of these rivers from where rainfall drains into these rivers totals about 1.74 million km² and the amount of water coming through Bangladesh varies from less than 5000 cubic metres per second in the driest period (March-April) to 80,000-140,000 m³/s in late August to early September. Therefore higher rainfall outside of Bangladesh in the monsoon is likely to lead to more frequent and severe floods from swollen rivers, while less rain in the winter will mean less water in rivers in the dry season affecting river fed irrigation, industry, fisheries, travel by launch/ferries and increase salinity around the coast (Alam, 2004).

4.3.5 As only 7% the catchment of these major rivers lies inside Bangladesh, it is also vulnerable to extraction for irrigation and hydroelectric schemes further upstream. The Ganges/Padma River is particularly affected and in India, barrages control all of the tributaries to the Ganges and divert roughly 60% of river flow to large scale irrigation. India also controls the flow of the Ganges into Bangladesh with over 30 upstream water diversions and the 5th largest dam in the world; the Farraka Barrage only 18km from the Bangladeshi border was shown to reduce the average monthly flow by 86%! As India's 'garland of rivers' project aims to build many more dams as well as seek to interlink rivers and divert water from the Ganges and Brahmaputra Rivers to its drier southern states. Despite the 1996 Ganges Water Sharing Treaty with Bangladesh the amount of water entering the smaller, less powerful

Bangladesh is expected to be further reduced due to climate change and accentuated by India's irrigation and electricity generation plans (Wong *et al*, 2007). This is likely to increase political tensions between the countries and may lead to conflict at least diplomatically.

Figure 5. Ganges/Padma, Brahmaputra/Jamuna and Megna Basins (Mirza, 2002).



4.4 Flooding

4.4.1 Bangladesh is situated on a low-lying flood plain made up of the lower reaches of the Ganges (known in Bangladesh as the Padma), the Brahmaputra (known in Bangladesh as the Jamuna) and the Megna rivers. As about 60% of the country is lower than 6 metres above sea level with an average river gradient of only 6cm/km in the delta Bangladesh is very vulnerable to large volumes of water flowing down these rivers and other types of flooding. Annually around 20% of the country is temporarily flooded but in extreme cases this may rise to as high as 70% of the country (Mirza, 2002). In the past the seasonal floods were seen as a blessing bringing fertility in the form of deposited silt onto farmland, but due to population pressure the poorest-of-the-poor have been pushed onto flood prone land and environmental damage is making floods more severe.

4.4.2 There are four main types of floods in Bangladesh: flash floods, river floods, rain floods and coastal storm-surge floods. Flash floods occur in the eastern and northern rivers, along the borders of Bangladesh. They are identified by a quick rise in water level and high speed of water flow, as a result of exceptionally heavy rainfall occurring over neighbouring hills and mountains in India (Mirza, 2002), and tend to occur between April-May and between September-November (NAPA, 2005). One result of increased rainfall in the monsoon due to climate change is likely to be more flash flooding in the Sylhet and Chittagong Divisions as heavy rainfall leads to a rapid rise and fall in river levels as it flows quickly down from the hills (BCAS *et al*, 1994).

4.4.3 River floods from the spilling of major rivers and their tributaries and distributaries generally rise and fall slowly over 10–20 days or more and can cause extensive damage to property and the loss of life. Depth and extent of floods and associated damage are extensive when the major rivers reach their peaks simultaneously (Mirza, 2002), during June to September (NAPA, 2005). River floods have caused the most devastating floods in Bangladesh with extreme floods occurring in 1974, 1980, 1984, 1987, 1988, 1998, and 2004. They are often triggered when high volumes of water flow down two or all three rivers at around the same time (Tanner *et al*, 2007). The effects of climate change will mean that about 18% of current lowly flooded areas will be susceptible to higher levels of flooding, and about 12-16% of new areas will be at risk of flooding of various levels. While in an average year flood prone areas will increase from 25% to 39% (Ahmed, 2006).

4.4.4 Rain floods are caused by high-intensity local rainfall of long duration in the monsoon. From year to year, the extent and depth of rain water flooding varies with the monsoon, depending on the amount and intensity of local precipitation and current water levels in the major rivers that control drainage from the land (Mirza, 2002). The warmer wetter monsoon as a result of climate change is likely to increase floods caused by rainfall runoff because it is expected that the rain will fall in more intense bursts. High rainfall over short time periods can be very devastating as was shown by a record-breaking one-metre of rainfall in just 24 hours in August 2005 that flooded parts of Mumbai to a depth of 3 metres. Schools, banks, the stock exchange, and the airport all had to be closed, while hundreds of cases of dysentery and cholera

were recorded as a result of contaminated water (Stern, 2006). Cities like Mumbai and Dhaka are particularly at risk due to poorly regulated development that has resulted in poor drainage systems and the concreting over of most of the land surface. Residents of Dhaka comment that only moderate rainfall that previously drained away easily through the many former canals and open spaces, having no effect on the city, now cause serious flooding in the capitals streets halting traffic and making movement difficult. A massive health crisis occurred during the flood of 2004 as sewage mixed with floodwater spread all over Dhaka putting 10 million people at a high risk from water-borne diseases. Sewage sludge was gushing out of manholes in many parts of Dhaka, and diseases such as acute respiratory infections, diarrhoea, dysentery, jaundice, typhoid and scabies were being reported (Alam & Rabbani, 2007).

4.4.5 Storm surge floods occur in the coastal area of Bangladesh, which consists of large estuaries, extensive tidal flats, and low-lying islands. Storm surges generated by tropical cyclones cause widespread damage to property and the loss of life in coastal area (Mirza, 2002). They are not the result of rainfall but of sea water being pushed inland by the strong winds of a cyclone.

4.4.6 Extensive floods particularly affect the poorest-of-the-poor in the country who lose whatever assets they have and suffer from lack of work and wages. In fact people who live in areas which regularly flood have low levels of health, nutrition and education. Floods also contribute to the concentration of landownership due to distress sale by the poor in the post-flood situation to the richer people in the community (Chowdhury, 2002). Therefore increasing floods due to climate change are likely to increase the poverty of those already poor as well as threaten those so-called 'middle poor' or those working class people just above the poverty line with becoming 'ultra-poor'.

4.4.7 However, floods also affect everyone from rich to poor with over 30 million in 52 of the 62 districts (Mirza, 2002), including a third of the population of the capital Dhaka affected in 1998 (Tanner *et al*, 2007). For the floods have a huge impact on industry such as in 1998 when 111,000 industrial units and 110 textile mills were closed down (Chowdhury, 2002), with losses of roughly 160,000 million Taka. While the highest death toll was 2,379 people in 1988, followed by 1,987 people in 1974 and 1,657 people in 1987 (Tanner *et al*, 2007).

4.4.8 Extreme floods like those in 1988 and 1998 are expected to occur as 50-100 year events (Ahmed, 2006) but environmental damage including climate change is thought to be making them occur more often, they are expected to become even more common in the future due to global warming. The next magnitude of flood down, the 20-50 year flood such as in 2004 are expected to increase by 2.5% with a 2ºC rise in average temperature (Mirza, 2002), so by 2050 instead of every 20-50 years they are expected to occur every 4-20 years

4.4.9 Food supply will be another problem caused by river floods; for the 1998 flood reduced agricultural production by 45% (Ahmed, 2006). It will also affect on rural incomes, where agriculture still employs 70% of the population. High-yielding *aman* rice varieties are very easily destroyed by floods as they

are unable to grow fast enough to keep up with the increasing depth of flood water and if the flood water rises faster than 4-5cm deep per day other rice varieties will also be lost. Monsoon vegetables also die when under water (Karim *et* al, 1999).

4.4.10 *Boro* rice on the other hand, cultivated in the winter usually gives a very good harvest after a high flood in the previous year, due to a good supply of moisture and the growth of blue–green algae. However, other climatic changes due to global warming such as temperature rise and carbon dioxide levels may reduce *boro* rice harvests by 4% by 2050 (Karim *et* al, 1999) and arsenic contaminated irrigation water increasingly necessary in the expected dryer winters will also significantly reduce *boro* harvests (Jahiruddin, *et al* 2005). The quality of floodwater may also be reducing, threatening rice production, including the bumper harvests of *boro* rice after flooding. For instead of depositing silt, that boosts soil fertility, floods are now carrying more sands which often cover whole fields making them useless for agriculture (Chowdhury, 2002), probably from bare deforested hillsides upriver. Heavier rainfall on these hillsides and greater flooding due to climate change may make further reduce floodwater quality.

4.4.11 Flooding increases the risk of diseases by extending the range of vectors such as mosquitoes, bacteria and other pathogens as well as by washing agricultural pesticides into drinking water (Walter & Simms). Leading to water-borne diseases including cholera and the diarrhoeal diseases caused by organisms such as *Giardia*, *Salmonella* and *Cryptosporidium* (Cruz *et al*, 2007), as well as chemical poisoning. A recent study found that extreme climatic conditions enable the water living cholera bacteria *Vibrio cholerae* to rapidly multiply and spread more easily. Floods caused by heavy monsoon rain can contaminate drinking water with the cholera bacterium, while in droughts, the cholera bacteria can grow better in the stagnating water in ponds and rivers (Haq, 2005).

4.5 River Bank Erosion

4.5.1 Higher volumes of water flowing down rivers due to climate related changes such as increased rainfall and summer glacier melt will also increase the erosion of land beside Bangladesh's rivers. As most of the country is made up of soft silt soils riverbanks are very washed away by river currents and wave action. River bank erosion includes channel shifting, the creation of new channels during floods, bank slumping due to undercutting and local scour from turbulence caused by obstruction (Ahmed, 2006).

4.5.2 The Bangladesh Water Development Board estimated that 1,200 km of riverbank has been actively eroded and more than 500 km has been facing severe problems related to erosion, and every year despite some deposition of silt, a net area of 8,700 hectares of land was being lost (Ahmed, 2006). The Christian Commission for Development in Bangladesh estimate that a million people are pushed off their land by river erosion each year and many of these end up permanently displaced (Christian Aid, 2006). Increased river erosion

due to climate change is therefore expected to displace more and more people from their homes and farms.

4.6 Drought

4.6.1 Every year Bangladesh experiences a dry period for seven months, from November to May, when rainfall is normally low. During this period about 2.7 million hectares of land in Bangladesh are vulnerable to annual drought; and according to the Government of Bangladesh there is about a 10% probability that 41-50% of the country experiences drought in a given year (Tanner *et al*, 2007).

4.6.2 Devastating and regular droughts caused by a lack or a late/early arrival of rainfall happens very often in many parts of Bangladesh, badly affecting agriculture. Drought impact, associated with late or early monsoon rains or even complete failure of monsoon, spreads over a much larger geographical area than areas affected by other natural hazards. Bangladesh experienced major droughts in 1973, 1978-79, 1981-82, 1989, 1992 and 1994-95 and the foodgrain production lost in the 1978-79 drought was probably 50 to 100% more than was lost in the great flood of 1974, directly affecting 42% of cultivated land showing that drought can be as devastating as a major flood or cyclone. Rice, jute and other crops were greatly affected and livestock also suffered. More recently the droughts of 1994-95 in the northwestern districts of Bangladesh led to a 3.5 million tonnes shortfall of rice and wheat production while the 1997 drought caused a around 1 million tonnes of foodgrain, of which about 0.6 million tonnes was transplanted *aman* rice valued at around US$500 million to be lost (Selvaraju *et al*, 2006).

4.6.3 Rice is the main crop in Bangladesh covering 80% of the total cultivated area of the country and is important both in terms of the nutrition and income it gives to the people of Bangladesh. However, drought can affect the rice crop in three different seasons: Firstly *Pre-Karif* droughts in March and April prevent land preparation and ploughing, delaying the planting of crops during the monsoon season; secondly *Karif* droughts in July and August delay the transplantation of *aman* rice in highland and medium high areas, as well as in Modhupur Tract and western Rajshahi Division, while *Karif* droughts in September and October reduce yields of both broadcast and transplanted *aman* rice and delay sowing of pulses and potatoes in the west of Rajshahi Division and along major rivers. Meanwhile *Rabi* droughts in winter months affect *boro* rice, wheat and other crops grown in the dry season, most severely in the Barind Tract and west of Khulna division, severely in areas of the Chittagong Hilltracts, southern Sylhet Division and other parts of Rajshahi Division and slightly in remaining areas of western, northern and central Bangladesh (Selvaraju *et al*, 2006; Agricultural Research Council, 2005).

4.6.4 Already climate change is thought to be increasing the numbers of droughts for there were only five devastating droughts in the hundred years from 1800 to 1900, yet since 1981, four major droughts have occurred in the last 25 years mostly in northwestern Bangladesh (Selvaraju *et al*, 2006). The area affected is also expected to get larger during droughts, for example the area severely

affected by *Rabi* droughts could increase from 4000 km² to 12000 km² as global warming increases (Huq *et al*, 1996).

4.6.5 While the progressive development of groundwater for both water supplies and agriculture has meant that dry season water availability in recent years has been less of a problem and has even allowed dry season agriculture to become the main source of increased food production over the past 20 years in Bangladesh (Tanner *et al*, 2007). Groundwater supplies that have allowed large areas of Bangladesh to become irrigated, can not be taken for granted. For as well as having a direct impact on rainfall sustained agriculture in the dry season, reducing rainfall in Bangladesh during its winter months will also reduce the annual refilling of groundwater storing aquifers. This has huge implications for groundwater based irrigation which is already experiencing difficulties in different parts of the country in sustaining supply due to over-extraction of water and insufficient refill in the monsoon. For the Survey and Monitoring of Groundwater Project has shown that the reducing groundwater levels mean that already 46% of cropland irrigated through shallow-tubewells can not draw enough water to supply farms in the dry season (Roy, 2008). While deeper pump operated tubewells may help in the short term if groundwater levels continue to drop deeper and deeper in the dry season irrigating land will become harder and harder, with cost forcing out the poorer farmers quickest. Dryer districts on the western border with India, in Khulna and Rajshahi Divisions that experience a more 'continental' climate, will suffer the greatest.

4.7 Glacier / snow melt

4.7.1 Glaciers which are actually slow moving 'rivers of ice' cover about three million hectares or 17% of the mountain area of the Himalayas and they make up the third largest area of ice in the World after the ice in the North and South Poles. Himalayan glacial snowfields store about 12,000 km³ of freshwater and about 15,000 Himalayan glaciers form a reservoir which supplies rivers such as the Indus, Ganges/Padma and Brahmaputra. However, Glaciers in the Himalaya are melting much faster than before and they are now getting shorter in length faster than in any other part of the world and the total area of ice is expected to shrink from the present 500,000² to 100,000km² and glaciers may even completely disappear there by the year 2035 (Cruz *et al*, 2007).

4.7.2 In the Himalaya-Hindu Kush Mountains, meltwater from glaciers feeds seven of Asia's largest rivers, including 70% of the summer flow in the Ganges, which provides water to around 500 million people, including much of the population of Bangladesh (Stern, 2006). Therefore any change to the amount of water stored as ice in glaciers affects these rivers.

4.7.3 In the short term faster melting of glaciers is likely to increase water flowing down rivers like the Ganges/Padma in the spring and monsoon months (Stern, 2006), which already contributes along with rainfall to causing devastating river floods (Ahmed, 2006). This may be made worse by Glacial Lake Outburst Floods, that occur as ice melts and water build up behind natural dams in the mountain rivers, until the weight of water becomes too much, the

dam breaks and the water escapes down the river. The main damage is likely to be in mountainous areas such as Nepal in the form of powerful flash floods down the river valleys but large outbursts could possibly make river floods in Bangladesh even worse (Stern, 2006).

4.7.4 However, in the long term the shrinking and thinning of Himalayan glaciers will lead to shortages of water in rivers and rivers may disappear permanently in some places once the glacier has completely melted. Less ice melting into rivers is likely to make the effect of seasonal droughts even more severe (Stern, 2006).

4.8 Sea Level Rise

4.8.1 Due to various natural processes such as water flow between oceans, continental plate movement, and land surfaces rising or lowering sea level rise will vary geographically from place to place (Cruz *et al*, 2007). Processes not related to global warming in Bangladesh that are actively causing sea level rise include: 'Tectonic subsidence' which means that coastal Bangladesh is very gradually sinking due to the weight of the silt being deposited by its rivers and the continued rise of the Himalayas that is slightly tipping Bangladesh seawards; 'compaction of peat layers' which are soft layers of organic dead plant and animal material that are gradually being squeezed tightly together by the weight of the land above; and 'human activities' such as removal of water from the ground for irrigation which speeds up compaction and the building of dams, dykes, embankments and other measures to prevent floods, for these prevent new layers of silt raising the land level as older layers compact and sink (Mohal & Hossain, 2007).

4.8.2 Predictions on sea level rise in Bangladesh therefore vary depending on how natural processes and sea level rise are examined. Some think that the silt and other material being carried by Bangladesh's rivers and deposited as sediment will cancel out the effect of natural subsidence lowering the coastline, so that sea level rise will be more or less in line with global climate change caused sea level rise (Mohal & Hossain, 2007). So according to this view a net sea level rise would be between 18 cm and 59 cm by the year 2100 (Alley *et al*, 2007). Others however, believe that lowering of the coastal zone through subsidence could alone lead to relative sea level rises of 70 cm by 2050 and 1.2 metres by 2100 (Broadus, 1993). More assessments by the Bangladesh Water Development Board however, believe the combined effect of global warming and subsidence will only result in a net sea level rise of at the most 30 cm by 2030 (Jenkins, 2006) and 50 cm by 2100 (A. Jenkins *pers com*, 2008), by taking lower estimates for both. In conclusion sea level rise by 2100 can be realistically expected to be at least 40 cm higher than today's levels (Cruz *et al*, 2007) and possibly as high as 1 metre.

4.8.3 Likewise claims on how sea level rise will affect Bangladesh vary widely, with more recent reports using newer and better research data, such as the latest IPCC reports, showing a slightly smaller rise of sea level rise than previously predicted. Following Government of Bangladesh National Action Plan for Adaptation (NAPA) assumptions; recent estimates expect that land

permanently lost to the sea may amount to 3% and 6% of Bangladesh by the 2030s and 2050s respectively (Tanner *et al*, 2007). While if sea level rise reaches the 1 metre mark by 2100 over 10% of Bangladesh lies below this height (Singh, 2001). However, other reports that take into account the influence of the embankments, dykes or polders, of which there are 145 of a total length of 500 km (Tanner *et al*, 2007), as well as sedimentation are more conservative still and expect only 13% of land in the coastal zone will be covered by seawater due to sea level rise, although when a higher rainfall in Bangladesh is also taken into account 16% of land in the coastal zone is expected to disappear permanently under water by 2080, assuming a sea level rise of 62 cm. The most vulnerable areas along the Bangladesh coastline are the areas without polders like Patuakhali, Pirojpur, Barisal, Jhalakati, Bagerhat (Mohal & Hossain, 2007).

4.8.4 However, the IPCC were uncertain on the impact of the melting ice caps at the North and South Poles and their potential effects tend not to be included in predictions (Hodson & Hodson, 2008), but if worst fears are confirmed and the Greenland Ice Sheet eventually completely melts it would lead to a sea level rise of about 7 m, which would lead to most of Bangladesh disappearing under the sea (Alley *et al*, 2007). This means that sea levels could rise a lot faster in Bangladesh than presently expected.

4.8.5 Bangladesh has been ranked as the 3rd most vulnerable in the world to sea level rise in terms of the number of people and in the top ten in terms of percentage of population living in the low elevation coastal zone. Therefore the threat of the communities being forced away due to the effects of climate change is one of the most severe on earth (McGranahan *et al*, 2006). Currently almost 40 million live in the coastal areas of Bangladesh but depending on the rate of population growth, by 2080 when the situation begins to get more serious it could be between 51-97 million in this vulnerable area. In year 2050 assuming a sea level rise of 27 cm, around 26 million people will be at a low risk and almost 7 million will be at medium risk of flooding, of which 58% of these people will be from Khulna, Jhalokati, Barisal and Bagerhat districts. In year 2080 assuming a sea level rise of 62 cm, 17 million, 12 million and 14 million people are expected to be at low, medium and high risk respectively, of being permanently flooded by the sea (Mohal & Hossain, 2007).

4.8.6 'Drainage congestion' means that water flowing down rivers towards the sea is slowed down by various factors, very much like a 'traffic jam'. Drainage congestion is already a growing important problem in Bangladesh and is likely to be made worse by climate change (Tanner *et al*, 2007). Climate change will cause drainage congestion due to a number of factors: Firstly the higher sea water levels means the rivers' gradients are reduced in other words their 'slope' from the mountains to the sea is not as steep which will lead to higher river levels due to a 'backwater effect'; subsidence of earlier deposits of sediment may also slow the rivers' flow; siltation of estuary branches will block channels and make water flow more difficult; higher riverbed levels will mean they will not be able to transport as much water as quickly but there will be higher water levels in rivers; and reduced sedimentation in flood-protected areas will mean they do not rise in height to match the sinking effect of silt

subsidence. Generally all these factors linked to climate change will make drainage more difficult and gradually increase water logging problems. This will be made even worse by the expected rise in monsoon rainfall and its effect will be particularly strong in the coastal zone. This water logging will harm agriculture, make flooding worse and increase water borne diseases (NAPA, 2005). Drainage congestion occurs mainly from July to October when cultivation of transplanted *Aman* rice is damaged if water depth is more than 30cm for over 3 days (Mohal & Hossain, 2007).

4.8.7 The total length of the Bangladesh coastline is 710 km long (Mohal *et al*, 2006) and historically, the coastline has been undergoing erosion and deposition. However, the balance between the two is being affected by climate change, such as more powerful cyclones and a higher sea level; with the result that more erosion is likely to occur but less deposition of sediments. As a result for a 2 cm rise in sea level the coast may go back 2-3 metres a year or 80-120 metres by the year 2030, which means Cox's Bazar beach the longest in the world will completely disappear (Islam, 1994). In terms of area this means that 5,800 hectares of land could be lost to sea erosion by 2030 and 11,200 hectares by 2075, together with 13,750 tons of foodgrain production by 2030 and 252,000 tons of foodgrain production by 2075 (Islam *et al*, 1999). People will also be displaced, for example the island of Kutubdia, just off the coast of the southern district of Cox's Bazar, has shrunk by half in less than 50 years and is expected to vanish completely in another 70 years due to erosion, partly caused by the 1991 cyclone. 20,000 people from the island have been forced to move to a slum on the mainland and the remaining 150,000 may soon have to join them (Christian Aid, 2006).

4.8.8 Writing for the Los Angeles Times on February 21st 2007, Henry Chu visiting the coastal zone in Bangladesh wrote: "Global Warming has a taste in this village. It is the taste of salt. Only a few years ago, water from the local pond was fresh and sweet on Samit Biswas' tongue. It quenched his family's thirst and cleansed their bodies. But drinking a cupful now leaves a briny flavour in his mouth. Tiny white crystals sprout on Biswas' skin after he bathes and in his clothes after he washes them" (Rahman, 2007). This story highlights the issue of increasing penetration of saltwater through the groundwater and along rivers inland from the coast. Saline meaning 'salty' water intrusion into river flows and run off is increased by low river flow in the dry season, sea level rise and land subsidence (NAPA, 2005).

4.8.9 Currently, about 6.0 million people are already exposed to high salinity (>5 ppt), but due to climate change this is expected to increase to 13.6 million in year 2050 and 14.8 million in 2080 and the population in Khulna, Satkhira and Bagerhat will be most affected (Mohal & Hossain, 2007). This will be due to the boundary to the area of high salinity 'the salinity front' moving gradually north by 40 km (Mohal *et al*, 2006) to 60 km (NAPA, 2005) inland from the coast by 2100. But as well as making household water supply problematic, salinity negatively affects agricultural production and a study in Khulna, Bagerhat and Satkhira districts of southwest region of Bangladesh found that the suitable area for transplanted *Aman* rice cultivation will reduce from 88% to 60% with 32 cm rise in sea level and 12% with an 88 cm rise in sea level (CEGIS, 2005). Potentially increased salinity in coastal areas could mean that

659,000 metric tonnes of annual rice production could be lost due to climate change (Habibullah *et al*, 1999).

4.8.10 Sea level rise could potentially force around 33 million of their land by 2050 and up to 43 million of their land by 2080 (Mohal & Hossain, 2007) and this is only taking into account the direct effect of sea level flooding. If salinity, river gradient reduction, drainage congestion, erosion and other indirect effects of sea level rise are taken into account the almost the entire 51-97 million expected to be living in the coastal zone by 2080, may have to eventually leave their homes. The problem in terms of migration is that these refugees will have nowhere to go as by 2030 the small densely populated Bangladesh is expected to have 186 million people (NAPA, 2005) and every available patch of land is already farmed. While Dhaka already struggles to maintain basic services like electricity and sanitation as its population swells, and in Asia migration from rural areas is already responsible for 64% of urban growth (Cruz *et al*, 2007). Meanwhile neighbouring India is currently building a fence round Bangladesh so it can prevent further immigration, and has previously deported large numbers of illegal Bangladeshi immigrants.

4.8.11 Perceived 'empty' areas like the Chittagong Hilltracts with its Adivasi tribes will appear an attractive solution to a future climate change refugee crisis, despite the small percentage of cultivatable land there. Overpopulation and the political idea of having ethnic Bengalis in border areas, has already led to around 100,000 Adivasi tribes people being forced off their land to make way for the resettlement of 400,000 Bengalis in the hills and has already reduced the percentage of Adivasis in the Hilltracts to only just over half (Mohsin, 2000). Similar policies and processes have led to the loss of ancestral land by other ethnic minorities such as the Adivasis like the Santal and Oraon in the north-west of whom 85% are now landless (Gain, 2005b). Likewise the Garos in Halluaghat; made up 80% of the population in the north of Mymensingh District until 1964 when thousands of Bengali Muslim refugees came up down from Assam in India and others from the south, while the Garos were called communists and driven out by the Pakistani Government, with only half later returning, many to find their land now occupied by Bengalis (Robinson, 2002). These policies and processes may happen again if climate change displaces millions of Bengalis, furthermore many Adivasis are already vulnerable to climate change by being in drought prone, flood prone or hilly areas in Bangladesh.

4.8.12 The land and property of religious minorities may also be at risk from the migration of poor Muslim Bengalis driven from their lands and homes by the effects of climate change. Bengali Hindus in particular have been particularly targeted for bad treatment such as by the Pakistani army during the liberation war and by 'Bihari' migrants after partition from India. It is estimated that discrimination by employers against Hindus and low intensity hostility towards them by sections of the majority population, along with better opportunities in India has led to more than 500 Hindus on average leaving Bangladesh each day (Chowdhury, 2002). The so-called 'Hindu-belt' across southern coastal areas of Bangladesh will also be particularly hit by the effects of flooding and sea level rise, but Hindus will be more vulnerable due to

discrimination which will make it harder for them to rebuild their lives if climate change forces them to leave their land and homes.

4.8.13 In Bangladesh, women are more vulnerable than men generally to all kinds of disasters and climate related impacts due to gender inequalities in various social, economic and political institutions. Men tend to control income distribution, property, access to credit, decision-making processes, and sources of food. Women have limited access to and control over natural resources, or money and more importantly are less mobile and have limited access to information. When a cyclone and floods hit Bangladesh in 1991, the death rate for women was almost five times higher than for men. Men were able to warn each other as they met in public spaces, but they rarely communicated information to the rest of the family. Many women are not allowed to leave their homes without a male relative, and simply waited for their relatives to return home and take them to a safe place. Moreover, as in many Asian countries, most Bengali women have never learned to swim. In saline and drought prone areas where fresh water is in short supply further stress is put on women who have responsibility to supply it to their families; often being forced to walk long distances, risking their health and their safety in the process (ActionAid, Bangladesh in Reid *et al*, 2007).

4.8.14 Despite having a high human population Bangladesh still has a lot of wildlife especially in its wide variety of forests but climate change will put them under threat. Increased evapotranspiration, drought and moisture stress will harm the *Sal* forest in the Modhupur and Barind tract, while flash floods and erosion due to heavier rainfall will damage hill forest in Chittagong Division (NAPA, 2005), however, the Sundabans will be most severely affected (Ahmed *et al*, 1999). The biodiversity of Bangladesh's rivers, lakes and ponds is also particularly rich with over 400 species (NAPA, 2005) but many of these could also be affected by salinity and drought due to climate change.

4.8.15 The Sundabans is the largest mangrove forest in the world covering an area of about 1 million hectares of which about 60% lies within Bangladesh (Islam, 1994), with a rich biodiversity comprising the Bengal Tiger and Gangetic Dolphin both getting increasingly rare and in need of conservation, as well as 50% of all the bird species found in Bangladesh (Nishorgo, 2006). The Sundabans is already tidal and saline but with increasing sea level allowing saline water to penetrate further with tidal and storm surges; higher evapotranspiration due to hotter weather; and a reduction of freshwater in the dry season flowing into its rivers due to changing rainfall patterns; it is expected to get more saline (Ahmed *et al*, 1999). This will result in that the most biodiverse areas in the Sundabans will reduce from 60% to 30% in the year 2100 with 88 cm SLR (CEGIS). The forest floor may be experiencing a natural uplift due to sedimentation, but whether natural uplift is strong enough to counterbalance sea level rise is very uncertain. In a worst case scenario 32 cm of sea level rise may flood 84% of the Sundarbans possibly by 2050 and with an 88 cm sea level rise possible by 2100 the whole of Sundarbans will be lost (Mohal *et al*, 2006).

4.9 Winds and Cyclones

4.9.1 Cyclonic storms also known as typhoons, hurricanes or cyclones are common along the 700 km coastline of Bangladesh (Tanner *et al*, 2007) and severe cyclones currently occur at a rate of 1.3 per year with speeds as high as 275 km per hour (Chowdhury, 2002). But although only 1% of the world's total cyclones happen in Bangladesh it has sustained over half of the world's deaths from cyclones (Tanner *et al*, 2007). Most terrible was the 224 km/h cyclone on November 12th 1970 that killed at least 300,000 people and more recently the 225 km/h cyclone on April 29th 1991 that killed 140,000 people (Chowdhury, 2002). Cyclones occur all along the coastal zone of the south and south-east of Bangladesh usually in late May and in early November but wind risk areas stretch far inland (Islam, 1994). Most recently Cyclone Sidr with 250 km/hr winds and a tidal surge of 5 metres killed over 3000 people on November 15th 2007 (Gentleman & Ahmed, 2007).

4.9.2 As a result of climate change it is likely that future tropical cyclones will become stronger, with larger peak wind speeds and more heavy rainfall associated with ongoing increases of tropical sea surface temperatures (Alley *et al*, 2007). Cyclones are expected to become 10 to 20% more powerful if sea-surface temperatures rise by of 2 to 4°C in South Asia, therefore the number of devastating cyclones will increase (Knutson and Tuleya, 2004 in Cruz *et al*, 2007). Cyclones are expected to have 3% to 12% faster wind speeds by the 2020s, rising to 4% to 20% faster by the 2050s (Tanner *et al*, 2007).

4.9.3 Sea level rise and beach erosion due to climate change causing shoreline retreat, which will result in a larger basin area, will also increase the power of cyclones by increasing their path length. This will allow the cyclone to have more time in the water, acquire and release more latent heat, resulting in more energy, intensity and wind speed (Climate Change Cell, 2006).

4.9.4 Storm surges in which sea water is pushed far inland by the strong cyclonic winds are among the highest in the world (Huq *et al*, 1999) and are far more dangerous than the actual winds generated by the cyclone. Storm surges cause most of the deaths during cyclones as well as destroying peoples' homes and livelihoods; in fact it is the height of the surge rather than the power of the storm that makes a cyclone devastating or not (Chowdhury, 2002). This can be seen when the two most devastating cyclones of recent years are examined for the severe cyclones of 1970 and 1991 both had exceptionally storm surges of 7.6 and 6.75 metres respectively (Tanner *et al*, 2007).

4.9.5 The increased wind speeds resulting from higher sea surface temperatures due to climate change means that storm surge heights will increase from 15% to 25% in the 2020s and 32% in the 2050s (Tanner *et al*, 2007). A cyclonic storm similar like the one in 1991 would have a surge around a metre higher (Mohal & Hossain, 2007) and would penetrate up to 10 km further inland than at present to almost 50 km in places in a worst case global warming scenario (Tanner *et al*, 2007). This would mean that instead of the current 7.4 million people at risk of storm surge flooding for cyclones as powerful as the one 1991, nearly 15 million will be at risk by 2050. While the number of people at

risk of a storm surge flood over a metre in depth would rise from 2 million to 5 million by 2050 (Mohal & Hossain, 2007).

4.9.6 Hotter summers have also seen a rise in increase in the number of other damaging winds in Bangladesh namely: tornadoes and north-westerns. The north-westerns cause havoc with their accompanying hail storms destroying standing crops, while the tornadoes crumble everything in their paths (Roach, 2005). A 'tornado' is a violently rotating column of air which touches both the surface of the earth and a cloud. They are often in the form of a visible funnel whose narrow end touches the earth and are often surrounded by a cloud of debris. Most tornadoes have wind speeds between 40 mph (64 km/h) and 110 mph (177 km/h), and are approximately 250 feet (75m) wide, and travel only a few kilometres before dying out. But some attain wind speeds of more than 300 mph (480 km/h), stretch more than 1.6 km wide, and stay on the ground for more than 100 km. They are associated with thunderstorms in the autumn and spring when there is more chance of cooler air meeting warm moist air. As for cyclones an increase in sea surface temperature in the Bay of Bengal due to climate change will increase air moisture content, potentially fuelling an increase in tornado activity and other severe storms particularly in the cool season (Wikipedia, 2008). Bangladesh is particularly vulnerable as tornadoes are commoner here than anywhere else in the world killing around 179 people per year (Bhuiyan, 2004). Very powerful tornadoes in 1989 in Manikganj and 1996 in Tangail/Jamalpur districts however, killed over 800 and 500 people respectively, with crop and livestock losses also very high (Chowdhury, 2002). Unlike cyclones, tornadoes can occur anywhere in Bangladesh.

SECTION 5: CLIMATE CHANGE ADAPTATION

5.1 What is 'Adaptation'

5.1.1 The word 'adaptation' has evolved from the term 'adapt', which means 'making things/conditions/situations better by changing' (Ahmed, 2006). Adapting to changes around us to have a better way of life is a basic human response and due to the slow action of industrialised countries to implement mitigation measures to reduce their greenhouse gas emissions communities will need to adapt to the already inevitable effects of a changing climate. Adaptation to climate change is therefore the process through which people reduce the negative effects of climate on their health and well-being and adjust their lifestyles to the new situation around them. 'In a nutshell adaptation is being better prepared or adapting to climate change, not fighting it, but learning to live with it' (Rahman, 2008).

5.1.2 It is important to remember that any adaptation strategies undertaken will need to be holistic and take other community needs into account. For people's vulnerability is not only determined by climate change, but also by factors like population growth and access to resources for example (Klein, 2005). Furthermore although it is difficult to precisely predict climate change effects

in any given place, many adaptation policies make good sense even without climate change, for example improving natural resource management, bettering social conditions, and adapting to present day climatic variability including natural disasters are all vital for promoting sustainable development (SouthSouthNorth, 2006).

5.1.3 Adaptation actions are an essential and often overlooked part of the response to climate change; however they are not intended as a substitute for mitigation actions! For if runaway climate change is not stopped the cost of adaptation measures will rise higher and higher and the ranks of the poor and vulnerable will be increased (Rahman, 2002) due to an increasingly hostile environment. There may also come a point when due to the severity of climate change effects in many places, adaptation measures will be useless. Therefore Saleemul Huq (2007), at the 2nd International Workshop on Community Based Adaptation to Climate Change stated: "Mitigation is the best form of adaptation".

5.1.4 Due to their failure to quickly reduce greenhouse gas emissions and due to the United Nations Framework Convention on Climate Change that they have ratified Christian Aid (2007) point out that 'this means that all developed countries including the USA and Australia, are legally as well as morally obliged to help poorer countries adapt'.

5.2 Different Adaptation Strategies

5.2.1 There are a number of basic strategies that can be taken in response to climate change that categorise various ways to adapt to the altered situation. All of these strategies may be the right thing depending on time and place. However, the choice of strategy should ideally be one that allows the community to remain *in situ* and maintain similar or improved income if at all possible.

5.2.2 Islam (1994), in reference to adaptation in the coastal zone categorised strategies into 'retreat, accommodation and protection' in response to the effects of climate change: A strategy of 'retreat' would mean resettling the inhabitants elsewhere; abandoning structures in currently developed areas; and requiring that new developments should all be set back some distance from the sea or other potential hazard. A strategy of 'accommodation' would mean people continue to live in vulnerable areas but accept the risk, of for example greater flooding and converting their farms to fishponds. A strategy of protection would mean defending vulnerable areas, especially towns and villages, economic activities and natural resources. This includes building dykes, embankments and sea walls in coastal areas for example.

5.2.3 Rahman *et al* (1999), are more comprehensive, categorising adaptation strategies into 'bearing losses, sharing losses, modifying the threat, preventing effects, changing use, changing location and restoration': 'Bearing losses' means 'doing nothing' except accepting the losses, obviously the least ideal strategy as the poor in Bangladesh can barely afford any losses, but in practise due to lack of adaptive capacity this strategy is common; 'sharing losses' means those affected do not bear the full cost of the effects of climate change,

this may include insurance schemes as well as international aid; 'modifying the threat' includes changing agricultural cropping patterns or building a breakwater on an island to safeguard tourism and industries; 'preventing effects' usually requires pre-planning and investments such as the building of large embankments to protect from flooding; 'changing use' would mean a different use of resources such as growing shrimps in newly submerged areas; 'changing location' would be moving homes or businesses to safer area; and 'restoration' would be the repairing of an area damaged by the effects of climate change to its previous condition though this is not wise if the same effects are likely to be repeated soon.

5.3 Community Based Adaptation

5.3.1 A process that therefore starts in and with the local community and its adaptive capabilities is vital; especially as climate change adaptation is context specific (Alam, 2007). For as Helmer (2007), has observed: "Local people are the real experts" in terms of climate change, as they know about any changes that are occurring best, as well as having traditional responses to cope with many of them.

5.3.2 The key characteristic of local and indigenous knowledge is that their methods are locally appropriate, flexible and usually socially or environmentally responsible. Including this knowledge into disaster preparedness, climate change adaptation and the development process can contribute to local empowerment and build sustainability. However, the coping strategies of the poor are constrained by their lack of resources and information as well as organisational capacity (Mallick & Jilan, 2006). Their local strategies may end up therefore being either inappropriate to maintain their livelihoods in the longer term or may end up with the richer members of the community successfully adapting at the expense of the poor, as in a salinity affected areas in southwest Bangladesh (Pouliotte *et al*, 2006).

5.3.3 So according to Tanner (2005), while we do need to integrate local knowledge, communities do not hold all the answers. Therefore there is clearly a need to bring the scientific expertise on future climate changes and adaptation techniques, together with the experience, traditional knowledge and locally defined vulnerabilities of the community, so that the best information from both sources can be combined into a strong community based adaptation response.

5.3.4 Features of Community Based Adaptation include: Allowing the community to make choices and not having them imposed from outside; enhancing the ability of the community to have a wider range of choices in the future; climate risks are addressed together in a broader developmental framework; and it is a process that evolves over time, not a set of static assessments (Jones & Rahman, 2007).

5.4 Mainstreaming

5.4.1 Mainstreaming climate change adaptation into development thinking and practices has been recommended by many as a priority (Ahmed, 2006) and the Government of Bangladesh's National Action Plan on Adaptation has recommended mainstreaming adaptation to climate change into policies and programmes in different sectors (NAPA, 2005).

5.4.2 'Mainstreaming' is a commonly used term that means integrating or including a cross-cutting issue like gender or climate change into all aspects of development work carried out. For an issue such as climate change threatens the success of almost all development activities currently carried out in Bangladesh and will need actions across the whole range of development projects to address it. Basically climate change adaptation and mitigation measures will be needed in almost all areas of life and therefore development interventions.

5.4.3 Mainstreaming is important as it will mean that there will be consistency between climate change and poverty reduction efforts so that: Climate change adaptation will not work against poverty reduction and development policies; development policies do not inadvertently increase vulnerability to climate change factors; and it is guaranteed that climate change is treated as a centrally important issue with regard to human well-being (Tanner, 2005).

5.4.4 As most government and big donor projects are not considering the effects of future climate change (Alam, 2004), there is scope for those working in social development such as NGOs to get involved in campaigning for mainstreaming and giving technical assistance at district and upozila/sub-district level, as well as mainstreaming climate change within their own organisations.

5.4.5 However, there has also been criticism for example Murray *et al*, (2006) state that 'mainstreaming climate change adaptation into development policy and planning may not give it the attention it merits in certain circumstances.' While Douma (2007), said: "Mainstreaming is not enough, specific measures are needed too". Many have seen in relation to gender mainstreaming that if care is not taken the issue can get lost and all that is left is the jargon. Perhaps the issue is more about how mainstreaming is done.

5.4.6 So how might climate change as a key component as well as mainstreamed into all programmes look like in an organisation? The Church of Bangladesh Social Development Programme following an 'integrated community development' approach is in many ways typical of many organisations in Bangladesh. Its programmes though varying slightly from area to area typically include: People's Organisation Building, including empowerment, gender rights and cultural strengthening; Income Generation including microcredit and vocational training; Agriculture and Environment; Disaster Preparedness; Community Health; Education and Training including youth development.

5.4.7 How organisations arrange their activities into projects and programmes can vary but it is suggested that an enlarged Environment Programme renamed

perhaps ‘Climate Change and Environment Programme’ and including agriculture, disaster preparedness and training/awareness in relation to climate change is a good set up. While all other programmes must also purposefully include climate change perhaps by having a climate change project with various components within each programme or a climate change activity in each project. In this way climate change is addressed individually in its own right as a key issue as well as being mainstreamed into other areas of work in order to insure they are resilient to climate change or ‘*climate proofed*’.

5.4.8 In all that is done however, central aims must be to reduce the vulnerability and increase the adaptive capacity of communities or systems. *Adaptive capacity* is the ability of a system or community to adjust to the effects of climate change, therefore attempts must be made to reduce potential damages, to take advantage of opportunities, or to cope with the consequences. *Vulnerability* is the degree to which a community or system is susceptible to, or unable to cope with, the negative effects of climate change. Vulnerability will depend on the character, magnitude, speed of climate change, as well as the areas’ sensitivity, and its adaptive capacity (Adger *et al*, 2007). Vulnerability of communities will be reduced by direct measures to reduce the hazard or threat by ‘delivering adaptation actions’ (Stern, 2006) or indirectly through the increasing of their adaptive capacity.

5.4.9 The following sections aim to give some ideas of possible adaptation measures to include within the various areas of work development NGOs are usually involved in, this section will not include every one of the 228 measures possible outlined by IPCC Working Group II (Rahman *et al*, 1999), and there will be new ideas arising in the future, but hopefully it will help organisations get ideas to make a start in addressing the effects of a changing climate in Bangladesh.

5.5 Disaster Preparedness

5.5.1 A ‘hazard’ is an extreme event or occurrence that has the ability to cause loss of life or property and damage the environment. A ‘disaster’ is caused when a hazard affects a vulnerable community damaging life, assets of livelihoods beyond the community’s ability to cope. To avoid this situation ‘disaster mitigation’ are measures taken in advance of a disaster, aimed at reducing the adverse impact of the hazard upon people property and the environment. While ‘disaster preparedness’ measures are activities which increase people’s ability to predict, prepare for, respond to and recover from the effects of a hazard (Hansford, 2006).

5.5.2 As can be seen by the definitions above the terms used have the potential to cause confusion for at a community level; *disaster mitigation* measures are often the same as *climate change adaptation* measures, and are very different to measures to mitigate climate change which are actually to do with reducing greenhouse gas emissions. *Disaster preparedness* measures meanwhile are often the same as areas of *climate change awareness*.

5.5.3 As one of the effects of climate change is that many types of natural disasters will become more frequent and/or more severe. In fact according to Helmer (2002), 'the frequency and effect of disasters, particularly in the last decade, has increased at such an alarming rate that vulnerable populations do not always have the opportunity to recover from one disaster before the next on strikes.' In many ways 'disaster mitigation' measures already look very much like 'climate change adaptation' measures. But if disasters are to become worse or happen more often disaster management must also change to reflect that.

5.5.4 Perhaps the key is that presently disaster management focuses very much on disaster mitigation and preparedness in relation to current climate/weather variability but if it is to move up a level from 'disaster mitigation and preparedness' to become 'climate change adaptation and awareness' it must also take into account future climate change and variability as a result of global warming. So while actual measures look identical their scale may vary as the 'adaptation' ones are taking predictions on future climate change into account while 'disaster mitigation' ones are not. Stern (2006) explains that it is important that disaster risk assessments take new climate-change risks into account because otherwise, *mal-adaptation* can be the result. This was the case in Bangladesh where flood defences had been designed for lower levels of floods and were then poorly maintained, so that they were inadequate for the higher flood levels of recent years, becoming counter-productive; trapping and prolonging the floods of 1999 (Stern, 2006).

5.5.5 Effective early warning systems are a very good adaptation strategy for reducing death and damage due to disasters. Already Bangladesh has an effective early warning system that monitors cyclone formation and their track in the Bay of Bengal using satellite technology. Cyclone warnings issued well ahead of time then allow measures such as evacuation to cyclone shelters and concrete buildings. These measures have already saved thousands of lives during two severe cyclones in 1994 and 1997 (Alam, 2004), as well as more recently in November 2007 during cyclone Sidr, in which over half a million people were evacuated (Tiempo, 2008). However, early warning systems and responses to flooding need improvement (Alam, 2004). Early warning systems and responses, could also potentially be developed for other kinds of disaster: For example in India the M. S. Swaminathan Research Foundation has established an observatory managed by farmers with some technical assistance, and has an arrangement to receive medium range weather forecasts that can then be given to local communities (Nambi, 2007).

5.5.6 Physical measures are also effective and larger scale adaptation measures include: Creation and maintenance of polders/embankments to prevent flooding from surges and high river flow (Jenkins, 2006); dredging and re-excavation of blocked rivers, creeks or drainage canals; construction of drainage structures such as ditches, culverts, bridges and regulators/sluices; rehabilitation of roads and other infrastructure (Ahmed, 2006); controlled flooding in combination with compartmentalisation, in which certain areas are flooded preventing erosion and flooding elsewhere, as well as allowing nutrients in fresh silt to sediment onto the floodplain; desalination plants and equipment to provide salt free drinking water; cross dams to enhance the build

up of land through accretion and to reduce erosion (Alam, 2004); making buildings and homes stronger or raised on mounds or pillars to make them resistant to disasters (NAPA, 2005); gabion spurs along a river to deflect flood flows away from bankside houses (Practical Action, 2006); and better drainage systems, proper pollution/sewage disposal and improved urban planning in cities (Douglas, 2007), but which are also careful to safeguard the rights and livelihoods of poor slum dwellers (Satterthwaite, 2006).

5.5.7 Climate change adaptation measures that reduce a people's or areas' vulnerability to disasters can also be taken effectively at a smaller community based level, with minimal outside input: The Church of Bangladesh Social Development Programme has installed culverts through dykes/polders or under roads, constructed small bridges, built concrete raised flood/cyclone shelters and cleared ditches/canals of vegetation, or obstacles to improve drainage of water away from the community during floods (Dutta, 2007). Other possible adaptation measures include: Elevated food and seed storage facilities; the building of 'flood platforms' which are simple earth mounds providing safe elevated areas for people and livestock; designing and improving evacuation routes; terracing to prevent landslides and soil erosion or for water trapping in drought prone areas; building rainwater harvesting tanks/storage jars; mangrove/other tree conservation and planting programmes to prevent erosion; starting community seed bank development, in which local communities build up a safety buffer ready to face shortages during droughts or floods (van Aalst & Helmer, 2004); portable clay cooking stoves/chulas made that can be carried for use on dry ground during floods (Field Group 4, 2007); trained volunteers to organise evacuation to places of safety during disasters; and cages for fish culture for when floods cover fishponds allowing fish to escape or river flows are too fast for safe fishing (Practical Action, 2006).

5.5.8 A focus on disasters is important especially in a country like Bangladesh which faces them regularly in various forms. However, Cannon (2007) made the observation that actually "most people die early because of problems of everyday life", and it is the climate change trends such as increasing salinity or temperature and its affect on food production that will effect people the most in the long term in Bangladesh. A gradually changing climate and its significant but almost unnoticeable effects may therefore be more dangerous to life and livelihoods in the long term. It could be seen as one kind of slow-onset disaster and as Cannon (2007) highlights; between 1900 and 1999 only 10.7 million people were killed by rapid-action disasters, while 70 million were killed by slow-onset disasters! The focus of climate change adaptation therefore needs to expand from mainly focusing on [rapid-action] disaster management, to also covering the effects of gradual and relatively small changes in climate and weather, but which will have huge effects on communities, livelihoods, biodiversity, agriculture and health.

5.6 Community Involvement

5.6.1 Under the Community Based Floodplain Resource Management project the establishment of local institutions for sustainable development and then the

empowering and training of them to be effective was a high priority. For community based organisations are the number one priority for the sustainability of a participatory resource management initiative (Hussain & Reza, 2006). Climate change adaptation will need participatory community action on an even greater scale, so community based organisations are absolutely essential to facilitate this. Many development NGOs have already created suitable community organisations through their Development Groups, Village Organisations and Union Federations. These empowerment structures have already seen many poor mostly women villages trained up and highly motivated in encouraging social development in their communities. The Church of Bangladesh Social Development Programme is now seeking to use their energy and enthusiasm by using Group and Village Organisation leaders to carry out training, to put pressure on local government bodies to obtain their rights and in forming sub-committees on issues such as 'dowry and divorce' or 'sanitation' to improve situations in their localities.

5.6.2 It will not be a large step to start using them to also spread climate change awareness and to train or encourage people in using climate change adaptation measures. The Network on Climate Change in Bangladesh has gone even further in terms of community involvement with: Community seed stores being established in ten locations; facilitating the re/excavation of three 3 ponds; 34 village based youth brigades being formed; and the reconstruction of damaged dams by voluntary community labour (Kulsum, 2007). It has also tried to resource communities through workshops; the establishment of small libraries; a website; a data bank holding weather and climate records; and various publications (Habib, 2007).

5.6.3 Although the science of climate change is now well established, its predicted effects on communities are a fairly new issue for most people. The level of awareness on climate change issues is therefore rather low, especially in developing countries. However, awareness on climate change related matters is essential for looking at any meaningful adaptation. Stakeholders at different levels including communities need to know about climate variability, change, impacts and risks related to such issues in order to prepare for the coming changes (Uddin *et al*, 2006).

5.6.4 The Reducing Vulnerability to Climate Change Project funded by CIDA and implemented by CARE, Bangladesh is working with communities and institutions to raise awareness on climate change, adapt to environmental changes that could be exacerbated by climate change, and influence relevant policy. The project is working to at four levels: Household level, community level, institutional level and national level. At a 'household level' the project is improving the capacity of vulnerable households to adapt to climate change impacts by making them aware of new livelihood strategies, using a group-based approach. At a 'community level' local partner organizations are being trained to work with Union Parishads/councils and community leaders to increase their awareness of climate change impacts and to develop and implement community-level adaptation strategies. At an 'institutional level' the capacity of six local organizations is being built up in four areas: Collection and dissemination of information related to climate change; advocacy on salinity and its impact on potable water; and awareness

campaigns on climate change issues, using a flipchart that has been developed with over 50 pictures, illustrating the causes and effects of climate change and possible adaptation strategies, traditional folk songs, drama shows, posters and a series of radio programs will be developed, focusing on proven adaptation strategies. Local journalists are also participating in field visits and writing articles for national and regional newspapers. While Eco-clubs are conducting awareness sessions on climate change at the village level. An 8-session module on climate change has been developed (including a flipchart, easy-to-read book and teacher's handbook) and will be implemented within selected secondary schools starting in March 2004, by school teachers that have received training on the impacts of climate change and potential adaptation strategies. At a 'national level' the project will be advocating with national-level stakeholders to increase awareness of local climate change implications and local people's needs, focusing on lack of potable water due to salinity. (Thomalla, 2006).

5.6.5 A similar approach to CARE would be good in other areas of Bangladesh. Their focus on education is particularly important. As to create the community understanding needed for adaptation; building awareness among children and young adult who are often more open to change and can influence their families is likely to be a very effective process. Therefore climate related issues need to be included in the education system and as part of the routine curriculum of academic institutions. It is expected that continued education on relevant aspects of climate change mitigation and adaptation would help prepare a pool of national level experts, who in turn would provide critical services in future years to come (Uddin *et al*, 2006).

5.6.6 Any work to raise climate change awareness or to promote adaptation measures needs to prioritise women, for the poor are most vulnerable to climate change and 70% of human beings living below the poverty line worldwide are women. In addition as women are primary care-givers in times of disaster and environmental stress, these burdens are likely to make them less mobile, and therefore able to get to safety. Also, since climate change is expected to reduce scarce resources further, the time taken to fetch water or wood, usually the responsibility of women, will increase their workloads thus limiting their opportunities to use adaptation measures or start alternative income generation schemes (Röhr, 2006). Focussing on women's needs may include measures that men do not normally consider: Like providing sanitation facilities that can be used in disasters (Dutta, 2007) or providing swimming lessons as most Bengali women have never learned to swim, which significantly reduces their survival chances during floods or storm surges (Röhr, 2006).

5.7 Micro-finance

5.7.1 Microcredit has had a huge profile in Bangladesh, and internationally after the award of the Nobel Peace Prise to Mohammed Yunis the founder of this concept through the Grameen Bank. Many development NGOs such as the Church of Bangladesh Social Development Programme constructed its development programmes around the operation of microcredit. Microcredit

undoubtedly has its limitations, and is particularly criticised for not reaching the very poorest-of-the-poor who either do not qualify for credit or are unable to handle the credit when they receive it. However, for many of the poor of Bangladesh it has been a valuable tool in developing livelihoods and reducing their vulnerability.

5.7.2 Sadly though the many disasters that have occurred in Bangladesh in recent years have often killed livestock or destroyed businesses developed through microcredit. In these circumstances loan repayments need to be delayed, or cancelled and new loans will often be needed. Disaster relief and rehabilitation such as vegetable seeds may help families but they can not replace the hard work, effort and finance put into these small businesses. As disasters and other adverse effects of climate change will increasingly hit villages and urban areas in Bangladesh microcredit must adapt to maintain a useful tool to combat poverty.

5.7.3 Many developed countries have mature insurance markets that provide additional adaptive capacity by spreading the risks of extreme weather events across a large pool of individuals or businesses. However, the poor would not be served by insurance companies and in any case conventional insurance schemes that usually require those at greatest risk to pay more for their insurance cover, would penalise the vulnerable (Stern, 2006).

5.7.4 The answer to this is 'micro-finance' which is specially designed to provide insurance to the poor and vulnerable, indeed the Church of Bangladesh began its development in Meherpur District in 1984 with a fire insurance scheme, although it was eventually fazed out when brick houses with iron sheet rather than straw roofs became more common. Currently the big micro-finance NGOs Grameen Bank, BRAC and ASA are offering 'life insurance', while micro-insurance currently offered by a few other NGOs includes: Health insurance, livestock insurance, and fire insurance. However, the number of organisations working in micro-finance and the variety of micro-insurance is presently extremely limited (Khan, 2007).

5.7.5 Micro-insurance of this kind would be useful to poor Bangladeshis throughout the country who are especially vulnerable to climate change and could be expanded such as to cover crops, disability, or disasters (Khan, 2007). This kind of adaptation to climate change would also fit in very easily with existing microcredit and development group structures set up by many NGOs. It may even be possible to modify microcredit schemes so that as well as contributing to group savings when they pay back a loan, a certain proportion could be set aside for micro-insurance particularly relating to livelihoods. Alternatively group savings could perhaps be used by members for livelihood rehabilitation or adaptation following a disaster or a gradual change in local climatic conditions.

5.7.6 Microcredit itself could also be used as an actual tool of climate change adaptation and help communities reduce their vulnerability to climate change by diversifying their livelihoods and increasing their incomes. If individuals are also encouraged to consider future climate effect scenarios in their area, loans may be taken to adjust, 'climate proof' or change livelihoods to those

more appropriate and resilient to future situations. This may include: Changing from fish or crop farming to shrimp or crab farming, in areas threatened by increased salinity and flooding (Pouliotte *et al*, 2006); selling a more profitable product to boost incomes, such as banana chips in the Solomon Islands (Hunt, 2006); buying back mortgaged farm land to improve food security (Caritas, 2007); introducing an appropriate new livelihood such as reed cultivation and mat making (Thomalla, 2006); moving from chicken to duck rearing in flood prone areas; and making homes stronger or raising them above flood levels.

5.8 Health

5.8.1 Human health is another area where climate change awareness and various adaptation measures will be needed. The main threat will be an increase in waterborne diseases and heat stress. However, medical workers must monitor diseases such as Black Fever *Leismaniasis*, spread by the sand fly in dry areas in Rajshahi Division, that may become commoner in drought conditions and dengue fever and malaria that may spread throughout Bangladesh as conditions in the summer become wetter and hotter. Regular cleaning-up of sites where disease vectors like mosquitoes are found such as stagnant or polluted water will also be helpful to improve community health (van Aalst & Helmer, 2004).

5.8.2 Bangladesh is already vulnerable to outbreaks of cholera and other waterborne diseases but the effects of climate change will make these more common. Adaptation measures to this threat are well known and include the use of a mixture of lime, bleaching powder and alum to water to purify it (Ahmed, 2006), or according to the World Health Organisation even just bleaching powder. A good technique is to: Take a 300 ml soft drink bottle, then add two level spoons of bleaching powder, fill with water that is as clean water to the top, cork the bottle and mix well for two minutes, leave the bottle to stand for 1 hour, put in a dark place away from children, then add 3 drops of this solution for every litre of water, leave for one hour and then taste, you should just be able to taste the chlorine, if you cannot taste the chlorine, then add 1 drop per litre until you can have a light smell of chlorine, the water will only be safe to drink for 24 hours, so each day, make up only as much as you need for that day. If the water that you are using is very cloudy or dirty, then that will reduce the effectiveness of the chlorine. If this is the case, then it would be helpful to let the water settle overnight before using the chlorine. Pour the clear water off the top and throw away the settled water on the bottom. If you are collecting surface water with a kolshi/bucket/jar/other container, then if a piece of thin cloth such as an old sari is folded eight times and then the folded sari is put over the mouth of the container before you fill it with water. This will also help to reduce the amount of germs in the water (Phillips, 2004).

5.8.3 Other techniques for making water safe to drink that can be used in disaster or flood situations include a ‘vigorous, rolling boil for one minute’ (WHO, 1993), so in other words once it has started boiling strongly let it boil for a further 1 minute. Practises of boiling for 15 or 20 minutes in Bangladesh are simply unnecessary and a waste of fuel. Portable household filters such as

slow sand filters, the chuli water filter, or solar sterilisation using the SODIS method of leaving clear water in a plastic bottle in the sun for a minimum of 6 hours would also be recommended, particularly in flood or disaster situations (Peletz, 2007).

5.8.4 Reducing rainfall due to climate change in the west of Bangladesh will make people more reliant on shallow tubewell water and as many areas have dangerous levels of arsenic contaminating groundwater supplies alternative sources of water will have to be supplied in these areas such as: Deep tubewells, very shallow tubewells, dugwells, or household filters which are modified to contain iron filings, nails or iron-containing Sylhet sand. Awareness on avoiding arsenic containing water, encouraging nutrition or treatment for people who are suffering from arsenic poisoning will also be needed in these areas. Further concern is now also being raised about groundwater irrigation of crops in areas where arsenic contamination is high, as high levels of arsenic have been found in food from these areas; the *boro* rice crop is particularly affected in this way, so agricultural patterns will also require adaptation to techniques which require less water (Pender, 2005).

5.8.5 Saline contamination of drinking water in coastal and storm surge affected areas is another problem in relation to health. Deep tubewells and community or household rainwater harvesting tanks are the best solution (Ahmed, 2006). At the most basic if bamboo guttering were added to roofs buckets or clay jars could be used to collect water as this author observed villagers in a dry area in Ghana, West Africa doing in the rainy seasons.

5.8.6 Heat-stress related illness must be tackled by increased awareness especially in the hotter western districts in Khulna and Rajshahi Divisions (Ahmed, 2006). Heatwave action plans such as by authorities in France, Philadelphia, USA and Shanghai, China are one innovative way of addressing this threat to health and although so far it is local and national governments that have taken these initiatives there is no reason why NGOs and other community-based organisations cannot also have heatwave action plans that: Monitor the weather and keep people informed on forecasted hot weather; ask TV, radio stations and newspapers to publicised the upcoming conditions, along with information on how to avoid heat-related illnesses; promotion of a "buddy" system friends, relatives and neighbours are encouraged to visit elderly people during the hot weather and make sure they have sufficient water and proper ventilation to cope with the weather; set up a telephone "Heatline" to provide information and counselling to the public on avoidance of heat stress; mobile field teams make home visits to vulnerable households; shelters set up for high-risk individuals with ceiling fans or air-conditioned facilities; and measures to ensure an adequate supply of water to communities (Stern, 2006). Other climate change effect which relate to health could have similar plans prepared.

5.9 Environment

5.9.1 Very little research has so far been undertaken to fully understand how climate change will affect ecosystems and biodiversity in Bangladesh. However, it is

suggested that wildlife may be at greatest risk of all from the effects of climate change (Ahmed, 2006). Assisting natural systems to adapt to climate change is therefore vital if rare animals like the Bengal Tiger and important places like Bangladesh's rainforests are to survive.

5.9.2 Biodiversity and ecosystems are also often valuable economic natural resources; for example the Sundabans mangrove forest in the Southwest of Bangladesh is important for tourism, timber, and honey collection. In Bangladesh the honey harvest from the nests of the Giant Honey Bee *Apis dorsata* is estimated to be between 130 and 185 tonnes per years, while the wax harvest is estimated to be between 42 and 45 tonnes (FAO 2001). In Bangladesh there also traditionally a great reliance on 'Non Timber Forest Products' for food such as wild tree fruits, fish, and roots and tubers, during seasonal nutrition gaps known as 'hunger' or 'lean' periods and during disasters (FAO 1989). While natural habitats such as mangroves protected or planted as an adaptation measure to protect coastal communities from storms and cyclones have benefited the local economy by protecting it from loss (Stern, 2006).

5.9.3 As Bangladesh's most famous natural area the Sundabans is threatened by salinity proposed adaptation measures centre around supplying the area with more freshwater. Unfortunately these are costly infrastructure reliant options such as a Ganges barrage; diverting more water down the Gorai River; construction of closures on main river systems such as on the Pussur, Shibsha and Kobadak rivers; and improving channel drainage (CEGIS, 2005). Community level actions might include discouraging illegal hunting, cutting and fishing so that the ecosystem's natural ability to adapt is not limited and working with communities to encourage alternative adaptations to improve their ability to withstand climate change and to protect the forest.

5.9.4 The natural forests of Bangladesh elsewhere are now much reduced in size, fragmented into small patches of trees and of reduced quality due to forestry, hunting, and clearance for agriculture, due to both legal and illegal actions (Gain, 2002b). Coastal and wetland areas are meanwhile threatened by disturbance to wildlife, such as nesting birds, conversion to agriculture, over fishing, using fixed nets which catch and kill non-commercial species as well as undersize immature fish, and water pollution. In this condition the added stress due to a changing climate will result in trees/plants dying, soils eroding and species becoming extinct. In order to give biodiversity and ecosystems the greatest change advocacy must be put of government bodies to protect wildlife and ecosystems like wetlands and forests, as well as to expand the system of nature reserves and national parks.

5.9.5 Species of tree, bird and animal will need to move north to slightly cooler areas to survive as temperatures increase, and as natural habitats change in response, becoming less suitable for the wildlife living there. Therefore '*wildlife corridors*' which are belts of natural habitat such as trees or rivers that connect different areas of high biodiversity will be necessary and also possible to create at a community level by planting native species of tree along roadsides or by allowing wild plants and wildlife to flourish along river banks. In the Madhumati Floodplain of Chanda Beel, in Gopalgonj District such a

corridor has been established by rehabilitating 7.9 km of connecting canal that allows fish migration (Hussain & Reza, 2007).

5.9.6 Areas of natural wildlife habitat/ecosystems could also benefit by being expanded in size to preserve the genetic resources of animals and plants within them which enables them to naturally evolve and adapt more effectively. Adaptation measures that benefit both wildlife and communities by expanding areas of suitable habitat, include: Mangroves that reduce coastal erosion (Practical Action, 2006), native *Sal* forest plantations for timber (Choudhury & Faisal, 2005) reed sanctuaries to prevent erosion and benefit nature; and fish sanctuaries to allow source areas for fish to safely breed to improve fishing yields, as well as protect fish species and other wildlife such as wetland birds from local extinction (Hussain & Reza, 2007).

5.9.7 Community based tree plantation establishment has been shown to benefit communities in the short term with: Fuel, fodder for livestock, reduced erosion, flood prevention, storm wind control, more medicinal plants, and creation of job opportunities, such as for those growing seedlings in nurseries. Then in the long term after 15-20 years timber and fruit will be available for sale. While biodiversity also benefits through swamp grove and wetland restoration, enhancement of tree cover, an increase in numbers of birds, squirrels, bats and butterflies and the conservation of rare tree species (Faisal *et al*, 2005).

5.9.8 As therefore people rely on biodiversity and ecosystems for things like food, livelihoods and medicine there can be no excuse for any social development organisation not to include environmental conservation in its list of climate change adaptation actions.

5.10 Agriculture

5.10.1 Almost two-third of the 40 million strong labour force in Bangladesh is engaged in agriculture and related activities, which are largely nature and water-dependent. However, these are the sectors likely to be hit hardest by climate change (NAPA, 2005), for agriculture is Bangladesh is highly vulnerable to variation in weather patterns and is therefore extremely at risk from climate change, which will affect food security (Ahmed, 2006), particularly in the southern coastal and northern drought-prone areas of Bangladesh (NAPA, 2005).

5.10.2 Many in Bangladesh are already malnourished but a reduction in foodstuffs in the market such as caused by last year's floods and Cyclone Sidr as well as overseas events; lead to rapid increases in prices. According to Joachin von Braun Director General of the International Food Policy Research Institute, a family in Bangladesh that has $5 a day income typically spends $3 on food, but the recent increase in price of basic foodstuffs, some of which have risen by 50%, takes away $1.50 of their purchasing power, leading to under-nutrition (Newsweek International, 2008).

5.10.3 The adaptation strategy of 'bearing' or tolerating crop, fish or livestock losses is not really possible in Bangladesh (Ahmed, 2006) as most farmers are poor either growing for subsistence use or for very small profit margins. Many can not even survive one serious disaster, let alone regular disasters or permanent changes in weather due to climate change. Poulliotte *et al* (2006), have observed how financial difficulties due to climate change caused salinity increases, pushes poor farming families into adopting 'bad adaptation' or 'mal-adaptation' strategies such as: Selling or leasing their land to others; women and children becoming day labourers; decreasing food intake; selling livestock; and prostitution.

5.10.4 Sharing losses is potentially a good adaptation strategy, already occurring informally within extended families or in the sense of international disaster relief and rehabilitation in Bangladesh (Ahmed, 2006) but these are not satisfactory long term sustainable options for the poor, while micro-insurance is unavailable to most (Khan, 2007). Likewise change of location as a strategy is also not really possible for land resources per capita is already high and there is hardly any unproductive land due to Bangladesh's huge population density (Ahmed, 2006). However, some adaptation is possible along these lines by being creative with the little space that is owned such as growing vegetables on house roofs (Hussain & Reza, 2007), or by fencing fishponds and growing vegetables on their margins such as in Barguna District (*per obs*, 2008).

5.11 Agricultural Modification

5.11.1 Modifying the threats to crop production seems to be the most practised adaptation strategy in Bangladesh (Ahmed, 2006). UBINIG has developed a system of rice farming with its beneficiaries that involves sowing two varieties of rice in the same field, one that needs 8 months to mature but which can survive a relatively long period under water during floods along with a non-flood resistant variety which can produce a yield in only 4 months. The early crop is harvested while the 8 month duration rice crop is still growing, but because it is then still small damage is not done in harvesting the 4 month duration rice, then later the second crop is harvested. This system means that flooding is less likely to do so much damage to the rainy season crop (Osbourne, 2008).

5.11.2 'Wet bed no-tillage' is an adaptation that is used after loss of the *Transplanted Aman* rice crop has been lost due to tidal surge flooding. Water recedes late from the crop field and keeps soil muddy at the time of appropriate sowing of the next candidate crops and traditional land preparation is not possible. The aim of this adaptation is to cultivate relatively quick growing maize before the next winter *Boro* rice crop is sown. Its advantage is that it can produce food, fuel and fodder for communities and make valuable use of the land and compensate to some degree for incurred losses. The wet bed no-tillage adaptation technique has also been used for potato cultivation after *T. Aman* has been lost to flash flooding (NAPA, 2005).

5.11.3 Practical Action meanwhile has been working to develop saline tolerant rice varieties, through testing traditional varieties that used to be grown in soils with a high salt content. Their process was participatory; getting farmers to grow some or all 10 of the varieties being tested and then for the farmers to rank the types of rice that they grew according to certain criteria: Plant height, duration, grain quality, grain color, saline tolerance, and the grain yield. The best varieties were than promoted through farmer to farmer extension and awareness creation. Supporting adaptation techniques included: Leaving the lands fallow for some seasons and then washing away the saline topsoil during the early monsoon rains; digging deep canals in the field to drain the saline water away; and the use of organic matter (rice husks) to improve soil texture (Hettige, 2007).

5.11.4 Transplanted *Aman* is the major rice crop in the Barind tracts under rain fed conditions, but the crop is frequently affected by drought at different growth stages in varied intensities: Farmers start preparing seedbeds with the first rains in early June and transplant the seedlings in early July. Often transplanting is delayed by a month due to delayed monsoon onset, resulting in the crop facing drought conditions in October/November, and these weather patterns are likely to become more problematic with climate change. In this situation, farmers require an alternative seedbed method so they can start producing seedlings in June/July, even if there is delayed onset of monsoon (Selvaraju *et al*, 2006).

5.11.5 A number of adaptation techniques can be used: Firstly by raising 'mat type seedlings in trays' that results in less seed, water, labour and seedbed area being needed. In addition seedlings will be healthy and uniform in growth, uprooting of seedlings is very easy with less labour and cost involved, and seedlings can be protected from drought. Secondly a 'dry bed method' which is a system that of nurseries is prepared in dry soil conditions, can be used. In this method seedbeds of are prepared by raising the soil to a height of about 5-10 cm, a layer of half-burnt paddy husk or saw dust is then distributed on the nursery bed mainly to facilitate uprooting and then dry seed or seeds that just sprouted are sown in rows. Seedlings are short and strong, have longer root system than wet bed and are ready in 25 days. Thirdly, there is the 'Dapog' method in which: The ground surface is covered with banana leaves with the mid-rib removed, polyethylene sheets or any flexible material to prevent seedling roots from penetrating to the bottom soil layer. Then the seed bed is covered with a thin layer of burnt paddy husk or compost. Sowing with pre-germinated seeds uniformly on the seed bed to a thickness of two to three seeds follows and afterwards the germinating seeds are splashed with water and pressed down by hand or with a wooden flat board in the morning and afternoon for three to four days to prevent uneven growth. While too much watering is prevented. Less area is needed with this method, the cost of uprooting seedlings is minimal and very young seedlings from dapog nurseries have less transplanting shock than the ones from other nurseries making them more suitable for short duration varieties (Selvaraju *et al*, 2006).

5.11.6 Rice cultivation can also be modified in other ways: In irrigated areas food security could be improved by using the System of Rice Intensification (SRI) that can increase rice harvests by 50-100%; direct-seeded rice can allow more

reliable establishment of *rabi* crops on residual moisture immediately after the rice harvest, such as Chickpea or mustard, drought-tolerant and high-value crops; an earlier rice harvest can also be achieved by planting early-maturing rice varieties; drought tolerant rice varieties can be used; and if *T. aus* rice is harvested early, there is a possibility to grow a crop of short-duration *Chini atap* fine rice (Selvaraju *et al*, 2006).

5.11.7 Improving livestock rearing productivity has been done in a number of places as a climate change adaptation, such as in Nepal where improved breeds of goats are being promoted (Practical Action, 2006). Practical Action in Kenya has also focussed on livestock for they note that they provide food, income and drought security. Local breeds are hardy, but low in productivity, so cross breeding with non-native breed has maintained resilience, yet at the same time increased meat and milk production. Training local people as para-vets has complimented this work by improving animal health (Berger, 2007).

5.11.8 Livestock are frequently killed during natural disasters this is often related to lack of food for them, especially during droughts. In Ethiopia successive droughts have led to the death of large numbers of cattle, while increased population puts pressure on the land to support more households. Prolonged drought between 2000 and 2002 meant traditional pastures failed to re-grow and two-thirds of livestock died! Their adaptation method has led to the planting of indigenous trees that can survive in dry conditions and whose leaves can be fed to cattle in times of hardship, as well as establishing feed reserves by enclosing sections of grazing land for emergency use (Dadi, 2007). In Bangladesh CBSDP-Meherpur has planted *Acacia* along roadside as climate change adaptation for as its leaves and fruit can be fed to livestock, its branches used for fencing and it produces good timber (J.P. Biswas *pers com*, 2008). In India adaptation to a similar problem has led to the establishment of 'fodder banks' (Nambi, 2007).

5.11.9 Household vegetable garden or 'kitchen gardens' have been pursued by the Church of Bangladesh Social Development Programme as well as many other organisations as a means of improving community nutrition as well as providing homes with improved food security in the face of climate change. This will insulate them from rising costs of vitamin rich vegetables, especially following disasters when costs increase rapidly, even in areas not directly affected by the disaster in question. The idea of vegetable gardens can be improved upon further by encouraging types and varieties of vegetables which grow well under new situations resulting from climate change. For example in southwest Bangladesh communities are being trained to develop saline or salt water tolerant vegetable gardens (Pouliotte *et al*, 2006).

5.11.10 Use of organic manures and composts has long been used to improve the fertility and water-holding capacity of the soil. Water hyacinth *Eichhornia crassipes* is one new commonly available raw material that makes good compost. Application of organic manure or compost is an important climate change adaptation for soil applied with organic manure/compost can supply water to plants for 11 or 12 days, even without rain, while soil without adequate organic manure holds water for only 7 days in the high Barind Tracts (Selvaraju *et al*, 2006).

5.11.11'*Vermiculture*' that is the cultivation of worms to aid composting, is supposed to speed up the production of usable compost as well as improve its quality. Vermicompost is cheaper to produce than chemical fertilisers, does not harm the environment as it is natural, reduces weeds, improves soil aeration, improves soil texture, improves fertility, promotes better root growth, improves nutrient uptake by crops, makes transplantation of seedlings easier, as well as improving the water/moisture holding capacities of soils which is an important climate change adaptation. Typically, a one acre farm needs about four tons of 'biomass' or plant/animal material, which can be converted to about 2.5 tons of vermicompost. The vermicompost is produced from pits/troughs that contain the worms, usually 6000 to 7000 to a pit of 1 cubic metre in size. Two foreign species *Eisenia foetida* and *Eudrilis eugeniae* are best, although local Bangladeshi species *Perionyx exavatus* and *Perionyx sansibaricus* can also be used though slightly less efficient. 8 parts agricultural and household are waste mixed with 1 part cow dung and allowed to decompose for 2 weeks before worms are first added, if outside a thatched roof is needed as the pits need to keep moisture in the 40-50% range and a temperature of 20-30ºC. Then in a week 45kg of wet biomass can be converted to 25kg of vermicompost in only 1 week (Choudhury & Faisal, 2005).

5.11.12 Introduction of green manure crops into the existing *T. aman* rice cultivation system can also improve the fertility status and water-holding capacity of the soil. In the Barind tract there is an opportunity to introduce green manure crops which at 50 to 55 days old, could be ploughed into the soil just before transplanting of *T. aman* rice. The most suitable green manure crop for this purpose is *Sesbania rostrata*, a leguminous plant that can obtain nitrogen from the air (Selvaraju *et al*, 2006). In other areas of the country *Sespinia* known in Bengali as *Shola* is grown and then ploughed into the soil as green compost, this is quite a tall crop and can withstand flooding (T. Biswas *pers com*, 2008; and S. Vashist *pers com*, 2007).

5.11.13 Water conservation is another important adaptation to an increasingly drought-prone environment. In Rajasthan concrete rainwater cisterns about 3-4metres wide and 4 metres deep collect surface water from channels which run into the cistern in the rainy season have been built. Additionally rainwater '*bunds*' which are earth walls 1-2 metres in heights, built round fields following the contour lines, help to prevent soil erosion from wind and rain, as well as help to hold water in the soil by preventing rainwater from flowing away (Chadburn, 2007). In the dry Barind Tract of north-western Bangladesh another adaptation has been drip-feed irrigation of household vegetable gardens using old plastic bottles with a string inserted through a hole in the cap and leading to the base of the plant (Caritas, 2007).

Figure 6. Bottle drip-feed irrigation

5.11.14 Crop planting and harvesting times can also be changed that recognise changing climatic conditions (Nambi, 2007). For instance in the southern dry

zone of Sri Lanka it is now recommended that farmers delay their cultivation of vegetables by 2-3 weeks as rains are now coming later due to a changing climate, which would avoid the need for irrigation (Navaratne, 2007).

5.12 Agricultural Protection

5.12.1 The adaptation strategy of preventing adverse effects is anticipatory and might require large-scale investments. The building of large scale embankments or polders to protect valuable agricultural lands from excessive flooding is one such example (Ahmed, 2006).

5.12.2 River or canal bank stabilisation through planting various species of tree along the banks themselves, including fruit and fodder producing species and allowing reeds to grow along the margins of rivers, ditches and canals is a form of adaptation that plays a vital role in slowing down water erosion, which is a major threat to homes and agricultural fields. Species such as *hijal* and *karoch* have a slightly different role when planted along river banks as they indirectly prevent erosion by combating the wave actions that destroy homesteads (Faisal *et al*, 2005).

5.12.3 Coastal or riverside belts of salt tolerant trees including mangroves are an important adaptation to reduce the erosive impact of wave action (Practical Action, 2006) and saltwater intrusion. They benefit communities by: Protecting the fresh water supply from salt water, providing harvestable mangrove for firewood, they generate income from the sale of mature mangrove trees for timber and they have also created a carbon sink to mitigate climate change (Field Group 4, 2007). Belts of trees in dryer inland areas such as those planted along roadsides by CBSDP-Meherpur are also a useful adaptation, for by reducing wind flow across fields they reduce evapo-transpiration from crops and the soil, which prevents water loss.

5.12.4 Manual closing of soil cracks is one way to protect fields in the Barind Tract or Modhupur Tract where soils are clayey. As cracks are formed even when there are high moisture levels immediately after the disappearance of ponded water. Once surface cracks are formed, they become wider and very quickly expose the subsurface, leading to higher rate of evaporation and percolation of subsequent rainfall. Once cracks are allowed to form, twice the amount of water is required to close the cracks. Traditionally, farmers stirred the surface soil manually to avoid development of early cracks when the soil was nearing saturation. Such a practice known as '*ghata ghati'*, avoided development of cracks for a few days, even without rain and should be encouraged as a way to minimize the impact of dry spells during *T. Aman* rice season (Selvaraju *et al*, 2006).

5.12.5 Irrigation in dry areas is a further important climate change adaptation that may be done at a community level like the construction of small dams across streams (Lima, 2007), or digging or re-excavating mini-ponds (Selvaraju *et al*, 2006).

5.12.6 Irrigation is also being practised on a very large scale in Bangladesh's dry northwest, where the water table lies deep below the clay soils, by the Barind

Multipurpose Development Authority whose objectives include: Re-excavate canals, ponds and other water bodies as rainwater reservoirs; extend irrigation facilities through rainwater conservation; to irrigate crops using deep wells for groundwater extraction; and to channel water inland from the Ganges/Padma River for irrigation via a pipe line to the Sharmongla Canal (BMDA, 2007). The Authority has been very successful in increasing crop yields, as well as stimulating employment, that even improves the situation of the poorest-of-the-poor by making day labouring work a year round rather than a seasonal occupation. However, groundwater levels are dropping and there are concerns for the sustainability of the use of groundwater for irrigation, as well as suspicion that the irrigation by the Authority may be part of the problem (Pervez *et al*, 2007).

5.12.7 Fish cultivation is a very popular and profitable activity throughout Bangladesh but during floods water levels that overtop the ponds allow the valuable cultivated fish to escape, raising fish in cages common for Salmon cultivation in Scotland or the construction of banks, 'chicken-wire' fences or nets around the pond will stop at least the larger fish from being lost (CEGIS, 2005).

5.13 Agricultural Change of Land Use

5.13.1 In case it becomes extremely risky to continue existing agricultural activities under an altered climate scenario, an alternative land use might be considered as the next available option. However, such changes in land usage should ideally lead to acceptable economic returns, optimising social goods and services (Ahmed, 2006).

5.13.2 The cane climber 'Rattan' is one potential alternative source of income as they grow easily in seasonally flooded areas such as *haors* and floodplains, of which 11 species can be found in Bangladesh. The main marketable product of rattan is its stem which is 0.5-0.8cm in diameter and can grow as long as 25 metres. The pealed off outer stem provides an important raw material for cottage industries and is used for making baskets, chair seats and backs and for other handicrafts. While the tender shoot of rattan is used for cooking as a vegetable. These products have both local and export potential (Choudhury & Faisal, 2005).

5.13.3 '*Kochu*' also known as 'Arum', 'Cocoa Yam' or 'Taro' appears to be another alternative crop to rice in regularly flooded areas for it can tolerate water-logging and even after flooding unlike rice the crop can still be harvested from under the water (Ahmed, 2006).

5.13.4 '*Baira*' also known as 'floating gardens' are one of the best known agricultural adaptation techniques in Bangladesh and are an ancient form of 'hydroponics' which means 'growing plants in nutrient containing water but without soil'. As more than two-thirds of Bangladesh consists of wetland areas and seasonal flooding has covered large areas of land for centuries it is not surprising that this traditional adaptation to seasonal flooding has developed in the south of Bangladesh in Gopalganj, Pirojpur and Barisal

Districts. Rice straw was the main item for making a baira until 40 years ago but since then the water hyacinth plant has taken its place. Initially a bamboo pole the length of the required floating garden is places over a floating bed of water hyacinth, then more water hyacinth and other rotting 'aquatic plants' or 'plants that grow in water' are pulled together, after a week or so more decomposable plants like water hyacinth from the water bodies are piled on top, bamboo poles are used to keep the baira in place, then later either a ball or cushion made from aquatic plants or coconut husks are used to make a bed ready for seed planting. Either summer vegetables or winter vegetable seedings are cultivated on baira for sale and they simply rise and sink along with floodwaters. When finished with the material is used as compost. As floods are predicted to cover larger areas on a more regular basis due to climate change this technique is now being promoted outside the areas in which it originated (Irfanullah, 2005).

5.13.5 Intercropping is a method of farming in which two different crops are cultivated in alternate rows, and in terms of agro-forestry a line of trees or shrubs separates small strips or fields of crops. In Bangladesh the main use of intercropping has been for Mulberry *Morus sp.* which is a promising crop for dry areas which can come up well throughout the year, and is resistant to drought. Mulberry is mainly cultivated for the silk industry as silkworm larvae *Bombyx mori* are reared to produce silk cocoons by feeding them mulberry leaves. The silk industry is a labour-intensive industry providing jobs for both male and females. In addition the mulberry fruit can be harvested and rice in the monsoon season, wheat/mustard/garlic/chickpea in winter, and mung bean in pre-kharif can be intercropped with it (Selvaraju *et al*, 2006).

5.13.6 Mango and Jujube *Ziziphus jujube*, are alternative and promising crops to grow in drought risk areas in western Bangladesh. The region is known for its quality mango production and mango cultivation is increasing. The crop is drought resistant and many times more profitable than *T.aman* rice, while the inter-spaces in the young mango plantations can be intercropped with *T.aman* and *boro* rice. Jujube is a tropical fruit crop able to survive within a wide temperature range and is even more tolerant of drought conditions. The crop can be cultivated successfully in dry areas like the Barind Tracts with little irrigation and the Jujube can also be intercropped with *T.aman* rice (Selvaraju *et al*, 2006). Increasing the tree cover in this way is also an adaptation that will benefit other crops in the area by increasing local humidity levels and reducing evapo-transpiration and soil moisture loss due to reducing wind flow across fields.

5.13.7 Alley cropping is one intercropping technique that is very useful for improving poor soils, providing fodder for livestock, protecting the soil from heavy rainfall, and may also help to trap irregular rainfall in the soil, although not suitable for very dry areas. Alley cropping is a simple way of combining tree-growing with crops: Rows of '*leguminous*' trees species that are able to obtain the nutrient nitrogen from the air are planted about 5 metres apart, on sloping ground following the contours and in between the rows of trees, crops or vegetables are grown as usual. The trees, ideally of mixed species are planted close together so they form a hedge, which is cut down to 20-30cm

whenever it reaches 1-2 metres in height. Cutting can be used for animal fodder or compost (Carter, 2007).

5.13.8 The 'Zai technique' is a traditional agricultural practise that is particularly useful in poor infertile soils: Small pits measuring 20-30cm across and 10-20cm deep are dug, then two handfuls of crop waste or animal manure are placed in the pit and covered with a little soil, then when the rainy season arrives seeds are sown in the pits. These pits are useful because rainwater collects in them and they make the most effective use of small quantities of organic waster and manure. Although currently used for growing of sorghum and millet in Burkina Faso (André, 2007), this technique may also be suitable in the dryer Barind Tract and Modhupur Tract areas or for dry season agriculture.

5.13.9 Setting some land aside for a famine-reserve crop in the northwestern region of Bangladesh which is often hit by '*monga*' a seasonal famine condition where food is scarce and prices of whatever food is available are high. The vulnerable groups during *monga* are small and marginal farmers, farm labourers, women, children and old people, for after transplanting *aman* rice crops, the men and women have no work to earn money for investment in food. Cassava *Manihot esculenta* and yams *Diascorea spp*. can be suitable for cultivation as a famine-reserve crop on highland soils if they do not become waterlogged, especially on the high Barind Tracts where there are moderately light textured soils. These crops are drought resistant, can be cultivated with little water and can be grown on homestead land and raised cultivation platforms to provide families with an emergency food reserve in case of need (Selvaraju *et al*, 2006).

5.13.10 Increasing salinity in many inland areas may also require fish farmers to adapt by switching to salt tolerant species (NAPA 2005). More dramatically many rice paddies are being converted to shrimp farms as salinity pushes further and further inland from the coast. At one level this is a very effective and profitable adaptation and in Bangladesh, shrimp export is the third largest foreign exchange earning commodity, after garments and jute, contributing 9% 0f national export earnings. However, in terms of its current practise there are disadvantages in environmental terms as: Shrimp culture relies almost entirely on the collection of wild fry, with hatchery operations in only a very small minority of businesses; the collection of wild shrimp fry involves non target species also being caught but then discarded for example, it has been estimated that 10 kg of fish and shrimp larvae were destroyed for every 1kg of tiger shrimp fry caught in the Sundaban region of West Bengal; and in some areas mangroves have been cleared to make shrimp farms. There are also concerns in terms of their impact on the poor for: Shrimp farms employ less people than rice cultivation, so when rice paddy is converted to shrimp farms many day labourers will become unemployed; about 30% of fry collectors around the coast are women and girls and the people who work on the shrimp farms are mostly female who are forced to work for lower wages; salinity can be increased on lands of small and poor farmers next to shrimp farms due to the flow of saline water; and village livestock that formerly grazed rice stubble after harvest now have a lack of food (Hoq, 1999).

CONCLUSION

Many more adaptation techniques than those listed here need to be either transferred from other parts of the world or developed in the country, and then trialled in Bangladesh. There is also a need for organisations to disseminate their ideas and experiences among likeminded NGOs in Bangladesh. Furthermore continued research is necessary to determine more accurately future and present effects of climate change on Bangladesh. NGOs in particular with their community linkages should seek to do climate change vulnerability assessments and action plans for their respective working areas, as well as engage vigorously in advocacy for climate change mitigation both internally with the various layers of the Bangladesh Government and internationally through their partners and donors. It is hoped that this paper will assist Bangladeshi and international organisations to achieve some of these aims.

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