**Climate Change: Impacts, Vulnerabilities, Adaptations and Mitigation strategies: world, sectorial and regional**

**Lonkham Boruah**

**Climate Change: Introduction**

Rising fossil fuel burning and land use changes have emitted, and are continuing to emit, increasing quantities of greenhouse gases into the Earth’s atmosphere. These greenhouse gases include carbon dioxide, methane and nitrogen dioxide, and a rise in these gases has caused a rise in the amount of heat from the sun withheld in the Earth’s atmosphere, heat that would normally be radiated back into space. This increase in heat has led to the greenhouse effect, resulting in climate change. The main characteristics of climate change are increases in average global temperature (global warming); changes in cloud cover and precipitation particularly over land; melting of ice caps and glaciers and reduced snow cover; and increases in ocean temperatures and ocean acidity – due to seawater absorbing heat and carbon dioxide from the atmosphere.

**Vulnerabilities**

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) dispelled many uncertainties about climate change. Warming of the climate system is now unequivocal. It is now clear that global warming is mostly due to man-made emissions of greenhouse gases (mostly carbon dioxide). Over the last century, atmospheric concentrations of carbon dioxide increased from a pre-industrial value of 278 parts per million to 379 parts per million, and the average global temperature rose by 0.74° C. According to scientists, this is the largest and fastest warming trend that they have been able to discern in the history of the Earth. An increasing rate of warming has particularly taken place over the last 25 years, and 11 of the 12 warmest years on record have occurred in the past 12 years. The IPCC Report gives detailed projections for the 21st century and these show that global warming will continue and accelerate. The best estimates indicate that the Earth could warm by 3° C by 2100. Even if countries reduce their greenhouse gas emissions, the Earth will continue to warm. Predictions by 2100 range from a minimum of 1.8° C to as much as 4° C rise in global average temperatures Human beings have been adapting to the variable climate around them for centuries. Worldwide local climate variability can influence peoples’ decisions with consequences for their social, economic, political and personal conditions, and effects on their lives and livelihoods. The effects of climate change imply that the local climate variability that people have previously experienced and have adapted to is changing and changing at relatively great speed.

**The need for Adaptation:**

Adaptation is a process through which societies make themselves better able to cope with an uncertain future. Adapting to climate change entails taking the right measures to reduce the negative effects of climate change (or exploit the positive ones) by making the appropriate adjustments and changes. There are many options and opportunities to adapt. These ranges from technological options such as increased sea defenses or flood-proof houses on stilts, to behaviour change at the individual level, such as reducing water use in times of drought and using insecticide-sprayed mosquito nets. Other strategies include early warning systems for extreme events, better water management, and improved risk management, various insurance options and biodiversity conservation.

**Impacts:**

**Global:**

The major impacts and threats of global warming are widespread. Increasing ocean temperatures cause thermal expansion of the oceans and in combination with melt water from land-based ice this is causing sea level rise. Sea levels rose during the 20th century by 0.17 metres. By 2100, sea level is expected to rise between 0.18 and 0.59 metres. There are uncertainties in this estimate mostly due to uncertainty about how much water will be lost from ice sheets, for example Greenland is showing rising loss of landmass in recent years. Increased melting of sea ice and freshwater influx from melting glaciers and ice sheets also has the potential to influence global patterns of ocean circulation. As a result of global warming, the type, frequency and intensity of extreme events, such as tropical cyclones (including hurricanes and typhoons), floods, droughts and heavy precipitation events, are expected to rise even with relatively small average temperature increases. Changes in some types of extreme events have already been observed, for example, increases in the frequency and intensity of heat waves and heavy precipitation events.

Climate change will have wide-ranging effects on the environment, and on socio-economic and related sectors, including water resources, agriculture and food security, human health, terrestrial ecosystems and biodiversity and coastal zones. Changes in rainfall pattern are likely to lead to severe water shortages and/or flooding. Melting of glaciers can cause flooding and soil erosion. Rising temperatures will cause shifts in crop growing seasons which affects food security and changes in the distribution of disease vectors putting more people at risk from diseases such as malaria and dengue fever. Temperature increases will potentially severely increase rates of extinction for many habitats and species (up to 30 per cent with a 2° C rise in temperature). Particularly affected will be coral reefs, boreal forests, and Mediterranean and mountain habitats. Increasing sea levels mean greater risk of storm surge, inundation and wave damage to coastlines, particularly in Small Island States and countries with low lying deltas. A rise in extreme events will have effects on health and lives as well as associated environmental and economic impacts.

**Regional and Sectoral**

When we consider climate change on regional basis, we can see that Asia is also experiencing the effects of climate change on a wide range. The region faces formidable environmental and socio-economic challenges in its effort to protect valuable natural resources. Land and ecosystems are being degraded, threatening to undermine food security. In addition, water and air quality are deteriorating while continued increases in consumption and associated waste have contributed to the exponential growth in the region’s existing environmental problems. Furthermore, the region is highly subject to natural hazards, such as the 2004 Indian Ocean Tsunami, the 2005 Pakistan Earthquake, and the 2006 landslides in the Philippines. There is evidence of prominent increases in the intensity and/or frequency of many extreme weather events such as heat waves, tropical cyclones, prolonged dry spells, intense rainfall, tornadoes, snow avalanches, thunderstorms, and severe dust storms in the region. Impacts of such disasters range from hunger and susceptibility to disease, to loss of income and livelihoods, affecting human survival and well-being. For example the extreme weather events in China during 2006 included major storms and flooding in the east and south, as well as heat and drought in central, western and northeastern regions, killing more than 2700 people and causing USD 20 billion in damages.

Climate change will affect many **sectors (Sectoral),** including water resources, agriculture and food security, ecosystems and biodiversity, human health and coastal zones. Many environmental and developmental problems in Asia will be exacerbated by climate change. Under climate change, predicted rainfall increases over most of Asia, particularly during the summer monsoon, could increase flood-prone areas in East Asia, South Asia and Southeast Asia. In Central and South Asia, crop yields are predicted to fall by up to 30 per cent, creating a very high risk of hunger in several countries. Global warming is causing the melting of glaciers in the Himalayas. In the short term, this means increased risk of flooding, erosion, mudslides and GLOF in Nepal, Bangladesh, Pakistan, and north India during the wet season. Because the melting of snow coincides with the summer monsoon season, any intensification of the monsoon and/or increase in melting is likely to contribute to flood disasters in Himalayan catchments. In the longer term, global warming could lead to a rise in the snowline and disappearance of many glaciers causing serious impacts on the populations relying on the 7 main rivers in Asia fed by melt water from the Himalayas. Throughout Asia one billion people could face water shortage leading to drought and land degradation by the 2050s. In Asia, the principal impacts of climate change on health will be on epidemics of malaria, dengue, and other vector-borne diseases. The global burden of climate change-attributable diarrhoea and malnutrition are already the largest in the world in Southeast Asian countries including Bangladesh, Bhutan, India, Maldives, Myanmar and Nepal in 2000. Illness and death are expected to increase from diarrhoeal diseases due to drought and flooding, and are also expected from increased amounts of cholera bacteria in coastal waters. An increase in the frequency and duration of severe heat waves and humid conditions during the summer is likely to increase the risk of mortality and morbidity, principally in the old and urban poor populations of temperate and tropical Asia and high temperatures and poor urban air quality, such as in Chongqing, China and in Jakarta, Indonesia, could contribute to widespread heat stress and smog induced illnesses in urban populations.

In recent years, enormous pressures have been put on Asia’s ecosystems to support the ever growing demand for natural resources. The most affected areas are coastal and marine ecosystems, forests and mountainous regions and the flora and fauna within them. Climate change will have a profound effect on the future distribution, productivity, and health of forests throughout Asia, for example northeast China may become deprived of conifer forest. Grassland productivity is expected to decline by as much as 40-90% for an increase in temperature of 2-3° C, combined with reduced precipitation, in the semi-arid and arid regions of Asia.

Fisheries in both fresh water and sea water could be affected. Fisheries at higher elevations are likely to be adversely affected by lower availability of oxygen due to a rise in surface air temperatures. In the plains, the timing and amount of precipitation could also affect the migration of fish species from the river to the floodplains for spawning, dispersal, and growth. Sea level rise and changes in sea water temperature, salinity, wind speed and direction, strength of upwelling, mixing layer thickness and predator response to climate change have the potential to substantially alter fish breeding habitats and food supply for fish and ultimately the abundance of fish populations in Asian waters with associated effects on coastal economies.

Projected sea level rise could flood the residence of millions of people living in the low lying areas of South, Southeast and East Asia such as in Viet Nam, Bangladesh, India and China and 30 percent of coral reefs could be lost in the next 10 years. The loss may be as high as 88 per cent (59 per cent of global) in the next 30 years.

**Table 1: Regional and Sectoral Impacts and Vulnerabilities to Climate Change in Asia**

|  |  |  |
| --- | --- | --- |
| **Impacts Adaptive Capacity** | **Sectoral vulnerabilities** | **Adaptive Capacity** |
| Temperature  – Warming above the global mean in central Asia, the Tibetan Plateau, and northern, eastern and southern Asia. Warming similar to the global mean in Southeast Asia.  – Fewer very cold days in East Asia and South Asia. | Agriculture and food security  – Decreases in crop yield for many parts of Asia putting many millions of people at risk from hunger.  – Reduced soil moisture and evapotranspiration may increase land degradation and desertification.  – Agriculture may expand in productivity in northern areas. | Adaptive capacity varies between countries depending on social structure, culture, economic capacity, geography and level of environmental degradation.  Capacity is increasing in some parts of Asia, for example the success of early warning systems for extreme weather events in Bangladesh and the Philippines. However, capacity is still constrained due to poor resource bases, inequalities in income, weak institutions and limited technology. |
| Precipitation, snow and ice  – Increase in precipitation in most of Asia. Decrease in precipitation in central Asia in Summer.  – Increase in the frequency of intense precipitation events in parts of South Asia, and in East Asia.  – Increasing reduction in snow and ice in Himalayan and Tibetan Plateau glaciers | Health  – Heat stress and changing patterns in the occurrence of disease vectors affecting health.  – Increases in endemic morbidity and mortality due to diarrhoeal disease in south and Southeast Asia.  – Increase in the abundance and/or toxicity of cholera in south Asia. |
| Extreme Events  Increasing frequency and intensity of extreme events particularly:  – droughts during the summer months and El Niño events;  – increase in extreme rainfall and winds associated with tropical cyclones in East Asia, Southeast Asia and South Asia;  – intense rainfall events causing landslides and severe floods;  – heat waves/hot spells in summer  of longer duration, more intense and more frequent, particularly in  East Asia. | Terrestrial Ecosystems  – Increased risk of extinction for many species due to the synergistic effects of climate change and habitat fragmentation.  – Northward shift in the extent of boreal forest in north Asia, although likely increase in frequency and extent of forest fires could limit forest expansion. |
|  | Coastal Zones  – Tens of millions of people in low-lying coastal areas of south and Southeast Asia affected by sea level rise and an increase in the intensity of tropical cyclones.  – Coastal inundation is likely to seriously affect the aquaculture industry and infrastructure particularly in heavily populated mega deltas.  – Stability of wetlands, mangroves, and coral reefs increasingly threatened. |

*Source:* Christensen *et al*. (2007), Cruz *et al*. (2007)

**Adaptation Strategies**

Adapting to climate change will entail adjustments and changes at every level – from community to national and international. Communities must build their resilience, including adopting appropriate technologies while making the most of traditional knowledge, and diversifying their livelihoods to cope with current and future climate stress. Local coping strategies and traditional knowledge need to be used in synergy with government and local interventions. The choice of adaptation interventions depends on national circumstances. To enable workable and effective adaptation measures, ministries and governments, as well as institutions and non-government organizations, must consider integrating climate change in their planning and budgeting in all levels of decision making

Sectoral adaptation measures look at actions for individual sectors that could be affected by climate change. For example, in agriculture, reduced rainfall and higher evaporation may call for the extension of irrigation; and for coastal zones, sea level rise may necessitate improved coastal protection such as reforestation. Often adaptation measures in one sector will involve a strengthening of the policy that already exists, emphasizing the importance of including long term climate change considerations along with existing local coping mechanisms and integrating them into national development plans.

Adaptation to climate change must also occur through the prevention and removal of maladaptive practices. Maladaptation refers to adaptation measures that do not succeed in reducing vulnerability but increase it instead. Examples of measures that prevent or avoid maladaptation include: better management of irrigation systems; and removal of laws that can inadvertently increase vulnerability such as destruction of mangroves and relaxation of building regulations on coasts and in floodplains.

Parties to the UNFCCC have all agreed to undertake national adaptation measures and cooperate in preparing for the impacts of climate change. The UNFCCC plays an important catalytic role in promoting the development of adaptation strategies and plans. The UNFCCC secretariat developed a compendium on methodologies for assessing vulnerability and adaptation, and a database on existing local coping strategies to climate variability and hazards, which can be replicated in countries which are now facing similar threats as these but due to climate change. The Nairobi work programme is fostering knowledge exchange among the research and stakeholder communities to help countries make informed decisions on practical adaptation options. The initial activities of the Nairobi work programme during 2007 – 2008 involve workshops and reports on nine key areas of work: methods and tools; data and observations; climate modelling, scenarios and downscaling; climate related risks and extreme events; socio-economic information; adaptation planning and practices; research; technologies for adaptation; and economic diversification. Outcomes of the Nairobi work programme are expected to lead to enhanced knowledge on adaptation options at all levels and integration of actions into planning and sustainable development.

Table 2: Adaptation measures in key vulnerable sectors

|  |  |  |
| --- | --- | --- |
| **Vulnerable sectors** | **Reactive adaptation** | **Anticipatory adaptation** |
| Water Resources | -Protection of groundwater resources  – Improved management and maintenance of existing water supply systems  – Protection of water catchment areas  – Improved water supply  – Groundwater and rainwater harvesting and desalination | -Better use of recycled water  – Conservation of water catchment areas  – Improved system of water management  – Water policy reform including pricing and irrigation policies  – Development of flood controls and drought monitoring |
| Agriculture and food security | – Erosion control  – Dam construction for irrigation  – Changes in fertilizer use and application  – Introduction of new crops  – Soil fertility maintenance  – Changes in planting and harvesting times  – Switch to different cultivars  – Educational and outreach programmes on conservation and management of soil and water | -Development of tolerant/resistant crops (to drought,  salt, insect/pests)  – Research and development  – Soil-water management  – Diversification and intensification of food and plantation crops  – Policy measures, tax incentives/subsidies, free market  – Development of early warning systems |
| Human health | – Public health management reform  – Improved housing and living conditions  – Improved emergency response | – Development of early warning system  – Better and/or improved disease/vector surveillance and monitoring  – Improvement of environmental quality  – Changes in urban and housing design |
| Terrestrial ecosystems | – Improvement of management systems including  control of deforestation, reforestation and afforestation  – Promoting agroforestry to improve forest goods and services  – Development/improvement of national forest fire management plans  – Improvement of carbon storage in forests | – Creation of parks/reserves, protected areas and  biodiversity corridors  – Identification/development of species resistant to climate change  – Better assessment of the vulnerability of ecosystems  – Monitoring of species  – Development and maintenance of seed banks  – Including socioeconomic factors in management policy |
| Coastal zones and marine ecosystems | – Protection of economic infrastructure  – Public awareness to enhance protection of coastal and marine ecosystems  – Building sea walls and beach reinforcement  – Protection and conservation of coral reefs, mangroves, sea grass and littoral vegetation | – Integrated coastal zone management  – Better coastal planning and zoning  – Development of legislation for coastal protection  – Research and monitoring of coasts and coastal ecosystems |

Priority adaptation projects identified by NAPAs (National Adaptation Programme of Action) include:

• Improved forecasting for farming, extreme events and disaster management;

• Improved water management for drinking and agriculture through understanding water flows and water quality, improved rainwater harvesting and water storage and diversification of irrigation techniques;

• Improved food security through crop diversification, developing and introducing drought, flood and saline tolerant crops, improving livestock and fisheries breeding and farming techniques, developing local food banks for people and livestock, and improving local food preservation;

• Better land and land use management through erosion control and soil conservation measures, agro-forestry and forestry techniques, forest fire management and finding alternative energy sources to wood and charcoal, as well as better town planning;

• Coastal zone management including coral monitoring and restoration and improving coastal defences through afforestation, reforestation, set-back areas and vegetation buffers;

• improved health care through flood shelters and assistance shelters as part of community emergency preparedness programmes, better health education, better access to primary health care such as distribution of treated mosquito nets and better malaria surveillance programmes and habitat clearance;

• Capacity-building to integrate climate change into sectoral development plans, involving local communities in adaptation activities, raising public awareness and education on climate change, and enabling representation at international meetings;

• Promotion of sustainable tourism.

**Local Coping Strategies**

In Asia, farmers have traditionally observed a number of practices to adapt to climate variability, for example intercropping, mixed cropping, agro-forestry, animal husbandry, and developing new seed varieties to cope with local climate. Various water use and conservation strategies include terracing, surface water and groundwater irrigation; and diversification in agriculture to deal with drought. Structural and non-structural measures are used to deal with flood and coastal inundation. For example, in the Philippines, after Typhoon Sisang in 1987, which completely destroyed over 200,000 homes, the Department of Social Welfare and Development decided to instigate a programme of providing typhoon-resistant housing designed to withstand wind speeds of 180 km/h for those living in the most typhoon prone areas. In Bangladesh, the Cyclone Preparedness Program has been set up over 11 coastal area districts by the Bangladesh Red Crescent Society, and is partly funded by the government. Volunteers have been trained to help in cyclone warning, evacuation, rescue, first aid emergency relief and the use of radio communication equipment.