A Survey on Adaptation to Climate Change

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Abstract

In this 21st century, human civilization faces the toughest challenge to tackle the climate change for sustainable development. Civil society should adopt the climate change and reduce vulnerability for non-declining welfare. This paper reviews major papers on adaptation to climate change and provides an overview on the climate change and developing adaptive mechanism across the globe. Following major important articles this study provides clarity of the concept of adaptation, types of adaptation, measurement of adaptation, determinants of adaptive capacity, and also highlights on limitations and its possible future directions. Finally it concludes.

Key Words: Adaptation, Climate Change, Adaptive Capacity, Risk, Sustainable Development, Vulnerability.

JEL *Classifications*: O_{40}, Q_2, Q_3,

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1. Introduction

Climate change is the most severe problem that we are facing today. Climate change is one of the greatest threats to the human civilization and the toughest challenge for the economic development in the 21st century. Accumulation of fossil fuel consumption in developed countries during industrialization is the main cause of climate change in the world. They have contributed a lot to change the climate. Less Developed Countries (LDCs) have contributed negligible or little to cause climate change, yet face its harshest impacts and have the weakest capacity to adapt to these impacts. This chapter reviews adaptation and sustainability issues under climate change conditions.

1.1 Climate Change

Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time. Climate change refers to a change in average weather conditions, or in the time variation of weather around longer-term average conditions. Climate change is real, and the causal link to increased greenhouse gas emissions that is now well established (Coondoo and Dinda 2002). Globally, the ten hottest years on record have occurred since 1991, and in the past century, temperatures have increased by about 0.6^0 C (See, IPCC reports for details). In the same period, global sea level has risen by about 20 cm – it is partly due to melting of mountain ice and partly due to thermal expansion of the oceans. Scientific research finds evidences that in last two centuries anthropogenic activities have increased atmospheric greenhouse gases concentration that is more than pre-industrial levels. Only increasing pressure of greenhouse gas emissions and aerosol concentrations in atmosphere could explain the rising trend in temperature in last 100 years (IPCC reports).

Recent climate change is the result of human actions and specially from the burning of fossil fuels and land use changes. Development activities increase the atmospheric concentrations of greenhouse gases (GHG) – mainly carbon dioxide, methane and nitrous oxide. The GHGs are accumulated in the upper level of atmosphere and acts like the roof of GHG that is tapping solar long-wave radiation which raises temperature. It also provokes other forms of climate disruption and accelerates the process. This depends on a complex interplay of many factors, including rates of population expansion, economic growth and patterns of consumption. The effects are not uniform. The changes differ from one location to another. There are different weather consequences, while some regions have intense rainfall, others have more prolonged dry period and few areas have both.

1.1.1 Threats of Climate Change

As a consequence of continued global warming, millions and millions of people around the World are facing risk of flooding, droughts and debilitating diseases like Malaria, Dengue, Swine Flu, Chickengunia, Encephalitis, etc. Poor people in under developed nations are likely to be most vulnerable in health and their livelihoods. The social consequences also vary and it depends on level of development. There are different social impacts within the same society – heat stress affects older people more than young. Across the world and in every country those most at risk are typically the poor, and in developing countries those who depends most for their survival on a healthy natural environment, such as ethnic tribes, fishing communities, and livestock herders. There is still good chance of mitigating the bad effects of climate change through stabilizing atmospheric carbon dioxide concentration relatively at lower level which can be achievable target.

Taking action to tackle the climate change may provide better standard of living and may also create economic opportunity in terms of job creation or employment opportunity. We need to investigate all means of reducing atmospheric carbon dioxide concentration like sequestration, fusion, fuel cells, renewable energy, etc. Climate change is causing the earth's surface temperature to rise and increasing the prospect of extreme weather events. To some extent this affects everybody, but it is difficult to predict climatic event at a specific location and at particular point of time. It is certain that people living in fragile and difficult ecosystems become more vulnerable with risks to their health, their livelihoods. It is possible to adjust to most of these changes and to protect those most at risk.

1.2 Action for Adaptation

Already the World has considerable experience of many types of adaptation and knowledge that can fruitfully be shaped both within and between countries. The important lesson is that many measures are essentially social and political – people living in poor housing conditions, or living from small plots of land with poor soil and little water, have always suffered most from climatic extremes. The remedies are difficult but technologically they are relatively straightforward. Adaptation requires the application of technology. It is clear that all countries should devise national strategies for adaptation, assessing the communities, risk and planning appropriately. This is becoming urgent need of the civilized human society.

The quality of today's decision-making on agricultural or industrial development or on the layout of towns might be tested against future variations in climate. A new climate is on the way and adaptation is no more choice, it is a necessity. Several studies observed impacts of climate change on ecological system over the last several decades (Parmesan and Yohe (2003), McCarthy et al. (2001)). The Earth system faces irreversible due to change in mean

climatic conditions. Along with changes in climatic conditions the earth faces sever catastrophic events and that will cause huge damage of natural productive capital in the economy. Societies and individuals have to adjust their behaviour in response to past climatic changes. People are contemplating adapting to altered future climatic conditions. These adapting actions are some time reactive that are based on current assessments, it is also anticipatory. There are several factors that motivate individuals and society to adapt climate change for protecting economic well-being or reducing risk related to climate change.

Adaptation can be motivated for improvement of safety and that is possible through market exchanges (Smit et al. 2000) and expansion of social networks. Adaptation is an issue relevant at local, national and international levels. Success of an adaptation strategy depends on its objectives that affect the ability to meet adaptation goal. Success of adaptation depends on scale of implementation and the criteria used to evaluate it at each scale. So, it is necessary to clarify the concept of adaptation and review adapting agents of climate change.

In this context, even there is lot of limitations or obstacles for development; adaptation to climate change minimizes risks and also provides certain opportunity to grow with sustainable development. There are more than thousand research articles on climate change, adaptation, and sustainable development but I shall cover few important papers and try to provide a clear concept on it.

This paper is organized as follows. Next Section clearly defines the concept of adaptation, nature of adaptation, measurements, cost, etc. Section 3 briefly describes adaptive capacity. Section 4 presents future adaptation and finally, Section 5 concludes.

2. Adaptation to Climate Change

2.1 Conceptualisation of Adaptation to Climate Change

Adaptation is an adjustment in non-normal condition, which is created or regenerated due to several reasons – climate change is one of them. Adger and others, in their several papers, provide few definitions and finally a concept of adaptation emerges in the context of climate change effects. So, adaptation to climate change is an adjustment in socio-economic or/and ecological systems in response to impacts of climate change. Adaptation is the adjustment or change of traditional practices for non-declining wellbeing due to climate change effects. Truly, adaptation refers to changes in practices, processes, or restructures to minimise or offset potential damages associated with changes in climate. Adaptation involves adjustments to reduce the vulnerability of communities, or society, or regions, or nations. Adaptation to climate change is important for us because of (a) assessment of impacts and vulnerabilities,

and, (b) development and evaluation of response options. It is important to know the vulnerability and find out the possible solution for it. So, the understanding expected adaptations are essential to impact and vulnerability assessment that is a fundamental base to estimate the costs or risks of climate change. Adaptation is considered an important *strategy*. Development of planned adaptation strategies to deal with risks is regarded as a necessary complement to mitigation actions. Human society formulates and implements to facilitate adequate adaptation to climate change. Truly, human society promotes and facilitates adaptation and deploys adaptation technologies to address climate change.

2.2 Nature of Adaptation

Adaptation is both to the *process* of adapting and to the *condition* of being adapted. The term, *adaptation*, can be interpretive or has specific interpretations in particular disciplines. In the social sciences, adaptation refers to adjustments by individuals and the collective behaviour of socioeconomic systems for their survival or for sustainable development in long run, where as in ecology, adaptation refers to changes by which an organism or species becomes fitted to its environment.

2.2.1 A Process

Adaptation is a process for a given condition. Adaptation is a relative term; it involves an alteration in the system of interest to the climate related stress. Description of an adaptation requires specification of who or/and what adapts, the stimulus for which the adaptation is undertaken, and the process and form it takes (Downing *et al.*, 1996; Feenstra et al., 1998).

2.2.2 Conditional Adaptation

The climate change-related adaptations are not limited to changes in average annual conditions; they include variability and associated extremes. Climatic conditions are inherently variable over time. Variability goes along with climate change. Adaptation to climate change necessarily includes adaptation to variability (Smit *et al.*, 1999). Other term *climate hazard is* used to capture those climate stimuli, in addition to changes in annual averages, to which the system of interest is vulnerable. In general, changes in the mean condition commonly fall within the coping range, whereas many systems are especially vulnerable to changes in the frequency and magnitude of extreme events or conditions outside the coping range (Kelly and Adger, 1999).

2.2.3 Coping

Many social and economic systems—including agriculture, forestry, industry, human health, and water resource management—have evolved to accommodate some deviations from normal conditions. The capacity of systems to accommodate variations in climatic conditions

from year to year is captured in the coping type and range. This capacity also is referred to as the vulnerability or damage threshold. The coping range, which varies among systems and regions, need not remain static. The coping range itself may change reflecting new adaptations in the system (Smit *et al.*, 2000). The coping range can be regarded as the adaptive capacity of a system to deal with current variability. Adaptive capacity to climate change would refer to both the ability inherent in the coping range and the ability to move or expand the coping range with new or modified adaptations. Initiatives to enhance adaptive capacity would expand the coping range.

2.3. Adaptation Types

Adaptation *types* have been differentiated according to numerous attributes. Major distinctions are purpose or objectives and, time and space. Spontaneous adaptations are considered to be those which take place—invariably in reactive response to climate change without the intervention of a public agency. Estimates of these autonomous adaptations are used in impact and vulnerability assessment. Planned adaptations can be either reactive or anticipatory. Adaptations can be short or long term, localized or regionalized, and they can serve various functions and take numerous forms. Adaptations have been distinguished according to individuals' choice options. The choice pattern has been extended to include the role of community structures, institutional arrangements, and public policies (Downing *et al*., 1996; Feenstra et al., 1998).

2.3.1 Classification Base: Adaptation can also be *classified on the basis of purpose, mode of implementation or institutional structure*. Adaptation is a continuous stream of activities, including to actions, decisions and attitudes. It helps to form decisions about all aspects of life that reflects existing social norms and processes. Adaptations are not isolated from other decisions, but occur in the context of demographic, cultural and economic change as well as transformations in information technologies, global governance, social conventions and the globalising flows of capital and labour. It can be difficult to separate climate change adaptation decisions or actions from actions triggered by other social or economic events.

2.3.2 Non-Climatic driving factors: Adaptations can also arise as a result of other *non-climate-related social or economic changes.* One householder decides to move from an increasing risk area to an area at lower risk. The movement of this household may not be primarily motivated by climate change, but rather by other demographic or economic factors. If this movement is due to, say, increasing risk of flooding, that may be connected with climate change. Irrespective of motivation for adaptation, both purposeful and unintentional adaptations can generate short-term or long-term benefits, but they may also generate costs

when wider issues or longer timeframes are considered. Adaptations may amplify the impacts of climate change by ineffectual and unsustainable anticipatory action, as can be seen in the changing demand for air conditioning in cars and homes following a series of hot summers. Adaptations to non-climate drivers can increase vulnerability to climate change stress. More recent awareness of the heightened flood risk associated with living in flood prone areas may change the price signals that currently place a premium on coastal or riverside properties. The success of climate related adaptation actions may be negated by reactive adjustments by economic actors and it is a part of the process of continual adjustment to social and ecological change driven by multiple factors.

2.1 Goals of Adaptation

Objectives of actors and action processes focus on goals of adaptation. Action is interconnected with the scale and decision-making unit. Understanding the scale and unit of adaptation decision-making reveals the diverging goals of adaptation to climate change. These goals will differ within a sector, a society, between nations and, most intractably, between different generations. However, the goals of adaptation are not clearly stated explicitly. For some agents adaptation concerns conservation of status quo, while for others the current situation is undesirable and hence adaptation is about progress. The goal of adaptation will likely depend on who or what is adapting. Developed institutions and wealthier societies or individuals may seek to maintain their current state or standard of living through adaptation, whilst developing countries may be aiming to continue developing and enhance the standard of living of their citizens. For those on the margins of society, the immediate priority will be to secure their livelihoods or protect their assets from climate change effects and other risks. In ecosystems, successful adaptation is demonstrated by survival of the species in a changing environment, but not necessarily the survival of an individual. These divergent goals for adaptation emerge from different attitudes to risk to disposition, and to the adaptive capacity of future generations. There is a variation due to optimistic or pessimistic views of individuals, or community, or society or nation.

2.4.1 ***Risk Management***: The risk management literature focuses on adaptation to natural hazards, including both climate and non-climate related hazards. Adaptations, adjustments or coping strategies are used to respond to the perceived risk of, or experienced impact of, a hazard. Burton et al. (1993) have classified these strategies as *share the loss, bear the loss, modify the events, prevent the effects, change use or change location*. These various strategies reveal different objectives of adaptation, although the overarching goal remains that of reducing the negative effects and increasing any benefits resulting from a hazard. Within the

context of the climate change debate, the purpose of adaptation is often seen as to reduce vulnerability or to enhance resilience to climate change and climate variability (Smit et al. 2000). Other perspectives on adaptation are related to sustainable development.

Adaptation can be viewed as providing broader benefits, not just specifically to cope with climate impacts but as part of the development process. The resilience approach, as applied to linked social and ecological systems, views learning and adaptation as important processes that improve system resilience to a range of shocks, achievable through adaptive management (Folke 2006; Nelson et al. 2007). Adaptation actions can be used either to build resilience to prevent collapse of a system or to reorganise the system and recover once a shock has caused a collapse. There are trade-offs between the goals of building resilience and reducing vulnerability. Adaptive management approaches that promote resilience seek to learn from failure and promote the ongoing structures and functions of overall systems.

Vulnerability approaches focus on the most endangered individuals or ecosystems and seeks adaptations that protect those, perhaps at the expense of robustness and resilience of the overall system (Eakin et al. 2009). Hence there are a range of possible goals of adaptation. The choice between them is taken by institutions of collective response based on the underlying values of society.

2.2 Decision Making Agents

Adapting to climate change involves making decisions across a landscape made up of agents from individuals, firms and civil society, to public bodies and governments at local, regional and national levels, and international agencies. As mentioned above, a broad distinction can be drawn between action that often involves creating policies or regulations to build adaptive capacity and action that implements operational adaptation decisions. The latter will often be constrained and influenced by a higher-level adaptation framework as well as the institutions that define all aspects of activity in that society. For both public and private agents, where objectives of adaptation are explicit, they are often diverse.

Actions associated with building adaptive capacity may include communicating climate change information, building awareness of potential impacts, maintaining well-being, protecting property or land, maintaining economic growth, or exploiting new opportunities. The objectives associated with implementing adaptation decisions are more likely to focus on reducing the cumulative impacts of climate change, ensuring that adaptive measures taken by one organisation do not adversely impact upon others, avoiding anticipated adverse impacts of climate change, and ensuring that the distributional impacts of adaptation are minimised. Adaptation occurs without explicit recognition of changing risk, while other adaptations

incorporate specific climate information into decisions. Unintentional adaptation may reduce the effectiveness of purposeful adaptation. Hence, the integration of adaptation actions and policies across sectors remains a key challenge to achieve effective adaptation in practice.

2.2.1 Adaptive Decision Strategy

Classifications of purposeful adaptations based on objectives of adaptation strategies frequently focus on measures which share the loss, bear the loss, modify the event, prevent effects, change use or change location (Burton et al., 1993). This classification is an expansion of the three cornerstones of adaptation: (i) reduce the sensitivity of the system to climate change; (ii) alter the exposure of the system to climate change; and (iii) increase the resilience of the system to cope with changes.

Increasing the resilience of social and ecological systems (Adger, 1999; Tompkins et al 2005) can be achieved through generic actions which not only aim to enhance well-being and increase access to resources or insurance, but also include specific measures to enable specific populations to recover from loss. The spatial scale over which these three dimensions of adaptation can be implemented varies, as does the role of international and national policy, individual and collective action. All dimensions of adaptation can be implemented at any scale.

2.2.2 Scale and Agency

In general, efforts to improve the ability of whole populations to recover from loss are more often tackled through public policy intervention at national level. Individual action will be adequate and specific public policy intervention may not be required to generate individual benefits from adaptation, although the adaptation actions are clearly reliant on permissive regulatory frameworks. This implies an appreciation of the nature of the operational, managerial or strategic decision that is at stake. This in turn requires the scale and agency of decision-making to be defined. Understanding the values that drive an adaptation decision is usually easier for decisions made at the micro-scale and by well defined agents than at the macro-scale and by diffuse agents. This perspective also requires some appreciation of the differences between adaptation decisions seen as private or public. The values that are brought to bear on adaptation decisions become more diverse and contradictory as one moves from small-scales and single agents to larger scales and multiple agents. If one of the roles of government is to resolve conflicts between agents to engender collective action, then the importance of governance in adaptation decisions becomes increasingly important as one moves along this continuum (Cash et al. 2006). Adaptation decisions taken today may impose negative environmental and social impacts on a future generation. The values of future

generations are most often explicitly incorporated into today's decisions through formal discounting methods in economics. But issues around critical natural capital, the non-material aspects of choice and culture, are effectively excluded from economic analysis.

The dependency of adaptation decisions on scale and agency may point to hidden limits to adaptation in an increasingly complex and inter-connected society. Sobel and Leeson (2006) suggest that the impacts of Hurricane Katrina on New Orleans may be an example of complexity leading to failure. Here society was exposed to an environmental shock, to which it's weakening ability to resolve or reconcile divergent values through a complex governance structure induced catastrophic failure.

Climate change has significant impacts on development, poverty alleviation and other social security, and new threats emerges to water and food security, agricultural production, public health. Countries or regions that fail to adapt contributes to global insecurity through spread of disease, and a degradation of the economic system. Considering adverse impacts of climate change, adaptation is an integral component of an effective strategy to address climate change along with mitigation. The World's poor, who have contributed the least to the greenhouse gas emissions, will suffer the worst impacts of climate change and have the least capacity to adapt.

Adaptation is about building resilience and reducing vulnerability. It is not simply a matter of designing projects or putting together lists of measures to reduce the impacts of climate change. A national policy response should be anticipatory, not reactive, and should be anchored in a country's framework for economic growth and sustainable development, and integrated with its poverty reduction strategies.

The global climate is changing and will continue to do so even if greenhouse gas emissions are dramatically curbed. Therefore, countries face the challenge of adaptation to climate change. Developing countries are highly sensitive and vulnerable to climate change. There remains much to learn about the optimal adaptation. The best way to adapt to climate change is simply to focus on traditional growth and developmental goals with climate-proofing productive capital. Millner and Dietz (2011) model the task of apportioning investment between productive capital and adaptation to climate change. The scale and composition of productive and adaptive capital investments depend on empirical context. It is optimal to invest in adaptive capital over the coming years. Adaptations occur in the *system of interest*, *unit of analysis*, *exposure unit*, *activity of interest*, or *sensitive system*.

2.2.3 Intervention Strategy

In *unmanaged natural systems,* adaptation is autonomous and reactive and is the means by which species and communities respond to changed conditions. Human system adaptation can be motivated by private or public interest. *Private* decision makers include individuals, households, businesses, and corporations; *public* interests are served by governments at all levels. The roles of public and private participants are distinct but not unrelated. Planned adaptation often is interpreted as the result of a deliberate policy decision on the part of a public agency, based on an awareness that conditions are about to change or have changed and that action is required to minimize losses or benefit from opportunities. Autonomous adaptations are widely interpreted as initiatives by private actors rather than by governments, usually triggered by market or welfare changes induced by actual or anticipated climate change. Smith *et al.* (1996) describe autonomous adaptations as those that occur *naturally*, without interventions by public agencies, whereas planned adaptations are called *intervention strategies*. The extent to which society can rely on autonomous, private or market adaptation to reduce the costs of climate change impacts to an acceptable or non-dangerous level is an issue of great interest. Autonomous adaptation forms a baseline against which the need for planned anticipatory adaptation can be evaluated.

Distinguishing among the various decision makers involved in adaptation is important. The case of African agriculture and water resources illustrates that stakeholders and potential adapters range from vulnerable consumers to international organizations charged with relief and research. Poor and landless households have limited resources, yet failure to adapt can lead to significant deprivation, displacement, morbidity, and mortality. Subsistence farmers do not have the same adaptation options as commercial producers. Water supply adaptations may involve landowners, private traders, local authorities, water-dependent businesses, national governments, and international organizations. Each stakeholder has distinct interests, information, risks, and resources and hence would consider distinct types of adaptive responses (Downing *et al*., 1996).

2.3 Processes and Evaluation of Adaptations

In order to predict autonomous adaptations and provide input to adaptation policies, there is a need for improved knowledge about processes involved in adaptation decisions. This knowledge includes information on steps in the process, decision rationales, handling of uncertainties, choices of adaptation types and timing, conditions that stimulate or dampen adaptation, and the consequences or performance of adaptation strategies or measures (Rayner and Malone, 1998; Smit *et al*., 2000).

Decisions regarding adaptations can be undertaken at any of several scales, by private individuals, local communities or institutions, national governments, and international organizations. Where these adaptations are consciously planned activities, whether by public agencies or individuals, there is an interest in assessing the performance or relative merits of alternative measures and strategies. This *evaluation* can be based on criteria such as costs, benefits, equity, efficiency, and implementation ability.

2.3.1 Analysis of Adaptations

Adaptive behaviours provide information on the processes, constraints, and consequences of adaptations. Knowledge of the processes by which individuals or communities actually adapt to changes in conditions over time comes largely from analogy and other empirical analyses (Smit *et al*., 2000). Conceptual models of adaptation processes describe sequential relationships and feedback involving climate change. The contributions of spatial analogy are limited. Case studies document adaptive responses to climate change in resource-based economic sectors and communities over periods of several decades. Other empirical analyses have examined adaptive behaviour in key sectors such as agriculture in light of climatic variability and extremes over even shorter time periods. These direct empirical analyses of adaptation processes tend to start with the system of interest, then, assess its sensitivity and adaptability to climate change. This analytical strategy is consistent with vulnerability assessment and *shift-in-risk* perspectives. For systems such as agriculture, forestry, water resources, and coastal zone settlements, the key climatic stimuli are not average conditions but variability and extremes.

A direct climatic condition prompts adaptation less often than the economic and social effects or implications of the climatic stimuli that are fundamental in triggering adaptive responses. Non-climatic conditions are important in moderating and sometimes overwhelming the influence of climate stimuli in the decision making of resource users. Decisions on adaptation are rarely made in response to climate stimuli alone. These findings are important for predicting autonomous adaptations and for improving adaptation assumptions in impact models.

In estimating future adaptations and developing adaptation policies, it is helpful to understand factors and circumstances that hinder or promote adaptation. As Rayner and Malone (1998) conclude, the consequences of a climate event are not direct functions of its physical characteristics; they also are functions of the ways in which a society has organized its relation to its resource base, its relations with other societies, and the relations among its members. Numerical impact assessment models tend to *use*, rather than *generate*, information

on adaptations to estimate future impacts of climate stimuli, after the effects of adaptation have been factored in. They indicate the potential of human systems to adapt autonomously and thus to moderate climate change damages.

2.4 Costs of Adaptation

As assessments of climate impacts (commonly measured as *costs* that include damages and benefits) increasingly have incorporated expected adaptations, and particularly as impact models and *integrated assessment* models have shown the potential of adaptation to offset initial impact costs, interest has grown in calculating the costs of autonomous adaptations. Whether climate change or another climate stimulus is expected to have problematic or "dangerous" impacts depends on the adaptations and their costs. Climate change impact cost studies that assume adaptation also should include the "adjustment of costs" of these adaptations. Tol (1995, 1999) provide comprehensive summary of analyses of the costs of autonomous, mainly reactive adaptations, undertaken privately (i.e., not adaptation policies of government). A common basis for evaluating impact costs is to sum adaptation costs and residual damage costs.

Procedures for defining and calculating such adaptation costs are subject to ongoing debate. Tol (1995, 1999) note adaptation costs but ignore transition costs. Most research to date on adaptation *costs* is limited to particular economic measures of well-being. Any comprehensive assessments of adaptation costs are consider not only economic criteria but also social welfare and equity. Cost estimation for autonomous adaptations is not only important for impact assessment; it also is a necessary ingredient in the *base case, reference scenario*, for evaluations of policy initiatives, with respect to both adaptation and mitigation (Smit *et al.*, 2000).

2.4.1 Adaptation experiences and learning

Climate change will be experienced via conditions that vary from year to year, as well as for ecosystems and human systems; these variations are important for adaptation. Research in many sectors and regions indicates an impressive human adaptive capacity to long-term average climate conditions but less success in adapting to extremes and to year-to-year variations in climatic conditions. Although human settlements or agricultural systems have adapted to be viable in a huge variety of climatic zones around the world, those settlements and systems often are vulnerable to temporal deviations from normal conditions. As a result, adaptations designed to address changed mean conditions may or may not be helpful in coping with the variability that is inherent in climate change.

All socioeconomic systems, especially climate-dependent systems such as agriculture, forestry, water resources, and human health, are continually in a state of flux in response to changing circumstances, including climatic conditions. The evidence shows that there is considerable potential for adaptation to reduce the impacts of climate change and to realize new opportunities. Adaptation options occur generally in socioeconomic sectors and systems in which the turnover of capital investment and operating costs is shorter and less often where long-term investment is required.

Although an impressive variety of adaptation initiatives have been undertaken across sectors and regions, the responses are not universally or equally available. Viability of crop insurance depends heavily on the degree of information, organization, and subsidy available to support it. Similarly, the option of changing location in the face of hazard depends on the resources and mobility of the affected part and on the availability and conditions in potential destination areas.

Adoption of adaptive measures is constrained by other priorities, limited resources, or economic or institutional barriers. There is some evidence that the costs of adaptations to climate conditions are growing. There is strong evidence of a sharp increase in damage costs of extreme climatic or weather events. Growing adaptation costs reflect, at least in part, increases in populations and/or improvements in standards of living, with more disposable income being used to improve levels of comfort, health, and safety in the short run. Many adaptations to reduce vulnerability to climate change risks also reduce vulnerability to current climate variability, extremes, and hazards (Rayner and Malone, 1998). Adaptation strategies in agriculture should be clear applications to climate change, including moisture-conserving practices, hybrid selection, and crop substitution. In the water resources sector, Current management practices might represent useful adaptive strategies for climate change. Societal responses to large environmental challenges tend to be incremental and ad hoc rather than fundamental (Rayner and Malone, 1998). There is little evidence that efficient and effective adaptations to climate change risks will be undertaken autonomously.

A consistent lesson from adaptation research is that climate is not the singular driving force of human affairs that is sometimes assumed—but neither is it a trivial factor. Climate is an important resource for human activities and an important hazard. Climate change is a source of significant stresses or opportunities for societies, yet it has always been only one factor among many. The consequences of a shift in climate are not calculable from the physical dimensions of the shift alone; they require attention to human dimensions through which they are experienced.

Some studies show faith in market mechanisms and suggest considerable capacity of human systems to adapt autonomously. Other studies highlight the constraints on *optimal* autonomous adaptation, such as limited information and access to resources, adaptation costs, and residual damages; these studies emphasize the need for planned, especially anticipatory, adaptations undertaken or facilitated by public agencies.

3. Adaptive Capacity

Adaptive capacity is the potential ability of a system, and the region or community adapts to the effects or impacts of climate change. Enhancement of adaptive capacity represents a practical means of coping with changes and uncertainties in climate, including variability and extremes. Enhancement of adaptive capacity reduces vulnerabilities. Thus, it promotes sustainable development (Munasinghe, 2002; Smit *et al.*, 2000). Considerable attention has been given to the characteristics of communities, countries, and regions that influence their propensity or marginal additional ability to adapt. Hence, their vulnerability to risks is highly associated with climate change.

Considerable attention has been devoted to the characteristics of systems that influence their propensity or ability to adapt and/or their priority for adaptation measures. These characteristics have been called *determinants of adaptation*. Generic concepts such as sensitivity, vulnerability, susceptibility, coping range, critical levels, adaptive capacity, stability, robustness, resilience, and flexibility have been used to differentiate systems according to their likelihood, need, or ability for adaptation (Kelly and Adger, 1999). These characteristics influence the occurrence and nature of adaptations and thereby circumscribe the vulnerability of systems and their residual impacts. In the hazards literature, these characteristics are reflected in socially constructed or endogenous risks. Together represents the adaptive capacity of a system.

3.1. Adaptive Capacity and Vulnerability

Adaptive capacity refers to the potential, capability, or ability of a system to adapt to climate change impacts. Adaptive capacity greatly influences the vulnerability of communities and regions to climate change effects and hazards (Kelly and Adger, 1999). Human activities and groups are considered sensitive to climate to the degree that they can be affected by it and vulnerable to the degree. Because vulnerability and its causes play essential roles in determining impacts, understanding the dynamics of vulnerability is as important as understanding climate itself.

The significance of climate variation or change depends on the change itself and the characteristics of the society exposed to it (Munasinghe, 2002). These characteristics of

society determine its adaptive capacity and its adaptability. Adaptive capacity refers to the ability to prepare for hazards and opportunities in advance and to respond or cope with the effects. Studies of similar hazardous events recurring at different times in a given region show vastly different consequences because of societal transformations that occurred between the events. As per observation of researchers, rainfall and temperature fluctuations in Western Europe have far milder effects on human well-being today, in other words, society generally is less vulnerable than they did in the medieval and early modern periods, essentially as a result of enhanced adaptive capacity that reflects changes in practices, economics, and government programs. Similarly, particular climate events or hazards can have *vastly different consequences for those on whom they infringe because of differences in coping ability* (Rayner and Malone, 1998). An extreme climatic event will result in higher losses of life in a developing country than in a developed country because of differential adaptive capacity. It should be noted that in most poor developing countries, socioeconomic, technical, and political barriers will mean that the changed health risks will not be addressed.

Research on comparative adaptive capacity and vulnerability is evolving, and its difficulties are well recognized. Estimates of adaptive capacity tend to be based on premises such as the position that highly managed systems, given sufficient resources, are likely to be more adaptable (and at a lower cost) than less managed ecosystems (Toman 2006). It is also widely accepted that systems with high levels of capacity to cope with high adaptive capacity for stresses associated with climatic change.

3.2. Determinants of Adaptive Capacity

The *determinants of adaptive capacity* relate to the economic, social, institutional, and technological conditions that facilitate or constrain the development and deployment of adaptive measures (Rayner and Malone, 1998; Kelly and Adger, 1999) and we discuss these in detail later. As per IPCC adaptation is the adjustment in ecology, socio-economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of change or take advantage of new opportunities. Adaptation involves (i) building adaptive capacity that increases the ability of individuals, groups, and organisations to adapt to changes, and (ii) implementing adaptation decisions that transform the capacity into action. Both dimensions of adaptation are required to prepare for or in response to impacts generated through changing climate.

Adaptation to climate change and related risks takes place in a dynamic social, economic, technological, biophysical, and political context that varies over time. This complex mix of conditions determines the capacity of systems to adapt. Although scholarship on adaptive

capacity is extremely limited in the climate change field, there is considerable understanding of the conditions that influence the adaptability of societies to climate change in the fields of resource management, and sustainable development. From this literature, it is possible to identify the main features of communities or regions that seem to determine their adaptive capacity: economic resources, technology, information, knowledge and skills, infrastructure, institutions etc.

3.2.1. Resources

Resources can be expressed as the economic assets, capital resources, financial means, wealth, or poverty, the economic condition of nations and groups. Clearly resource is a determinant of adaptive capacity (Brooks *et al.*, 2005). It is true that developed nations are better prepared to bear the costs of adaptation to climate change impacts and risks than poorer nations. Poverty is directly related to vulnerability and it is a rough indicator of the ability to cope. The poor are among the most vulnerable to famine, malnutrition, and hunger. There is a situation in India in which pastoralist communities are *locked into* a vulnerable situation in part because of a lack of financial power that would allow them to diversify and engage in other sources of income. At a local level, the highest levels of household vulnerability in coastal area may be characterized by low household incomes in conjunction with poor housing quality and little community organization. Community with higher levels of household income are better able to manage vulnerability through the transfer of flood impacts from health to economic investment and loss. Kelly and Adger (1999) demonstrate the influence of poverty on a region's coping capacity; poor regions tend to have less diverse and more restricted entitlements and a lack of empowerment to adapt. There is ample evidence that poorer nations and disadvantaged groups within nations are especially vulnerable to disasters.

3.2.2. Technology

Lack of technology has the potential to seriously impede a nation's ability to implement adaptation options by limiting the range of possible responses. Adaptive capacity is likely to vary, depending on availability and access to technology at various levels (i.e., from local to national) and in all sectors. Many of the adaptive strategies identified as possible in the management of climate change directly or indirectly involve technology (e.g., warning systems, protective structures, crop breeding and irrigation, settlement and relocation or redesign, flood control measures).

Hence, a community's current level of technology and its ability to develop technologies are important determinants of adaptive capacity. Moreover, openness to the development and

utilization of new technologies for sustainable extraction, use, and development of natural resources is key to strengthening adaptive capacity. For example, in the context of Asian agriculture and the impact of future climate change, the development of heat-resistant rice cultivators will be especially crucial. Regions with the ability to develop technology have enhanced adaptive capacity.

3.2.3. Knowledge

Successful adaptation depends on knowledge, information and skill. Success of adaptation requires recognition of the necessity to adapt, knowledge about available options, the capacity to assess them, and the ability to implement the most suitable ones. As information on weather hazards becomes more available and understood, it is possible to study, discuss, and implement adaptation measures. Building adaptive capacity requires a strong, unifying vision; scientific understanding of the problems; an openness to face challenges; pragmatism in developing solutions; community involvement; and commitment at the highest political level. Lack of trained and skilled personnel can limit a nation's ability to implement adaptation options. In general, countries with higher levels of stores of human knowledge are considered to have greater adaptive capacity than developing nations and those in transition.

Illiteracy along with poverty is a key determinant of low adaptive capacity in under developed countries. It is important to ensure the systems that are in place for the dissemination of climate change and adaptation information nationally and regionally and that there are forums for discussion and innovation of adaptation strategies at various levels.

3.2.4. Infrastructure

Adaptive capacity is likely to vary with social infrastructure. Some researchers regard the adaptive capacity of a system as a function of *availability of* and *access to* resources by decision makers, as well as vulnerable subsectors of a population (Kelly and Adger, 1999). In the coastal area of Hong Kong, the capacity to adapt to the risk of typhoons differs for existing urban areas and for new coastal land reclamation. For existing urban areas, there is no possibility of retreat or accommodation, although during urban renewal the formation level of the ground could be raised, thereby decreasing the vulnerability of settlements. At the community level, the lack of flexibility in formal housing areas where dwelling form and drainage infrastructure were more fixed reduced the capacity to respond to contemporary environmental conditions.

3.2.5. Institutions

In general, countries with well developed social institutions are considered to have greater adaptive capacity than those with less effective institutional arrangements—commonly,

developing nations and those in transition. The role of inadequate institutional support is frequently cited in the literature as a hindrance to adaptation. Kelly and Adger (1999) show how institutional constraints limit entitlements and access to resources for communities in coastal Vietnam and thereby increase vulnerability. Inherent institutional deficiencies and weaknesses in managerial capacities are difficult to cope with the anticipated natural event. It would be extremely difficult for the country to reduce vulnerability to climate change. Unstable agricultural policies increased the vulnerability of the food production sector in Less developed countries (LDC). Drastic changes in economic and policy conditions are expected to make agricultural systems more vulnerable to changes in climate. Some time, resilient to climate change is the need to change tenure conditions and other arrangements may create conflicts that are beyond the capacity of local institutions to resolve. In the water resource sector, present day strategies, demand management tools, and measures (i.e., institutions) have evolved over time and are capable of serving as a basis for adaptive response strategies to climate change.

3.2.6 Accessibility

Adaptive capacity of a society depends on resource and information availability, and these should be easily accessible and equal justice to all. Truly, the determinants of adaptive capacity are not independent of each other, nor are they mutually exclusive. Adaptive capacity is the outcome of a combination of determinants and varies widely between countries and groups, as well as over time. Not only are conditions for adaptive capacity diverse, they also behave differently in different countries and regions, particularly depending on the level of development. These determinants represent conditions that constrain or enhance the adaptive capacity and hence the vulnerability of regions, nations, and communities.

3.3. Enhancing Adaptive Capacity

The adaptive capacity of a system or nation is likely to be greater when the following requirements are met:

i) The nation has a stable and prosperous economy. Regardless of biophysical vulnerability to the impacts of climate change, developed and wealthy nations are better prepared to bear the costs of adaptation than developing countries.

ii) There is a high degree of access to technology at various levels (i.e., from local to national) and in all sectors. Moreover, openness to development and utilization of new technologies for sustainable extraction, use, and development of natural resources is key to strengthening adaptive capacity.

iii) The roles and responsibilities for implementation of adaptation strategies are well delineated by central governments and are clearly understood at national, regional, and local levels.

iv) Systems are in place for the dissemination of climate change and adaptation information, nationally and regionally, and there are forums for the discussion and innovation of adaptation strategies at various levels.

v) Social institutions and arrangements governing the allocation of power and access to resources within a nation, region, or community assure that access to resources is equitably distributed because the presence of power differentials can contribute to reduced adaptive capacity.

vi) Existing systems with high adaptive capacity are not compromised. For example, in the case of traditional or indigenous societies, pursuit of western/European-style development trajectories may reduce adaptive capacity by introducing greater technology dependence and higher density settlement and by devaluing traditional ecological knowledge and cultural values.

3.4. Scale of Adaptive Capacity

There is considerable variation among countries with regard to their capacity to adapt to climate change. Given their economic affluence and stability; their institutions and infrastructures; and their access to capital, information, and technology, developed nations are broadly considered to have greater capacity to adapt than developing regions or countries in economic transition. In general, countries with well-developed social institutions supported by higher levels of capital and stores of human knowledge are considered to have greater adaptive capacity (Smith and Lenhart, 1996). Adaptation options—including traditional coping strategies—often are available in developing countries and countries in transition; in practice, however, those countries' capacity to effect timely response actions may be beyond their infrastructure and economic means (IPCC, 1997). For those countries, the main barriers are: i) asymmetry in financial/market that leads to uncertain pricing, availability of capital, lack of credit ii) weak institutional structure, institutional instability iii) Social/cultural rigidity in land-use practices, social conflicts iv) technological existence, access v) lack of information, trained personnel.

It should be noted that a considerable disparity between developed and developing countries in terms of potential adverse effects of climate change on agricultural systems; and developing countries suffer the greatest losses. In addition, poorer, developing regions presumably will face stricter constraints on technology and institutions and those measures

taken in response to climate change may be very demanding financially. Researchers also believe that compared to industrialized countries, developing countries possess a lower adaptive capacity as a result of greater reliance on climatic resources.

Various studies have attempted to identify overall trends that cause increased or decreased vulnerability to environmental hazards; unfortunately, however, the concept of vulnerability does not rest well on a developed theory. Empirical local-level studies of vulnerability are so complex, however, that attempts to describe patterns or estimate trends at global or regional scales are extremely difficult. Social change has the potential to make individuals or activities more vulnerable in some ways and less vulnerable in others (Rayner and Malone, 1998). The influence of changes in the determinants of adaptive capacity are not necessarily direct or clear, rendering the attempt to develop systematic indices for measurement and comparison a difficult task.

3.4.1. Capacity Enhancement by Scale

The vulnerabilities and anticipated impacts of climate change will be observed at different scales and levels of society—and enhancement of adaptive capacity can be initiated at different social scales. Truly, there are four scales –namely: micro, meso, macro and mega. Using the example of sea-level rise as a climate change impact, the authors describe adaptation options at each scale. The process of sea-level rise occurs at the mega-scale and is global in its effect. At the macro-scale, an associated increase in surface water and groundwater has the potential to similarly affect neighbouring rivers and flood plains in China, Nepal, India, Bhutan, and Pakistan. Adaptive capacity at this scale is a function of international economic and political structures, with implications for the country's capital and technological resources and institutions. At the meso-scale, different communities within Bangladesh are differentially vulnerable, depending on adaptive capacity and physiographic characteristics. At this scale, location-specific adaptation options would need to be considered. Finally, at a micro-scale, family units and individuals would experience vulnerabilities irrespective of the origin of the processes and would employ adaptations within their particular economic and socio-cultural constraints. Vulnerabilities of climate change occur at various scales, successful adaptation will depend on actions taken at a number of levels. Examples of initiatives to enhance adaptive capacity at various scales follow:

3.4.1.1 ***Global Level***

Greater cooperation between industrialized and developing countries to align global and local priorities by improving policy/science interactions and working toward greater public

awareness of climate change and adaptation issues; inclusion of global institutions for global-level adaptation, which would include research and facilitation of policy, funding, and monitoring at all levels; removal of barriers to international trade. It is argued that improving market conditions, reducing the exploitation of marginal land, accelerating the transfer of technology, and contributing to overall economic growth will promote both sustainability and adaptive capacity; effective global economic participation. Benefits go beyond direct financial gain and include technology transfers, technical and managerial skills transfers, and other skills transfers associated with the learning by doing process.

3.4.1.2 *National Level*

Development of climate change policy that is specifically geared toward more vulnerable sectors in the country (Mustafa, 1998), with an emphasis on poverty reduction (Kelly and Adger, 1999); Establishment of broadly based monitoring and communication systems or establishment of public policy that encourages and supports adaptation at local or community levels and in the private sector; Pursuit of sustainable economic growth, which, in turn, allows for greater dedication of resources to development of adaptive technologies and innovations.

3.4.1.3 *Local Level*

Establishment of social institutions and arrangements that discourage concentration of power in a few hands and prevent marginalization of sections of the local population; arrangements need to consider representativeness of decision making bodies and maintenance of flexibility in the functioning of local institutions; Encouragement of diversification of income sources (and therefore risk-spreading), particularly for poorer sectors of society (Adger and Kelly, 1999); Encouragement of formal or informal arrangements for collective security (Kelly and Adger, 1999); Identification and prioritization of local adaptation measures and provision of feedback to higher levels of government. These efforts would have to be reinforced by the adequate provision of knowledge, technology, policy, and financial support.

3.4.2 Successful Adaptation

Adaptation to climate change impacts is observed in both physical and ecological systems as well as in human adjustments to resource availability and risk at different spatial and societal scales. Adger et al. (2005) outline a set of normative evaluative criteria for the success of adaptations at different scales. They argue that elements of effectiveness, efficiency, equity and legitimacy are important in judging success in terms of sustainability of development path.

3.4.2.1 Sustainable Development

Sustainable development refers to maintaining development over time. Adaptive capacity to deal with climate risks is closely related to sustainable development. Enhancement of adaptive capacity is fundamental to sustainable development. Several researchers study by assessing differences in vulnerability among regions and groups and by working to improve the adaptive capacity of those regions and groups, planned adaptation can contribute to equity considerations of sustainable development.

In the context of African agriculture, Downing *et al.* (1996) conclude that enhancement of present resource management activities is necessary to prepare for potential impacts of climate change. In Malawi, economic progress ensures food production and reduces vulnerability to climate risks that is consistent with Malawi's planning and development initiatives. Because vulnerability to climate depends on the adaptive capacity of a wide range of attributes, it may be unrealistic to focus on development programs that deal with adaptation to climate alone (Rayner and Malone, 1998).

Ability to adapt clearly depends on the state of development or developmental position. Underdevelopment basically constrains adaptive capacity. The reason is lack of resources to hedge against extreme or expected events. The process of enhancing adaptive capacity is not simple; it involves spurts of growth inter-dispersed with periods of consolidation, refocusing and redirection.

3.4.2.1.1 Adaptive Capacity for Sustainable Development: Enhancement of adaptive capacity involves similar requirements as promotion of sustainable development, including (i) Improved access to resources; (ii) Reduction of poverty; (iii) Lowering of inequities in resources and wealth among groups; (iv) Improved education and information; (v) Improved infrastructure; (vi) Diminished intergenerational inequities; (vii) Respect for accumulated local experience; (viii) Moderate long-standing structural inequities; (ix) Assurance that responses are comprehensive and integrative, not just technical; (x) Active participation by concerned parties, especially to ensure that actions match local needs and resources; (xi) Improved institutional capacity and efficiency. Actions taken without reference to climate have the potential to affect vulnerability to it, enhancement of adaptive capacity to climate change can be regarded as one component of broader sustainable development initiatives (Munasinghe, 2002). Hazards associated with climate change have the potential to undermine progress with sustainable development. So, it is important for sustainable development initiatives to explicitly consider hazards and risks associated with climate change.

Yet there is surprisingly little recognition of climate hazards and risks associated with climate change in established development projects and programs. O'Brian et al. (2004) show how

climate change can have serious implications for development projects planned or underway in Mexico, including hydroelectric and irrigation initiatives. Torvanger (1998) shows how climate flexibility considerations that can be built into development investments at modest incremental costs are applicable regardless of the uncertainties of climate change.

4 Future Adaptations

The degree to which a future climate change risk is dangerous depends greatly on the likelihood and effectiveness of adaptations in the system. An improved process of adaptation or/and better information on the conditions under which adaptations of various types are expected to occur. Adaptation is necessary to make informed judgments on the vulnerabilities of sectors, regions, and communities. Insights into processes of adaptation have been gained from several types of analysis, including listing of possible adaptation measures, impact assessment models, adaptation process models, historical and spatial anagoges, and empirical analysis of contemporary adaptation processes.

4.1 Possible Adaptation Measures

There are many arbitrary lists of possible adaptation measures, initiatives, or strategies that have a potential to moderate impacts, if they were implemented. Such *possible* adaptations are based on experience, observation, and speculation about alternatives that might be created; they cover a wide range of types and take numerous forms (UNEP, 1998).

Similarly, in coastal zone studies, comprehensive lists of potential adaptation measures are presented; these adaptations include a wide array of engineering measures, improvements, or changes, including agricultural practices that are more flood-resistant; negotiating regional water-sharing agreements; providing efficient mechanisms for disaster management; developing desalination techniques; planting mangrove belts to provide flood protection; planting salt-tolerant varieties of vegetation; improving drainage facilities; establishing setback policies for new developments; developing food insurance schemes; devising flood early warning systems; and so forth. They show that there is a large variety and number of possible adaptations, including many with the potential to reduce adverse climatic change impacts.

Many of these adaptations—especially in agriculture, water resources, and coastal zone applications—essentially represent improved resource management, and many would have benefits in dealing with current climatic hazards as well as with future climatic risks.

4.2 Planned Adaptations and Evaluation of Policy Options

This section considers *planned*, mainly *anticipatory* adaptations, undertaken or directly influenced by *governments* or collectives as a public policy initiative. These adaptations represent conscious policy options or response strategies to concerns about climate change. Public adaptation initiatives may be direct or indirect, such as when they encourage or facilitate private actions.

4.2.1 Objectives for Planned Adaptations

Several reasons have been given for pursuing planned adaptations. Public adaptation initiatives are necessary strategy to manage the impacts of climate change. Adaptation can yield benefits regardless of the uncertainty and nature of climate change. Public adaptation policies rely on private actions. Public agencies should undertake planned adaptation strategies, particularly following relationships with other policy and management objectives, and the evaluation criteria. There are five major objectives of adaptation: a) Enhancing the adaptability of vulnerable natural systems, b) Reversing trends that increase vulnerability. It is also termed as *mal-adaptation*. c) Improving societal awareness and preparedness, d) Increasing robustness of infrastructural designs and long-term investments, e) Increasing the flexibility of vulnerable managed systems.

4.2.2 Identification of Adaptation Policy Options

Research addressing future adaptations to climate change tends to be normative, suggesting anticipatory adaptive strategies to be implemented through public policy. Generally, such adaptation recommendations are based on forecasts of expected climate change. Recommended adaptations tend to be in response to changes in *long-term mean climate*, though more specific elements of climate change (e.g., sea-level change) gain focus when sector specific adaptations are proposed (e.g., integrated coastal zone management) (Smith *et al*., 2000), and some studies specifically examine potential adaptations to variability and extreme events.

Range in scope from very broad strategies for adaptation (enhancing decision makers' awareness of climatic change and variability) to recommendations of sector specific policy. Sectors receiving particular attention include water resources, coastal resources, agriculture, and forest resources.

Tend to be *regionally focused*, in recognition of the fact that vulnerability to the impacts of climate change is highly spatially variable. There is interest in developing countries and nations with economies in transition, given their greater reliance on natural systems-based economic activity (like agriculture) (Smith *et al*., 2000; Kelly and Adger, 1999). Because no single set of adaptive policy recommendations can be universally appropriate, several studies

suggest means by which proposed adaptations may be selected and evaluated. At a very basic level, the success of potential adaptations is seen to depend on the *flexibility* or effectiveness of the measures, such as their ability to meet stated objectives given a range of future climate scenarios, and their potential to produce *benefits that outweigh costs*. Clearly, these are difficult criteria to assess, given the complexity of adaptation measures, the variable sensitivities and capacities of regions, and uncertainties associated with climate change and variability. Some research (Smith *et al.*, 2000) offers supplementary characteristics of, or criteria for, the identification of adaptations:

The measure generates benefits to the economy, environment, or society under current conditions. The measure addresses high-priority adaptation issues such as irreversible or catastrophic impacts of climate change, long-term planning for adaptation, and unfavourable trends. The measure targets current areas of opportunity. The measure is feasible—that is, its adoption is not significantly constrained by institutional, social/cultural, financial, or technological barriers. The measure is consistent with, or even complementary to, adaptation or mitigation efforts in other sectors.

4.2.3 Evaluation of Adaptation Options and Adaptation Costs

There are some important steps should be identify and evaluate planned adaptations, and anticipatory adaptation policies in the climate change context. This approach should covered management of institutional processes and players and proposes net benefits and implementability as central evaluative criteria. Numerous other considerations are noted, including flexibility, benefits independent of climate change, local priorities, levels of risk, and time frames of decisions.

From a disaster management perspective, Tol (1995, 1999) argue that policies must be evaluated with respect to economic viability, environmental sustainability, public acceptability, and behavioural flexibility. Tol (1995, 1999) apply these observations in an examination of adaptation to increased risk of river floods in the Netherlands. They note several possible adaptations, but none could be accomplished without creating significant distributional and/or ecological impacts. None, therefore, would be feasible without enormous political will and institutional reform. There should be multi-criteria methodologies for evaluation, including cost-benefit, cost-effectiveness, risk-benefit to evaluate possible adaptation options have been demonstrated for coastal zones and agriculture.

In an economic efficiency framework, adaptation actions are justified as long as the additional costs of adaptation are lower than the additional benefits from the associated reduced damages. Optimal levels of adaptation are based on minimizing the sum of

adaptation costs and residual damage costs. Such studies require the definition of a base case that involves estimation of autonomous adaptations. These and other normative studies illustrate the range of principles and methods that have been proposed for identifying, evaluating, and recommending adaptation measures. Adaptation is a continuous and iterative cycle, involving several steps: information collection and awareness raising, planning and design, implementation, monitoring, and evaluation.

4.2.4. Public Adaptation Decisions, Uncertainty, and Risk Management

Research increasingly addresses how adaptation is considered in actual policy decision making. Institutions and planning processes can deal with climate change; such processes essentially represent adaptive management. As in many other sectors and circumstances, adaptation to climate change hazards in the coastal zone is part of ongoing coastal zone management. Adaptation to sea-level rise and extreme climate events is being included in Japanese coastal policies, British shoreline management, and Dutch law and coastal zone management.

Planning of adaptation invariably is complicated by multiple policy criteria and interests that may be in conflict. For example, the economically most efficient path to implement an adaptation option might not be the most effective or equitable one. Moreover, decisions have to be made in the face of uncertainty, which is pertinent to adaptation that are associated with climate change itself, its associated extremes, their effects, the vulnerability of systems and regions, conditions that influence vulnerability, and many attributes of adaptations, including their costs, implement ability, consequences, and effectiveness. Adaptation strategies are described as forms of risk management. For example, adaptations to deal with climate change impacts or risks to human health can be biological (acquired immunity), individual (risk-aversion options), or social. Most social adaptation strategies are measures to reduce health risks via public health programs. Similarly, public adaptations via *disaster loss mitigation* are mainly risk management initiatives such as improved warning and preparedness systems, less vulnerable buildings and infrastructure, risk-averse land use planning, and more resilient water supply systems.

To recognize uncertainties, decision tools to help evaluate adaptation options include risk-benefit and multi-criteria analyses. Such evaluations are further complicated by the existence of secondary impacts related to the adaptation itself. For example, water development projects (adaptations to water supply risks) can have significant effects on local transmission of parasitic diseases, including malaria. Improved water supply in some rural areas of Asia has resulted in a dramatic increase in Aedes mosquito breeding sites and, consequently,

outbreaks of dengu. Existing resource management programs do not necessarily consider changed risks or recognize local interests and inequities. The reactive crisis management is ineffective and hence, the need is for proactive and cooperative planning. Nonetheless, it is widely accepted that planned adaptations to climate risks are most likely to be implemented when they are developed as components of existing resource management programs or as part of national or regional strategies for sustainable development (Munasinghe, 2002).

4.2.5 Limitations of Adaptation

There is a recognised need to adapt to changing climatic conditions. At the same time there is an emerging discourse of limits to such adaptation. Limits are immutable thresholds in biological, economic or technological parameters. Limits to adaptation are endogenous to society and hence contingent on ethics, knowledge, attitudes to risk and culture. Adger et al. (2009) review insights from history, sociology and psychology of risk, economics and political science to develop four propositions concerning limits to adaptation: (i) any limits to adaptation depend on the ultimate goals of adaptation underpinned by diverse values, (ii) adaptation need not be limited by uncertainty around future foresight of risk, (iii) social and individual factors limit adaptation action, and (iv) systematic undervaluation of loss of places and culture disguises real, experienced but subjective limits to adaptation. Truly, these issues of values and ethics, risk, knowledge and culture construct societal limits to adaptation, but that these limits are mutable.

Successful adaptation to climate change is bounded by limiting factors. Societal adaptation is not necessarily limited by exogenous forces outside its control. Adaptation to climate change is limited by the values, perceptions, processes and power structures within society. What may be a limit in one society may not be in another, depending on the ethical standpoint, the emphasis placed on scientific projections, the risk perceptions of the society, and the extent to which places and cultures are valued. The role of *ethics* and its manifestation in the diverse goals of adaptation of different actors is critical. One failure of adaptation may in fact be a successful adaptation for another actor, resulting from the different priorities and values held within society. Lack of precise *knowledge* about future climate impacts is often cited as a reason for delaying adaptation actions. It becomes a limit in itself, even where greater foresight will not facilitate adaptation. Adaptation decisions depend on the perceptions of *risk* held by society, which may act as limiting factors if the society does not believe the risk is great enough to justify action. The undervaluing of *places and cultures* may limit the range of adaptation actions. The current methods of valuing loss do not include cultural and symbolic

values, leading to an undervaluation in comparison with more easily valued and tangible assets.

The major implication arises from literature that diverse and contested values —underpinned by ethical, cultural, risk and knowledge considerations — underlie adaptation responses and subjective limits to adaptation. Given diverse values of diverse actors, there is a compelling need to identify and recognise implicit and hidden values and interests in advance of purposeful adaptation interventions. As a consequence, there is a requirement for governance mechanisms that can meaningfully acknowledge and negotiate the complexity arising from the manifestation of diverse values for adaptive action involving wide sets of stakeholders. It is true that locality, place and cultural values are likely to loom large in adaptation decisions.

Climate change adaptation is not only limited by exogenous forces, but importantly by societal factors that could possibly be overcome. An adaptable society is characterized by awareness of diverse values, appreciation and understanding of specific and variable vulnerabilities to impacts, and acceptance of some loss through change. The ability to adapt is determined in part by the availability of technology and the capacity for learning but fundamentally by the ethics of the treatment of vulnerable people and places within societal decision-making structures.

5 Conclusion

Adaptation is an important part of societal response to global climate change. This chapter provides clear concept of adaptation to climate change, different types of adaptation, measurement and adaptation capacity. Planned or anticipatory adaptation has the potential to reduce vulnerability and realize opportunities associated with climate change effects and hazards. There are numerous examples of successful adaptations that would apply to climate change risks and opportunities. Substantial reductions in climate change damages can be achieved, especially in the most vulnerable regions, through timely deployment of adaptation measures.

In the absence of planned adaptation, communities will adapt autonomously to changing climatic conditions, but not without costs and residual damages. Societies and economies have been making adaptations to climate for centuries. However, losses from climate-related extreme events are substantial and, in some sectors, increasing—indicating patterns of development that remain vulnerable to temporal variations in climatic conditions.

Most communities, sectors, and regions are reasonably adaptable to changes in average conditions, unless those changes are particularly sudden or not smooth. However, these

communities are more vulnerable and less adaptable to changes in the frequency and/or magnitude of conditions other than average, especially extremes. Changes in the frequency and magnitude of extremes underlie changes in mean conditions and thus are inherent in climate change; adaptation initiatives to these hazards are of particular need. Adaptations to current climate and climate-related risks (recurring droughts, storms, floods, and other extremes) generally are consistent with adaptation to changing and changed climatic conditions. Adaptations to changing climatic conditions are more likely to be implemented if they are consistent with or integrated with decisions or programs that address non-climatic stresses. More research is needed on spatial adaptive culture based on traditional knowledge.

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