Perspective of Adaptation as Responses to Global Warming

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Abstract

The Kyoto Protocol, which became effective in February 2005, has been promoting a series of countermeasures against global warming on an international scale under the UN Framework Convention on Climate Change (UNFCCC). As a result of overwhelming impacts of the heat wave in Europe in 2003 and Hurricane Katrina that devastated the city of New Orleans in August 2005, there has been a growing concern over widespread climatic anomalies. This in turn has triggered increased interest in adaptation as a long-term countermeasure against the effects of global warming. In particular, developing countries, including small islands in tropical and subtropical zones, are vulnerable to climate change and variability, though they emit only small amounts of greenhouse gases. Therefore, adaptation is widely recognized as a primary countermeasure against global warming in these countries. In this paper, we attempt to draw a picture of the current understanding of the role and scope of adaptation by examining its purposes, nature and tools, as well as gaps in implementation and the social capacity for adaptation.

Key words: adaptability, adaptation, climate change, sustainability, vulnerability

1. Introduction

In February 2005, after the Kyoto Protocol became effective, a new stage of the international framework for regulating the emission of greenhouse gases (GHGs) was initiated under the UN Framework Convention on Climate Change (UNFCCC). The protocol imposed targets on industrial countries and countries in economic transition of formerly Soviet Eastern Europe to reduce their GHG emissions to achieve reduction targets for the first commitment period of 2008 to 2012. At the same time, the heat wave which hit Europe in 2003 and Hurricane Katrina, which devastated New Orleans in the U.S.A. in August 2005, evoked strong concern throughout the world that global warming had already begun affecting the earth's climate system on a large scale. Long-term problems, such as how to reduce the future effects of global warming, have emerged along with concerns over increasing numbers of extreme weather events. Adaptation can address such problems. Interest in adaptation is growing most rapidly in developing countries, including small islands in tropical and sub-tropical regions which are vulnerable to impacts of climate change and variability while they contribute little to GHG emissions.

Studies on adaptation, however, are still at a conceptual stage. Because adaptation is becoming a major issue in responses to global warming, it would be useful to review the current state of recognition and future tasks of adaptation. In this paper, we try to show an overview of the concept of adaptation and adaptive measures for the coastal zones as an example.

2. International Activities on Adaptation

2.1 Adaptation in the international framework of responses to global warming

The UNFCCC stipulates the ultimate target of countermeasures for global warming in Article 2.

"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

The target of this convention, i.e., stabilization of greenhouse gas concentrations in the atmosphere, means suppressing global warming below a particular

level that would have a serious effect on ecosystems, food production, and economic development. To this end, there are two directions: one is mitigation to regulate GHG emissions, and the other, adaptation to reduce its harmful effects.

Mitigation consists of measures to reduce GHG emissions and stabilize their atmospheric concentrations. On an international level, the UNFCCC was agreed upon at the UN Conference on Environment and Development in 1992, and agreement was reached in 1997 on the Kyoto Protocol, which sets specific targets for reduction of greenhouse emissions and plans for their execution. The Kyoto Protocol went into force in February 2005 after tortuous negotiations, though unfortunately the US withdrew from the Protocol. In the first commitment period of 2008 to 2012, developed countries and countries with economies in transition are required to reduce their GHG emissions by an average of 5% of their respective 1990 levels. Each country is trying to meet the target by promoting energy-saving domestically and by enhancing multilateral cooperative measures, such as joint implementation and the clean development mechanism (CDM).

The effect of the reduction targets set by the Kyoto Protocol is limited to achieving the ultimate objectives of the UNFCCC, and no framework for emissions reductions after 2013 has yet been agreed on. Therefore, global warming will advance to a greater or lesser extent, because it would be very difficult to arrest global warming completely. In any event, it will be necessary to incorporate adaptation into responses. Adaptation can cover every field that is affected by climate change: adaptive measures encompass a wide range of areas, such as agriculture and food production, water resources, disaster prevention, health, energy, industry and the natural environment.

Both mitigation and adaptation are effective at addressing global warming, and this effect can be maximized by forming an optimal combination. Based upon this recognition, COP10 of the UNFCCC held in 2004 agreed on the "Buenos Aires programme of work on adaptation and response measures," and a five-year plan (Kubota, 2006a) for studies on adaptation was initiated. Developing countries strongly seek financial assistance from developed countries for adaptation, because such measures are effective both for preventing the adverse effects of global warming and improving and upgrading infrastructures for disaster prevention, water resources and agriculture. However, there is neither a common recognition on what constitutes adaptation to global warming, nor a clear distinction between adaptation and infrastructure development. As a result, adaptation is expected to become a major issue in future negotiations. It is understandable that the "Buenos Aires programme of work" started with research-type activities to deepen and share understanding of regions' and countries' vulnerability to global warming and discuss what constitutes adaptation measures (UNFCCC, 2005).

2.2 Dangerous level of global warming and adaptation

The Intergovernmental Panel on Climate Change (IPCC) presented future climate projections in its third assessment report published in 2001 (IPCC WGI, 2001). Because the degree of global warming depends on GHG emissions, particularly that of carbon dioxide, it varies with the evolution of human socioeconomic systems. The IPCC's climate projections were based on SRES scenarios of future societies, which were developed in the Special Report on Emission Scenarios (IPCC, 2000). In the projections, the degree of temperature rise ranged between 1.4°C and 5.8°C from 1990 to 2100, although the estimate varied depending on the scenarios and climate models used. The sea-level rise is estimated to be 0.09 to 0.88 meters by 2100, and rainfall is projected to increase throughout this century with larger yearly fluctuations.

Changes in typhoons are a major concern in climate change. Theoretical estimates suggest that the rise in sea surface temperature intensifies evaporation, which is the energy source for typhoons, thus creating more-powerful typhoons (Emanuel, 1987). Walsh (2004) estimated that the central atmospheric pressure would decrease by 5%-10% by 2050 and, accordingly, the peak rainfall intensity from typhoons would increase by 25%. The climate model has indicated recently that strong, long-lasting typhoons will tend to occur, though the number of typhoons generated will decrease by about 30% (Oouchi *et al*, 2005).

Negotiations around a future framework to stabilize global warming including the post-Kyoto Protocol frame should be based on the recognition of the dangerous levels referred to in Article 2 of the UNFCCC. In the studies to determine the dangerous levels of global warming, two kinds of impacts have been recognized: Type 1 impacts, which are those that intensify gradually with the progress of global warming, and Type 2 impacts, which are abrupt large-scale changes occurring in an irreversible and discontinuous manner (Schneider, 2004; Harasawa, 2006). Type 2 impacts induce fatal changes in the earth's environment when global warming exceeds a certain threshold. Examples include a rise of several meters in the sea level caused by the collapse of the Western Antarctica ice sheet (Nicholls *et al*., 2005) and the disruption of the thermohaline ocean circulation. Because it is impossible to adapt to these kinds of changes, Type 2 effects should be avoided at any cost.

On the other hand, Type 1 impacts, by their nature, increase gradually with the degree of warming. Because such effects can be alleviated to some extent by adaptive measures, the actual outcome of Type 1 impacts varies considerably with the level of adaptation. Therefore, we will focus on these types of impacts in the following discussions.

3. Structure of Vulnerability to Global Warming – Susceptibility, Resistance, and Vulnerability

The impacts of global warming can be divided into two: direct physical impacts (primary effects) and indirect effects (secondary and higher-order effects). Direct impacts cause changes in the physical environment, such as droughts due to less rainfall and coastal inundation caused by sea-level rise. Indirect impacts propagate into the socioeconomic system and the natural environment as a result of the direct impacts. For example, migration of inhabitants occurs as a result of flooding; restructuring of industries and conversion from agriculture may happen due to yield decreases; and infrastructures become dysfunctional under the changed climate. Developing countries in the Asia and Pacific region will be highly susceptible to these indirect effects.

On the other hand, industrialized countries including Japan, will take necessary measures to avoid or reduce adverse impacts if they face such problems. They may raise coastal dikes to protect lands against sea-level rise, and upgrade water resource management to prepare for droughts. In many cases, private companies will also implement measures to avoid risks. Such measures, either public or private, entail financial costs: this means that society as a whole bears the cost of avoiding risks of climate change. Even if substantive damages take place, victims are covered by insurance. In this way, developed countries have a capacity to redirect or share the damage costs in a well-developed social system.

However, developed countries cannot always avoid, redirect or distribute all physical impacts. As estimates of climate change have a certain degree of uncertainty, external forces, such as torrential rainfall and severe droughts, may become too devastating and exceed the design criteria of infrastructural facilities. Other socioeconomic systems may also suffer from large-scale impacts if disaster-prevention facilities are damaged. For examples, the flood disaster in the Tokai area, Japan, in 2000 (JSCE, 2000), the torrential rainfall in Tokyo in 2005, and Hurricane Katrina in 2005 showed that flooding of city centers could cause tremendous disruption of many societal activities. Large numbers of underground facilities, such as underground malls, transformer stations, and information networks, could suffer from major disruption in the event of flooding.

Such consideration suggests that the onset of damage due to climate change is determined by several factors. They can be classified as follows: 1) Climatic stimuli: the degree and extent of external forces, 2) Susceptibility: the weakness of an exposed system to particular influences, and 3) Resilience: the ability of the system to resist damage (also called adaptability). Vulnerability can be defined as a combination of these factors. We can consider vulnerability in various spatial scales, such as global, national and regional, and for sectors as well.

Although vulnerability has been defined in several ways, the following definition is commonly acceptable (IPCC WGII, 2001). “The susceptibility of a system to adverse effects from external forces, and the ability of the system to change and adapt to or utilize those effects.”

This definition implies that vulnerability is not merely passive damage to an exposed system, but a balance among the factors causing the damage and the system’s ability to handle them. We can express this relationship as follows.

$$\text{Vulnerability} = \frac{\text{External force}}{\text{Resilience} - \text{Susceptibility}}$$

This relationship shows that the vulnerability of a system increases with external force and susceptibility and decreases with resilience. Therefore, if the degree of the external force (climate change, extreme events, or sea-level rise) is constant, we need to increase resilience to decrease vulnerability. It is the basic role of adaptability to increase the system’s resilience.

4. Characteristics of Adaptation and Its Current Status

4.1 Kinds of adaptation and their characteristics

Adaptation can be defined as the process of developing, formulating, and implementing a strategy and policy to alter the effects of climate change and adapt to it. The basic concepts of adaptation can be summarized as follows (Hay & Mimura, 2006).

1. Avoidance and reduction of the risks of harmful impacts
   This means taking preventive measures against the anticipated effects, such as regulation of development in vulnerable areas and improvement of disaster-prevention systems.
2. Mitigation of damages
   This involves measures to diminish damages that have already occurred. Examples are measures to relieve adverse consequences of a disaster and support recovery from the damages.
3. Dispersion of risk
   The concept behind this measure is to lessen the costs of the damage by dispersing them among many people or over a longer period of time rather than concentrating damages in a short time. Insurance is a typical example.
4. Acceptance of risk and doing nothing
   This means doing nothing at a particular time and accepting the risk of harmful effects.

For the classification of adaptive measures, there are several axes such as the exposed societal sectors, intentionality and timing of implementation (Mimura & Yokoki, 1998; Kubota, 2006). Adaptation involves a

range of sectors including agriculture and food production, water resources, disaster prevention, health, energy, industry and the natural environment. Examples of adaptive measures in each field are listed in Harasawa *et al*. (2003).

Let us take the coastal zone as an example of an exposed sector, as it is among the most susceptible to climate change and sea-level rise. In fact, adaptive measures for coastal zones have been intensively studied since the beginning of climate change studies. Even in its first report, the IPCC proposed three categories of planned retreat, accommodation and protection for coastal zones (IPCC WGII, 1990). These categories comprise the countermeasures listed in Table 1. In the earlier stages of discussions, planned retreat was promoted mainly by western developed countries. However, the importance of protective measures has remerged since the Indian Ocean Tsunami in 2004 and Hurricane Katrina in 2005.

In its policy on coastal management, Japan has been examining incorporation of long-term measures against sea-level rise *e.g*. (Research Group on National Land Prevention against Sea-Level Rise due to Global Warming, 2002). In addition, damages have

Table 1 Options for Adaptation of Coastal Areas. (after Harasawa *et al*., 2003)

Classification of Adaptive options	Options
Retreat	Development regulations for disaster-prone coastal areas Land use and regional planning Evacuation from highly vulnerable coastal areas Subsidies for relocation
Accommodation	Proactive planning to avoid harmful impacts Changes of land use patterns Protection of coastal ecosystems such as mangroves Strict regulations in disaster-prone areas Disaster insurance
Protection	Protection through hard structural measures – Disaster prevention: dikes, seawalls, floodgates – Anti-erosion measures: jetties, detached breakwaters – Water resource management: weirs, walls against salt water intrusion Protection through soft technologies – Anti-erosion measures: beach nourishment, protection of sand beaches – Conservation of coastal ecosystems: protection of marshes, afforestation – Early-warning systems – Evacuation systems

Table 2 Examples of adaptive measures. (Hosomi *et al*., 2005)

Classification	Countermeasures	Description
Changes in land use		
Changes in land use for disaster prevention	Buffers	Conservation and improvement of sand dunes, coastal forests, and securing spaces as flood buffers
	Flood-control basins	Improvement of flood-control basins and reservoirs to reduce flood damage
Regulation of land use	Community relocation	Relocation of residences away from disaster-prone areas; support for relocation
	Regulation of buildings	Prohibition and regulation of the construction of new buildings in flood-prone areas
	Regulation of development	Limiting the construction of buildings to conserve coastal zones
Changes in architecture	Reinforcement and foundation raising	Pilotis; Using reinforced concrete; Elevating the ground
	Setbacks	Making the establishment of setbacks mandatory for the construction of buildings in designated areas
Integrated coastal management	Management systems, including laws	Development and implementation of ICM plans on the basis of laws
No measures	Do nothing	No short-term measures to conserve the natural environment
Measures to improve disaster-prevention systems		
Support for evacuation	Evacuation routes and evacuation zones	Designation of evacuation zones in uplands and safe routes for evacuation
Information, education and community-based abilities	Hazard maps	Publication of hazard maps showing risk zones for flooding, evacuation zones, and evacuation routes; Dissemination of this information to local residents
	Information	Promoting collection of information on observations and climate projections, and disseminating the information
	Emergency drills	Implementing disaster drills by local residents on a regular basis
	Education on disaster prevention	Education of local residents and children in local communities and schools
	Community-based disaster prevention organizations	Establishment of community-based volunteer organizations to help senior citizens
Support for recovery	Disaster-recovery funds and subsidies	Establishment of funds to support recovery from damage
Economic measures	Flood insurance	Establishment of economic measures such as flood insurance
Structural measures		
Flood prevention	Coastal protection facilities	Improvement of coastal dikes, seawalls, breakwaters, and water gates; Renewal of aged facilities
Reducing damage from flooding	Drainage systems	Improvement of drainage pumps to minimize damage resulting from flooding

been caused by high tide levels and waves that exceeded their historical maxima during the past decade. Such a tendency has triggered studies on new coastal protection policies to secure higher levels of safety, taking into account demographic and financial constraints (Hosomi *et al*., 2005), as Japan's population is anticipated to decrease as a result of the falling birthrate. Table 2 shows possible concrete measures. Integration of hard and soft measures is emphasized through combining protective structures, such as dikes and seawalls, and non-engineering measures such as land use plans and information transfer for evacuation.

Secondly, regarding intentionality, there is a difference between autonomous and planned adaptation. Autonomous adaptation is a reactive response with no proactive intervention, whatever the actor happens to be, natural ecosystem or human society. Planned adaptation, on the other hand, is intentional actions aimed at predicting effects of climate change and mitigating their adverse consequences. At the same time, adaptation can also be divided into reactive and proactive types, according to the timing of implementation of the measures.

Table 3 shows adaptive measures classified based on the criteria mentioned above. The affected systems are divided into natural and human social systems. All adaptation by natural systems is reactive in its nature. However, this does not mean that it is impossible to decrease impacts on natural systems. For example, landward migration of mangrove forest may be a natural adaptation to sea-level rise, but it can maintain its area if an evacuation corridor is created landward behind it to support its autonomous adaptation.

4.2 Factors affecting adaptation

As mentioned above, adaptation to climate change occurs at various levels ranging from the national to community, family and individual. The adaptive capacity required by each is determined by many interrelated factors. Major factors indicated in Table 4 are financial resources, human resources, scientific knowledge, accessibility of information, technology, institutional systems and infrastructure (Yoho & Tol, 2002; Smit & Pilifosova, 2001; The World Bank, 2006). These factors can be roughly classified into resource availability, scientific knowledge and its acceptability, and levels of institutional arrangement. Because the adaptability of each country is determined by its comprehensive abilities, it is not easy to promote. Even if an infrastructure system, such as disaster-prevention facilities, is constructed with temporary foreign aid, such facilities cannot continue to work without capital, awareness of residents and institutions to support it. In this sense, building adaptability means building long-term social capacity.

Furthermore, it should be noted that both the impacts of climate change and adaptation differ greatly among regions. Because water availability, frequency of natural disasters, and agricultural patterns vary markedly with the geographical and social conditions of a region, adaptive measures cannot be formulated without consideration of these conditions. In the development of adaptation, it is essential to strengthen the resilience of the region by enhancing the traditional knowledge, technology and social institutions (Barnett, 2001).

Table 3 Classification of adaptation – reactive and proactive. (after Klein and Tol, 1997; Harasawa *et al*., 2003)

System		Reactive measures	Proactive measures
Natural environment		Change of growth period Change in species in ecosystem Migration of plants Migration of habitats	
Human society	Individual	Change in cultivation methods Installation of air-conditioners	Insurance Elevating house foundations Migration to safer areas
	Local and national government	Improvement of water management system Improvement of dikes Anti-erosion measures Beach nourishment Subsidies Compensation for damage	Information dissemination Early-warning systems Change in building codes and design criteria for facilities Land use and regional planning

Table 4 Controlling factors of adaptability. (Yohe & Tol, 2002; Smit & Pilifosova, 2001)

Factors	Contents
Financial Resources	Amounts of available capital and other economic resources
Human resources	Human capacities, such as skill, experience and educational level
Knowledge and awareness	Fundamental knowledge for understanding environmental changes and their effects and implications
Information management	Personal and collective ability to understand and process information on impacts and adaptation
Technology	Ability to utilize the appropriate technologies and access to the necessary information on them
Social institutions	Status of social systems for ensuring access to information and supporting decision making
Community	Human networks to respond to impacts collectively in the social community
Risk management	Framework and capacity for sharing and distributing risks among people

4.3 Current status of adaptation

Some studies have been performed on the adaptation to climate change including IPCC WGII (2001), Huq *et al*. (2003), IPCC (2004), Parry *et al*. (2005) and Hay & Mimura (2005, 2006). In this section, we will discuss some of the major points based on these studies.

4.3.1 Some points on adaptation

It is obvious that adaptation has the ability to reduce the adverse impacts of climate change and to utilize its favorable effects. Countermeasures against current metrological extreme events, such as droughts and floods, are also effective as adaptive measures to future climate changes. Since the projections of future climate entail uncertainties, major adaptive options are no-regret measures, which are effective at improving today's preparedness for hazards even if there is no future change in climate. The costs of adaptation are usually less than those of development, and, therefore, forecasting and planning for adaptation is more cost-effective than reactive responses.

Mainstreaming adaptation is another emphasized point. This means incorporating the adaptation consideration in major policies, such as disaster-prevention plans, water-resource management, agricultural and food security policies, and environmental management, rather than highlighting the isolated adaptation. Only this can ensure effective adaptation to climate change.

Adaptation to climate change and sustainable development share the same direction. Strengthening adaptive capacity includes many activities such as reducing human pressure on resources, management of environmental risk and social adaptability, which are essentially the same as those for sustainable development. This means that adaptation is an important component of sustainable development.

Regarding the lead time of responses, it has been argued that adaptation can have an immediate effect, whereas a considerable lead-time is required for mitigation, i.e., reduction of greenhouse gas emissions. However this is not necessarily true. For example, Japan accelerated improvement of its coastal-protection facilities after the devastation by the Ise Bay Typhoon in 1959 and the Chilean Earthquake Tsunami in 1960, but it took 30 to 40 years to increase safety throughout the country. It will be difficult for developing countries to increase their safety against natural disasters to a satisfactory level quickly. It should be noted that some adaptive measures require considerable lead time for implementation.

4.3.2 Adaptive capacity

The degree of adaptation depends on the adaptive capacity of each country, region, or exposed sector. This is because the adaptive capacity to climate change relies on various factors, such as financial and human resources, scientific knowledge, access to information, technology, social institutions and infrastructure. As mentioned above, a community's ability is important to its adaptation on the ground.

4.3.3 Differences in vulnerability and adaptability between developed and developing countries

Finally, we will consider differences in vulnerability and adaptability between developed and developing countries. Vulnerability of developed countries is relatively low, because they have developed multiple safety nets consisting of social institutions and infrastructure. In addition, developed countries can use their financial and technological capacities to reduce damaging effects when they face climate change. Though they may sometimes suffer severe damage from extreme events as seen in the case of Hurricane Katrina in the US, the major impacts will appear as a form of additional social costs rather than crude damages.

On the contrary, developing countries in the Asia-Pacific region are highly susceptible to the impacts of climate change, because many are located on low-lying deltas, small islands, and areas prone to tropical cyclones. For these countries, the impacts of climate change could appear in more violent direct damage. In addition, the Asia and Pacific region is expected to undergo high economic growth and a rapid increase in population. Mega-cities are growing in the coastal zones. These factors may increase the vulnerability of the region. On the other hand, the economic growth may enhance its adaptive capacity by increasing technological capabilities, economic strength and social safety nets. However, it is uncertain how much the fruits of the economic growth can reduce the vulnerability.

As discussed above, vulnerability differs between developed and developing countries. Accordingly, the threshold for the dangerous level of global warming differs in these countries; i.e., the threshold is higher for less vulnerable countries and the damage will be relatively small unless climate change proceeds considerably. On the other hand, developing countries with a high degree of vulnerability can be badly affected even by small changes in climatic conditions. This aspect needs to be taken into account in global climate policy from the equity viewpoint.

5. Conclusions

Although adaptation is one of two major responses to climate change, no concrete policy movement has emerged on how to strengthen the adaptive capacity of developing countries or how to incorporate adaptation into major policies. In order to overcome this problem, several tasks can be proposed for future studies.

5.1 Adaptive options and technologies

Since adaptation is a set of policies, it needs technologies and policy options as its elementary tools. Guidelines and a menu of technologies should be prepared for adaptation in each field and sector. Because adaptation is highly dependent on the geo-

graphical, environmental, social and cultural conditions of each country, these conditions should be carefully considered in developing guidelines and the menu of technologies. To develop relevant adaptation, it is important to understand the resilience of each region, and to assess its traditional and indigenous knowledge and technologies. At present, many research institutes around the world have launched studies on adaptation along this direction.

5.2 Capacity building for adaptation

The success of adaptation depends on the adaptive capacity of each country and local community. Studies are necessary to identify the roles of factors which can strengthen the adaptability, particularly for community-based adaptation. This aspect has increasingly attracted international attention. In communities, traditional mutual cooperation and consanguineous networks are important. In addition, it will be a major challenge to incorporate the traditional knowledge and technologies of the communities in modern science and technology. So far, the policies of central and local governments have rarely considered the local situation properly.

5.3 The world under multiple stresses and sustainable development

Global warming is not the only issue facing our society. Human society also faces other problems, such as environmental pollution, loss of biodiversity, changes in land use due to economic development, population growth and economic globalization. It is important to address these pressures in parallel with global warming. The real world is under multiple stresses, and sustainable development can be achieved by solving these problems in a holistic manner. This approach may pave the way to sustainable development.

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