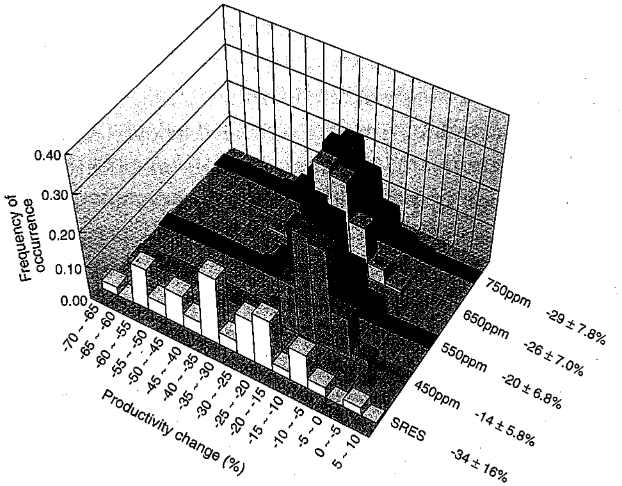


Change in wheat productivity in India considering CO_2 fertilization effect (% change of 2100 relative to 1990)
(Courtesy of NIES and Kyoto University)

Figure 4. An example of estimated crop impacts at several CO_2 stabilization levels (Courtesy of NIES and Kyoto University).

3.2 Impacts on Japan

In the early 1990s, Japan began actively conducting studies on the impacts and risks of global warming, the same when time international studies centered on the IPCC were proceeding. These studies covered a wide range of fields, including water resources and water environment; terrestrial ecosystems; agriculture, forestry and fisheries; marine environments; coastal zones; land preservation, disaster prevention, and people's lifestyles; industry and energy; and human health. Recently these studies have included estimates of impacts on developing countries in the Asia-Pacific region, and adaptive measures against these impacts.

The results of these studies and current knowledge regarding the impacts of warming on Japan (Harasawa and Nishioka (editors), 2001) are described below.

3.2.1 Emerging Impacts of Global Warming

Trend for Rising Mean Temperatures in Japan

There is a rising trend in the mean annual temperature in Japan, as evidenced by a rise of about 1.0°C over the past 100 years (see Fig. 2 in Chapter 1, Part 2). This rise in temperature began accelerating in the mid 1980s. Of the ten hottest years in the past century, eight were in the past decade, coinciding with the global trend. The rise in temperature in urban areas over the past 100 years has been more than 2°C, with that in Tokyo reaching 3°C. This large rise in the urban areas is partly due to the heat island phenomenon peculiar to cities. Even excluding this, however, Japan is clearly warming.

Changes in Organisms Sensitive to Warming

Living organisms and ecosystems detect warming and respond in various ways. In a worst-case scenario, a warming environment can lead a species to extinction.

Among the phenological observations conducted nationwide by the Meteorological Agency since 1953, the changes in the flowering date of the Japanese cherry (*Prunus yedoensis*) are particularly striking. These trees now flower 5 days earlier on average than they did 50 years ago (Fig. 5). In spring 2002, they blossomed at an unprecedented early date; holding cherry blossom festivals after the blossoms had already fallen to the ground was a first in people's memories.

There are a number of other examples of warming.

- Decreased alpine flora in Hokkaido, the north island in Japan.
- Expanded distribution of southern broad-leaved evergreen trees such as the Chinese Evergreen Oak.
- Nagasakiageha butterfly (*Papilio memnon thunbergii*), the northern border for which has been Kyushu and Shikoku Islands, appeared in Mie Prefecture in the 1990s.
- Appearance of the southern tent spider, seen only in western Japan in the 1970s, in the Kanto Region in the 1980s.
- Expansion of the wintering spot of the White-Fronted Goose to Hokkaido.
- Appearance of tropical fish in Osaka Bay.

- Shifting habitats of ermine and grouse on mountains such as Hakusan and Tateyama to higher elevations. There is some danger of complete disappearance.

These and other indications of diverse changes have been observed, and demonstrate that impacts of warming have begun to appear in organisms and ecosystems of Japan.

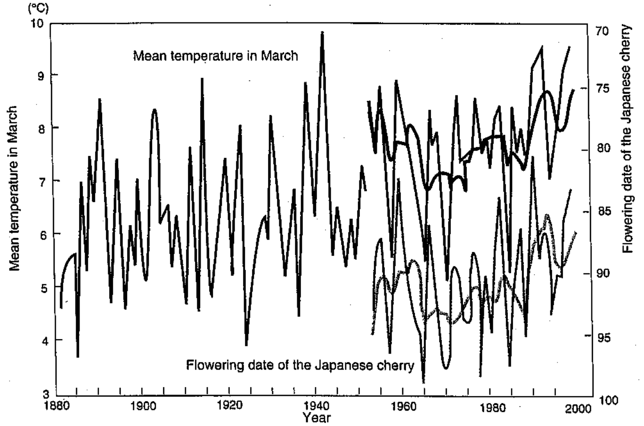


Figure 5. Annual changes in flowering date of the Japanese cherry (*Prunus yedoensis*) and mean temperature in March in Kyoto, Japan. Bold lines indicate five-year running means (after Dr. Keiko Masuda).

3.2.2 Impacts on Natural Environment

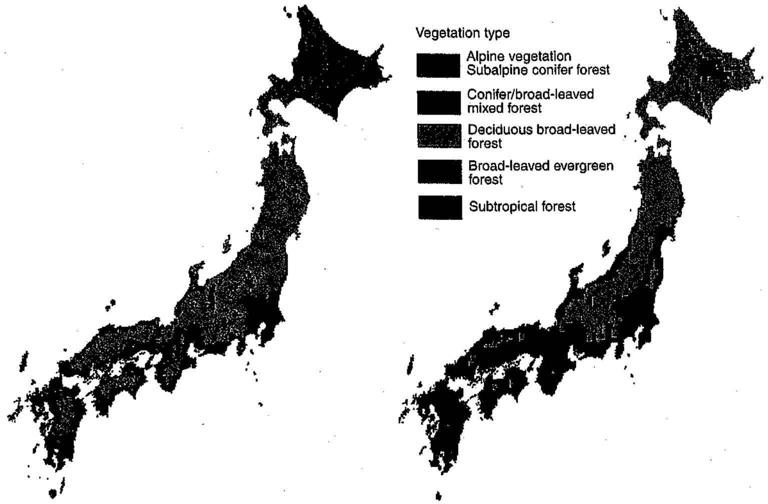
Impacts on Forests and Vegetation

Beech forests are typical of the cool temperate zone and are widely distributed in Japan. However, at the southern limit of their distribution, atmospheric warming will cause the transition of these forests into evergreen forests. Today, more than 40% of forests in Japan are artificial, but as the surface temperature increases, the environments where Japanese cedar and cypress have been planted are changing from beech zones to *shii* and *kashi* zones, two varieties of oak, and evergreen trees become competing species in these afforested lands.

The habitat range of large mammals such as deer, monkeys, and boar

that live in forest zones is expanding, due to decreased snow accumulation volume and period due to climate change. If there is less snow, the survival rate of wild animals increases, as does the number of individuals. This results not only in damage to crops as these animals forage, but also more conflicts with humans.

Among the changes in potential vegetation in Japan, a great decline in the distribution of alpine vegetation and subalpine coniferous forests is predicted to occur by 2050. There is also risk that northern coniferous forests will change to broad-leaved deciduous forests, and that southern broad-leaved deciduous forests will change to broad-leaved evergreen forests, as shown in Fig. 6. This figure also shows a marked reduction in mountain ecosystems with a northward shift in the vegetation zone for the entire Japanese archipelago.



Left: Distribution of potential natural vegetation at present
Right: Distribution of potential natural vegetation for 2050 climate predicted by CCSR-98 scenario

Figure 6. Predicted changes in the distribution of potential natural vegetation between the present day and 2050 (Ishigami *et al.*, 2000).

Impacts on Biodiversity

Impacts from warming also include the risk of decreased biodiversity. Lands susceptible to impact include mountain and alpine regions, islands and isolated shorelines and beaches, and trees in urban areas. Since these ecosystems cover small areas, it may be difficult for them to maintain the numbers of individuals needed to prevent extinction.

Particularly at risk are organisms that live in a limited area. Examples include species with many varieties with mostly low survival capacities, such as *yakutanegoyo* in Japan, a variety of Armand's pine that lives only on Yakushima and Tanegashima Islands. Plant communities native to islands of the Southwest group or other small islands are highly susceptible to risks due to warming.

Deteriorating Water Environment and Fresh Water Ecosystems

In shallow lakes such as Kasumigaura, rising water temperatures and increased precipitation are thought to lead to higher chemical oxygen demand (COD) and concentration of nutrients such as nitrogen and phosphorous, which contribute to deteriorated water quality such as decreased transparency and eutrophication. In coastal waters as well, oxygen-deficient water bodies are more readily formed than in the past.

Moreover, as the sea-level rise causes further seawater invasion into estuaries, the salt concentration in many brackish lakes will increase, resulting in changes of ecosystems.

In river ecosystems, there is concern that fish habitats in cold water, such as Dolly Varden trout and white-spotted char, will greatly decrease. However, even if some species decrease, the diversity of the ecosystem would be maintained by the introduction of new species, although a decrease in the diversity of species will be unavoidable if this does not keep pace with the climate change.

Changing Ocean Environment

Recently, observations have demonstrated that the water temperature of the deep layer of the Japan Sea has been rising, and that a shrinking area of sea ice in the Sea of Okhotsk was caused by rising sea-surface temperatures. In addition, trends in sea-level changes over the past 100 years indicate elevated levels on the Sanriku coasts and the Pacific Ocean side, and lower levels along the Japan Sea coast. This is because the impacts of the global rise in sea level are superceded by rising and falling ground motion due to plate tectonics around Japan.

As sea-water temperature rises, plankton that had previously lived only in the tropical and semitropical regions have begun appearing in the seas around Japan. Southern planktons that were not previously seen have appeared around Japan, triggering harmful damage to cultivated oysters and other shellfish. In addition, the appearance of rivals may reduce sardine catches, diminishing the value of fishing grounds in coastal regions, as sardine is a major target for fishing.

Changes in ocean ecosystems also impact large mammals situated at the top of the food chain. Indeed, it is reported that the number of polar bears has been decreasing in the Arctic Ocean.

Coastal Land Features and Ecosystems

Coastal zones contain the habitats of organisms extremely vulnerable to climate change. One of these is coral reefs. Coral reefs grow upward at a rate of about 40 cm in 100 years in average. Therefore, if the future sea-level rise exceeds that rate, reefs will not be able to keep pace. Even more serious is the rising sea-water temperature. The optimum water temperature for coral reef growth is 18 to 28°C. If high water temperature of more than 30°C continues, the algae that coexist in the coral symbiotically will separate from the reef, and the coral becomes discolored and dies. This is called coral bleaching. Coral bleaching occurred on a large scale in all parts of the world after the El Niño/La Niña in 1997–98. If such phenomena occur more frequently in the future, it will likely cause serious damage to precious coral reef ecosystems (Fig. 7).

Another major problem is the erosion of sandy coastlines. While the main causes of erosion are a decreasing sediment supply and block of longshore sand transport, sea-level rise will accelerate beach erosion. If the sea level rises 30 cm, it is estimated that at least 56.6% of the sand beaches in all Japan will be eroded (Fig. 8). If the sea level rises 65 cm to 1 m, sand beach erosion will reach as much as 81.7% to 90.3%.

Tidelands, which support rich ecological communities, are no exception. Because tidelands are cut off from the hinterland by dikes or other structures, they cannot recede inland even if sea levels rise, and they are drowned. Therefore tidelands, which have an extremely gentle mean slope of 1/300, will lose an area 150 m wide with a rise in sea level of 50 cm. If such disappearance of tidelands continues, it is likely to have a huge impact on migratory birds such as snipes and plovers.

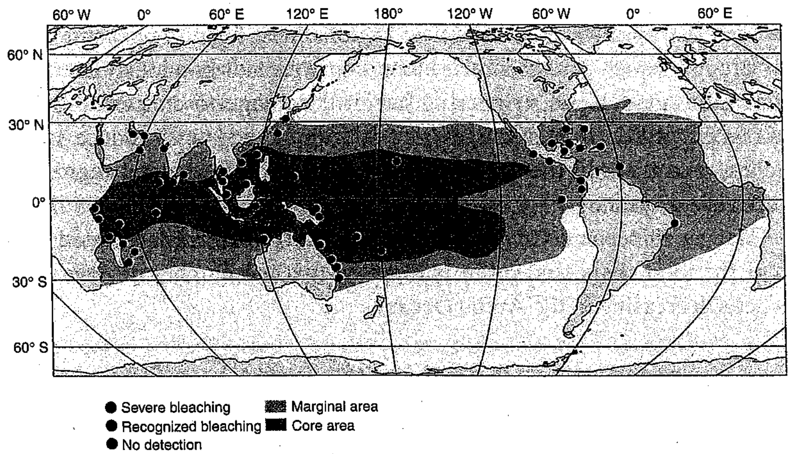


Figure 7. Coral bleaching during 1997 and 1998.

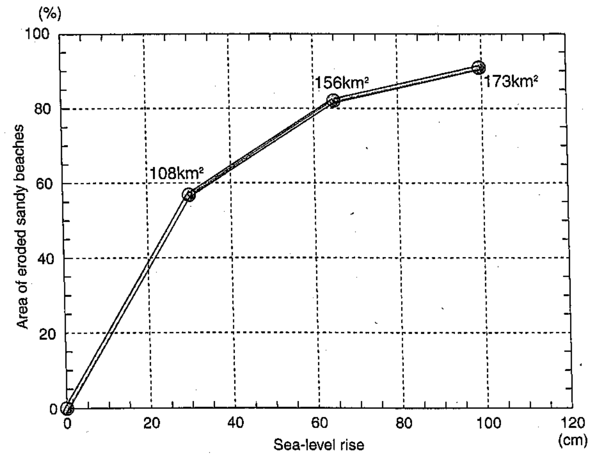


Figure 8. Predicted beach erosion due to sea-level rise (Mimura and Kawaguchi, 1996).

Considerations for Natural Adaptation

As described in the previous sections, the impacts of global warming are predicted to appear over a wide range of the natural environment. Whether natural environments can survive warmer conditions will depend on their adaptive capacity. Some environments will be very resilient against rising temperatures, changes in rain and snowfall, and rising sea levels, while others will be extremely vulnerable.

There will also be cases where the impact is further bolstered by human activities, as in the example of coastal tidelands or wetlands. These could survive by moving inland if sea level rises, but since most coastlines are covered by seawalls or dikes, they are blocked from receding. Ultimately, the areas of these landforms will shrink.

All adaptation of natural ecosystems to the warming will be reactive in nature. Therefore, to facilitate the natural adaptation we must provide natural systems with room to adapt. An example is creating spaces behind the present places in advance that can be used as evacuation corridors.

3.2.3 Impact on Human Society

Water Resources — Concerns of Flooding and Drought

The largest problems relating to water are flooding and drought. Recently, we hear news of intensified flooding in various regions of the world as well as drought reported in Africa and China.

In Japan, the frequency of extreme weather events of drought and flooding are increasing. There has been an upward trend in the last 100 years of incidences with very little annual rainfall (which generally occur once every ten years) across the country. The frequency of days with intensive rainfall is also increasing, which tends to cause severe urban flooding. These phenomena have a substantial impact on human society. For example, the 1994 drought in western Japan caused 11.76 million people to experience reduced pressure and restricted hours of water supply. Calculating the effect in simple economic terms, damage from the drought reached 140.9 billion yen or 1.2 billion US$.

The effect of climate changes will differ with areas depending on the extent of future rainfall change. One prediction for Japan indicates that flooding will be intensified, and that the river flow in snow regions will increase from January to March, and decrease from April to June.

Impact on Agriculture in Japan

In Japan, approximately 2 million ha of paddies provide about 10 million tons of rice each year, but a change in temperature would affect this productivity. Roughly, rice production will increase in high latitude and decrease in low latitude due to differences in growth and development efficiency. If the same cultivars are introduced in the future, it will be necessary to grow rice earlier in the Tohoku and Hokkaido regions, the northern parts of Japan, and later in the other regions to maintain current level of the yields.

Recent progress in research on the effects of carbon dioxide (CO_2) concentrations has revealed that a doubling the CO_2 condition would cause rice to ripe about 5% faster; and that over northern Japan, yields would increase by about 10 to 25% having no relation with variety of rice. While over middle and western Japan, the response would change depending on the variety of rice cultivated (Fig. 9). However, considering the general understanding, coupling with the problems caused by temperature rise, the impact would be predominantly negative. Further research in this area, therefore, is needed.

With regard to insect pests, a rise in winter temperature would push up potential wintering areas of pupa stage to the north, resulting in northward expansion of the habitats. It is predicted that the range and period of activity of insect pests would expand.

Impact on Food Security

As the Japanese diet has been westernized since the high economic growth period of the 1960s, the yield from domestic agricultural production continues to decrease with a rapid increase of food imports. As a result, the food self-sufficiency in calories has dropped to about 40%.

Japan depends in particular on imports from abroad for feed crops such as wheat and soybeans, which makes the country extremely vulnerable to impacts of climate change on the producing country. In 1999 the amount of imported wheat was 7 to 10 times the domestic production; those of soybeans and corn about 25 and 90 times their domestic production.

The major grain produced domestically is rice. Since irrigation facilities

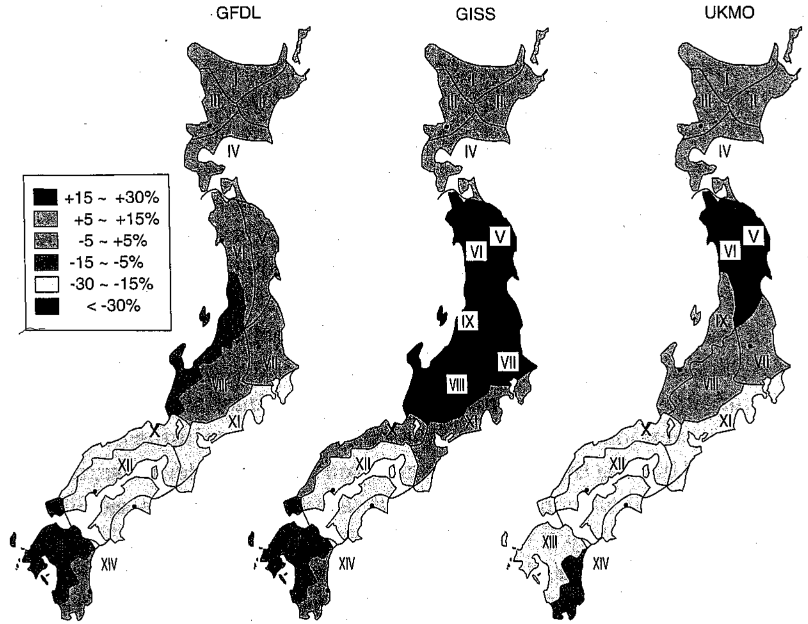


Figure 9. Effects of doubling CO_2 and increased temperature on rice yield (High temperature sensitive variety) (Horie *et al.*, 1995). These results were calculated based on the climate predictions given by Geophysical Fluid Dynamics Laboratory(GFDL), Goddard Institute for Space Studies(GISS), and United Kingdom Metrological Office(UKMO).

are fully developed, rice production is relatively robust to changes in climatic conditions. Regarding vegetables and fruits, as protected horticulture is widespread, negative impacts are not likely to threaten their stable production. Therefore, if food security in Japan is to be threatened in the future, it will probably be from plant disease or pests due to warming and frequent occurrence of unusual events including cold-weather damage.

It has been estimated that in the Asian region including Japan, the food supply will need to be increased up to twice present levels by 2050 to meet the increased demand by population growth and higher living standard. Climate change and sea-level rise may have serious effects on the food supply. We should recognize the possibility that the political and social problems would happen, if large-scale food instability occurs in Asian countries with enormous populations. To prepare for these problems, measures need to be implemented in both Japan and Asian countries to improve crop varieties for adaptation to warming, irrigation systems, and cultivation methods.

Coastal Disaster Prevention

Coastal regions are vital in terms of socioeconomic activity. Cities and towns facing the ocean account for 48% of the population, 48% of industrial shipment value, and 62% of commercial sales. Today two million people live in areas below the high-water level, with assets of 54 trillion yen. With a 1 m rise in sea level, these figures would more than double to 4.1 million people and 109 trillion yen.

In addition, sea-level rise would reduce the function and stability of disaster prevention facilities on the coasts. To maintain the function of seawalls and dikes at their current levels against a 1 m sea-level rise, seawalls should be raised 2.8 m on open sea coasts, and harbor quays raised 3.5 m in semi-enclosed bays.

Flooding and high waves are likely to affect the numerous other infrastructures on coasts as well, such as harbor and fishing port facilities, coastal roads, reclaimed land, pump stations, and drainage systems. Estimated costs required to prevent this are 7.9 trillion yen for harbor facilities and 3.6 trillion yen for neighboring coastal structures for a 1 m sea-level rise. Total expenditures would thus climb to 11.5 trillion yen.

Rising sea levels would also result in rising groundwater levels and increased salinity. This will weaken the supporting capacity of ground and make liquefaction more likely to occur during earthquakes. Because so much infrastructure and buildings are concentrated in the coastal areas with soft ground in Japan, the safety of cities against earthquakes would become a serious concern.

Investigations have begun to ensure the safety of coastal regions in the future (National Land Preservation Study Group for Sea-Levels Accompanying Global Warming, 2002). These studies include close monitoring of mean sea-level changes, and incorporation of the effects of future sea-level rises in the design of harbor and disaster prevention facilities. Internationally, adaptation strategies for coastal regions are classified into protection, accommodation, and planned retreat. The strategy thus does not rely solely on protection by disaster prevention facilities; investigations are also being conducted to change land use in regions at future risk, and to reduce vulnerability of coastal regions, including planned retreat.

Impacts on Industry and Energy

As global warming proceeds, human consumption patterns will also change, leading to changes in industrial structure. For example, if the mean temperature in June to August increases 1°C, consumption of summer products will increase about 5%, and if the period of high temperatures in summer lengthens, the consumption of air conditioning, beer, soft drinks, and frozen desserts will increase, so that electronics and food makers will likely need to reinforce their production systems for seasonal goods. However, it is still not possible to accurately forecast the extent of future effects.

Various impacts will also be felt in the supply and demand for electricity. Forty percent of the power demand in summer is for air conditioning, so a 1°C rise in temperature will cause an increase in power demand of approximately 5 million kW (amount for 1.6 million general households). In addition, the operating rate of factories producing summer products will increase, further increasing the demand for power (Fig. 10).

Changes in the amounts of rain and snowfall also have large impacts on hydroelectric power. The generation efficiency of thermal and nuclear power plants depends on the temperature of the cooling water, and a 1°C rise in coolant temperature will reduce the thermal power output 0.2 to 0.4%, and nuclear power output 1 to 2%.

Heightened Health Risks

Rising temperatures will have a direct impact on human health, with an increased overall death rate from heat stroke and other disorders. The elderly and people with underlying medical conditions will be at greatest risk.

Worsening atmospheric pollution and epidemics of vector-borne infectious diseases such as malaria and dengue are also possibilities. There have been recent reports of mosquitoes that transmit communicable diseases moving northward to the Tohoku region, and the risk of infectious disease may become a reality as the mosquito habitat expands.

However, social aspects play a greater role in the stress healthy people feel in daily life and work, as well as in the chronic diseases. Future research is needed with regard to the extent of the impact, the length of time, and how early it is likely to occur, and the regions where it is more likely to occur, given these social aspects.

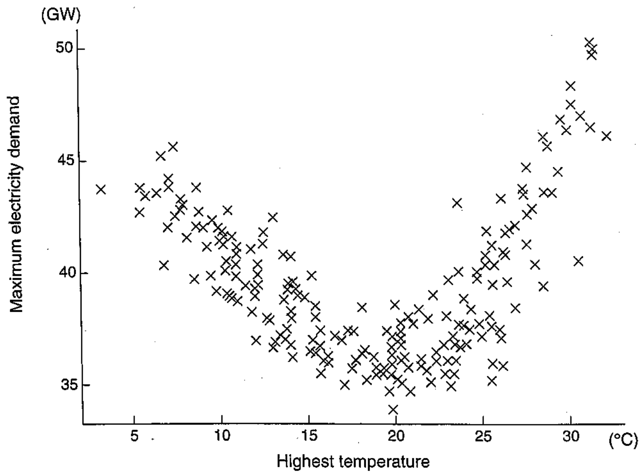


Figure 10. Relation between temperature and maximum electricity demand (Ohsaka *et al.*, 1996).

3.2.4 Status of Research and Adaptation —What Kind of Information will be Needed?

As we have seen, research continues to clarify the impacts of global warming in an extremely broad range of areas. Table 3 lists the distribution of research activities to date. Numerous results have been obtained for terrestrial ecosystems; the agriculture, forestry, and fisheries industries; and coastal zones compared with other fields.

Table 3. Achievement map for impact and risk studies in Japan.

	Water resources Water environment	Terrestrial ecosystem	Agriculture, forestry and fishery	Ocean environment	Coastal zones	Land preservation, disaster prevention, and human settlement	Industry Energy	Human health
Impact detection		○○○		○○	○			○
Element studies on assessment methodology etc	○○	○○○	○○○	○	○○○	○○	○	○○○
National assessment Impact map	○	○○○	○○○		○○○	○		○
Threshold of impacts Vulnerable sectors and areas Economic assessment	○	○○	○○	○○	○○		○	○○
Adaptation	○		○○	○	○	○	○	○
Impacts on the Asia and Pacific region	○	○○	○○		○○			○

○○○ : Studies with results in most areas   ○ : Studies in limited areas
○○ : Studies with results in some areas   Blank : No studies or unapparent situation

In impact and risk studies, a wide range of research is needed, including detection of emerging impacts, impacts on individual sectors, nationwide assessments, identification of threshold of impacts and vulnerable areas, and adaptation strategy and measures. Many of the studies to date focused on fundamental aspects such as methods of predicting impact. However, to tie these with countermeasures against global warming, we need clear answers to the following questions.

- What extent (e.g., number of people at risk and monetary amount to be lost) will these impacts reach on a national scale?
- Which sectors in which regions will sustain the severest impacts?
- Threshold of impacts - How many degrees can the surface temperature rise and how many centimeters can sea levels rise before the world will have intolerable impacts?
- When will these occur?

Table 4 summarizes our current understanding of the critical values for impacts. Although we have obtained certain amounts of information, our knowledge remains insufficient to answer the fundamental questions above.

Measures against warming can be classified as either measures to mitigate global warming or those to adapt to a warmer world. Large efforts are clearly needed to prevent warming; however, we must also investigate adaptive measures to eliminate the deleterious effects of warming, as we cannot completely prevent warming by the current institutional and technical countermeasures. While improving the accuracy of impact forecasts, we must also investigate adaptive measures for severe impacts that will appear at an early stage.

Table 4. Threshold of impacts in vulnerable sectors.

Vulnerable Sector	Exposure System	Threshold
Ecosystem	Plants in high mountain Mangrove	Apparent effects for 2°C increase Cannot survive for 50cm SLR
Agriculture	Rice	Heat effect by over 35°C during flowering
Marine Ecosystem	Coral reef	Bleaching by 1-2°C increase in water temperature
Coastal Zone	Sandy beach Port and coastal structure	Erosion of 56.6% and 90.3% of sandy beaches by 30cm and 1.0m SLR 100 billion US$ for countermeasures against 1m sea-level rise
Human Health	Elder people	Increase of mortality rate for over 33-35°C of daily high temperature (regional dependence)
Economy	National economy Electricity	Negative effects for 2-3°C increase Demand increase of 5MkW for 1°C increase in summer

CHAPTER 4

ASSESSMENT OF GLOBAL WARMING RESPONSE POLICIES

4.1 Introduction

The area of research on "global warming response policy studies" should be promoted based entirely on actual policy needs and practical policy development. This should not be at the mercy of individual, short-term policy responses, but providing systematic learning and fundamental knowledge to form policies that must have a higher order of priority in the long-term perspective.

Full-fledged global warming response policy studies began in the United States in the mid-1980s when the Department of Energy initiated a carbon dioxide research project. In the latter half of that decade, the Environmental Protection Agency followed with further comprehensive studies on policy options for stabilizing the global climate. Against the background of an international heightening of political interest in this area and reflected by the establishment of the Intergovernmental Panel on Climate Change (IPCC), studies in the global warming response policy area began in European nations, Japan, and other countries.

Regarding global environmental studies in Japan, the Environment Agency (now the Ministry of the Environment) appropriated a budget for the Global Environment Research Fund in 1989. It initiated funding for study and prediction of climate change and its impact as well as for studies on assessing response policies and mitigation technologies in the global warming area. These study programs played a very important role in advancing Japan's subsequent global warming response policy studies to the international level.

The Ministry of Education, Culture, Sports, and Science and Technology (formerly the Ministry of Education) has promoted global warming response policy studies by allocations under the Grants-in-Aid for Scientific Research as well as the Research for the Future Program. Ministries and agencies closely related to the global warming mitigation area, such as the Ministry of Economy, Trade and Industry (formerly the Ministry of International Trade

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