# Chapter 5

# Vulnerability Assessment, Climate Change Impacts and Adaptation Measures

This chapter is a summary of the present knowledge and understanding regarding the projected impacts of climate change in Japan. Specifically, this chapter reviews the results of research being conducted on climate change in Japan (please refer to Chapter 7) and presents quantitative evaluations of the projected impacts.

Research to date indicates that climate change may have a major effect on Japan's agriculture, forestry, fisheries, water resources, coastal management, natural ecosystems, and human health. For example, it is estimated that, due to global warming, the number of typhoons will decrease and their maximum intensity will increase slightly. In terms of rice cultivation in paddy fields, it is estimated that the production volume will increase in upper latitudes while problems may occur with growth due to higher temperatures in lower latitudes. It is thought that demand for water supply will increase by 1.2 ~ 3.2 percent per 3°C increase in temperature. Furthermore, it is thought that heat stress will increase due to higher temperatures in summer, with effects also seen on human health due to increased vectors and improved growth conditions for pathogenic organs and parasites.

Meanwhile, several important items are considered to be issues for future research but are not addressed in this report. These include forecasting climate changes per area, and indirect effects on Japan's socioeconomic system such as problems with importing foodstuffs, energy, and other resources. It is also clear that climate changes will have a massive effect on natural ecosystems, but at present it is extremely difficult to quantitatively assess such an effect.

Thus, among the vast and diverse impacts of global warming, this chapter only addresses a small number of items for which concrete research results have already been obtained. Accordingly, in using this report for evaluating performance under Article 4.1 (b) and (e) of the Framework Convention on Climate Change, it is important to recognize that there could be serious impacts from global warming that are not discussed herein.

## 5.1 Impacts on Japan's Climate

### 5.1.1 Impacts on Temperature

The potential impact of global warming on Japan's climate is evaluated based on projections made from experiments using 11 coupled atmosphere-ocean general circulation models (CGCMs) at nine of the world's leading research institutes. [1)]

The experiments with 11 models indicate that when an increase in atmospheric concentration of carbon dioxide by 1 percent per year (compound) is assumed (or in cases IS92a scenario), the annual mean surface temperature would increase by +4°C in southern Japan and + 5°C in northern Japan over the 100 years. The experiments also indicate that the annual mean global surface temperature would increase by +3.6°C, which would be slightly lower than that around Japan. The differences of temperature increase among the models are within the range of about 2°C in and around Japan.

### 5.1.2 Impacts on Meteorological characterisitc of Japan

The results of climate model projection are summarized as follows, although we cannot discuss in details due to coarse spatial resolutions of the coupled atmosphere-ocean GCMs and a limited performances of current regional climate models:

- During winter, Asian monsoon will become significantly weak, but there are large inconsistencies in predicted precipitation among models.
- Many models show that precipitation will increase during the summer monsoon in India. As for changes in summer rainfall in East Asia, many models show an increase if only greenhouse gases increase is taken into account, but no consistency is shown among models when the effects of aerosols are also considered.
- Uncertainties are still large on changes in typhoon behaviors due to global warming. However, it is estimated that the number of typhoons will decrease and their maximum intensity will increase slightly. The amount of precipitation produced by typhoons is estimated to increase by 10 - 30 percent.

(Note 1) Canadian Center for Climate Modelling and Analysis (CCCma); Center for Climate Research Studies (CCSR), University of Tokyo / National Institute for Environmental Studies (NIES), Japan; Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO); Deutsches Klimarechenzentrum (DKRZ), Germany; Geophysical Fluid Dynamics Laboratory (GFDL), USA; Hadley Centre for Climate Prediction and Research (HCCPR), UK [2 types]; Max Planck Institute for Meteorology (MPIfM), Germany; Meteorological Research Institute of the Japan Meteorological Agency (MRI), Japan [2 types]; and National Centre for Atmospheric Research (NCAR), USA

## 5.2 Impacts on Agriculture, Forestry and Fisheries

### 5.2.1 Impacts on Agriculture

Blessed with a mild climate and abundant precipitation averaging 1,800 mm per year, Japanese agriculture has supported a large population, primarily through the production of rice, despite the nation's relatively small land resource. Since 1950, Japan's agricultural technology has progressed rapidly through the development of new varieties, fertilizers, agricultural chemicals, and agricultural machinery. The advance of agriculture has also been supported by farm land consolidation. As a result, contemporary Japanese farming takes place under highly sophisticated management. Nevertheless, agricultural production is already significantly influenced by climate change, and future global warming is projected to have a severe effect on the nation's agriculture in general.

Rice is staple crop in Japan, accounting for more than 90 percent of the total grain production, most of which is cultivated in paddy fields. 9 million tons of rice is produced on 1.7 million hectares of paddy fields. It is expected in general that production will increase in relatively high latitude due to global warming, while problems will occur at lower latitudes due to high temperatures. In order to maintain the same amount of production as at present, the cultivation period will need to be brought forward in the Tohoku and Hokkaido regions, and delayed in other regions.

Recent studies have evaluated the effects of increased carbon dioxide finding that the number of days from seeding to the heading for the current varieties will be reduced by about 5 percent if the density of carbon dioxide is doubled, and the weight of dried products and harvested crops will increase by about 25 percent. However, some negative effects are anticipated when various factors are considered, for example, the increase in sterility due to high temperature when carbon dioxide density is high.

The effects on crop cultivation other than rice are as follows. With wheat, the length of time until the heading is shorter when cultivated at higher temperature. As a result, for wheat sown in winter, the maturity period (period during which the seeds grow) is in early spring when the temperature rapidly changes, so it is thought that risks related to low temperature cultivation are high. As for soybeans, it has been proved that their growth is restricted if the ground temperature around their roots increases. It has also been proved that for corn, there is a risk of sterility if temperature is too high during the latter half of its growth period.

### 5.2.2 Impacts on Forestry

Even though the percentage of non-forest land such as agricultural, industrial, and residential has increased, Japan is covered with forest of 252,300 $km^2$, or 67 percent of the national land area, which is far more than the international average of 29 percent. In terms of the effects of global warming, if we consider Sugi (Japanese cedar : *Cryptomeria japonica*) as a representative example of tree species, higher temperatures and longer periods of sunshine may offer some advantageous effects, but worse water-related conditions

resulting from increased temperatures may cause reduction of growth rate and death of old trees generally due to dehydration. Furthermore, increased temperature may cause an expansion in areas blighted by diseases and pests.

Although numerous points concerning the effects on forestry have not been analyzed yet, it may have an effect on forestry as an extremely long period of time is required to nurture forestry resources, and function for the public benefits from forests such as conservation of headwaters may be hindered as a result.

### 5.2.3 Impacts on Fisheries

The subtropical Japan Current *(Kuroshio)* and the subarctic Kurile Current *(Oyashio)* meet in Japan's coastal waters, which provide the habitat for a rich variety of fish and make for some of the most productive fishing areas on Earth. The most direct effect from global warming is projected to be changes in epipelagic fish resources. Japan's future fishery production will mostly depend upon changes in the course and flow of the Japan Current caused by global warming.

As for phytoplankton, it is expected that species that used to live in the lower latitudes will appear in seas nearer Japan in line with increased water temperatures. When the stratification is strengthened in line with increased water temperatures and the supply of nutrients from such stratification becomes more difficult, a transition from large diatoms to small flagellum alga is expected. Furthermore, it is expected that the production capability of the Sea of Okhotsk will degenerate as the amount of ice algae attached to ice in the sea declines in line with the reduction in the actual amount of ice in the sea.

It is expected that zooplankton will be smaller in line with any increase in water temperature. If warmer winters continue in line with increases in the water temperature, the number of jellyfish that can survive the winter increases, and the fishery value of coastal waters may decline due to competition with sardines, which are rivals at the effective stage of the food chain.

### 5.2.4 Impacts on Food Security

If Japan's food security is threatened, the followings may occur in Japan. New harmful insects will rapidly be produced in line with any warming, abnormal weather will become more frequent, and rainfall patterns will change markedly. However, accurate forecasting is difficult based on existing data. It is thought that drought will be occurred by global warming, and the harvests will reduce in major countries and areas from which food is exported. That has the possibility to cause a very great influence in Japan in which the self-sufficiency ratio is low. Soybeans, corn and wheat are very dependant on rainfall and their crop status rapidly changes. Slight climatic changes may cause significant fluctuations in production and chaos on the market, leading to irregular supply of various other agricultural products.

## 5.3 Impacts on Hydrological Conditions and Water Resources

### 5.3.1 Impacts on Hydrological Conditions and Water Resources

Despite abundant precipitation, it is difficult for Japan to fully utilize its water resources due to its physical constraints. The precipitation varies greatly by time and place, and the nation's rivers are short and steep, with relatively small catchment basins. Numerous studies using warming scenarios and long-term discharge models have been carried out. The following conclusions have been gained from such research so far.

- The effects on flow from a 10 percent change in precipitation are greater than those from a 3°C temperature increase.

- If a 3°C temperature rise is accompanied by a 10 percent increase in precipitation, on average the flow will not decline significantly in low-flow conditions and will increase by about 15 percent in high-flow conditions. However, if evaporation and melting winter snow are excessive, even though rainfall increases by 10 percent, highland flow may decline.

- Temperature increases lead to less snowfall and earlier snow melting. As a result, the flow will increase from January through March, and decrease from April through June.

It is important to analyze the relationship between water demand caused by various human activities, natural water resource systems, and artificial water resource systems such as dams to consider the effects on water resources. It is considered that water supply demand would increase by 1.2 - 3.2 percent per 3°C increase in temperature.

## 5.4 Impacts on Social Infrastructure and Economy

### 5.4.1 Characteristics and Impacts on Coastal Zone in Japan

Japan is an island nation with long coastlines, and the nation's population and economic activities are concentrated in coastalzone. Accordingly, there is great concern about the possible effects of rising sea levels and increasingly frequent storm surges on the nation's natural environment and socioeconomic system. The existing social infrastructure and socioeconomic system has been optimized for the present climate conditions. With global warming, the effects from higher sea levels and temperatures and from changing precipitation and typhoon patterns would be serious and wide-ranging.

The functions and stability of shore protection facilities (facilities and equipments for countermeasures against disaster) will be degraded in the event of raised sea levels. Waves will pound harder on embankments, and revetments will need to be higher while overtopping quantity will also increase. In

order to maintain safety at the current level, coastal embankments will need to be raised by 2.8 meters per one-meter increase in sea level, while quaywalls within bays will need to be raised by 3.5 meters. It is anticipated that global warming would have a deleterious effect on all types of social infrastructures located in coastal zone including harbors, fishing port facilities, man-made islands, reclaimed land, inland water drainage and sewerage systems, etc.

In particular, rising subterranean water tables may lower the loading strength and liquefaction resistance of the subsoil. Many social infrastructure facilities and buildings are concentrated on weak ground in coastal areas, so any increase in the risk of loading strengths and liquefaction resistance of subsoil in the event of an earthquake would cause serious problems for urban safety.

At present, about two million people reside on the 861 $km^2$ of Japanese land which is located below the high water level, and 54 trillion yen of assets have accumulated in these areas. If sea levels rise by one meter (slightly higher than the 88 cm projected for the global mean rise in 2100 under the highest case scenario of the IPCC Third Assessment Report), the land area below the high water level will increase by more than 2.7 times to 2,339 $km^2$. The susceptible population and assets will grow to 4.1 million people and 109 trillion yen.

### 5.4.2 Economic Assessment on Social Infrastructure in Coastal Zone

Potential damage through flooding in harbor areas in Japan, and fees to maintain the functions and stability of port and harbor facilities, and coastal structures have been estimated. 7.8 trillion yen will be required to maintain port and harbor facilities, and 3.6 trillion yen will be required to maintain coastal structures, giving a total of 11.5 trillion yen if sea levels were to rise by one meter, which is close to the 88 centimeters projected as the global mean rise in 2100 under the highest case scenario of the IPCC Third Assessment Report.

### 5.4.3 Impacts on Industries and Energies

According to an analysis, one direct effect on human habitation is that the consumption mechanism will change. It is estimated that if the average temperature between June and August increases by 1°C, consumption of summer-related goods will increase by about 5 percent.

40 percent of electricity demand in summer relates to air conditioner use. When the temperature goes up by 1°C, electrical demand increases by about 5 million kW (equivalent to normal use in 1.6 million typical houses). It is estimated that demand for electricity in summer will increase in line with increases in factory operations resulting in increased production of summer-related goods and thus an increase in demand for air conditioners in cities.

Global warming also has various other effects on electricity supply. Changes in snow and rainfall will have significant effect on the generation of hydropower. Furthermore, it is estimated that changes in river and sea water temperature will have an impact on the operational efficiency of power generators at thermal and nuclear power plants where such water is used as a coolant.

## 5.5 Impacts on Nature

### 5.5.1 Vulnerability of Japan's Natural Environment

Japan is blessed with a great variety of natural environments. The nation's forest ecosystems occupy diverse climate zones that range from subtropical to subarctic and are located in close proximity to one another. If global warming results in an average temperature rise of 3°C over the next 100 years, existing ecosystems will have to move approximately 500 kilometers to the north or to altitudes about 500 meters higher than at present. This is equivalent to an annual movement of five kilometers or an altitude gain of five meters per year, respectively. It is not possible to make a simple projection of how the ecosystems will respond to this change because each species has a different environmental tolerance and a different capacity for migration, and because of the competition with existing ecosystems.

Moreover, there are numerous obstacles that may interfere with the migration of ecosystems. Japan is geographically complex, with many intricate mountain folds, and also geologically diverse. Other obstacles include ocean straits, cities, roads, and railroads. These may represent major restrictions when biota and ecosystems try to adapt to global warming. Species which are isolated in small habitats may find it impossible to migrate and become extinct.

Lake, marsh, and coastal ecosystems located adjacent to densely inhabited districts are already subject to stress from human activities, and experts have noted that such ecosystems are highly sensitive to the additional stresses that will be brought about by global warming. For all of these reasons, it is currently nearly impossible to conduct a macro-scale quantitative evaluation of the effects of global warming on Japanese ecosystems.

### 5.5.2 Impacts on Mountainous Ecosystems

One of the major factors in deciding the blooming period for many alpine plants is when the snow melts. Changes in the amounts of snow falling due to global warming have not yet clarified, but if temperatures increase when the snow melts, it is anticipated that this will affect the timing of any future blooming.

Recently, the outer fringes of *'Hai-matsu'* pine tree branches have died off in early spring mainly in the Chubu mountainous region as well as in Hokkaido. One reason that has been suggested for this is that the diminished protection offered by the snow in line with the reduced snowfall.

### 5.5.3 Impacts on Forest Ecosystems

Japan lies in the monsoon region of East Asia between latitudes 25 degrees and 45 degrees north, extending 3,000 kilometers from north to south. The quantity of precipitation in Japan is sufficient for the establishment of forests. One characteristic of Japan is that changes in snowfall resulting from global warming would have a significant effect on the spread of forests and the composition of species as well as a direct effect on the temperature.

Buna (beech : *Fagus crenata*)forests, typical in cool-temperate zone, are located in cool, moist areas or those with lots of snow. On the other hand, Mizunara (Japanese oak : *Quercus crispula*) forests are located in drier areas or regions with less snow. However, as a result of global warming, even in areas which will remain relatively cool in temperature terms, the climate will be drier with reduced snowfall due to the general increase in temperature, and the buna (beech) forests may be replaced by other type of forest such as mizunara (Japanese oak) forests, while the southern limits of buna (beech) forests may change to evergreen broad-leaved forests. For example, it is expected that most of the beech forests in western Japan will be outside the appropriate area.

Movement of insects to higher latitudes and altitudes has already been recognized as a result of global warming. Under such circumstances, the existing environment will be fundamentally altered and – as the movement of plants is comparatively difficult – so the extinction of insects in unique environments (such as high in the mountains), and species whose distribution is restricted by temperature give cause for concern, such as increased damage of the Pine wilt disease caused by the pine wood nematode (*Bursaphelenchus xylophylus*) resulting from the expanding inhabiting area of the Japanese Pine Sawyer (*Monochamus alternatus*).

Areas inhabited by larger mammals such as Sika Deer, Japanese macaque, and wild boar have recently been expanding. It is thought that this is mainly because the amount of snow falling and the duration of its cover have been reduced due to climate changes. In little snow conditions, due to rising the survival rate of wildlife, their numbers will increase and their habitat will expand. This may result much damage to agriculture and forestry.

### 5.5.4 Impacts on Grasslands

Most natural grasslands in Japan have been subjected to natural or artificial pressures in some way. Thus, the relationship between grassland vegetation and climatic factors were unknown until now. Therefore, vegetation zone classification has been studied based on the relationship with climatic factors, and the results were standardized based on temperature and snowfall measurements. Changes in the vegetation zone at the global warming stage created based on such criteria were estimated.

According to the estimate, subarctic zone vegetation will become extinct in the Ishikari lowlands or southern area within about 50 years, and vegetation typical of cool temperate regions will become extinct in

Kyushu, Shikoku, and the Kii peninsula, while subtropical vegetation will appear at the southern tip of Kyushu. After 100 years, subarctic vegetation will become extinct everywhere except in mountainous areas of Hokkaido, cool temperate vegetation will be reduced to only mountainous areas in Honshu, warm temperate vegetation will occupy most of Honshu, and subtropical vegetation will expand to low-lying plains in Kyushu, Shikoku and southern Honshu.

### 5.5.5 Impacts on Biodiversity

In particular, there is concern that global warming will affect species whose distribution is geographically restricted in Japan. For example, this applies to many species of yakutanegoyo (*pinus armandii var amanminana*) found only on the Yakushima and Tanegashima islands, most of which are struggling to survive. It is considered that plants unique to the temperate zone in the southwestern islands and other small islands may face a critical situation due to global warming.

### 5.5.6 Impacts on Coral Reefs

Japan's coral reefs are at the northern extremity of global distribution. Higher water temperatures from global warming will have a positive effect on coral growth.
However, the maximum rate of coral growth in the past has been about 4 meters per 1,000 years. If the rate of sea level rise exceeds 40 centimeters per 100 years, coral growth cannot keep pace, and it too may wither. The optimal water temperature for hermatypic coral to grow is between 18 and 28°C, so if the water temperature peaks at 30°C or higher, the coral will die and bleach out. Just before and after the El Nino phenomenon occurred in 1997 to 1998, large-scale destruction of coral reefs – as evidenced by its whitening – was seen in most seas throughout the world, including those around the Okinawan islands.

### 5.5.7 Impacts on Mangroves

Mangrove ecosystems, whose north limit is at Kiire in Kagoshima prefecture, are located along shorelines, and they neutralize the interaction between sea and land. If the rate of sea level rise is 50 centimeters or less per century, their ecosystems can be maintained through the accumulation of their own corrosion and so on. In the case of tides, there is at least a 2-meter difference between high and low tides, so even if the sea level rises by about 50 centimeters per 100 years, most of the area will be at a depth above the average sea level, so mangroves can be maintained. Large-scale mangrove distribution around Iriomote Island will shift in line with raised sea levels in the near future, and it is anticipated that vegetative distribution within the forest will also change.

### 5.5.8 Impacts on Desertification

There is currently no danger of desertification in Japan. However, climatic change caused by desertification on the Eurasian continent may indirectly affect the climate in Japan.

## 5.6 Impacts on Human Health

Global warming may directly affect human health via the increased heat stress from high temperatures during the summer months. The indirect effects on human health may include conditions promoting the growth of parasites, pathogens, and creatures that function as carriers of infectious diseases. Global warming may also harm human health via the increase of photochemical air pollution.

### 5.6.1 Direct Impacts from Increased Heat Stress

The direct effects on human health from increased heat stress include higher incidences of heat stroke and thermoplegia, and research is being conducted in these fields.

Studies show that the number of heat stroke and pneumonia patients amongst the elderly (65 and older) whose capability to handle heat is lower will increase in line with the rise in maximum temperatures recorded in summer in a relationship between high-risk ailments, maximum daily temperatures, and air pollution. It has already been clarified that there is a V-shaped relationship between the maximum daily temperature and the mortality rate amongst the elderly. Studies have shown that the V shape shifts in the higher temperature direction in line with increases in temperature.

### 5.6.2 Indirect Impacts from the Spread of Infectious Diseases via Animal Vectors

Global warming will expand the habitat and activity periods of animals that serve as carriers of infectious diseases. This may result in increases in the number of cases of malaria, dengue fever, and other infectious diseases carried via animal vectors. The areas where these diseases occur may expand.

In Japan, the northern limit of the habitat of the anopheles, the mosquito which carries malaria, is said as Miyako Island and Isigaki Island. However, so that their habitat will go north and their activity will become active as a result of global warming, it will have the possibility of increasing malaria in subtropical zone of Japan

## 5.7 Adaptive Measures

While various measures, including the restriction of greenhouse gas emissions, are being implemented to arrest global warming, the Framework Convention also calls for measures to mitigate the adverse effects of climate change and for adaptive measures that will facilitate adaptation to climate change. With this in mind, Japan is studying adaptive measures related to coastal areas, social infrastructure, and agricultural production.

### 5.7.1 Countermeasures for Coastal Zone and Social Infrastructure

As proposed by the IPCC, there are three countermeasures, namely, deliberate withdrawal, adaptation, and prevention. In Japan, where coastal land is used to the maximum, adaptation and prevention on assumption of continuous use of risky areas must be considered the main priority. There are a variety of strategies from software-related ones such as planning and systems to hardware-related ones such as physical structures, so studies must be promoted with a view to the future to minimize any effects.
In order to better understand the trend of increasing sea levels for ports, harbors, and coasts, continuous monitoring must be undertaken by each organization, and the observation results must be evaluated regularly.

### 5.7.2 Countermeasures for Agriculture

It is anticipated that global warming will have an effect on future domestic agricultural production. Any environmental changes can be adapted to by developing varieties better suited to the changed climate, and by changing crop types and cultivation methods.

## References


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