Key Vulnerabilities and Critical Levels of Impacts in East & South East Asia

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1. Introduction

Asian region, especially East and South East Asia, is very vulnerable to climate change. In TAR of IPCC, the Asian region was divided into four sub-regions: Boreal Asia, Arid and semi-arid Asia, Temperate Asia, and Tropical Asia based on broad climatic and geographical features. The future potential impacts and risks due to climate changes for these regions in TAR are listed in **Table 1** [1].

In this paper, I introduce recent results of impacts and risk analysis caused by the current and future climate change as follows:

2. Observed Impacts
3. Future Impacts
4. Future Research Needs
5. References

Table 1 Impacts for Sectors in Temperate and Tropical Asia in TAR

	Potential Impacts
Agriculture	
Temperate Asia **Tropical Asia**	・Crop production and aquaculture would be threatened by a combination of thermal and water stresses, sea-level rise, increased flooding, and strong winds associated with intense tropical cyclones.
Water Resources	
Temperate Asia **Tropical Asia**	・Freshwater availability is expected to be highly vulnerable to anticipated climate change. ・Increased precipitation intensity, particularly during the summer monsoon, could increase flood-prone areas.
Ecosystem and Biodiversity	・Climate change would exacerbate threats to biodiversity resulting from land-use/cover change and population pressure.
Coastal Resources	
Temperate Asia **Tropical Asia**	・The large deltas and coastal low-lying areas could be inundated by sea-level rise. ・Tropical cyclones could become more intense. Combined with sea-level rise, this impact would result in enhanced risk of loss of life and properties in coastal low-lying areas of cyclone-prone countries.
Human Health	
Temperate Asia **Tropical Asia**	・Warmer and wetter conditions would increase the potential for a higher incidence of heat-related and infectious diseases.

2. Observed Climate Change Impacts

2.1 Climate change observed in Japan

The IPCC TAR shows the change in the global surface temperature for the last 100 years is 0.6 ^{o}C.

Through the 20th century, the Japan Meteorological Agency has been monitoring the annual mean surface temperature at 17 observation sites where human interference in temperature changes due to urbanization can be considered as minimal. The temperature changed within the lower level until 1940, then turned sharply upwards in the 1960s and 1990s. The temperature increase in the 20th century is 1.0 ^{o}C, which is higher than the global mean value of 0.6 ^{o}C. This rise in temperatures began accelerating in the mid 1980s, and temperatures were clearly higher than before in the 1990s. The rise in temperature in urban areas for the past 100 years has been more than 2 ^{o}C, with that in Tokyo reaching 3 ^{o}C . This large rise in the urban areas is caused by both global warming and heat island phenomenon.

Recent research shows increasing trend of the number of days with maximum temperatures higher than 35 ^{o}C and decreasing trend of incidences of extremely low temperatures in 1990's. In July of 2004, many places in Japan experienced record breaking extremely high temperature, and the number of heat stroke patients who were transported to hospitals is more than 600 cases in Tokyo metropolitan area. Extremely high temperature and heat wave are now public concern, but it has not yet been examined with observed data, which a major factor is, global warming or urban heat islands effects. In July, 2004, some locations in Japan experienced very heavy precipitation caused by baiu-front and typhoons. These events caused large damage to the society and human activities, and general public as well as insurance companies are now concerned about a relationship between current warming and extreme events.

2.2 Observed Impacts

Impacts caused by current global warming have been identified in Asian region. The major impacts caused by climate change observed in China are as follows:

• Sea level rise in coastal areas is 1mm-3mm per year;
• Glacier area in the northwest China has been reducing by 21%;
• Yield of pasturing area in Qianhai Province and the southern part of Gansu Province has reduced;
• Plant spring flowering has advanced by 2-4 days;
• Area of drought disaster in the North China has expanded, resulting in severe losses in agriculture, and area of flood disaster in the South China also has expanded with severe economic and life losses;
• Coral reef in maritime areas in Guangxi Province and Hainan Province has shown albinistic.

In Japan, many Impacts caused by global warming have been identified [2]. Living organisms and ecosystems detect warming and respond in various ways. 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. There are a number of other examples of warming.

•Sea level rise observed 2mm per year from the past 30 years observation
• Reduction in the thickness of snowy ravine at Tsurugidake, Toyoma Prefecture
• *Omiwatari* (“the divinity’s pathway” observed at Lake Suwa in winter) has not been seen very often in recent years, due to a series of warm winters.

• Decreased alpine flora in Hokkaido, the north island in Japan and other high mountains.
• 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, then in Tokyo area in early 2000s.
• 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.
• Breaching of Coral Reef in Okinawa islands.
• Shifting habitats of ermine and grouse on mountains such as Hakusan and Tateyama to higher elevations.

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

3. Future Impacts

Impacts research has progressed since TAR. In this section, some cases are introduced.

3.1 Development of Regional Climate Scenario

So far impact research in general has used a regional climate scenarios using a GCM output, so that it is difficult to predict regional impacts in small countries like Japan and Korea. Fortunately development of GCMs and RCMs, impact research can use regional climate model outputs in recent years. For example, the Global Warming Research Initiative launched by the Council for Science and Technology Policy of Japan makes close linkage between climate model research and impact/risk research. For impact study, Japan Meteorological Research Institute has developed a regional climate model (RCM20) of which spatial resolution is about 20km. **Figure 1** shows a present and future temperature in Kanto District including Tokyo predicted by RCM20 [3].

3.2 Future Heavy Rain Damage

Figure 2 shows future 100-year heavy rain probability predicted using this RCM20. Using this simulated results, Wada[4] predicted future probability of heavy rain using statistical Gumbel method. rain. From this figure, some areas will suffer from heavy rainfall resulting damage on human lives and assets.

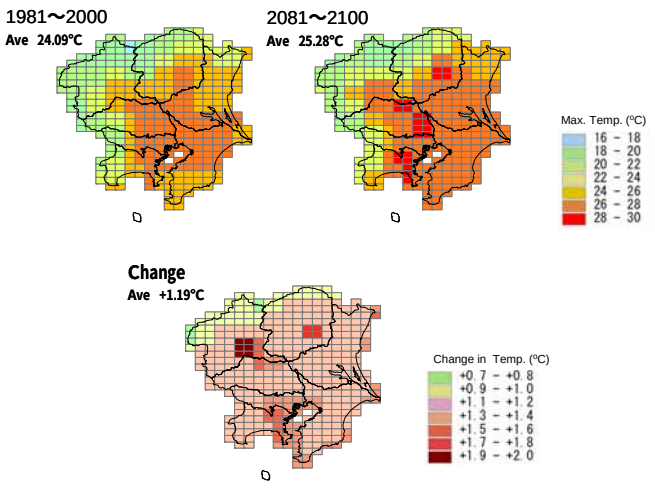

Figure 1 Change in maximum temperature in August in Kanto District by RCM20

From the recent results of GCM developed by NIES/CCSR/JAMSTEC using the Earth Simulator, Emori et al. [5] predicted future change in heavy rain, and the number of heavy rain (>100 mm/day) would increase by 2 to 3 times in 2100.

3.3 Impacts on Vegetation

(1) Predicted impacts on vegetation in Japan

Figure 3 shows the present and predicted distribution of beech forests. Beech forests are typical of the Cool Temperate Zone, and are distributed widely in Japan. At their southern limit of the distribution, global warming will cause the transition of these forests into evergreen forests. Matsui et al [6] predicted about 90% of beech forests would disappear when annual average temperature will increase by 3.6 ^{o}C in 2090.

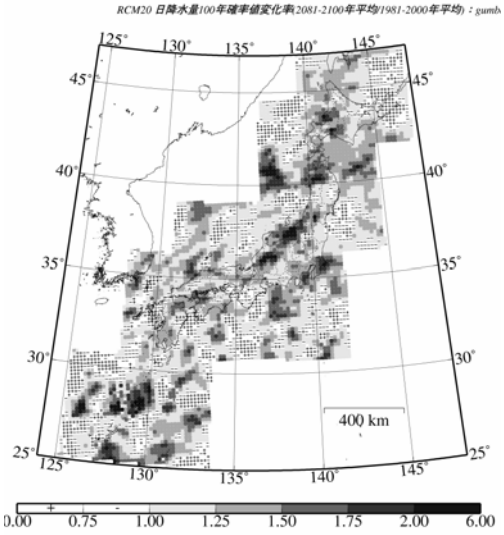

Figure 2 Future heavy rain probability

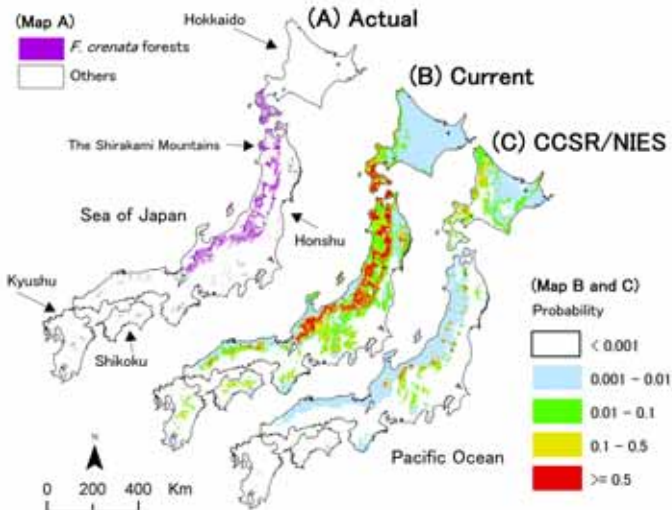

Figure 3 (A) Actual distribution and predicted probability distributions of buna (*Fagus crenata*) under (B) the current climate and (C) the CCSR/NIES climate change scenario in the 2090s (modified from Matsui et al. 2004, by Dr. N. Tanaka (Forestry and Forest Products Research Institute))

(2) Impact on Korean forest

Figure 4 shows the extent of forest vegetation damage caused by climate change on the Korean Peninsula by 2100. Whether current forest vegetation will be damaged or not is identified by comparing potential velocity of forest moving (VFM) with

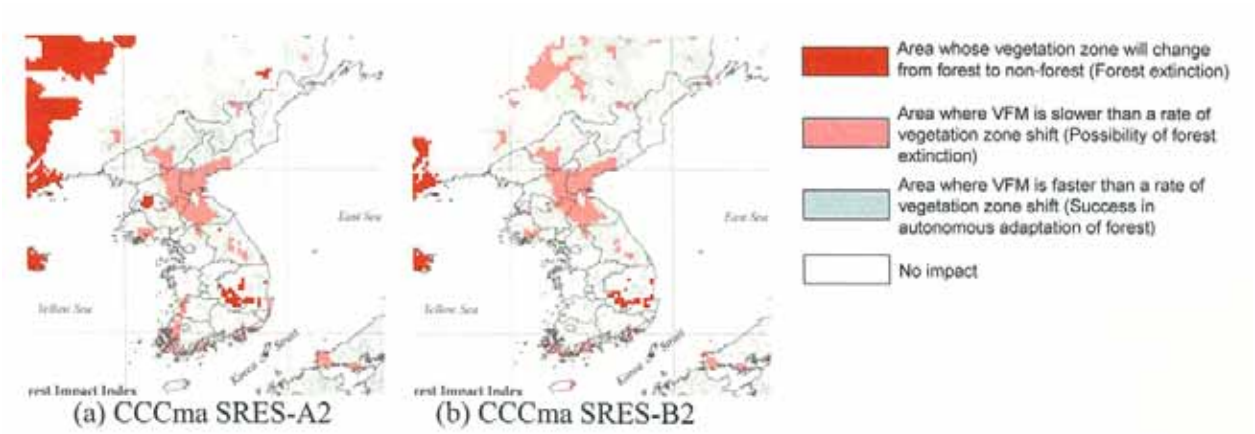

Figure 4 Climate change impact on Korean natural vegetation in 2100

the velocity of vegetation zone shift that is estimated considering climate change scenario. VFM is assumed to be in the range from 0.25 to 2.0km/year. In SRES A2 scenario, whose temperature increase is higher than the other SRES scenarios, the extinction area will be 2.08% of the Korean Peninsula if VFM is assumed to be 0.25km/year.

(3) Vegetation change in SE Asia

Lasco et al. [7] predicted the potential impacts of climate change on Philippine forests quantitatively, using GIS and the Holdridge Life Zones. Three synthetic scenarios each of precipitation (increase of 50%, 100% and 200%) and air temperature (increase of 1^{o}C, 1.5^{o}C and 2^{o}C) were used. The research showed that dry forests (more than 1 M ha) are the most vulnerable to climate change. However, the wet and rain forest life zones will significantly expand as dry and moist forests become wetter.

3.4 Impacts due to Sea level Rise [2]

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. 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 ^{o}C. If high water temperature of more than 30 ^{o}C continues, the algae that coexist in the coral symbiotically will separate from the reef, and the coral becomes discolored and dies (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.

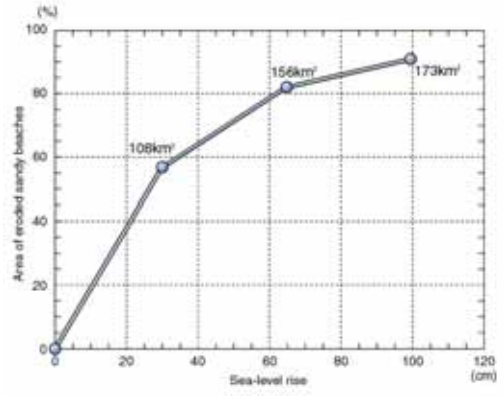

Figure 5 SLR and sandy beach

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 Japan will be eroded (**Figure 5)**. 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 eroded. 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.

Combined impacts of high tide, storm surge, and sea level rise were predicted by Mimura et al. [8]. **Figure 6** shows an example of their research. The fifteen percent of national land in Bangladesh will be disappeared in case of 1m sea level rise, and if cyclone attacks, about half of the land will be inundated.

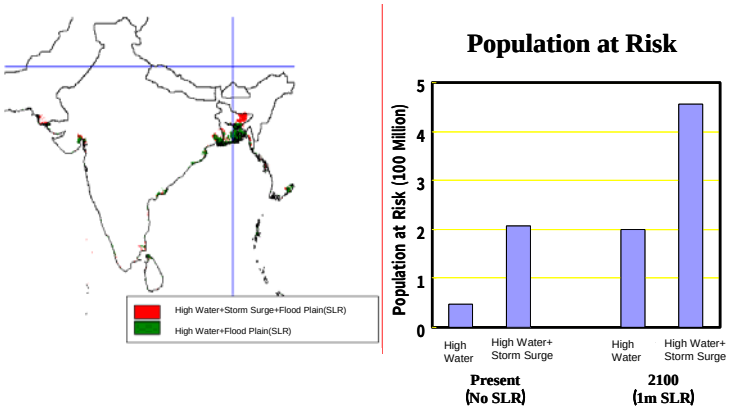

Figure 6 High tide, storm surge and SLR

3.5 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. **Figure 7** shows daily maximum temperature and number of heat stroke patient who were transported to hospitals in 2004. Worsening atmospheric pollution and epidemics of vector-borne infectious diseases such as malaria and dengue are also concerned. There have been recent reports of mosquitoes which transmit communicable diseases moving northward to the Tohoku region, and the risk of infectious disease may become reality as the mosquito habitat expands.

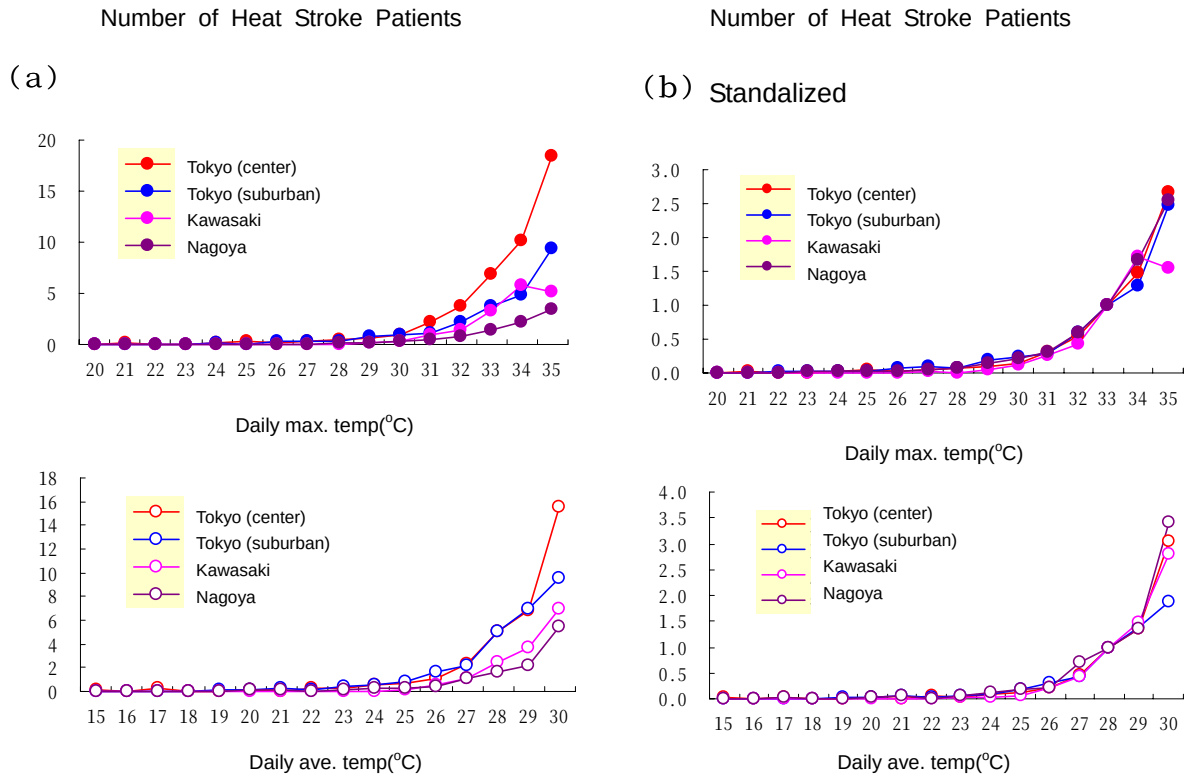

Figure 7 Heat wave and its impacts in Tokyo (Summer in 2004)

3.6 Impacts on Industry, Energy, and Transportation

Fukushima et al. [9] estimated future climate change impacts on ski industry in Japan. Using a model and the relationship between daily snow depth and number of skiers, the changes in skier numbers in the seven ski areas were predicted for several scenarios with respect to air temperature changes; e.g. a more than 30% drop in visiting skiers was forecast in almost all ski areas in Japan except northern region (Hokkaido) und/or high altitude regions (center of the Main Island) under the condition of a 3 ^{o}C increase in air temperature.

The direct impact of global warming on industry and energy at the level currently projected from climate fluctuations and changes (significance, speed, time period) is expected to be small because such impact will be handled by spare capacity to meet changing demands and long-term facility renewal to deal with changing supply. **Table 2** shows examples of the direct effects of changes due to global warming on the industrial and energy (electric power) sectors.

Table 2 Sensitivity of industries to climate change [10]

Element	**Industry**	**Energy (Electricity)**
Change in amount and pattern of rainfall	Water demand (Industry, Municipal water use) Water deficit/drought and food/product manufacturing	Hydraulic power generation. Management and control of dam facilities Rreservation of cooling water
Temperature Increase	Cooling/Warming apparatus Insulated house/building Industries sensitive to seasonal change Winter: clothing, aircondioner Summer: summer product, vebaledy	Control of snow melt water to dam and storage
Water Temperature Increase (sea water, fresh water)	Demand for natural gas to heating water of aquaculture	Decline of turbine efficiency (electric generation) Increase in adhesion living thing
Sea Level Rise	Location of reinsure industry, embankment	Inundation to coastal facilities / equipments
Moisture		Demand for air conditioner/cooler
Typhoon	Factory/facility, Transportation/communication , Information apparatus industry	Typhoon proof design, measures to salt water, thunderstorm, snowfall, natural energy generation(wind energy)

Relationship between summer temperature and consumption of summer products were analyzed [9]. He indicated that if the mean June–August temperature rises by 1°C, consumption of summer products such as air conditioners, beer, soft drinks, clothing, electricity will increase about 5%. **Table 3** shows a summary of impacts on global warming on industries and energy sectors identified in Japan. These impacts identified in Japan will be of help in impact research in Asian region.

Table 3 Impacts of climate change on industries and energy sectors [10]

Changes in Climate Parameters	Impacts
1°C temperature increase in June to August	About 5% increase of consumption of summer products
Extension of high temperature period	Increase of consumption of air conditioners, beer, soft drinks, ice creams
Increase in sunder storms	Damage on information devices and facilities
1°C temperature increase in summer	Increase in electricity demand by about 5 million kW Increase in electricity demand in factories to enhance production
Increase in annual average temperature	Increase of household electricity consumption in southern Japan Decrease in total energy consumption for cooling, warming in northern Japan
Change in amount and pattern of rainfall	Hydro electric power generation, management and implementation of dams, cooling water management
1°C increase in cooling water	0.2 – 0.4% reduction of generation of electricity in thermal power plants 1－2% reduction in nuclear power plant

4. Future Research Needs

Research continues to clarify the impacts of global warming in an extremely broad range of areas. **Table 4** lists the matrix of research activities to date. Numerous results have been obtained for terrestrial ecosystems; the agriculture, forestry, and fisheries industries; and coastal zones in case of Japan.

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 regions, and adaptation strategy and measures. Many of the studies to date focused on elementary 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 Asian country will have intolerable impacts?
- When will these occur?

Hijioka et al. [11] summarizes 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 Impacts research matrix

	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	○	○○	○○		○○			○

○○○: Results obtained in most areas ○ : Studies in limited areas
○○ : Results obtained in some areas Blank : No studies or unapparent situation

5. References

[1] IPCC, 2001: Climate Change 2001.

[2] Ichikawa, A. ed., 2004: Global Warming – The Research Challenges A Report of Japan's Global Warming Initiative, Springer, 160pp.

[3] Kurihara, K., 2004: Development of regional climate model for impact studies, Proceedings of Global Warming Research Initiative Symposium, 17-18. (In Japanese)

[4] Wada, K., 2004: Assessment of natural disaster risk due to global warming, Proceedings of Global Warming Research Initiative Symposium, 21-22. (In Japanese)

[5] Emori, S., 2005: Japan as a possible hot spot of flood damage in future climate illustrated by high-resolution climate modeling using the Earth Simulator. Proceedings of this Symposium.

[6] Matsui, T. et al., 2004: Probability distributions, Fagus crenata forests following vulnerability and predicted climate sensitivity in changes in Japan. Journal of Vegetation Science, 15, 605-614.

[7] Lasco, R.D. et al., 2005: Assessment of climate change impacts on and vulnerability of forests ecosystems in the Philippines using GIS and the Holdrige Life Zones, forthcoming.

[8] Mimura, N. et al., 2004: Personal Communication.

[9] Fukushima, T., et al., 2002: Influences of air temperature change on leisure industries: case study on ski activities. Mitigation and Adaptation Strategies for Global Change, 7, 173-189.

[10] Harasawa, H. and S. Nishioka, eds., 2001: Global Warming Impacts on Japan, Kokon Pub. (in Japanese).

[11] Hijioka, Y. et al., 2005: Long-term Emissions Scenarios and Short-term Targets - Application of AIM model-. Proceedings of this Symposium.