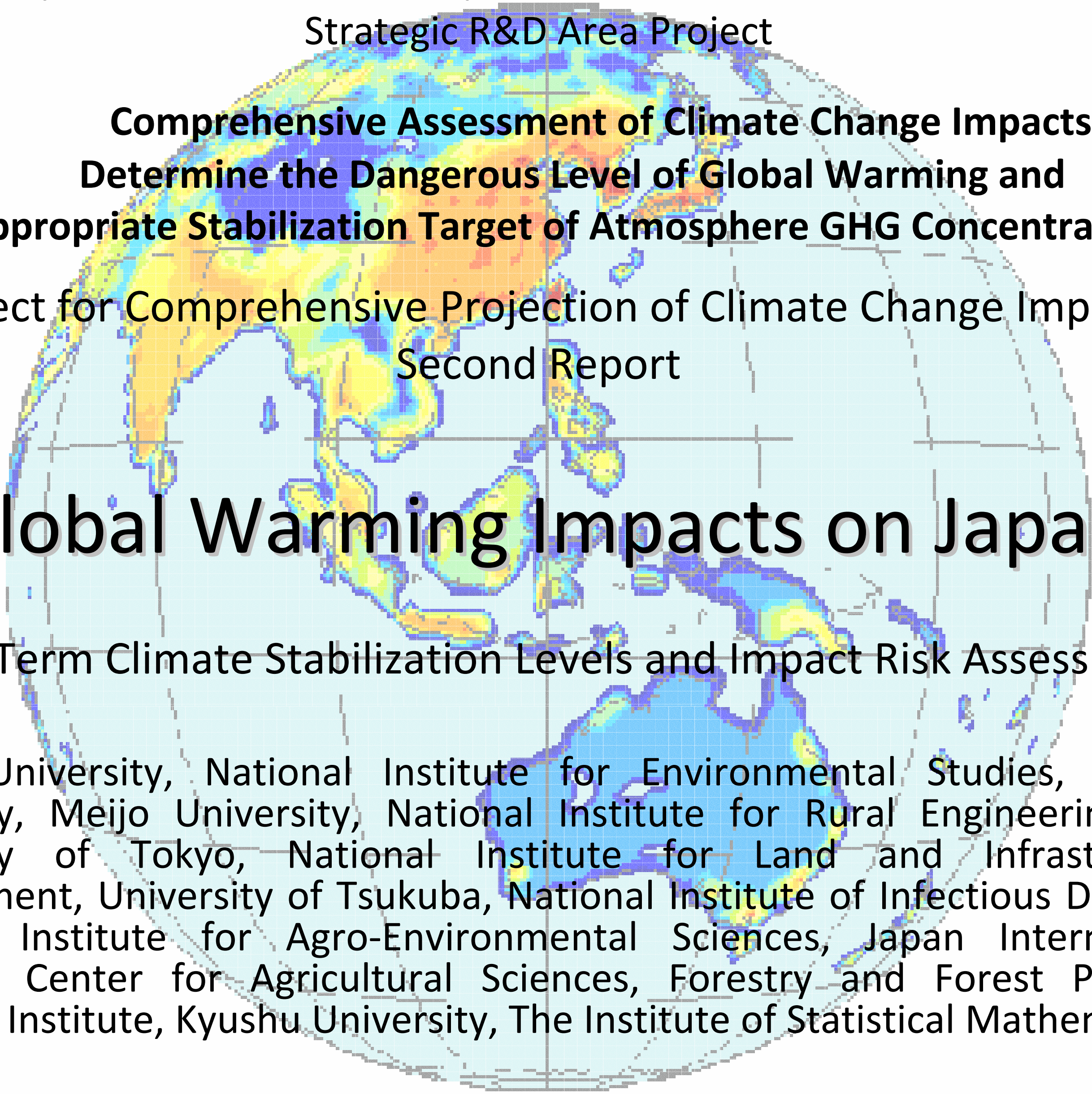


Ministry of the Environment, Japan Global Environment Research Fund
Strategic R&D Area Project

S-4 Comprehensive Assessment of Climate Change Impacts to Determine the Dangerous Level of Global Warming and Appropriate Stabilization Target of Atmosphere GHG Concentration

– Project for Comprehensive Projection of Climate Change Impacts –
Second Report

Global Warming Impacts on Japan

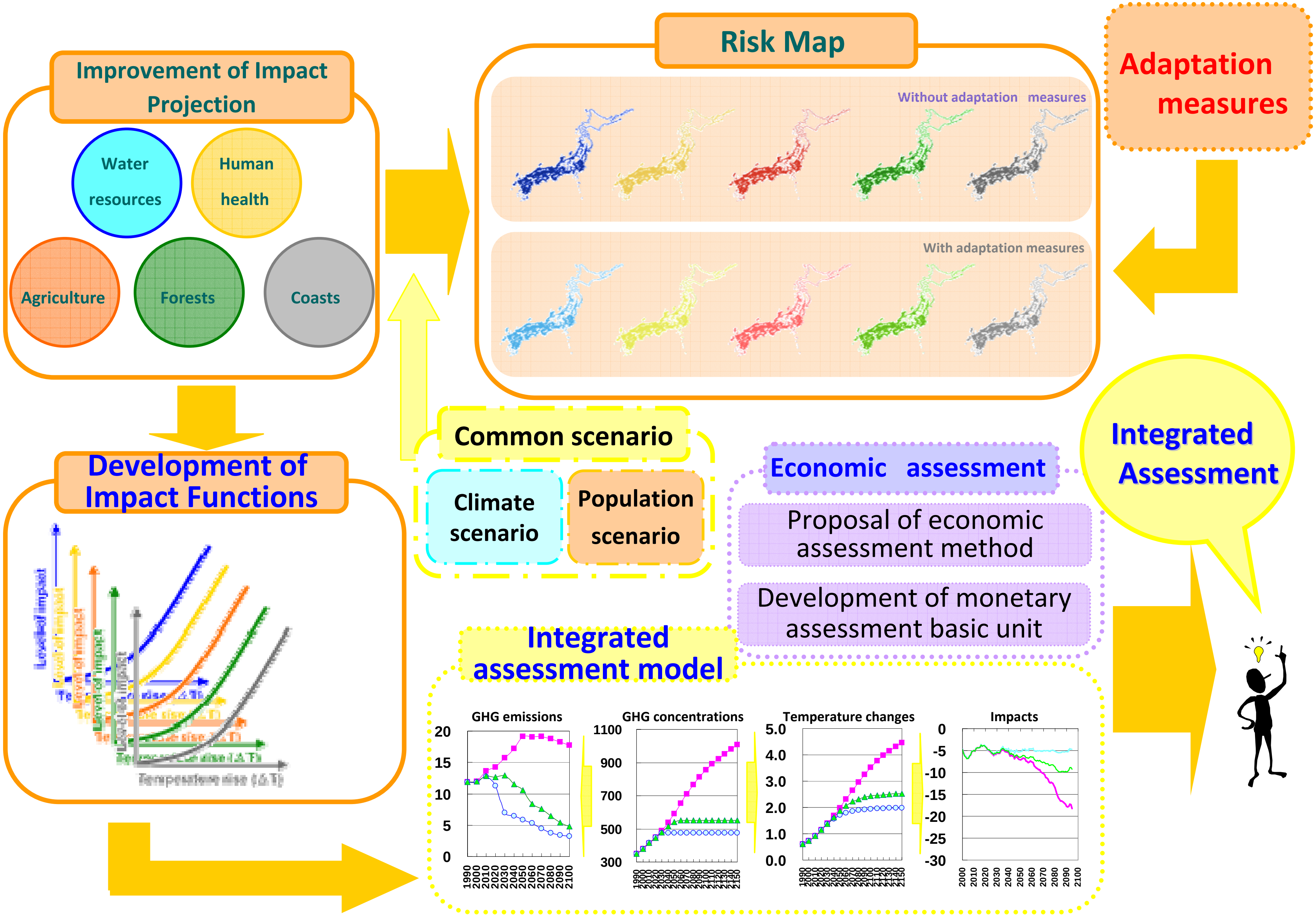
– Long-Term Climate Stabilization Levels and Impact Risk Assessment –

Ibaraki University, National Institute for Environmental Studies, Tohoku University, Meijo University, National Institute for Rural Engineering, The University of Tokyo, National Institute for Land and Infrastructure Management, University of Tsukuba, National Institute of Infectious Diseases, National Institute for Agro-Environmental Sciences, Japan International Research Center for Agricultural Sciences, Forestry and Forest Products Research Institute, Kyushu University, The Institute of Statistical Mathematics

Research System and Objectives

- **Results up to the fourth year of the Project for Comprehensive Projection of Climate Change Impacts (Ministry of the Environment, Global Environment Research Fund S-4, 2005-2009)**
- **Research system**
  - Project leader: Nobuo MIMURA, Ibaraki University
  - Research period: Period I (2005-2007) + Period II (2008-2009)
  - Number of subthemes: Seven; Number of participating research institutions: 14 (2008); Number of participating researchers: 42 (2008)
- **Targeted fields: Water resources, forests, agriculture, coastal zones, human health**
- **Objectives of the research project**
  - To obtain quantitative knowledge on climate change impacts in key fields such as water resources, forests, agriculture, coastal zones, and human health in the Asian region including Japan, targeting the period up to the end of the century while focusing on the period up to around 2050.
  - To comprehensively grasp the impacts on Japan and elucidate the relationships with the level of global warming.
  - To elucidate differences in impacts according to emission stabilization paths (stabilization scenarios).

Research Scheme of the Project for Comprehensive Projection of Climate Change Impacts



Objectives of This Report

– Points of Difference from Last Year's Report –

- **This report presents new research results obtained since those for the first three years of this project were published in *Global Warming Impacts on Japan–Latest Scientific Findings* on May 29, 2008.**

① Impact assessments by stabilization level of atmospheric GHG concentration using an integrated assessment model

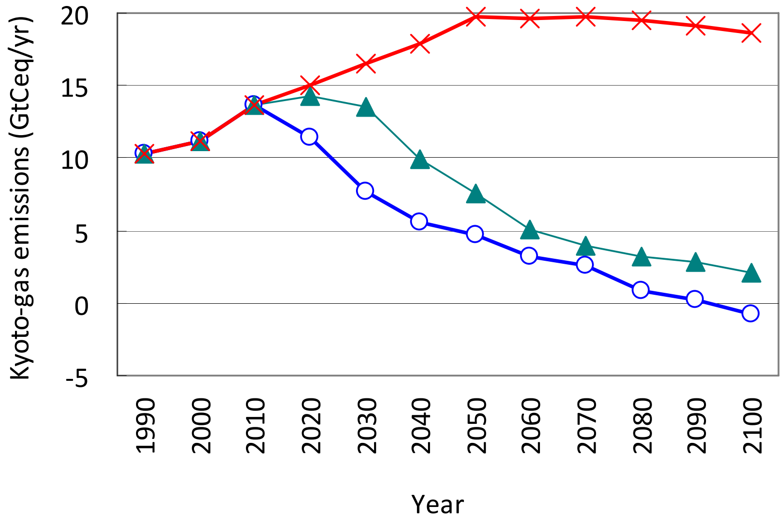
② Regional-level as well as nationwide impact assessments

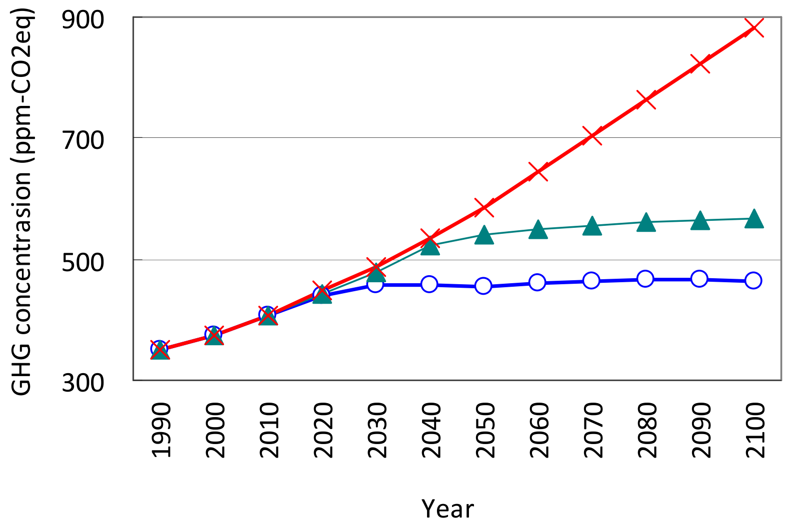
③ Assessments of damage costs as well as physical impacts

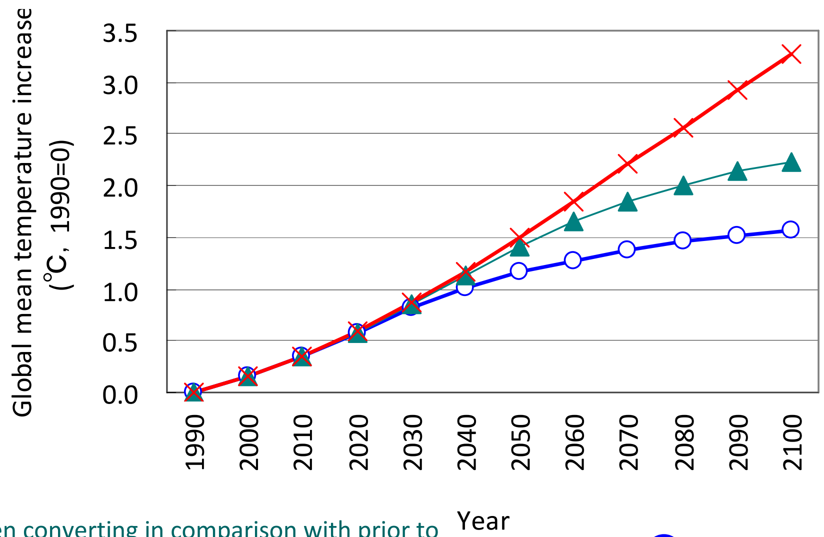
Outline of Integrated Assessment Model and Stabilization Scenarios

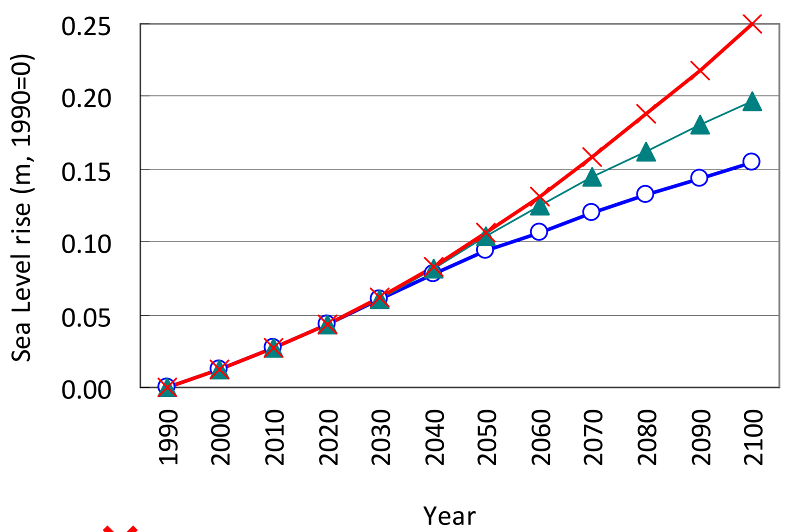
- **Integrated assessment model**
  - An integrated assessment model is used to comprehensively analyze and assess global warming control targets such as the stabilization of GHG concentrations, etc. and economically efficient emission paths to realize these targets, as well as the impacts and risks under such targets
  - Equilibrium climate sensitivity: 3℃; the carbon feedback effect is not taken into consideration.
  - There are various possible emission paths to realize the stabilization scenarios, among which one example is presented.
  - GCM used for preparation of climate scenarios by region from global mean temperature changes (pattern scaling) : MIROC3.2-hires
  - The impacts of global warming are the increment when 1981-2000 (or 1990) is taken the base period or year
- **One Business as Usual (BaU) scenario and two GHG concentration stabilization scenarios**
- **Including GHGs and cooling effects of aerosol**
  - ✓ 450s: 450 ppm GHG concentration (CO_2 equivalent concentration) stabilization scenario
    - Overshooting of GHG concentrations occurs.
    - Equilibrium temperature increase of approx. 2.1℃ (compared with prior to the industrial revolution) , which can be converted by subtracting 0.5℃ for comparison with the 1990 level.
  - ✓ 550s: 550 ppm GHG concentration (CO_2 equivalent concentration) stabilization scenario
    - Overshooting of GHG concentrations occurs.
    - Equilibrium temperature increase of approx. 2.9℃ (compared with prior to the industrial revolution; approx. 2.7℃ in 2100 in the present analysis), which can be converted by subtracting 0.5℃ for comparison with the 1990 level.
  - ✓ BaU (Business as Usual scenario)
    - Temperature increase of approx. 3.8℃ in 2100 (compared with prior to the industrial revolution), which can be converted by subtracting 0.5℃ for comparison with the 1990 level.
    - Corresponding to IPCC SRES B2

Global GHG Emissions (Six Types of Greenhouse Gases Established under the Kyoto Protocol), GHG Concentration, Global Mean Temperature Increase, and Sea Level Rise by Scenario









When converting in comparison with prior to the industrial revolution: +0.5° C

450S 550S BaU

Impacts of Floods (Flooded Area)

An increase in flooded area is expected due to increases in rainfall intensity and the frequency of rainfall with strong intensity. Even in the case of the strictest stabilization level (450s), damage is expected to significantly increase

■ Outline of impact assessment index

- It is assumed that Japan's average level of protection corresponds to that for downpour rainfall occurring once every 50 years under the present circumstances, and that no damage occurs in the case of rainfall with a lower intensity than that. On the further assumption that the three major metropolitan areas have a higher level of protection, corresponding to that for downpour rainfall occurring once every 150 years under the present circumstances, the flooded areas of the three major metropolitan areas and other regions are estimated.
- It is assumed that the level of protection remains unchanged in the future.
- Adaptation measures are not taken into consideration.

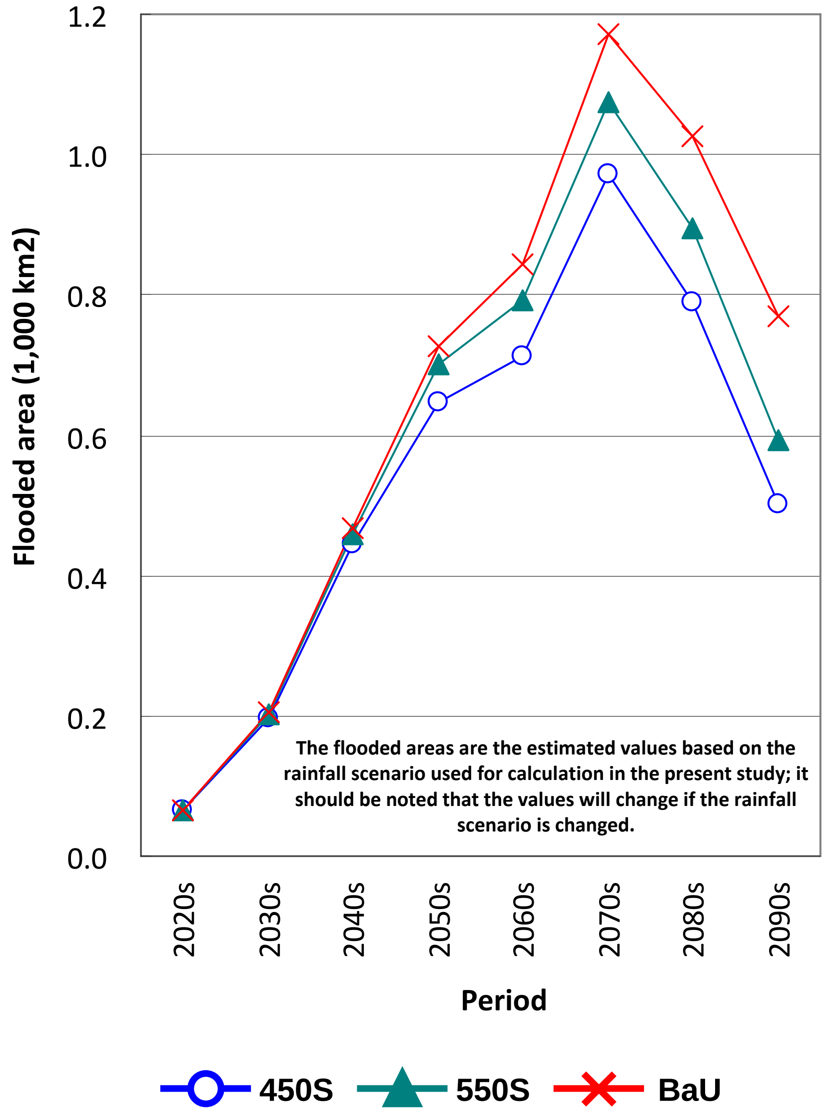
□ Future impacts

● Nationwide trends

- The lower the level at which GHG concentration is stabilized, the smaller the flooded area will be. Even under the 450s scenario, however, damage is expected to significantly increase.
- Significant differences in the flooded area nationwide under the 450s, 550s, and BaU scenarios are not seen until around mid-century (up to the 2050s). Thereafter, differences appear according to the scenario, with the maximum flooded area expected to reach approx. 1,000 km2, 1,100 km2, and 1,200 km2, respectively.

● Regional trends

- Although the timings differ, major damage is expected in each region, with increases in the flooded area expected in the Kanto/Koshinetsu/Hokuriku region in particular.



Impacts of Floods (Flood Damage Cost Potential)

An increase in flood damage cost is expected due to increases in rainfall intensity and the frequency of rainfall with strong intensity. Even in the case of the strictest stabilization level (450s), damage is expected to significantly increase.

■ Outline of impact assessment index

- (1) Establishment of method for calculation of the cost of damage according to each type of land use, with reference to "assets subjected to direct damage" in the *Manual for Economic Evaluation of Flood Control Investment* of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). (2) Extraction of distribution of flood depth and flood period obtained from the flood calculation. (3) Calculation applying the method described in (1) above, taking the land use classification of each grid cell into consideration.
- It is assumed that the level of protection remains unchanged in the future.
- Depreciation of asset values due to damage is not taken into consideration.
- Adaptation measures are not taken into consideration.

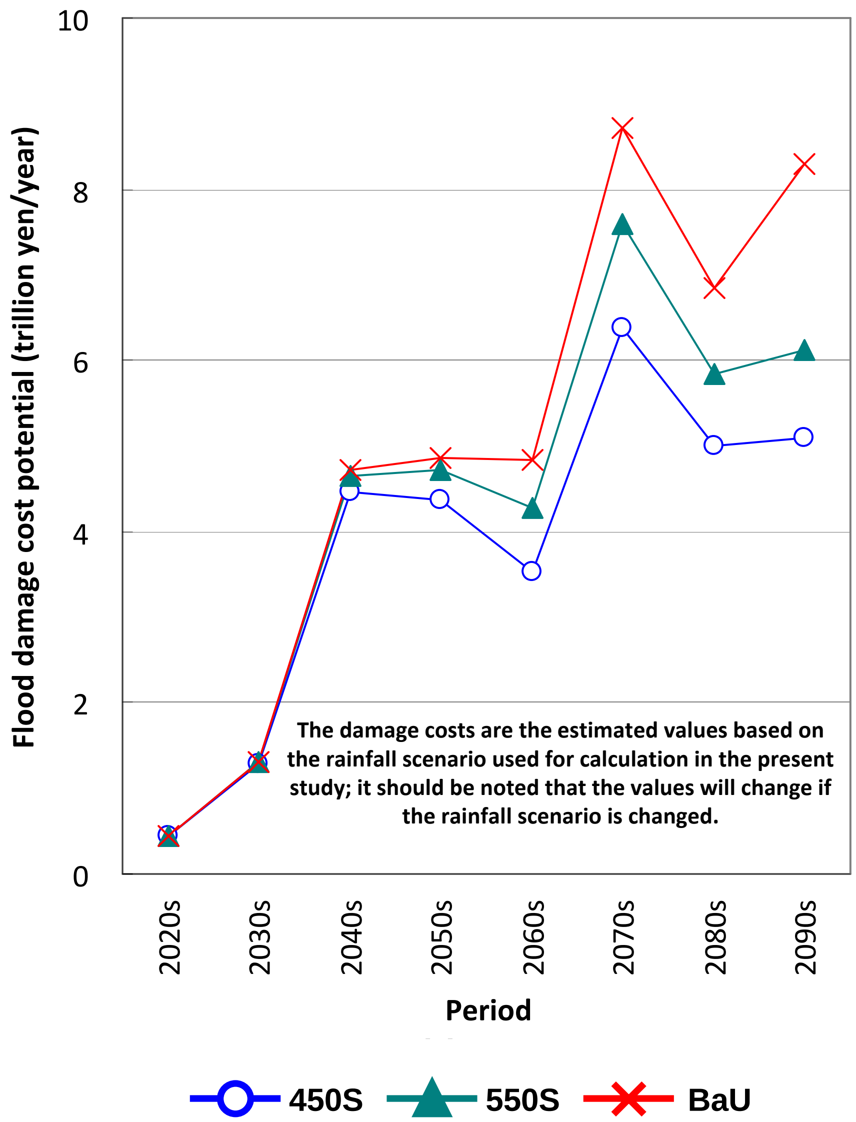
□ Future impacts

● Nationwide trends

- The lower the level at which GHG concentration is stabilized, the smaller the flood damage cost potential will be. Even under the 450s scenario, however, damage is expected to increase accompanying the progress of global warming.
- Significant differences among scenarios are not seen until around mid-century (up to the 2050s), and around 2050, the flood damage cost potential is slightly less than 5 trillion yen/year. By around the end of the century (up to the 2090s), significant differences appear according to the scenario, with the maximum flood damage cost potential expected to reach approx. 6.4 trillion yen/year (450s), approx. 7.6 trillion yen/year (550s), and approx. 8.7 trillion yen/year (BaU).

● Regional trends

- Major damage is seen in the Kanto/Koshinetsu/Hokuriku and Tokai/Chubu/Kinki regions, where assets are concentrated on flood plains. By around the end of the century (up to the 2090s), significant differences appear according to the scenario, with the flood damage cost potential for each of these two regions expected to reach approx. 3.5 trillion and 2.5 trillion yen/year, approx. 4.1 trillion and 2.9 trillion yen/year, and approx. 4.6 trillion and 3.7 trillion yen/year under the 450s, 550s, and BaU scenarios, respectively.



Impacts of Landslide Disaster (Probability of Slope Failure)

An increase in the probability of slope failure is expected due to increases in rainfall intensity and the frequency of rainfall with strong intensity. In the case of the strictest stabilization level (450s), the increase in probability shows a tendency to reach a ceiling

■ Outline of impact assessment index

- Probability of slope failure in the case of rainfall exceeding 50 mm/day (annual daily maximum precipitation in the future)
  - It is assumed that up to a precipitation of 50 mm/day, the probability is uniformly zero throughout the country (one assumption in terms of model analysis). In reality, the precipitation intensity causing slope failure is considered to differ according to the region; detailed investigation is therefore necessary in the future.
  - Adaptation measures are not taken into consideration.

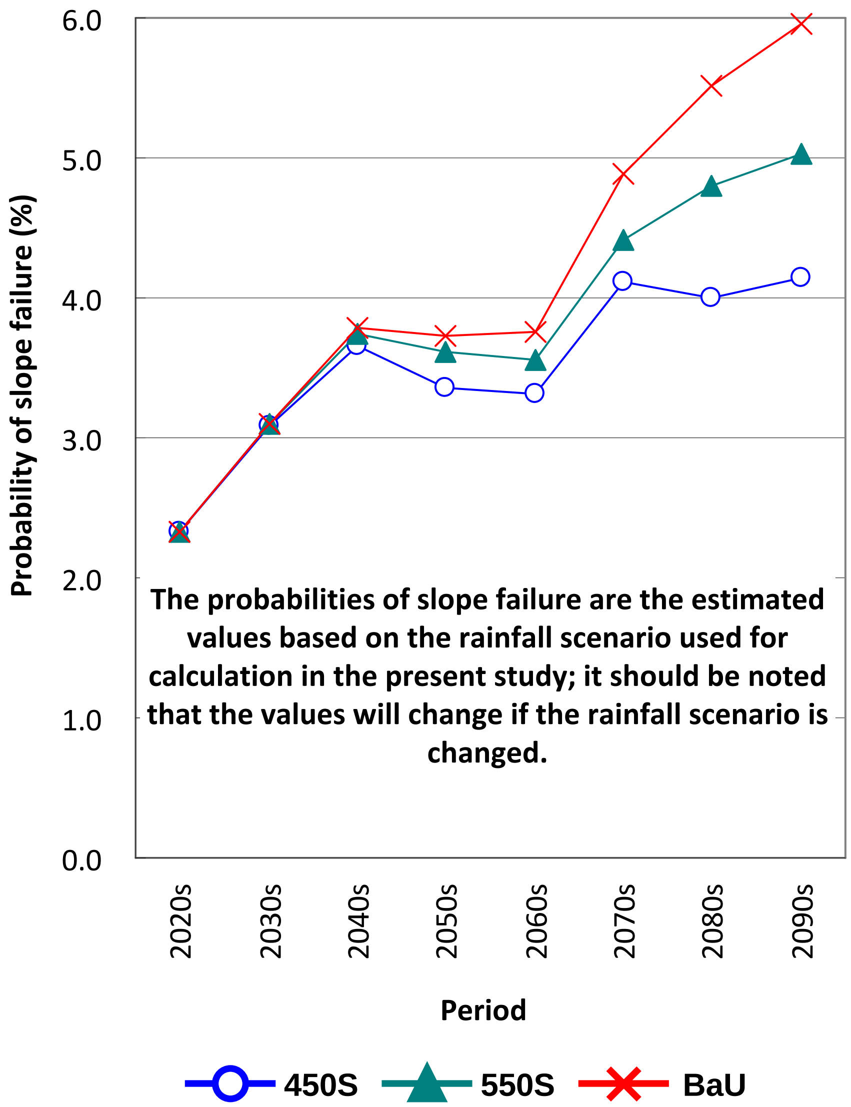
□ Future impacts

● Nationwide trends

- The lower the level at which GHG concentration is stabilized, the lower the probability of slope failure will be. Under the 450s scenario, the increase in probability of slope failure shows a tendency to reach a ceiling.
- Significant differences in the probability of slope failure nationwide under the 450s, 550s, and BaU scenarios are not seen until around mid-century (up to the 2050s). However, by around the end of the century (up to the 2090s), differences in the probability of slope failure appear according to the scenario, with expected maximum increases of approx. 4%, 5%, and 6%, respectively.

● Regional trends

- The Hokkaido/Tohoku region will continue to show an increasing probability of slope failure until roughly around the end of the century irrespective of the scenario, whereas in the Kanto/Koshinetsu/Hokuriku region the probability tends to significantly change according to the period. Such regional differences are due to differences in future rainfall of 50 mm/day or more. It is therefore necessary to note that the trends will differ according to the setting of the critical rainfall intensity.



Impacts of Landslide Disaster (Slope Failure Damage Cost Potential)

An increase in the cost of damage due to slope failure is expected as a result of increases in rainfall intensity and the frequency of rainfall with strong intensity. In the case of the strictest stabilization level (450s), the cost of such damage is expected to reach a ceiling.

Outline of impact assessment index

- Damage cost potential due to slope failure in the case of rainfall exceeding 50 mm/day (annual daily maximum precipitation in the future) (up to a precipitation of 50 mm/day, the damage cost is assumed to be uniformly zero throughout the country).
- Amount of economic loss: Amount of economic loss = Economic value (basic economic unit) x Scale (area) of land use x Probability of slope failure.
- Depreciation of asset values in areas that have suffered from such a disaster in the past and future changes in asset values are not taken into consideration.
- Adaptation measures are not taken into consideration.

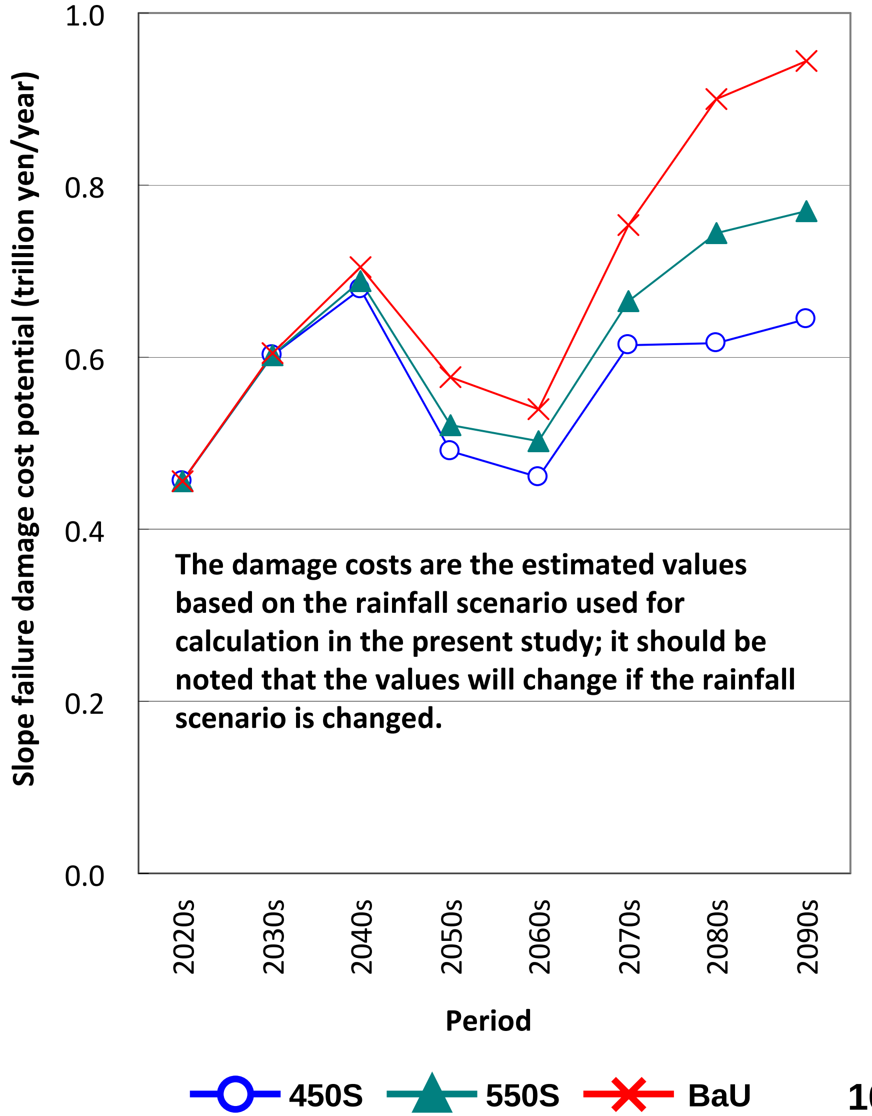
Future impacts

Nationwide trends

- The lower the level at which GHG concentration is stabilized, the lower the slope failure damage cost potential will be. Under the 450s scenario, the damage is expected to reach a ceiling.
- Significant differences in slope failure damage cost potential nationwide are not seen among scenarios until around mid-century (up to the 2050s). However, by around the end of the century (up to the 2090s), significant differences appear according to the scenario, with the value under the 450s scenario not varying conspicuously from that up to around mid-century, as compared with maximum expected values reaching approx. 0.77 trillion yen/year under the 550s scenario and approx. 0.94 trillion yen/year in the case of BaU.

Regional trends

- Major future damage is expected in the Tokai/Chubu/Kinki region in this category as well. There is a conspicuous increase in damage in the Hokkaido/Tohoku and Kanto/Koshinetsu/Hokuriku regions accompanying the progress of global warming, with the maximum slope failure damage cost potential in each of these two regions by around the end of the century (up to the 2090s) expected to increase to approx. 0.14 trillion and 0.09 trillion yen/year, approx. 0.17 trillion and 0.10 trillion yen/year, and approx. 0.22 trillion and 0.13 trillion yen/year under the 450s, 550s, and BaU scenarios, respectively.



Impacts on Forests (Suitable Habitats for the *F. crenata* Forest)

Suitable habitats for the *Fagus crenata* (Siebold's beech) forest are disappearing accompanying the progress of global warming. Although the rate of decrease is slowed down in the case of the strictest stabilization level (450s), a decrease of about 36% is expected to be unavoidable.

■ Outline of impact assessment index

- Estimations were made with changes in four climatic variables, cumulative temperature (warmth index), daily minimum temperature of the coldest month, winter precipitation (December-March), and summer precipitation (May-September) .
- It is assumed that suitable habitats for the *F. crenata* forest (areas suitable for the formation of *F. crenata* forests) are determined by the above climatic variables.
- *F. crenata* forests on areas which are no longer serve as suitable habitats will not immediately decline and disappear. However, there is a high possibility that *F. crenata* in such forests will be replaced by other tree species over the course of time.
- The migration of *F. crenata* and land use are not taken into consideration.

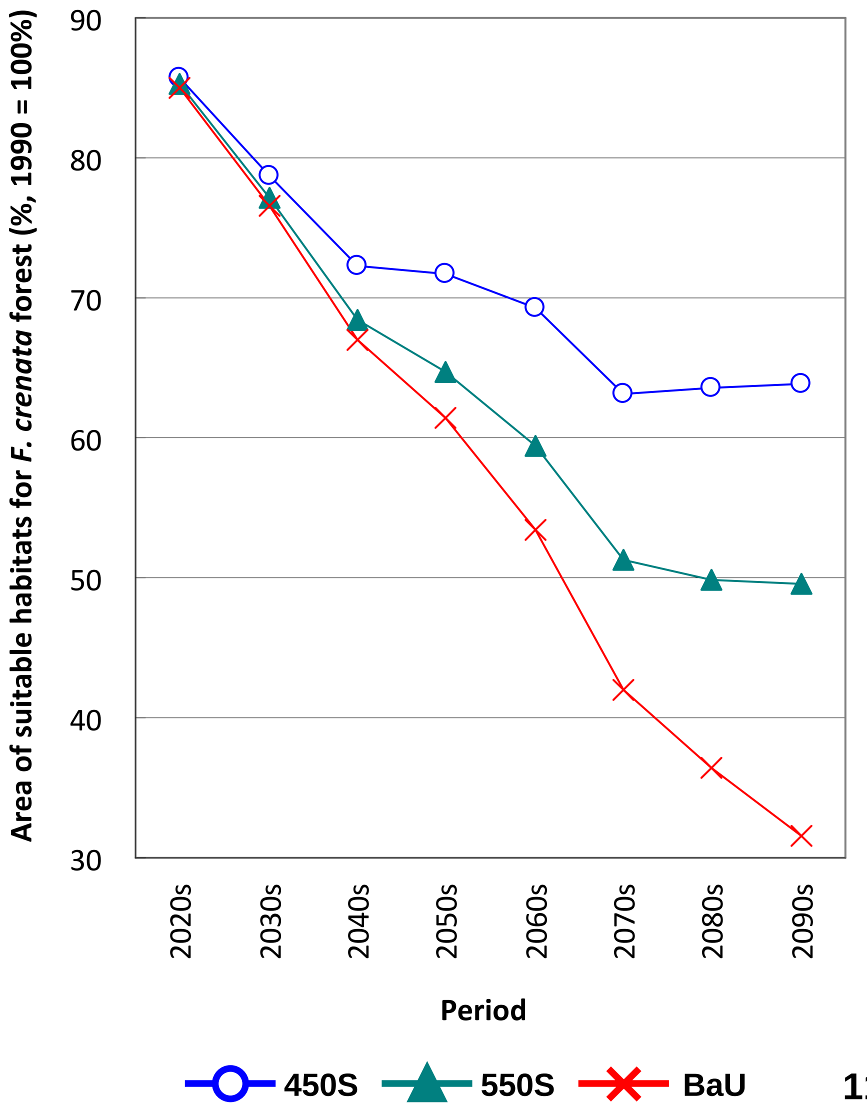
□ Future impacts

● Nationwide trends

- Slight differences in the decrease in area of suitable habitats for *F. crenata* forests under the 450s, 550s, and BaU scenarios are expected around mid-century (2050s), with the decrease rates of 28%, 35%, and 39%, respectively. However, large differences appear among the scenarios around the end of the century (2090s), with those of 36%, 50%, and 68%, respectively.
- In the case of the strictest stabilization level (450s), the rate of decrease in suitable habitats is slowed down. However, a decrease of about 36% is expected to be unavoidable, so monitoring for conservation will become important.

● Regional trends

- In particular, the Tokai/Chubu/Kinki and Chugoku/Shikoku/Kyushu regions are considered to be vulnerable to, with significant losses in suitable habitats for the *F. crenata* forest in these regions accompanying the progress of global warming.



Impacts on Forests (Cost of Damage due to Decrease in Suitable Habitats for the *F. crenata* Forest)

Accompanying the progress of global warming, the cost of damage due to the decrease in suitable habitats for *F. crenata* forests will also increase. In the case of the strictest stabilization level (450s), the increase in the cost of such damage will be slowed down, although large losses are expected to be unavoidable.

Outline of impact assessment index

- Focusing on the biodiversity maintenance function of *F. crenata* forests, their environmental economic value is estimated by the contingent valuation method (CVM).
- The environmental economic value estimated in the present research is the nonmarket value (the value of items not traded on the market). For accurate cost-benefit analysis, it is necessary to also estimate the market value.

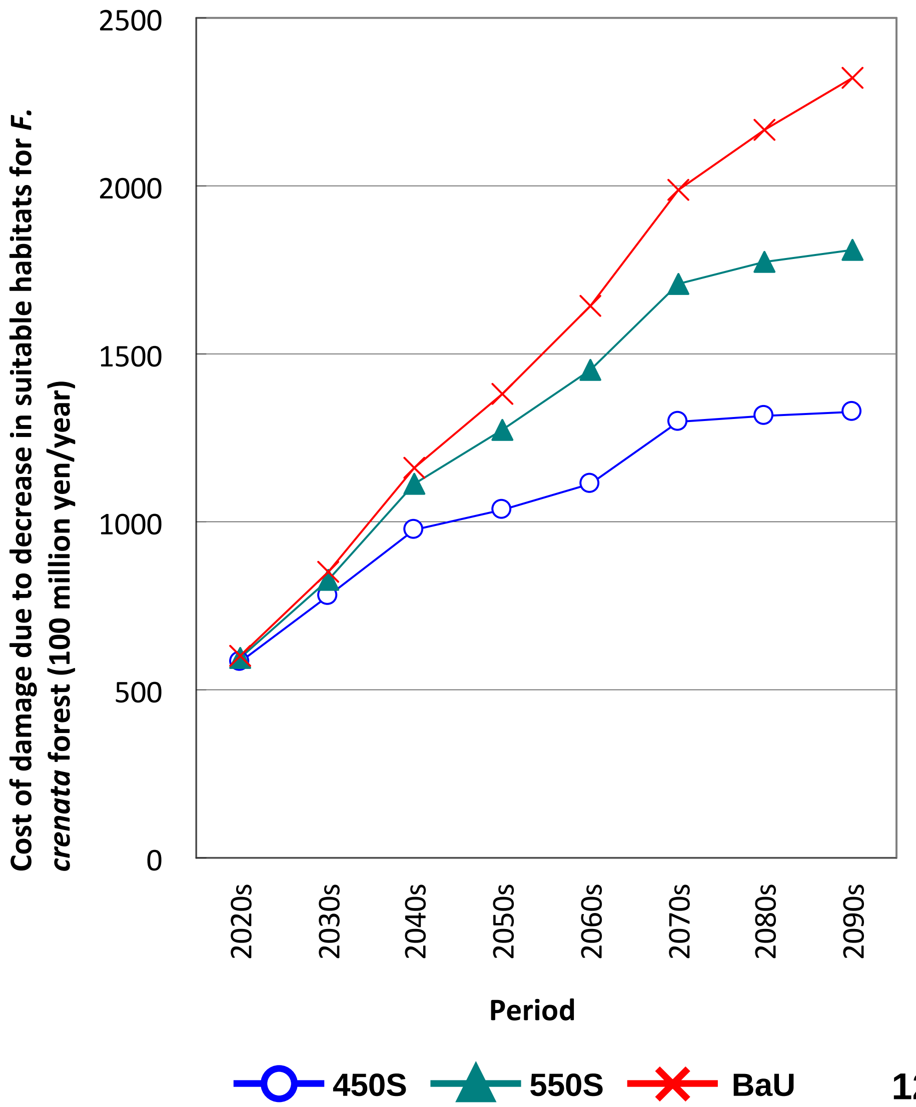
Future impacts

Nationwide trends

- Under the 450s and 550s GHG concentration stabilization scenarios, the rate of increase in the cost of damage is expected to be reduced.
- Slight differences are seen in the cost of damage under the 450s, 550s, and BaU scenarios around mid-century (2050s), with the cost of 103.4 billion, 127.3 billion, and 138.1 billion yen/year, respectively. However, significant differences appear among the scenarios by around the end of the century (2090s), with the cost of 132.5 billion, 181.1 billion, and 232.4 billion yen/year, respectively (present value: 7.8 trillion yen).

Regional trends

- In the Hokkaido/Tohoku region where the present area of suitable habitats for the *F. crenata* forest is large, the cost of damage around the end of the century (2090s) is expected to reach 83.2 billion yen/year (450s), 114.6 billion yen/year (550s), and 147.9 billion yen/year (BaU).



Impacts on Forests (Areas at Risk of Pine Wilt)

Areas at risk of pine wilt will expand accompanying the progress of global warming. Although the rate of expansion is slowed down in the case of the strictest stabilization level (450s), an expansion of about 27% is expected to be unavoidable.

Outline of impact assessment index

- Changes in the areas at risk of pine wilt are estimated, assuming temperature increase in future.
- Taking present forms of land use into consideration, the changes in area at risk of pine wilt accompanying global warming are estimated by an impact function that estimates the areas at risk based on the cumulative mean temperature of each month with a threshold of 15° C (MB index).
- The ratio of area at risk of pine wilt in the future to area at no risk in 1990 is estimated.

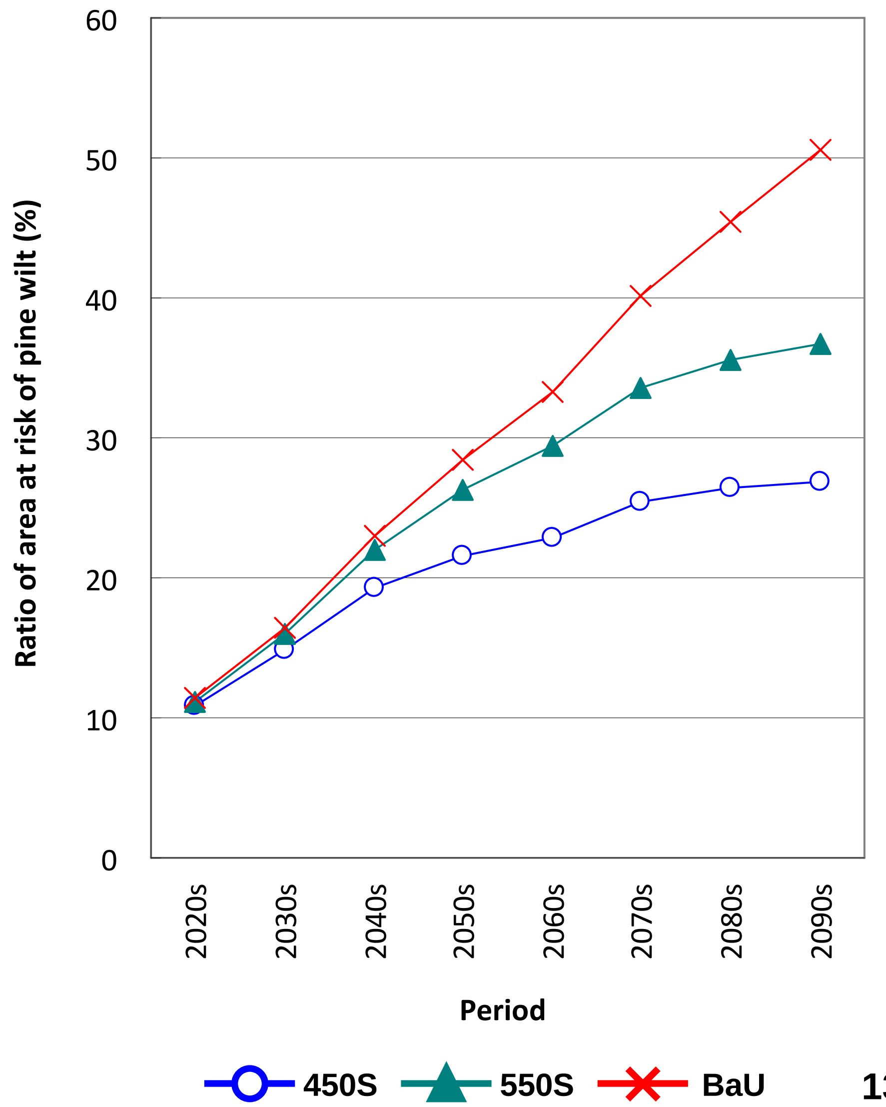
Future impacts

Nationwide trends

- Regardless of the stabilization level, areas at risk of pine wilt are expected to continue to expand in the future. However, under the 450s scenario, in which the stabilized GHG concentration is the lowest, there is a possibility that the trend of expansion will be halted around the end of the century.
- Slight differences in ratio of area at risk of pine wilt nationwide under the 450s, 550s, and BaU scenarios are seen around mid-century (2050s), at approx. 22%, 26%, and 28%, respectively. However, significant differences appear among the scenarios around the end of the century (2090s), with ratios of area at risk expected to reach 27%, 37%, and 51%, respectively.

Regional trends

- Greater increase in area of at risk of pine wilt is expected in Hokkaido and Tohoku accompanying the progress of global warming although area at risk will increase in every region.



Impacts on Agriculture (Rice Yield)

An increase in rice yield is expected accompanying the progress of global warming. With further rises in temperature, however, the trend will reverse to a decrease in yield, and interannual variations in yield are also expected to become large.

Outline of impact assessment index

- Climatic variables: Changes in accumulated insolation in the warm season (May-October), mean temperature change in summer (July, August), mean temperature change and CO2 concentration in the warm season excluding summer (May, June, September, October)
- The biomass of rice plant is determined by the trade-off between the decrease accompanying the reduction in the growth period due to temperature rise and the increase accompanying the CO2 fertilization effect. The final rice yield is determined by the positive effect due to the reduction in cold weather damage in currently cool regions, and the negative effect due to high-temperature-induced sterility in currently warm regions.
- Adaptation measures are not taken into consideration.

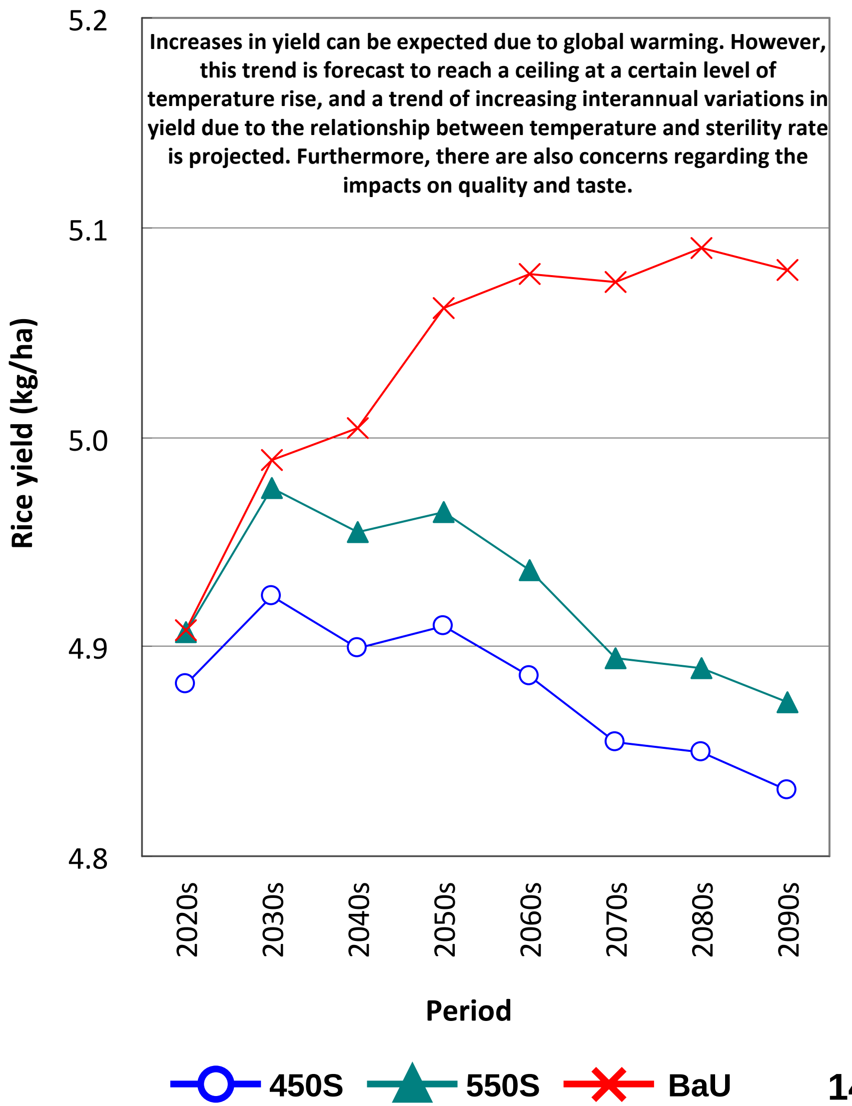
Future impacts

Nationwide trends

- Until around mid-century (up to the 2050s), increases in yield are seen due to effect of the reduction in growth period being less than the CO2 fertilization effect, and also as a result of the reduction in cold weather damage. Thereafter, under the 450s and 550s scenarios, the trend reverses to one of decreasing yields toward the end of the century (up to the 2090s) because of the effect of the reduction in growth period being greater than the CO2 fertilization effect, as well as reductions in yield due to high temperature. Under the BaU scenario, on the other hand, although the trend will not reverse to a reduction in yield, the rate of increase is expected to become gradually lower.

Regional trends

- In all regions, the yield increases until the negative effect of temperature rise exceeding the CO2 fertilization effect appears, after which it decreases. The positive effect of temperature rise is especially pronounced in the Hokkaido/Tohoku region, with the result that the year in which the yield reverses to a decreasing trend is later than in other regions. Under the BaU scenario, yields increase in the Chugoku/Shikoku/Kyushu and Kanto/Koshinetsu/Hokuriku regions due to the CO2 fertilization effect. However, in the Tokai/Chubu/Kinki region, the temperature will become higher than other regions due to the effect of the Pacific high-pressure system ("Pacific high"), and since the flowering stage of rice coincides with the period of high temperature, the trend in yield can be forecast to reverse to a declining trend from 2050 onwards.



Impacts on Agriculture (Rice Yield Variation)

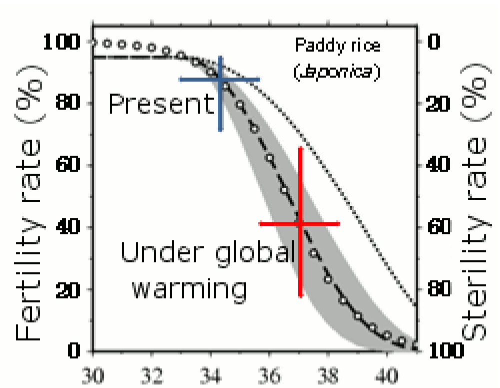
A trend of increasing interannual variations in yield due to the relationship between the progress of global warming and the sterility rate is projected.

Outline of impact assessment index

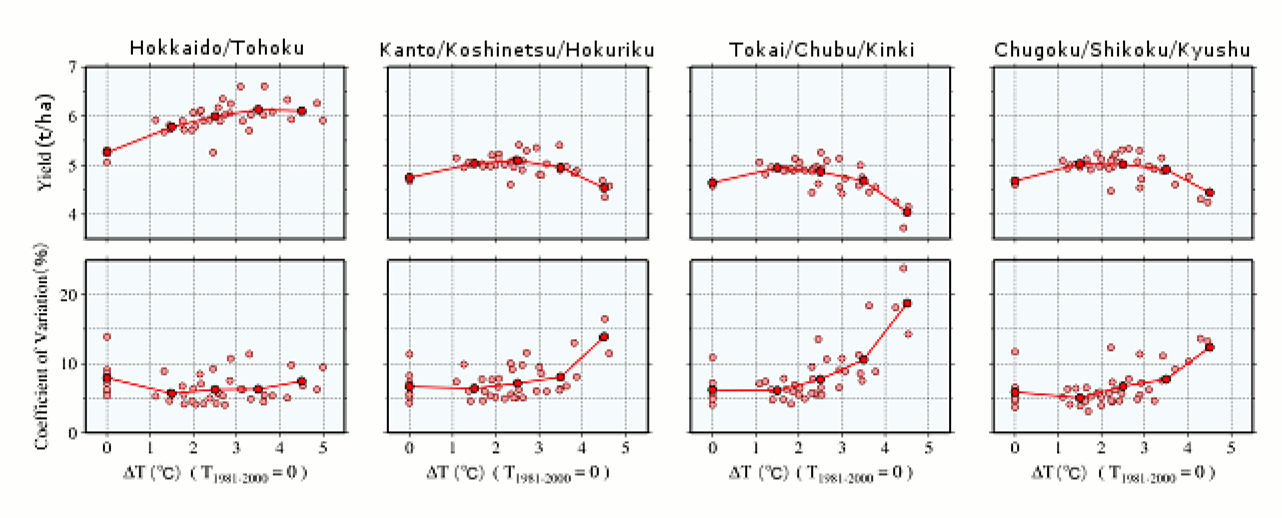
- Since the reproducibility of interannual variations in yield is low in the integrated assessment model, the regional impacts of variability are analyzed using a process-based model (PRYSBI).
- The results of calculations of changes in regional average rice yields are presented with respect to the level of rise of the mean temperature in Japan in the warm season (May-October) for 43 cases of climate change scenarios (including the present climate).
  - The above approach is adopted because of the use of multiple scenarios of climate change including GHG emission scenarios and the difficulty of comparing impacts annually due to the differences in progress of climate change according to the scenarios.
  - Although the x-axis shows only the mean temperature in the warm season, in actuality the variations in daily temperature and insolation are included.

Future impacts

- Nationwide trends: When the mean temperature in the warm season in Japan increases by 3° C or more (compared with 1981-2000), an increase in variations in yield is expected in all regions.
- Regional trends: Particularly in the Tokai/Chubu/Kinki region, the Pacific High will be strengthened with climate change and its edge will reach this region, thereby intensifying the high-temperature trend in summer. This characteristic has also been seen in recent years, and it is possible that it will become a further cause of decreases in yield and the amplification of variations in yield in this region in the future.



Mean value of maximum temperature in flowering stage



Impacts of Sea Level Rise (Economic Value of Sandy Beach Loss)

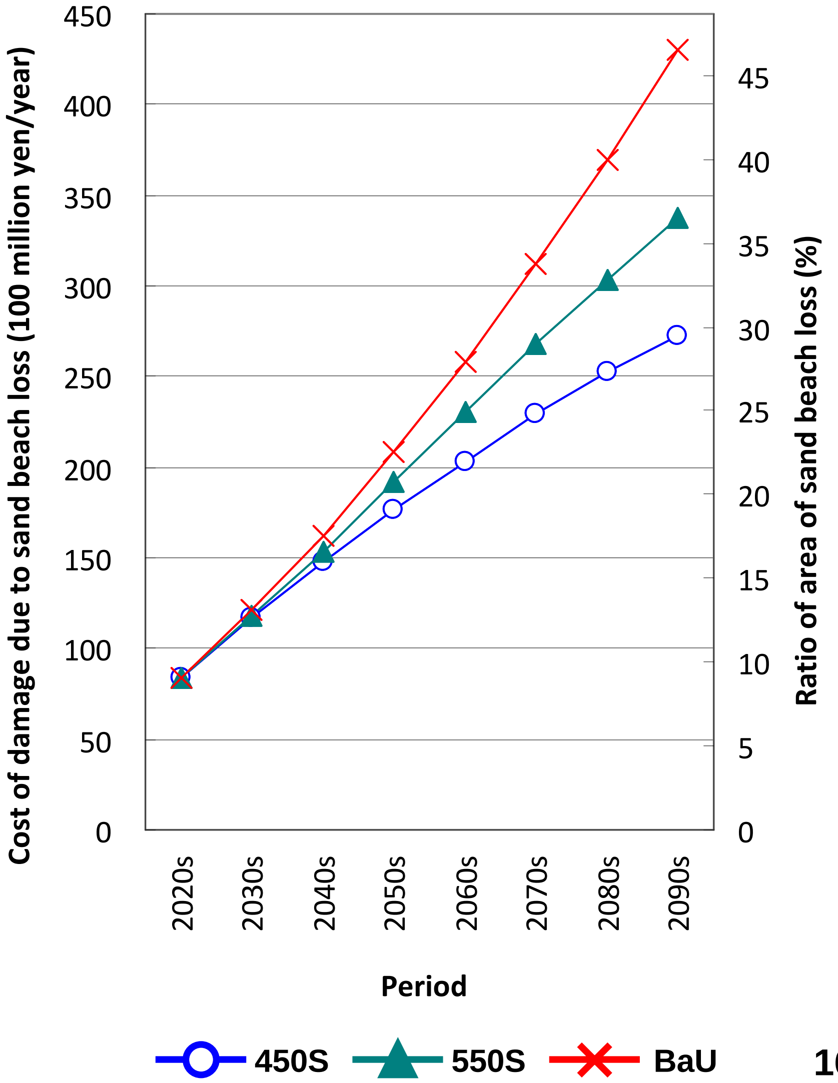
The sea level rise accompanying the progress of global warming will not stop during this century even in the case of the strictest stabilization level (450s), with the result that further losses are expected in sandy beaches and their economic value.

Outline of impact assessment index

- Given future sea level rises, the area of beaches encroached on is estimated by prefecture.
- The area of sandy beach loss in the base year (1990) is assumed to be zero.
- Sea level rises in 2090s: 0.15 m (450s), 0.19 m (550s), 0.24 m (BaU)
- Differences in sea level rises among regions are not taken into consideration and it is assumed that sea level changes occur uniformly throughout Japan.
- Adaptation measures are not taken into consideration.
- The use- value of sandy beaches is 2,179 yen/visit. When the annual recreational value of sand beaches is calculated by multiplying the number of annual users of sandy beaches (for sea bathing) by prefecture by this basic unit, the annual recreational value of sandy beaches throughout Japan becomes 92.2 billion yen/year. When this value is converted to present value using a social discount rate of 4% per year, the amount of 2,304.6 billion yen is obtained.

Future impacts

- Even under the 450s scenario, the area of sand beach loss due to sea level rise continues to increase until around the end of the century (up to the 2090s), with approx. 29% of the area of sand beaches expected to be lost. On the other hand, under the 550s and BaU scenarios, approx. 37%, and 47%, respectively, is expected to be lost during the same period.
- The cost of damage due to sandy beach loss by around the end of the century (up to the 2090s) is expected to reach approx. 27.3 billion yen/year (450s), 33.8 billion yen/year (550s), and 43.0 billion yen/year (BaU). When compared with BaU, a substantial damage reduction effect can be expected under the 450s scenario. However, damage due to the rise in sea level is expected to continue for a long period, including under the 450s scenario, so adaptation measures from the long-term viewpoint are important.



Impacts of Sea Level Rise (1) (Affected Population, Area, and Cost of Damage due to Storm-Surge Flooding)

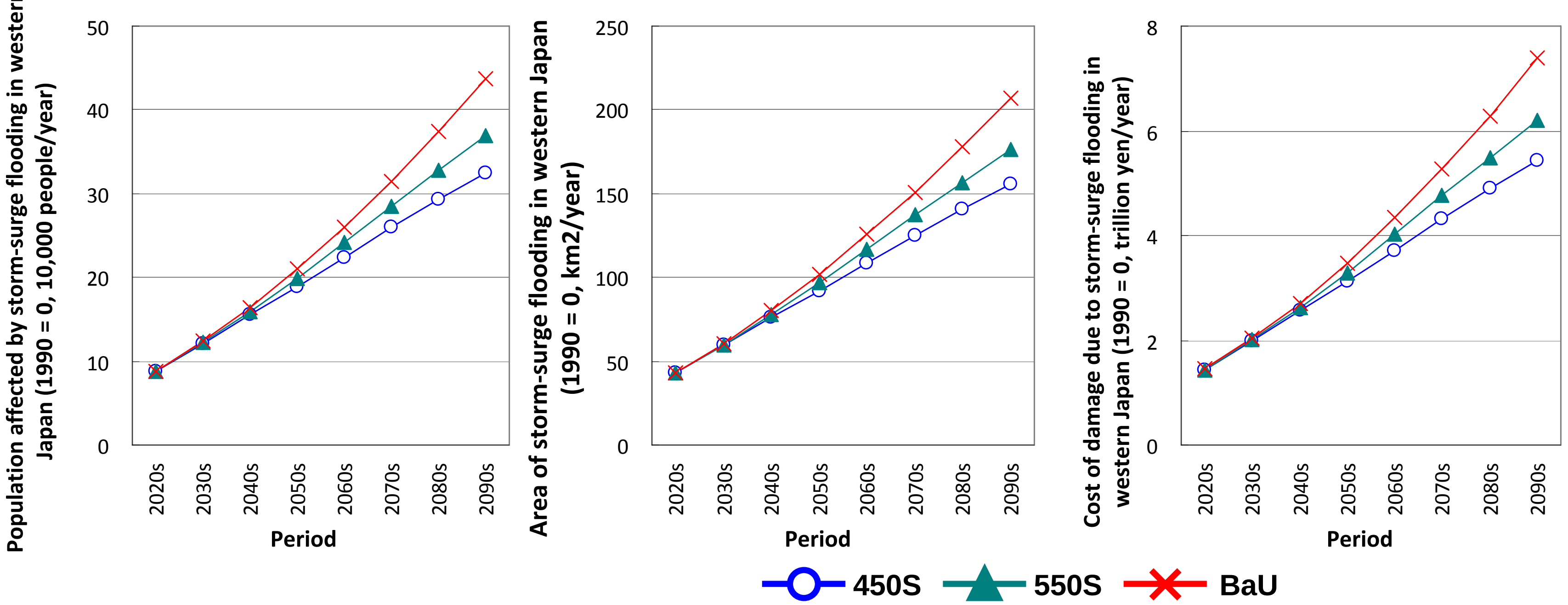
With the occurrence of sea level rises and more powerful typhoons accompanying the progress of global warming, damage is expected to increase in western Japan.

■ Outline of impact assessment index

- The affected population, area, and cost of damage due to storm-surge flooding in western Japan is estimated using a storm-surge flood model that incorporates the modeling of storm-surge protection facilities, combining the impact functions of affected population, area, and cost of damage due to storm-surge flooding obtained from numerous storm-surge flood calculations for various typhoon intensities and sea-level rises, as well as sea level rise scenarios by stabilization level estimated by the integrated assessment model.
- The damage occurring every year is estimated.
- Sea level rises in the 2090s: 0.15 m (450s), 0.19 m (550s), 0.24 m (BaU)
- The typhoon intensity is varied linearly to reach 1.3 in 2100 with 1990 = 1.

□ Future impacts: Damage in western Japan at the end of the century (2090s)

- 450s: Approx. 320,000 people/year, 155 km2/year, 5.4 trillion yen/year; 550s: approx. 370,000 people/year, 176 km2/year, 6.2 trillion yen/year; BaU: approx. 440,000 people/year, 207 km2/year, 7.4 trillion yen/year



Impacts of Sea Level Rise (2) (Affected Population, Area, and Cost of Damage due to Storm-Surge Flooding)

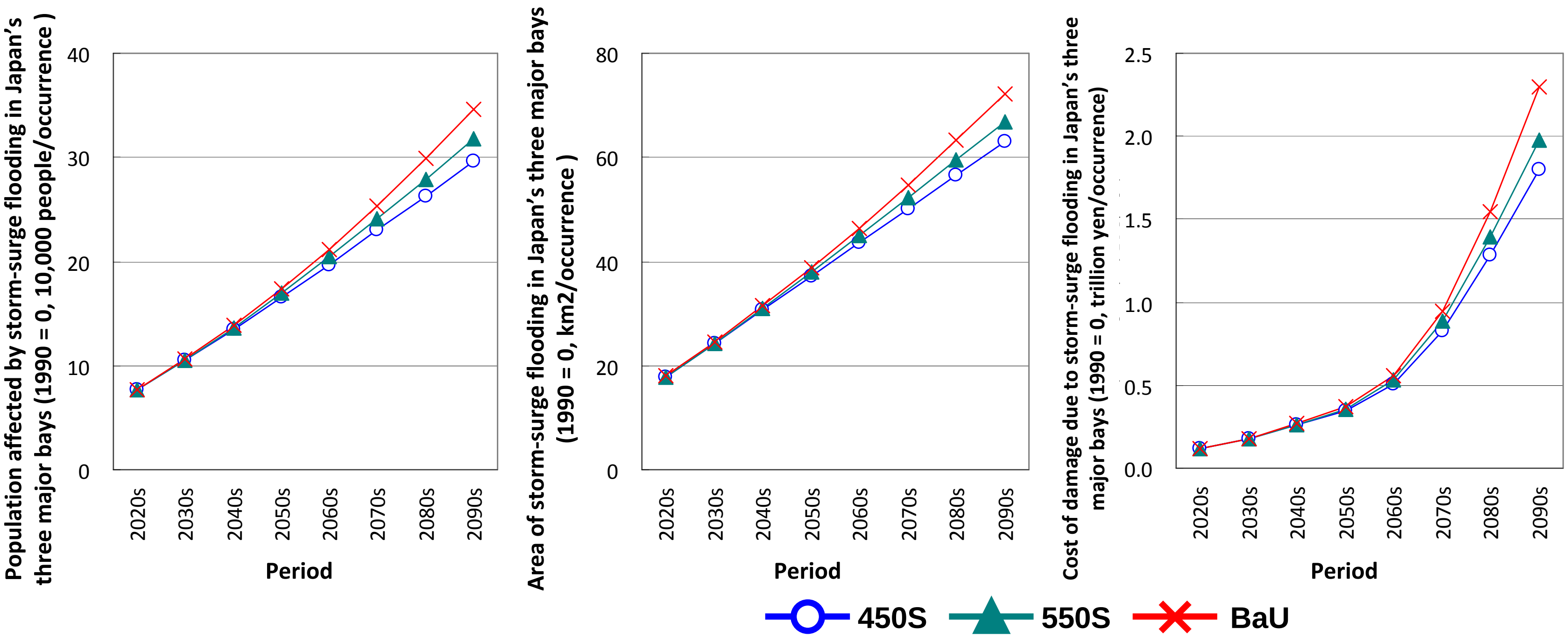
With the occurrence of sea level rises and more powerful typhoons accompanying the progress of global warming, damage is expected to increase in Japan’s three major bays.

■ Outline of impact assessment index

- The affected population, area, and cost of damage due to storm-surge flooding in Japan’s three major bays is estimated using a storm-surge flood model that incorporates the modeling of storm-surge protection facilities, combining the impact functions of affected population, area, and cost of damage due to storm-surge flooding obtained from numerous storm-surge flood calculations for various typhoon intensities and sea-level rises, as well as sea level rise scenarios by stabilization level estimated by the integrated assessment model.
- The degree of damage caused by the strongest category of typhoon (per occurrence) toward the end of the century is estimated.
- Sea level rises in the 2090s: 0.15 m (450s), 0.19 m (550s), 0.24 m (BaU)
- The typhoon intensity is varied linearly to reach 1.3 in 2100 with 1990 = 1.

□ Future impacts: Damage in Japan’s three major bays at the end of the century (2090s)

- 450s: Approx. 300,000 people/occurrence, 63 km2/occurrence, 1.8 trillion yen/occurrence; 550s: approx. 320,000 people/occurrence, 67 km2/occurrence, 2.0 trillion yen/occurrence; BaU: approx. 350,000 people/occurrence, 72 km2/occurrence, 2.3 trillion yen/occurrence



Impacts on Human Health (Heat Stress Mortality Risk)

Heat stress mortality risk increases with the progress of global warming. In the case of the strictest stabilization level (450s), the rate of increase in risk is expected become lower toward the end of the century.

■ Outline of impact assessment index

- The probability of a person dying of heat stress during a year is estimated using a model for estimating excess mortality due to heat stress and its input data (Changes in the number of days with temperature higher than optimal temperature)
- Climatic variable: Change in annual mean temperature
- Population data: The value for 1990 is used with future values remaining unchanged. Population composition is not taken into consideration.
- Only changes in excess mortality at high temperatures due to temperature rise are examined, and changes in excess mortality at low temperatures are not targeted.
- It is assumed that adaptation does not occur.

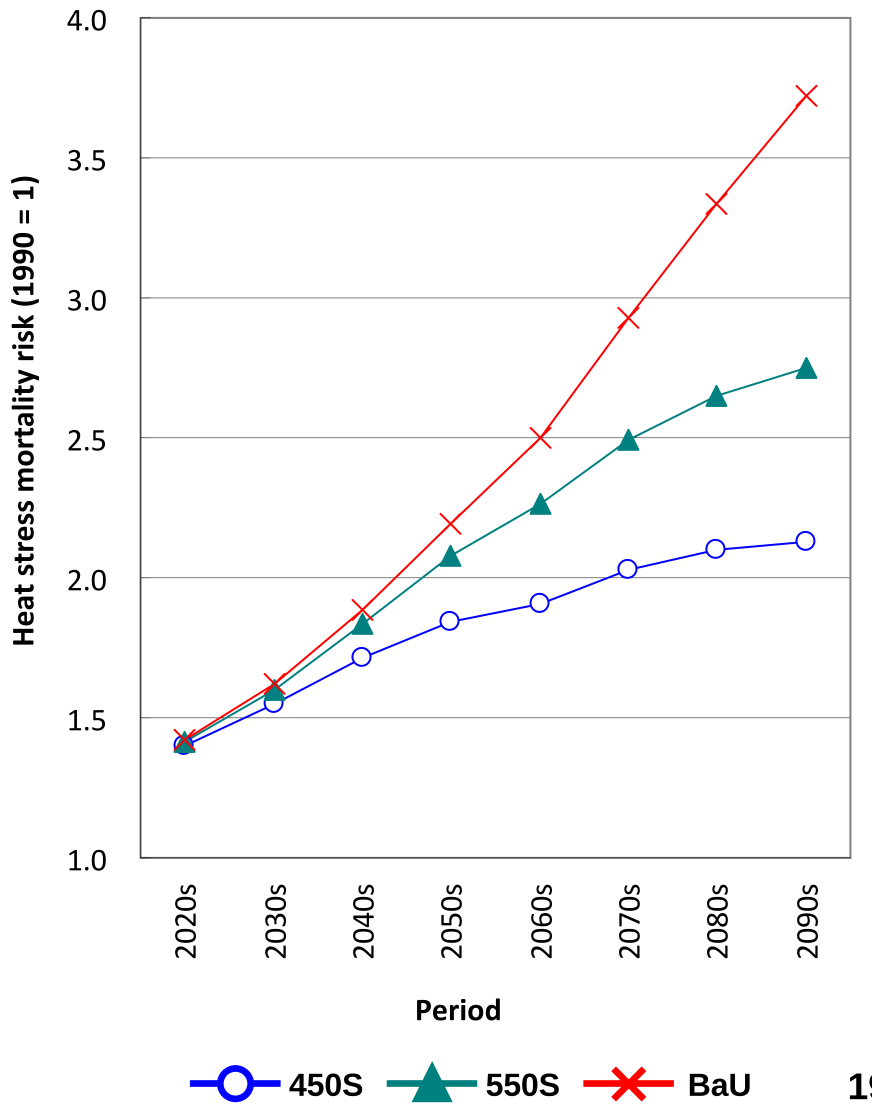
□ Future impacts

● Nationwide trends

- The lower the level at which GHG concentration is stabilized, the smaller the heat stress mortality risk becomes. In the case of the 450s scenario, the rate of increase in mortality risk is expected to gradually become lower toward the end of the century.
- Differences in heat stress mortality risk under the 450s, 550s, and BaU scenarios remain comparatively small around mid-century (2050s), at approx. 1.8 times, 2.1 times, and 2.2 times, respectively. At the end of the century (2090s), however, large differences are expected according to the scenario, at approx. 2.1 times, 2.8 times, and 3.7 times, respectively.

● Regional trends

- At all stabilization levels, the largest change in risk (approx. seven times under BaU) is expected to occur in the Chugoku/Shikoku/Kyushu region. This is not because larger temperature rise is expected there than in other regions, but because the estimated value of heat stress mortality risk during the base period in this region is comparatively small (the optimal temperature is high, and the number of days with a daily maximum temperature exceeding the optimal temperature during the base period is small).



Impacts on Human Health
(Cost of Damage due to Heat Stress (Heatstroke) Mortality)

The cost of damage due to heat stress (heatstroke) mortality increases accompanying the progress of global warming. In the case of the strictest stabilization level (450s), the cost of such damage is expected to roughly reach a ceiling.

■ Outline of impact assessment index

- In the present study, focusing on the mortality risk due to heatstroke, which is one of the typical causes during hot days, the cost of damage is measured by the contingent valuation method (CVM).
- Changes in heatstroke mortality are estimated by multiplying the current average mortality due to heatstroke by the future changes in risk estimated using a model for estimating excess mortality due to heat stress, and the results are multiplied by the value of a statistical life (VSL) to estimate the cost of damage from mortality due to future heat stress (heatstroke).

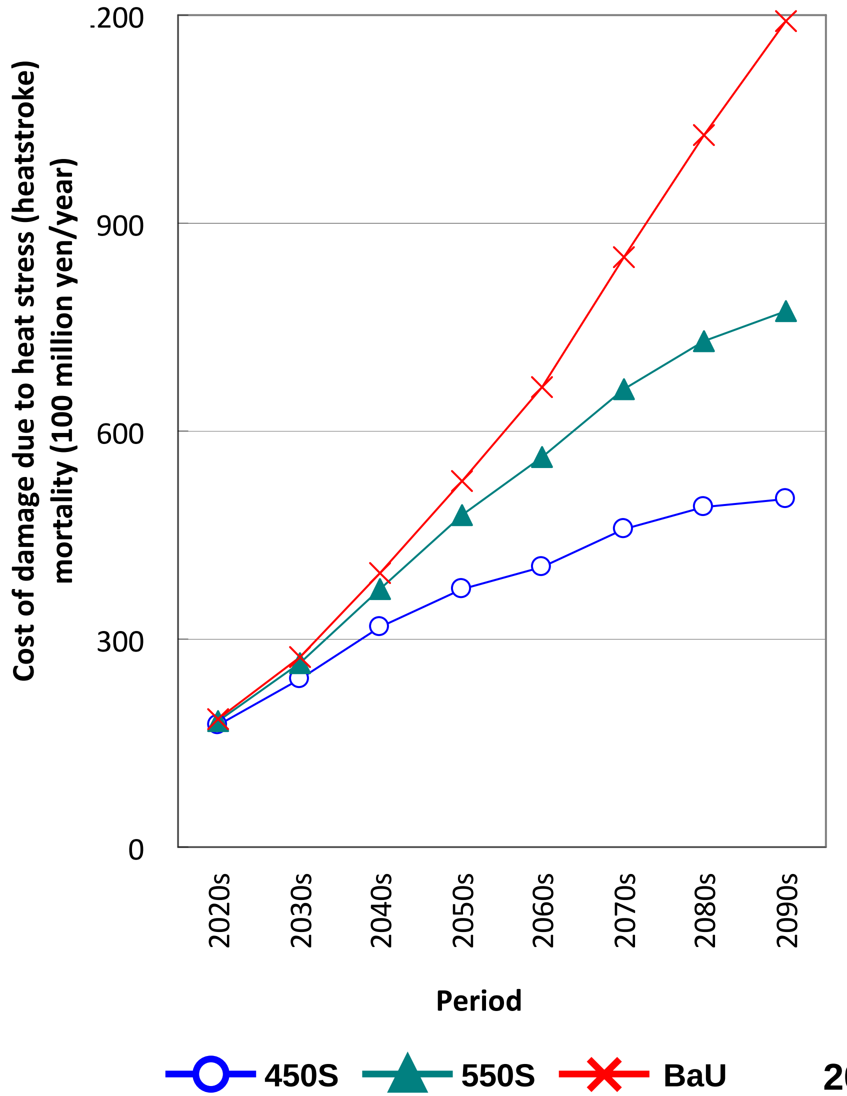
□ Future impacts

● Nationwide trends

- The lower the level at which GHG concentration is stabilized, the lower the cost of damage due to heat stress (heatstroke) mortality becomes. Particularly in the case of the strictest stabilization level (450s), the cost of such damage is expected to roughly reach a ceiling at approx. 50 billion yen/year.
- Differences in the cost of such damage remain comparatively small around mid-century (2050s), at approx. 37.3 billion yen/year (450s), 48.0 billion yen/year (550s), and 52.9 billion yen/year (BaU). However, at the end of the century (2090s), large differences are expected according to the stabilization level, reaching approx. 50.1 billion yen/year (450s), 77.5 billion yen/year (550s), and 119.2 billion yen/year (BaU), respectively.

● Regional trends

- The costs of damage are large in the Kanto/Koshinetsu/Hokuriku and Tokai/Chubu/Kinki regions, which have high estimated values of heat stress mortality risk during the base and future periods as well as large populations. The rate of increase in the cost of damage is expected to become larger in the Chugoku/Shikoku/Kyushu region, where a high increase in risk is expected.



Points to be Noted regarding the Projection Results

Attention should be paid to the following points when examining the projection results.

- Impact projections depend on the preparation method used for climate scenario development (downscaling method, bias correction method) selected for the climate scenarios. As the field of climate scenario preparation methods used for climate scenario development is an area of ongoing research, the assessment results presented here should be considered as an example within the range of uncertainty.
- The relationship between global mean temperature rise and changes in the spatial distribution of various climatic factors as well as sea level rise differs according to the GCM. In this research, it is based on the results of one GCM (MIROC3.2-hires). The results presented here should be considered as an example within the range of uncertainty of projection of the GCM.
- Multiple emission paths are possible in order to achieve a certain stabilization level. Moreover, the timings when impacts are expected to emerge differ according to the path selected. In this research, economically rational emission paths were calculated using an energy-economic model. The assessment results presented here should be considered as an example among multiple possible choices

Summary (1)

- In Japan as well, even greater impacts of global warming are expected in the future in a broad range of fields related to people's lives. If a significant cut in global GHG emissions is achieved, the damage to Japan is also expected to be reduced to a considerable extent. However, even when the GHG concentration is stabilized at 450 ppm, the occurrence of a certain amount of damage is unavoidable.

Climate scenario/impact field		Unit	2030s			2050s			2090s		
			450s	550s	BaU	450s	550s	BaU	450s	550s	BaU
	Change in annual mean temperature (1990 = 0° C)	℃	0.9	0.9	1.0	1.3	1.6	1.7	1.6	2.3	3.2
	Change in annual mean precipitation (1990 = 100%)	%	100	101	101	105	106	107	107	110	113
	Sea level rise (1990 = 0 m)	m	0.06	0.07	0.07	0.10	0.11	0.12	0.15	0.19	0.24
Floods	Flooded area	$1000km^2$	0.2	0.2	0.2	0.6	0.7	0.7	0.5	0.6	0.8
	Flood damage cost potential	Trillion yen/year	1.3	1.3	1.3	4.4	4.7	4.9	5.1	6.1	8.3
Landslide disaster	Probability of slope collapses	%	3	3	3	3	4	4	4	5	6
	Slope collapse damage cost potential	Trillion yen/year	0.60	0.60	0.60	0.49	0.52	0.58	0.65	0.77	0.94
Fagus crenata (Japanese beech) forests	Suitable habitats for F. crenata forests	%	79	77	77	72	65	61	64	50	32
	Cost of damage due to loss of suitable habitats for F. crenata forests	100 million yen/year	778	829	851	1034	1273	1381	1325	1811	2324
Pine wilt	Area at risk of pine wilt	%	15	16	16	22	26	28	27	37	51
Rice	Rice yield	t/ha	4.9	5.0	5.0	4.9	5.0	5.1	4.8	4.9	5.1
Sand beaches	Loss of sand beach area	%	13	13	13	19	21	23	29	37	47
	Damage due to loss of sand beaches	100 million yen/year	116	118	121	176	192	208	273	338	430
Storm surges	Population affected by storm-surge flooding (western Japan)	10,000 people/year	12	12	12	19	20	21	32	37	44
	Population affected by storm-surge flooding (Japan's three major bays)	10,000 people/occurrence	11	11	11	17	17	17	30	32	35
	Area of storm-surge flooding (western Japan)	km^2/year	60	60	61	92	97	102	155	176	207
	Area of storm-surge flooding (Japan's three major bays)	km^2/occurrence	24	24	24	37	38	39	63	67	72
	Cost of damage due to storm-surge flooding (western Japan)	Trillion yen/year	2.0	2.0	2.0	3.1	3.3	3.5	5.4	6.2	7.4
	Cost of damage due to storm-surge flooding (Japan's three major bays)	Trillion yen/occurrence	0.2	0.2	0.2	0.3	0.4	0.4	1.8	2.0	2.3
Heat stress	Heat stress mortality risk	—	1.5	1.6	1.6	1.8	2.1	2.2	2.1	2.8	3.7
	Cost of damage due to heat stress (heatstroke) mortality	100 million yen/year	243	265	274	373	480	529	501	775	1192

Summary (2)

- **Global warming is expected to progress in the coming 20 years regardless of whether additional mitigation measures are implemented. However, differences in impacts reflecting differences in the global climate stabilization level are expected to become larger from around mid-century onward. Therefore, in addition to the active implementation of mitigation measures for stabilizing the climate, it is necessary to study and implement adaptation measures from the long-term viewpoint without delay in preparation for the occurrence of certain levels of adverse impacts.**
  - The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) states as follows: “For the next two decades, a warming of about 0.2° C per decade is projected for a range of SRES emission scenarios.” As global warming progresses, its adverse impacts will extend over a prolonged period and a long time will be required for the effects of climate stabilization to appear. Therefore, in order to minimize future damage and avoid passing the burden of measures on to future generations, it is necessary to study and implement adaptation measures from the long-term viewpoint.

Reference Materials

Impacts of Global Warming

Water resources	Ecosystems	Agriculture (food)	Disaster prevention	Human health
Water shortages (municipal water)	Forest ecosystems (*F. Crenata* and pine)	Agriculture (rice)	Floods	Heat
Water shortages (agricultural water)	Forest ecosystems (other than *F. Crenata* and pine)	Agriculture (other than rice)	Landslide disasters	Atmospheric pollution
Water shortages (industrial water)	Alpine plants	Fruit trees	Storm-surge flooding	Infectious diseases
Snow water resources	Natural grasslands	Tea	Liquefaction	
Water quality	Bogs	Vegetables	Sand beaches	
Groundwater	Oceans	Livestock		
	Coasts	Marine products		
	Fresh water			
	Tidal flats			

Items shown in blue: Impacts evaluated in terms of physical quantity and economic damage in this report. Items shown in green: Impacts evaluated in terms of physical quantity only.

* Impacts that show a gradual increase are targeted. The Project for Comprehensive Projection of Climate Change Impacts has not studied destructive phenomena such as a sea level rise of several meters resulting from collapse of the Greenland and West Antarctic ice sheets.

Targeted Indexes, Regions, and Periods

- **Targeted indexes**
  - Flooded area/cost of damage, landslide disaster risk/cost of damage, loss of sand beach area/cost of damage, heat stress mortality risk/cost of damage, rice yield, suitable habitats for *F. crenata* forests/cost of damage, areas at risk of pine wilt, affected population/area/cost of damage due to storm-surge flooding
- **Targeted regions: Four regions**
  - Hokkaido/Tohoku: Hokkaido, Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima
  - Kanto/Koshinetsu/Hokuriku: Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo, Kanagawa, Niigata, Toyama, Ishikawa, Fukui, Yamanashi, Nagano
  - Tokai/Chubu/Kinki: Gifu, Shizuoka, Aichi, Mie, Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama
  - Chugoku/Shikoku/Kyushu: Tottori, Shimane, Okayama, Hiroshima, Yamaguchi, Tokushima, Kagawa, Ehime, Kochi, Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki Kagoshima, Okinawa
  - ✓ However, Okinawa Prefecture is not included in the scope of study of flooded area/cost of damage, rice yield, suitable habitats for *F. crenata* and forests/cost ofdamage, areas at risk of pine wilt, and affected population/area/cost of damage due to storm-surge flooding.
- **Targeted periods: The values estimated for each year within a period (20 years) are added and the average annual value is calculated.**
  - 2020s: 2011-2030; 2030s: 2021-2040; 2040s: 2031-2050; 2050s: 2041-2060; 2060s: 2051-2070; 2070s: 2061-2080; 2080s: 2071-2090; 2090s: 2081-2100