Report on Assessment of Impacts of Climate Change in Japan and Future Challenges (Comment Submission)

March 2015

Central Environment Council

1. Purpose of Submission

1.1 Context

From September 2013 to November 2014, Plenary Sessions of the IPCC[1] approved and released the IPCC's Fifth Assessment Report ("The Physical Science Basis"; "Impacts, Adaptation, and Vulnerability"; "Mitigation of Climate Change"; and "Synthesis Report"), which includes summaries of the latest scientific findings on climate change. The Fifth Assessment Report shows "Warming of the climate system is unequivocal" and "It is extremely likely that human influence has been the dominant cause of the observed warming." Under a scenario in which the necessary measures are taken to limit warming to relatively low levels, global mean surface temperature change will likely be in the range of 0.3°C to 1.7°C and global mean sea-level rise will likely be in the range of 0.26 to 0.55 m for the period 2081–2100, compared to 1986–2005. For the same period, under a scenario with greenhouse gas emissions continuing at a relatively high level, global mean surface temperature change will likely be in the range of 2.6°C to 4.8°C,[2] and global mean sea-level rise will likely be in the range of 0.45 to 0.82 m. Furthermore, the report also shows that changes in climate have caused impacts on natural and human systems on all continents and across the oceans, and without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead to high to very high risk of severe, widespread and irreversible impacts globally. Meanwhile, there are multiple mitigation pathways that are likely to limit warming to below 2°C relative to pre-industrial levels, but these pathways would require substantial emission reductions over the next few decades and near zero emissions of greenhouse gases by the end of the 21st century.

Meanwhile, even if the increase in global mean temperature can be kept below 2°C relative to pre-industrial levels in accordance with the international agreement[3] reached at the COP 18 climate conference in Doha in November 2012, it is likely that Japan will experience various changes in climate such as an increase in temperature, and changes in precipitation, as well as sea- level rise and acidification of the ocean—and it is projected that impacts would occur in various aspects such as disasters, food, and health. Therefore, it is important to diligently promote mitigation efforts, and to promote systematic efforts for adaptation to impacts that have already occurred as well as other unavoidable impacts in the mid-and long-term.

Regarding trends outside of Japan, e.g., countries in Europe and North America, it can be noted that the Netherlands published an impact assessment report in 2005 and an adaptation plan in 2007, and revised the impact assessment report in 2013. The United Kingdom published an impact assessment report in 2012 and

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1 IPCC: Intergovernmental Panel on Climate Change

2 The Fourth Assessment Report (AR4) projected a maximum increase of 6.4℃ at the end of this century compared to the end of the twentieth century. However, it is difficult to make simple comparisons of projections, due to differences in the base years, emission scenarios, and the range of uncertainty of projections. This projection corresponds to AR4.

3 The agreement is to take action as soon as possible to significantly reduce greenhouse gas emissions to limit the global mean temperature increase below 2℃ relative to pre-industrial levels.

an adaptation plan in 2013. The United States of America published an impact assessment report in 2009, had a presidential executive order signed in 2013 on adaptation to climate change, and in 2014 revised the impact assessment report. In Asia, South Korea published both an impact assessment report and an adaptation plan in 2010. Thus, outside of Japan, efforts for the assessment of climate change impacts and formulation of adaptation plans have already occurred.

In this context, regarding Japan, it is also meant to be formulating a "national adaptation plan" as a summary of the efforts of the government, from the perspective of adapting to climate change impacts, with the aim of releasing the plan around the summer of 2015.

1.2 Purpose

To formulate the "national adaptation plan," it is necessary to ascertain what kind of impacts could be occurring due to climate change in Japan, and to develop plans based on the findings. That is why the Expert Committee on Climate Change Impact Assessment (hereinafter "Expert Committee") was formed under the Global Environment Committee of the Central Environment Council (an advisory body to the Japanese Cabinet), and in the committee, "the projections of climate change in the future based on existing research" and "the assessments of climate change impacts on nature and human society in Japan" (hereinafter "impacts") are compiled. In this way, the impacts of climate change in Japan have been discussed. This report is a summary of climate change impacts as well as future challenges, based on existing findings collected and compiled, as well as discussions of the Expert Committee so far.

From the scientific perspective, this report summarizes what kind of impacts could be occurring due to climate change in Japan, as well as the magnitude and probability (significance) of impacts, timing of occurrence of impacts, timing required to initiate adaptation measures and critical decision-making (urgency), and the certainty of information (confidence). Thus, when the government's "National Adaptation Plan" is being formulated, it is possible to select out the specific sector or category where impacts are likely to occur, and determine whether measures should be taken.

1.3 Procedure of Examination

In order to summarize and assess the impacts of climate change in Japan, this Expert Committee was formed under the Global Environment Committee of the Central Environment Council in July 2013, and it proceeded with discussions. During FY 2013, the Expert Committee held its first meeting in August, and four meetings in total by the end of March 2014. The Expert Committee examined the relevant evidence and literature, and considered the required information concerning future impacts and classifications of sectors and categories; as a result of the fourth meeting, it formulated the "Interim Report on Future Impacts and Future Challenges of Climate Change in Japan" (hereinafter "Interim Report").

In FY 2014, the Expert Committee continued to collect literature relating mainly to climate change impacts via public comments based on the Interim Report and communications with local governments and academics, and then, based on collected materials, compiled "current status" and "projected impacts" of climate change impacts from the scientific perspective, and assessed significance, urgency, and confidence. In the process of summarizing this report, it collected peer-reviewed papers and other literature, including the findings of the IPCC's Fifth Assessment Report relating mainly to climate change impacts in Japan—and through the discussion in the Expert Committee, 509 documents were ultimately used to prepare this report.

Considering assessments, at first the approach of assessment was discussed by the sixth Expert Committee meeting, in terms of significance, urgency, and confidence, and a basic approach was decided. Then, to accelerate discussions of the Expert Committee, "Sectoral working groups considering climate change impacts"[4] (Ministry of the Environment Commissioned Study Groups, hereinafter referred to as "Working Group" (WG)) were held. With the Expert Committee members and additional WG members, there was a total of 57 persons in five WGs, with each WG meeting three times: Agriculture, Forest / Forestry and Fisheries WG; Water environment / Water resources and Natural disasters / Coastal Areas WG; Natural Ecosystems WG; Human Health WG; and Industrial / Economic Activities and Life of Citizenry and Urban Life WG.

To begin with, in each sector, the classification of categories and sub-categories was discussed, and 30 categories and 56 sub-categories were identified in seven sectors. For each category, the current status and projected impacts were examined, based on literature and discussions by the Working Groups.

Next, impacts were assessed in terms of significance, urgency, and confidence. This was done in accordance with the assessment approach stipulated by the Expert Committee, for each sector; assessments were based on literature to the greatest extent possible, and expert judgment was applied. (Section 3.2 "Approach for Assessment of Climate Change Impacts" provides details of the assessment approach.) For assessments, the greatest possible effort was made to provide a clear basis for the assessment and to use expressions that were understandable for the layperson.

The results of deliberations by each Working Group were confirmed from a cross-sectoral perspective by this Expert Committee, and integrated into a final summary.

2. Overview of Climate Change in Japan

2.1 Major Efforts for Observation and Projection of Climate Change Impacts

(1) Observation of Climate Change

For the observation of climate change, under the Japan Meteorological Agency and related agencies, in addition to in situ and ship-based observation, in recent years observation has also been implemented by satellite for the distribution of sea ice, and by Argo floats[5] for water temperature and salinity.

[4] See Appendix 1: (1) Organization for This Review, (2) Sectoral Working Groups concerning Climate Change Impacts (Ministry of the Environment, Japan Commissioned Study Groups).

[5] Argo floats: Monitoring equipment that can measure parameters such as water temperature and salinity as they

Continuous monitoring of climate change is being conducted in a variety of ways, such as aircraft-based monitoring of GHG concentrations, satellite-based monitoring of column-averaged concentrations of CO_2 and methane by the Greenhouse gases Observing SATellite(GOSAT) "IBUKI," and precipitation and sea surface temperature by the Global Change Observing Mission – Water (GCOM-W) "SHIZUKU" satellite. In addition, under the Earth Observation Promotion Strategy (Council for Science and Technology Policy, 2004), priority has been assigned to elucidation of phenomena related to global warming, the projections of its impacts, and the mitigation of and adaptation to global warming; the efforts are being advanced through collaboration among various government ministries.

(2) Projections of Climate Change

For projections of climate change, in order to provide information to contribute to consideration of mitigation and adaptation, the Japan Meteorological Agency has been periodically publishing the results of numerical model experiments since FY 1996, under the title of "Global Warming Projection" reports; the latest version, "Global Warming Projection Vol. 8," was published in March 2013. Using that data, some local meteorological observatories also assess and publish local climate change reports.

From FY 2007 to FY 2011, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) conducted the "Innovative Program of Climate Change Projection for the 21st Century" (KAKUSHIN Program), under which three types of projection experiments were conducted (Long-Term Global Change Projection, Near-Term Climate Prediction, and Extreme Event Projection); other research was also conducted, targeting the themes of assessing the impacts of climate change on natural disasters, making further advances in climate models, and quantification of uncertainty. The Ministry is currently implementing the "Program for Risk Information on Climate Change (SOUSEI)," which started in FY 2012, with the aims of improving climate change projections as well as generating basic information required for managing various risks resulting from climate change.

Also, from FY 2007 to FY 2011, the Ministry of the Environment conducted a project named the "Integrated Research on Climate Change Scenarios to Increase Public Awareness and Contribute to the Policy Process (S-5)," which assessed uncertainty using the projection results of multiple climate models and conducted research on downscaling to obtain detailed projection information for Japan. In addition, in FY 2013 and FY 2014, the Ministry of the Environment and the Japan Meteorological Agency, through cooperation with the Data Integration and Analysis System Program (DIAS-P) on global environmental information (under MEXT) conducted detailed climate change projections for the region of Japan at the end of the 21st century based on scenarios used in the IPCC Fifth Assessment Report. Projection results were formulated, taking uncertainty into account by implementing multiple projection calculations with various conditions, and the findings were published on December 12, 2014 under the title "Results of Climate Change Projections in Japan Considering Uncertainty (Announcement)" (in

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automatically rise and sink in the ocean between the sea surface and a depth of 2,000 m.

Japanese).

Since FY 2009, the Ministry of Land, Infrastructure, Transport and Tourism has been promoting research relating to future projections including torrential rainfall, flood, storm surges, and urban rainfall under climate change conditions, for the purpose of showing what technological infrastructure is required for multi-faceted consideration and establishment of policies to respond to future climate change, from a view point of water disaster prevention, water utilization, and the environment.

2.2 Observation Results and Projections of Climate Change

The results of observation on climate change described below are based mainly on the “Climate Change Monitoring Report 2013” (Japan Meteorological Agency, available in Japanese and English).

The projections of climate change described below mainly utilize of the results of the Japan Meteorological Agency’s “Global Warming Projection Vol. 8” (2013) (hereinafter GWPV8), and the “Results of Climate Change Projections in Japan Considering Uncertainty (Announcement)” (in Japanese) (Friday, December 12, 2014: press release by the Ministry of the Environment and the Japan Meteorological Agency) detailed climate projections for the Japan region, implemented by the Ministry of the Environment and the Japan Meteorological Agency (hereinafter “Projection with Uncertainty”) (in Japanese). These projections for the end of the 21st century rely on dynamic downscaling using a non-hydrostatic regional climate model (NHRCM) developed by the Meteorological Research Institute, and each is calculated as shown below.

Summary of Projections

		GWPV8	Projection with Uncertainty
Period for reproduction of current climate		(1980–1999)	September 1984 – August 2004
Period for projection of future climate		(2016–2035) (2076–2095)	September 2080 – August 2100
Horizontal resolution of regional climate model		5 km	20 km
General features of projections with global climate models used for boundary conditions	Model	MRI-AGCM3.2S	MRI-AGCM3.2H
	Scenario (Numbers in parentheses indicate the number of ensemble members with various conditions)	SRES A1B[6] (1 member)	RCP2.6 (3 members) RCP4.5 (3 members) RCP6.0 (3 members) RCP8.5 (9 members)
	Horizontal resolution	20 km	60 km

Note: In GWPV8, to input global model projection results to the NHRCM, a regional climate model with horizontal resolution of 15 km was used.

Note: Please refer to the following URL for general descriptions of the each set of projections.

GWPV8

http://ds.data.jma.go.jp/tcc/tcc/products/gwp/gwp8/index.html (excerpt)
http://www.data.jma.go.jp/cpdinfo/GWP/Vol8/pdf/all.pdf (full, in Japanese)

Projection with Uncertainty

http://www.env.go.jp/press/19034.html (in Japanese)
http://www.jma.go.jp/jma/press/1412/12a/21141212_kikouhendou.html (in Japanese)

In the following discussion, citations from the “Climate Change Monitoring Report 2013” are indicated by *I, GWPV8 by *II, and “Projection with Uncertainty” by *III. Other citations are indicated by their respective sources.

Climate change projections are calculated by climate models based on scenarios of how atmospheric concentrations of greenhouse gases, aerosols, and other substances change; those projections of the future involve a certain degree of uncertainty due to such factors as the uncertainty of the models, imperfections in the models, and internal variability of climate systems.

Also, in day-to-day weather and seasonal variations, high or low temperature events, torrential rainfall,

[6] SRES A1B scenario: One of the scenarios in the Special Report on Emission Scenarios (SRES) by the IPCC, which characterizes future society with continued rapid economic growth, a reduction in regional disparities caused by globalization, and the rapid spread of new technologies, along with a balanced emphasis on all energy sources. It is expected that emissions increase until the middle of the 21st century, and after peaking, follow a gently-declining trend to reach atmospheric CO_2 concentrations of about 700 ppm by approx. the year 2100. Compared using radiative forcing in approx. the year 2100, this corresponds roughly to the RCP6.0 scenario (van Vuuren and Carter 2014).

heavy snowfall, or other events can sometimes be observed that diverge significantly from the long-term trends. Because of this, to ascertain the impacts of global warming, it is important to have the long-term perspective of time in terms of several decades.

(1) Current Greenhouse Gas Emissions

i) Observation Results

・The Working Group I contribution to the IPCC's Fifth Assessment Report shows that atmospheric concentrations of the greenhouse gases such as carbon dioxide, methane, and nitrous oxide have increased to unprecedented levels in at least the past 800,000 years, and that all of them have been increasing since 1750 due to human activities. According to the latest observations, the concentrations of these greenhouse gases in 2013 were 396.0±0.1 ppm, 1824±2 ppb, and 325.9±0.1 ppb, respectively.[7]

・Observation results by the Japan Meteorological Agency of atmospheric CO_2 concentrations[8] show that atmospheric CO_2 concentrations continue to increase, and in 2013 the monthly mean values exceeded 400 ppm at all three observation sites in Japan; in 2014, 400 ppm was also recorded on the ocean and aerial observations in the vicinity of Japan.[9]

・Based on observation results of the Greenhouse gases Observing SATellite (GOSAT) "IBUKI",[10] analysis of the monthly mean of CO_2 column average concentrations in Japan from June 2009 to May 2014 revealed that CO_2 concentrations increased year by year, and in April 2013, the monthly mean concentration exceeded 400 ppm for the first time.[11] The results also show annual variations as concentrations decrease in summer due to plant photosynthesis, and increase in winter due to a reduction in plant photosynthesis activity.[12]

ii) Projections

・Simulations used for consideration in the IPCC's Fifth Assessment Report were implemented based on

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7 From World Meteorological Organization (WMO) Greenhouse Gas Bulletin No. 10 (September 9, 2014).

8 GHG observation is being conducted at three locations in Japan that are relatively unaffected by local pollution sources: Ryori (Ofunato city, Iwate Prefecture), Minamitorishima (Ogasawara village, Tokyo), and Yonaguni Island (Yaeyama county, Okinawa Prefecture). Marine atmospheric observations are also conducted by marine meteorological observation ships, while aircraft-based observations are also conducted in southeastern Japan (route from Ayase city, Kanagawa Prefecture to Minamitorishima island).

9 Source: Japan Meteorological Agency news release, "Northwestern Pacific observation network data show atmospheric CO2 concentration exceeding 400 ppm" May 26, 2014.

10 Jointly developed by the Ministry of the Environment, National Institute for Environmental Studies, and Japan Aerospace Exploration Agency (JAXA), this was the world's first observation satellite designed specifically to measure greenhouse gases. Since its launch on January 23, 2009, it has continue to operate smoothly to the time of this report in December 2014. Its successor is now being developed to have improved precision, with a launch expected in FY 2017, and the aim is for continuous development and operations, including discussions about a third satellite in the series.

11 Ibuki data are not corrected for bias.

12 Data from National Institute for Environmental Studies.

the GHG concentrations or anthropogenic emissions pre-specified in the four scenarios. Future atmospheric CO_2 concentrations are dependent on future anthropogenic emissions and the global carbon cycle; the scenarios have been defined with concentrations reaching 421 ppm (RCP2.6 scenario), 538 ppm (RCP4.5 scenario), 670 ppm (RCP6.0 scenario) and 936 ppm (RCP8.5 scenario) by the year 2100, respectively.

(2) Atmospheric Temperature

i) Observation Results

- The annual mean temperature in Japan fluctuates on different time scales ranging from years to decades, and it is virtually certain that it has increased from 1898 to 2013, at a rate of 1.14°C per 100 years (statistically significant at a confidence level of 99%). (*I)
- It is virtually certain that seasonal mean temperatures for winter, spring, summer and autumn have risen at rates of about 1.15°C, 1.28°C, 1.05°C and 1.19°C per 100 years (all statistically significant at a confidence level of 99%). (*I)
- The annual number of days with maximum temperatures of 30°C or higher shows no discernible trend in the period 1931 to 2013. Meanwhile, the annual number of days with maximum temperatures of 35°C or higher is extremely likely to have increased (statistically significant at a confidence level of 95%). (*I)
- It is virtually certain that the annual number of days with minimum temperatures below 0°C has decreased during the statistical period 1931–2013, while the annual number of days with minimum temperatures of 25°C or higher has increased (both statistically significant at a confidence level of 99%). (*I)
- In addition to the impact of climate change, a long-term temperature increase trend is also evident in cities[13] due to urbanization. The rate of increase per 100 years in annual mean temperature since 1931 was 1.5°C at 15 stations on average where the impacts of urbanization are considered to be relatively small.[14] In comparison, a significant increasing trend is evident in large cities such as Tokyo (3.2°C), Osaka (2.7°C), and Nagoya (2.9°C), and the differences in the long-term trends of urban stations from the average of 15 stations largely represent the influence of urbanization. The long-term trend of daily minimum temperature is particularly noticeable in winter, with Tokyo showing an increase of 6.1°C

[13] This refers to 11 cities: Sapporo, Sendai, Niigata, Nagoya, Tokyo, Yokohama, Kyoto, Hiroshima, Osaka, Fukuoka, and Kagoshima.

[14] This is the average of fifteen meteorological observatories which are relatively least affected by the change of environment due to urbanization, and their observation data's homogeneity is consistent over a long period.(Abashiri, Nemuro, Suttsu, Yamagata, Ishinomaki, Fushiki, Iida, Choshi, Sakai, Hamada, Hikone, Miyazaki, Tadotsu, Naze, and Ishigakijima). For Iida and Miyazaki, the data are corrected for the effects of relocation during the statistical period. However, these observation sites as well are not entirely unaffected by urbanization.

per 100 years.[15]

ii) Projections

・The higher the GHG emissions, the more the temperature will increase. (*II, *III)

・Annual mean temperature will increase, with more increase at higher than lower latitudes, and in winter more than in summer. (*II, *III)

・The number of hot days and hot nights will increase, and the number of cold days will decrease. (*II, *III)

<Low emissions of GHGs (GHG concentrations stabilize at low levels) RCP2.6 scenario>

・Annual mean temperature will increase by 1.1°C in Japan, relative to the end of the 20th century (confidence interval[16] 0.5–1.7°C). An increase in temperature will be greater at higher than lower latitudes, and in winter more than in summer. (*III)

・The annual number of days with maximum temperatures of 30°C or higher will increase by a national average[17] of 12.4 days relative to the end of the 20th century, in particular, with an increase of an average 26.8 days in Okinawa and Amami. (*III)

・On the other hand, for the annual number of days with maximum temperatures below 0°C, the national average will decrease by 4.4 days relative to the end of the 20th century, and in particular, the average will decrease by 9.8 days and 9.4 days, respectively, on the Sea of Japan side and the Pacific Ocean side of northern Japan, respectively. (*III)

<High emissions of GHGs (GHG concentrations stabilize at high levels) SRES A1B scenario>

・Annual mean temperature will increase by 3.0°C in Japan, relative to the end of the 20th century. (*II)

・The maximum temperature on extremely hot summer days (the 20-year return value of annual maximum temperature) will increase by 2°C to 3°C, depending on the region, relative to the end of the 20th century. Also, the minimum temperature on extremely cold winter days (the 20-year return value of annual minimum temperature) will increase by 2.5°C to 4°C, relative to the end of the 20th century. (*II)

・The annual number of days with daily minimum temperatures below 0°C and annual number of days with daily maximum temperatures below 0°C will decrease relative to the end of the 20th century,

[15] Excerpt from "Heat Island Observation Report" (2013), Japan Meteorological Agency (in Japanese).

[16] Confidence interval: The product of standard deviation calculated as a combination of uncertainties multiplied by a constant in the standard distribution table (approx. 1.64), based on the results of multiple projection calculations conducted using modified criteria. In the case of normal distribution, approximately 1.64 times the standard deviation corresponds to a 90% confidence interval.

[17] Averages indicated here are the arithmetic means of multiple projection calculations conducted under various conditions.

particularly in northern Japan. The annual number of days with daily minimum temperatures above 25°C and daily maximum temperatures above 35°C will increase relative to the end of the 20th century, in eastern Japan, western Japan, Okinawa and Amami. (*II)

<Very high emissions of GHGs (GHG concentrations reach very high levels) RCP8.5 scenario>

- Annual mean temperature will increase by 4.4°C in Japan relative to the end of the 20th century (confidence range 3.4°C to 5.4°C). (*III)
- The annual number of days with daily maximum temperatures of 30°C or higher will increase an average of 52.8 days in Japan, relative to the end of the 20th century; in particular, the average increase will be 86.7 days in Okinawa and Amami. (*III)
- The annual number of days with daily maximum temperatures less than 0°C will decrease by an average of 15.5 days in Japan relative to the end of the 20th century; in particular, the average will decrease by 38.1 days and 33.3 days, on the Sea of Japan side and the Pacific Ocean side of northern Japan, respectively. (*III)

(3) Precipitation

i) Observation Results

- For annual precipitation, no long-term trend is evident for the period 1898–2013, but Japan experienced relatively large amounts of rainfall until the mid-1920s, and around the 1950s, and the annual figure has become more variable since the 1970s. (*I)
- It is extremely likely that the annual number of days with precipitation of ≥ 100 mm has increased from 1901 to 2013 (statistically significant at a confidence level of 95%). It is also extremely likely that the annual number of days with precipitation of ≥ 200 mm has increased over the same period (statistically significant at a confidence level of 95%). On the other hand, the annual number of days with precipitation of ≥ 1.0 mm has decreased (statistically significant at a confidence level of 99%); these results suggest decrease in the annual number of wet days including light precipitation and in contrast, an increase in extremely wet days. (*I)

ii) Projections

- Annual precipitation is characterized by a large range of inter-annual variability; changes in both national and regional averages (Sea of Japan side of northern Japan, Pacific side of northern Japan, Sea of Japan side of eastern Japan, Pacific side of eastern Japan, the Sea of Japan side of western Japan, Pacific side of western Japan, and Okinawa/Amami) exhibit no clear trend that depends on differences in scenarios; in some cases, the projections are for increases in precipitation, and in other cases, for decrease, relative to the end of the 20th century. (*III)
- The frequency of heavy rainfall and short-term intense rainfall will increase across Japan relative to

the end of the 20th century (*II, *III)

- The annual number of dry days (days with daily precipitation of less than 1.0 mm) will increase relative to the end of the 20th century. (*II, *III)
- The northward shift of the Baiu front (which brings rainfall widely in Japan) will be delayed, and the end of the Baiu will be delayed.[18]

<Low emissions of GHGs (GHG concentrations stabilize at low levels) RCP2.6 scenario>

- The amount of precipitation from heavy rainfall (amount of precipitation in one day from the top 5% of precipitation events) will increase by an average of 10.3% relative to the end of the 20th century. (*III)
- The annual number of dry days (daily precipitation of less than 1.0 mm) will be almost unchanged, or will increase slightly relative to the end of the 20th century. (*III)

<High emissions of GHGs (GHG concentrations stabilize at high levels) SRES A1B scenario>

- The annual number of dry days (daily precipitation of less than 1.0 mm) will increase by 7.7 days relative to the end of the 20th century. (*II)

<Very high emissions of GHGs (GHG concentrations reach very high levels) RCP8.5 scenario>

- The amount of precipitation from heavy precipitation (amount of precipitation in one day from the top 5% of precipitation events) will increase by an average of 25.5% relative to the end of the 20th century. (*III)
- The annual number of dry days (days with daily precipitation of less than 1.0 mm) will increase by an average of 10.7 days relative to the end of the 20th century. (*III)

(4) Snow Cover / Snowfall

i) Observation Results

- The annual maximum snow depth for the period 1962 to 2013 onward on the Sea of Japan side of eastern and western Japan is extremely likely to have decreased at rates of 12.3% per decade and 14.5% per decade, respectively (both statistically significant at a confidence level of 95%). The annual maximum snow depth on the Sea of Japan side of northern Japan shows no discernible trend. As the annual maximum snow depth is subject to large annual variations and the period covered by observation records is still relatively short, the addition of further observation to the data series is expected to increase the reliability of statistical trend detection. (*I)

[18] Kusunoki et al. (2006), Kitoh and Uchiyama (2006), Hirahara et al. (2012)., and other literature

ii) Projections

- Snow cover and snowfall will decrease mainly on the Sea of Japan side of eastern Japan.[19] In some inland areas in Hokkaido, snow cover and snowfall will both increase. (*II)
- The snow cover duration and snowfall season will be shorter (beginning of the season will be later, and ending will be sooner). (*II)

(5) Oceans

i) Observation Results

- The rate of increase of sea surface temperature (annual mean)around Japan over the last 100 years up to 2013 was +1.08°C/100 years, which is greater than for the North Pacific overall (+0.45°C/100 years). (*I)
- Regarding sea levels along the coast of Japan, no clear long-term increasing trend is evident since 1906. A maximum increase was shown in about 1950, and until the 1990s there was a noticeable variation on a cycle of about 20 years. Since the beginning of the 1990s, an increasing trend has been confirmed, as well as variation on a cycle of about 10 years. Note that since 1960 when the current observation regime began, an increasing trend is clearly evident, and the annual rate of increase until 2013 was 1.1 mm per year (rate of increase statistically significant at a confidence level of 99%). However, because this assessment is based on a small number of years, it will be important to continue careful monitoring in the future. (*I)

ii) Projections

- Sea surface temperature around Japan will increase in the long-term, and the long-term trend is for a greater increase in the Sea of Japan than in Japan's southern waters.[20]
- Even if the necessary global warming measures were taken to limit the extent of temperature increase to a relatively low level, global mean sea levels are projected to continue rising during the 21st century.[21] However, regarding sea levels in the vicinity of Japan, for uncertainty of projections, it is also necessary to take into account the conspicuous periodic variations in sea level.[22]

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[19] There is uncertainty associated with bias error between the climate models used and the current climate, so some caution is needed for use. However, examples of projections for the Sea of Japan side of eastern Japan show a reduction of an average 17 cm in annual maximum snow depth and average 26 cm in annual snowfall under the RCP2.6 scenario, and a reduction of an average 78 cm in annual maximum snow depth and average 146 cm in annual snowfall under the RCP8.5 scenario. (*III)

[20] Projections calculated by primary regression analysis based on climate projections for 1981–2100 using the high-resolution North Pacific Ocean General Circulation Model (NPOGCM), applying the SRES A1B and B1 scenarios. (Source: GWPV7, Japan Meteorological Agency.)

[21] Covered in projections under RCP scenarios in the Working Group I contribution to the IPCC's Fifth Assessment Report.

[22] Excerpted from "Synthesis Report on Observations, Projections, and Impact Assessments of Climate Change, *"Climate Change and Its Impacts in Japan"* (FY 2012 edition)".

(6) Sea Ice

i) Observation Results

- According to observation results from 1971 to 2013, there is large annual variation in the accumulated sea ice extent[23] and the maximum sea ice extent[24] in the Sea of Okhotsk, but these parameters are decreasing in the long term (statistically significant at a confidence level of 99%). (*I)
- During the period 1971–2013 the accumulated sea ice extent (an index that shows the potency of sea ice) in the Sea of Okhotsk declined at a rate of 1.75 million km^2 per decade, and the maximum sea ice extent declined at a rate of 58,000 km^2 (equivalent to 3.7% of the total area of the Sea of Okhotsk) per decade. (*I)

ii) Projections[25]

- Sea ice extent in the Sea of Okhotsk from January to April will decline by approximately 75% relative to the end of the 20th century.
- The maximum sea ice extent observed around March will decline by approximately 75% relative to the end of the 20th century.
- Due to the advance of climate change, freezing will begin later in late autumn, and sea ice retreat northward in spring will be earlier.

(7) Typhoons

i) Observation Results

- During the period from 1951 to 2013, the numbers of formations show no discernible long-term trend, but have often been lower since the latter half of the 1990s than in previous years. Since 1977 when the collection of complete data on maximum wind speed near the typhoon centers began, no trend is shown in the incidence of typhoons with maximum wind speeds of 33 m/s or higher, and for the numbers of formations. (*I)

ii) Projections

- An increasing trend is projected relative to the present in the number of occurrences of strong typhoons, the maximum intensity of typhoons, and rainfall intensity at the time of maximum typhoon intensity. It should be noted that the number of occurrences of typhoons in the western Pacific is

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[23] Accumulated sea ice extent: The sum of sea ice extent every five days from December 5 of the previous year to May 31.

[24] Maximum sea ice extent: The extent of sea ice for the five-day period when the sea ice extent was at its maximum for the year.

[25] From comparison of the 20-year average for 2081–2100 projected by Coupled atmosphere-ocean Regional Climate Model (CRCM), applying the SRES A1B scenario, and the 20-year mean for 1981–2000. (Source: GWPV7, Japan Meteorological Agency).

projected to decrease slightly in the long term.[26]

・Some research results indicate that extremely strong typhoons may increase in Japan's southern seas relative to the present, and that these extremely strong typhoons may reach the vicinity of Japan while relatively maintaining their strength.[27]

3. Overview of Impacts of Climate Change in Japan

3.1 Major Efforts for Observation and Projection of Climate Change Impacts

(1) Cross-sectoral and Integrated

Under the Environment Research and Technology Development Fund from FY 2005 to FY 2009, the Ministry of the Environment funded a project named the "Comprehensive Assessment of Climate Change Impacts to Determine the Dangerous Level of Global Warming and Appropriate Stabilization Target of Atmospheric GHG Concentration (S-4)." The project did a comprehensive assessment of global warming impacts in five sectors (water resources, forests, agriculture, coastal areas/disaster prevention, and human health), and quantified the differences in impacts depending on the climate stabilization scenario, including assessments by region, and assessments of damage costs. The "Comprehensive Study on Impact Assessment and Adaptation for Climate Change (S-8)" has been under way since FY 2010, with the aim of responding to policy demands such as climate projections and projections of impacts based on those, and development of adaptation measures at the regional level. Under the program, research is being conducted relating to high-confidence quantitative assessments of nationwide climate change impacts on Japan; impact assessments and comprehensive adaptation policies at the municipal level; and indicators of vulnerability and effectiveness of adaptation in the Asia-Pacific region. From FY 2007 to FY 2011, the "Integrated Research on Climate Change Scenarios to Increase Public Awareness and Contribute to the Policy Process (S-5)" was involved in projections of impacts.

Since FY 2010, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) has been conducting the "Research Program on Climate Change Adaptation (RECCA[28])," aiming to provide scientific findings from the results of global-scale climate change projections for developing climate change adaptation at the regional scale (e.g., prefectures, municipalities). The program has been developing advanced data downscaling methods, data assimilation technology, and simulation technology for climate change adaptation. As a part of those efforts, under the "Program for Risk Information on Climate Change" implemented since FY 2012, precise impact assessments in response to key issues which are important for creating information that can contribute to climate change risk management are being developed.

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[26] Based on, the Working Group 1 contribution to the IPCC's Fifth Assessment Report (2013), and Knutson et al. (2010).

[27] Tsuboki et al. (2015) and Murakami et al. (2012)

[28] RECCA: Research Program on Climate Change Adaptation

Research programs such as these that deal with impact projections make use of each other's findings, and collaboration is encouraged in order to obtain better outcomes. Programs such as S-8, RECCA, and the Program for Risk Information on Climate Change mentioned above also organize activities such as research exchange meetings.

MEXT has also been implementing the "Data Integration and Analysis System Program (DIAS-P[29])" since FY 2011 as an effort to create data infrastructure. This program integrates and analyzes an enormous amount of diverse data (e.g., climate change projections data, global observation data, socioeconomic data) to create useful scientific findings for policy development on climate change adaptation, and it improves upon the "Data Integration and Analysis System" (DIAS) information platform, which was designed to promote the use of this data internationally and domestically.

(2) Agriculture, Forest/Forestry, Fisheries

As for Japan's Ministry of Agriculture, Forestry and Fisheries, a program entitled "Development of technology for impacts, mitigation and adaptation of climate change" was conducted from FY 2006 to FY 2009 involving projections of displacement of suitable growing areas for fruit trees, enhancements of offshore marine ecosystem models, development of global warming impact assessment technologies for fisheries industries, and projections of impacts on existing production areas for major migratory fish species in the Sea of Japan. Currently, as part of the "Technology Development for Circulatory Food Production Systems Responsive to Climate Change," being implemented since FY 2010, some of the work being conducted involves doing accurate assessments of the mid- and long-term impacts of climate change on Japan's agriculture, forestry and fisheries industries, and assessing the impacts on agricultural water resources of extreme events, which are expected to increase in frequency (e.g., flood, water shortages, droughts, disasters in mountain areas). In addition, in order to ascertain the impacts of global warming, studies have been conducted in Japan since FY 2007 in cooperation with prefectures, regarding the occurrence of climate change impacts such as heat damage in food growing areas, and the results have been published in "Report of Global Warming Impacts Studies" (in Japanese) and elsewhere.

(3) Water Environment, Water Resources

From FY 2009 to FY 2012, the Ministry of the Environment conducted work to ascertain the impacts of climate change on issues such as water quality of public waters, and to project the impacts of future climate change on water quality, based on analysis of observational data, development of water quality project models, and on analytical results. The findings were published in the "Report on the Impacts of Climate Change on Water Quality." (in Japanese) Since FY 2013, based on studies until previous years, projections of future impacts on water quality and ecosystems and consideration of necessary adaptation measures have been implemented (especially for lakes and marshes).

[29] DIAS-P: Data Integration & Analysis System Program

(4) Natural Ecosystems

The Ministry of the Environment is conducting ongoing monitoring of ecosystems that are especially susceptible to climate change impacts such as alpine zones and coral ecosystems, and made reference to the impacts of global warming on biodiversity (e.g., magnitude of current damage) in the "Report of Comprehensive Assessment of Biodiversity in Japan," published in FY 2010.

(5) Natural Disasters, Coastal Areas

Since FY 2009, the Ministry of Land, Infrastructure, Transport and Tourism has been implementing analyses of the impacts of future climate change on water disaster prevention measures for first-class river systems nationwide; analysis of the impacts of increases in torrential rainfall on urban rainwater management; analysis of the characteristics of future anomalies in storm surges in Japan's three major bays; preparation of risk maps for inundation damage from storm surges considering the impacts of global warming, and damage functions for coastal inundation; sensitivity analysis of flood inundation to global warming by storm surges in Japan's three major bays; consideration of impacts from global warming; and studies to measure and assess the impacts of sea-level rise.

(6) Human Health

Since FY 2010, the Ministry of the Environment, as part of the "Comprehensive Study on Impact Assessment and Adaptation for Climate Change (S-8)" under the Environment Research and Technology Development Fund, has been conducting research work relating to the impacts of increasing temperature on heat stress. Examples include refining and simplifying a model for climate change mortality impacts, developing a heat-wave warning system, and assessing the effectiveness and economic viability of those systems. This research is also examining the impacts of climate change on infectious diseases, including studies regarding the habitat distribution of mosquitoes that are vectors of dengue fever.

(7) Life of Citizenry, Urban Life

In FY 2008, the Ministry of the Environment implemented studies about the impacts on comfort levels particularly in urban areas, in the context of impacts of increases in temperature, including the heat island effect. The research paid special attention to sleep impacts by studying the relationship between temperature and sleep interruption, and the results have been published in a report.

(8) Local Governments

In terms of the efforts of local governments to date, the Tokyo Metropolitan Government, Saitama Prefecture, Nagano Prefecture, Mie Prefecture, Nagasaki Prefecture, and others have been conducting efforts to monitor and assess the local impacts of climate change. In FY 2010, the National Governors' Association formulated a summary report entitled "Projections of Changes in Local Communities due to Impacts from Global Warming," (in Japanese) on the impacts from global warming on local communities, as well as case studies of efforts that have been attempted.

3.2 Approach for Assessment of Climate Change Impacts

(1) Purpose of Assessment

The purpose of this assessment is to identify important impacts in Japan in order to formulate the national adaptation plant.

(2) Approach of Assessment

The assessment was done as described below, with reference to approaches used in the IPCC Fifth Assessment Report to identify major risks and approaches used in other countries to evaluate risks (e.g., the U.K.'s Climate Change Risk Assessment, hereinafter referred to as "UK-CCRA").

i) Basic Approach

Assessments are done for the sub-categories indicated in Table 1, in terms of significance, urgency, and confidence. It is difficult to mechanically and quantitatively establish assessment criteria across the board due to the unique characteristics of each sector. As a result, it was decided to use expert judgment based on scientific findings in each Working Group, while using common metrics in each sector for "significance," "urgency," and "confidence."

In addition, the Expert Committee considered the results of the discussions in each sector.

ii) Criteria for Assessment

- Significance—Assess in terms of three criteria: social, economic, and environmental. See page 21 for details.
- Urgency—Assess in terms of two criteria: Timing of occurrence of impacts, and timing required to initiate adaptation measures and critical decision-making. See page 23 for details.
- Confidence—To some extent, applying to the approaches to confidence used in the IPCC Fifth Assessment Report, assess in terms of two criteria: Type of research/report (e.g., quantitative projection based on model simulation; projection using an index such as degree of increase in temperature; qualitative analysis or estimates); and degree of agreement. Where the amount of research or reporting is rather limited (examples are only one or two cases), judgment is used to determine whether the contents are reasonable. See page 24 for details.

iii) Method of Summarization

For each sector and sub-category a table format is used to summarize the assessment results for significance, urgency, and confidence. See page 26 for details.

Table 1. Classification of Sectors and Categories

Sectors	Categories	Sub-categories	Related Working Group
Agriculture, Forest/Forestry, Fisheries	Agriculture	Paddy field rice	Agriculture, Forest/Forestry, and Fisheries WG
		Vegetables	
		Fruit trees	
		Barley/Wheat, Soybean, Feed crops, and other crops	
		Livestock Farming	
		Plant pests and weeds	
		Water, Land and Agricultural Infrastructure	
	Forest/Forestry	Timber production (e.g. Plantations)	
		Non-wood forest products (e.g. Mushrooms)	
	Fisheries	Migratory fish stocks (Ecology of fishes)	
		Propagation and Aquaculture	
Water Environment, Water Resources	Water environment	Lakes/ Marshes, Dams (Reservoir)	Water environment / Water resources and Natural disasters / Coastal areas WG
		Rivers	
		Coastal areas and Closed sea areas	
	Water resources	Water supply (Surface water)	
		Water supply (Groundwater)	
		Water demand	
Natural Ecosystems	Terrestrial ecosystems	Alpine/Subalpine zone	Natural Ecosystems WG
		Natural forests / Secondary forests	
		Countryside-landscape (Satochi-Satoyama)	
		Planted forests	
		Damage from wildlife	
		Material balance	
	Freshwater ecosystems	Lakes / Marshes	
		Rivers	
		Marshlands	
	Coastal ecosystems	Subtropics	
		Temperate / Subarctic	
	Marine ecosystems		

Sectors	Categories	Sub-categories	Related Working Group
	Phenology		
	Shifts in distribution and populations		
Natural disasters, Coastal areas	Rivers	Floods	Water environment / Water resources and Natural disasters / Coastal areas WG
		Inland waters	
	Coastal areas	Sea-level rise	
		Storm surges, High waves	
		Coastal erosion	
	Mountain areas	Debris flows, Landslides, and other disasters	
	Others	(e.g., Strong winds)	
Human Health	Winter warming	Mortality in winter season	Human health WG
	Heat stress	Risk of mortality	
		Heat illness	
	Infection	Water- and food-borne diseases	
		Vector-borne diseases	
		Other infectious diseases	
	Others		
Industrial / Economic activities	Manufacture		Industrial / Economic Activities and Life of Citizenry and Urban Life WG
	Energy	Energy demand and supply	
	Commerce		
	Finance, Insurance		
	Tourism	Leisure	
	Construction		
	Medical		
	Others	Other impacts (e.g., Overseas impact)	
Life of Citizenry, Urban Life	Urban infrastructure, Critical services	Water supply, Transportation, and the others	
	Life with sense of culture and history	Phenology, Traditional events / local industry	
	Others	Impacts on life due to heat stress	

Approach for Assessment of Significance

- The assessment of significance of impacts is done from three criteria social, economic, and environmental. Reference was made to four elements listed in the IPCC Fifth Assessment Report as a basis to identify key risks (see below) as "Criteria used in the IPCC Fifth Assessment Report as a basis to identify key risks" ("timing of impacts" to assess urgency and "potential to reduce risks through adaptation or mitigation" were excluded), and also to the UK-CCRA approach.
- The assessments are conducted, in principle, based on science, including the contents of research papers and other materials. Also based on the assessment approach shown in Table 2, expert judgment is used to determine if an impact is "particularly high" or "not particularly high."
- Also, the term "N/A (currently cannot be assessed)" is used to indicate cases where assessment is difficult to do under current conditions.
- As for "the potential to reduce risks through adaptation or mitigation," the potential to reduce risk through *mitigation* is not considered because it is difficult to make an assessment for each impact formulated, but for the potential to reduce risk through *adaptation*, comments are provided as required, for reference.

○ Criteria used in the IPCC Fifth Assessment Report as a basis to identify key risks

- Magnitude (of impacts)
- Probability
- Irreversibility
- Timing (of impacts)
- Persistent vulnerability or exposure contributing to risks
- Limited potential to reduce risks through adaptation or mitigation

Table 2. Approach for Assessment of Significance

Criteria for Assessment	Metrics for Assessment (Approach)		Means of Indicating Final Assessment
	Particularly High	**Not Particularly High**	
	Assess significance in terms of social, economic, environmental impacts based on the following criteria: ● Magnitude of impacts (area, duration) ● Likelihood of occurrence of impacts ● Irreversibility of impacts (difficulty of restoring original conditions) ● Persistent vulnerability or exposure contributing to the impacts of concern		Indicate the degree of significance, and where it is particularly large, indicate the criteria.
1. Social	At least one of the following applies: ● Involves the loss of human life, or on the health dimension, the extent of impacts and likelihood of occurrence are particularly high (abbreviated as "extent" below). e.g.: Hazards (disasters) could result in the loss of human life Health impacts for large numbers of people ● Magnitude of impacts on local society and community is particularly high e.g.: Impacts are nationwide Impacts are not nationwide, but are serious locally ● Magnitude of impacts on cultural assets and community services is particularly high e.g.: Irreversible impacts on cultural assets Serious impacts on life of citizenry	An assessment of "particularly high" does not apply.	
2. Economic	The following applies: ● Magnitude of economic losses is particularly high e.g.: Large-scale losses occur to assets and infrastructure Loss of employment opportunities for a large number of citizens Large-scale disruptions of transportation networks over a large area	An assessment of "particularly high" does not apply.	

3. Environment	The following applies: ● Magnitude of losses to environment and ecosystem functions is particularly high e.g.: Large-scale loss of important species, habitats, and landscapes For ecosystems, significant deterioration in quality of places that are important internationally and nationally Significant decline in land/water/atmospheric/ecological functions over a broad area	An assessment of "particularly high" does not apply.	

Approach for Assessment of Urgency

- For criteria corresponding to urgency, reference was given to the IPCC Fifth Assessment Report "timing of impacts" and UK-CCRA "timing of impacts" and "urgency with which adaptation decisions need to be taken." These are different concepts, but here, it was decided to consider both approaches and adopt the one that has the highest urgency. It should be noted that because adaptation includes measures that need to be implemented in the long term and on an ongoing basis, for the "timing of impacts" and "urgency with which adaptation decisions need to be taken" it is necessary to consider the amount of time required to implement measures.
- Also, the term "N/A (currently cannot be assessed)" is used to indicate cases where assessment is difficult to do under current conditions.

Table 3. Approach for Assessment of Urgency

Criteria for Assessment	Metrics for Assessment			Means of Indicating Final Assessment
	High Urgency	**Medium Urgency**	**Low Urgency**	
1. Timing of impacts	Impacts are already evident.	High likelihood that impacts will occur by about 2030.	High likelihood that impacts will occur after about 2030. Or level of uncertainty is extremely high.	The level of urgency is to be indicated for each sub-category as one of three levels, with criteria 1 and 2 both considered.
2. Timing needed to initiate adaptation measures and make critical decisions	Decisions need to be made as soon as possible.	Major decisions need to be made before about 2030.	There is not much need to make major decisions before about 2030.	

Approach for Assessment of Confidence

- The assessment of confidence is conducted, in principle, based on the IPCC Fifth Assessment Report's "type, amount, quality, and consistency of evidence," and "degree of agreement," and the assessment is expressed with five terms (very high, high, medium, low, and very low).

  Types of evidence: Monitoring/observation to date, models, experiments, paleoclimatic analogues

  Quantity of evidence: Numbers of research and reports

  Quality of evidence: Qualitative content of research and reports (e.g., ask whether assumptions are reasonable)

  Consistency of evidence: Consistency of research and reports (e.g., consistency of scientific mechanisms)

  Agreement of opinion: Agreement of opinion among research/reports

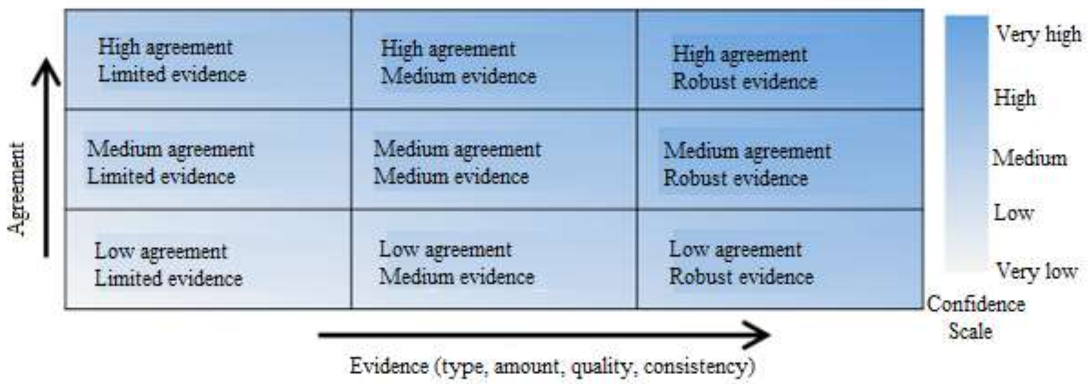

Figure 1. Evidence and agreement statements and their relationship to confidence

Confidence increases toward the top right corner. Generally, evidence is most robust when there are multiple, consistent, independent lines of high-quality evidence.

Source: Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties (IPCC 2010)

- Here, the same two metrics are utilized as in the IPCC Fifth Assessment Report ("type, amount, quality, and consistency of evidence" and "degree of agreement"). Regarding "type, amount, quality, and consistency of evidence," integrated judgment is to be used, but the amount of research and reports with projections of future impacts in Japan is believed to be less available than in IPCC discussions. Thus, as an approach and metric for judgment, evaluators could consider whether or not research and reports with quantitative analysis are available.
- Regarding the assessment levels, it may not be possible to obtain a sufficient amount of literature, so only three options are used: high, medium, and low.

- When assessing confidence, the assessment shall also take into account the degree of certainty of projections (e.g., the amount of precipitation) from climate models on which projections are based.
- Also, the term "N/A (currently cannot be assessed)" is used to indicate cases where assessment is difficult to do under current conditions.

Table 4. Approach for Assessment of Confidence

Considerations for Assessment	**Levels of Assessment (Approach)**			**Means of Indicating Final Assessment**
	High Confidence	**Medium Confidence**	**Low Confidence**	
IPCC Assessment of Confidence ○ Type, amount, quality, and consistency of research/reports ○ Degree of agreement in research/reports	Corresponds to IPCC confidence rating of "high" and above.	Corresponds to IPCC confidence rating of "medium."	Corresponds to IPCC confidence rating of "low" and below.	Using the IPCC's level of confidence, indicate the level of confidence for each sub-category using one of three levels.

Presentation of Outcomes

For each sub-category, the final assessments of significance, urgency, and confidence are to be reported in the format indicated in the following table, together with an overview of the current status and projected future impacts.

Table 5. Impacts of Climate Change in Japan (Summary Table) (Example)

Example of summary for food sector (colors are illustrative and provisional only)

Categories	**Sub-categories**	**Current status**	**Projected impacts**	**Significance**			**Urgency**	**Confidence**	**Note**
					Criteria	**Rationale**			
Agriculture	Rice				Social, economic, environmental				
	Grains (except rice)				Social, economic				
	Vegetables				Social, economic				
	Fruit trees				Social, economic				
Livestock industry	Livestock								
	Feed crops			—			—	—	
Fisheries	Migratory fish				Social, economic				
Others				+					

Note: The contents of Table 5 are for illustrative purposes only. They do not reflect actual sector/sub-category structure or assessments.

In the "Current status" column, indicate clearly any phenomena that could be considered to be a climate change impact – not only observed impacts but also other phenomena even if it cannot be stated with confidence that they are caused by climate change.

In this column indicate the projected future impacts of climate change.
Description shall include as much as possible, including occurrence conditions (e.g., expected temperature increase), timing and place of occurrence, description of impacts, magnitude of impacts, and likelihood of impacts. Also, indicate magnitude. For some sub-categories, the description of impacts includes multiple topics.
Note that overview of impacts is to include not only negative but also positive impacts.

Indicate rationale for assessment of magnitude.

Indicate criteria for assessment where "magnitude is high."

In the "Notes" column, indicate to the extent possible the rationale for the assessment of urgency, and confidence, as well as information such as the potential for adaptation to respond as required, relationship with other sectors/sub-categories.

Legend for Significance

■ Red: Particularly high ■ Green: Not particularly high —: N/A(currently cannot be assessed)

Legend for Urgency

■ Red: High ■ Yellow: Medium ■ Blue: Low —: N/A(currently cannot be assessed)

Legend for Confidence

■ Red: High ■ Yellow: Medium ■ Blue: Low —: N/A(currently cannot be assessed)

3.3 Projections of Climate Change Impacts (Overview)

Impacts that may be associated with climate change have already been observed in sectors such as agriculture and ecosystems, and it has been pointed out there may be a relationship between climate change and impacts such as more frequent occurrences of heat illness due to extreme high temperature, floods due to intense heavy rainfall, and damage from sediment-related disasters. This section provides an overview of the "current status" and "projected impacts" in each sector covered in the "Report on Assessment of Impacts of Climate Change in Japan" (hereinafter "Impact Assessment Report") as discussed and formulated by each Working Group and this Expert Committee. For more detailed information, please refer to the Impact Assessment Report.

Regarding the impacts of climate change, for this report an effort was made to cover the impacts to the greatest extent possible, but this is not a complete list of all impacts. Further and ongoing information collection as well as analysis of long-term trends will be required.

Also, when referring to this report and considering the current status as well as projected impacts, it is important to keep the following points in mind.

1. Scientific findings are the basis for the preparation of this report. More specifically, to the greatest extent possible, assessments were based on existing literature, and on expert judgment based on this literature.[30]

2. Regarding the descriptions of the current status, there is not a direct correlation with climate change in every single case, although examples are also introduced that have been indicated to be possible impacts of climate change.

3. Climate change projections (e.g., increases in temperature and changes in precipitation) vary in the range of magnitudes of projected changes and involve some uncertainty, due to differences in the greenhouse gas emission scenarios and climate models utilized. Differences in projected impacts also arise due to differences in assumptions for climate projections. Also, extreme events including short-term intense rainfall have a high degree of spatial uncertainty in terms of the location of their occurrence.

[30] There are differences between the climate prediction models, emission and concentration scenarios, and impact assessment models, therefore the "projected impacts" described in this report also come with mention of the assumptions made in the referenced literature.

4. Impacts in each sector might not all necessarily be caused only by climate change. Almost all phenomena exhibit changes due to a variety of factors other than climate change.
5. It is also important to remember that it can be difficult to research the contribution to climate change impacts of events associated with climate change that already affect human society or that could affect human society in the future.
6. On the other hand, natural disasters and other negative impacts would not all necessarily disappear in the absence of climate change.
7. The ways in which impacts are manifested can vary significantly depending on the characteristics of what is affected by natural hazards. Disaster risks depend not only on the intensity of weather events and phenomena but also the exposure[31] and vulnerability[32] of the sectors subjected to the impacts. Thus, future decisions of society can influence the ways in which impacts are manifested.

3.3.1 Agriculture, Forest/Forestry, Fisheries

Note: In agriculture, forest/forestry, and fisheries, for projecting the future impacts of climate change, it is also necessary to assess the impacts of a variety of social, economic, and environmental aspects, including globalization and changes in population and industrial structure. However, since findings for such integrated assessments are currently limited, it is important to note that information compiled and assessments in this report focus only on the direct impacts of climate change.

Agriculture

(1) Paddy Field Rice

Current Status

- Already, impacts of increases in temperature have been confirmed nationwide, including deterioration in quality (e.g., occurrence of white immature grain,[33] decreases in the ratio of first-class rice). Decreases in yields have also been observed in some regions and in years with extreme high temperature.

Projected Impacts

- Under the A1B scenario[34] or increasing of 3°C above current temperature, almost all projections are for an increase in rice yields in Japan until the mid-21st century; however, for increasing above those

[31] Exposure: The presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected. For example, if a population is concentrated in a place that could be damaged by flood, it has a higher degree of exposure.

[32] Vulnerability: The propensity or predisposition to be adversely affected. That predisposition consists of inherent characteristics of the elements that are subject to the impacts; in the area of disaster risk, that can include the characteristics of a person or population to predict adverse impacts of natural phenomena, respond to and resist the adverse impacts, and to influence the capacity to recover from adverse impacts; it can also include the setting in which those people are placed. For example, a place that has unstable ground could be considered highly vulnerable to heavy rain.

[33] White immature grain: Kernels have a whitish hue and protein fails to build up, due to damage such as high temperature.

[34] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 97.

temperature, as a reduction in yields is projected for all areas except northern Japan, there is general consistency in projections, with higher yields in Hokkaido, and no change or a decrease in yields in relatively warmer areas such as southern Kyushu.

- Rice quality is projected to decline nationally, with a smaller ratio of first grade rice being produced, due to an increase in temperature during the ripening period. More specifically, in the Kyushu region, some cases under A1B and A2 scenarios[35] indicate nearly a 30% decrease in the ratio of first grade rice by the mid-21st century and a decrease of approx. 40% by end of the 21st century.
- Free Air CO_2 Enrichment (FACE) experiments have demonstrated that an increase in CO_2 concentrations increases rice yields through the fertilization effect, but there is some uncertainty relating to interactions with increase in temperature.

(2) Vegetables

Current Status

- Past studies have reported that the impacts[36] of climate change are already evident in more than 40 prefectures, it is clear that climate change impacts are evident nationwide.
- In particular, for open-field vegetables including leafy vegetables such as cabbage, root vegetables such as daikon radish, and fruit vegetables such as watermelon, there is a trend toward earlier harvests for many types of produce, and there has also been an observed increase in the frequency of decreasing growth.
- For vegetables grown in greenhouses, problems such as poor fruit bearing occur frequently with tomatoes, and there is an increasing need for measures to deal with high temperature. On the other hand, there are also reports of reduced fuel consumption for greenhouse production, due to an increase in temperature in winters.

Projected Impacts

- For vegetables, the likelihood that cultivation will become impossible is expected to be low, as many vegetables have a short growing season, and adjustments can be made in the timing and types of vegetable crops grown.
- At present, concrete examples are limited
- However, further climate change in the future may pose challenges for planned vegetable shipments/supplies.

[35] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 97.

[36] Regarding the impacts of climate change, it is important to note that in cases where it is difficult to ascertain the continuous long-term impacts mainly due to improvements in plant varieties, the judgement is made based on short-term climate impacts.

(3) Fruit Trees

Current Status

- A nationwide study implemented in 2003 on the state the impacts[37] of warming reported that public research institutes dealing with fruit growing in all prefectures had found that the impacts of climate change were already appearing in the fruit-tree growing industry.
- Fruit trees are extremely poor at adapting to climate, and once planted, the same tree typically grows for 30 to 40 years. Many trees producing today have been growing since the 1980s when temperature was cooler, and there have not been major changes in cultivars and cultivation methods, so in many cases the trees have not been able to adapt to the increase in temperature since the 1990s.
- Damage from warming in recent years (e.g., peel puffing of citrus fruit, and poor coloring of apples) has affected almost all tree species and regions.
- As for fruit quality, there is a tendency for taste to improve in some fruits (e.g., apples), but also a tendency for fruit to be softer, which leads to a reduction in storage ability.

Projected Impacts

- For satsuma mandarin oranges and apples, projections using the IS92a scenario[38] show a year-by-year shift northward of the optimal temperature zone for growing, as follows:
  - For satsuma mandarin oranges, the climate in the 2060s is projected to be more difficult than today for growing in many of today's prime production areas, and growing will become possible in areas that are currently not suited, including inland areas in the warm southwestern region (relatively warmer areas such as southern Kyushu) and coastal areas along the Sea of Japan and southern Tohoku region.
  - For apples, by the 2060s, the climate is projected to be more difficult than today for growing in the central Tohoku plains, and many of today's prime production areas such as the northern Tohoku plains will reach temperature similar to areas that today produce warm-climate apple varieties.
- For grapes, peaches, and cherries, high temperature is expected to cause problems for cultivation in major-producer prefectures.

(4) Barley/Wheat, Soybean, Feed crops, and other crops

Current Status

- For wheat, a trend toward shorter growing seasons due to warmer winters and springs has been confirmed, with delays nationwide in the timing of seeding and the earlier emergence of ears.
- For feed crops, there are reports that in some parts of the Kanto region, an annual increasing trend was

[37] Regarding the impacts of climate change, it is important to note that in cases where it is difficult to ascertain the continuous long-term impacts mainly due to improvements in plant varieties, the judgement is made based on short-term climate impacts.

[38] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 97.

observed in dry matter yields for feed corn during the period 2001 to 2012.

Projected Impacts

- For wheat, projected impacts include an increase in risk of frost and freezing damage due to faster growth after seed planting due to high temperature, and a decrease in protein content due to elevated CO_2 concentrations.
- For soybean, an increase in yields are projected under elevated CO_2 concentrations (where temperature is at or only slightly above optimal temperature), but for temperature above the optimal range, reductions are projected for dry matter weight,[39] grain weight, and harvest indexes.[40]
- In Hokkaido, projections for the 2030s under the IS92a scenario[41] indicate the potential for an increase in yields of sugar beet, soybean and azuki beans (although there are concerns about disease and lower quality), but for wheat and potatoes, a decrease in yields and a decline in quality.
- Some studies have made projections including pasture grass production, but no projections have been made for certain trends such as increases or decreases in revenues.

(5) Livestock Farming

Current Status

- Judging from livestock production trends, no impact of climate change on livestock is clear at present.
- Reports have included a decrease in growth and meat quality of beef cattle and pigs in summer, as well as a decrease in egg-laying rates and egg weights of laying hens, a decrease in growth of meat-type chickens, and lower milk production and grade of milk components from dairy cows.
- It has been reported that extreme summer temperature during the record heat wave of 2010 resulted in greater losses compared to previous years for all types of livestock and regions, due to mortality and non-productive animals and poultry.

Projected Impacts

- Magnitude of impacts is likely to depend on livestock type and feeding method, but projections are for the impacts on the growth of fat hogs and meat-type chickens to increase, an expansion of regions with diminished animal growth, and an increase in the magnitude of growth decline.

(6) Plant pests and weeds

Current Status

- The southern green stink bug (*Nezara viridula*) was previously present in warm regions in

[39] Dry matter weight: A weight obtained after being dried and having water content reduced, that is, the weight of a substance that a plant actually produced and accumulated.
[40] Harvest index: A ratio of the dry matter weight of harvested parts against the total dry matter weight.
[41] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 97.

southwestern Japan (relatively warmer areas such as southern Kyushu), but its distribution has expanded to include a large area from western Japan to parts of the Kanto region, and this has been pointed out to be an impact of warming.

- At present no clear cases have been identified in which there has been an increase in damage from disease due to the impacts of climate change.
- There are cases in which grass weed varieties (*Poaceae*) that grew on the Amami Islands and further south are now able to survive over winter and have invaded Kyushu in recent years.

Projected Impacts

- As for pests, due to an increase in temperature, an increase is expected in the number of annual generations (number of annual cycles of growth from egg to adult) of parasitic natural enemies, some parasitoids, and pests; and as a result, changes are expected to occur in the composition of rice paddy pests and natural enemies.
- For pests other than rice paddy pests as well, studies have indicated the potential increase of damage due to the northward shift and expansion of the winter survival range and increase in annual generational cycles.
- As for crop damage due to disease, some studies project increases in the occurrence of disease in experiments with higher CO_2 conditions (with 200 ppm increase in concentrations from current levels).
- Studies have pointed out the possibility that the range where some species of weeds may become established will expand and shift northward associated with warming.

(7) Water, Land and Agricultural Infrastructure

Note: Water, Land and Agricultural Infrastructure: Agricultural land, agricultural irrigation, land improvement infrastructure (e.g., dams, water control structures, agricultural effluent canals)

Current Status

- Regarding changes in precipitation that could have an impact on water, land and agricultural infrastructure, analysis of the maximum rainfall amounts in three consecutive days from 1901 to 2000 found a trend for rainfall to fall more intensely over short periods, and that in particular this trend is getting stronger in Shikoku and southern Kyushu.
- Also for the 10-year moving coefficient of variation for annual precipitation, the moving average was found to be increasing year after year, with the trend being progressively larger toward the south.
- High temperature damage to crops has also been observed, e.g., a decline in rice quality, and in response there have been impacts on usage methods of water resources, including changes in rice cropping season and use of irrigation water, as well as the method of irrigation by surface flooding.

Projected Impacts

- Regarding impacts on water, land and agricultural infrastructure mainly due to water shortages and accelerated snow melt, there are projections for a reduction in runoff from snow melt due to an increase in temperature, with impacts on water intake for agricultural water control facilities such as irrigation canals. Specifically, for the A2 scenario,[42] there is a decreasing trend in almost all regions in runoff during April and May when demand for irrigation water is elevated; responses will likely be needed to address regional and temporal imbalances.

- Regarding impacts on water, land and agricultural infrastructure from flood due to an increase in intensity of rainfall, the risk of damage to farmland is expected to increase due to longer periods of low-elevation rice paddies being submerged.

Forestry

(1) Timber Production (e.g., Plantations)

Current Status

- In some areas, there have been reports on decline of Japanese cedar (sugi) forests, and some studies have attributed the cause to an increase in water stress resulting from a drier atmosphere. However, there is no clear evidence that the drier atmosphere or increase in water stress of Japanese cedar due to drier atmosphere is caused by climate change-induced warming or a reduction in precipitation. It is also unclear how the decline of Japanese cedar forests and soil drying tendency are related
- At present, examples are limited regarding whether wind damage is increasing in planted forests due to an increase in typhoon strength, so the relationship is not clear.

Projected Impacts

- Examples have pointed out thatif temperature increases by 3°C above current levels, transpiration rate will increase and the possibility that the vulnerability of Japanese cedar plantations could increase, especially in areas with low rainfall.
- Examples have projected thatcarbon stocks and carbon sequestration in Japanese cedar plantations will decrease, assuming that current forestry practices continue.
- As well, regarding Japanese cypress (hinoki) seedlings examples haveshown no clear increase in biomass growth rate due to temperature increase; other reseahches have found that the area at risk of pine wilt disease will expand; and others have found that damage and mortality of spruce species will increase due to an increase in the number of annual generations of spruce bark beetles.
- Wind damage to Japanese cedar and cypress plantations might increase as these forests become overmature.

(2) Non-Wood Forest Products (e.g., Mushrooms)

Current Status

[42] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 97.

- Regarding the *Hypocreales* genus of fungus, which affects shiitake mushroom cultivation, it has been reported that higher summer temperature may increase damage from the *Hypocreales* fungus.

Projected Impacts

- Regarding shiitake cultivation on bed logs, reports have indicated a correlation between increasing temperature in summer and the occurrence of pathogenic fungi, and a reduction in fruiting (mushroom) of shiitake.
- The impact of an increase in temperature in winter on shiitake cultivation on bed logs is not clear at present.

Fisheries

(1) Migratory Fishery Stocks (e.g., Ecology of Fishes)

Current Status

- Around the world there have been reports of shifts in the distribution of marine organisms associated with changes in seawater temperature.
- There have also been reports of shifts in the distribution and migration areas of migratory fishery products in the seas around Japan, such as Japanese amberjack (*Seriola quinqueradiata,* or *buri* in Japanese), Japanese Spanish mackerel (*Scomberomorus niphonius*, or *sawara* in Japanese), and Japanese common squid (also known as Pacific flying squid; *Todarodes pacificus*; or *surumeika* in Japanese), reportedly caused by higher water temperature, and fish catches have declined in some areas.

Projected Impacts

- For migratory fishery products, there have been many reports on projected impacts relating to changes in distribution/migratory range and body size. The followings are some specific examples.
  - For chum salmon, under the IS92a scenario,[43] studies have indicated the potential reduction of habitat in waters near Japan, and by 2050 the potential disappearance of suitable water temperature in the Sea of Okhotsk.
  - For Japanese amberjack, the distribution is predicted to shift northward, along with changes in wintering areas.
  - For Japanese common squid, under the A1B scenario,[43] marine areas with low distribution density are projected to expand to coastal areas of northern Honshu by 2050, and to Hokkaido coastal areas by 2100.
  - For Pacific saury (*samma* in Japanese), studies have projected slower growth due to a deterioration of feeding conditions, but there are also predictions that feeding conditions could improve during

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[43] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 97.

spawning season due to changes in the migration range, resulting in increased spawning.

  - For Japanese sardine (also known as pilchard; *maiwashi* in Japanese), studies have projected a northward shift of the distribution of adult fish and sea areas suitable for the survival of larval and juvenile fish, in response to increasing sea surface temperature.

- Regarding changes in fish catches and impacts on local industries, high-precision projections have not been obtained, due to the high level of uncertainty arising from correlation with factors not connected with climate change, such as resource management policies.

(2) Propagation and Aquaculture

Current Status

- There have been reports of increases in the number of southern fish species and decreases in the number of northern fish species present in many areas.
- For nori seaweed cultivation, the start of seeding has been delayed due to increasing seawater temperature in autumn, and annual harvests are declining in many areas.
- Decreases in catches of Japanese spiny lobster (*Panulirus japonicus*; *isseiebi* in Japanese) and abalone (*awabi* in Japanese) have been reported, due to a deterioration of seagrass beds from algae-eating fish.

Projected Impacts

- Impact assessments have not been conducted using ecosystem models and climate projection scenarios, but the distribution areas of many commercially-fished species are projected to shift northwards.
- Changes in seaweed species composition and abundance due to increasing seawater temperature are expected to reduce the catches of sea-bottom resources such as abalone.
- Some areas that produce farmed fish are expected to become unsuitable for fish farming due to increasing water temperature in summer.
- An increase in mortality risk to organisms including bivalves is expected due to the occurrence of red tide in connection with increasing seawater temperature.
- In inland waters, a decrease in fish catches of Japanese smelt (*wakasagi* in Japanese) is expected due to high water temperature in lakes.
- IPCC reports have expressed concern about the impacts of ocean acidification on shellfish aquaculture.

3.3.2 Water Environment, Water Resources

Water Environment

(1) Lakes/ Marshes, Dams (Reservoir)

Factors in Climate Change Impacts

- A climate change-induced increase in temperature increases the water temperature of lakes /marshes and dams (reservoirs).

- An increase in water temperature of lakes /marshes and dams (reservoirs) may cause a deterioration of water quality as a result of an increase in the probability of occurrence of phytoplankton. A reduction in water circulation due to increasing water temperature in winter may lead to a reduction of dissolved oxygen (DO) levels in deep water layers.
- A climate change-induced increase in the frequency of heavy rainfall events is expected to increase suspended solid (SS) concentrations due to an increase in sediment runoff into dams and reservoirs.

Current Status

- Studies of water temperature changes over approximately thirty years (FY 1981 to FY 2007) at 4,477 monitoring stations in public waters (rivers, lakes, and seas) nationwide in Japan found a warming trend at 72% of the stations in summer and 82% in winter, confirming that warming is occurring in many water bodies. Changes in water quality due to increasing water temperature have also been pointed out.
- However, research reports indicate that at present it cannot be stated with certainty that the changes of water temperature are an impact of climate change.
- Meanwhile, some reports also indicate a greater probability of occurrence of blue-green algae if the annual mean temperature exceeds 10°C, and long-term analysis is required in the future.

Future Projections

- In projections using the A1B scenario,[44] Lake Biwa is projected to see a decrease in dissolved oxygen (DO) and deterioration of water quality in the 2030s due to increasing water temperature.
- Studies using the same A1B scenario have confirmed projections of an increase to 21 of the 37 multi-purpose dam reservoirs in Japan being classified as eutrophic water bodies in 2080-2099, with the largest increase in number being in eastern Japan.
- No examples have yet been confirmed regarding specific projections of impacts on lakes/marshes and dam reservoirs accompanied by changes in river flows or increases in frequency and magnitude of extreme weather events due to climate-change-induced changes in the amount of precipitation or the spatial and temporal distribution of precipitation.

(2) Rivers

Factors in Climate Change Impacts

- A climate change-induced increase in temperature may increase water temperature of rivers.
- An increase in river water temperature is expected to affect water quality, through such factors as a decrease in levels of dissolved oxygen, enhanced organic matter decomposition by microorganisms involved in dissolved oxygen consumption, enhanced nitrification, and an increase in algae growth.

[44] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 97.

- A climate change-induced increase in precipitation may increase sediment runoff and lead to an increase in turbidity in river water.
- Impacts on river water quality are also expected due to changes in the spatial and temporal and distribution of precipitation.
- Increases in the amount of precipitation are also expected to increase sediment production and the amount of suspended sediments.

Current Status

- Studies of water temperature changes over approximately thirty years (FY 1981 to FY 2007) at 4,477 monitoring stations in public waters (rivers, lakes/marshes, and seas) nationwide in Japan found a warming trend at 72% of the stations in summer and 82% in winter, confirming that warming is occurring in many water bodies. Changes in water quality due to increasing water temperature have also been pointed out.
- However, increasing river water temperature can also be affected by factors such as urban activities (artificial exhaust heat and wastewater) or reductions in river flow, so it is necessary to quantitatively analyze the magnitude of impact of climate change.

Projected Impacts

- Future projections have not been done for water temperature in each river, although one projection for future temperature changes in the Omono River (Akita Prefecture) using the A1B scenario[45] showed an increase in water temperature to 12.4°C in 2030-2039 compared to 11.9°C in 1994-2003, with impacts being the highest in winter.
- Studies using the same A1B scenario have projected an 8 to 24% increase in suspended sediments for all of Japan by 2090; the largest increase in the amount of suspended sediments being in September due to an increase in extreme weather events such as typhoons; and a 1 to 20% increase in river flow and a 1 to 30% increase in sediment production if August precipitation increases by 5 to 75%.
- Other projections include lower levels of dissolved oxygen due to increases in water temperature, organic matter decomposition and enhanced nitrification by microorganisms associated with dissolved oxygen consumption, and an increase in abnormal odors and taste due to an increase in algae.

(3) Coastal Areas and Closed Sea Areas

Factors in Climate Change Impacts

- An increase in temperature due to climate change is expected to increase water temperature of coastal areas and closed sea areas.
- Increases in water temperature of coastal areas and closed sea areas are also expected to affect water

[45] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 97.

quality.

- Impacts on water quality are also expected as a result of factors such as increased influx of contaminants due to the changes in the spatial and temporal distribution of precipitation.

Current Status

- From analysis of sea surface temperature data (1970s to 2010s), a significant increasing trend has been reported at 132 of 207 sites nationwide (ave. 0.039°C/year, min. 0.001°C/year, max. 0.104°C/year). It is important to note that there may be anthropogenic impacts at some of the measurement sites where this increasing trend was observed.
- There are also other research reports stating that no significant warming or cooling trend was observed in seawater temperature in coastal areas around the island of Okinawa.

Projected Impacts

- Although examples making quantitative projections have not yet been confirmed at present, it is expected that there will be an expansion of areas affected by salt water intrusion in coastal areas due to sea-level rise.

Water Resources

(1) Water Supply (Surface Water)

Factors in Climate Change Impacts

- With climate change-induced changes in precipitation and snow cover, river flow volumes will change. In particular, decreases in precipitation, increases in the number of rainless days, and decreases in snow cover are factors that cause drought.
- Changes in the timing of snow melt are a factor that could result in water supply shortages during periods when the water demand is high mainly for agriculture.
- A reduction in water being stored in dam reservoirs due to increased severity of drought resulting from changes in precipitation trends over time is a factor that could reduce the potential volume of irrigation water supply derived from dams.
- In addition, sea-level rise expands the area affected by seawater (saltwater) intrusion in river estuaries, and be a factor causing salinization of freshwater.

Current Status

- Year-to-year fluctuations in annual precipitation have increased, and there have been confirmed examples of water restrictions being implemented for reasons such as extended periods with little or no rainfall.
- Although snow melt tended to come earlier in alpine areas from 1980 to 2009, the annual variation from watershed to watershed is large.
- No examples have been confirmed at present regarding the impacts of drought on water to maintain

the normal functions of river flow, and expansion of the extent of seawater (salt water) intrusion at river estuaries due to sea-level rise.

Projected Impacts

- A study using the A1B scenario[46] projects increased severity of drought starting in the near future (2015-2039) excluding in northern Japan and central mountain areas. In addition, a reduction of river flow during periods of water demand is projected to result from an earlier snow-melt season, and as a result, mismatches between water supply and water demand.
- Besides this, although no examples making quantitative projections have been confirmed at present, there are concerns that include the impacts of drought on water to maintain the normal functions of river flow, and disruptions to water intake due to seawater (salt water) intrusion at the river estuaries due to sea-level rise.

(2) Water Supply (Groundwater)

Factors in Climate Change Impacts

- Groundwater levels will change due to climate change-induced changes in the amounts and time trends of precipitation, affecting water utilization.
- Generally speaking, changes in the amount of groundwater usage are also related to factors other than climate change.
- Excessive intakes of groundwater due to more frequent droughts, as a result of an increase in the number of rainless days, promote ground subsidence.
- Sea-level rise is also a factor causing groundwater salinization.

Current Status

- At present, no concrete examples have been confirmed regarding the current state of changes in groundwater levels associated with climate change-induced changes in precipitation amounts and precipitation trends over time.
- Generally speaking, changes in the amount of groundwater usage can also be related to factors other than climate change.
- Ground subsidence is occurring in some areas due to excessive groundwater intake during years or periods with little rain (e.g., 1994, a year of drought nationwide).
- At present, no concrete examples have been confirmed regarding the current status of salinization of groundwater due to sea-level rise.

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[46] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 97.

Projected Impacts

- Regarding changes in groundwater levels associated with changes in precipitation amounts and precipitation trends over time due to climate change, some examples have examined specific areas, but there are challenges with refinement of assessment approach.
- At present, no concrete examples have been confirmed regarding an increase in groundwater use and the occurrence of ground subsidence associated with drought.
- Although examples making quantitative projections have not yet been confirmed at present, there are concerns that include the salinization of groundwater and disruptions of water intake due to sea-level rise. The impacts on water sources of groundwater salinization are expected to be not particularly high, because rivers are a major source of water for irrigation and for Japan's large cities situated on alluvial plains. However, there are concerns that municipalities that rely on groundwater will be significantly affected by salinization.

(3) Water Demand

Factors in Climate Change Impacts

- A climate change-induced increase in temperature may increase demand on municipal water supplies, such as demand for drinking water and cooling water.
- An increase in temperature may cause changes in the timing of crop planting and increase the amount of evapotranspiration, which may increase the demand for agricultural water.

Current Status

- As for the relationship between increasing temperature and water usage, it has been shown that water usage in Tokyo does increase in response to increasing temperature.
- In the agricultural sector, there have been impacts on water demand as a response to high heat damage, including changes in the timing of rice planting and use of irrigation water, as well as use of irrigation by surface flooding.

Projected Impacts

- Although no examples have been confirmed regarding the impacts of climate change with quantitative projections, there are concerns about an increased demand for drinking water due to an increase in temperature.
- A reduction in potential water resources is projected in the 2030s in Kyushu due to an increase in evapotranspiration from paddy fields, and in other areas as well, it is expected that there will be an increase in demand for agricultural water due to increase in temperature.

3.3.3 Natural Ecosystems

Natural ecosystems provide the foundations for human livelihoods and a variety of industries, so it is important to conserve them, including the benefits humans gain from ecosystems (i.e., ecosystem services).[47]

The impacts of climate change in this sector are broadly divided into two dimensions: impacts on natural ecosystems themselves, and impacts on ecosystem services. Thus, the assessments in this sector for significance, urgency, and confidence are divided into "impacts on ecosystems" and "impacts on ecosystem services (impacts on people's livelihoods)."

Regarding climate change impacts on ecosystem services, few existing examples have been published yet in general, so it is currently difficult to assess these impacts. However, this does not mean that the significance of impacts on ecosystem services is low. In the future it will be important to encourage research in this area.

As for the sector of natural ecosystems, although the impacts are subject to be found earlier, there are ultimately limitations on what can be done in terms of adaptation measures, and in some cases the only measures may be to try to limit climate change (i.e., through mitigation). In such cases, it is difficult to assess urgency from the perspective of "timing to need undertaking adaptation and important decision-making" so assessment is only done from the perspective of "timing of impacts."

Terrestrial Ecosystems

(1) Alpine/Subalpine Zone

Factors in Climate Change Impacts

- Climate change-induced increases in temperature, changes in the amount of precipitation, and changes in the snow pack environment, affect alpine plants. Specifically, it is thought that alpine plants will shift toward higher elevations and higher latitudes due to increases in temperature, but such shifts may be constrained by various factors, including topographic factors and land use. Also, such shifts are not possible mainly at mountain tops and in coastal areas. A shortening of the snow cover duration is expected to result in drier soil, leading to vegetation changes and the deterioration or disappearance of snow fields and high moors. An increase in temperature and earlier snow melt cause changes in phenology, such as earlier and shorter flowering periods for alpine plant communities.

Current Status

- Deterioration and shifts in distribution of vegetation in alpine and sub-alpine zones have been reported, due to factors such as an increase in temperature and earlier snow melt.
- Gaps (changes in phenological interrelationships) have also been reported between alpine plants and activity periods of pollinator insects due to earlier flowering of alpine plants and shorter flowering time.

Projected Impacts

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[47] Ecosystem services: Benefits (e.g., food, water, climate stability) that humans obtain from ecosystems and the involvement of a large diversity of organisms. The Millennium Ecosystem Assessment (2005) conducted under the auspices of the United Nations provides four categories: "provisioning services" (e.g., the provision of food and water, timber, fiber, and medicinal resources), "regulating services" (e.g., water purification, climate regulation, natural disaster prevention and damage mitigation, disease/pest suppression by the existence of natural predators), "cultural services" (e.g., the provision of spiritual and religious values, aesthetic values including natural landscapes, and recreational places), and "supporting services" (e.g., nutrient cycling, soil formation, the supply of oxygen through photosynthesis).

- For plant species in alpine and sub-alpine zones, suitable habitats are projected to change or shrink. For example, the area of suitable habitat for the Japanese stone pine (*haimatsu*) is projected to be reduced by the end of the 21st century compared to the present.
- In some regions, the disappearance of populations of alpine plants is projected to occur due to earlier snow melt.
- Other projections include more competition between plant species, with enhanced growth of alpine plants due to a warmer growing season, as well as other changes to vegetation such as the expansion of distribution for shrub species.

(2) Natural Forests / Secondary Forests

Factors in Climate Change Impacts

- Climate change-induced impacts such as increases in temperature, changes in the amount of precipitation, and changes in the snow pack environment, affect plants in natural and secondary forests. Specifically, it is thought that plants will shift toward higher elevations and higher latitudes due to increases in temperature, but such shifts may be constrained by various factors, including topographic factors and land use. Also, such shifts are not possible at mountain tops and in coastal areas.

Current Status

- Regarding the current status of climate change-induced displacement and expansion of suitable habitat for natural forests and secondary forests, at present, confirmed examples are limited.
- It is considered to be likely that in some places, evergreen broad-leaved forest has replaced what was previously deciduous broad-leaved forest, due to increase in temperature.

Projected Impacts

- The suitable habitats of many of the component species of cool temperate forests are projected to shift to higher latitudes and higher altitudes, resulting in the reduction of suitable habitat. In particular, it has been shown that the area of suitable habitat for beech forests (*buna*) will be reduced by the end of the 21st century compared to the present.
- The suitable habitats of many of the component species of warm temperate forests are projected to shift to higher latitudes and higher altitudes, resulting in the expansion of suitable habitat.
- However, there are many factors of uncertainty. For example, there are also projections for the shrinking of actual distribution, due to terrain factors, land use, and constraints on the expansion of distribution.

(3) Countryside-Landscape ("Satochi-Satoyama")

Factors in Climate Change Impacts

- A climate change-induced increase in temperature and changes in special and temporal distribution of precipitation may alter the species composition of countryside landscape ecosystems.

- However, because they are also susceptible to impacts of human activities and factors other than climate change, many uncertainties are involved.

Note: Impacts on people such as the appreciation of season, culture and history (e.g., enjoyment of autumn foliage) are addressed in the section on “Life of citizenry, urban life”

Current Status

- At present, there have been no comprehensive examples of the current status of climate change-induced changes in the component species of Japanese countryside landscape systems.
- It has been pointed out that Japanese oak wilt and the expanded distribution of bamboo in some regions may also be climate change-induced impacts, but this has not been scientifically proven.

Projected Impacts

- Some studies project small impacts of climate change in natural grassland vegetation zones[48] in the warm temperate zone or further south. Suitable habitat of secondary forests of “satoyama” landscapes including looseflower hornbeam (*Carpinus laxiflora*; *akashide* in Japanese) and Asian hornbeam (*Carpinus tschonoskii*; *inushide in Japanese*) may shrink in low mountain elevations and in southwest Japan.
- However, there is currently not sufficient evidence regarding climate change impacts on satochi-satoyama ecosystems, so more research is needed in the future.

(4) Planted Forests

Factors in Climate Change Impacts

- A climate change-induced increase in temperature and changes in spatial and temporal distribution of precipitation may cause an increase in water stress, and may affect the growth of Japanese cedar and other planted forest species.
- Increasing temperature may increase the rate of tree respiration and have a negative effect on carbon stocks and carbon sequestration.
- An increase in atmospheric CO_2 concentrations is thought to affect biological processes of trees, such as the rate of photosynthesis and stomatal response.
- An increase in temperature may cause an expansion in the distribution of insect pests.
- An increase in temperature may expand the areas at risk of pine wilt disease.

Current Status

- There have been reports of degeneration of cedar tree forests in some areas due to increases in water stress caused by increasing temperature, as well as changes in the spatial and temporal distribution of

[48] Vegetation zones: Distribution of vegetation in zones as determined by factors such as climatic zone and elevation.

precipitation.

Projected Impacts

- Particularly in areas with low precipitation, greater vulnerability of cedar tree plantations has been projected due to an increase in annual transpiration[49] if temperature increases by 3°C above the current level, but only a small ratio of land area would become unsuitable for growing.
- A projection of impacts by 2050 using MIROC3.2-hi (A1B scenario)[50] for all of Japan found a negative effect on the carbon stock and amount of sequestration, based on the high proportion of plantations (which are high in forest respiration) in Shikoku and Kyushu, and on the large proportion of 40- and 50-year-old stands, which represent a large forest stock and amount of respiration. However, that projection did not take into account the impacts of increasing CO_2 concentrations in the atmosphere. Further research is needed regarding the physiological responses of trees to project impacts on cedar tree plantation ecosystems.
- An expansion of the area at risk of pine wilt disease has been projected if the temperature increases by 1 to 2°C above the current level. There are concerns that along with pine wilt, there could also be damage to areas engaged in Japanese red pine (*akamatsu*) forestry and that produce pine mushrooms (*matsutake*).

(5) Damage from Wildlife

Factors in Climate Change Impacts

- An increase in temperature and a reduction in snow cover due to climate change may expand the suitable habitat for wildlife.
- Associated with expanded distribution of wildlife, there may be an increase in ecosystem impacts, such as soil runoff, a decline in watershed conservation capacity, and landscape degradation, caused by the loss of understory vegetation and tree death due to foraging, bark stripping damage, and ground trampling.

Current Status

- Longitudinal comparative research of sika deer (*Cervus nippon*) and wild boar nationwide in Japan has confirmed an expansion of their distribution.
- It has been confirmed that their wintering range have expanded to higher elevations due to a decrease in snow depth.
- An increase in sika deer populations has been attributed to complex factors, including a reduction in pressure from hunting, changes in land use, and a reduction in snow depth.

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[49] Transpiration: The amount of water vapor released into the atmosphere from the above-ground portion of a plant.

[50] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 97.

- Feeding damage and bark-stripping damage due to expanded distribution of sika deer have been reported.
- Impacts on ecosystem services due to expanded distribution of wildlife have been reported, but no direct causal relationship with climate change and the degree of contribution of climate change have yet been clarified.

Projected Impacts

- An increase in temperature and shorter snow cover duration have been projected to expand the habitat of sika deer and other wildlife, but only a small number of examples has been confirmed, so further research is needed in the future.

(6) Material Balance

Note: Material balance here refers to the circulation (inflows, outflows) of materials (e.g., carbon, nitrogen) in ecosystems.

Factors in Climate Change Impacts

- By increases in annual mean temperature and lengthening rainless periods, climate change may cause an increase in ground temperature; the reduction of moisture content in forest soils and drying of surface soil; the alteration of material balance between soil and atmosphere; the runoff of fine soil particles due to precipitation; a lengthening of the time required for river and other water bodies to return to regular turbidity levels; rainwater to run off in a shorter period of time; and an alteration of the amount of carbon in soils.

Current Status

- Regarding the current status of impacts on material balance associated with climate change, at present, examples are limited.
- Regarding soil GHG flux[51] in the forests of Japan, there has been a confirmed increase in CO_2 and N_2O released between 1980 and 2009, as well as an increase in CH_4 absorption.
- Changing trends in the spatial and temporal distribution of precipitation may have impacts on the water balance and sediment dynamics of forests, but the lack of long-term data makes it difficult to ascertain the status of changes.

Projected Impacts

- Increases in annual mean temperature and lengthening rainless periods may result in the reduction of moisture content in forest soils, leading to drying of surface soil, then more runoff of fine sediment and prolonged time to reduce turbidity, and ultimately, to shorter rainfall-runoff response times.[52] However, these are inferences based on circumstantial evidence, so further consideration is needed.

[51] Soil GHG flux: Releases and absorption of greenhouse gases originating from soil.
[52] Shorter rainfall-runoff response times: The amount of time elapsed from the start of rainfall to the time it is discharged into a river or stream.

- For forest soil carbon stocks, A1B scenario[53] projected a 14% increase in net primary production[54] and a 5% decrease in soil organic carbon.

Freshwater Ecosystems

(1) Lakes / Marshes

Factors in Climate Change Impacts

- In deep lakes and marshes where eutrophication is occurring, a climate change-induced increase in water temperature may weaken the vertical water circulation, reduce dissolved oxygen at the bottom, and promote oxygenation deficiency. Deoxygenation of lakes and marshes has impacts on shellfish and other benthic organisms, and is also expected to promote the release of nutrients from bottom sediment and accelerate eutrophication.
- An increase in temperature and CO_2 concentrations of lake and marsh water enhances stratification and reduces the upwelling of nutrient-rich deep water. In ecosystems with a deficient nutrient supply, this may reduce nutrient content and biomass of algae, and inhibit the growth of algae-consuming zooplankton.

Current Status

- Lake and marshes ecosystems are affected by the nutrient loads from land uses in their watersheds, making it difficult to isolate the impacts of climate change, and no studies in Japan have yet revealed any direct impacts of climate change.
- However, in Lake Ikeda (Kagoshima Prefecture), it has been confirmed that the circulation period has completely disappeared due to the warm winters, dissolved oxygen at the lake bottom has decreased, and an oxygen deficiency trend is evident.

Projected Impacts

- Although no examples making quantitative projections of impacts in Japan have been confirmed at present, for deep lakes where eutrophication is occurring, there are concerns about interruption of vertical circulation in lakes and oxygen deficiency due to increases in water temperature, as well as the resulting impacts on benthic organisms, including shellfish, and further eutrophication.
- Laboratory experiments have shown that increases in lake water temperature and CO_2 concentrations reduce the growth of zooplankton.

(2) Rivers

Factors in Climate Change Impacts

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[53] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page97.

[54] Net primary production: Value calculated from total primary production (carbon sequestration by plant photosynthesis) in one year minus carbon emissions from respiration.

- A climate change-induced increase in river water temperature alters the growth and suitable habitat of organisms. In particular, the habitat range of cold-water fish may be reduced or fragmented.
- Depending on changes in snow cover and timing and scale of snowmelt runoff, there may be impacts on river biotas that move upstream, move downstream, and spawn, in ways that are timed with snowmelt.
- The amount of fine sediment increases with greater frequency of large flood due to changes in the spatial and temporal distribution of rainfall, as well as with increases in human activities. The deposition and settling of fine sediment may affect the riverbed environment and may also affect organisms including fish, benthic organisms, and attached algae. Also, if spaces between sand particles are blocked by fine sediment, the penetration by flowing water is expected to be suppressed, resulting in a deficient supply of oxygen to spawning beds and asphyxiation of eggs.
- Climate change-induced water shortages may result in an increase in water temperature, reduce dissolved oxygen, and affect river biota.

Current Status

- Because water intake and flow control is conducted on Japan’s rivers, it is difficult to detect impacts of climate change on river ecosystems, and no research results on direct impacts of climate change have been confirmed at present.

Projected Impacts

- If the maximum water temperature increases by 3°C above current levels, the total area in Japan that can support cold-water fish is projected to decrease to about 20% of the current area, and the habitat especially on the island of Honshu would become extremely limited.
- Also, no examples with quantitative projections have been confirmed at present, the followings are some of the impacts that could be expected.
  - Impacts on river biota that move upstream, move downstream, and spawn, timed with snow-melt runoff, which depends on changes in the timing and magnitude of snow cover and snow-melt runoff.
  - Impacts on river bed environment by constituents of turbidity due to increases in frequency of large flood caused by changes the spatial and temporal distribution of precipitation, and related to that, impacts on fish, benthic organisms, attached algae, and other creatures.
  - Impacts on river organisms due to increases in water temperature caused by drought, and by a reduction in dissolved oxygen.

(3) Marshlands

Factors in Climate Change Impacts

- A climate change-induced increase in temperature and decrease in amount of precipitation, reduction in humidity due to a reduction in the number of foggy days, and increase in evapotranspiration, may result in a drying-out of marshlands and impacts on marshland ecosystems.

Current Status

- Marshland ecosystems are strongly affected by anthropogenic impacts other than climate change, and no examples have directly addressed the impacts of climate change at present.
- In some marshlands, it has been pointed out that a drying-out of marshlands may have resulted from a reduction in rainfall, a decrease in humidity, and a reduction in snow depth due to climate change.

Projected Impacts

- Although no examples with quantitative projections have been confirmed at present, the followings are some of the possible impacts that could be expected.
  - Impacts on marshlands in Hokkaido, which account for about 80% of the area of all marshlands in Japan.
  - Impacts of a reduction in precipitation and lower groundwater levels on plant communities (sphagnum) in high marshlands that are nourished by rainwater.
  - Transition from marshlands herbaceous communities to woody plant communities in low marshlands due to watershed loads (sediments and nutrients) caused by climate change; and increases in evapotranspiration.

Coastal Ecosystems

(1) Subtropics

Factors in Climate Change Impacts

- With typical subtropical corals in subtropical coastal ecosystems, coral bleaching has been observed where symbiotic algae die off due to stresses such as an increase in water temperature; if those conditions persist, the coral dies, unable to obtain the nutrients from the symbiotic algae.
- If seawater temperature increases due to climate change, coral distribution may shift northward, and marine areas where coral currently exists may die off due to bleaching.
- If changes occur in the growth and distribution of coral, they also affect many organisms and ecosystems that depend on coral reefs for habitat.
- Mangrove forests consist of tree populations that grow in estuaries and tidal flats influenced by the ebb and flow of seawater. Mangroves are salt-tolerant, but cannot grow in water. Thus, if sea level rises at a pace that exceeds the pace of sediment buildup, it is thought that mangroves will be unable to survive in some areas. There may also be impacts on organisms when coastal erosion occurs due to sea-level rise.

Current Status

- In the Okinawa region, there has been an increase in the frequency of bleaching of subtropical coral due to increasing seawater temperature.
- The distribution of temperate coral in the Pacific Ocean has been moving northward in areas south of the Boso Peninsula and along the west and north coasts of Kyushu.

- Laboratory experiments have pointed out the possibility that the amount of calcification is decreasing in some reef-building coral species.

Projected Impacts

- A study using the A2 scenario[55] projects a reduction to half of the current sea area suitable for the growth of reef-building coral in the tropics and subtropics by 2030, and disappearance by 2040, due to increasing seawater temperature and ocean acidification. In waters away from areas most suitable for growth, an increase in bleaching and other stresses is projected, as well as a reduction in calcification, but no projections have been done regarding whether or not these will result in the complete disappearance of existing coral reefs situated away from the optimal waters.
- Ecosystems in mangroves are also unique in subtropical coastal areas. There are reports that they will not grow in some locations if they cannot cope with a rapid pace of sea-level rise, but the reports only assess their capacity for carbon sequestration, and any projections about future changes in ecosystems are limited to qualitative discussions.
- It is expected that the impacts on various resources in coral reef areas (including tourism resources and marine resources) in subtropical areas will be significant. Meanwhile, where subtropical coral extends northward into the temperate zone, there may be positive impacts on these resources with the northward migration of coral.

(2) Temperate / Subarctic

Note: Please refer to the section on fisheries for more details about the impacts on coastal fisheries.

Factors in Climate Change Impacts

- Because the habitat of organisms depends on the distribution of seawater temperature, a climate change-induced increase in seawater temperature may also change the distribution of species that have lived there until now.
- Ocean acidification is a phenomenon in which acidity of the seawater increases when atmospheric CO_2 dissolves in the ocean, altering the chemical equilibrium of the carbonate system in seawater, increasing the hydrogen ion concentration (pH level decreases). The atmospheric CO_2 concentration is increasing due to an increase in the amount of CO_2 released by human activities, resulting in a higher amount of CO_2 dissolving in the oceans. Changes in chemical equilibrium of the seawater carbonate system reduce the carbonate ion concentration, and this is expected to affect calcification processes (the formation of calcium carbonate) that produce exoskeletons and shells of coral, shellfish, sea urchins, and other creatures.
- If coastal erosion occurs due to sea-level rise, there may be impacts on organisms living there.

[55] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 97.

Current Status

- In various places along the coast of Japan, a transition has been confirmed to be underway from cool-temperature to warm-temperature species accompanied by increasing seawater temperature.
- It is reportedly difficult to determine at present whether or not the changes already occurring in marine ecosystems are a result of ocean acidification.

Projected Impacts

- With increasing seawater temperature, it is expected that there will be a shift toward warm-water species, for example, in the case of sea urchins, from *Strongylocentrotus intermedius* (*ezobafununi* in Japanese) to *Strongylocentrotus nudus* (*kitamurasakiuni*), and this may lead to impacts on entire ecosystems, but quantitative examples are limited.
- As for the impacts of ocean acidification, for medium to high CO_2 emission scenarios, it is thought that there will be considerable risk to highly vulnerable marine ecosystems in particular, such as ecosystems in polar regions and coral reefs. Coral reefs have many species that are sensitive to impacts, such as mollusks and echinoderms that have calcium carbonate skeletons and shells, and as a result, there may be negative impacts on species that are fisheries resources. Also, the situation is complex due to interactions between factors occurring simultaneously, such as increasing water temperature and a reduction in oxygenation, so the impacts may be amplified.
- There are also concerns that changes in coastal ecosystems could impact species that are resources for coastal fisheries. It is expected that there could also be impacts on local culture, as in many cases fishing communities depend on coastal scenery and fisheries harvest species such as seagrass beds.
- Sea-level rise is expected to have impacts on salt marshes in coastal areas.

Marine Ecosystems

(1) Marine Ecosystems

Note: This section does not deal with organisms such as fish or cetacean species. Some of them are covered in "Migratory fishery products (e.g., ecology of fishes)" under "Fisheries."

Factors in Climate Change Impacts

- A climate change-induced increase in seawater temperature may affect ocean currents and the rate of vertical mixing of seawater, leading to changes in material circulation via the distribution and behavior of organisms and biological groups in the entire ocean.
- Increasing sea surface temperature may result in earlier spring algal blooms[56] due to earlier development of temperature stratification and salinity stratification by the melting of sea ice.
- It has also been pointed out that net primary production declines due to a decrease in nutrient supply

[56] Spring algal bloom: A phenomenon that occurs in the region where the Oyashio and Kuroshio ocean currents mix. It is due to the proliferation of phytoplankton at a time when the seawater mixing layer is stable during the spring season, and is due to the supply of nutrients from deeper ocean layers as a result of significant vertical mixing during the winter season.

as a result of stratification. Meanwhile, regarding the amount of biomass of meso-zooplankton, even with a reduction in net primary production, it has been pointed out that a large change will not occur in the Oyashio region, as the worsening of the feeding conditions during the adult stage due to a reduction in net primary production will be roughly offset by better feeding conditions during the juvenile stage due to the earlier spring bloom.

- Potential impacts are also expected to affect fisheries resources, because organisms such as phytoplankton and zooplankton are consumed by fish in marine areas.

Current Status

- In the sea around Japan, particularly in the Oyashio Region and mixed water region, phytoplankton biomass and primary productivity may have begun to decline. However, opinion has not converged on a unified view.

Projected Impacts

- Along with climate change, changes may also occur with phytoplankton biomass. Globally, it is projected to decrease in tropical and subtropical waters and projected to increase in subarctic waters, but models for the sea around Japan have low reliability, making it difficult at present to project future changes. As well, for projections about changes in the biomass of zooplankton, the reliability of projections for the sea around Japan is not high. Moreover, it is difficult at present to project the impacts of changes in each region, caused by above changes.

Phenology

(1) Phenology

Note: The term phenology refers to the responses of fauna and flora to seasonal changes such as temperature and sunlight. Note that this category mainly discusses ecosystem impacts and ecosystem services (excluding phenology perceived by people in their lives, so-called "sense of season"), while "Life with sense of culture and history" in the section on "Life of citizenry, Urban Life" deals mainly with phenology related to human life and culture.

Factors in Climate Change Impacts

- The breaking from dormancy of plants will be earlier due to factors such as an increase in winter temperature, so flowering is expected to occur earlier. If temperature increases further, it is also possible that winter dormancy will be insufficient, and breaking from dormancy will be delayed, or plants will be unable to flower due to being unable to break from dormancy.
- An increase in winter temperature also causes changes in temperature-dependent phenology of fauna, such as changes to the winter hibernation schedule and the frequency of occurrence of insects, or the timing of bird migration. Indirect impacts are also expected. For example, animals are expected to stop hibernating if nuts or other foods they consume become available even in winter.
- Increasing seawater temperature and ocean acidification affect the timing of proliferation of plankton, which affects higher levels in the ecosystems.
- For phenomena that have their timing determined not only by temperature but also by day length,

there may be impacts from a mismatch between day length and temperature.

- If species differ in their response to temperature changes, there are also expected to be impacts on inter-species interactions. If those inter-species interactions are an important factor in survival of populations of individual species, serious impacts are expected to arise.

Current Status

- Many reports have been confirmed regarding changes in the phenology of flora and fauna, such as earlier flowering of plants and earlier initiation of calling by animals.

Projected Impacts

- Impacts for a variety of species are projected as a result of changes in phenology, such as earlier flowering of the Yoshino cherry tree (*Prunus yedoensis; someyoshino* in Japanese).
- The impacts are not limited to individual species, but various interactions between species are also expected.

Shifts in Distribution and Populations

(1) Shifts in Distribution and Populations

Factors in Climate Change Impacts

- Climate change-induced changes such as increases in temperature and changes in rainfall—and through them, changes in snow cover and natural factors such as soil, water temperature and water quality—are expected to lead to distribution changes, species extinction, and changes in the rate of incursion and settlement of invasive alien species, due to changes in the habitat of flora and fauna, as well as changes in their life-cycle and the time periods when they are active each day.

Current Status

- Regarding organisms such as insects, there have been confirmed cases of shifts in distribution and changes in their life cycles that could be explained as impacts of increases in temperature due to climate change, including expansion of northern limits of distribution to higher latitudes. However, a variety of factors other than climate change could also be involved, so it is difficult to show to what extent the observed changes are a result of climate change.
- No examples relating to the invasion and settlement of invasive alien species due to climate change have been confirmed at present.
- Impacts on ecosystem services due to expanded distribution of wildlife have been reported, but any direct causal relationship with climate change and the degree of contribution of climate change have not yet been clarified.

Projected Impacts

- Climate change is expected to lead to the extinction of certain species by causing shifts in species distribution and changes in their life-cycles, by causing further adverse impacts from changes in inter-species interactions due to species migration or localized extinction, and by species being unable to shift to keep up with climate change due to fragmentation of habitat. With an increase of temperature more than 2°C by 2050, it is projected that more than 30% of all species on earth would be at risk of extinction.

- Although no examples making quantitative projections have been confirmed at present, it is expected that there would be a higher probability of invasion and settlement of invasive alien species due to climate change.
- The habitat for wildlife species such as sika deer (*Cervus nippon*) is expanding, but regarding the question of whether climate change would further expand their habitat, only a small number of examples has been confirmed, so further research is needed in the future.

3.3.4 Natural Disasters, Coastal Zones

Rivers

(1) Floods

Explanation of flood

- The term "flood" here refers to events that occur when heavy rainfalls and the water volume flowing from a watershed into a river exceeds the regular flow by a large margin. As a result, the river's water level rises, and eventually a large volume of water overflows from the river course into the surrounding area.
- Because levees have been built in major segments of rivers in Japan, floods often occurs due to spill overtopping from levees or levee breaking by breaching. The term "riverine flooding" ("gaisui" in Japanese) is used to emphasize that the flooding is caused by flood waters that were flowing downward in the upstream of a river channel defined by levees on both river banks.
- The occurrence of riverine flooding is determined by heavy rainfall events with the spatial and temporal scale corresponding to each specific watershed, and therefore a localized intense rainfall with a smaller spatial scale than that of the watershed does not necessarily lead to riverine flooding.

Mechanisms of Climate Change Impacts

- Impacts of climate change may include an increase in frequency of heavy rainfall events and an increase in the amount of precipitation. As a result, flood waters exceeding the capacity of water disaster prevention facilities may flow downstream along a river, resulting in floods and a greater possibility of damage occurring.
- In low-lying coastal areas, sea-level rise due to climate change may lead to water-level rise in rivers and poorer drainage to the sea. These factors may increase the likelihood of floods and result in longer durations of inundation due to flooding.

Current Status

- Analysis of past rainfall data for heavy rainfall events that occur relatively frequently reveals an increasing trend over time in the frequency of occurrence. There is not yet a sufficient scientific basis to say that this trend is due to climate change.
- The total inundation area has been on a decreasing trend over time. Progress with water induced disaster reduction measures can be cited as a key factor to explain this trend. However, the cost of damage per unit of inundation area is on an increasing trend.
- The degree of safety against water disasters due to water disaster prevention improvements at present is considerably below planned design level, even based on current climate conditions.
- Japan is still vulnerable to water damage from floods so if climate change results in more severe rainfall conditions, the impacts may become considerably high.

Projected Impacts

- Many published studies are consistent with the view that, according to future projections such as the A1B scenario,[57] heavy rainfall events that can cause floods in typical river basins in Japan will increase significantly by the end of the 21st century compared to the present, and rainfall amounts of the same frequency will increase by an order of 10 to 30%.
- Regarding the increasing ratio of rainfall amounts causing floods, multiple published studies have indicated an increase (amplification) in the ratio of increase of flood peak flow and probability of occurrence of flooding. It is expected that the degree of increase of probability of occurrence of flooding will be significantly larger than the degree of increase of flood peak flow.
- If the frequency of flooding occurrence in areas protected by river levees from flood increases significantly, the likelihood of water disasters increases significantly.
- In low-lying coastal areas, it is expected that sea-level rise will lead to an increase in likelihood of floods and longer periods of inundation due to flooding.
- Climate models are an important factor in determining reliability of future projections, so to improve that reliability it will be necessary to improve the spatial resolution to reproduce phenomena, and also increase the number of computational cases.

(2) Inland Waters

Explanation of Inland Flooding

- When heavy rains fall on flat land that has only limited capacity to allow water to penetrate the ground surface or drain away, the rainwater accumulates in certain locations with limited drainage. Eventually the water depth and area increase and that causes flooding and damages. This type of event is referred to here as inland flooding.
- The occurrence of inland flooding is mainly governed by the correlation between rainfall intensity and

[57] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 97.

infiltration or drainage capacity. Therefore, in contrast to riverine flooding, inland flooding may occur in the event of intense rainfall, even if it is localized and of relatively short duration.

- Examples of land conditions that are prone to inland flooding: urban areas that inherently have limited infiltration capacity, where the capacity of sewer systems and other drainage infrastructure to drain rainwater is unable to cope with intense rainfall; areas that cannot drain properly due to inadequate drainage capacity if there are elevated water levels in sewers, canals and streams that drain the area.
- The amount of water from an individual inland flooding event is generally less than riverine flooding with a levee break by a flood, but significant damage may still occur if the land use makes the area vulnerable in terms of infiltration capacity. Also, in urban areas, inland flooding sometimes occurs abruptly and leads to human suffering.

Mechanisms of Climate Change Impacts

- Impacts of climate change will include increases in frequency of heavy rainfall events and increases in the amount of precipitation. These impacts will include a greater frequency of short and concentrated rainfall events and higher intensity of rainfall, resulting in an increase in the possibility of occurrence of inland flooding.

Current Status

- Analysis of historical rainfall data for heavy rainfall events that occur relatively frequently reveals an increasing trend over time in the frequency of occurrence, and there has been a significant increase over the past 50 years in the intensity of rainfall concentrated over short durations with an annual probability of exceedance of 1/5 and 1/10. There is not yet a sufficient scientific basis to say that these trends of change are due to climate change.
- The degree of safety against water disasters, achieved by sewer system improvements at present is considerably short of planned targets, even based on current climate conditions.
- Increasing frequency and intensity of intense rainfall concentrated over short durations may contribute to the more frequent inland water damage that has occurred in recent years in urban areas where only a low level of measures against inundation has been achieved.

Projected Impacts

- Estimates of the climate change impacts of localized intense rainfall events are not yet sufficiently advanced, as it is difficult to obtain fine resolution and to model weather disturbances that cause localized intense rainfall.
- Literature has indicated the likelihood of an increase in the amount of rainfall in short durations over the next 50 years, by extrapolating past trends in heavy rainfall events and other trends over the past 50 years; this literature has provided useful information about the likelihood of future increases in heavy rainfall events that cause damage to inland flooding.
- In low-lying areas and other locations near rivers, it is expected that an increase in frequency of higher

river levels could lead to prolongation of inundation duration, due to the likelihood of an increase in inland flooding as it becomes more difficult to discharge rainwater from sewer systems.

- Urban areas can have large impacts due to special vulnerability to flooding and inundation, if short-duration intensive rainfall events increase due to the impacts of climate change, combined with higher sea levels.
- It is also expected that increases in heavy rainfall will cause inundation damage to farmland outside of non-urban areas.

Coastal Areas

(1) Sea-Level Rise

Factors in Climate Change Impacts

- A climate change-induced increase in temperature increases sea levels by causing the thermal expansion of seawater, melting glaciers and ice sheets, and triggering their slippage.
- Sea-level rise is expected to result in reduced functioning of built structures on rivers and coastal areas, as well as ecosystem changes in the tidal zone[58] of tidal flats and rivers.

Current Status

- It has been reported that sea levels near Japan have been on an increasing trend (+1.1 mm/year) since 1980, based on analysis of tidal observation records.
- At present, there have been no reports of damage due to sea-level rise.
- When using tidal records, it is necessary to accurately assess the magnitude of tectonic movement in order to isolate the variations in sea level attributable to climate change and changes in ocean currents.

Projected Impacts

- Many studies have examined sea-level rise due to climate change.
- The studies found that there is a high possibility that, compared to the average for the years 1986 to 2005, the increase in global mean sea level from 2081 to 2100 will be in the range of 0.26 to 0.55 m (RCP2.6 scenario),[59] 0.32 to 0.63 m (RCP4.5 scenario),[59] 0.33 to 0.63 m (RCP6.0 scenario),[59] and 0.45 to 0.82 m (RCP8.5 scenario).[59] They found some sea-level rise to be inevitable even if greenhouse gas emissions are suppressed.
- If sea-level rise increases by 80 cm, the impacts will extend to all of Japan’s coastlines, and the area of land exactly at sea level around the three major bays in Japan will increase to 1.6 times the current area.
- If sea-level rise occurs, disaster risk from storm surges and high waves will increase compared to the

[58] Tidal zone: A zone near the mouth of a river where tide affects the water level and flow rate.
[59] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 97.

present, even without increases in intensity of typhoons and low pressure systems.

- It is expected that impacts will include a reduction in functioning of river and coastal artificial structures, submergence/inundation of coastal areas, problems for harbor and fishing port functions, and ecosystem impacts in the tidal zones of tidal flats and rivers.

(2) Storm Surges, High Waves

Factors in Climate Change Impacts

- Climate change-induced sea-level rise may increase the risk of occurrence of storm surges and high waves. This is expected to affect human life, harbors and port facilities, fishing port facilities, business activities, and cultural assets.
- Typhoons are the direct cause of most storm surges, and trends in the occurrence of storm surge are determined by factors such as the number of typhoons, their paths, and intensities.

Current Status

- Regarding damage associated with the influence of climate change-induced sea-level rise and increases in typhoon intensity on storm surge and high waves, at present, no concrete examples have been confirmed. Regarding storm surge, it has been pointed out that the occurrence of extreme storm surges may have been increasing globally since 1975.
- Regarding high waves, along Japan's Pacific coast, examples have confirmed an increase in wave height from autumn to winter, and along the Sea of Japan coast, an increase in wave height and frequency due to changes in atmospheric pressure patterns in winter. However, no scientific basis has been obtained yet to indicate that these are climate-change induced.

Projected Impacts

- Typhoons are the main factor for storm surges, and technologies are being developed to project typhoon behavior in the context of climate change (e.g., path, scale). However, already the results of predictive calculations can be assessed with a certain degree of precision, including the increase in water levels and extent of inundation when a typhoon makes landfall in a coastal area.
- The possibility is extremely high that sea level will rise due to climate change and the risk of storm surge will increase.
- Regarding high waves, there are projections of the possibility of increases in risk of high waves in coastal areas of the Pacific Ocean due to increases in typhoon strength, and damage to breakwaters in harbors and fishing ports due to increased wave height and storm surge anomalies.
- For harbors and fishing ports, particularly where the design depth of facilities is shallow, it is projected that there will be an increase in the number of places where safety cannot be adequately ensured due to increasing mean sea levels and an associated increase in wave height.

(3) Coastal Erosion

Factors in Climate Change Impacts

- Climate change-induced sea-level rise and increases in typhoon intensity may promote further coastal erosion where erosion is already occurring, and trigger erosion on coasts where erosion is not currently occurring.
- Increases in the amount of rainfall may result in increasing slope failure and river flow volumes, and by increasing the amount of sediment supply from rivers to coastlines, cause sediment deposition on the shorelines near estuaries.
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Current Status

- Regarding whether or not climate change-induced sea-level rise and increases in typhoon intensity are already having impacts on coastal erosion, no concrete examples have been confirmed at present.

Projected Impacts

- It is projected that coastlines will be eroded by sea-level rise and increases in typhoon intensity due to climate change. Specifically, it is projected that with sea-level rise of 30 cm and 60 cm, about 50% and 80% of Japan's sandy beaches will disappear, respectively.
- Meanwhile, studies have reported the possibility of changes in the sediment supply from rivers with an increase in rainfall due to climate change, and the possibility for sediment deposition on coastlines including around estuaries. However, the possibility for increases in sediment volume to be sufficient to replenish the losses from coastal erosion due to climate change is not considered to be high, so it is expected that coastal erosion will progress more than at present.

Mountain Areas

(1) Debris flows, Landslides, and other disasters

Factors in Climate Change Impacts

- Climate change-induced increases in the probability of intense rainfall over short periods and large total precipitation amounts, as well as changes in special and temporal distribution of rainfall, may increase in the frequency of occurrence of sediment-related disasters, alter their timing, increase their scale, and change their occurrence patterns.
- Changes in precipitation amounts and temperature are expected to change the ground structure and ground cover conditions (e.g., vegetation), and affect the factors involved in slope failure and erosion. Changes in the amount of snowfall and spatial and temporal distribution of snowfall are also expected to affect avalanches and other types of snow damage. However, many aspects of the kinds of impacts are currently unclear.

Current Status

- Little research and reporting has analyzed any direct correlation between climate change and the scale of damage from sediment-related disasters, and at present, much is still unknown regarding the relationship between climate change and the patterns of occurrence of sediment-related disasters.
- However, over approximately the past thirty years there have been reports of increases in the frequency of torrential rainfall of 50 mm or greater per hour, and increases in the number of annual cases of sediment-related disasters affecting human settlements. Also, despite a scarcity of data, an increasing trend has been reported in recent years in the frequency of occurrence of deep-seated slope failure.
- There have been reports of greater variation in snowfall in some regions, with a trend toward warmer winters with lower snowfall followed by heavy snowfall, but at present, no concrete examples relating to snow damage have been confirmed.

Projected Impacts

- The following is a list of conditions that could change under more severe rainfall conditions. (Severe rainfall conditions include extremely intense torrential rainfall and prolonged periods of heavy rainfall, and heavy rainfall that deliver an extremely large amount of total rainfall)
  - Frequency of intensive failure, slope failure, debris flows, and its impacts on social and livelihood in mountain regions and areas around slopes
  - A reduction in relative effectiveness of material measures (e.g., physical infrastructure) and non-material measures (e.g., institutional, organizational), increased extent of damage
  - Prolongation of direct and indirect impacts due to increase of large-scale events such as deep-seated slope failure
  - Expansion of damage beyond locations currently exposed to landslide hazard, as a result of increasing scale of events
  - A reduction in system capacities of water disaster prevention and water utilization due to increases in sediment supply to rivers

Others

(1) Strong Winds and Other

Factors in Climate Change Impacts

- Climate change may increase strong typhoons and increase damage such as tree blow-down due to typhoons.
- As the frequency of occurrence of supercells[60] which cause strong tornadoes increases due to climate change, the number of tornadoes increases, and which may affect damage that occurs.

[60] Supercells: Systems with large cumulonimbus clouds that can lead to severe weather events such as strong winds and tornadoes.

Current Status

- Regarding increases in damage by increases of strong winds and strong typhoons accompanied by climate change, at present, no concrete examples have been confirmed.
- Regarding changes in the frequency of occurrence of climate change-induced tornadoes as well, at present, no concrete examples have been confirmed.

Projected Impacts

- A study using the A1B scenario[61] projects increases in strong winds and strong typhoons due to climate change, starting in the near future (2015-2039).
- In addition, projections for the end of the 21st century (2075-2099) in Japan nationwide are for a higher frequency conditions suitable for the occurrence of tornadoes mainly from March to May.
- Although no examples making quantitative projections have been confirmed at present, there are concerns about an increase in damage from tree blow-down in mountain regions accompanied by increase of intense typhoons.

3.3.5 Human Health

Human health is not only affected by climate change, but by a wide range of factors, such as the enormous movement of people and goods due to globalization, and major changes in the natural environment from land development. When assessing the impacts of climate change, it is necessary to do so based on an understanding that those many other factors exist.

Winter Warming

(1) Mortality in Winter Season

Factors in Climate Change Impacts

- A climate change-induced warming of winter temperature may reduce winter mortality if it reduces the frequency of events such as cold waves and heavy snows that occur on a scale resulting in disasters. It is unclear whether winter mortality rates will decline with an increase in mean temperature in winter, as studies have not verified any increase in mortality risk in response to lower temperature on a day-to-day basis.

Current Status

- Regarding any decrease in mortality in winter associated with increasing temperature in winter, no concrete examples have been confirmed at present.

Projected Impacts

- Using the RCP4.5 scenario,[62] the mean temperature in winter was projected to increase in the 2030s

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[61] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 97.

[62] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 97.

nationally compared to the 2000s, and cold mortality as a proportion of total mortality (non-accidental) was projected to decrease. However, this projection was based on a study conducted before isolating seasonal impacts from impacts due to differences in winter temperature. By separating seasonal effects, the decrease in the proportion of deaths due to cold mortality is expected to be smaller than that projection.

Heat Stress

Among the impacts of heat stress, this section deals mainly with impacts such as mortality risk and heat illness. In the category of "Life of Citizenry, Urban Life" the section "Other–Impacts on life due to heat stress" deals mainly with impacts such as heat stress, sleep inhibition, and heat discomfort.

(1) Risk of Mortality

Factors in Climate Change Impacts

- Due to the physiological effects of heat stress, a climate change-induced increase in temperature increases the risk of heat illness, as well as mortality risk for the elderly and persons with circulatory and respiratory system problems. Indirectly, increasing temperature may increase mortality risk due to respiratory and circulatory disease as a result of an increase of photochemical oxidant concentrations associated with increasing temperature.

Current Status

- It has been confirmed globally that excess mortality (an indicator showing the extent to which total mortality from a given illness has increased, whether directly or indirectly) is already occurring due to an increase in temperature.

Projected Impacts

- The frequency of summer heat waves is projected to increase in Tokyo and several other Asian cities, and it is also projected that heat stress related to mortality and morbidity may also increase.
- The mortality risk from heat stress is projected to increase in Japan by the mid-21st century (2050s) to about 1.8–2.2 times the level in 1981 to 2000, and to about 2.1–3.7 times by the end of the 21st century (2090s), respectively, under the 450s scenario[63] and BaU scenario.[63]
- Even for the RCP2.6 scenario,[63] the excess mortality from heat stress is projected to more than double in all prefectures, regardless of age group.

(2) Heat Illness

Factors in Climate Change Impacts

- An increase in summer temperature may increase the number of heat illness patients. The impacts may be particularly serious for the elderly.

Current Status

- Increases in the number of heat illness patients transported by ambulance have been reported nationwide, although it cannot be stated with certainty that all of the increases are an impact of climate change.
- Only a limited number of reports has been published in Japan relating to health impacts that do not lead to mortality or morbidity, such as impacts on labor efficiency.

Projected Impacts

- The rate of increase of incidence of heat illness is projected to be larger in Hokkaido, Tohoku, and Kanto, and smaller in Shikoku, Kyushu, and Okinawa, in projections for 2031–2050 and 2081–2100.
- By age group, the rate of increase in incidence of heat illness is highest for the elderly over 65 years of age, and considering the future aging of the population, the impact is considered to be more serious.
- A projection using the RCP8.5 scenario[63] projected more than a doubling of heat illness patients transported by ambulance in the majority of prefectures (with the exception of Shikoku) by the middle of the 21st century, and by the end of the century, with the exception of a projection using RCP2.6 scenario,[63] more than a doubling in almost all prefectures.
- Regarding health impacts of climate change that do not lead to clinical symptoms (e.g., impacts on the labor efficiency), studies have been reported in overseas, and the IPCC Fifth Assessment Report also addressed these issues. Few reports have been published in Japan, however.

Infection

Note: This section covers infectious diseases for which a considerable amount of research exists, including water-borne and food-borne diseases, and vector-borne diseases. Infectious diseases for which existing research knowledge is limited is covered together under “Other infectious diseases.” They are covered together for convenience, but this does not necessarily mean the “other infectious diseases” are less important.

(1) Water- and Food-Borne Diseases

Factors in Climate Change Impacts

- A climate change-induced increase in temperature of seawater and fresh water is expected to increase the amount of microbes in water, and increase the risk of water-borne diseases.
- An increase in temperature is expected to increase the risk of food-borne diseases, through bacterial contamination and proliferation in food, via various processes, including food processing, distribution, storage, and cooking.

Current Status

- Regarding the increasing risk of water-borne and food-borne diseases due to climate change, at present, confirmed examples are limited, and the connection with climate change is not clear.

[63] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 97.

Projected Impacts

- The expansion of water-borne and food-borne diseases due to climate change is also a concern, but at present, confirmed examples are limited.

(2) Vector-borne Diseases

Factors in Climate Change Impacts

- Climate change-induced increases in temperature and changes in spatial and temporal distribution of precipitation may change the suitable habitat for arthropods that are vectors for infectious diseases, and increase the risk of vector-borne diseases.

Current Status

- It has been confirmed that the habitat of mosquitoes (*Aedes (Stegomyia) albopictus*) that are vectors of infectious diseases such as dengue fever have expanded to rural northern parts of the Tohoku region. Also, though not directly connected to climate change, there were instances of many persons falling ill with dengue fever[64] in metropolitan parks in 2014.
- There are other infectious diseases for which the risk of spread may increase due to climate change impacts, but no concrete examples in Japan have been confirmed at present.

Projected Impacts

- A projection using the RCP8.5 scenario[65] projected the possible distribution of the Asian tiger mosquito (*hitosujishimaka*, or *Aedes (Stegomyia) albopictus*) to reach some area of Hokkaido by the end of the 21st century. However, the expansion of possible distribution, does not necessarily lead immediately to more occurrences of disease.
- There are other infectious diseases may be affected by climate change, but no examples specifically on the risk of spread of infectious diseases in Japan have been confirmed at present.

(3) Other Infectious Diseases

Factors in Climate Change Impacts

- For infectious diseases other than water-borne, food-borne, and vector-borne infectious diseases, climate change-induced increases in temperature and changes in the amount of precipitation are expected to increase the risk of infection and change the characteristics of outbreaks.
- However, since the impacts of other societal and biological factors are significant, findings about detailed mechanisms are inadequate at present.

Current Status

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[64] Dengue fever: An infectious disease caused by the dengue virus, which is transmitted by vectors such as the Asian tiger mosquito (*Aedes (Stegomyia) albopictus*) and the yellow fever mosquito (*Aedes (Stegomyia) aegypti*).

[65] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 97.

- For infectious diseases other than water-borne and food-borne, and vector-borne types as well, reports have been confirmed that point out seasonal changes in occurrence and correlations between occurrence, and temperature and humidity.
- However, since the impacts of other societal and biological factors are significant, findings about detailed mechanisms are inadequate at present.

Projected Impacts

- For infectious diseases other than water-borne and food-borne and vector-borne types as well, the potential exists for seasonal changes and changes in risk of occurrence due to an increase in temperature, but quantitative assessment is difficult due to the lack of research literature.

Others

(1) Others

Factors in Climate Change Impacts

- A climate change-induced increase in temperature is expected to alter the concentrations of various pollutants, by promoting reactions that generate air pollutants such as ozone.
- If there is an increase in frequency of combined sewage overflow associated with increase in localized torrential rainfall due to climate change, it is expected to affect the occurrence of diarrhea in regions where water is supplied from closed water systems that have become contaminated.
- The elderly and children are vulnerable to the effects of summer heat and expected to be more affected by increases in temperature.
- Though quantitative information is limited, serious impacts (e.g., impacts on labor efficiency) are also expected to affect society and the economy, even if the impacts are not as serious as death or illness.

Current Status

- There have been many reports of health-related combined impacts connected with an increase in temperature and air pollution; changes have been reported in the concentrations of particulate matter and a variety of other pollutants, due to factors such as their formation being promoted by an increase in temperature.
- It is expected that diarrhea outbreaks will occur if water becomes contaminated in closed water bodies and rivers downstream, in the event of overflow of combined sewer systems due to flood associated with localized torrential rainfall. There are reports in the United States introducing rainwater treatment approaches similar those used in Japan, but there is no specific report in Japan.
- The elderly are frequently referred to as a population vulnerable to heat stress, but in the United States there have been reports of impacts on young children and fetuses (expectant mothers). In Japan, information on these aspects is not available.
- Also, only a limited number of reports has been published in Japan relating to health impacts that do not lead to mortality or morbidity, such as impacts on labor efficiency.

Projected Impacts

- It is expected that damage to health will increase with higher oxidant concentrations due to an increase in temperature in urban areas, but these impacts are greatly affected by future air pollution levels, and it is not easy to make projections.
- It is expected that the incidence of diarrhea will increase due to greater pollution of closed waters with increasing amounts of heavy rain, but epidemiological data is insufficient to make projections.
- There is a lack of information about impacts on vulnerable populations, children in particular.
- Regarding health impacts of climate change that do not lead to clinical symptoms (e.g., impacts on the labor efficiency), studies have been reported in other countries, and the IPCC Fifth Assessment Report also addressed these issues. Few studies have been reported from Japan, however.

3.3.6 Industrial/Economic Activities

Manufacture

(1) Manufacture

Factors in Climate Change Impacts

- Due to the limited number of research case studies, the mechanisms of climate change impacts on the manufacturing industry are not entirely clear.
- Some examples suggest that an increase in mean temperature has impacts on production and sales processes of businesses and on site selection for production facilities. Some examples also suggest that a possible long-term sea-level rise and increase in the frequency and intensity of extreme events could cause direct physical damage to production facilities. Meanwhile, some examples suggest that climate change could lead to the creation of new business opportunities.

Current Status

- A variety of climate change-induced impacts are expected, but at present, only a limited number of examples have been confirmed on the impacts on manufacturing (the only study that could be confirmed is a report of one case study on natural agar production, a traditional industry in Chino city, Nagano Prefecture). At present, it has not been determined if there are significant impacts on manufacturing.

Projected Impacts

- There is a lack of published examples assessing future impacts of climate change on the manufacturing industry to be large; therefore, based on available information, it is difficult to say that the impacts will be high.
  - Assuming the highest range of sea-level rise, research has found that the value of lost production in the manufacturing sector around the Tokyo Bay area due to sea-level rise would be very high in the 2090s in the absence of measures against sea-level rise in coastal areas.

- Examples done in the apparel and other industries, while not quantitative projections, found reasons to be concerned that changes in average temperature would have direct and physical impacts on a company's production and sales processes, and the siting of production facilities.

Energy

(1) Energy Demand and Supply

Factors in Climate Change Impacts

- Factors such as a climate change-induced increase in temperature may have both positive and negative impacts on energy demand.
- Due to the limited number of examples, it cannot be inferred that there is consensus regarding the damage and impacts on the energy infrastructure due to an increase in the frequency and intensity of extreme events or long-term sea-level rise.

Current Status

- No concrete examples regarding the impacts of climate change on energy demand and supply have been confirmed at present.

Projected Impacts

- A limited number of examples have quantitatively assessed future impacts of climate change on energy demand and supply; therefore, based on available information, it is difficult to say that the impacts will be high.
  - The followings are examples of reports projecting the impacts of increases in temperature on energy consumption.
    - ✓ Almost no change in the industrial sector and the transport sector
    - ✓ A reduction in demand in the residential sector (for a 1.0°C increase in temperature, household energy consumption declines 3-4% in Hokkaido and Tohoku regions, and 1-2% in other regions)
    - ✓ An increase in demand in the commercial sector including the service industry (for a 1.0°C increase in temperature, demand in commercial sector increases 1-2%)
    - ✓ In the residential/commercial sector overall, no major impact, but there may be decreases in some areas
  - It has been pointed out that increases in summer temperature may accentuate the peaks of electricity supply.

Commerce

(1) Commerce

Factors in Climate Change Impacts

- There are complex factors involved in the mechanisms of climate change impacts on the commercial industry and the collection of examples of research is limited, so the actual mechanisms of climate change impacts on the commercial industry are not entirely clear.

- Some studies suggest that changes in the climate affect the sales of seasonal products and marketing plans of businesses. It has also been suggested that proper adaptation to changes in the climate could lead to the creation of new business opportunities.

Current Status

- No concrete examples regarding the impacts of climate change in the commercial sector in Japan have been confirmed at present.

Projected Impacts

- There are very few examples that future impacts of climate change on the commercial sector in Japan, so it is not possible to assess impacts on the commercial sector at present.
  - In the apparel industry, some reports have pointed to impacts on sales of seasonal products, and on marketing plans.
  - In CDP projects, there are examples that companies in the apparel, hotel, and other industries estimated and assessed impacts and economic losses associated with future climate change.

Finance, Insurance

(1) Finance, Insurance

Factors in Climate Change Impacts

- An increase in natural disasters associated with increases in the frequency and intensity of climate change-induced extreme events may increase the amounts of insured losses and the resulting insurance payments.
- An increase in the frequency and intensity of extreme events and increases in uncertainty of the future climate may affect insurance premium calculations for insurance underwriting, as well as risk diversification.
- Meanwhile, appropriate responses to climate change risk are expected to create new business opportunities in the insurance industry.
- While there are threats such as the damage to property in the financial industry due to natural disasters associated with an increase in climate change-induced extreme events, appropriate responses to climate change risk are expected to create new business opportunities.

Current Status

- Based on trends in natural disasters and associated insured losses over approximately 30 years since 1980, insured losses have increased significantly and it has been confirmed that the likelihood that losses will regularly occur has been increasing.
- There are reports that it has become difficult for insurance companies to project future trends using

traditional risk quantification methods alone, and that development of new methods of risk hedging and diversification that consider the future impacts of climate change will be necessary.

- At present, no concrete examples of research regarding the impacts of climate change on the Japanese financial sector have been found.

Projected Impacts

- Projections have indicated increases in insured losses associated with a growing number of natural disasters, increases in insurance payments, and increases in reinsurance premiums. However, at present, examples of research are limited in Japan.
- No quantitative examples with projections for Japan have been found at present, but impacts such as the following can be expected.

(Insurance Industry)

- ➢ Threats such as the emergence of some categories that cannot be insured, and difficulty of reinsurance
- ➢ Business opportunities, such as increase in demand for insurance, and potential for new product development.

(Financial Industry)

- ➢ Threats such as damage to property or increase in economic costs due to changes in weather
- ➢ Business opportunities, such as adaptation business financing and development of weather derivatives

- At present, no concrete examples of researches related to the impacts of climate change on the Japanese financial sector have been found.

Tourism

(1) Leisure

Note: This section mainly covers leisure activities that use natural resources, including forests, snowy mountains, sandy beaches, and tidal flats.

Factors in Climate Change Impacts

- For leisure industries that utilize natural resources (e.g., forests, snowy mountains, sandy beaches, and tidal flats), a climate change-induced increase in temperature, changes in the amount of rainfall and snowfall, changes in the spatial and temporal distribution of precipitation, and sea-level rise, may have impacts such as elimination or shrinking of resources and areas where these activities are possible, and changes in the period of year best suited for these activities.
- An increase in the frequency and intensity of extreme events may also affect areas and resources suitable for leisure activities that utilize natural resources.

Current Status

- Leisure industries that utilize natural resources (e.g., forests, snowy mountains, sandy beaches, and wetlands) may be subject to impacts from an increase in temperature, changes in rainfall, snowfall, and the special and temporal distribution of precipitation, and sea-level rise; however, at present, confirmed examples are limited.

- Examples have been confirmed about a reduction in snow depth at ski resorts due to an increase in temperature.

Projected Impacts

- A study using the A1B scenario[66] projected that in about 2050, the tourism climate index[67] will be reduced in summer due to an increase in temperature, and increased in spring and autumn to winter.
- Regarding skiing, it is projected that snowfall and maximum snow depth in 2031 to 2050 will be reduced (with the exception of some areas inland in Hokkaido and Honshu), and that almost all ski resorts will see a reduction in snow depth.
- A loss of sandy beaches is projected to occur due to sea-level rise, with impacts on leisure industries in coastal areas.

Construction

(1) Construction

Factors in Climate Change Impacts

- A climate change-induced increase in the frequency and intensity of extreme events is expected to cause damage directly to the field site of construction work.
- An increase in temperature is expected to affect building materials and the structural integrity of buildings.
- Indirect impacts on the construction industry are also expected, via damage to infrastructure from flood and storm surges, and from the introduction of adaptation measures.

Current Status

- At present, no concrete examples regarding the impacts on the construction industry have been confirmed.
- However, impacts on infrastructure have been considered in the "Urban infrastructure, critical services" section, so readers are encouraged to refer to it.

Projected Impacts

- At present, confirmed examples are limited regarding impacts on the construction industry.
- However, impacts on infrastructure have been considered in the "Urban infrastructure, critical services" section, so readers are encouraged to refer to it.

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[66] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 97.

[67] Tourism climate index: An index for the level of comfort for tourisms based on climate, in terms of factors such as temperature, amount of precipitation, and amount of solar radiation.

Medical

(1) Medical

Factors in Climate Change Impacts

- There are concerns about increasing risks such as the risk of heat illness and risk of the spread of infectious diseases such as those transmitted by water or arthropods, as a result of a climate change-induced increase in temperature. Thus it is expected that there will be some kinds of impacts on the medical industry.
- Impacts on the medical industry are also expected from an increase in disaster risk associated with an increase in the frequency and intensity of extreme events and an increase in drought due to changes in the amount of precipitation.

Current Status

- At present, no concrete examples regarding the impacts on the medical industry have been confirmed, with the exception of impacts on dialysis treatment due to interruption of water supply and turbid water.
- However, impacts on health have been considered in the "Human health" sector, so readers are encouraged to refer to it.

Projected Impacts

- At present, no concrete examples regarding the impacts on the medical industry have been confirmed.
- However, impacts on health have been considered in the "Human health" sector, so readers are encouraged to refer to it.

Others

(1) Other Impacts (e.g. Overseas Impact)

Factors in Climate Change Impacts

- There are complex factors involved in the mechanisms of how climate change impacts arising outside Japan affect supply chains and Japan's domestic industry and economy, and the collection of examples of research is limited, so the actual mechanisms of climate change impacts are not entirely clear.
- Examples of how climate change impacts arising outside the United Kingdom would have impacts within the United Kingdom makes reference to the following impacts:
  - Companies with supply chains overseas may be affected by direct physical damage to their economic activities, due to climate change-induced locally impacts such as sea-level rise and increases in frequency and intensity of extreme events.
  - An increase in the frequency of severe storms at sea and changes in their patterns of occurrence may lead to changes in time required for marine shipping as well as changes in marine routes, which would affect supply chains and could lead to delivery delays for products and materials, as well as impacts such as higher transportation costs.

- A climate change-induced increase in the frequency and intensity of extreme events may cause damage to energy-related infrastructure of import counterparts of energy, thereby having impacts on energy security and fuel import prices.
- Increases in the frequency and duration of extreme events, a reduction of water resources, ocean acidification, and changes in water temperature, may lead to poor harvests of agricultural and fisheries products that are being imported, thereby affecting the import prices of those products.
- Changes in infectious disease patterns associated with an increase in temperature could increase the numbers of disease carriers overseas, which may lead to larger outbreaks domestically via immigration and incoming travel.

Current Status

- At present, no examples regarding the impacts of climate change outside of Japan will have within Japan have been confirmed.
- Although it is difficult to clearly determine whether or not it was an impact of climate change, the flood of Thailand's Chao Phraya River in 2011 resulted in losses for Japanese companies. There was one case of an estimated 315 billion yen in losses for Japanese companies involved in the supply chain for computer hard disks, and another case of an expected 900 billion yen in insurance payouts to Japanese firms by Japanese insurance companies.

Projected Impacts

- Impacts that might be experienced within Japan due to impacts from overseas center on secondary impacts, would include social sciences, and involve complex factors; at present no concrete examples covering these topics have been confirmed.
- However, based on the examination cases conducted in the U.K., there are concerns in Japan as well about changes in import prices of energy and prices of agricultural and fisheries products; direct and physical impacts on manufacturing plants operating overseas; and impacts of the spread of infectious diseases via migrants and incoming travel, associated with an increase of disease carriers overseas.

3.3.7 Life of Citizenry, Urban Life

Urban Infrastructure, Critical Services

(1) Water supply, Transportation, and the others

Factors in Climate Change Impacts

- Climate change-induced impacts such as increases in the frequency of short-term intense rainfall events and droughts, and increases in strong typhoons, may affect infrastructure and critical services.

Current Status

- Impacts have been confirmed in many places in recent years, including underground inundation, power outages and impacts on subway systems due to record torrential rainfall; impacts on water supply infrastructure due to droughts and flood; and impacts on cut-off slopes of highways due to torrential rainfall and typhoons.

- However, it is difficult to clearly determine whether or not these incidents were impacts of climate change.

Projected Impacts

- Regarding possible climate change impacts on infrastructure and critical services, at the global level it has been pointed out that extreme weather events may expose systems to risks by disrupting the functioning of infrastructure networks and critical services such as electrical and water supply services, but could also affect national security policies.
- Meanwhile, for Japan, reports have focused on secondary impacts including those mainly in the social sciences, and involve complex factors; at present only a limited number of published examples has been confirmed. Overseas, some examination cases have pointed to an increase in risks for communications and transportation infrastructure.
- There are concerns about impacts on infrastructure and critical services if climate change results in impacts such as increase in the frequency of short-term intense rainfall events and droughts, and an increase in strong typhoons.

Life with Sense of Culture and History

(1) Phenology, Traditional Events/ Local Industry

Note: The term phenology refers to phenomena manifested by fauna and flora in response to seasonal changes such as temperature and sunlight. This section mainly covers phenology relating to human activities and culture (phenology perceived by people in their lives, or sense of season), while the section for “Phenology” under “Natural Ecosystems” mainly covers ecosystem services and impacts on ecosystems.

Factors in Climate Change Impacts

- A climate change-induced increase in temperature may result in changes in phenology, such as the germination and flowering of plants, the timing of autumn foliage, and the initiation of calling by birds and insects. In this regard, these changes may affect citizens’ sense of the seasons, traditional events at popular places for viewing of cherry blossoms and autumn foliage, and tourism.
- There may also be impacts on local traditional events, tourism, and industries, as a result of an increase in temperature, increases in the amount of precipitation, changes in the spatial and temporal distribution of precipitation, sea-level rise, and changes in the frequency and intensity of extreme events.

Current Status

- Reports have been confirmed regarding phenological changes for flora and fauna that people commonly experience, including cherry blossoms, the Japanese maple, and cicadas. However, regarding the impacts of these changes on citizens’ sense of the seasons and on local traditional events and tourism, no concrete examples have been confirmed at present.

- At Lake Suwa, there have been reports of the impacts of an increase in temperature on local traditional events, tourism, and industries; these include an increase in the frequency of years without "omiwatari"[68], and impacts on local sake (rice wine) production. However, it is difficult to clearly determine whether or not they are an impact of climate change, and at present, confirmed examples are limited.

Projected Impacts

- For flowering dates and the duration of full blooming of cherry blossoms, the A1B and A2 scenarios[69] indicate a trend for earlier flowering dates in the future in northern Japan, but later dates in southwestern Japan. Also, by the middle and end of this century, they indicate a shortening of the duration from flowering until full bloom, due to an increase in temperature. Associated with that, impacts are projected for a reduction in the number of days for flower blossom viewing, and then for regions that treat cherry blossoms as a touristic resource.
- Regarding the impacts on unique regional traditional events, tourism, and local industries, at present, confirmed examples are limited.

Others

(1) Impacts on Life due to Heat Stress

Note: This section mainly covers impacts in urban areas such as heat stress, sleep inhibition, discomfort due to heat, while the "Heat Stress" section under "Health" mainly covers impacts such as relating to mortality risk and heat illness.

Factors in Climate Change Impacts

- In urban areas, an increase in temperature due to climate change combined with an increase in temperature due to the heat island effect lead to an increase in heat stress, with impacts on the comfort of urban living, including not only an increase in heat illness, but also other impacts such as sleep inhibition, heat discomfort, and impacts on outdoor activities.[70]

Current Status

- Reports have been confirmed stating that the rate of increases in temperature per 100 years in small- and medium-sized cities is 1.5°C, compared to 2.0 to 3.2°C in major large cities, and that in large cities the effects of an increase in temperature due to climate change are combining with the heat island effect.
- The heat island effect has also been confirmed in small- and medium-sized cities.
- In terms of impacts of an increase in temperature particularly in large cities, it has been pointed out

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[68] Omiwatari: translated as "The God's Crossing" a natural phenomenon related to pressure ridges forming on lake ice, with records dating back to 1443.

[69] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 97.

[70] When considering the impacts of climate change, the heat island effect can be seen as a factor that increases the vulnerability of cities.

that there is an increase in heat stress experienced by people, including an increase in the risk of heat illness, as well as sleep inhibition, and impacts on outdoor activities.

Projected Impacts

- The heat island effect in Japan's large cities is expected to increase only slightly in the coming years, but the heat island effect already observed in combination with an increase in temperature associated with climate change can be expected to result in a continuation of an increase in temperature in cities.
- For example, a case projecting August temperature in the city of Nagoya in the 2070s (using the A2 scenario)[71] indicated an increase of about 3°C compared to the average August temperature for 2000 to 2009, and also suggests an increasing trend in the WGBT[72] sensory index associated with an increase in temperature.
- Future projections of temperature for urban areas will differ depending on the design of each city, but increases have been projected for temperature and sensory indices. Regarding the thermal environment after an increase in temperature, there are concerns about significant impacts on urban living, from the perspective of heat illness risk and comfort levels.

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[71] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 97.

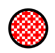
[72] WBGT: Wet Bulb Globe Temperature, an indicator of temperature. It provides an indicator of the level of heat felt. It is calculated from natural web bulb temperature (°C), black bulb temperature (°C), and temperature (°C).

3.4 Assessment of Climate Change Impacts (Summary Table)

Legend:
Significance ● Very High ◇ Not “Very High” — N/A(currently cannot be assessed) [Criteria include Soc (Social), Ec (Economic), Env (Environmental)]
Urgency ● High △ Medium □ Low — N/A(currently cannot be assessed)
Confidence ● High △ Medium □ Low — N/A(currently cannot be assessed)

Sector	Category	Sub-category	Current status	Projected impacts	Significance			Urgency	Confi-dence	Rationale
						Criteria	Rationale			
Agricul-ture, Forest/Forestry, Fisheries[1]	Agriculture	Paddy field rice	● Already, impacts of temperature increase have been confirmed nationwide, including deterioration in quality (e.g., occurrence of white immature grain,[2] decreases in the ratio of first-class rice). Decreases in yields have also been observed in some regions and in years with extreme high temperature.	● Under the A1B scenario[3] or increasing of 3℃ above current temperature, almost all projections are for an increase in rice yields in Japan until the mid-21st century; however, for increasing above those temperature, as a reduction in yields is projected for all areas except northern Japan, there is general consistency in projections, with higher yields in Hokkaido, and no change or a decrease in yields in relatively warmer areas such as southern Kyushu. ● Rice quality is projected to decline nationally, with a smaller ratio of first grade rice being produced, due to an increase in temperature during the ripening period. More specifically, in the Kyushu region, some cases under A1B and A2 scenarios[3] indicate nearly a 30% decrease in the ratio of first grade rice by the mid-21st century and a decrease of approx. 40% by end of the 21st century. ● Free Air CO_2 Enrichment (FACE) experiments have demonstrated that an increase in CO_2 concentrations increases rice yields through the fertilization effect, but there is some uncertainty relating to interactions with increases in temperature.	●	Soc/Ec	The scope of impacts (also including positive ones) on changes in rice yields and quality is national, and there are direct impacts on the supply of rice (a staple food in Japan) and increasing or decreasing of farmers’ revenues.	●	●	
		Vegetables	● Past studies have reported that the impacts[4] of climate change are already evident in more than 40 prefectures, it is clear that climate change impacts are evident nationwide. ● In particular, for open-field vegetables including leafy vegetables such as cabbage, root vegetables such as daikon radish, and fruit vegetables such as watermelon, there is a trend toward earlier harvests for many types of produce, and there has also been an observed increase in the frequency of decreasing growth. ● For vegetables grown in greenhouses, problems such as poor fruit bearing occur frequently with tomatoes, and there is an increasing need for measures to deal with high temperature. On the other hand, there are also reports of reduced fuel consumption for greenhouse production, due to an increase in temperature in winters.	● For vegetables, the likelihood that cultivation will become impossible is expected to be low, as many vegetables have a short growing season, and adjustments can be made in the timing and types of vegetable crops grown. ● At present, concrete examples are limited. ● However, further climate change in the future may pose challenges for planned vegetable shipments/supplies.	—		Impacts are already evident, but since future impacts are not entirely known, it is difficult to assess their significance.	△	△	

[1] In agriculture, forest/forestry, and fisheries, for projecting the future impacts of climate change, it is also necessary to assess the impacts of a variety of social, economic, and environmental aspects, including globalization and changes in population and industrial structure. However, since findings for such integrated assessments are currently limited, it is important to note that information compiled and assessments in this report focus only on the direct impacts of climate change.
[2] White immature grain: Kernels have a whitish hue and protein fails to build up, due to damage such as high temperature.
[3] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 98.
[4] Regarding the impacts of climate change, it is important to note that in cases where it is difficult to ascertain the continuous long-term impacts mainly due to improvements in plant varieties, the judgement is made based on short-term climate impacts.

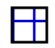
Sector	Category	Sub-category	Current status	Projected impacts	Significance			Urgency	Confi-dence	Rationale
						Criteria	Rationale			
		Fruit trees	● A nationwide study implemented in 2003 on the state the impacts[5] of warming reported that public research institutes dealing with fruit growing in all prefectures had found that the impacts of climate change were already appearing in the fruit-tree growing industry. ● Fruit trees are extremely poor at adapting to climate, and once planted, the same tree typically grows for 30 to 40 years. Many trees producing today have been growing since the 1980s when temperature was cooler, and there have not been major changes in cultivars and cultivation methods, so in many cases the trees have not been able to adapt to the increase in temperature since the 1990s. ● Damage from warming in recent years (e.g., peel puffing of citrus fruit, and poor coloring of apples) has affected almost all tree species and regions. ● As for fruit quality, there is a tendency for taste to improve in some fruits (e.g., apples), but also a tendency for fruit to be softer, which leads to a reduction in storage ability.	● For satsuma mandarin oranges and apples, projections using the IS92a scenario[6] show a year-by-year shift northward of the optimal temperature zone for growing, as follows: ➢ For satsuma mandarin oranges, the climate in the 2060s is projected to be more difficult than today for growing in many of today's prime production areas, and growing will become possible in areas that are currently not suited, including inland areas in the warm southwestern region (relatively warmer areas such as southern Kyushu) and coastal areas along the Sea of Japan and southern Tohoku region. ➢ For apples, by the 2060s, the climate is projected to be more difficult than today for growing in the central Tohoku plains, and many of today's prime production areas such as the northern Tohoku plains will reach temperature similar to areas that today produce warm-climate apple varieties. ● For grapes, peaches, and cherries, high temperature is expected to cause problems for cultivation in major-producer prefectures.		Soc/Ec	Warming is already having impacts nationwide, and may affect the revenues of farmers directly, as well as general households via food prices. In particular, local brands have been established for fruit in many cases, such as apples in eastern Japan and satsuma mandarin oranges in western Japan. In some prefectures, fruit bring in even more revenue than rice, and there are important peripheral industries such as storage and processing. Thus, if growing becomes difficult as a result of shifts in optimal growing areas, there would be local economic impacts. Also, fruit (especially citrus) is a primary crop in some hilly and mountainous areas, so the impacts of any shift in growing areas are significant, especially in areas with few other industries.			
		Barley/Wheat, soybean, feed crops, and other crops	● For wheat, a trend toward shorter growing seasons due to warmer winters and springs has been confirmed, with delays nationwide in the timing of seeding and the earlier emergence of ears. ● For feed crops, there are reports that in some parts of the Kanto region, an annual increasing trend was observed in dry matter yields for feed corn during the period 2001 to 2012.	● For wheat, projected impacts include an increase in risk of frost and freezing damage due to faster growth after seed planting due to high temperature, and a decrease in protein content due to elevated CO_2 concentrations. ● For soybean, an increase in yields are projected under elevated CO_2 concentrations (where temperature is at or only slightly above optimal temperature), but for temperature above the optimal range, reductions are projected for dry matter weight,[7] grain weight, and harvest indexes.[8] ● In Hokkaido, projections for the 2030s under the IS92a scenario[6] indicate the potential for increased yields of sugar beet, soybean and azuki beans (although there are concerns about disease and lower quality), but for wheat and potatoes, a decrease in yields and a decline in quality. ● Some studies have made projections including pasture grass production, but no projections have been made for certain trends such as increases or decreases in revenues.		Soc/Ec	Changes in grain yields and quality (including positive impacts) may affect the revenues of farmers directly, as well as general households, via food prices.			
		Livestock farmiing	● Judging from livestock production trends, no impact of climate change on livestock is clear at present. ● Reports have included a decrease in growth and meat quality of beef cattle and pigs in summer, as well as a decrease in egg-laying rates and egg weights of laying hens, a decrease in growth of meat-type chickens, and lower milk production and grade of milk components from dairy cows. ● It has been reported that extreme summer temperature during the record heat wave of 2010 resulted in greater losses compared to previous years for all types of livestock and regions, due to mortality and non-productive animals and poultry.	● Magnitude of impacts is likely to depend on livestock type and feeding method, but projections are for the impacts on the growth of fat hogs and meat-type chickens to increase, an expansion of regions with diminished animal growth, and an increase in the magnitude of growth decline.		Soc/Ec	The scope of impacts on livestock and poultry will depend on type of animal and method of feeding, but since the livestock industry accounts for about 30% of total value of agricultural production, changes will directly affect livestock supply and livestock farm management in Japan.			

[5] Regarding the impacts of climate change, it is important to note that in cases where it is difficult to ascertain the continuous long-term impacts mainly due to improvements in plant varieties, the judgement is made based on short-term climate impacts.

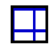
[6] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.

[7] Dry matter weight: A weight obtained after being dried and having water content reduced, that is, the weight of a substance that a plant actually produced and accumulated.

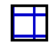
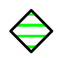
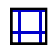
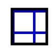
[8] Harvest index: A ratio of the dry matter weight of harvested parts against the total dry matter weight.

Sector	Category	Sub-category	Current status	Projected impacts	Significance			Urgency	Confi-dence	Rationale
						Criteria	Rationale			
		Plant pests and weeds	● The southern green stink bug (*Nezara viridula*) was previously present in warm regions in southwestern Japan (relatively warmer areas such as southern Kyushu), but its distribution has expanded to include a large area from western Japan to parts of the Kanto region, and this has been pointed out to be an impact of warming. ● At present no clear cases have been identified in which there has been an increase in damage from disease due to the impacts of climate change. ● There are cases in which grass weed varieties (*Poaceae*) that grew on the Amami Islands and further south are now able to survive over winter and have invaded Kyushu in recent years.	● As for pests, due to an increase in temperature, an increase is expected in the number of annual generations (number of annual cycles of growth from egg to adult) of parasitic natural enemies, some parasitoids, and pests; and as a result, changes are expected to occur in the composition of rice paddy pests and natural enemies. ● For pests other than rice paddy pests as well, studies have indicated the potential increase of damage due to the northward shift and expansion of the winter survival range and increase in annual generational cycles. ● As for crop damage due to disease, some studies project increases in the occurrence of disease in experiments with higher CO_2 conditions (with 200 ppm increase in concentrations from current levels). ● Studies have pointed out the possibility that the range where some species of weeds may become established will expand and shift northward associated with warming.		Soc/Ec	Regarding the expanded distribution and increased occurrence of disease, pests, and weeds, there may be impacts on crop yields and quality, plus a need to take various control measures such as the application of pesticides; therefore, directly and indirectly, there may be economic losses such as a reduction in farm revenues.			
		Water, land and agricultural infrastructure[9]	● Regarding changes in precipitation that could have an impact on water, land and agricultural infrastructure, analysis of the maximum rainfall amounts in three consecutive days from 1901 to 2000 found a trend for rainfall to fall more intensely over short periods, and that in particular this trend is getting stronger in Shikoku and southern Kyushu. ● Also for the 10-year moving coefficient of variation for annual precipitation, the moving average was found to be increasing year after year, with the trend being progressively larger toward the south. ● High temperature damage to crops has also been observed, e.g., a decline in rice quality, and in response there have been impacts on usage methods of water resources, including changes in rice cropping season and use of irrigation water, as well as the method of irrigation by surface flooding.	● Regarding impacts on water, land and agricultural infrastructure mainly due to water shortages and accelerated snow melt, there are projections for a reduction in runoff from snow melt due to an increase in temperature, with impacts on water intake for agricultural water control facilities such as irrigation canals. Specifically, for the A2 scenario,[10] here is a decreasing trend in almost all regions in runoff during April and May when demand for irrigation water is elevated; responses will likely be needed to address regional and temporal imbalances. ● Regarding impacts on water, land and agricultural infrastructure from flooding due to an increase in intensity of rainfall, the risk of damage to farmland is expected to increase due to longer periods of low-elevation rice paddies being submerged.		Soc/Ec	Large increases are projected for the two extremes of (high and low) water flow rates. Impacts are nationwide, but particularly large in regions that depend on snow melt as a water source; decreased flow rates and changes in the timing of snow melt will have a large impact on paddy field management. Water shortages may affect agricultural irrigation, and there may be other impacts such as soil erosion, as well as poor drainage of lowlands due to an increase in rainfall. Social and economic impacts of both are large. In short, it will be important to pay attention to an increase in frequency of both extremes, including floods and droughts.			
	Forestry	Timber production (e.g., plantations)	● In some areas, there have been reports of declining of cedar tree forests, and some studies have reported that the cause is an increase in water stress as a result of a drier atmosphere. However, there is no clear evidence that the drier atmosphere or increase in water stress of cedar trees is caused by climate change-induced warming or a reduction in precipitation. There is also no clear correlation between the declining of cedar tree forests and an increase in tendency for soil drying. ● At present, examples are limited regarding whether wind damage is increasing in planted forests due to an increase in typhoon strength, so the relationship is not clear.	● Examples have pointed out that the rate of transpiration increases if temperature increases by 3°C above current levels, and the possibility that the vulnerability of cedar tree plantations could increase, especially in areas with low rainfall. ● Examples have projected a decrease in the carbon stocks and carbon sequestration in Japanese cedar tree plantations, assuming current forestry practices continue. ● As well, regarding Japanese cypress seedlings, examples have been inconclusive about any increase in biomass growth due to increases in temperature; other examples have found that the area at risk of pine wilt will expand; others have found that mortality and damage to spruce species will increase due to an increase in the number of annual generations of spruce bark beetles. ● There are concerns about an increase in wind damage in cedar tree and Japanese cypress plantations as forests mature.		Soc/Ec/Env	For major plantation species including Japanese cedar tree, Japanese red pine, Japanese black pine, and Japanese cypress, if impacts occur, their scope will be nationwide (excluding Hokkaido). Such a deterioration and decline in productivity of plantation forests may cause a decline in the ecosystem services of forests, with large consequential impacts on society, economy, and environment. Society: Impacts on livelihoods in hilly and mountainous area communities due to a decline in forest ecosystem services. Economy: Impacts on forestry and tourism. Environment: A decline in ecosystem services of forests (e.g., watershed conservation/water disaster prevention, sediment runoff prevention, flood prevention, biodiversity conservation, carbon sequestration, and scenic beauty/landscape).			

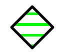
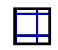
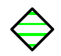
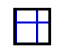
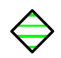
[9] Water, Land and Agricultural Infrastructure: Agricultural land, agricultural irrigation, land improvement infrastructure (e.g., dams, water control structures, agricultural effluent canals)
[10] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 98.

Sector	Category	Sub-category	Current status	Projected impacts	Significance			Urgency	Confi-dence	Rationale
						Criteria	Rationale			
		Non-wood forest products (e.g., mushrooms)	● Regarding the *Hypocreales* genus of fungus, which affects shiitake cultivation, it has been reported that higher summer temperature may increase damage from the *Hypocreales* fungus.	● Regarding shiitake cultivation on bed logs, reports have indicated a correlation between increasing temperature in summer and the occurrence of pathogenic fungi, and a reduction in fruiting (mushroom) of shiitake. ● The impacts of an increase in temperature in winter on shiitake cultivation on bed logs is not clear at present.		Soc/Ec/Env	The value of production of cultivated mushrooms accounts for half the value the forest industry output (in Japan). If there are impacts for bed log-based shiitake cultivation, which accounts for the majority of mushroom production, they will be nationwide in scope. A decline in productivity of shiitake cultivation on bed logs may have large social, economic, and environmental impacts. Society: Impacts on hilly and mountainous area communities that depend on mushroom production, due to a decline in the productivity of bed log-based mushroom production. Economy: Very large economic losses due to a decline in bed log-based mushroom productivity. Environment: A decline in ecosystem services due to a decline in forest management resulting from the collapse of communities.			
	Fisheries	Migratory fishery stocks (e.g., ecology of fishes)	● Around the world there have been reports of shifts in the distribution of marine organisms associated with changes in seawater temperature. ● There have also been reports of shifts in the distribution and migration areas of migratory fishery products in the seas around Japan, such as Japanese amberjack (*Seriola quinqueradiata*, or *buri* in Japanese), Japanese Spanish mackerel (*Scomberomorus niphonius*, or *sawara* in Japanese), and Japanese common squid (also known as Pacific flying squid; *Todarodes pacificus*; or *surumeika* in Japanese), reportedly caused by higher water temperature, and fish catches have declined in some areas.	● For migratory fishery products, there have been many reports on projected impacts relating to changes in distribution/migratory range and body size. The followings are some specific examples. ➢ For chum salmon, under the IS92a scenario,[11] studies have indicated the potential reduction of habitat in waters near Japan, and by 2050 the potential disappearance of suitable water temperature in the Sea of Okhotsk. ➢ For Japanese amberjack, the distribution is predicted to shift northward, along with changes in wintering areas. ➢ For Japanese common squid, under the A1B scenario,[11] marine areas with low distribution density are projected to expand to coastal areas of northern Honshu by 2050, and to Hokkaido coastal areas by 2100. ➢ For Pacific saury (*samma* in Japanese), studies have projected slower growth due to a deterioration of feeding conditions, but there are also predictions that feeding conditions could improve during spawning season due to changes in the migration range, resulting in increased spawning. ➢ For Japanese sardine (also known as pilchard; *maiwashi* in Japanese), studies have projected a northward shift of the distribution of adult fish and sea areas suitable for the survival of larval and juvenile fish, in response to increasing sea surface temperature. ● Regarding changes in fish catches and impacts on local industries, high-precision projections have not been obtained, due to the high level of uncertainty arising from correlation with factors not connected with climate change, such as resource management policies.		Soc/Ec	The scope of impacts is nationwide. Increases or decreases in fish catch, and changes in distribution and fishing grounds, will vary depending on fish species. There are concerns that impacts of increases or decreases in fish catches will be especially large in regions that are home to major fishing ports.			

[11] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.

Sector	Category	Sub-category	Current status	Projected impacts	Significance			Urgency	Confi-dence	Rationale
						Criteria	Rationale			
		Propagation and Aquaculture	● There have been reports of increases in the number of southern fish species and decreases in the number of northern fish species present in many areas. ● For nori seaweed cultivation, the start of seeding has been delayed due to increasing seawater temperature in autumn, and annual harvests are declining in many areas. ● Decreases in catches of Japanese spiny lobster (*Panulirus japonicus*; *isseiebi* in Japanese) and abalone (*awabi* in Japanese) have been reported, due to a deterioration of seagrass beds from algae-eating fish.	● Impact assessments have not been conducted using ecosystem models and climate projection scenarios, but the distribution areas of many commercially-fished species are projected to shift northwards. ● Changes in seaweed species composition and abundance due to increasing seawater temperature are expected to reduce the catches of sea-bottom resources such as abalone. ● Some areas that produce farmed fish are expected to become unsuitable for fish farming due to increasing water temperature in summer. ● An increase in mortality risk to organisms including bivalves is expected due to the occurrence of red tide in connection with increasing seawater temperature. ● In inland waters, a decrease in fish catches of Japanese smelt (*wakasagi* in Japanese) is expected due to high water temperature in lakes. ● IPCC reports have expressed concern about the impacts of ocean acidification on shellfish aquaculture.		Soc/Ec	Impacts are nationwide in Japan. The social and economic impacts will be particularly significant in regions with a high dependency on fisheries industries.			
Water Environment, Water Resources	Water environment	Lakes/ Marshes, Dams (Reservoir)	● Studies of water temperature changes over approximately thirty years (FY 1981 to FY 2007) at 4,477 monitoring stations in public waters (rivers, lakes, and seas) nationwide in Japan found a warming trend at 72% of the stations in summer and 82% in winter, confirming that warming is occurring in many water bodies. Changes in water quality due to increasing water temperature have also been pointed out. ● However, research reports indicate that at present it cannot be stated with certainty that the changes of water temperature are an impact of climate change. ● Meanwhile, some reports also indicate a greater probability of occurrence of blue-green algae if the annual mean temperature exceeds 10°C, and long-term analysis is required in the future.	● In projections using the A1B scenario,[12] Lake Biwa is projected to see a decrease in dissolved oxygen (DO) and deterioration of water quality in the 2030s due to increasing water temperature. ● Studies using the same A1B scenario have confirmed projections of an increase to 21 of the 37 multi-purpose dam reservoirs in Japan being classified as eutrophic water bodies in 2080-2099, with the largest increase in number being in eastern Japan. ● No examples have yet been confirmed regarding specific projections of impacts on lakes/marshes and dam reservoirs accompanied by changes in river flows or increases in frequency and magnitude of extreme weather events due to climate-change-induced changes in the amount of precipitation or the spatial and temporal distribution of precipitation.		Soc/Ec/Env	The scope of impacts is lakes/marshes and dam reservoirs nationwide. Lakes and reservoirs are expected to undergo water quality changes more severely than rivers due to temperature stratification in the water and the impacts on phytoplankton activity, as a result of warmer air and water temperature. Changes in water temperature and water quality of lakes and reservoirs would have enormous impacts on society due to their role as a source of water, and increased water purification costs due to water quality deterioration would have inevitable impacts on the economy. Also, the deterioration and loss of recreational value cannot be ignored. When one also considers impacts on ecosystems, once the water environment has deteriorated, the situation cannot easily be reversed.			
		Rivers	● Studies of water temperature changes over approximately thirty years (FY 1981 to FY 2007) at 4,477 monitoring stations in public waters (rivers, lakes/marshes, and seas) nationwide in Japan found a warming trend at 72% of the stations in summer and 82% in winter, confirming that warming is occurring in many water bodies. Changes in water quality due to increasing water temperature have also been pointed out. ● However, increasing river water temperature can also be affected by factors such as urban activities (artificial exhaust heat and wastewater) or reductions in river flow, so it is necessary to quantitatively analyze the magnitude of impact of climate change.	● Future projections have not been done for water temperature in each river, although one projection for future temperature changes in the Omono River (Akita Prefecture) using the A1B scenario[12] showed an increase in water temperature to 12.4°C in 2030-2039 compared to 11.9°C in 1994-2003, with impacts being the highest in winter. ● Studies using the same A1B scenario have projected an 8 to 24% increase in suspended sediments for all of Japan by 2090; the largest increase in the amount of suspended sediments being in September due to an increase in extreme weather events such as typhoons; and a 1 to 20% increase in river flow and a 1 to 30% increase in sediment production if August precipitation increases by 5 to 75%.. ● Other projections include lower levels of dissolved oxygen due to increases in water temperature, organic matter decomposition and enhanced nitrification by microorganisms associated with dissolved oxygen consumption, and an increase in abnormal odors and taste due to an increase in algae.			The scope of impacts is nationwide and includes problems with turbidity, but for the risks of changes in temperature and quality of river water arising from climate change, magnitude and scope of impacts are considered to be limited in terms of all aspects (social, economic, and environmental impacts).			

[12] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 98.

Sector	Category	Sub-category	Current status	Projected impacts	Significance	Significance: Criteria	Significance: Rationale	Urgency	Confi-dence	Rationale
		Coastal areas and Closed sea areas	● From analysis of sea surface temperature data (1970s to 2010s), a significant increasing trend has been reported at 132 of 207 sites nationwide (ave. 0.039°C/year, min. 0.001°C/year, max. 0.104°C/year). It is important to note that there may be anthropogenic impacts at some of the measurement sites where this increasing trend was observed. ● There are also other research reports stating that no significant warming or cooling trend was observed in seawater temperature in coastal areas around the island of Okinawa.	● Although examples making quantitative projections have not yet been confirmed at present, it is expected that there will be an expansion of areas affected by salt water intrusion in coastal areas due to sea-level rise.			The scope of impacts affects marine waters (coastal areas and closed sea areas) nationwide, and there are concerns about a reduction in oxygenation, and impacts on seaweed and seagrass beds due to an increase in influx of contaminants from rivers, as well as impacts of water quality deterioration due to combined sewer overflow. However, considered from the perspective of losses of human life and property, and environmental and ecological functions, the extent and scope of impacts are considered to be limited.			
	Water resources	Water supply (Surface water)	● Year-to-year fluctuations in annual precipitation have increased, and there have been confirmed examples of water restrictions being implemented for reasons such as extended periods with little or no rainfall. ● Although snow melt tended to come earlier in alpine areas from 1980 to 2009, the annual variation from watershed to watershed is large. ● No examples have been confirmed at present regarding the impacts of drought on water to maintain the normal functions of river flow, and expansion of the extent of seawater (salt water) intrusion at river estuaries due to sea-level rise.	● A study using the A1B scenario[13] projects an increase in severity of drought starting in the near future (2015-2039) excluding in northern Japan and central mountain areas. In addition, a reduction of river flow during periods of water demand is projected to result from an earlier snow-melt season, and as a result, mismatches between water supply and water demand. ● Besides this, although no examples making quantitative projections have been confirmed at present, there are concerns that include the impacts of drought on water to maintain the normal functions of river flow, and disruptions to water intake due to seawater (salt water) intrusion at the river estuaries due to sea-level rise.		Soc/Ec	Large increases are projected for the two extremes including (high and low) flow rates. Impacts are nationwide, but particularly large in regions that depend on snow melt for water resources; decreased flow rates and changes in the timing of snow melt will have a large impact on paddy field management. Water shortages may have impacts in many sectors, including municipal water supplies, agricultural water, and industrial water, so social and economic impacts could be large. It will be important to pay attention to increased frequency of occurrence of extreme events such as flood and drought.			
		Water supply (Groundwater)	● At present, no concrete examples have been confirmed regarding the current state of changes in groundwater levels associated with climate change-induced changes in precipitation amounts and precipitation trends over time. ● Generally speaking, changes in the amount of groundwater usage can also be related to factors other than climate change. ● Ground subsidence is occurring in some areas due to excessive groundwater intake during years or periods with little rain (e.g., 1994, a year of drought nationwide). ● At present, no concrete examples have been confirmed regarding the current status of salinization of groundwater due to sea-level rise.	● Regarding changes in groundwater levels associated with changes in precipitation amounts and precipitation trends over time due to climate change, some examples have examined specific areas, but there are challenges with refinement of assessment approach. ● At present, no concrete examples have been confirmed regarding an increase in groundwater use and the occurrence of ground subsidence associated with drought. ● Although examples making quantitative projections have not yet been confirmed at present, there are concerns that salinization of groundwater and impacts of water intake due to sea-level rise. The impacts on water sources of groundwater salinization are expected to be not particularly high, because rivers are a major source of water for irrigation and for Japan's large cities situated on alluvial plains. However, there are concerns that municipalities that rely on groundwater will be significantly affected by salinization.			The scope of impacts is nationwide. Regions that rely on groundwater as a water source will have social and economic impacts. However, Japan's large cities situated on alluvial plains use surface water as a major water source, and irrigation largely relies on river water. Thus, it is expected that the impacts of salinization of groundwater on water sources will not be particularly significant.			
		Water demand	● As for the relationship between increasing temperature and water usage, it has been shown that water usage in Tokyo does increase in response to increasing temperature. ● In the agricultural sector, there have been impacts on water demand as a response to high heat damage, including changes in the timing of rice planting and use of irrigation water, as well as use of irrigation by surface flooding.	● Although no examples have been confirmed regarding the impacts of climate change with quantitative projections, there are concerns about an increase in demand for drinking water due to an increase in temperature. ● A reduction in potential water resources is projected in the 2030s in Kyushu due to an increase in evapotranspiration from paddy fields, and in other areas as well, it is expected that there will be an increase in demand for agricultural water due to an increase in temperature.			The scope of impacts is nationwide. Impacts are expected for both agricultural water and domestic water. In particular, this could be a factor causing persistent vulnerability or exposure for regions that use a large amount of water for crop cultivation, or for welfare and medical facilities as well as other public facilities that require a reliable supply of water. However, there is not sufficient evidence at present to judge the significance of these impacts as particularly large or high.			

[13] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.

Sector	Category	Sub-category	Current status	Projected impacts	Significance		Significance: Criteria	Significance: Rationale	Urgency	Confidence	Rationale
Natural ecosystems[14]	Terrestrial ecosystems	Alpine/Sub alpine zones	● Deterioration and shifts in distribution of vegetation in alpine and sub-alpine zones have been reported, due to factors such as an increase in temperature and earlier snow melt. ● Gaps (changes in phenological interrelationships) have also been reported between alpine plants and activity periods of pollinator insects due to earlier flowering of alpine plants and shorter flowering time.	● For plant species in alpine and sub-alpine zones, suitable habitats are projected to change or shrink. For example, the area of suitable habitat for the Japanese stone pine (*haimatsu*) is projected to be reduced by the end of the 21st century compared to the present. ● In some regions, the disappearance of populations of alpine plants is projected to occur due to earlier snow melt. ● Other projections include more competition between plant species, with enhanced growth of alpine plants due to a warmer growing season, as well as other changes to vegetation such as the expansion of distribution for shrub species.	Ecosystems	●	Env	The scope of impacts extends to mountainous regions nationwide. Constraints on plant migration to higher altitudes and latitudes are one factor of persistent vulnerability with respect to the said impacts. In addition, a shortening of the snow cover duration can result in dryer soil, resulting in rapid vegetation changes and the deterioration or disappearance of snow fields and higher moors. These factors can lead to the disappearance of rare species, habitats, biodiversity, and landscapes. In addition, there is a high likelihood that warming and earlier snow melt will significantly alter the phenology of alpine plant communities, thereby increasing the occurrence of frost damage and altering biological interactions.	●	▲	Details of assessment of urgency: Timing of impacts: High Timing needed to initiate adaptation measures and make critical decisions: High
					Services[15]	–		It is difficult to assess the impacts on ecosystem services (e.g., recreational uses, watershed conservation, land conservation) from changes in distribution of plants in alpine and sub-alpine zones, or from the disappearance of alpine plants, as no reports making projections or assessments have been confirmed at present.	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
		Natural forests / Secondary forests	● Regarding the current status of climate change-induced displacement and expansion of suitable habitat for natural forests and secondary forests, at present, confirmed examples are limited. ● It is considered to be likely that in some places, evergreen broad-leaved forest has replaced what was previously deciduous broad-leaved forest, due to an increase in temperature.	● The suitable habitats of many of the component species of cool temperate forests are projected to shift to higher latitudes and higher altitudes, resulting in the reduction of suitable habitat. In particular, it has been shown that the area of suitable habitat for beech forests (*buna*) will be reduced by the end of the 21st century compared to the present. ● The suitable habitats of many of the component species of warm temperate forests are projected to shift to higher latitudes and higher altitudes, resulting in the expansion of suitable habitat. ● However, there are many factors of uncertainty. For example, there are also projections for the shrinking of actual distribution, due to terrain factors, land use, and constraints on the expansion of distribution.	Ecosystems	●	Env	The scope of impacts is nationwide. In particular, in areas west of central Honshu, there is a high likelihood that suitable habitats for cool temperate component species will shrink or disappear. In addition, the fragmentation and isolation of habitats and low ability for plants to migrate (low speed of migration) are among the elements of persistent vulnerability with respect to the said impacts. These impacts can lead to disappearance of important species, habitats, and landscapes, so the significance on the environmental dimension is high.	▲	●	Details of assessment of urgency: Timing of impacts: Medium Timing needed to initiate adaptation measures and make critical decisions: Medium
					Services	–		It is difficult to assess the impacts on ecosystem services (e.g., recreational uses, water source conservation, land conservation) from shifts in the distribution of plants in natural and secondary forests, as no examples making projections or assessments have been confirmed at present.	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.

[14] Natural ecosystems provide the foundations for human livelihoods and a variety of industries, so it is important to conserve them, including the benefits humans gain from ecosystems (i.e., ecosystem services).
The impacts of climate change in this sector are broadly divided into two dimensions: impacts on natural ecosystems themselves, and impacts on ecosystem services. Thus, the assessments in this sector for significance, urgency, and confidence are divided into "impacts on ecosystems" and "impacts on ecosystem services (impacts on people's livelihoods)."
Regarding climate change impacts on ecosystem services, few existing examples have been published yet in general, so it is currently difficult to assess these impacts. However, this does not mean that the significance of impacts on ecosystem services is low. In the future it will be important to encourage research in this area.
As for the sector of natural ecosystems, although the impacts are subject to be found earlier, there are ultimately limitations on what can be done in terms of adaptation measures, and in some cases the only measures may be to try to limit climate change (i.e., through mitigation). In such cases, it is difficult to assess urgency from the perspective of "timing to need undertaking adaptation and important decision-making" so assessment is only done from the perspective of "timing of impacts."

[15] Ecosystem services: Benefits (e.g., food, water, climate stability) that humans obtain from ecosystems and the involvement of a large diversity of organisms. The Millennium Ecosystem Assessment (2005) conducted under the auspices of the United Nations provides four categories: "provisioning services" (e.g., the provision of food and water, timber, fiber, and medicinal resources), "regulating services" (e.g., water purification, climate regulation, natural disaster prevention and damage mitigation, disease/pest suppression by the existence of natural predators), "cultural services" (e.g., the provision of spiritual and religious values, aesthetic values including natural landscapes, and recreational places), and "supporting services" (e.g., nutrient cycling, soil formation, the supply of oxygen through photosynthesis).

Sector	Category	Sub-category	Current status	Projected impacts	Significance				Urgency	Confi-dence	Rationale
							Criteria	Rationale			
		Countryside-landscape ("Satochi-Satoyama")	● At present, there have been no comprehensive examples of the current status of climate change-induced changes in the component species of Japanese countryside landscape systems. ● It has been pointed out that Japanese oak wilt and the expanded distribution of bamboo in some regions may also be climate change-induced impacts, but this has not been scientifically proven.	● Some studies project small impacts of climate change in natural grassland vegetation zones[16] in the warm temperate zone or further south. Suitable habitat of secondary forests of "satoyama" landscapes including looseflower hornbeam (*Carpinus laxiflora; akashide in Japanese*) and Asian hornbeam (*Carpinus tschonoskii; inushide in Japanese*) may shrink in low mountain elevations and in southwest Japan. ● However, there is currently not sufficient evidence regarding climate change impacts on satochi-satoyama ecosystems, so more research is needed in the future.	Ecosystems	◇		It cannot be assumed that future climate change impacts will be particularly high, the limited research and reporting does not provide evidence of impacts, and secondly, satochi-satoyama ecosystems themselves were formed especially through human intervention.	△	□	Details of assessment of urgency: Timing of impacts: Medium Timing needed to initiate adaptation measures and make critical decisions: Medium
					Services	–		It is difficult to assess impacts on ecosystem services due to changes in satochi-satoyama ecosystems. Some studies have reported a reduction in suitable habitat for some species of the most sensitive wild edible plants, but no examples making projections or assessments have been confirmed at present.	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
		Planted forests	● There have been reports of degeneration of cedar tree forests in some areas due to increases in water stress caused by an increase in temperature, as well as changes in the spatial and temporal distribution of precipitation.	● Particularly in areas with low precipitation, greater vulnerability of cedar tree plantations has been projected due to an increase in annual transpiration[17] if temperature increases by 3°C above the current level, but only a small ratio of land area would become unsuitable for growing. ● A projection of impacts by 2050 using MIROC3.2-hi (A1B scenario)[18] for all of Japan found a negative effect on the carbon stock and amount of sequestration, based on the high proportion of plantations (which are high in forest respiration) in Shikoku and Kyushu, and on the large proportion of 40- and 50-year-old stands, which represent a large forest stock and amount of respiration. However, that projection did not take into account the impacts of increasing CO_2 concentrations in the atmosphere. Further research is needed regarding the physiological responses of trees to project impacts on cedar tree plantation ecosystems. ● An expansion of the area at risk of pine wilt disease has been projected if the temperature increases by 1 to 2°C above the current level. There are concerns that along with pine wilt, there could also be damage to areas engaged in Japanese red pine (*akamatsu*) forestry and that produce pine mushrooms (*matsutake*).	Ecosystems	●	Env	The scope of impacts is nationwide. Particularly in areas with low precipitation, there could be greater vulnerability of cedar tree plantation ecosystems, with impacts on the landscape of entire watershed.	△	△	Details of assessment of urgency: Timing of impacts: Medium Timing needed to initiate adaptation measures and make critical decisions: Medium
					Services	–		It is difficult to assess the impacts on ecosystem services from reduced capacity to suppress soil erosion due to changes in planted forests, as no examples making projections or assessments have been confirmed at present.	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
		Damage from wildlife	● Longitudinal comparative research of sika deer (*Cervus nippon*) and wild boar nationwide in Japan has confirmed an expansion of their distribution. ● It has been confirmed that their wintering range have expanded to higher elevations due to a decrease in snow depth ● An increase in sika deer populations has been attributed to complex factors, including a reduction in pressure from hunting, changes in land use, and a reduction in snow depth. ● Feeding damage and bark-stripping damage due to expanded distribution of sika deer have been reported. ● Impacts on ecosystem services due to expanded distribution of wildlife have been reported, but no direct causal relationship with climate change and the degree of contribution of climate change have yet been clarified.	● An increase in temperature and shorter snow cover duration have been projected to expand the habitat of sika deer and other wildlife, but only a small number of examples has been confirmed, so further research is needed in the future.	Ecosystems	●	Env	Feeding and bark-stripping damage due to expanded distribution of sika deer have been reported. The scope of impacts is nationwide, and the impacts can lead to changes for important species, habitats, and landscapes. The impacts include damage to agricultural and forestry industries, as well as a reduction in soil, water and ecosystem functions over large areas. Climate changes impacts are expected, verification examples are limited.	●	–	Details of assessment of urgency: Timing of impacts: High Timing needed to initiate adaptation measures and make critical decisions: High
					Services	–		It is difficult to assess the impacts on ecosystem services (including damage to crops and forest trees and soil runoff from the expansion of wildlife habitat), as no examples making projections or assessments have been confirmed at present.	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.

16 Vegetation zones: Distribution of vegetation in zones as determined by factors such as climatic zone and elevation.
17 Transpiration: The amount of water vapor released into the atmosphere from the above-ground portion of a plant.
18 For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.

Sector	Category	Sub-category	Current status	Projected impacts	Significance		Criteria	Rationale	Urgency	Confi-dence	Rationale
		Material balance[19]	● Regarding the current status of impacts on material balance associated with climate change, at present, examples are limited. ● Regarding soil GHG flux[20] in the forests of Japan, there has been a confirmed increase in CO_2 and N_2O released between 1980 and 2009, as well as an increase in CH_4 absorption. ● Changing trends in the spatial and temporal distribution of precipitation may have impacts on the water balance and sediment dynamics of forests, but the lack of long-term data makes it difficult to ascertain the status of changes.	● Increases in annual mean temperature and lengthening rainless periods may result in the reduction of moisture content in forest soils, leading to drying of surface soil, then more runoff of fine sediment and prolonged time to reduce turbidity, and ultimately, to shorter rainfall-runoff response times.[21] However, these are inferences based on circumstantial evidence, so further consideration is needed. ● For forest soil carbon stocks, A1B scenario[22] projected a 14% increase in net primary production[23] and a 5% decrease in soil organic carbon.	Ecosystems		Env	The scope of impacts is nationwide. Also, besides material balance being important as a basis of ecosystems, soil formation requires long periods of time, and these are elements of persistent vulnerability with respect to the said impacts.			Details of assessment of urgency: Timing of impacts: Medium Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
					Services	–		Regarding impacts on ecosystem services from changes in the material balance of forests, no examples making projections or assessments have been confirmed at present.	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
	Freshwater ecosystems	Lakes / Marshes	● Lake and marshes ecosystems are affected by the nutrient loads from land uses in their watersheds, making it difficult to isolate the impacts of climate change, and no studies in Japan have yet revealed any direct impacts of climate change. ● However, in Lake Ikeda (Kagoshima Prefecture), it has been confirmed that the circulation period has completely disappeared due to the warm winters, dissolved oxygen at the lake bottom has decreased, and an oxygen deficiency trend is evident.	● Although no examples making quantitative projections of impacts in Japan have been confirmed at present, for deep lakes where eutrophication is occurring, there are concerns about interruption of vertical circulation in lakes and oxygen deficiency due to increases in water temperature, as well as the resulting impacts on benthic organisms, including shellfish, and further eutrophication. ● Laboratory experiments have shown that increases in lake water temperature and CO_2 concentrations reduce the growth of zooplankton.	Ecosystems		Env	Lakes and marshes are known to have unique biota, and their constituents are constrained by geological history and topographical factors. Moreover, lakes and marshes could be described as very vulnerable ecosystems, as they are closed systems compared to rivers, and populations have difficulty to change their habitat area due to climate change. Therefore, the impacts of climate change extend to lakes and marshes nationwide and could lead to the loss of important species, habitats, and landscapes. Also, many lakes and marshes and surrounding areas have transformed over time, being used by people, sustained by water flowing in from a watershed, and also receiving sediment and nutrient loads. Thus, if changes occur to the water and material circulation due to climate change, there is high likelihood for many living species to be affected.			Details of assessment of urgency: Timing of impacts: Medium Timing needed to initiate adaptation measures and make critical decisions: Medium
					Services	–		It is difficult to assess the impacts on ecosystem services, as no examples making projections or assessments have been confirmed at present.	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.

[19] Material balance here refers to the circulation (inflows, outflows) of materials (e.g., carbon, nitrogen) in ecosystems.
[20] Soil GHG flux: Releases and absorption of greenhouse gases originating from soil.
[21] Shorter rainfall-runoff response times: The amount of time elapsed from the start of rainfall to the time it is discharged into a river or stream.
[22] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.
[23] Net primary production: Value calculated from total primary production (carbon sequestration by plant photosynthesis) in one year minus carbon emissions from respiration.

Sector	Category	Sub-category	Current status	Projected impacts	Significance		Significance: Criteria	Significance: Rationale	Urgency	Confi-dence	Rationale
		Rivers	● Because water intake and flow control is conducted on Japan's rivers, it is difficult to detect impacts of climate change on river ecosystems, and no research results on direct impacts of climate change have been confirmed at present.	● If the maximum water temperature increases by 3°C above current levels, the total area in Japan that can support cold-water fish is projected to decrease to about 20% of the current area, and the habitat especially on the island of Honshu would become extremely limited. ● Also, no examples with quantitative projections have been confirmed at present, the followings are some of the impacts that could be expected. ➢ Impacts on river biota that move upstream, move downstream, and spawn, timed with snow-melt runoff, which depends on changes in the timing and magnitude of snow cover and snow-melt runoff. ➢ Impacts on river bed environment by constituents of turbidity due to increases in frequency of large floods caused by changes the spatial and temporal distribution of precipitation, and related to that, impacts on fish, benthic organisms, attached algae, and other creatures. ➢ Impacts on river organisms due to increases in water temperature caused by drought, and by a reduction in dissolved oxygen.	Ecosystems	●	Env	The impacts of global warming extend nationwide, but they are expected to be more pronounced in small mountain streams upstream in watersheds, where the flow rate is limited and there is a close relation with temperature. In addition, individuals of eggs and young populations, are believed to be vulnerable to increases in water temperature. In the face of increases in water temperature and other changes in the habitat environment, fish species are likely to attempt migrating to suitable habitat upstream, but in the case of Japan, some species are distributed in isolated mountain areas, and in many cases the continuity is interrupted by dams and weirs, making migration difficult. It is expected that, compared to fish, impacts will be small on insects that can fly at the adult stage (e.g., aquatic insects).	▲	■	Details of assessment of urgency: Timing of impacts: Medium Timing needed to initiate adaptation measures and make critical decisions: Medium
					Services	–		There are also concerns about impacts on ecosystem services such as fish biomass, but no research and reports have been confirmed at present.	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
		Marshlands	● Marshland ecosystems are strongly affected by anthropogenic impacts other than climate change, and no examples have directly addressed the impacts of climate change at present. ● In some marshlands, it has been pointed out that a drying-out of marshlands may have resulted from a reduction in rainfall, a decrease in humidity, and a reduction in snow depth due to climate change.	● Although no examples with quantitative projections have been confirmed at present, the followings are some of the possible impacts that could be expected. ➢ Impacts on marshlands in Hokkaido, which account for about 80% of the area of all marshlands in Japan. ➢ Impacts of a reduction in precipitation and lower groundwater levels on plant communities (sphagnum) in high marshlands that are nourished by rainwater. ➢ Transition from marshlands herbaceous communities to woody plant communities in low marshlands due to watershed loads (sediments and nutrients) caused by climate change; and increases in evapotranspiration.	Ecosystems	●	Env	Marshland ecosystems consist of unique biota and are sustained and strongly affected by topographical factors. Therefore, marshland plants could be described as ecosystems very vulnerable to climate change, as similar to species that make up forests, they cannot easily change their habitat in the lateral or vertical direction to respond to climate change. Also, many marshland ecosystems, especially low-marshland, are sustained by water flowing in from the surrounding watershed, and have been transformed over time while receiving sediment and nutrient loads. Thus, if changes occur to the water and material circulation due to climate change, there is high potential for many living species to be affected.	▲	■	Details of assessment of urgency: Timing of impacts: Medium Timing needed to initiate adaptation measures and make critical decisions: Medium
					Services	–		It is difficult to assess the impacts of climate change on ecosystem services, as no examples making projections or assessments have been confirmed at present.	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
	Coastal ecosystems	Subtropics	● In the Okinawa region, there has been an increase in the frequency of bleaching of subtropical coral due to increasing seawater temperature. ● The distribution of temperate coral in the Pacific Ocean has been moving northward in areas south of the Boso Peninsula and along the west and north coasts of Kyushu.	● A study using the A2 scenario[24] projects a reduction to half of the current sea area suitable for the growth of reef-building coral in the tropics and subtropics by 2030, and disappearance by 2040, due to increasing seawater temperature and ocean acidification. In waters away from areas most suitable for growth, an increase in bleaching	Ecosystems	●	Env	Changes would occur in the growth and distribution of coral itself, resulting in significant impacts on many organisms and ecosystems that depend on coral reefs for habitat.	●	▲	Details of assessment of urgency: Timing of impacts: High Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.

[24] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.

Sector	Category	Sub-category	Current status	Projected impacts	Significance		Significance: Criteria	Significance: Rationale	Urgency	Confi-dence	Rationale
			● Laboratory experiments have pointed out the possibility that the amount of calcification is decreasing in some reef-building coral species.	and other stresses is projected, as well as a reduction in calcification, but no projections have been done regarding whether or not these will result in the complete disappearance of existing coral reefs situated away from the optimal waters. ● Ecosystems in mangroves are also unique in subtropical coastal areas. There are reports that they will not grow in some locations if they cannot cope with a rapid pace of sea-level rise, but the reports only assess their capacity for carbon sequestration, and any projections about future changes in ecosystems are limited to qualitative discussions. ● It is expected that the impacts on various resources in coral reef areas (including tourism resources and marine resources) in subtropical areas will be significant. Meanwhile, where subtropical coral extends northward into the temperate zone, there may be positive impacts on these resources with the northward migration of coral.	Services	–		Impacts on various resources in coral reef areas (including tourism resources and marine resources) in subtropical areas will be significant. Meanwhile, where subtropical coral extends northward into the temperate zone, there may be positive impacts for tourism with the northward migration of coral. However, it is difficult to assess the impacts on ecosystem services, as no literature could be found that makes projections such as impacts on recreational uses, and increases or decreases in fish biomass.	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
		Temperate / Subarctic[25]	● In various places along the coast of Japan, a transition has been confirmed to be underway from cool-temperature to warm-temperature species accompanied by increasing seawater temperature. ● It is reportedly difficult to determine at present whether or not the changes already occurring in marine ecosystems are a result of ocean acidification.	● With increasing seawater temperature, it is expected that there will be a shift toward warm-water species, for example, in the case of sea urchins, from *Strongylocentrotus intermedius* (*ezobafununi* in Japanese) to *Strongylocentrotus nudus* (*kitamurasakiuni*), and this may lead to impacts on entire ecosystems, but quantitative examples are limited.	Ecosystems		Env	It is expected that a shift will occur from cool-water species toward warm-water species, for example, in the case of sea urchins, from *Strongylocentrotus intermedius* (*ezobafununi* in Japanese) to *Strongylocentrotus nudus* (*kitamurasakiuni*), and this may lead to impacts on entire ecosystems.			Details of assessment of urgency: Timing of impacts: High Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
				● As for the impacts of ocean acidification, for medium to high CO_2 emission scenarios, it is thought that there will be considerable risk to highly vulnerable marine ecosystems in particular, such as ecosystems in polar regions and coral reefs. Coral reefs have many species that are sensitive to impacts, such as mollusks and echinoderms that have calcium carbonate skeletons and shells, and as a result, there may be negative impacts on species that are fisheries resources. Also, the situation is complex due to interactions between factors occurring simultaneously, such as increasing water temperature and a reduction in oxygenation, so the impacts may be amplified. ● There are also concerns that changes in coastal ecosystems could impact species that are resources for coastal fisheries. It is expected that there could also be impacts on local culture, as in many cases fishing communities depend on coastal scenery and fisheries harvest species such as seagrass beds. ● Sea-level rise is expected to have impacts on salt marshes in coastal areas.	Services	–		Changes in coastal biota are directly associated with changes in species being harvested in coastal fisheries. There could also be impacts to local culture, as in many cases fishing communities depend on coastal scenery and fisheries harvest species such as seagrass beds. However, it is difficult to assess the impacts on ecosystem services, as no literature could be found that makes projections such as impacts on scenery and culture	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.

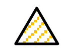
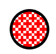
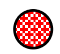
[25] Please refer to the section on fisheries for more details about the impacts on coastal fisheries.

Sector	Category	Sub-category	Current status	Projected impacts	Significance		Criteria	Rationale	Urgency	Confi-dence	Rationale
	Marine ecosystems[26]		● In the sea around Japan, particularly in the Oyashio Region and mixed water region, phytoplankton biomass and primary productivity may have begun to decline. However, opinion has not converged on a unified view.	● Along with climate change, changes may also occur with phytoplankton biomass. Globally, it is projected to decrease in tropical and subtropical waters and projected to increase in subarctic waters, but models for the sea around Japan have low reliability, making it difficult at present to project future changes. As well, for projections about changes in the biomass of zooplankton, the reliability of projections for the sea around Japan is not high. Moreover, it is difficult at present to project the impacts of changes in each region, caused by above changes.	Ecosystems	●	Env	Marine ecosystems account for 70% of area of all ecosystems on Earth, so it is essential to maintain their biodiversity and ecosystem functions. Through the food chain, changes in the low primary productivity stage in these ecosystems have a broad range of impacts on entire ecosystems.	▲	⊞	Details of assessment of urgency: Timing of impacts: Medium Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
					Services	●	Soc	Changes in the biomass of food organisms for fishery resources could also have significant potential impacts on fish biomass. Marine ecosystems, including the level of zooplankton and phytoplankton, do not have special importance from the perspective of human society. Only their distribution changes, and the risk of species extinction cannot be described as being high. However, for cold-water coral and other organisms that live in special environments such as ice edge ecosystems or on continental slopes or other areas where anoxia could occur, the risk of extinction cannot be described as being low.	–	⊞	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
	Phenology[27]		● Many reports have been confirmed regarding changes in the phenology of flora and fauna, such as earlier flowering of plants and earlier initiation of calling by animals.	● Impacts for a variety of species are projected as a result of changes in phenology, such as earlier flowering of the Yoshino cherry tree (*Prunus yedoensis; someyoshino* in Japanese). ● The impacts are not limited to individual species, but various interactions between species are also expected.	Ecosystems	◆		The scope of impacts is nationwide. In addition, the timing of a broad range of biological phenomena could be advanced or delayed due to the impacts of climate change. It has been projected that the impacts of climate change will differ between species and biological phenomena and that this can also lead to changes in interactions between organisms. These changes have also been observed in reality. Such changes could have negative impacts on ecosystem services and the survival of species and populations. However, at present, there is not sufficient material available to assess the severity of those impacts.	●	●	Details of assessment of urgency: Timing of impacts: High Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
					Services	–		Regarding impacts on ecosystem services from changes in phenology due the impacts of climate change, no reports making projections or assessments have been confirmed at present.	–	–	Details of assessment of urgency: Timing of impacts: Cannot currently be assessed. Timing needed to initiate adaptation measures and make critical decisions: Cannot currently be assessed.
	Shifts in distribution and populations	Native species	● Regarding organisms such as insects, there have been confirmed cases of changes in life cycles and shifts in distribution and their life cycles that could be explained as impacts of increases in temperature due to climate change, including expansion of northern limits of distribution to higher latitudes. However, a variety of factors other than climate change could also be involved, so it is difficult to show to what extent the observed changes are a result of climate change. ● No examples relating to the invasion and settlement of invasive alien species due to climate change have been confirmed at present.	● Climate change is expected to lead to the extinction of certain species by causing shifts in species distribution and changes in their life-cycles, by causing further adverse impacts from changes in inter-species interactions due to species migration or localized extinction, and by species being unable to shift to keep up with climate change due to fragmentation of habitat. With an increase of temperature more than 2°C by 2050, it is projected that more than 30% of all species on earth would be at risk of extinction. ● Although no examples making quantitative projections	Ecosystems	●	Env	Rapid climate change has the potential to lead to the extinction of many species, whether through direct or indirect effects. Research has been conducted to estimate the probability of extinction based on projections of climate-change-induced changes to livable habitats and area for individual species; it has projected serious impacts, including expectations that in some conditions there is a risk that over 30% of species could go extinct.	●	●	

[26] This section does not deal with organisms such as fish or cetacean species. Some of them are covered in "Migratory fishery products (e.g., ecology of fishes)" under "Fisheries."
[27] The term phenology refers to the responses of fauna and flora to seasonal changes such as temperature and sunlight. Note that this category mainly discusses ecosystem impacts and ecosystem services (excluding phenology perceived by people in their lives, so-called "sense of season"), while "Life with sense of culture and history" in the section on "Life of citizenry, Urban Life" deals mainly with phenology related to human life and culture.

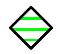
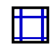
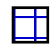
Sector	Category	Sub-category	Current status	Projected impacts	Significance		Significance: Criteria	Significance: Rationale	Urgency	Confidence	Rationale
			● Impacts on ecosystem services due to expanded distribution of wildlife have been reported, but any direct causal relationship with climate change and the degree of contribution of climate change have not yet been clarified.	have been confirmed at present, it is expected that there would be a higher probability of invasion and settlement of invasive alien species due to climate change. ● The habitat for wildlife species such as sika deer (*Cervus nippon*) is expanding, but regarding the question of whether climate change would further expand their habitat, only a small number of examples has been confirmed, so further research is needed in the future.	Services	—		Species extinctions and shifts in species distribution could also have economic and social impacts.	—	—	
					Invasive alien species: Ecosystems	●	Env	There are concerns about the serious impacts if invasive alien species become established, but if the probability of invasion and establishment increases due to climate change, it is necessary to consider this as a serious issue, due to the seriousness of invasive alien species spreading. With increasing movement of humans and goods in the world, the invasive pressure of alien species is already at a high level, making this a factor of persistent vulnerability.	●	△	
					Invasive alien species: Services	—		Regarding impacts on ecosystem services, including impacts on society and economy due to changes in distribution of invasive alien species due to climate change, no examples making projections or assessments have been confirmed at present.	—	—	
Natural disasters, Coastal areas	Rivers	Floods	● Analysis of past rainfall data for heavy rainfall events that occur relatively frequently reveals an increasing trend over time in the frequency of occurrence. There is not yet a sufficient scientific basis to say that this trend is due to climate change. ● The total inundation area has been on a decreasing trend over time. Progress with water induced disaster reduction measures can be cited as a key factor to explain this trend. However, the cost of damage per unit of inundation area is on an increasing trend. ● The degree of safety against water disaster due to water disaster prevention improvements at present is considerably below the planned design level, even based on current climate conditions. ● Japan is still vulnerable to water damage from floods, so if climate change results in more severe rainfall conditions, the impacts may become considerably high.	● Many published studies are consistent with the view that, according to future projections such as the A1B scenario,[28] heavy rainfall events that can cause floods in typical river basins in Japan will increase significantly by the end of the 21st century compared to the present, and rainfall amounts of the same frequency will increase by an order of 10 to 30%. ● Regarding the increasing ratio of rainfall amounts causing floods, multiple published studies have indicated an increase (amplification) in the ratio of increase of flood peak flow and probability of occurrence of floods. It is expected that the degree of increase of probability of occurrence of flooding will be significantly larger than the degree of increase of flood peak flow. ● If the frequency of flooding occurrence in areas protected by river levees from flood increases significantly, the likelihood of water disasters increases significantly. ● In low-lying coastal areas, it is expected that sea-level rise will lead to an increase in likelihood of floods and longer periods of inundation due to flooding. ● Climate models are an important factor in determining reliability of future projections, so to improve that reliability it will be necessary to improve the spatial resolution to reproduce phenomena, and also increase the number of computational cases.		●	Soc/Ec/Env	The scope of impacts extends nationwide, and if they occur, they will become normalized. Likelihood of occurrence of impacts is high. The impacts have an aspect of irreversibility, because water disasters (including human losses) can occur, and depending on the scale of disaster, basic functions could be paralyzed for a long period of time in the disaster area. An area where floods has the likelihood of occurring has a persistent vulnerability to that risk, it is difficult to equip the area with significant water disaster prevention functions under the normal land uses, so it is persistently exposed to that risk. The scale and frequency of extensive social, economic, and environmental impacts increases due to water disasters caused by floods and inundation (including the associated deposition/accumulation of soil, sand, wood, and waste materials).	●	●	

[28] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.

Sector	Category	Sub-category	Current status	Projected impacts	Significance			Urgency	Confi-dence	Rationale
						Criteria	Rationale			
		Inland waters	● Analysis of historical rainfall data for heavy rainfall events that occur relatively frequently reveals an increasing trend over time in the frequency of occurrence, and there has been a significant increase over the past 50 years in the intensity of rainfall concentrated over short durations with an annual probability of exceedance of 1/5 and 1/10. There is not yet a sufficient scientific basis to say that these trends of change are due to climate change. ● The degree of safety against water disasters, achieved by sewer system improvements at present is considerably short of planned targets, even based on current climate conditions. ● Increasing frequency and intensity of intense rainfall concentrated over short durations may contribute to the more frequent inland water damage that has occurred in recent years in urban areas where only a low level of measures against inundation has been achieved.	● Estimates of the climate change impacts of localized intense rainfall events are not yet sufficiently advanced, as it is difficult to obtain fine resolution and to model weather disturbances that cause localized intense rainfall. ● Literature has indicated the likelihood of an increase in the amount of rainfall in short durations over the next 50 years, by extrapolating past trends in heavy rainfall events and other trends over the past 50 years; this literature has provided useful information about the likelihood of future increases in heavy rainfall events that cause damage to inland flooding. ● In low-lying areas and other locations near rivers, it is expected that an increase in frequency of higher river levels could lead to prolongation of inundation duration, due to the likelihood of an increase in inland water flooding as it becomes more difficult to discharge rainwater from sewer systems. ● Urban areas can have large impacts due to special vulnerability to flooding and inundation, if short-duration intensive rainfall events increase due to the impacts of climate change, combined with higher sea levels. ● It is also expected that increases in heavy rainfall will cause inundation damage to farmland outside of non-urban areas.		Soc/Ec/Env	The scope of impacts extends nationwide, and if they occur, they will become normalized. There is a large possibility for impacts to occur. The impacts can have irreversible impacts on the disaster area depending on the scale of damage, because water disasters (including human losses) can be significant. An areas where floods / inundation has the likelihood of occurring has a persistent vulnerability, it is difficult to equip the area with significant water disaster prevention functions under the normal land uses, so it is persistently exposed to that risk. The scale and frequency of extensive social, economic, and environmental impacts increases due to water disasters caused by floods and inundation of inland waters. Especially in urban areas, impacts may be larger, due to those areas' special vulnerability to floods and inundation, with the high concentration of population and economic activities, and the concentrated siting and underground use of a myriad of facilities and infrastructure that support those activities.			
	Coastal areas	Sea-level rise	● It has been reported that sea levels near Japan have been on an increasing trend (+1.1 mm/year) since 1980, based on analysis of tidal observation records. ● At present, there have been no reports of damage due to sea-level rise. ● When using tidal records, it is necessary to accurately assess the magnitude of tectonic movement in order to isolate the variations in sea level attributable to climate change and changes in ocean currents.	● Many studies have examined sea-level rise due to climate change. ● The studies found that there is a high possibility that, compared to the average for the years 1986 to 2005, the increase in global mean sea level from 2081 to 2011 will be in the range of 0.26 to 0.55 m (RCP2.6 scenario),[29] 0.32 to 0.63 m (RCP4.5 scenario),[29] 0.33 to 0.63 m (RCP6.0 scenario),[29] and 0.45 to 0.82 m (RCP8.5 scenario).[29] They found some sea-level rise to be inevitable even if greenhouse gas emissions are suppressed. ● If sea-level rise increases by 80 cm, the impacts will extend to all of Japan's coastlines, and the area of land exactly at sea level around the three major bays in Japan will increase to 1.6 times the current area. ● If sea-level rise occurs, disaster risk from storm surges and high waves will increase compared to the present, even without increases in intensity of typhoons and low pressure systems. ● It is expected that impacts will include a reduction in functioning of river and coastal artificial structures, submergence/inundation of coastal areas, problems for harbor and fishing port functions, and ecosystem impacts in the tidal zones of tidal flats and rivers.		Soc/Ec	The scope of impacts extends to coastlines nationwide. Sea-level rise could have extremely large social and economic impacts, due to the extensive and enormous damage it could cause to property, including infrastructure such as port facilities in coastal areas, industrial facilities, and residential areas. In particular, it could be a factor in persistent vulnerability and exposure for coastal metropolises with their concentration of population and industry, including Tokyo Bay, Osaka Bay, and Ise Bay.			

[29] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.

Sector	Category	Sub-category	Current status	Projected impacts	Significance			Urgency	Confi-dence	Rationale
						Criteria	Rationale			
		Storm surges, High waves	● Regarding damage associated with the influence of climate change-induced sea-level rise and increases in typhoon intensity on storm surge and high waves, at present, no concrete examples have been confirmed. Regarding storm surge, it has been pointed out that the occurrence of extreme storm surges may have been increasing globally since 1975. ● Regarding high waves, along Japan's Pacific coast, examples have confirmed an increase in wave height from autumn to winter, and along the Sea of Japan coast, an increase in wave height and frequency due to changes in atmospheric pressure patterns in winter. However, no scientific basis has been obtained yet to indicate that these are climate-change induced.	● Typhoons are the main factor for storm surges, and technologies are being developed to project typhoon behavior in the context of climate change (e.g., path, scale). However, already the results of predictive calculations can be assessed with a certain degree of precision, including the increase in water levels and extent of inundation when a typhoon makes landfall in a coastal area. ● The possibility is extremely high that sea level will rise due to climate change and the risk of storm surge will increase. ● Regarding high waves, there are projections of the possibility of increase in risk of high waves in coastal areas of the Pacific Ocean due to increases in typhoon strength, and damage to breakwaters in harbors and fishing ports due to increased wave height and storm surge anomalies. ● For harbors and fishing ports, particularly where the design depth of facilities is shallow, it is projected that there will be an increase in the number of places where safety cannot be adequately ensured due to increasing mean sea levels and an associated increase in wave height.	●	Soc/Ec	Storm surges have extremely large social and economic impacts, because they can cause risks to human life, as well as extensive and enormous damage to harbor and port facilities, fishing port facilities, business activities, and cultural assets, particularly in Japan's three major bays and other coastal areas that have experienced storm surge disasters. The impacts of high waves extend nationwide, and can have extensive and enormous impacts on human life, as well as infrastructure and wave calmness in harbors and fishing port facilities in coastal areas, and cultural assets located near the water in coastal areas.	●	●	
		Coastal erosion	● Regarding whether or not climate change-induced sea-level rise and increases in typhoon intensity are already having impacts on coastal erosion, no concrete examples have been confirmed at present.	● It is projected that coastlines will be eroded by sea-level rise and an increase in typhoon intensity due to climate change. Specifically, it is projected that with sea-level rise of 30 cm and 60 cm, about 50% and 80% of Japan's sandy beaches will disappear, respectively. ● Meanwhile, studies have reported the possibility of changes in the sediment supply from rivers with an increase in rainfall due to climate change, and the possibility for sediment deposition on coastlines including around estuaries. However, the possibility for increases in sediment volume to be sufficient to replenish the losses from coastal erosion due to climate change is not considered to be high, so it is expected that coastal erosion will progress more than at present.	●	Soc/Ec/Env	The scope of impacts extends to coastlines nationwide. Coastal erosion increases the likelihood of endangering human life and property, social infrastructure, and cultural assets, as it not only erodes the land but also the buffer zones that function to attenuate waves, thereby increasing the risk of damage from storm surges and high waves. In addition, coastal erosion, erodes the spaces for recreation and tourism, and also has significant impacts on natural ecosystems. Therefore the significance is particularly high.	△	△	
	Mountain areas	Debris flows, Landslide, and other disasters	● Little research and reporting has analyzed any direct correlation between climate change and the scale of damage from sediment-related disasters, and at present, much is still unknown regarding the relationship between climate change and the patterns of occurrence of sediment-related disasters. ● However, over approximately the past thirty years there have been reports of increases in the frequency of torrential rainfall of 50 mm or greater per hour, and increases in the number of annual cases of sediment-related disasters affecting human settlements. Also, despite a scarcity of data, an increasing trend has been reported in recent years in the frequency of occurrence of deep-seated slope failure. ● There have been reports of greater variation in snowfall in some regions, with a trend toward warmer winters with lower snowfall followed by heavy snowfall, but at present, no concrete examples relating to snow damage have been confirmed.	● The following is a list of conditions that could change under more severe rainfall conditions. (Severe rainfall conditions include extremely intense torrential rainfall and prolonged periods of heavy rainfall, and heavy rainfall that deliver an extremely large amount of total rainfall) ➢ Frequency of intensive failure, slope failure, debris flows, and its impacts on social and livelihood in mountain regions and areas around slopes ➢ A reduction in relative effectiveness of material measures (e.g., physical infrastructure) and non-material measures (e.g., institutional, organizational), increased extent of damage ➢ Prolongation of direct and indirect impacts due to increase of large-scale events such as deep-seated slope failure ➢ Expansion of damage beyond locations currently exposed to landslide hazard, as a result of increasing scale of events ➢ A reduction in system capacities of water induced disaster prevention and water utilization due to an increase in sediment supply to rivers	●	Soc/Ec	Scope of impacts on human life, settlements, transportation, social infrastructure, and natural ecosystems is nationwide; more than 500,000 locations have already been recognized as locations currently exposed to sediment-related disasters in Japan, land movement events also occur elsewhere, and production sediment is also transported downstream via rivers. In addition, the impacts could be a factor in declining vitality of mountain communities and settlements situated near steep slopes, and if they are also facing issues with depopulation and aging of society, these issues constitute persistent vulnerability and exposure to impacts.	●	△	

Sector	Category	Sub-category	Current status	Projected impacts	Significance			Urgency	Confi-dence	Rationale
						Criteria	Rationale			
	Others	Strong winds and other	● Regarding increases in damage by increases of strong winds and strong typhoons accompanied by climate change, at present, no concrete examples have been confirmed. ● Regarding changes in the frequency of occurrence of climate change-induced tornadoes as well, at present, no concrete examples have been confirmed.	● A study using the A1B scenario[30] projects increases in strong winds and strong typhoons due to climate change, starting in the near future (2015-2039). ● In addition, projections for the end of the 21st century (2075-2099) in Japan nationwide are for a higher frequency conditions suitable for the occurrence of tornadoes mainly from March to May. ● Although no examples making quantitative projections have been confirmed at present, there are concerns about an increase in damage from tree blow-down in mountain regions accompanied by increase of intense typhoons.		Soc/Ec/Env	The scope of impacts is nationwide. Strong winds have impact on natural ecosystems, and human society, such as infrastructure, dwellings, property, agriculture and forestry, and transportation, and combined with tornadoes and large typhoons, the impacts on human life and health will be enormous. However, even if the probability of occurrence increases, actual occurrence depends on chance, as these are low-frequency events.			
Human health[31]	Winter warming	Mortality in winter season	● Regarding any decrease in mortality in winter associated with increasing temperature in winter, no concrete examples have been confirmed at present.	● Using the RCP4.5 scenario[30], the mean temperature in winter was projected to increase in the 2030s nationally compared to the 2000s, and cold mortality as a proportion of total mortality (non-accidental) was projected to decrease. However, this projection was based on a study conducted before isolating seasonal impacts from impacts due to differences in winter temperature. By separating seasonal effects, the decrease in the proportion of deaths due to cold mortality is expected to be smaller than that projection.			A decrease in the winter mortality rate is in itself a positive impact, and does not lead to loss of human life, economic loss, or environmental impacts.			
	Heat stress[32]	Risk of mortality	● It has been confirmed globally that excess mortality (an indicator showing the extent to which total mortality from a given illness has increased, whether directly or indirectly) is already occurring due to increasing temperature.	● The frequency of summer heat waves is projected to increase in Tokyo and several other Asian cities, and it is also projected that heat stress related to mortality and morbidity may also increase. ● The mortality risk from heat stress is projected to increase in Japan by the mid-21st century (2050s) to about 1.8–2.2 times the level in 1981 to 2000, and to about 2.1–3.7 times by the end of the 21st century (2090s), respectively, under the 450s scenario[30] and BaU scenario[30]. ● Even for the RCP2.6 scenario[30], the excess mortality from heat stress is projected to more than double in all prefectures, regardless of age group.		Soc	The scope of impacts is nationwide. In addition, the ongoing aging of society is among the elements of persistent vulnerability with respect to the said impacts. The impacts are directly connected to the loss of human life, and the significance is high particularly from the social perspective.			
		Heat illness	● Increases in the number of heat illness patients transported by ambulance have been reported nationwide, although it cannot be stated with certainty that all of the increases are an impact of climate change. ● Only a limited number of reports has been published in Japan relating to health impacts that do not lead to mortality or morbidity, such as impacts on labor efficiency.	● The rate of increase of incidence of heat illness is projected to be larger in Hokkaido, Tohoku, and Kanto, and smaller in Shikoku, Kyushu, and Okinawa, in projections for 2031–2050 and 2081–2100. ● By age group, the rate of increase in incidence of heat illness is highest for the elderly over 65 years of age, and considering the future aging of the population, the impact is considered to be more serious. ● A projection using the RCP8.5 scenario[30] projected more than a doubling of heat illness patients transported by ambulance in the majority of prefectures (with the exception of Shikoku) by the middle of the 21st century, and by the end of the century, with the exception of a projection using RCP2.6 scenario,[30] more than a doubling in almost all prefectures. ● Regarding health impacts of climate change that do not lead to clinical symptoms (e.g., impacts on the labor efficiency), studies have been reported in overseas, and the IPCC Fifth Assessment Report also addressed these issues. Few reports have been published in Japan, however.		Soc	The scope of impacts is nationwide. In addition, the ongoing aging of society is among the elements of persistent vulnerability with respect to the said impacts. Also, the number of patients transported by ambulance in this sub-category has a high correlation with the number of deaths (vital statistics); increases in the number of patients also correlates to the loss of human life, so the significance is high.			

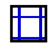
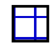
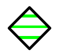
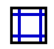
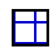
[30] For an overview of scenarios, see “Reference: Overview of Scenarios Being Used for Climate Projections” starting on page 98.
[31] Human health is not only affected by climate change, but by a wide range of factors, such as the enormous movement of people and goods due to globalization, and major changes in the natural environment from land development. When assessing the impacts of climate change, it is necessary to do so based on an understanding that those many other factors exist.
[32] Among the impacts of heat stress, this section deals mainly with impacts such as mortality risk and heat illness. In the category of “Life of Citizenry, Urban Life” the section “Other–Impacts on life due to heat stress” deals mainly with impacts such as heat stress, sleep inhibition, and heat discomfort.

Sector	Category	Sub-category	Current status	Projected impacts	Significance		Significance: Criteria	Significance: Rationale	Urgency	Confi-dence	Rationale
	Infection[33]	Water- and food-borne diseases	● Regarding the increasing risk of water-borne and food-borne diseases due to climate change, at present, confirmed examples are limited, and the connection with climate change is not clear.	● The expansion of water-borne and food-borne diseases due to climate change is also a concern, but at present, confirmed examples are limited.	–			The scope of impacts may be nationwide. The impacts relate directly to human health, but research to date in Japan has not been sufficient.	–	□	
		Vector-borne diseases	● It has been confirmed that the habitat of mosquitoes (*Aedes (Stegomyia) albopictus*) that are vectors of infectious diseases such as dengue fever have expanded to rural northern parts of the Tohoku region. Also, though not directly connected to climate change, there were instances of many persons falling ill with dengue fever[34] in metropolitan parks in 2014. ● There are other infectious diseases for which the risk of spread may increase due to climate change impacts, but no concrete examples in Japan have been confirmed at present.	● A projection using the RCP8.5 scenario[35] projected the possible distribution of the Asian tiger mosquito (*hitosujishimaka*, or *Aedes (Stegomyia) albopictus*) to reach some area of Hokkaido by the end of the 21st century. However, the expansion of possible distribution, does not necessarily lead immediately to more occurrences of disease. ● There are other infectious diseases may be affected by climate change, but no examples specifically on the risk of spread of infectious diseases in Japan have been confirmed at present.	●		Soc	The scope of impacts may be nationwide. The impacts are directly connected to human health, and the significance is high particularly from the social perspective. There are some diseases for which the distribution of pathogens is not necessarily expanding, but research in Japan to date is not sufficient. The distribution of vectors such as the Asian tiger mosquito is expanding, so there is a need for further research on the type and distribution of pathogens.	△	△	
		Other infectious diseases	● For infectious diseases other than water-borne and food-borne, and vector-borne types as well, reports have been confirmed that point out seasonal changes in occurrence and correlations between occurrence, and temperature and humidity. ● However, since the impacts of other societal and biological factors are significant, findings about detailed mechanisms are inadequate at present.	● For infectious diseases other than water-borne and food-borne and vector-borne types as well, the potential exists for seasonal changes and changes in risk of occurrence due to an increase in temperature, but quantitative assessment is difficult due to the lack of research literature.	–			The scope of impacts may be nationwide. The impacts related directly to human health, but research is very limited at present.	–	–	
	Others		● There have been many reports of health-related combined impacts connected with an increase in temperature and air pollution; changes have been reported in the concentrations of particulate matter and a variety of other pollutants, due to factors such as their formation being promoted by an increase in temperature. ● It is expected that diarrhea outbreaks will occur if water becomes contaminated in closed water bodies and rivers downstream, in the event of overflow of combined sewer systems due to flooding associated with localized torrential rainfall. There are reports in the United States introducing rainwater treatment approaches similar those used in Japan, but there is no specific report in Japan. ● The elderly are frequently referred to as a population vulnerable to heat stress, but in the United States there have been reports of impacts on young children and fetuses (expectant mothers). In Japan, information on these aspects is not available. ● Also, only a limited number of reports has been published in Japan relating to health impacts that do not lead to mortality or morbidity, such as impacts on labor efficiency.	● It is expected that damage to health will increase with higher oxidant concentrations due to an increase intemperature in urban areas, but these impacts are greatly affected by future air pollution levels, and it is not easy to make projections. ● It is expected that the incidence of diarrhea will increase due to greater pollution of closed waters with increasing amounts of heavy rain, but epidemiological data is insufficient to make projections. ● There is a lack of information about impacts on vulnerable populations, children in particular. ● Regarding health impacts of climate change that do not lead to clinical symptoms (e.g., impacts on the labor efficiency), studies have been reported in other countries, and the IPCC Fifth Assessment Report also addressed these issues. Few studies have been reported from Japan, however.	Combined impacts	–		There has been a relatively large number of research reports on the relationship between warming and ozone concentrations. However, future impacts will depend on future trends in the status of air pollution.	△	△	
					Vulnerable populations	–		These are mainly expected to be fetuses and infants. The magnitude of impacts cannot be assessed due to the lack of information, but they are projected to be larger than impacts adults are exposed to in relation to physical and meteorological changes. In addition, one cannot overlook the possibility that impacts of environmental change at this stage of development will be persistent and irreversible for life.	●	□	
					Non-clinical	–		Assessment is difficult due to the lack of quantitative information at present.	□	□	

[33] This section covers infectious diseases for which a considerable amount of research exists, including water-borne and food-borne diseases, and vector-borne diseases. Infectious diseases for which existing research knowledge is limited is covered together under "Other infectious diseases." They are covered together for convenience, but this does not necessarily mean the "other infectious diseases" are less important.

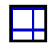
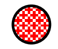
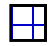
[34] Dengue fever: An infectious disease caused by the dengue virus, which is transmitted by vectors including the Asian tiger mosquito (*Aedes (Stegomyia) albopictus*) and the yellow fever mosquito (*Aedes (Stegomyia) aegypti*).

[35] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.

Sector	Category	Sub-category	Current status	Projected impacts	Significance			Urgency	Confi-dence	Rationale
						Criteria	Rationale			
Industrial /Economic Activity	Manufacture		● A variety of climate change-induced impacts are expected, but at present, only a limited number of examples have been confirmed on the impacts on manufacturing (the only study that could be confirmed is a report of one case study on natural agar production, a traditional industry in Chino city, Nagano Prefecture). At present, it has not been determined if there are significant impacts on manufacturing.	● There is a lack of published examples assessing future impacts of climate change on the manufacturing industry to be large; therefore, based on available information, it is difficult to say that the impacts will be high. ➢ Assuming the highest range of sea-level rise, research has found that the value of lost production in the manufacturing sector around the Tokyo Bay area due to sea-level rise would be very high in the 2090s in the absence of measures against sea-level rise in coastal areas. ➢ Examples done in the apparel and other industries, while not quantitative projections, found reasons to be concerned that changes in average temperature would have direct and physical impacts on a company's production and sales processes, and the siting of production facilities.			The scope of impacts is nationwide. The duration of the impacts will depend on the climate change event that causes the impact. There are also reports of direct impacts on production processes and the siting of facilities, and in manufacturing industries, there have also been reports projecting significant impacts on employment and production losses. On the other hand, some research also projects positive impacts on industry.			
	Energy	Energy demand and supply	● No concrete examples regarding the impacts of climate change on energy demand and supply have been confirmed at present.	● A limited number of examples have quantitatively assessed future impacts of climate change on energy demand and supply; therefore, based on available information, it is difficult to say that the impacts will be high. ➢ The followings are examples of reports projecting the impacts of increases in temperature on energy consumption. ✓ Almost no change in the industrial sector and the transport sector ✓ A reduction in demand in the residential sector (for a 1.0°C increase in temperature, household energy consumption declines 3-4% in Hokkaido and Tohoku regions, and 1-2% in other regions) ✓ An increase in demand in the commercial sector including the service industry (for a 1.0°C increase in temperature, demand in commercial sector increases 1-2%) ✓ In the residential/commercial sector overall, no major impact, but there may be decreases in some areas ➢ It has been pointed out that increases in summer temperature may accentuate the peaks of electricity supply.			The scope of impacts is nationwide. The duration of the impacts will depend on the climate change events that cause the impact. Various studies have reported that with climate change, energy consumption will vary; that disasters will increase at power generation plants, and that electricity generation efficiency will decline; and that there will be almost no change in energy demand in the residential sector and transportation sector. Meanwhile, there are also reports projecting a decrease in energy demand in the residential sector, and increases in the commercial sector. For energy demand as a whole, projections are for no significant impact, or a decrease. Literature that projects a major impact on energy demand is scarce at present.			
	Commerce		● No concrete examples regarding the impacts of climate change in the commercial sector in Japan have been confirmed at present.	● There are very few examples that future impacts of climate change on the commercial sector in Japan, so it is not possible to assess impacts on the commercial sector at present. ➢ In the apparel industry, some reports have pointed to impacts on sales of seasonal products, and on marketing plans. ➢ In CDP projects, there are examples that companies in the apparel, hotel, and other industries estimated and assessed impacts and economic losses associated with future climate change.	–		It is difficult to assess the impacts at present, because of the diversity of commercial industries, the need to examine both the direct impacts of climate change and indirect impacts through changes in consumption behavior and energy costs, as well as the lack of published literature.	–		

Sector	Category	Sub-category	Current status	Projected impacts	Significance			Urgency	Confi-dence	Rationale
						Criteria	Rationale			
	Finance, Insurance		● Based on trends in natural disasters and associated insured losses over approximately 30 years since 1980, insured losses have increased significantly and it has been confirmed that the likelihood that losses will regularly occur has been increasing. ● There are reports that it has become difficult for insurance companies to project future trends using traditional risk quantification methods alone, and the development of new methods of risk hedging and diversification that consider the future impacts of climate change will be necessary. ● At present, no concrete examples of research regarding the impacts of climate change on the Japanese financial sector have been found.	● Projections have indicated increases in insured losses associated with a growing number of natural disasters, increases in insurance payments, and increases in reinsurance premiums. However, at present, examples of research are limited in Japan. ● No quantitative examples with projections for Japan have been found at present, but impacts such as the following can be expected. (Insurance industry) ➢ Threats such as the emergence of some categories that cannot be insured, and difficulty of reinsurance ➢ Business opportunities, such as increase in demand for insurance, and potential for new product development. (Financial Industry) ➢ Threats such as damage to property or increase in economic costs due to changes in weather ➢ Business opportunities, such as adaptation business financing, development of weather derivatives ● At present, no concrete examples of research related to the impacts of climate change on the Japanese financial sector have been found.	●	Ec	When considering social and economic factors together, increases are projected in the value of losses due to natural disasters globally, including Japan; and in the absence of appropriate responses to the risk of losses due to such natural disasters, enormous impacts are projected in the insurance industry and a variety of other industries. The general principle in the insurance industry is to transfer risk through reinsurance, but because reinsurance is a system to transfer risk globally, an increase in global losses associated with natural disasters is also projected to have impacts on Japan's insurance industry. Increases in insurance premiums and changes to insured conditions would have a large impact not only on the insurance industry but also on society as a whole. Meanwhile, businesses that are able to address such risks adequately may also discover business opportunities.	▲	▲	
	Tourism	Leisure[36]	● Leisure industries that utilize natural resources (e.g., forests, snowy mountains, sandy beaches, and wetlands) may be subject to impacts from an increase in temperature, changes in rainfall, snowfall, and the spatial and temporal distribution of precipitation, and sea-level rise; however, at present, confirmed examples are limited. ● Examples have been confirmed about reductions in snow depth at ski resorts due to an increase in temperature.	● A study using the A1B scenario[37] projected that in about 2050, the tourism climate index[38] will be reduced in summer due to an increase in temperature, and increased in spring and autumn to winter. ● Regarding skiing, it is projected that snowfall and maximum snow depth in 2031 to 2050 will be reduced (with the exception of some areas inland in Hokkaido and Honshu), and that almost all ski resorts will see a reduction in snow depth. ● A loss of sandy beaches is projected to occur due to sea-level rise, with impacts on leisure industries in coastal areas.	●	Ec	For the tourism sector as a whole, some reports project positive impacts, but for ski resorts, coastal areas and other leisure industries that make use of natural resources, negative impacts have also been projected. This section assesses impacts on tourism activities that rely on natural assets. These impacts also leads to impacts on the tourism industries in the region. In terms of economic losses, regions and local residents that depend on tourism that makes use of natural resources are projected to see impacts of a particularly high significance.	▲	●	
	Construction		● At present, no concrete examples regarding the impacts on the construction industry have been confirmed. ● However, impacts on infrastructure have been considered in the "Urban infrastructure, critical services" section, so readers are encouraged to refer to it.	● At present, confirmed examples are limited regarding impacts on the construction industry. ● However, impacts on infrastructure have been considered in the "Urban infrastructure, critical services" section, so readers are encouraged to refer to it.	–		At present, it is difficult to assess the impacts, as no reports making projections or assessments have been confirmed.	–	–	
	Medical		● At present, no concrete examples regarding the impacts on the medical industry have been confirmed, with the exception of impacts on dialysis treatment due to interruption of water supply and turbid water. ● However, impacts on health have been considered in the "Human health" sector, so readers are encouraged to refer to it.	● At present, no concrete examples regarding the impacts on the medical industry have been confirmed. ● However, impacts on health have been considered in the "Human health" sector, so readers are encouraged to refer to it.	–		At present, it is difficult to assess the impacts, as no reports making projections or assessments have been confirmed.	–	–	

36 This section mainly covers leisure activities that use natural resources, including forests, snowy mountains, sandy beaches, and tidal flats .
37 For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.
38 Tourism climate index: An index for the level of comfort for tourisms based on climate, in terms of factors such as temperature, amount of precipitation, and amount of solar radiation.

Sector	Category	Sub-category	Current status	Projected impacts	Significance			Urgency	Confi-dence	Rationale
						Criteria	Rationale			
	Others	Other Impacts (e.g. Overseas Impact)	● At present, no concrete examples regarding the impacts of climate change outside of Japan will have within Japan have been confirmed. ● Although it is difficult to clearly determine whether or not it was an impact of climate change, the flooding of Thailand's Chao Phraya River in 2011 resulted in losses for Japanese companies. There was one case of an estimated 315 billion yen in losses for Japanese companies involved in the supply chain for computer hard disks, and another case of an expected 900 billion yen in insurance payouts to Japanese firms by Japanese insurance companies.	● Impacts that might be experienced within Japan due to impacts from overseas center on secondary impacts, would include social sciences, and involve complex factors; at present no concrete examples covering these topics have been confirmed. ● However, based on the examination cases conducted in the U.K., there are concerns in Japan as well about changes in import prices of energy and prices of agricultural and fisheries products; direct and physical impacts on manufacturing plants operating overseas; and impacts of the spread of infectious diseases via migrants and incoming travel, associated with an increase of disease carriers overseas.	–		Impact assessments have been done in existing literature for East Asia and the Pacific region, but the magnitude of impacts on Japan is poorly understood. Changes in food supply and demand in East Asia and the Pacific region are directly linked to Japan's food prices, imports and exports, and there may be economic impacts, but literature projecting major impacts is scarce at present. An assessment of climate-change impacts overseas impacting the U.K was formulated by the Government Office for Science, London in 2011, projecting impacts on the import prices of agricultural and fisheries products due to increases overseas in the frequency and duration of extreme weather events, reductions in water resources, ocean acidification, and changes in water temperature.	–		
Life of citizenry, urban life	Urban infrastructure, critical services,	Water supply, Transportation, and the others	● Impacts have been confirmed in many places in recent years, including underground inundation, power outages and impacts on subway systems due to record torrential rainfall; impacts on water supply infrastructure due to droughts and flooding; and impacts on cut-off slopes of highways due to torrential rainfall and typhoons. ● However, it is difficult to clearly determine whether or not these incidents were impacts of climate change.	● Regarding possible climate change impacts on infrastructure and critical services, at the global level it has been pointed out that extreme weather events may expose systems to risks by disrupting the functioning of infrastructure networks and critical services such as electrical and water supply services, but could also affect national security policies. ● Meanwhile, for Japan, reports have focused on secondary impacts including those mainly in the social sciences, and involve complex factors; at present only a limited number of published examples has been confirmed. Overseas, some examination cases have pointed to an increase in risks for communications and transportation infrastructure. ● There are concerns about impacts on infrastructure and critical services if climate change results in impacts such as increase in the frequency of short-term intense rainfall events and droughts, and an increase in strong typhoons.		Soc/Ec	Already at present, impacts on water utilities and transportation modes from events such as torrential rains and droughts have been observed as impacts on infrastructure and critical services. Also, reports indicating the potential for future impacts on water utilities and modes of transportation have been reviewed. It is difficult to clearly determine whether or not these impacts are due to climate change, but the frequency of torrential rains and droughts are projected to increase in the future, and if climate change progresses in line with these projections, damage may be more likely to occur to infrastructure and critical services in ways similar to impacts that have already been confirmed. Significance is assessed as particularly high, due to the large social and economic impacts of damage and losses to infrastructure and critical services.			

Sector	Category	Sub-category	Current status	Projected impacts	Significance				Urgency	Confi-dence	Rationale
							Criteria	Rationale			
	Life with sense of culture and history	Phenology,[39] traditional events / local industry	● Reports have been confirmed regarding phenological changes for flora and fauna that people commonly experience, including cherry blossoms, the Japanese maple, and cicadas. However, regarding the impacts of these changes on citizens' sense of the seasons and on local traditional events and tourism, no concrete examples have been confirmed at present. ● At Lake Suwa, there have been reports of the impacts of an increase in temperature on local traditional events, tourism, and industries; these include an increase in the frequency of years without "omiwatari"[40], and impacts on local sake (rice wine) production. However, it is difficult to clearly determine whether or not they are an impact of climate change, and at present, confirmed examples are limited.	● For flowering dates and the duration of full blooming of cherry blossoms, the A1B and A2 scenarios[41] indicate a trend for earlier flowering dates in the future in northern Japan, but later dates in southwestern Japan. Also, by the middle and end of this century, they indicate a shortening of the duration from flowering until full bloom, due to an increase in temperature. Associated with that, impacts are projected for a reduction in the number of days for flower blossom viewing, and then for regions that treat cherry blossoms as a touristic resource. ● Regarding the impacts on unique regional traditional events, tourism, and local industries, at present, confirmed examples are limited.	Pheno logy			The scope of impacts on phenology is almost nationwide. Changes in cherry blossom flowering dates and the duration of full bloom, as well as delays in the arrival of autumn foliage have the potential to have impacts on traditional events and tourism, in locations recognized for their beauty, so there would be broad social, economic, and environmental impacts. More specifically, it is thought that shifts in the timing of blossom flowering and autumn foliage would affect the number of tourists, with further impacts on the local economy. It is thought that the impacts of changes in autumn foliage would be smaller than for cherry blossoms, as the foliage duration is relatively longer. However, regarding the magnitude of impacts, there have been no reports making quantitative projections, so it is difficult at present to say that the impacts would be particularly large.			
					Traditions, locale	–		Impacts differ for different events, so it is difficult to make an assessment.			
	Others	Impacts on life due to heat stress[42]	● Reports have been confirmed stating that the rate of increases in temperature per 100 years in small- and medium-sized cities is 1.5°C, compared to 2.0 to 3.2°C in major large cities, and that in large cities the effects of an increase in temperature due to climate change are combining with the heat island effect. ● The heat island effect has also been confirmed in small- and medium-sized cities. ● In terms of impacts of an increase in temperature particularly in large cities, it has been pointed out that there is an increase in heat stress experienced by people, including an increase in the risk of heat illness, as well as sleep inhibition, and impacts on outdoor activities.	● The heat island effect in Japan's large cities is expected to increase only slightly in the coming years, but the heat island effect already observed in combination with an increase in temperature associated with climate change can be expected to result in a continuation of an increase in temperature in cities. ● For example, a case projecting August temperature in the city of Nagoya in the 2070s (using the A2 scenario)[43] indicated an increase of about 3°C compared to the average August temperature for 2000 to 2009, and also suggests an increasing trend in the WGBT[44] sensory index associated with an increase in temperature. ● Future projections of temperature for urban areas will differ depending on the design of each city, but increases have been projected for temperature and sensory indices. Regarding the thermal environment after an increase in temperature, there are concerns about significant impacts on urban living, from the perspective of heat illness risk and comfort levels.			Soc/Ec	In urban areas, a larger temperature increase is projected due not only to temperature increases by climate change but also impacts of the heat island effect arising from land-use changes and artificial exhaust heat. In addition, not only in major cities but also in regional cities, which have not yet experienced a noticeable degree of temperature increases, increasing temperature are projected to become more noticeable as a result of the heat island effect, combined with the impacts of climate change. In particular, the impacts on urban living are large, and economic losses are also large, considering the increase in heat stress in summer leading to higher heat illness risk and loss of comfort, plus impacts such as sleep inhibition due to lower sleep efficiency.			

[39] The term phenology refers to phenomena manifested by fauna and flora in response to seasonal changes such as temperature and sunlight. This section mainly covers phenology relating to human activities and culture (phenology perceived by people in their lives, or sense of season), while the section for "Phenology" under "Natural Ecosystems" mainly covers ecosystem services and impacts on ecosystems.
[40] Omiwatari: (translated as "The God's Crossing," a natural phenomenon related to pressure ridges forming on lake ice, with records dating back to 1443
[41] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.
[42] This section mainly covers impacts in urban areas such as heat stress, sleep inhibition, discomfort due to heat, while the "Heat Stress" section under "Health" mainly covers impacts such as relating to mortality risk and heat illness.
[43] For an overview of scenarios, see "Reference: Overview of Scenarios Being Used for Climate Projections" starting on page 98.
[44] WBGT: Wet Bulb Globe Temperature, an indicator of temperature. It provides an indicator of the level of heat felt. It is calculated from natural web bulb temperature (°C), black bulb temperature (°C), and temperature (°C).

4. Challenges for Assessment of Climate Change Impacts in Japan

This report is a summary of the first assessment of the impacts of climate change in Japan to have undergone a review by the Central Environment Council. To properly address the impacts of climate change, it is important to consider and implement adaptation measures based on a solid grasp of current status and future projections. Thus, it is necessary for the Government to make an effort to consider and create frameworks for comprehensive and strategic assessments of impacts, and to continue assessing those impacts on an ongoing basis. Specifically, the following initiatives should be promoted.

(1) Ongoing Observation and Monitoring, Promotion of Research and Studies, and Accumulation of Information and Findings

To begin with, assessments of climate change impacts need to be based on the status of climate change as it progresses. Thus, the relevant government bodies need to be engaged in ongoing observation and monitoring, and to enhance observation systems that use land-based fixed-point observation, as well as ship-, aircraft- and satellite-based systems. Existing observation equipment also needs to be maintained.

On the basis of the results of impact assessments covered in this report, the amount of research and studies to date has not been sufficient; thus, it is imperative to move ahead in a timely way with research and studies, particularly in areas that were found to need further collection of information and findings. It is also important to promote further research on climate change as well as its impact projections and assessments, on the basis of advances in science and information that has been observed. Examples include research relating to impacts on human society, the costs of adaptation, and synergy and trade-offs between adaptation and mitigation.

There is also a need to collect and accumulate the results of observation, monitoring, research and studies. In particular, there is a need for technology development and improved management systems, including improvements in observational databases and the information infrastructure (ICT: Information and Communication Technologies) to facilitate the sharing of a wide range of data.

(2) Periodic Assessments of Climate Change Impacts

There will be a need to conduct periodic climate change impact assessments that take into consideration the information that has been gathered through the above efforts, new findings, and the status of implementation of adaptation measures based on adaptation plans. It will also be necessary to create platforms and programs to implement those assessments.

To further enhance the value of impact assessments in the consideration of adaptation plans, it is also important to assess impacts quantitatively and to indicate the probability of occurrence of those impacts.

(3) Support for Local Governments and Other Bodies

When adaptation measures are being implemented, it is important to consider the special characteristics of each region. Because the impacts of climate change differ depending on local climate, geography, and culture. Thus, it is important to promote not only national-level efforts but also comprehensive and systematic efforts at the local-government level, In order to do that, it is important for the Ministry of the Environment and related government ministries and agencies to improve systems that support the adaptation efforts of local governments. This role includes providing guidelines and assessment approach for impact assessments, providing information on climate change impact assessments at the regional level, and developing common basic technologies such as projection techniques and impact assessment techniques to facilitate development of adaptation measures that are based on scientific evidence.

Also, recognizing the fact that the impacts of climate change are wide-ranging, it is also necessary to support adaptation efforts by the private sector and citizens.

The relevant government ministries and agencies need to share observational data summarized in sections (1) and (2) above, as well as data and information on projections and impact assessments of future climate change. The sharing should be not only among the relevant government ministries and agencies; there should also be cooperation to develop "one-stop" information platforms, provide information broadly to actors that implement adaptation measures (including citizens, local governments and businesses), and work to create frameworks to promote the utilization of this information.

(4) Promotion of Impact Assessments Overseas

It has also been suggested that the impacts of climate change occurring in rest of the world may also affect Japan domestically through trade and business activities. On the other hand, there is insufficient data and information available about impacts overseas, particularly in developing countries. Therefore, through Ministry of the Environment cooperation with the relevant ministries and agencies in Japan and with the countries concerned, it is necessary to conduct climate change projections and impact assessments in developing countries, and to gather data and information.

Reference: Overview of Each Scenario Being Used for Climate Projections

1. RCP Scenarios

Further work remained after the SRES scenarios (referring to the IPCC Special Report on Emissions Scenarios); for example, they did not take into account policy-directed measures to reduce emissions. For this reason, representative scenarios were selected from among a number of pathways that led to stabilized GHG levels in the future, based on the assumption that policy-based GHG mitigation measures were implemented. These are referred to as the Representative Concentration Pathways (RCP) scenarios.[1]

The RCP scenarios are characterized by the magnitude of impacts of radiative forcing from atmospheric greenhouse gas concentrations; they are referred to as RCP8.5 (high reference scenario), RCP6.0 (high stabilization scenario), RCP4.5 (medium stabilization scenario), and RCP2.6 (low stabilization scenario), and correspond to approximate radiative forcing at the end of this century of 8.5 W/m^2, 6.0 W/m^2, 4.5 W/m^2, and 2.6 W/m^2, respectively, compared to pre-industrial levels.[2]

Summary of RCP scenarios

Scenario	Estimate of radiative forcing compared to pre-industrial era	GHG concentrations (all gases) in 2100 (CO_2 equivalent)	Trend for concentrations
RCP8.5 (high reference scenario)	Exceeds 8.5 W/m^2 in 2100	Exceeds approx. 1,370 ppm	Continued increase
RCP6.0 (high stabilization scenario)	Stabilized at approx. 6.0 W/m^2 after 2100	Approx. 850 ppm (stabilizes after 2100)	Stabilization
RCP4.5 (medium stabilization scenario)	Stabilized at approx. 4.5 W/m^2 after 2100	Approx. 650 ppm (stabilizes after 2100)	Stabilization
RCP2.6 (low stabilization scenario)	Peaks at 3W/m^2 prior to 2100, then declines. Approx. 2.6W/m^2 in 2100	Peaks at approx. 490 ppm prior to 2100, then declines	Peaks then declines

Source: Prepared from IPCC, 2007b

[1] Statement relating to the release of the contribution of Working Group II (Impacts, Adaptation, Vulnerability) to the Fifth Assessment Report, Intergovernmental Panel on Climate Change (Ministry of Education, Culture, Sports, Science and Technology, Ministry of Economy, Trade and Industry, Japan Meteorological Agency, Ministry of the Environment, 2014) (in Japanese).

[2] Text and figures are excerpted from "Synthesis Report on Climate Change Observation, Prediction and Impact Assessment," in *Climate Change and Its Impacts in Japan* (2012 edition) (Ministry of Education, Culture, Sports, Science, Japan Meteorological Agency, Ministry of the Environment, 2013) (in Japanese).

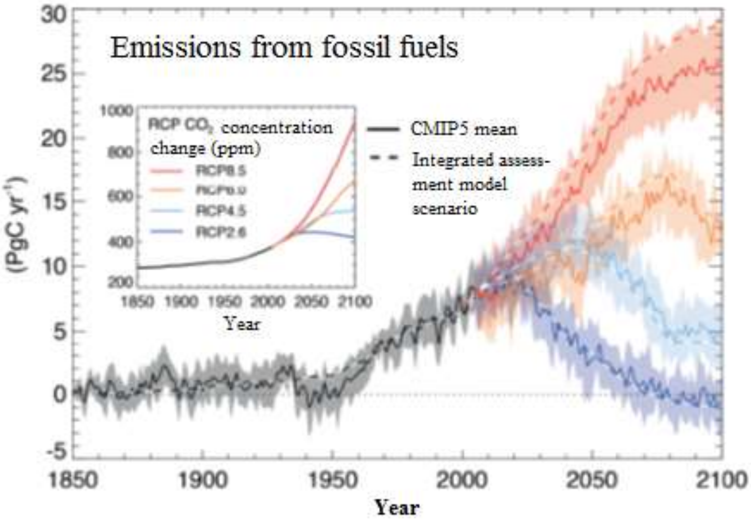


Figure. Radiative forcing based on RCP scenarios (in outer graph— solid lines indicate four radiative forcing pathways established by RCP scenarios; for comparison, dashed lines show radiative forcing calculated based on SRES scenarios), and CO_2 emissions from fossil fuels corresponding to RCP scenarios (inner graph—results of reverse calculation using Earth System Models; thin lines show results of each model; thick lines are average of multiple models)

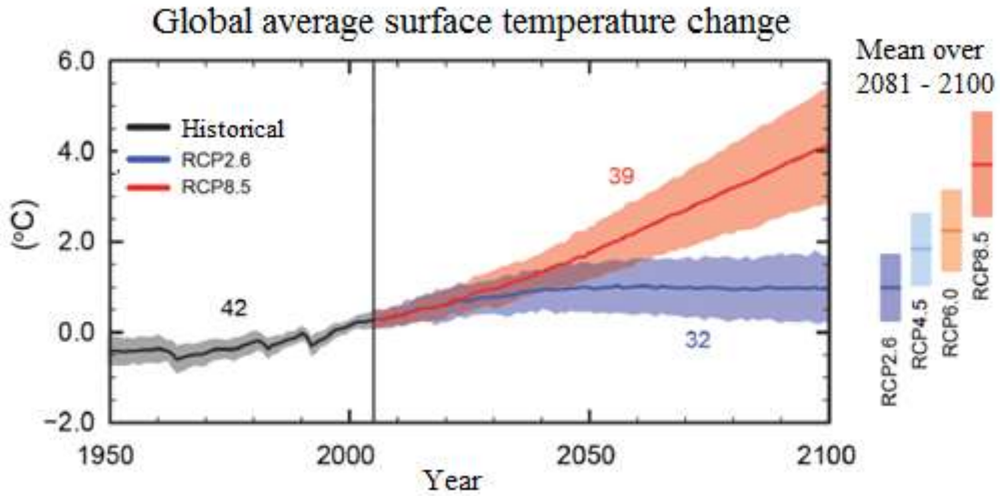


Figure. Time series simulation using multiple CMIP5 models (1950–2100). Change in global annual mean surface temperature relative to 1986-2005. Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). Black (gray shading) is the modelled historical evolution using historical reconstructed forcings. The mean and associated uncertainties averaged over 2081-2100 are given for all RCP scenarios as colored vertical bars. The numbers of CMIP5 models used to calculate the multi-model mean are indicated.

Source: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Figure SPM.7(a).

Table. Projected changes in global mean surface temperature and global mean sea level, by scenario

Concentration scenario	Temperature change (°C)		Sea-level rise (m)	
	Medium term (2046–2065)	Long term (2081–2100)	Medium term (2046–2065)	Long term (2081–2100)
RCP 2.6	0.4–1.6 (1.0)	0.3–1.7 (1.0)	0.17–0.32 (0.24)	0.26–0.55 (0.40)
4.5	0.9–2.0 (1.4)	1.1–2.6 (1.8)	0.19–0.33 (0.26)	0.32–0.63 (0.47)
6.0	0.8–1.8 (1.3)	1.4–3.1 (2.2)	0.18–0.32 (0.25)	0.33–0.63 (0.48)
8.5	1.4–2.6 (2.0)	2.6–4.8 (3.7)	0.22–0.38 (0.30)	0.45–0.82 (0.63)

・Projections indicate the change from the mean over the base period 1986–2005.

・( ) numbers in parentheses indicate the mean value of projections.

Prepared by the Secretariat from the following sources:

IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)].

Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Note:

・Climate projections based on the SRES scenarios are the assessment results of the Fourth Assessment Report, while climate projections based on RCP scenarios are the assessment results of the Fifth Assessment Report, and they differ not only in terms of emission scenarios but also approach for climate projections.

2. SRES Scenarios

These are emission scenarios used as common assumptions in climate prediction experiments assessed for the IPCC Fourth Assessment Report, and are classified as A1 scenario (rapid growth society), A2 scenario (heterogeneous society), B1 scenario (sustainable development society), and B2 (local coexistence society). A1 scenario is further classified as A1F1 (emphasis on fossil energy sources), A1T (emphasis on non-fossil energy sources), and A1B (emphasis on balance of energy sources).

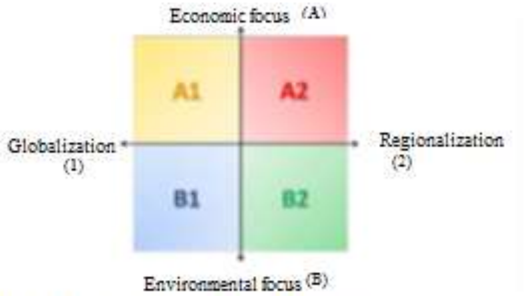
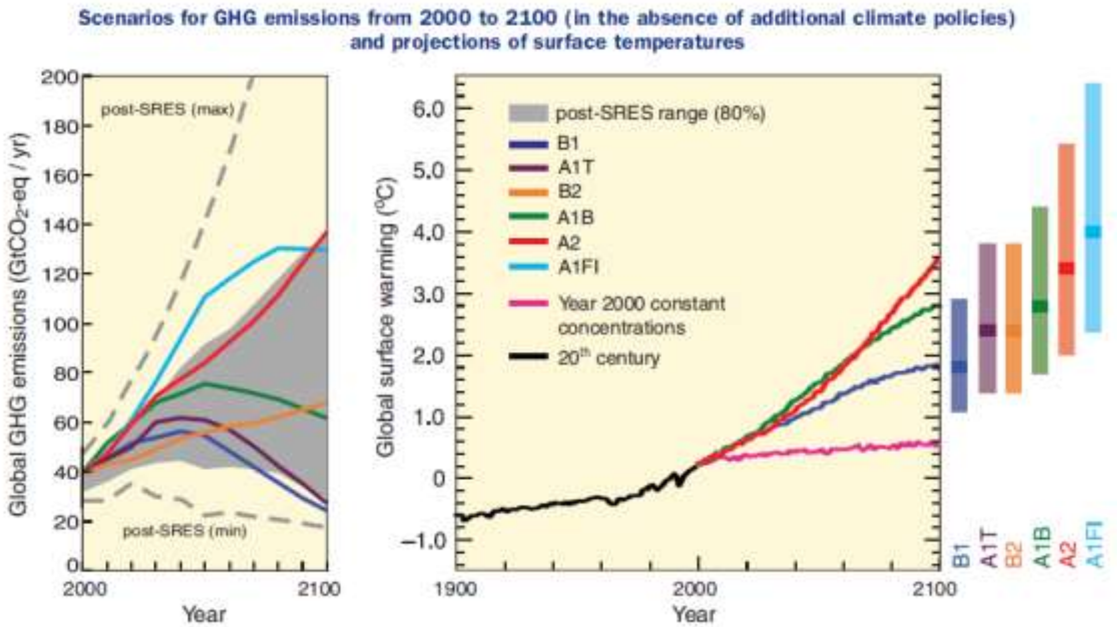


Figure 2.2.2. Four SRES scenario families

The A1 scenario is further broken down into A1B, A1T, and A1FI. The A1B scenario is used frequently (high-growth society with emphasis on balanced use of energy sources).
Source: Prepared from National Institute for Environmental Studies materials, 2001.

Source: "Climate Change Observation, Prediction and Impact Assessment, Synthesis Report," in *Climate Change and Its Impacts in Japan* (2012 edition) (Ministry of Education, Culture, Sports, Science, Japan Meteorological Agency, Ministry of the Environment, 2013) (in Japanese).



Figures Left Panel: Global GHG emissions (in $GtCO_2$-eq) in the absence of climate policies: six illustrative SRES marker scenarios (coloured lines) and the 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases. **Right Panel**: Solid lines are multi-model global averages of surface warming for scenarios A2, A1B and B1, shown as continuations of the 20th-century simulations. These projections also take into account emissions of short-lived GHGs and aerosols. The pink line is not a scenario, but is for Atmosphere-Ocean General Circulation Model (AOGCM) simulations where atmospheric concentrations are held constant at year 2000 values. The bars at the right of the figure indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios at 2090-2099. All temperatures are relative to the period 1980-1999.
Source: IPCC Fourth Assessment Report, Synthesis Report, Summary for Policymakers, Figure SPM.5.

Table. Projected global average surface warming and sea-level rise, by scenario

Emission scenario	Temperature change (°C)	Sea-level rise (m)
	Long term (2090–2099)	Long term (2090–2099)
SRES B1	1.1–2.9 (1.8)	0.18–0.38
A1T	1.4–3.8 (2.4)	0.20–0.45
B2	1.4–3.8 (2.4)	0.20–0.43
A1B	1.7–4.4 (2.8)	0.21–0.48
A2	2.0–5.4 (3.4)	0.23–0.51
A1F1	2.4–6.4 (4.0)	0.26–0.59

・Projections indicate change relative to 1980–1999.

・( ) Numbers in parentheses indicate best estimates.

3. IS92a Scenarios

IS92a scenarios are emission scenarios used mainly in IPCC Second Assessment Report. According to the climate model experiments of the time, they were scenarios that would see 1.3°C (or 1.6°C if the radiative forcing of sulfur dioxide aerosols is not included) as the best estimate of the range of increase in global average surface temperature in 2021–2050 relative to base years 1961–1990.[3]

The contribution of Working Group I to the IPCC Second Assessment Report indicates an increase in temperature of 2.0°C in 2100 compared to 1990 (and 2.4°C if aerosols do not change from the 1990 level), in the case of medium climate sensitivity (2.5°C) under the IS92a emission scenarios.[4]

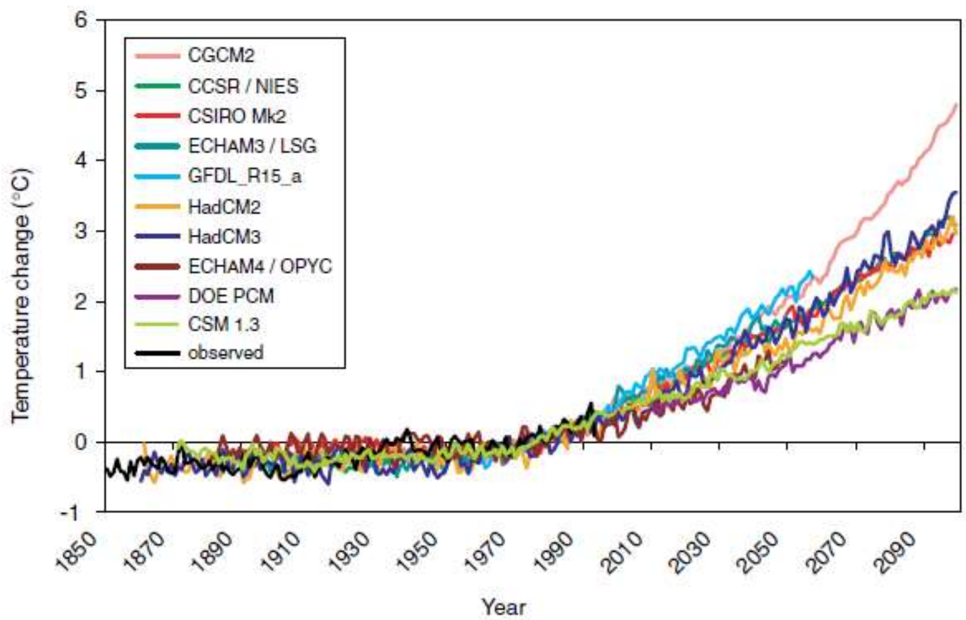


Figure. Changes in global average temperature for average of 1961–1990 (IS92a)

[3] Based on the contribution of Working Group I to the IPCC Third Assessment Report, section 9.3.1.2 Projection of future climate from forcing scenario experiments (IS92a). The figure is excerpted from that report.

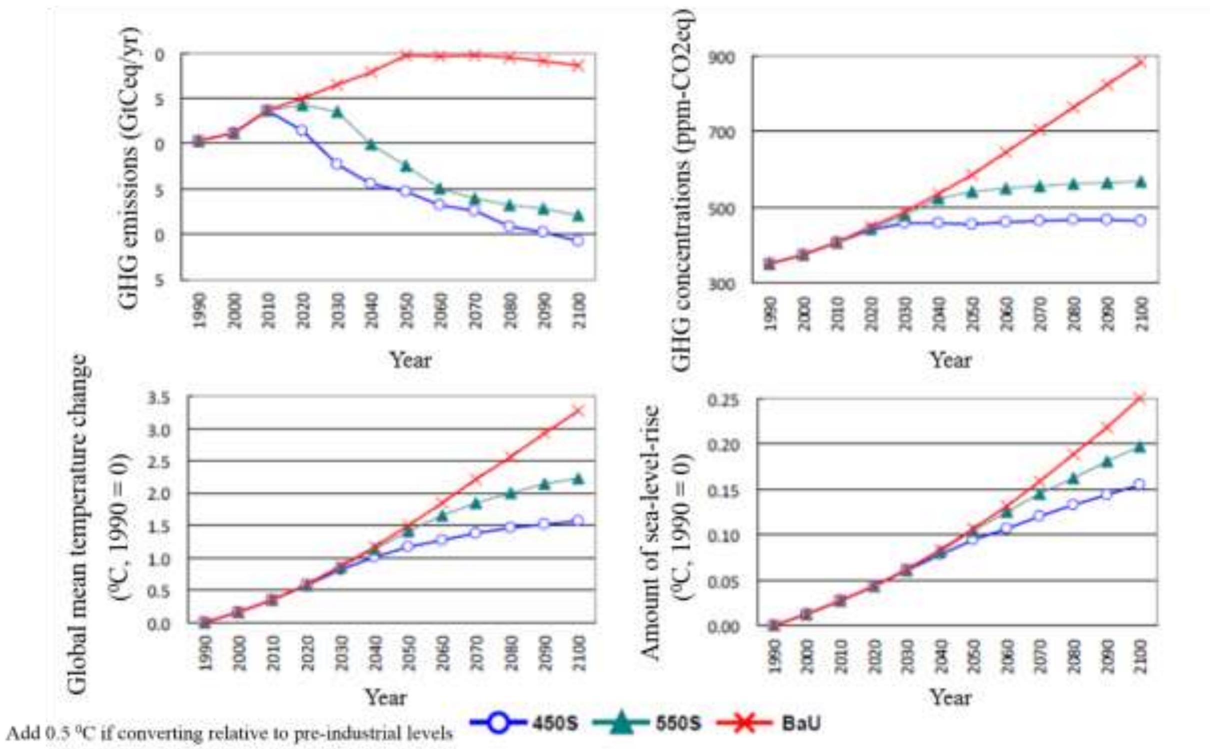
[4] Based on the contribution of Working Group I to the IPCC Second Assessment Report, Section 6.3.3 Temperature projections.

This figure also considers the impacts of sulfur dioxide aerosols. The black line indicates the observed temperature change, and other lines indicate the projections based on model simulation by different data centers.

4. Stabilization Scenarios of S-4 Research Project (BaU, 450s, 550s)

As for Japan, business-as-usual (BaU) scenarios as well as two GHG concentration stabilization scenarios (450s scenario and 550s scenario) were developed in FY 2005 to FY 2009 under the "Comprehensive Assessment of Climate Change Impacts to Determine the Dangerous Level of Global Warming and Appropriate Stabilization Target of Atmospheric GHG Consentration," which was Strategic R&D Area Project S-4 funded by the Global Environment Research Fund (Ministry of the Environment, Japan). They were established based on these conditions: (1) equilibrium climate sensitivity of 3℃, (2) carbon feedback effects are not taken into account, (3) MIROC3.2-hires is used to create regional climate scenarios from the global mean temperature change (pattern scaling), and (4) greenhouse gases as well as the cooling effect of aerosols are taken into account in consideration of greenhouse gas concentrations.[5]

Figure. Global GHG emissions, GHG concentrations, global mean temperature change, and amount of sea-level rise (by scenario)



5 Text and tables were prepared based on the "Global Warming Impacts on Japan -- Long-Term Climate Stabilization Levels and Impact Risk Assessment" as a second report on the results of research obtained from "Comprehensive Assessment of Climate Change Impacts to Determine the Dangerous Level of Global Warming and Appropriate Stabilization Target of Atmospheric GHG Consentration," implemented by the Global Environment Research Fund of the Ministry of the Environment, Japan (Global Warming Impacts Integrated Projection Team, 2009). The figure is excerpted from that report.

Table. Greenhouse gas concentrations (CO_2 equivalent) and average temperature rise, by scenario

Scenario	2100 GHG concentrations (CO_2 equivalent concentrations)	2100 Ave. temperature increase (relative to pre-industrial levels*)	Remarks
BaU scenario		About 3.8℃	Based on assumptions of SRES B2
450s scenario	450 ppm	About 2.1℃	With overshoot
550s scenario	550 ppm	About 2.9℃	With overshoot

Note: Increasing temperature relative to 1990 is calculated if 0.5℃ is reduced from the value relative to pre-industrial levels.

APPENDIX 1: ORGANIZATION FOR THIS REVIEW

(1) The Expert Committee on Climate Change Impact Assessment, the Global Environment Committee, Central Environment Council, Ministry of the Environment, Japan

(Japanese syllabary order, by family name)

Role	Name	Position and Affiliation
Expert	Michihiro Akiba	Research Managing Director, National Institute of Public Health
Expert	Keigo Akimoto	Group Leader and Chief Researcher, Systems Analysis Group, Research Institute of Innovative Technology for the Earth
Ad hoc	Masahiko Isobe	Vice President, Kochi University of Technology
Expert	Seita Emori	Head, Climate Risk Assessment Section, Center for Global Environmental Research, National Institute for Environmental Studies
Expert	Taikan Oki	Professor, Institute of Industrial Science, The University of Tokyo
Expert	Michio Kawamiya	Project Manager, Project Team for Risk Information on Climate Change, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology
Expert	Akio Kitoh	Senior Researcher, Faculty of Life and Environmental Sciences, University of Tsukuba
Expert	Hideaki Kidokoro (fromAugust 7, 2014)	Group Head, Fisheries Management Group, Fisheries Management Division, Japan Sea National Fisheries Research Institute, Fisheries Research Agency
Expert	Masahide Kimoto	Professor, Deputy Director-General, Atmosphere and Ocean Research Institute, The University of Tokyo
Expert	Ichiro Kurane	Deputy Director-General, National Institute of Infectious Diseases
Expert	Toshio Koike	Professor, School of Engineering, The University of Tokyo
Expert	Hidetaka Sasaki	Head, Third Laboratory, Atmospheric Environment and Applied Meteorology Research Department, Meteorological Research Institute
Regular	## Akimasa Sumi	President, National Institute for Environmental Studies
Expert	Kiyoshi Takahashi	Senior Researcher, Integrated Assessment Modeling Section, Center for Social and Environmental Systems Research, National Institute for Environmental Studies
Expert	Masamichi Takahashi	Principal Research Coordinator, Forestry and Forest Products Research Institute
Regular	Yukari Takamura	Professor, Graduate School of Environmental Studies, Nagoya University
Expert	Satoshi Takewaka	Professor, Graduate School of Systems and Information Engineering, University of Tsukuba
Ad hoc	Mitsuru Tanaka	Professor, Hosei School of Policy Sciences, Faculty of Social Sciences, Hosei University
Expert	Eiichi Nakakita	Professor, Hydrometeorological Disasters Research Section, Research Division of Atmospheric and Hydrospheric Disasters, Disaster Prevention Research Institute, Kyoto University
Ad hoc	Toru Nakashizuka	Professor, Graduate School of Life Sciences, Tohoku University

Role	Name	Position and Affiliation
Expert	Yukihiro Nojiri	Senior Principal Researcher, Center for Global Environmental Research, National Institute for Environmental Studies
Expert	Masahiro Hashizume	Professor, Institute of Tropical Medicine, Nagasaki University
Ad hoc	Hideo Harasawa	Director, National Institute for Environmental Studies
Expert	Koichi Fujita	Executive Director for Research Affairs, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism
Ad hoc	Hiroaki Furumai	Professor, School of Engineering, The University of Tokyo
Expert	Toshihiko Masui	Head, Integrated Assessment Modeling Section, Center for Social and Environmental Systems Research, National Institute for Environmental Studies
Expert	Mitsuo Matsumoto	Principal Research Coordinator, Forestry and Forest Products Research Institute
Expert	Kenji Morinaga (until August 6, 2014)	Senior Researcher, Research Center for Fisheries Oceanography & Marine Ecosystem, National Research Institute of Fisheries Science, Fisheries Research Agency
Expert	Kazuyuki Yagi	Principal Research Coordinator, National Institute for Agro-Environmental Sciences
Expert	Yoshifumi Yasuoka	Professor Emeritus, The University of Tokyo
Expert	Tadashi Yamada	Professor, Faculty of Science and Engineering, Department of Civil and Environmental Engineering, Chuo University

Chair of Committee

(2) Sectoral Working Groups concerning Climate Change Impacts (Ministry of the Environment, Japan Commissioned Study Groups)

1) Agriculture, Forestry, Fisheries WG

(Japanese syllabary order, by family name)

Role	Name	Position and Affiliation
Ad hoc	Tadashi Andoh	Chief Researcher, Stock Enhancement and Aquaculture Division, Seikai National Fisheries Research Institute, Fisheries Research Agency
Ad hoc	Osamu Enishi	Senior Researcher, Institute of Livestock and Grassland Science, National Agriculture and Food Research Organization
Regular	Michio Kawamiya	Project Manager, Project Team for Risk Information on Climate Change, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology
Regular	Hideaki Kidokoro	Group Head, Fisheries Management Group, Fisheries Management Division, Japan Sea National Fisheries Research Institute, Fisheries Research Agency
Ad hoc	Katsumi Kojima	Professor, Division of Biological Resources Development, Asian Natural Environmental Science Center, The University of Tokyo
Ad hoc	Toshihiko Sugiura	Senior Researcher, Plant Physiology and Fruit Chemistry Division, Institute of Fruit Tree Science, National Agriculture and Food Research Organization
Regular	Kiyoshi Takahashi	Senior Researcher, Integrated Assessment Modeling Section, Center for Social and Environmental Systems Research, National Institute for Environmental Studies

Role	Name	Position and Affiliation
Ad hoc	Motoki Nishimori	Senior Researcher, Agro-Meteorology Division, National Institute for Agro-Environmental Sciences
Ad hoc	Seishi Ninomiya	Professor, Graduate School of Agricultural and Life Sciences, Faculty of Agriculture, The University of Tokyo
Ad hoc	Takao Masumoto	Director, Research Division for Regional and Renewable Resource Engineering, National Institute for Rural Engineering, National Agriculture and Food Research Organization
Regular	Mitsuo Matsumoto	Principal Research Coordinator, Forestry and Forest Products Research Institute
Ad hoc	Tomonari Watanabe	Director, Agroinformatics Division, National Agriculture and Food Research Organization
Regular	# Kazuyuki Yagi	Principal Research Coordinator, National Institute for Agro-Environmental Sciences

Chair of Working Group

2) Water Environment / Water Resources and Natural Disasters / Coastal Areas WG

(Japanese syllabary order, by family name)

Role	Name	Position and Affiliation
Regular	Michihiro Akiba	Research Managing Director, National Institute of Public Health
Regular	Masahiko Isobe	Vice President, Kochi University of Technology
Regular	Seita Emori	Head, Climate Risk Assessment Section, Center for Global Environmental Research, National Institute for Environmental Studies
Regular	Taikan Oki	Professor, Institute of Industrial Science, The University of Tokyo
Ad hoc	Nobutomo Osanai	Director, Erosion and Sediment Control Research Group, Tsukuba Central Research Institute, Public Works Research Institute
Regular	Masahide Kimoto	Professor, Deputy Director-General, Atmosphere and Ocean Research Institute, The University of Tokyo
Regular	Yoshiaki Kuriyama	Research Director, Port and Airport Research Institute
Regular	# Toshio Koike	Professor, School of Engineering, The University of Tokyo
Regular	Masamichi Takahashi	Principal Research Coordinator, Forestry and Forest Products Research Institute
Regular	Satoshi Takewaka	Professor, Faculty of Engineering, Information and Systems, University of Tsukuba
Ad hoc	Yoshio Tsuboyama	Director, Department of Soil and Water Conservation, Forestry and Forest Products Research Institute
Regular	Eiichi Nakakita	Professor, Hydrometeorological Disasters Research Section, Research Division of Atmospheric and Hydrospheric Disasters, Disaster Prevention Research Institute, Kyoto University
Ad hoc	Yasuaki Hijioka	Head, Environmental Urban Systems Section, Center for Social and Environmental Systems Research, National Institute for Environmental Studies

Role	Name	Position and Affiliation
Regular	Koichi Fujita	Executive Director for Research Affairs, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism
Ad hoc	Masaharu Fujita	Professor, Research Center for Fluvial and Coastal Disasters, Disaster Prevention Research Institute, Kyoto University
Regular	Hiroaki Furumai	Professor, School of Engineering, The University of Tokyo
Ad hoc	Takao Masumoto	Director, Research Division for Regional and Renewable Resource Engineering, National Institute for Rural Engineering, National Agriculture and Food Research Organization
Ad hoc	Hiroshi Yagi	Group Head, Fisheries Infrastructure Group, Aquaculture and Fishing Port Engineering Division, National Research Institute of Fisheries Engineering, Fisheries Research Agency
Regular	Tadashi Yamada	Professor, Department of Civil and Environmental Engineering, Faculty of Science and Engineering, Chuo University

Chair of Working Group

3) Natural Ecosystems WG

(Japanese syllabary order, by family name)

Role	Name	Position and Affiliation
Ad hoc	Tomohiro Ichinose	Professor, Faculty of Environment and Information Studies, Keio University
Regular	Seita Emori	Head, Climate Risk Assessment Section, Center for Global Environmental Research, National Institute for Environmental Studies
Ad hoc	Tsuneo Ono	Group Head, National Research Institute of Fisheries Science, Fisheries Research Agency
Ad hoc	Gaku Kudo	Associate Professor, Section of Environmental Biology, Faculty of Environmental Earth Science, Hokkaido University
Ad hoc	Akio Takenaka	Directror, Biodiversity Research Program, Center for Environmental Biology and Ecosystem Studies, National Institute for Environmental Studies
Ad hoc	Hiroshi Tanaka	Senior Research Coordinator, Forestry Technology and Management Research, Forestry and Forest Products Research Institute
Regular	〇Toru Nakashizuka	Professor, Graduate School of Life Sciences, Tohoku University
Ad hoc	Futoshi Nakamura	Professor, Laboratory of Forest Ecosystem Management, Graduate School of Agriculture, Hokkaido University
Regular	Yukihiro Nojiri	Principal Senior Researcher, Center for Global Environmental Research, National Institute for Environmental Studies
Ad hoc	Yutaka Maruyama	Professor, Department of Forest Science and Resources, College of Bioresource Sciences, Nihon University
Regular	Yoshifumi Yasuoka	Professor Emeritus, The University of Tokyo
Ad hoc	Hiroya Yamano	Head, Biodiversity Conservation Planning Section, Center for Environmental Biology and Ecosystem Studies, National Institute for Environmental Studies

Chair of Working Group

4) Human Health Working Group

(Japanese syllabary order, by family name)

Role	Name	Position and Affiliation
Ad hoc	Masaji Ono	Fellow, Center for Environmental Health Sciences, National Institute for Environmental Studies
Regular	Akio Kitoh	Senior Researcher, Faculty of Life and Environmental Sciences, University of Tsukuba
Regular	# Ichiro Kurane	Deputy Director-General, National Institute of Infectious Diseases
Regular	Kiyoshi Takahashi	Senior Researcher, Integrated Assessment Modeling Section, Center for Social and Environmental Systems Research, National Institute for Environmental Studies
Regular	Masahiro Hashizume	Professor, Institute of Tropical Medicine, Nagasaki University
Ad hoc	Yasushi Honda	Professor, Faculty of Health and Sport Sciences, University of Tsukuba
Ad hoc	Chiho Watanabe	Professor, Faculty of Medicine, Graduate School of Medicine, The University of Tokyo

Chair of Working Group

5) Industry / Economic Activities and Life of Citizenry and Urban Life WG

(Japanese syllabary order, by family name)

Role	Name	Position and Affiliation
Regular	Keigo Akimoto	Group Leader and Chief Researcher, Systems Analysis Group, Research Institute of Innovative Technology for the Earth
Regular	Hidetaka Sasaki	Head, Third Laboratory, Atmospheric Environment and Applied Meteorology Research Department, Meteorological Research Institute
Regular	Yukari Takamura	Professor, Graduate School of Environmental Studies, Nagoya University
Regular	Mitsuru Tanaka	Professor, Department of Policy Science on Society, Faculty of Social Sciences, Hosei University
Regular	# Hideo Harasawa	Vice President, National Institute for Environmental Studies
Ad hoc	Fumiaki Fujibe	Director, Atmospheric Environment and Applied Meteorology Research Department, Meteorological Research Institute
Regular	Toshihiko Masui	Head, Integrated Assessment Modeling Section, Center for Social and Environmental Systems Research, National Institute for Environmental Studies
Ad hoc	Ikusei Misaka	Professor, Department of Architecture, Faculty of Engineering, Nippon Institute of Technology

Chair of Working Group