ISSN 2187-9486

NIES Annual Report 2025

AE - 31 - 2025

National Institute for Environmental Studies
https://www.nies.go.jp/

ISSN 2187-9486

NIES Annual Report 2025

AE - 31 - 2025

National Institute for Environmental Studies
https://www.nies.go.jp/

Foreword

It is our pleasure to present the Annual Report of the National Institute for Environmental Studies (NIES). Since its establishment in 1974, NIES is the unique research institute in Japan conducting a broad range of interdisciplinary, integrated environmental research closely related to society, social change, and the people of Japan. This Annual Report is the official record of activities at NIES in Fiscal Year 2024 (FY2024: April 2024 to March 2025) which marked the forth year of our Fifth Five-Year Plan (FY2021-FY2025).

Under the Fifth Five-Year Plan, NIES has been steadily engaged in basic and fundamental work to create scientific knowledge that should serve as a source to solve environmental issues by establishing six fields (Earth System; Material Cycles; Health and Environmental Risk; Regional Environment Conservation; Biodiversity; Social Systems) to form the pillars of environmental research and two fields (Environmental Emergency and Resilience; Climate Change Adaptation) which we aim to systemize over the long term. In addition to promotion of *Foresight and Advanced Basic Research* based on creative and cutting-edge science exploration, we are also steadily developing *Intellectual Research Infrastructure* to support academic and policy work through *Policy-Oriented Research* for practical research responding to policy needs, and global environmental monitoring which has been ongoing for long years.

The Eight Strategic Research Programs are set across research fields to solve urgent issues. These research programs are climate change and air quality, material flow innovation, comprehensive environmental risk, harmonization with nature, decarbonized and sustainable society, co-design approach for local sustainability, environmental emergency and resilience, and climate change adaptation. The programs are being conducted in a focused and comprehensive manner with awareness to achieve goals within the Fifth Five-Year Plan. The climate crisis issues are particularly promoted in an integrated manner under *Climate Crisis Research Initiative*, which coordinates four related programs.

Based on national plans, NIES continues to conduct the satellite-based global observation of greenhouse gases (GOSAT) and the nationwide birth cohort study of 100,000 pairs of parents and children on children's health and the environment as projects to be implemented beyond the Five-Year Plan period. Preparations for data processing for the third GOSAT to be launched, as well as continuation of the birth cohort study to children 13 years of age and onward has been approved. As for climate change adaptation, we are conducting research and providing technical assistance to local governments to promote adaptation.

As a core institute for environmental research in Japan, NIES will continue to cooperate with related organizations and contribute to the society. We conduct joint research with research institutions in Japan and abroad on a variety of environmental issues. In collaboration with local governments and citizens, we are also working on numerous initiatives to address climate change, promote nature restoration, and realize a recycling-oriented society. Furthermore, NIES has successfully launched our first startup company, which began operations in January 2025.

As the pandemic subsides, research activities such as environmental monitoring cooperation overseas are resuming. We will steadily achieve our goals for the current Five-Year Plan period.

This Annual Report aims to inform the public of our research activities. We would appreciate any forthright opinions on our status and future activities.

Masahide KIMOTO
President
December 2025

Contents

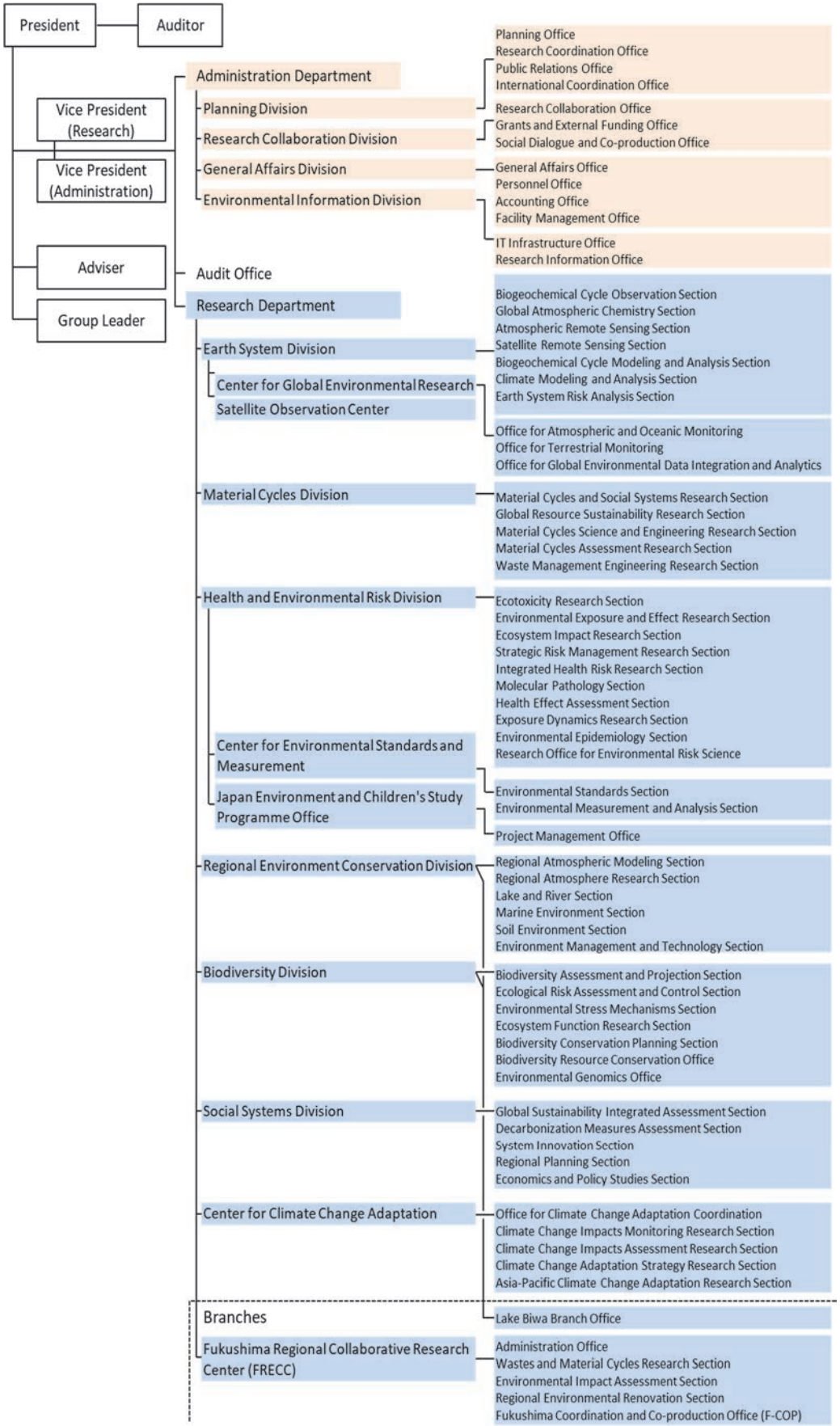
During the 1950s and 1960s, Japan experienced serious environmental pollution problems accompanying rapid economic growth. The Environment Agency was established in 1971 as part of the Japanese government to develop measures to counteract serious problems associated with environmental pollution, such as Minamata disease, which was caused by poisoning from organic mercury in factory wastewater, and chronic bronchitis and asthma caused by sulfur oxides from factories in large industrial complexes. Understanding that research on environmental sciences was necessary and could address public needs, the Environment Agency established the National Institute for Environmental Studies (NIES) in Tsukuba Science City, about 50 km north of Tokyo, in 1974. It is now Japan's primary institute for comprehensive research in environmental science.

During the two decades following the establishment of NIES, rapid technological progress, structural changes in industry, and lifestyle changes, created additional issues for environmental science to confront. Moreover, global environmental problems such as climate change; depletion of the stratospheric ozone layer; acid deposition; destruction of tropical rain forests; desertification; and decreasing biodiversity, attracted greater concern worldwide. NIES subsequently underwent a major reorganization in 1990, including the establishment of the Center for Global Environmental Research, to enable it to conduct more intensive research on conservation of the natural environment and on global environmental changes and their effects.

January 2001 saw the transition of the Environment Agency into the Ministry of the Environment as part of structural changes within the Japanese government, and the establishment of a Waste Management Research Division at NIES. That year also marked the establishment of NIES as an Incorporated Administrative Agency, giving it a degree of independence from the national government. The change in the administrative status of the institute allows more prompt and flexible responses to societal demands. Concurrently, NIES prepared a Five-Year Plan (2001–2005) in line with the objectives of the Ministry of the Environment.

Following the Second Five-Year Plan (2006-2010), the Third Five-Year Plan (2011–2015) was adopted in 2011. Research activities to respond to and recover from the Great East Japan Earthquake have also been ongoing since the direct aftermath of the disaster. In March 2013, the Five-Year Plan was revised following a directive of the Minister of the Environment and NIES relaunched as a National Research and Development Agency from April 2015. In the Fourth Five-Year Plan (2016-2020), NIES established Fukushima Branch in April 2016 and Lake Biwa Branch Office in April 2017. In December 2018, we also established the Center for Climate Change Adaptation in line with the enactment and enforcement of the Climate Change Adaptation Act to research and promote adaptation to climate change. Our latest organization chart is shown in Fig. 1.

Fig. 1 Organization



April 2021 marked the beginning of the Fifth Five-Year Plan (2021-2025). NIES established 8 Strategic Research Programs such as environmental emergency and resilience research and climate change adaptation research, and pursuing them in an integrated manner that transcends individual fields.

Furthermore, to produce scientific findings on environmental protection, NIES has been carrying out research projects that include consolidating the institute's research foundation through basic research, data acquisition and analysis, preservation and provision of environmental samples, and other efforts.

NIES plays a central role in research networks too, for example GOSAT/GOSAT-2 satellite observations and the Japan Environment and Children's Study (a large-scale environmental epidemiology survey). Also an important work among our tasks is actively disseminating environmental information in easy-to-understand formats, including the outcomes of our research efforts and projects.

As of April 1, 2024, there are 298 NIES permanent staff and 621 contract staff (Table 1; Figs. 2 to 5). The total budget for FY2024 was 21,466 million yen (Table 2).

Table 1 Numbers of permanent staff

(As of April 1, 2024)

Administration Department	70	
Research Department	222	(3)
Audit Office	1	
Executives and Advisers	5	
Total	298	(3)

Table 2 Budget for the Fifth Five-Year Plan

(Unit: million yen)

	Category	2021-2025 Budget (5 years)	Fiscal Year 2024 Budget
Revenue	Grants for Operating Costs	85,277	17,159
	Subsidies for Facilities	2,003	671
	Commissioned Work	18,428	3,636
	Total	105,708	21,466
Expenditure	Project Costs	66,315	13,108
	Facility Improvements	2,003	671
	Expenses for Commissioned Work	18,179	3,636
	Personnel Expenses	17,069	3,636
	General Administrative Expenses	2,141	415
	Total	105,708	21,466

Note: The budget for each annual work plan will be requested and decided for each fiscal year, based on the Mid-and-Long Term Plan.

Administration Department	:	70	
Research Department	:	222	(3)
Audit Office	:	1	
Executives and Advisers	:	5	
Total		298	(3)

Notes:
1. Data is as of April 1, 2024.

2. Figures in parentheses indicate number of foreign nationals.

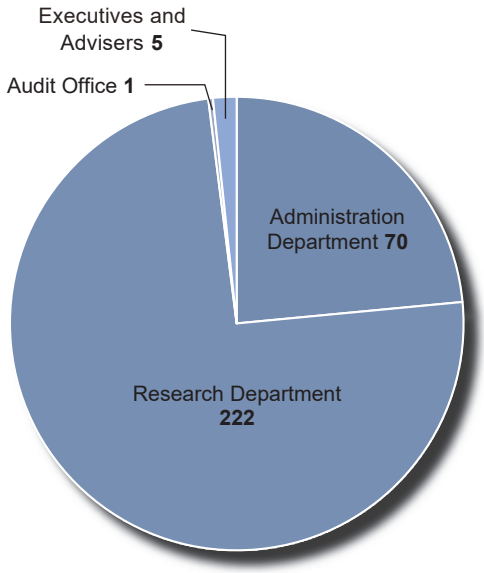


Fig. 2 Permanent staff breakdown

Basic Sciences	:	94	43.93%
Engineering	:	66	30.84%
Agricultural Sciences	:	33	15.42%
Medical Sciences	:	9	4.21%
Pharmaceutical Sciences	:	4	1.87%
Veterinary Medicine	:	2	0.94%
Social Sciences	:	6	2.79%
Total		214	

Note: Data is as of April 1, 2024.

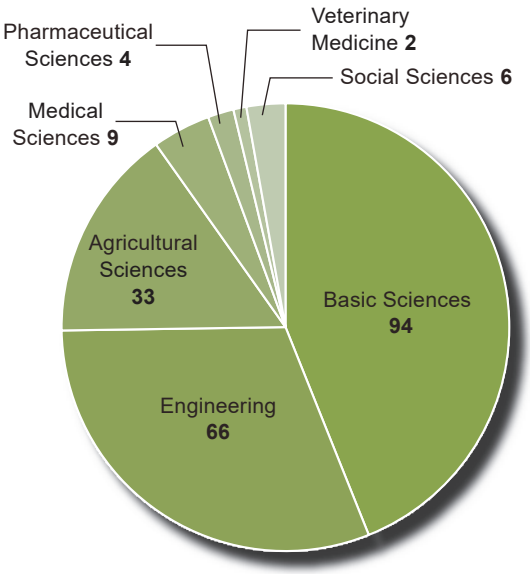


Fig. 3 Fields of expertise（Researchers holding doctorates（99.1%））

Fellow	:	5	
Research Associate	:	79	(43)
Junior Research Associate	:	6	(1)
Research Assistant	:	27	(10)
Senior Research Associate	:	11	(2)
Expert	:	246	(11)
Assistant Staff	:	241	
Senior Staff	:	2	
Specially Appointed Researcher		4	
Total		621	(67)

Notes:
1. Data is as of April 1, 2024.

2. Figures in parentheses indicate number of foreign nationals.

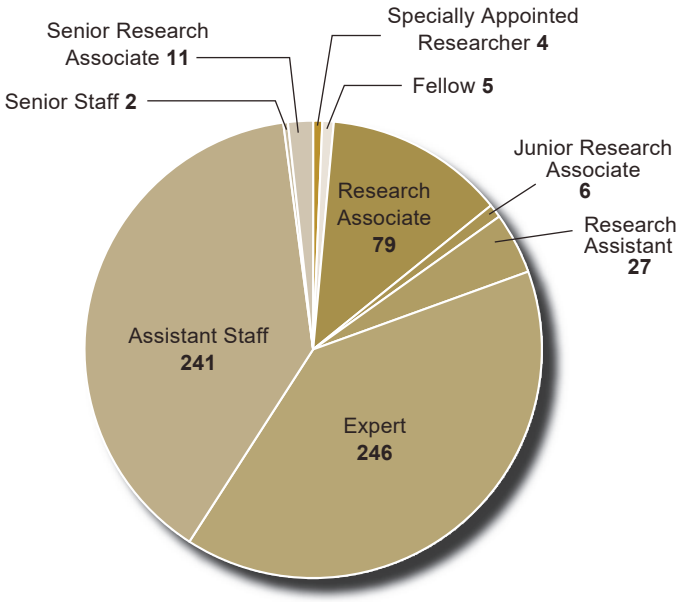


Fig. 4 Contract Staff Breakdown

Visiting Researcher	195	(18)
Collaborative Researcher	104	(13)
Research Student	47	(14)
Interns	16	(10)
Total	362	(55)

Notes:

1. Data is the total number accepted in FY2024.

2. Figures in parentheses indicate number of foreign nationals.

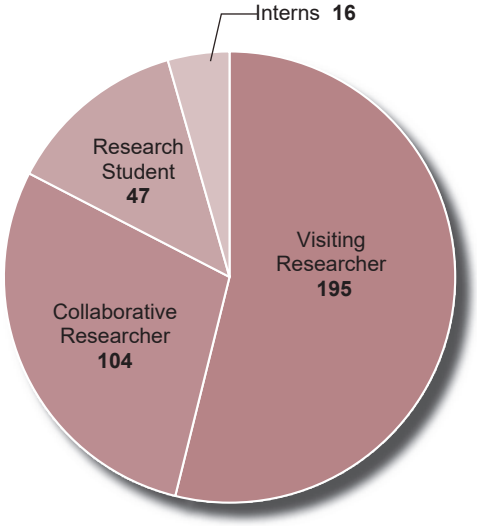


Fig. 5 Visiting and Collaborative Researchers, Research Students, and Interns

Strategic
Research Programs

Climate Change and Air Quality Research Program

By making the best combined use of the Earth observation data from ground-based, ship-based, aircraft, and satellite platforms, we intend to meet the challenge to establish an operational system to estimate greenhouse gas (GHG) emissions and uptake on a global scale. We will also develop a new methodology to estimate GHG and SLCF (short-lived climate forcer) emissions on national and city scales. In addition, by using the latest emission estimates and evaluations, we will improve the accuracy of hindcast and forecast of the changes and variability in climate and air quality. To do this, we will use state-of-the-art modeling that takes into account the latest emission estimates and the latest knowledge of the fundamental processes of microphysics and chemical reactions and of the interactions of Earth systems. Overall, we will provide the scientific basis needed to make policy decisions to achieve the long-term goal of global stabilization of climate and air quality (Fig. 1).

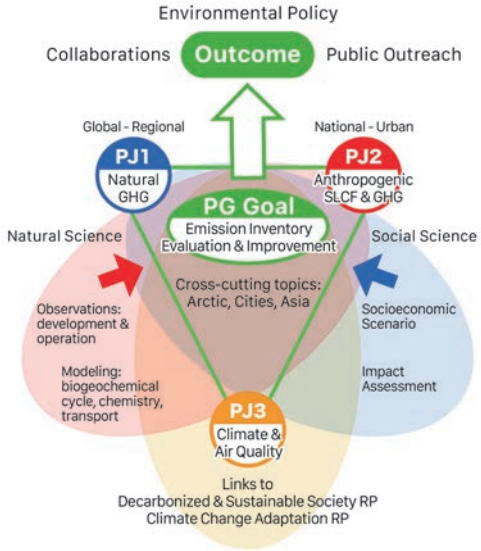


Fig. 1 Conceptual schematic of the Climate Change and Air Quality Research Program. PG, Program; PJ, Project; RP, Research Program

Project 1. Quantitative evaluation of natural/anthropogenic GHG sources and sinks on the global scale

This project aims to develop unified, neutral, and objective methods for estimating global GHG sources and sinks, from developed to developing countries, that are associated with different technical levels of preparation and compilation of emission inventories. To do this, we are making the best use of the data obtained from ground-based, ship-based, aircraft, and satellite observations. The project comprises three sub-themes: (1) GHG exchange over land and ocean, based on highly precise observations; (2) GHG budgeting over an extensive regional scale by atmospheric observation and modeling; and (3) GHG emissions and carbon (C) and nitrogen (N) dynamics associated with human activities.

Atmospheric methane (CH_4) growth rates reached unprecedented values in the years 2020–2022. To identify the main drivers of this increase, we used an inverse model

to estimate regional and sectoral emission changes for 2016–2022. Three inverse estimates based on different sets of atmospheric CH_4 observations—surface observations only, surface and aircraft observations, and GOSAT (Greenhouse gases Observing SATellite) observations—consistently suggest that there were notable emission increases from 2016–2019 to 2020–2022 in the tropics (15°S to 10°N) (10 to 18 Tg CH_4/year) and at northern low latitudes (10°N to 35°N) (about 20 Tg CH_4/year), the latter of which likely contributed to the growth rate surge from 2020 (Fig. 2). The emission increase in the northern low latitudes was attributable to emissions in South Asia and northern Southeast Asia, which abruptly increased from 2019 to 2020; elevated emissions were still continuing in 2022. The tropical emissions increase was dominated by Tropical South America and Central Africa; these emissions were increasing continuously before 2019. We found agreement in the sectoral estimates of the three inversions in the tropics and northern low latitudes, suggesting the largest contribution of biogenic emissions. Uncertainty reductions demonstrated that the flux estimates in Asia were well constrained by the surface and aircraft observations. Furthermore, a sensitivity test with the probable reduction of OH radicals yielded smaller emissions (by up to 2 to 3 Tg CH_4/year) in each Asian region in 2020, still suggesting that there were notable emission contributions. These results highlight the importance of the contribution of biogenic emissions in the Asian regions to the persistent high growth rate observed during 2020–2022.

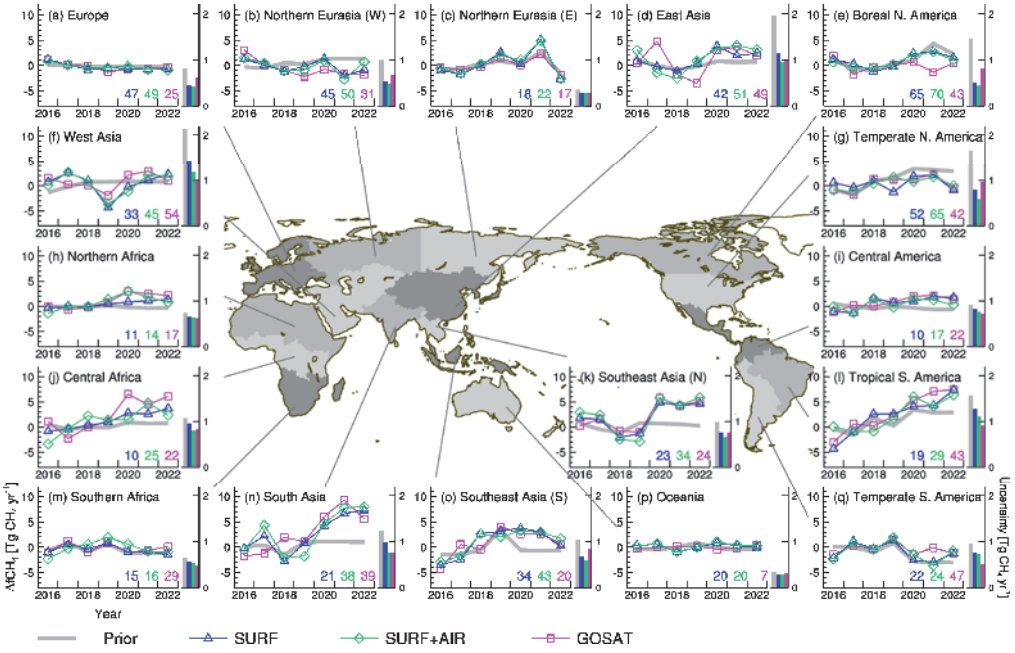


Fig. 2 Year-to-year variations of regional ΔfCH_4 (left) and regional annual flux uncertainty for 2020 (right). Emissions are integrated within each of the geographical regions defined in the center map. The numbers in each panel denote the uncertainty reduction ratio (%) of the annual flux for 2020 in each region, with the color corresponding to that of ΔfCH_4 (taken from Fig. 6 of Niwa et al., 2025). SURF, surface observations; SURF+AIR, surface and aircraft observations

Reference:

Niwa Y., Tohjima Y., Terao Y., Saeki T., Ito A., Umezawa T., Yamada K., Sasakawa M., Machida T., Nakaoka S.-I., Nara H., Tanimoto H., Mukai H., Yoshida Y., Morimoto S., Takatsuji S., Tsuboi K., Sawa Y., Matsueda H., Ishijima K., Fujita R., Goto D., Lan X., Schuldt K., Heliasz M., Biermann T., Chmura L., Necki J., Xueref-Remy I., Sferlazzo D. (2025) Multi-observational estimation of regional and

sectoral emission contributions to the persistent high growth rate of atmospheric CH_4 for 2020–2022. *Atmospheric Chemistry and Physics* 25, 6757–6785, https://doi.org/10.5194/acp-25-6757-2025

Project 2. Quantitative evaluation of anthropogenic SLCF and GHG emissions on regional, national, and city scales

This project aims to reduce the uncertainties in anthropogenic emissions inventories for SLCF and GHG. These inventories are based on international assessment reports and are used in modeling studies of both climate and air quality. We perform four main activities: (1) expansion of our network of observations from the ground and from ships and aircraft; (2) development of new analysis and observation methods; (3) development of a method of estimating emissions at a high spatial resolution; and (4) building of high-resolution inventories.

To assess the climate impact of black carbon (BC), accurate emissions inventories are crucial for climate model simulations. However, bottom-up emissions inventories have substantial uncertainties regarding anthropogenic BC emissions from China and struggle to capture rapid changes in emissions. Top-down analysis using atmospheric observations is a useful method to evaluate inventories and to immediately estimate BC emissions. We estimated the long-term trend of anthropogenic BC emissions from China for 2009–2022 by using observations at remote sites in Japan and a chemical transport model, GEOS-Chem. Our analysis revealed a continuous reduction in Chinese BC emissions of $-5.2\% \pm 0.4\%$ year^{-1} after the exclusion of data influenced by wet deposition (Fig. 3). This decreasing trend surpassed those of the bottom-up inventories, which estimated reduction rates ranging from -2.4% year^{-1} to -4.2% year^{-1} after 2010. Consequently, the differences between the observation-based estimates and inventories gradually increased toward the latest years of the inventories. The rapid reduction identified from this observation needs to be reflected in the historical inventory for the Coupled Model Intercomparison Project Phase 7 (CMIP7) to accurately assess the impact of aerosols on past and future climate change.

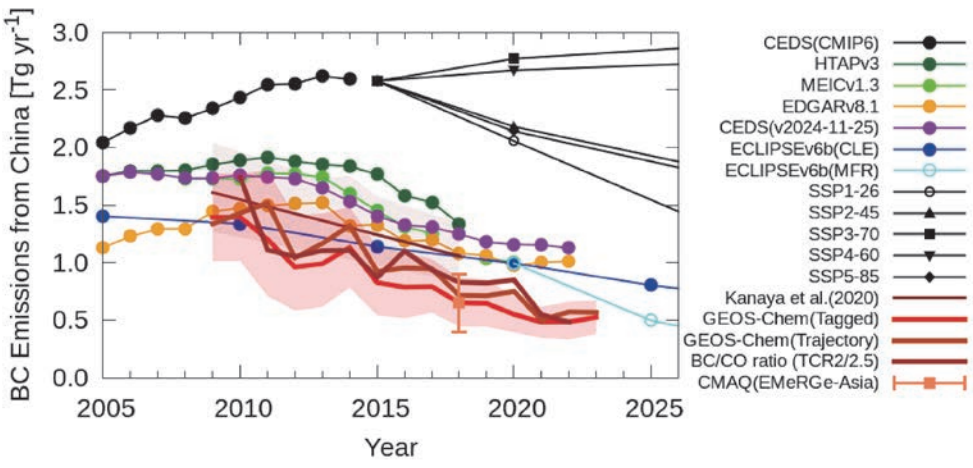


Fig. 3 Comparisons of trends in annual black carbon (BC) emissions from China, as estimated by top-down analysis using GEOS-Chem (bottom part of graph), with various bottom-up inventories (top part of graph) and future emissions scenarios (middle part) (taken from Fig. 3 of Tanimoto et al., 2025)

Reference:
Tanimoto H., Kanaya Y., Ikeda K., Morikawa T., Sekiya T., Ha P.T.M., Yamaji K. (2025) *East Asian Black Carbon Emission Report* 2024, 22 pp., https://doi.org/10.34462/0002000234

Project 3. Simulation and projection of climate air quality with enhanced numerical modeling capabilities

In this project, we are studying historical and future changes in climate and air quality by numerical simulation using global climate models (GCMs) that include aerosol and chemistry modules. Output data from the numerical simulations are useful for discussing measures for the mitigation of, and adaptation to, climate and air quality changes. By producing these output data, we intend to help to achieve the temperature goals in the Paris Agreement.

Climate change impact modelling studies often require not only mean temperature and precipitation but also other climate variables (e.g., solar radiation and wind speed) and extreme indices as input data. However, studies of observational constraints (emergent constraints) in relation to these variables and indices are limited. Linearities of future climate change as functions of global warming levels, along with biases in recent global mean temperature trends in simulations conducted with 40 Earth system models (ESMs), have revealed that the upper bounds of uncertainties in future changes of various variables (annual mean temperature, annual maximum daily maximum temperature, mean specific humidity, and mean downward longwave radiation) have been successfully lowered in most regions of the world (Fig. 4). We can also reduce the inter-model variances of regional changes in mean precipitation, annual maximum daily precipitation, mean downward shortwave radiation, mean sea-level pressure, and mean surface wind speed in some areas. These results would be useful in determining whether climate change impact studies should weight ESMs or exclude some ESMs to prevent possible biases in impact assessments.

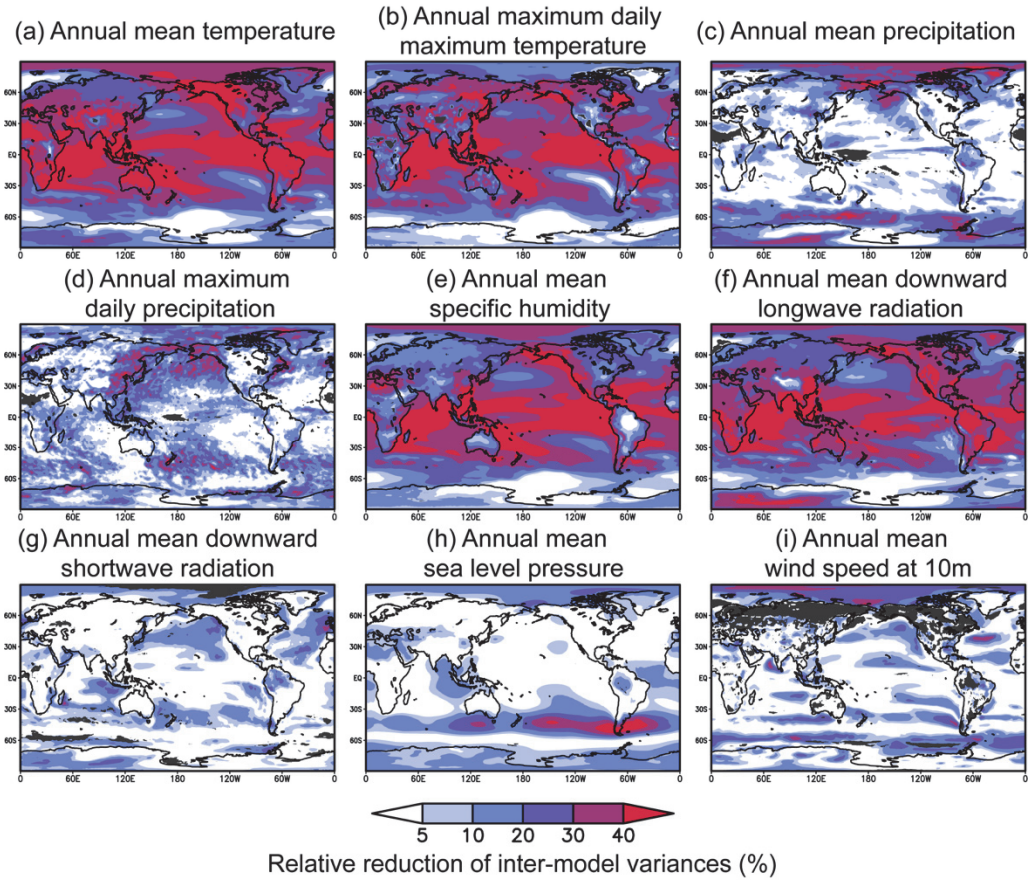


Fig. 4 Relative reductions of inter-model variances (%) in nine variables used in modeling studies (taken from Figs. 2 and 4 of Shiogama et al., 2024)

Reference:

Shiogama H., Hayashi M., Hirota N., Ogura T. (2024) Emergent constraints on future changes in several climate variables and extreme indices from global to regional scales. *Scientific Online Letters on the Atmosphere* 20, 122–129, doi:10.2151/sola.2024-017

Overview of Material Flow Innovation Research Program

The Material Flow Innovation Research Program is focused on the assessment and enhancement of material flows over entire product life cycles to achieve the sustainable utilization of resources. We have been implementing three research projects with the goal of qualitatively and quantitatively demonstrating future changes required in material flows (Fig. 1). The projects are: Project 1, Material flows transition and social adaptation (PJ1); Project 2, Chemical management for material flows transition (PJ2); and Project 3, Material circulation and sequestration technology (PJ3).

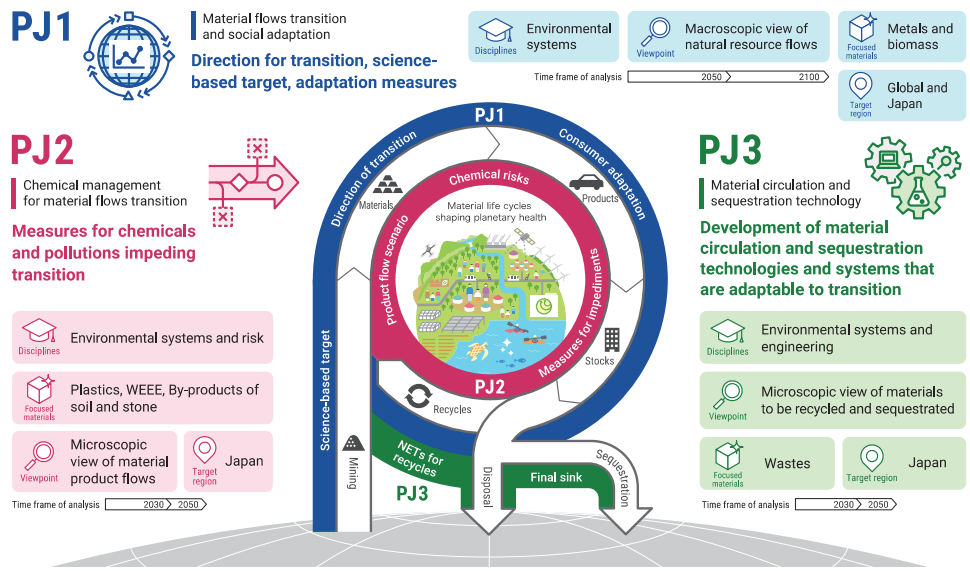


Fig. 1 Overall diagram of the project structure of the Material Flow Innovation Research Program. NETs, Negative Emission Technologies; WEEE, waste electrical and electronic equipment

In 2024, to obtain a wider understanding of the importance of the innovative transition of material flows and encourage its early start-up, we concentrated our energies on strategic outreach activities focusing on international organizations, material-intensive industries, consumers, environmental risk administration agencies, and resource recycling industries, not to mention the publication of international academic papers and press releases.

Specifically, four papers on the results of PJ1 were cited in the UNEP (United Nations Environment Programme) International Resource Panel's flagship report *Global Resource Outlook 2024*, and we received about 20 invitations from Japan and overseas to give lectures on our results on science-based targets of material flows. We also endeavored to publish articles in multiple media and to exchange opinions with industry. Articles on measures for adapting consumption were published in 14 media, and these measures were utilized by eight climate citizens' meetings and climate action plans.

Highlighted research findings

Project 1: Material flows transition and social adaptation

The decarbonization of materials production presents a major challenge to achieving a carbon-neutral society. The current carbon-neutral roadmap for materials generally assumes an uncertain dissemination of innovative production technologies, making the changes in material flows required for a carbon-neutral society unclear.

By analyzing the relationship between greenhouse gas (GHG) emissions and changes in Japan's material flow indicators up to the previous fiscal year, we calculated target values for material flow indicators consistent with achieving carbon neutrality (CN) by 2050[1)]. The current CN roadmap for Japan assumes the large-scale adoption of innovative technologies, including hydrogen utilization and carbon capture and storage (CCS), to reduce GHG emissions from materials such as iron and cement. However, it does not consider CN from the perspective of reducing material consumption and improving efficiency.

In this study, we developed six scenarios by combining different conditions: the presence or absence of reduction targets (2%, 3%, and 4% a year) for total material input (domestic resources + imported resources + domestic circulated resources), as well as options for improving material use efficiency and decarbonizing production technology. The feasibility of achieving CN by 2050 and the material flow structure required were evaluated.

We found that achieving the 2030 target (a 46% reduction from 2013 levels) will be impossible without a material reduction target and will be achievable only through progress in electricity decarbonization (BaU+ES, Business as Usual and Energy Strategy scenario). Even with electricity decarbonization and a 3% annual reduction in total material input (DA T3% in Fig. 2), the target would remain out of reach. However, with electricity decarbonization and a 4% annual reduction target (DA T4%), CN-level GHG emissions (203 million tonnes, an 83% reduction from 2015) could potentially be achieved. Nonetheless, this would require the implementation of 88% of the assumed maximum CCS capacity.

We confirmed that the CCS required would be reduced if consideration were also given to the material efficiency strategy (+MFT in Fig. 2) and the introduction of decarbonization technology for material production (+MFT+ITP). However, the GHG reduction effect of production decarbonization technologies was found to be very limited because the material reduction targets and material efficiency strategies would reduce material consumption itself.

These results underscore the urgent need to choose between emphasizing the dissemination of innovative decarbonization technologies within the limited time frame until 2050 or prioritizing technologies and policies that promote resource-saving and material-efficient lifestyles by continuously reducing material consumption throughout the supply chain connecting consumers and producers.

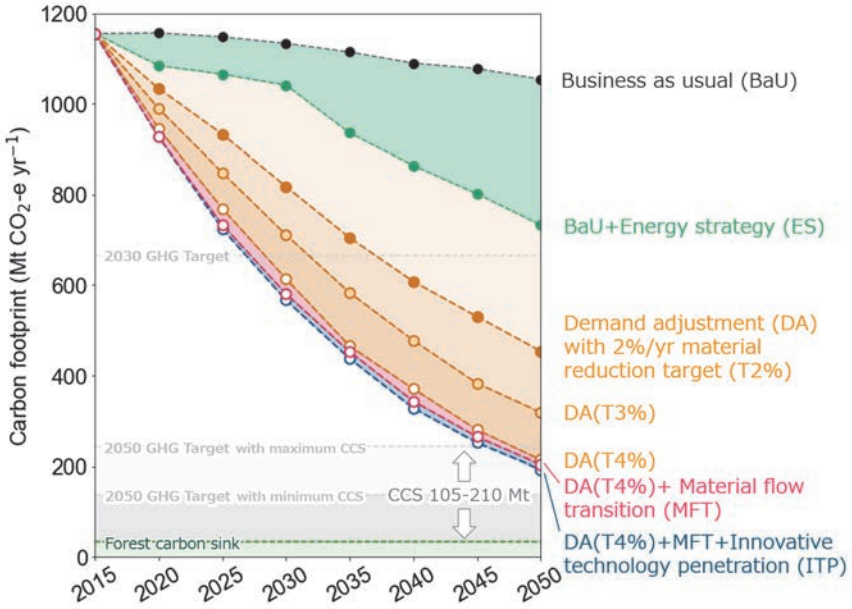


Fig. 2 Carbon-neutral pathways through material flows transition in Japan, 2015–2050 [1)]

Reference:

1) Hata S., Nansei K., Shigetomi Y., Kito M., Nakajima K. (2025) Material efficiency and circularity goals to achieve a carbon-neutral society by 2050. *Environmental Science and Technology* 2025, 59, 6025−6036

Project 2: Chemical management for material flows transition

Focusing on microplastics (MPs) generation during shredding in the mechanical recycling of plastics, we calculated MPs generation coefficients and estimated MPs generation and environmental discharge in Japan and globally. Shredding tests of plastics revealed that MPs smaller than 5 mm are generated through shredding in the mechanical recycling of plastics. By count, MPs under 1 mm dominated, whereas by weight, MPs between 1 mm and 5 mm were predominant. The generation coefficient for MPs sized 300 μm to 2 mm was calculated to be 0.0026 to 0.0290, and these values were consistent with those obtained from field surveys near mechanical recycling facilities. By using the calculated coefficients, MPs generation in 2017 in the shredding processes used in the mechanical recycling of plastics was estimated at 0.006 Mt in Japan and 0.206 Mt worldwide, with major contributions from Asia (non-OECD), Europe (OECD), and the US (OECD). Environmental discharge was estimated at 0.002 Mt in Japan and 0.095 Mt globally, with Asia (non-OECD) contributing the most (Fig. 3), owing to low wastewater treatment coverage and low MPs removal rates. The estimated global MPs discharge from the mechanical recycling of plastics ranked second after laundry-related textile MPs (0.26 Mt) reported by UNEP, indicating that it was an important pollution source. Assuming that the current wastewater treatment conditions remain the same, global MP discharge was projected to reach 0.749 Mt by 2060, with Asia (non-OECD) showing the highest increase, highlighting the critical role of this region in the future reduction of MPs from plastic recycling.

Fig. 3 Global discharge volumes of microplastics from mechanical recycling of plastic waste to the environment[2)]

To look at ways of preventing fire incidents attributable to portable lithium-ion batteries (LIBs) at waste treatment and recycling facilities, we identified high-risk products on the basis of a survey of LIBs used in small waste electrical and electronic equipment (sWEEE) and safety tests of LIB cells. A survey of over 1000 samples of sWEEE provided basic data on battery weight, energy, and removability of LIBs, by product category. Safety tests showed that batteries with residual energy of 3.6 to 5.4 Wh or more—particularly cylindrical cells at high states of charge—pose a high ignition risk. Assuming 10% remaining energy at disposal, products such as motor-assisted bicycles, laptops, tablets, cordless and robotic vacuum cleaners, and power banks were identified as posing a particularly high fire risk when misplaced in waste streams involving shredding. We then estimated the generation and flow of end-of-life LIBs and evaluated the effectiveness of management strategies. The generation of end-of-life portable LIBs in Japan was estimated at 8162 tonnes in 2020, largely consisting of identified high-risk products and smartphones. Only 14% was being collected through the existing collection schemes for batteries and sWEEE. We then estimated the effects of appropriate management measures—such as separate collection and sorting—on the amounts of LIBs discarded in inappropriate waste streams such as non-combustible waste. We found that thorough separate collection and pre-sorting would achieve reductions of approximately 75% to 85% compared with the baseline. In terms of cost-effectiveness, strict pre-sorting at waste treatment facilities is inefficient; focusing on thorough separate collection at the source is more effective. This indicates that, to prevent the increasing generation of end-of-life LIBs from posing a risk to safe waste treatment and recycling, countermeasures at the production stage—including clear labeling of collection routes on products and improvements of product design that facilitate battery removal—are necessary.

Reference:

2) Suzuki G., Uchida N., Tanaka K., Higashi O., Takahashi Y., Kuramochi H., Yamaguchi N., Osako M. (2024) Global discharge of microplastics from mechanical recycling of plastic waste. *Environmental Pollution* 348, 123855

Project 3: Material circulation and sequestration technology

We conducted air sampling at a waste recycling facility in Japan to better understand the types and concentrations of per- and polyfluoroalkyl substances (PFAS) released into the air from waste recycling facilities that produce refuse-derived fuel (RPF) from industrial waste. Both passive and active air sampling were conducted, and the samples collected were used to quantify the PFAS emitted into the air during the production of RPF. Overall, few ionic PFAS were detected in the air at the facility; however, high levels of neutral PFAS (8.21 to 53.4 ng/m^3; 20.7 to 130 pmol/m^3) were measured in the air near the heat molding machines. The two neutral PFAS detected at the highest concentrations were 6:2 fluorotelomer alcohol (6:2 FTOH) and 6:2 fluorotelomer methacrylate (6:2 FTMAC), which are currently unregulated under the Stockholm Convention, suggesting that product manufacturers have shifted away from using regulated PFAS. An analysis of PFAS concentrations in exhaust gases from heat molding machines revealed that the concentration of neutral PFAS (0.54 to 2.2 μg/m^3) was one to two orders of magnitude higher than that in ambient indoor air. There were two emission routes of neutral PFAS from the facilities to the environment: the ventilation line in the plant, and the exhaust-gas lines of the thermoforming machines. We estimated the total environmental emissions from the amount of air emitted from both lines and the concentrations of PFAS in the air and exhaust gas in the plant; the total emissions were estimated to be 68 to 162 mg/day. A contribution analysis of the emissions revealed that treatment of the exhaust gas from the thermoforming machines was very effective in reducing PFAS emissions from the facility, because exhaust gas from the machines accounted for more than 94% of the total emissions (Fig. 4).

This was the first report of real-world atmospheric PFAS concentrations at a waste treatment facility that produces RPF from industrial waste. The data revealed that the primary PFAS emitted were neutral species such as 6:2 FTOH and 6:2 FTMAC, with emissions originating mainly from the machines used to mold RPF briquettes. The study also showed that appropriate treatment of exhaust gases from these thermoforming machines could substantially reduce the facility's potential PFAS emissions to the environment. These findings will be valuable for developing PFAS emission-control strategies for RPF production, in alignment with the safe and responsible management of PFAS-containing waste.

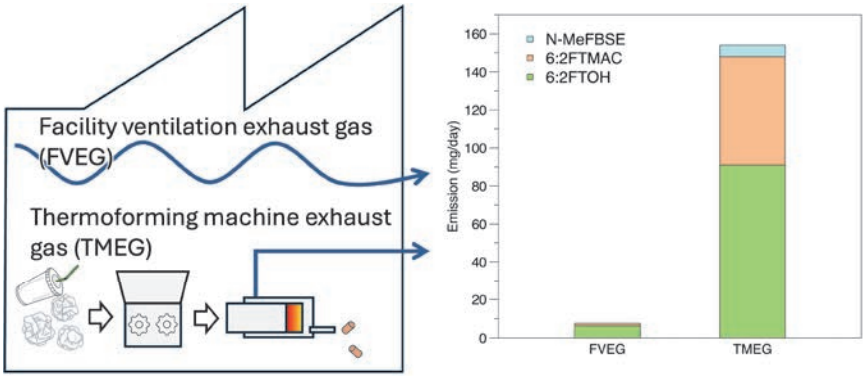


Fig. 4 PFAS emissions to air via exhaust gas from refuse-derived fuel manufacturing. N-MeFBSE, N-methyl perfluorobutane sulfonamidoethanol; 6:2 FTOH, 6:2 fluorotelomer alcohol; 6:2 FTMAC, 6:2 fluorotelomer methacrylate[3)]

Reference:

3) Kuribara I., Motoki T., Matsukami H., Takahashi Y., Kuramochi H. (2024) Atmospheric concentrations of per- and polyfluoroalkyl substances and their emissions at a waste recycling facility producing refuse-derived paper and plastics densified fuel. *Science of the Total Environment* 954, 176456

Comprehensive Environmental Risk Research Program

In this program, we conducted five projects to accomplish our annual goals. We aimed to more comprehensively investigate the environmental risks of all chemicals of concern and to consider vulnerable groups and life stages of humans (Project 1) and those of other organisms (Project 2). We also upgraded our comprehensive measurements of the pollutome (Project 3) and mathematical models of the environmental fate of chemicals (Project 4) to better assess the fate and transport of these chemicals, as well as the effects and risks that have been hard to quantify. As a result of these efforts, we established a preliminary version of comprehensive health risk indexes and ecological risk indexes (Project 5).

In the fourth year of this Research Program, we continued to emphasize cooperation by holding periodic workshops under Project 5 with project leaders and key members of Projects 1 to 4. As a result, we organized the overall picture of comprehensive health risk and ecological risk indicators by using two axes: "Comprehensive indicators for hazard assessment" and "Simultaneous assessment of chemical substances." We also continued to emphasize inter-project cooperation by extending the cooperation between Projects 2 and 3 to collect water samples at a total of 16 locations. Direct toxicity tests were conducted on the samples by using alga and daphnid, and the contribution of each chemical of concern to the detected toxicity was calculated (Fig. 1).

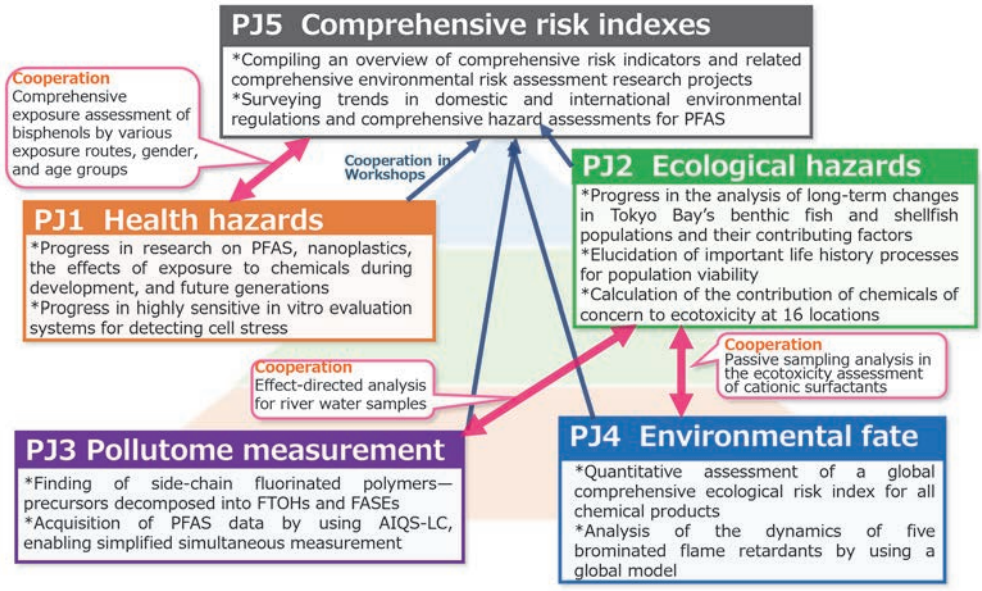


Fig. 1 Overview of inter-project cooperation and major progress in the Comprehensive Environmental Risk Research Program in FY 2024.
PFAS, per- and polyfluoroalkyl substances;
AIQS-LC, liquid chromatography with automated identification and quantification systems

Project 1. Health hazard assessment considering the real-life environment and vulnerabilities

We established methods for assessing the human health hazards of chemicals, taking into account exposure in the general environment and vulnerable populations, and we evaluated the effects of chemicals on disease, aging, and future generations. Our

major research findings, including those on immunotoxicity, neurodevelopmental toxicity, aging, and new *in vivo* and *in vitro* evaluation systems, were as follows.

We evaluated the effects of oral exposure to perfluorobutanoic acid (PFBA), a per- and polyfluoroalkyl substance (PFAS), at doses of 2, 20, and 200 ng/kg/day by using a newly established mouse model of allergic asthma. We found that 20 ng/kg/day of PFBA exacerbated allergic lung inflammation (Fig. 2a) and increased the production of inflammatory cytokines (interleukin (IL)-5 and IL-13) in the lungs (Fig. 2b). A similar trend in immune cell activation was also observed in lymphoid tissue. We are currently investigating the effects of oral exposure to perfluorooctanoic acid, a typical PFAS, in senescence-accelerated mouse prone 8 (SAMP8) mice.

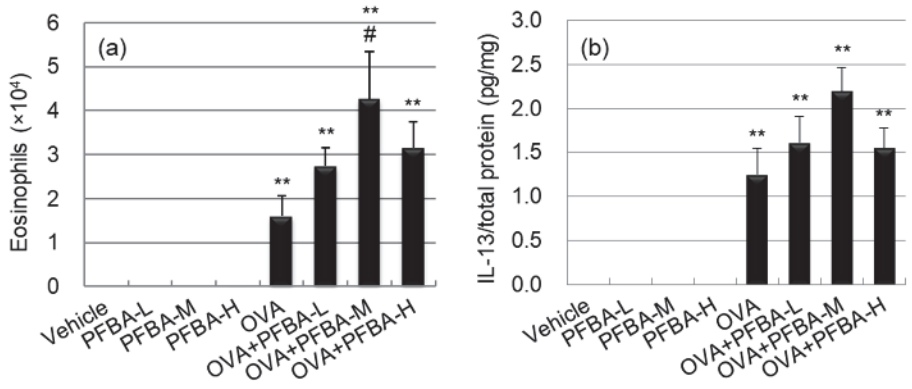


Fig. 2 Alterations in the numbers of eosinophils in bronchoalveolar lavage fluid (a) and in the protein level of IL-13 in lung tissue (b) following PFBA exposure.
Data are expressed as means ± SE for seven or eight animals per group. $^{**}P < 0.01$ versus Vehicle group. $\#P < 0.05$ versus ovalbumin (OVA) group.
PFBA-L: 2 ng/kg/day; PFBA-M: 20 ng/kg/day; PFBA-H: 200 ng/kg/day

To examine the uptake of nanoplastics by neurons, we used fluorescent polystyrene nanoplastics to assess cellular uptake and biodistribution. Lund human mesencephalic (LUHMES) cells, which are embryonic neuronal precursor cells, internalized 50-nm particles more efficiently than 500-nm particles, primarily via clathrin-mediated endocytosis and macropinocytosis. *In vivo*, orally administered 50-nm particles accumulated at substantial levels in the brains of neonatal mice especially near the ventricles. Light-sheet microscopy was used to map the distribution of nanoplastics across brain regions, and particle size was found to critically affect their biodistribution.

We established several cell lines that stably express intracellular energy sensors and constructed a system of using an in-cell analyzer to visualize sensitivity to chemicals by fluorescent live-cell observation. We also have begun a search for molecular markers that reflect behavioral phenotypes. To evaluate vulnerability to flame retardants (e.g., tris(1,3-dichloro-2-propyl) phosphate, TDCIPP) during the preimplantation embryonic stage, we classified the results with those of pesticides (and related inhibitors) for which the mechanisms of action have already been assumed to some extent.

Project 2. Ecological hazards and factor analysis considering vulnerabilities

We have investigated long-term changes in the megabenthic community (i.e., fishes, crustaceans, mollusks, and echinoderms) by using data from fisheries-independent trawl surveys conducted in the coastal waters off Fukushima, Japan, since October 2012, after the March 2011 Tohoku earthquake, tsunami, and nuclear disaster. We found decreasing trends in the population densities of many species among the megabenthic community, such as flounder, greenling, crabs, prawns, sea urchins, and starfishes. In contrast, increasing tendencies were observed in the population densities of several species, such as elasmobranchs, puffers, and cuttlefish. It is possible that these population declines are related to the rise in seawater temperature, decrease in prey abundance, and reproductive and/or recruitment failure (i.e., high mortality rates in the early-life stages), although the mechanism involved is still unclear. Further studies are needed to elucidate the causes and detailed mechanisms of population declines in the megabenthic community in the coastal waters off Fukushima.

Ecological risk assessments span biological levels from cells to ecosystems, with population-level evaluations being crucial for conservation. Although the Organisation for Economic Co-operation and Development (OECD) provides 54 standardized test guidelines, most of them focus on individual-level effects such as survival and reproduction. It remains unclear how well these tests reflect population-level dynamics. To analyze the relevance of these test protocols, we used matrix population models covering full life cycles. We calculated the summed elasticities of population growth rate to the test-measured parameters as an indicator of relevance. On average, the parameters explained only 30% to 40% of the total elasticity, with particularly low relevance for terrestrial invertebrate tests. Our results highlight the need for improved protocols that better capture population-level ecological risks.

Furthermore, to assess the ecological impacts of multiple chemical substances, we continued to conduct single and combined toxicity tests in algae, daphnids, and fishes. We tested antibacterial agents and insecticides that act on mitochondrial electron transport chain complexes I, II, and III, among other pesticides, and we grouped them by using their physical properties and the US Environmental Protection Agency's ToxCast program. We observed additive effects in a concentration-addition manner within the same complex, whereas in some combinations of different complexes we found additive effects in an independent-action manner. Additionally, in FY 2024, we used water samples collected at a total of 16 locations to conduct toxicity surveys, including algal growth inhibition tests and daphnid reproduction inhibition tests. Furthermore, research was conducted to identify the chemicals that may have been causing the toxicity. Subsequently, we calculated the contribution rate of each substance by using inductively coupled plasma-mass spectrometry (ICP-MS: metals) and Automated identification and quantification systems (AIQS) such as AIQS–gas chromatography (AIQS-GC) and

AIQS–liquid chromatography (AIQS-LC). A toxic effect equivalent to between 19% and 336% for all substances of concern (total toxicity) was detected in the alga and between 26% and 173% in the daphnid, indicating that the chemicals detected were likely to be causing at least some of the toxicity problems. However, there were issues with the accuracy of the analysis and toxicity testing; undetected toxic substances and both overestimation and underestimation of the results were recognized (Fig. 3).

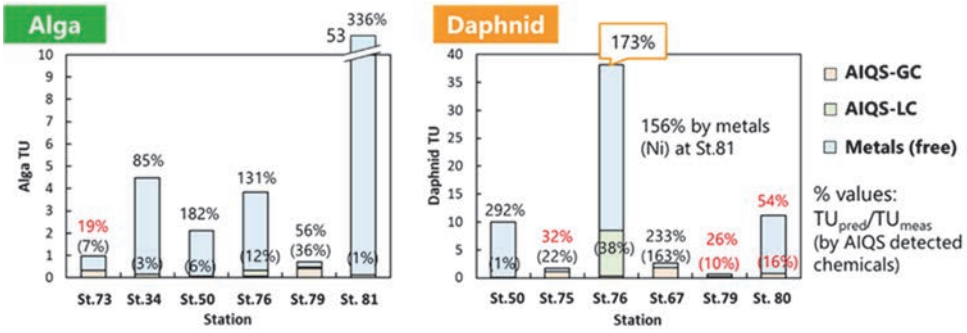


Fig. 3 Total predicted toxicities (TU_{pred}) of chemicals (metals and organic substances detected by AIQS) in river water samples of alga (left) and daphnid (right), and their rates of contribution (%) to the actual measured toxicity unit TU_{meas}. AIQS, automated identification and quantification system; GC, gas chromatography; LC, liquid chromatography

Project 3. Comprehensive pollutome measurement

In FY 2024, we broadened the scope of our comprehensive analytical measurements, refined our gas chromatography–mass spectrometry (GC-MS)-based screening methods for substances with similar structures, and developed more effective approaches for compounds that are difficult to measure.

Method of selecting groups of structurally similar substances from GC-MS measurement data: For structurally similar compound groups, we started developing an integrated analytical platform that can semi-automate a series of data processing steps by using comprehensive datasets acquired via time-of-flight mass spectrometry (ToFMS) and other instrumentation.

Standardization of negative ion mode in AIQS-LC: To enhance our analytical capabilities, we established and optimized the previously unimplemented negative ion mode in the AIQS-LC system. Following condition optimization and stability testing, six internal standards were selected for use across both ionization modes. Finalization of the parameters enabled us to acquire product ion spectra and calibration curves for 40 PFAS, which were subsequently integrated into the analytical database.

Development of a retention index method: To address retention time variability—a known bottleneck in chromatographic analysis—we developed a retention index method utilizing N-alkylpyridinium-3-sulfonate (NAPS). Comparative evaluation with a previously developed internal-standard-based retention-time correction

method revealed superior performance of the retention index approach. Consequently, this method was incorporated into the specifications of analytical support software currently under development.

Analytical strategies for difficult-to-measure PFAS: We continued to refine analytical methodologies for PFAS compounds that are challenging to quantify. Notably, we confirmed the presence of side-chain fluorinated polymers (SCFPs) that generate fluorotelomer alcohols (FTOHs) and perfluoralkane sulfonamido ethanols (FASEs) through hydrolysis, thereby identifying them as precursor substances of FTOHs and FASEs. On the basis of this finding, we assumed that a hydrolysis-based analytical method might be useful for comprehensively assessing the presence of PFAS in environmental samples.

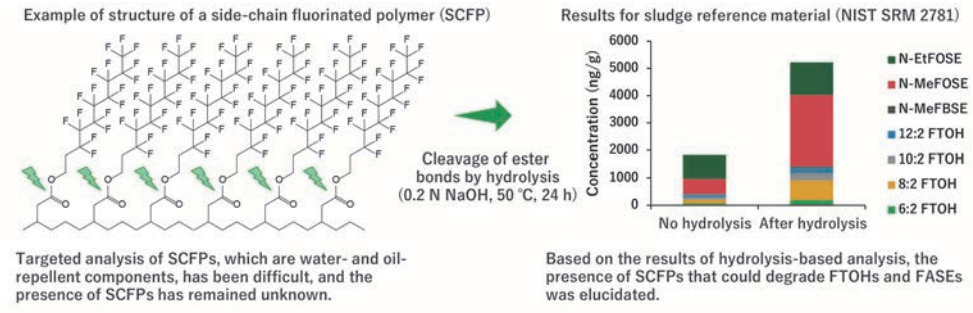


Fig. 4 Identification of side-chain fluorinated polymers with the potential to release fluorotelomer alcohols (FTOHs) and fluorinated alkyl sulfonate esters (FASEs) through hydrolysis.

In addition, we applied the hydrolysis-based analytical method to a standard reference material of domestic sludge (SRM 2781) available from the National Institute of Standards and Technology (NIST). As a result, this method revealed the presence of side-chain fluorinated polymers in the sludge sample, which generate FTOHs and FASEs through hydrolysis. These findings suggest that the hydrolysis-based analytical approach may be useful for comprehensively assessing the presence of PFASs in environmental samples (Fig. 4).

Project 4. Modeling the environmental fate of the pollutome

In this project, we are developing methods of deriving emission inventories, physicochemical parameters, and bioaccumulation properties to evaluate the environmental fates of all substances of concern for which we have only limited risk evaluation information. We are also improving environmental fate models to enable us to perform more reliable simulations and future predictions.

Environmental emissions of seven phthalate esters were estimated by using domestic and international data sources, particularly where national data on usage patterns and production volumes were unavailable. The validity of these emissions was estimated by comparing modeled concentrations in river water (derived via multimedia fate modeling from the estimated emissions) with observed concentrations. For six of the target substances, the modeled concentrations showed

good agreement with the observed values, generally within one order of magnitude.

Our global model for persistent organic pollutants was extended to include brominated diphenyl ethers (BDEs), and the environmental behavior of five BDE congeners was analyzed. Simulations of polychlorinated biphenyls (PCBs) were updated on the basis of emission estimates that considered non-environmental transport. As part of efforts to improve our global model for mercury, laboratory experiments using North Pacific seawater revealed that methylmercury decomposes in deep water, with decomposition rates increasing with decreasing temperature and increased apparent oxygen consumption in seawater.

To investigate the transport properties of PFAS, we developed a soil column chromatography method using small packed stainless-steel columns (e.g., 20 mm × 3 mm) coupled with mass spectrometry (Fig. 5). By measuring the retention of various PFAS, we determined the organic carbon–water distribution coefficient (K_{oc}). This method allowed us to demonstrate the pH-dependent sorption in soil organic matter. In addition, the bioaccumulation of five ionizable PFAS, used as replacements for perfluoroalkyl acids, was investigated in a polychaete sandworm species. The depuration half-lives were similar to those of the original compounds, whereas the respiratory uptake efficiency varied considerably among the alternatives.

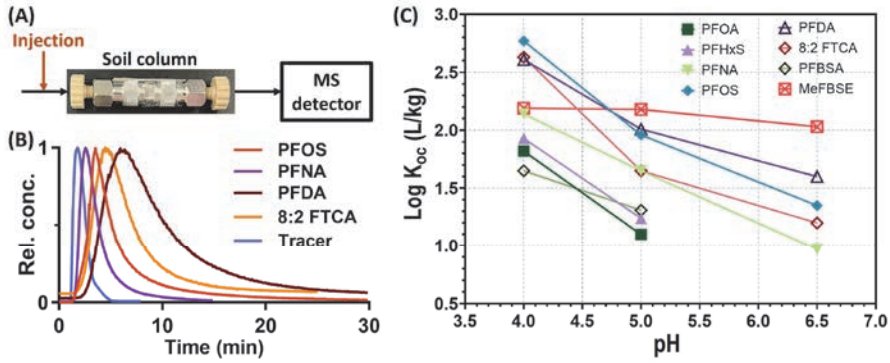


Fig. 5 (a) Setup used for soil column chromatography. (b) Examples of substance peaks obtained with soil column chromatography. (c) pH dependence of K_{oc} for PFAS

Project 5. Development of comprehensive health risk and ecological risk indexes

In this research project, we have continued to hold periodic workshops for the Program staff, including the leaders of other projects in the Comprehensive Environmental Risk Research Program. In these workshops, we have discussed the proposal of comprehensive environmental risk (i.e., health risk and ecological risk) assessment methods and assessment indicators for environmental risks.

As a result of these discussions, the following indicators and associated research projects were proposed as provisional outcomes of this 5-year Program phase. Conceptual diagrams (Figs. 6 and 7) were developed, with the vertical axis representing “comprehensive indicators of hazard assessment” and the horizontal

axis representing “simultaneously assessed chemicals,” to illustrate the positioning of the proposed comprehensive risk assessment indicators and methodologies. In the figures, the green sections correspond to items related to comprehensive risk assessment indicators, the blue sections correspond to items related to comprehensive exposure assessment based on the grouping of structurally similar chemicals, and the red sections represent research projects utilizing comprehensive risk assessment methodologies. Each research project is currently in progress, and we expect that outcomes regarding these indicators and research projects will be presented in the final year of the program.

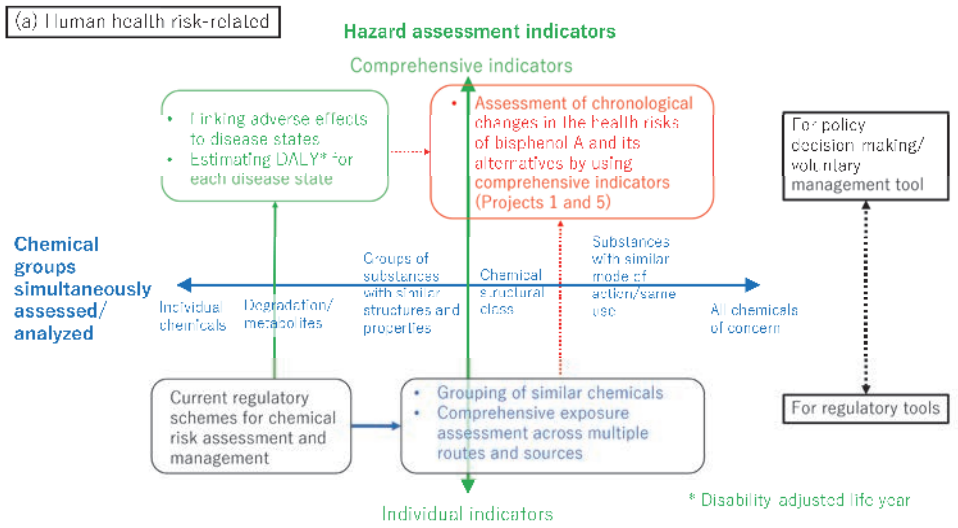


Fig. 6 Conceptual diagram of items related to comprehensive risk indicators and relevant research projects: (a) human health-risk-related Items (modified and translated from Ohno et al., 2025)

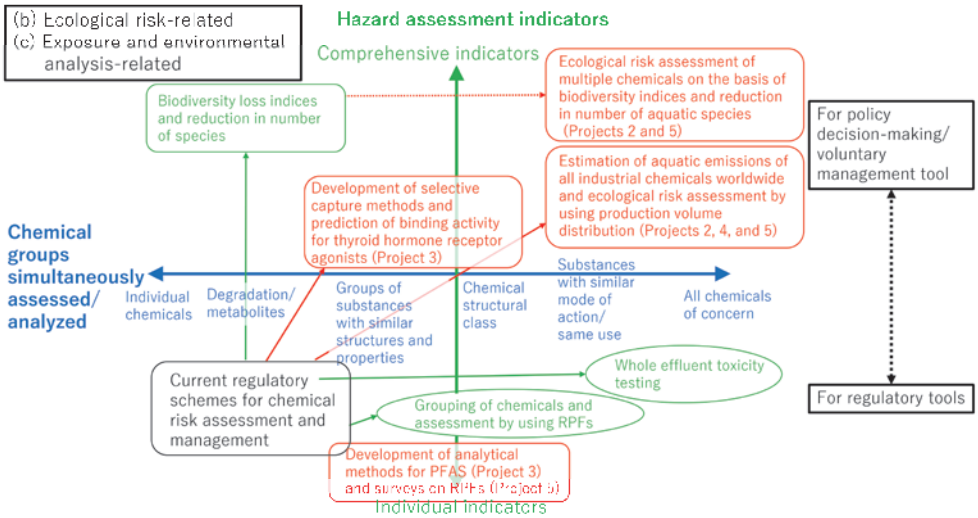


Fig. 7 Conceptual diagram of items related to comprehensive risk indicators and relevant research projects: (b) ecological-risk-related Items, (c) exposure- and environmental-analysis- related Items (modified and translated from Ohno et al., 2025). RPF, relative potency factor

In addition, we conducted a survey of domestic and international environmental regulatory trends concerning PFAS, as well as a survey of trends in estimating the relative potency factors for PFAS constituent substances overseas. From the results of these surveys, we considered the risk assessment of PFAS as a chemical structural class.

Reference:
Ohno K., Koike E., Nakajima D., Imaizumi Y., Koyama Y., Yokomizo H., Yamamoto H. (2025) Towards environmental risk assessment of all chemicals of concern. *Japanese Journal of Risk Analysis* 35(2), 55–61 [in Japanese]

Harmonization with Nature Research Program

The Harmonization with Nature Research Program conducts research into, and technological development of, measures for biodiversity conservation and the sustainable use of ecosystem services, which are essential for establishing a society in harmony with nature (Fig. 1). Our projects in FY 2024 were as follows:

Project 1: **Sustainable ecosystem management strategies for a society with a declining population**
Project 2: **Management of ecological risk causative factors that threaten biodiversity and human society**
Project 3: **Biological responses, acclimations, adaptations, and resiliencies to environmental changes**
Project 4: **Research on problem solving using ecosystem functions**
Project 5: **Integrated research for balancing conservation and utilization of biodiversity and behavioral change**

Through these activities, we aim to mainstream biodiversity and promote transformative changes, such as behavioral change, as well as to improve natural capital by synergizing the conservation and sustainable use of biodiversity. We will also contribute to the Kunming-Montreal Global Biodiversity Framework of the Convention on Biological Diversity, the National Biodiversity Strategy and Action Plan 2023–2030, and the regional circular and ecological sphere from the perspective of sustainable use of regional resources.

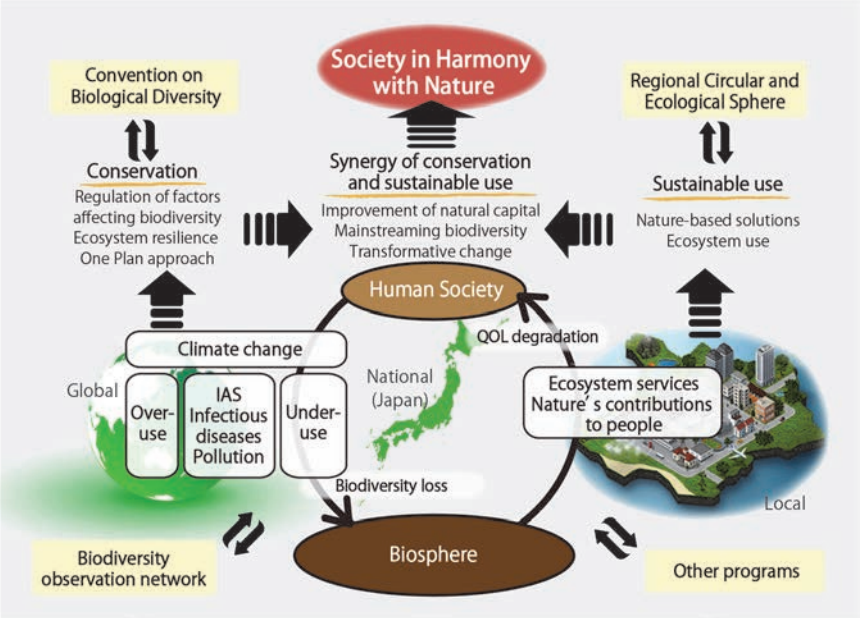


Fig. 1 Overall structure of the Harmonization with Nature Research Program.
IAS, invasive alien species; QOL, quality of life

Project 1. Sustainable ecosystem management strategies for a society with a declining population

Developing a statistical modelling approach

Conservation biologists face the complex challenge of identifying human-driven causes of species decline and predicting extinction risks. To address data limitations, especially for species with narrow distribution ranges, phylogenetic information—data derived from evolutionary relationships—can be used to improve modeling accuracy by leveraging traits of closely related species. However, applying Gaussian processes (GPs) to large numbers of species introduces computational difficulties because of the need to estimate massive covariance matrices.

We applied a phylogenetic generalized mixed model to 1010 endangered vascular plant taxa in Japan by using a nearest-neighbor Gaussian process (NNGP) approximation (Matsuba et al., 2024). NNGP allows for the flexible adjustment of species proximity on the phylogenetic tree, thus reducing the estimation variance while keeping computational costs manageable. We compared models with and without phylogenetic data to assess the predictive performance and explanatory power, focusing on the anthropogenic factors contributing to species decline.

The results showed that models incorporating phylogenetic information outperformed non-phylogenetic models in terms of prediction accuracy. These models more clearly revealed interspecies differences in responses to environmental pressures across all variables (Fig. 2).

Furthermore, by integrating phylogenetic signals, we identified evolutionary biases in species that would benefit from protected areas, thus helping to reduce the local extinction risks for 95% of the taxa analyzed.

In conclusion, incorporating phylogenetic data through NNGP enhances the ability to understand and predict the decline of endangered species. This approach offers a scalable and efficient framework for future biodiversity assessments. By applying extinction probability estimates to climate and land-use change scenarios, researchers can develop more comprehensive strategies to evaluate and mitigate threats to biodiversity across multiple ecological scales.

Reference:

Matsuba, M., Fukasawa, K., Aoki, S., Akasaka, M., Ishihama, F. (2024) Scalable phylogenetic Gaussian process models improve the detectability of environmental signals on local extinctions for many Red List species. *Methods in Ecology and Evolution* 15, 756–768. https://doi.org/10.1111/2041-210X.14291

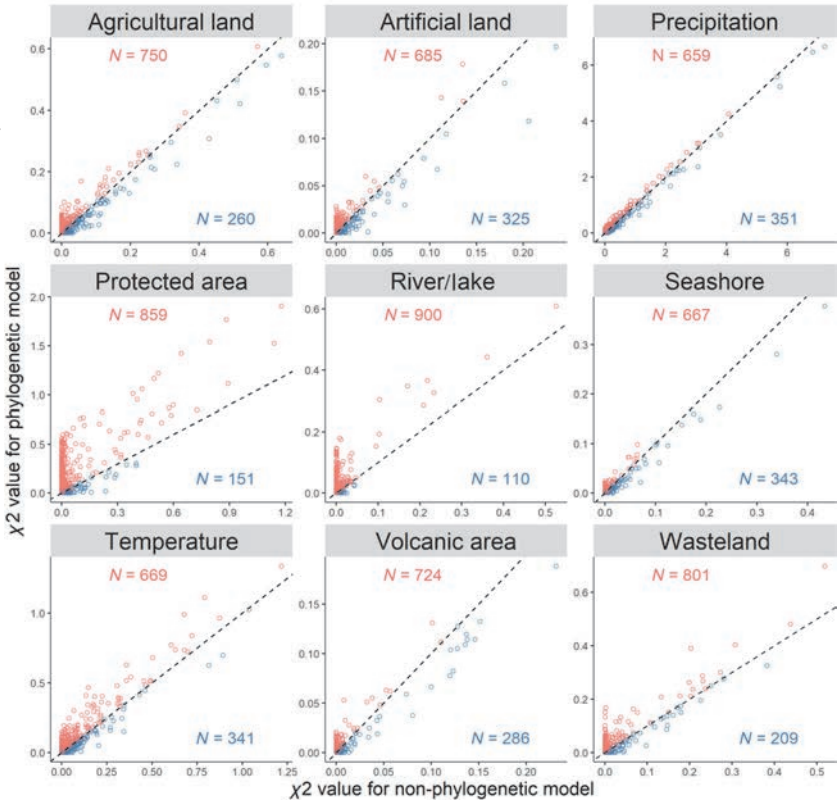


Fig. 2 Comparison of a precision measure (χ^2 values) between phylogenetic and non-phylogenetic models for 1010 endangered vascular plant taxa in Japan

Project 2. Management of ecological risk causative factors that threaten biodiversity and human society

Genetic population structure of the Asian longhorned tick, *Haemaphysalis longicornis*, in Japan

Ticks are blood-sucking arthropods that transmit a remarkably wide variety of pathogens—including bacteria, protozoa, and viruses—to wildlife, livestock, and humans. In recent years, it has been suggested that increasing contact between ticks and livestock, pets, and humans may be contributing to the emergence and spread of tick-borne zoonoses.

The Asian longhorned tick, *Haemaphysalis longicornis* (Fig. 3), is widely distributed across temperate regions of East Asia, including Japan, and uses a range of medium- to large-sized mammals and birds as hosts. Numerous reports of human bites have also been documented, making this species an important vector of concern for disease transmission.

One such human disease is severe fever with thrombocytopenia syndrome (SFTS), a highly fatal tick-borne illness that has seen increasing incidence in recent years. *Haemaphysalis longicornis* is considered to be one of the primary vectors of the virus that causes SFTS.

Although this tick species is widely distributed throughout Japan, cases of SFTS are concentrated in western Japan, with very few reports from the eastern part of the country. This geographic disparity may be due to physiological and ecological variations among regional populations of *H. longicornis*. Therefore, understanding the population genetic structure—that is, the geographic genetic clustering—of this species is crucial for assessing infection risk and implementing preventive measures.

Haemaphysalis longicornis individuals were collected from 15 prefectures across Japan. The mitochondrial DNA haplotypes of each individual were determined by nucleotide sequence analysis, and the geographic distribution of these haplotypes was then analyzed to clarify the genetic population structure of *H. longicornis* in Japan.

Analysis of the mitochondrial DNA sequences from 235 collected individuals of *H. longicornis* revealed 38 distinct haplotypes. Phylogenetic analysis based on these nucleotide sequences categorized the haplotypes into two major clades (Fig. 4A). This species includes both bisexual and parthenogenetic lineages. By comparing the DNA data we obtained here with those from previous studies, we determined that the two genetic groups corresponded to the bisexual lineage (Clade A) and the parthenogenetic lineage (Clade B).

An examination of the geographic distribution of haplotypes belonging to each group showed that those associated with the bisexual lineage were concentrated in southwestern Japan, whereas haplotypes of the parthenogenetic lineage were widely distributed across the country (Fig. 4B). On Tsushima Island, which lies close to the Korean Peninsula, the bisexual lineage was predominant. In contrast, in Hokkaido and the Tohoku region, only the parthenogenetic lineage was found, with no presence of the bisexual lineage.

As reports of SFTS cases have been limited to regions west of the Kanto area—and have been particularly concentrated in the southwestern regions where the bisexual lineage occurs—it is possible that genetic and physiological factors specific to the bisexual lineage are involved in the transmission of SFTS.

In the future, the gathering of data on ecological differences between the two reproductive lineages and differences in SFTS virus infection rates may help clarify the relationship between genetic variation in *H. longicornis* and the risk of SFTS outbreaks.

Fig. 3 An adult female *Haemaphysalis longicornis*

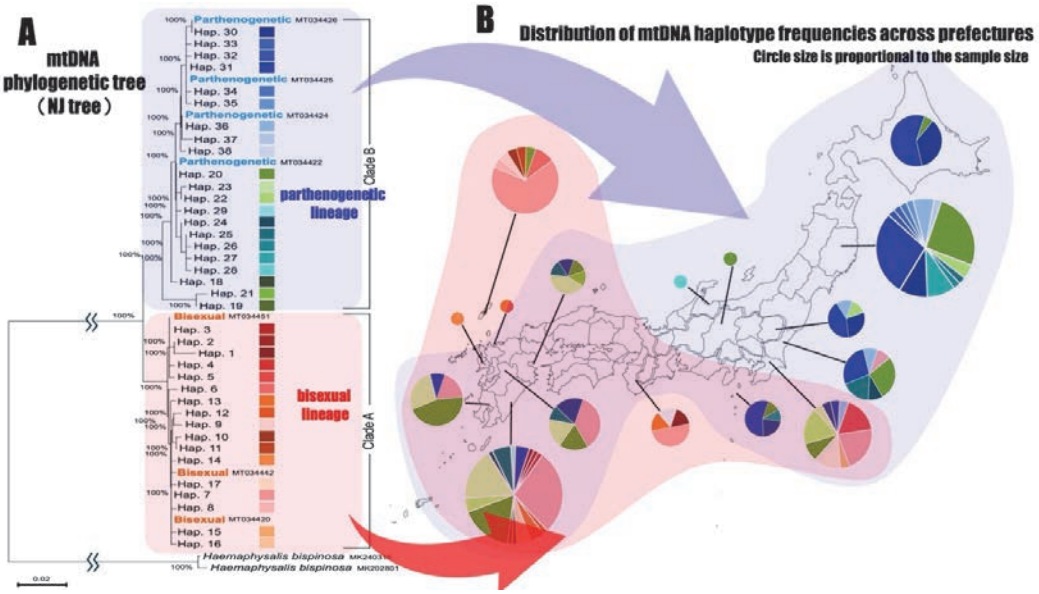


Fig. 4 (A) Mitochondrial DNA (mtDNA) phylogenetic neighbor-joining (NJ) tree and (B) geographic distribution of haplotypes of *Haemaphysalis longicornis*

Project 3. Biological responses, acclimations, adaptations, and resiliencies to environmental changes

Evolutionary changes in the reproductive traits of *Portulaca oleracea* in urban populations

The evolutionary impacts of urbanization on plants—particularly on reproductive traits—remain poorly understood. In this study, we examined how urbanization influences the reproductive traits of *Portulaca oleracea* in Japan's Kantō region. *Portulaca oleracea* exhibits a distinctive cleistogamous reproductive system, consisting of genetically determined chasmogamous (open, CH) and cleistogamous (closed, CL) individuals (Fig. 5). We collected seeds from 10 urban and 10 rural populations and cultivated them in a common garden. We recorded flower type (CH or CL), reproductive phenology, and seed production. Each individual produced

either CH or CL flowers, allowing classification as either CH or CL plants. We observed a significant difference in the distribution of flower types between urban and rural populations: CH plants were generally less common, particularly in urban populations ($P < 0.05$, Fig. 6). Compared with CH plants, CL plants exhibited earlier reproductive timing and produced heavier seeds—traits that are consistent with stress avoidance under the heat and drought conditions characteristic of urban environments. These findings suggest that urbanization may be driving evolutionary changes in the cleistogamous reproductive system of *P. oleracea*. CL plants, with their earlier phenology and larger seeds, may be better adapted to urban environments, where thermal and water stress are more severe. Future research should clarify the drivers of the shift toward CL plants, including other potential factors such as pollinator decline associated with urbanization (Fujita et al., 2025).

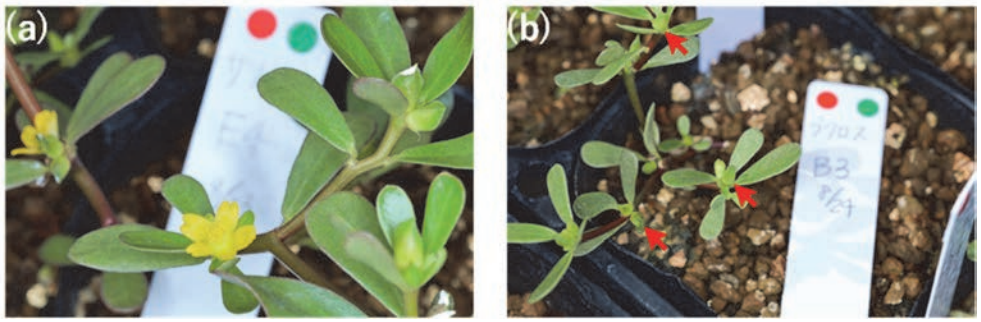


Fig. 5 (a) Images of chasmogamous flowers of *Portulaca oleracea*. **(b)** Images of cleistogamous flowers of *P. oleracea*, indicated by arrows

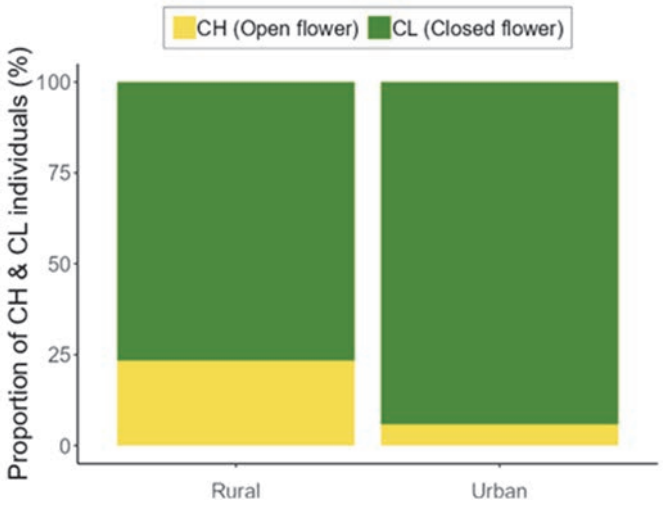


Fig. 6 Proportions of chasmogamous (CH) and cleistogamous (CL) individuals of *Portulaca oleracea* in rural and urban populations (total n = 288). The data were obtained from a common garden experiment using F2-generation seeds.

Reference:

Fujita T., Tsuda N., Koide D., Fukano Y, Inoue T. (2025) The flower does not open in the city: evolution of plant reproductive traits of *Portulaca oleracea* in urban populations, *Annals of Botany* 135, 269–276

Project 4. Research on problem solving by using ecosystem functions

Urban green spaces contributing to pollinator supply

With the degradation of pollination ecosystems becoming a serious issue worldwide, there are concerns in Japan about the impact on both wild plants and agricultural crops that require pollinators. However, there are also expectations that natural pollination by wild pollinators can be used to achieve more efficient agriculture. For natural pollination on farmland, it is important to have a stable supply of pollinators from the surrounding green scapce. The use of urban and suburban green spaces as habitats for pollinators can enhance the robustness of regional pollination ecosystems, including those in agricultural areas. The aim of our study was to find effective maintenance strategies and spatial configurations to promote the active use of urban green spaces for the conservation of regional pollinators.

In 2024, we investigated the effects of environmental factors, land management, and land use within and outside urban green spaces on the diversity of insect pollinators. The study area comprised 17 green spaces distributed across approximately a 10 km by 10 km area, extending from the foot of Mt. Tsukuba, through the urban area around Tsukuba Station, and into the city of Ushiku. A survey of insect pollinators conducted in April and May 2024 observed a total of 84 species and 515 individuals. Multiple regression analyses revealed that environmental factors within and around the green spaces significantly influenced the number and diversity of insect pollinators. Notably, green space type—such as classification under the Urban Parks Act—had a substantial effect, suggesting that differences in installation purpose and management entity may shape pollinator diversity through policy.

We conducted multiple regression analyses to examine the effects of environmental factors within green spaces, as well as the surrounding land use within ranges of 100, 250, 500, 750, 1000, 1500, and 2000 m of the survey site, on the diversity of insect pollinators. Within a short-range distance (100 to 500 m), the area of green space and wetland grassland positively influenced the diversity of insect pollinators (Fig. 7). However, the volume of floral resources was associated with reduced species diversity. This result suggests that excessive floral resources may attract a limited range of pollinator species, thereby lowering overall diversity.

Within the short-range distance, increases in the area of green residential zones and artificial grasslands (e.g., golf courses) negatively affected the diversity of insect pollinators possibly owing to pesticide use. Our ongoing analyses of the interactions between insect pollinators and flowering plants aim to identify the environmental factors in green space that support robust pollination networks. These insights will help to define the conditions under which green spaces can sustain pollinator communities across the study region.

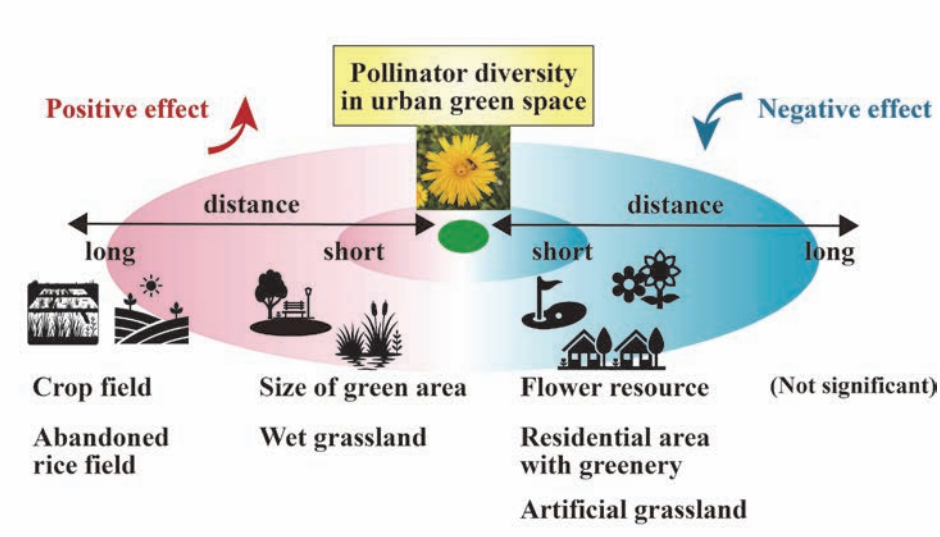


Fig. 7 Environmental factors that significantly affect the species diversity of insect pollinators in urban green spaces. Multiple regression analysis were performed by using environmental factors within green spaces, along with the land uses within seven different radii (100 to 2000 m) of the survey site, as explanatory variables.

Project 5. Integrated research for balancing conservation and utilization of biodiversity and behavioral change

Assessing the legacy impacts of food production on forest threatened species

The impacts of food production on biodiversity can vary markedly, depending on the crop types and the locations where the crops are cultivated. This variation is driven mainly by the spatial heterogeneity of land-use demand, including the crop type and cultivation intensity in each region, and by the distribution of biodiversity. Several studies have successfully assessed the impacts of cropland presence and expansion on biodiversity and linked these impacts to consumption. However, these studies have not fully accounted for both the spatial heterogeneity of land-use change through global cropland area data and the spatial heterogeneity of biodiversity; specifically, they have used species records at the national level or have relied on indices based on the number of species. Such indices are known to be sensitive to sampling bias in large-scale assessments (i.e., impacts are underestimated in areas with less or no research effort).

In this project, we aimed to quantify the impacts of food production on threatened forest species by crop and region, as well as to identify mitigation options for these impacts on the basis of the extinction risk of the species. We expected that these options would need to be widely implemented outside the food industry, as actions within the industry alone would be insufficient or ineffective. Therefore, we also examined social response options for reducing biodiversity loss across non-agricultural industries and sectors. Specifically, we assessed the biodiversity loss caused by the forest loss associated with crop production at a 10-km grid resolution worldwide. By using the IUCN (International Union for the Conservation of Nature) database on threatened species, we developed a risk-weighted forest loss (RFL) score, which weights the forest loss caused by agricultural drivers according

to the extinction risk category (from 0 for lowest risk to 5 for highest risk) of the threatened species inhabiting each grid. The RFL score for each grid was then divided by the total cultivation area and multiplied by the cultivation area for each crop, on the basis of the assumption that forest loss due to agriculture was allocated to each of the world's 42 major crops in proportion to its cultivation area within the grid. The RFL score for each crop was summed and divided by the total crop production in each country, resulting in a score per unit of crop production (points/tonne) at a national level.

Before proceeding with the full assessment, we first quantified the legacy impacts of food production on forest-threatened species. In other words, we evaluated the opportunity costs from foregone forest regeneration on land previously cleared for agriculture; we acknowledge that areas deforested before 2000 but still under cultivation may continue to contribute to biodiversity loss by hindering natural regeneration, emphasizing the importance of accounting for missed restoration opportunities. We summarized the legacy impacts of agriculture by 2000 attributed to each country and broke them down by taxon and crop (Fig. 8). For the top 20 countries with the greatest impact on biodiversity, those with developed or longer histories of agriculture, such as the USA, China, and Japan, are ranked. This differs from our preliminary results on recent impacts (i.e., from forest loss due to agriculture after 2000), where developing countries are more prominent in the top 20. On the basis of these findings, we argue that consideration of both the legacy and the ongoing impacts of agriculture is vital for society to accept responsibility for these impacts while promoting fairness among countries.

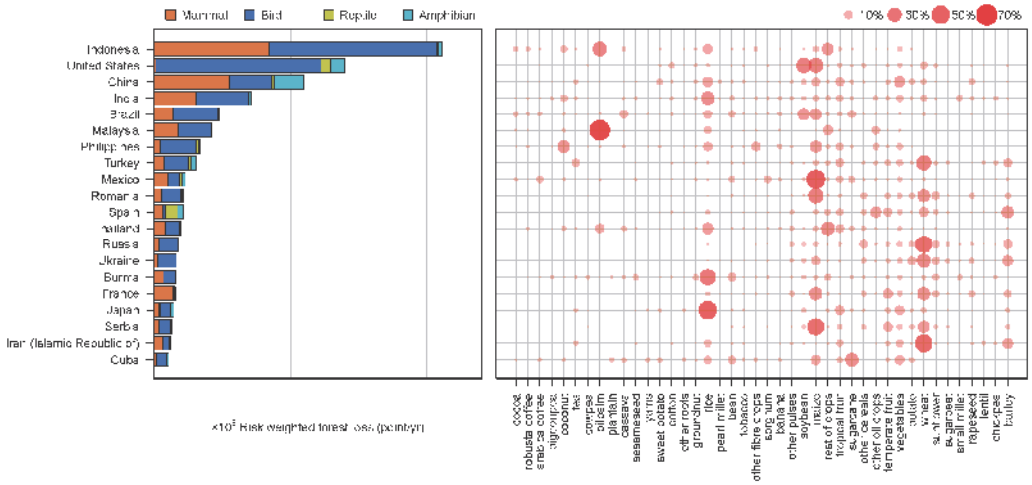


Fig. 8 Risk-weighted forest loss (RFL) for the legacy impacts of annual crop production by 2000. The bar chart on the left displays the breakdown of biodiversity loss by taxon. (Results for the top 20 countries with the greatest impact on biodiversity are shown.) The dot chart on the right illustrates the impacts broken down by crop.

Decarbonized and Sustainable Society Research Program

The goal of the Decarbonized and Sustainable Society Research Program is to present a vision and principle of a decarbonized and sustainable society at the global and national levels while ensuring intergenerational equity. To realize this goal, we will identify the long-term requirements for a decarbonized and sustainable society on a global scale. In addition to performing global scale analyses, by taking into account the current national development stages, we will identify the actions and institutions needed at the national level to develop a decarbonized and sustainable society in Asian countries, including Japan. We intend to use our integrated assessment model to evaluate the necessary countermeasures at the global and national levels. We will use the quantitative and narrative results to develop medium- to long-term roadmaps for achieving a decarbonized and sustainable society both globally and nationally.

This research program consists of the following three research projects:
Project 1: Simultaneous Achievement of Global Decarbonization and Sustainability
Project 2: Quantification of National Decarbonization and Sustainable Society Scenarios
Project 3: Establishment of a Regime Inclusive of Future Generations in a Sustainable Society.

Project 1. Simultaneous Achievement of Global Decarbonization and Sustainability

Project 1 consists of three subthemes with different target study periods: subtheme 1 (short- to medium-term: present to 2050); subtheme 2 (long-term: present to 2100); and subtheme 3 (extra-long-term: present to 2100 and beyond). With the whole Earth as the target area, each subtheme attempts to grasp the relationships between decarbonization and sustainability; examine policies, systems, and measures for the simultaneous achievement of decarbonization and sustainability; and assess these efforts through the quantification of scenarios.

Subtheme 1 is developing a group of global models to evaluate mitigation measures centered on a bottom-up technology model. It is also assessing the emission pathways of greenhouse gases (GHGs) and short-lived climate forcers (SLCFs) in the short to medium term to meet the targets of the Paris Agreement. We are quantitatively evaluating the potential of drastic reduction measures for these gases and the impacts of the spillover effects of such measures on sustainable development. We are also conducting qualitative evaluations of, for example, the progress of nationally determined contributions (NDCs) for GHG mitigation, as well as the progress of international institutions and funding mechanisms under the Paris Agreement.

In FY 2024, we promoted the improvement and expansion of the agricultural sector, which is the main source of CH_4, N_2O, and NH_3 emissions. The agricultural sector affects all of the following: climate change (N_2O is a GHG, CH_4 is an SLCF), air pollution (NH_3 is a component of $PM_{2.5}$, i.e., particulate matter with a diameter of

2.5 microns or less), ozone layer depletion (N_2O is an ozone-depleting substance), and nitrogen overload (N_2O and NH_3 are nitrogen wastes). Therefore, we used the estimation method of the IPCC (Intergovernmental Panel on Climate Change) GHG inventory guidelines to calculate the business as usual (BaU) scenario for CH_4, N_2O, and NH_3 that covered all emission sources in the agricultural sector. Next, to determine the technological reduction potential, we explored the maximum reduction scenario, which assumes that available measures are introduced to the maximum extent by 2060 in both developed and developing countries (Fig. 1). We found that, by 2060, global CH_4 and N_2O emissions would be reduced by 65% and 37%, respectively, compared with those in BaU. The remaining emissions would be 3.5 Gt CO_2eq; this would be a major barrier to achieving global GHG net-zero emissions.

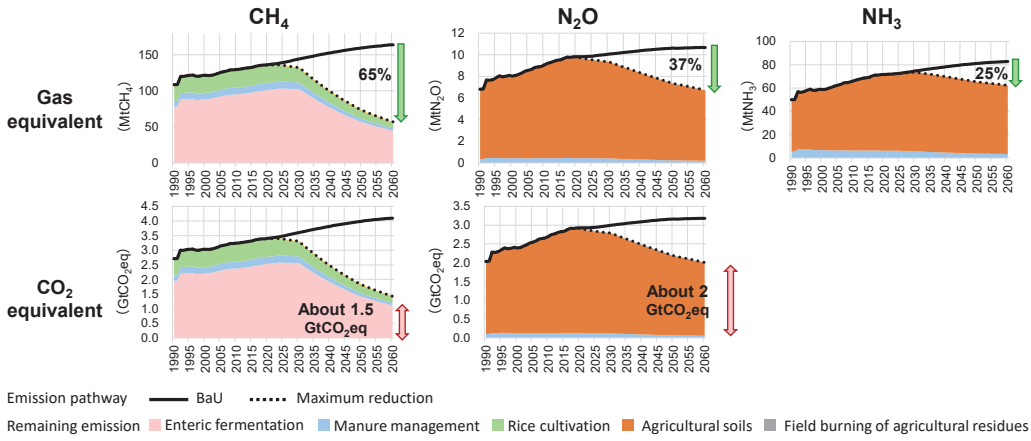


Fig. 1 Maximum reduction scenario for CH_4, N_2O, and NH_3 in the agricultural sector by 2060 compared with the business as usual (BaU) scenario

Subtheme 2 is developing a global sustainability assessment model that is based on the existing computable general equilibrium model and represents GHG emission pathways consistent with the Paris Agreement. We also intend to analyze the side effects of the mitigation measures employed for the emission pathways on sustainability, clarify the remaining climate risks under the emission pathways, and assess the equity of the expected consequences.

In FY 2024, as part of research related to the sustainability of food supply and demand consistent with decarbonization goals, we conducted an integrated assessment of the environmental and health impacts of replacing red meat (e.g., beef, pork, lamb) with small pelagic fish (e.g., sardines, mackerel) in dietary composition. We conducted a scenario analysis of the effect of changing dietary composition on the prevention of four non-communicable diseases (ischemic heart disease, stroke, diabetes, and colorectal cancer) that are rapidly increasing worldwide. We discussed the possibility that up to 8% of red meat consumption could be replaced with small pelagic fish by 2050, reducing the number of deaths from non-communicable diseases worldwide by 500,000 to 750,000. We also examined the need to work on strengthening the management of fishery resources and promoting awareness-raising about nutritional dietary habits.

Subtheme 3 is developing an Earth–human system model that incorporates a state-of-the-art Earth system model with human activity models that have critical impacts on climate states and policies on, for example, water use, crop growth, land use, and economic activities. By using this model (MIROC-INTEG-ES, Model for Interdisciplinary Research on Climate INTEGrated Earth System), we are investigating the long-term behavior of Earth–human systems under future socioeconomic scenarios, and we are trying to reveal the future social risks of climate change.

In FY 2024, we analyzed the impact of future climate change on the carbon cycle in the Amazon rainforest. By reducing the uncertainty of future predictions, we were able to obtain information about more reliable future predictions. From the relationship between the trend of global average temperature rise over the past 35 years and the projected changes in temperature, precipitation, and carbon absorption in the Amazon rainforest due to climate change at the end of the 21st century calculated by Earth system models, we found that the greater the trend of global average temperature rise over the past 35 years before the present, the greater the tendency for future increases in temperature, decreases in precipitation, and decreases in carbon absorption due to climate change in the Amazon. By assuming that models that reproduce past observational facts have greater reliability of future predictions, we reduced the uncertainty range of future predictions of carbon absorption in the Amazon rainforest due to climate change. The analysis in this study also showed that the climate change projected by the end of the 21st century could cause large-scale changes in atmospheric circulation. This would result in reduced precipitation in the Amazon rainforest, making it drier and hotter and decreasing the amount of carbon absorbed by forests through photosynthesis, as well as reducing carbon absorptions due to increased respiration.

Project 2. Quantification of National Decarbonization and Sustainable Society Scenarios

Project 2 consists of two subthemes with different target areas, namely Japan (subtheme 1) and Asian countries excluding Japan (subtheme 2). Through this project, future scenarios in Japan and other Asian countries will be quantified. For Japan and some Asian countries, we are proposing measures, policies, and systems to achieve net-zero GHG emissions, as well as to quantitatively formulate short- and medium-term sustainable decarbonization roadmaps that are consistent with achieving the 1.5 °C target scenarios. We are considering the diversity of Japan and other Asian countries, together with ways of resolving the challenges facing each country, including NDC (Nationally Determined Contribution; a climate action plan required by each party under the Paris Agreement) ambitions and the economic, technological, and institutional constraints on long-term strategy formulation.

In **subtheme 1**, for Japan, we are updating the AIM (Asia-Pacific Integrated Model) to assess the effects of innovative energy-saving technologies, power grid systems introducing huge renewable energy supplies, and social transformation reducing energy service demand to achieve net-zero GHG emissions. To analyze drastic mitigation

pathways, we are also considering socioeconomic issues, including demographic impacts such as the declining birth rate and the aging population, and the impacts on energy demand of innovative technologies that promote behavior change.

In FY 2024, to clarify the challenges faced in achieving a decarbonized society in Japan by 2050, we analyzed possible pathways to achieve this goal by making several assumptions regarding the share of renewable energy in the electricity supply and the proportion of domestic production of new fuel. Although electrification rates increase, the use of synfuels and hydrogen will expand after 2040. In addition, electricity demand in 2050 is projected to remain at current levels, as the increased demand from electrification will be offset by progress in energy conservation. Conversely, electricity demand for producing new fuels domestically will increase significantly. Meeting this increased electricity demand with renewable energy will become necessary. If new fuel production were to rely on overseas sources, however, domestic electricity consumption would decrease, but this would impose an additional electricity production burden on overseas new fuel-production sites and would therefore require careful consideration.

In **subtheme 2**, consistent with global GHG emission pathways for achieving the 2 °C and 1.5 °C targets analyzed in Project 1, we focused on scenario analyses for a sustainable and decarbonized society in major Asian countries. For example, in Thailand, the transportation sector accounts for the second-largest share of energy demand and is expected to continue growing. On the other hand, as a result of the COVID-19 pandemic, transportation demand decreased substantially between 2020 and 2021, so its impact must also be considered. By combining the AIM/Transport and AIM/Enduse models, we assessed transportation policies for passenger and freight transportation in Thailand and evaluated four scenarios: 1) the REF (reference) scenario, which estimates future transport demand based on trends before COVID-19; 2) the COVID scenario, which estimates transport demand by considering the impact of COVID-19 and a lack of full recovery to pre-COVID-19 levels; 3) the Transport Policy scenario, which assumes gradual recovery from the impact of COVID-19 and considers the modal shift policy from private to public transport proposed by the Thai government; and 4) the Decarbonization scenario, which is based on the Transport Policy scenario but further considers decarbonization measures. We plotted the results for passenger transport (Fig. 2). First, the impact of COVID-19 resulted in a 13% reduction in GHG emissions compared with the REF scenario. However, as the economy recovered and transport demand gradually returned to pre-COVID-19 levels, the modal shift policy from private to public transport would reduce GHG emissions by only 22% compared with the REF scenario; this is insufficient as a decarbonization measure. Promoting the Thai government's electric vehicle (EV) and fuel efficiency improvement policies in addition to the modal shift policy would reduce GHG emissions by 52% compared with the REF scenario by 2060, but this would still be insufficient toward achieving the carbon neutral target by 2050. Therefore, further consideration of transport policies such as EV and fuel cell vehicle policies and measures to reduce

transport demand is necessary.

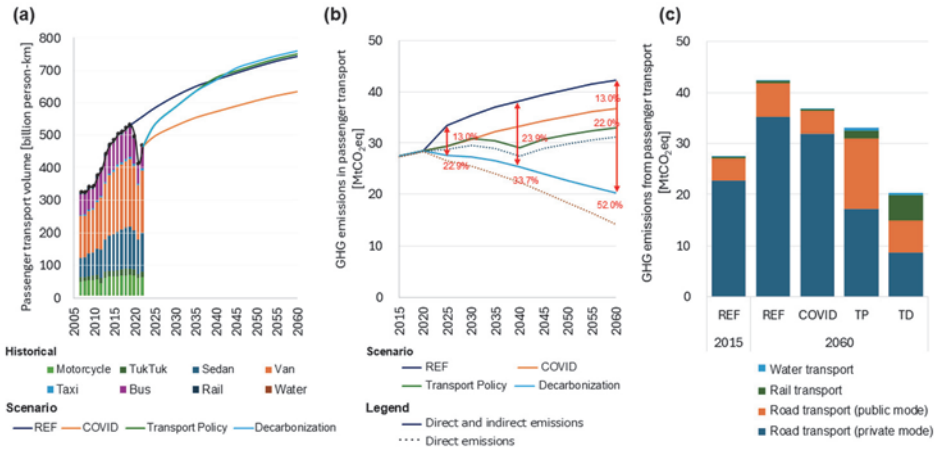


Fig. 2 Future scenarios for Thai passenger transport: (a) passenger transport volumes, (b) GHG emission pathways by scenario, and (c) GHG emissions by mode by scenario

Project 3. Establishment of a Regime Inclusive of Future Generations in a Sustainable Society

Project 3 aims to establish a regime that will help to improve intergenerational equity and enable future generations to inherit a better world. It consists of two subthemes with four elements of the regime: norms, indicators, institutions, and surveys. These elements are intertwined; subtheme 1 addresses mainly norms and indicators for intergenerational equity and justice, and subtheme 2 addresses institutions and surveys for the benefit of future generations.

In **subtheme 1**, we developed a framework for organizing the spillover effects of various policies through a flow diagram that evaluates the impacts on each affected group according to its characteristics. By classifying the affected groups targeted by the spillover effects of policies in more detail, it became easier to visualize the existence of "epistemic injustice," in which the effects on socially disadvantaged groups are ignored or disregarded. In addition, by including future generations as affected groups, normative issues specific to future generations can be arranged alongside those of the current generation, making it possible to visualize intra-generational and inter-generational conflicts in a single diagram. It is also possible to evaluate conflicts and synergies from four value axes (physical and mental health, economic and material standards, distribution and rights, and intrinsic value) and represent intra- and intergenerational conflicts in a single diagram.

An online questionnaire survey of environmental attitudes showed that general orientations toward future generation considerations are associated more strongly with perceptions of climate change impacts and causes than with ideology and knowledge. In addition, the two main orientations that constitute attitudes toward future generation considerations ("effects on future generations" and "inheritance") showed different patterns of association with perceptions and attitudes about climate change impacts,

causes, and measures, as well as with socioeconomic attributes. These findings suggest that the orientation and breakdown of future-generation considerations are more important factors in climate change communication than were previously thought.

In **subtheme 2**, we studied (a) how future-regarding institutions could contribute to the normative legitimacy of public governance and (b) the conditionality of political short-termism. For (a), we argued that future-regarding institutions could help to enhance the input legitimacy of public governance by representing future generations; they could enhance throughput legitimacy by improving the quality of governance processes, and they could enhance output legitimacy by reducing harmful short-termism. For (b), we identified the drivers and mitigators of political short-termism, drawing on a literature review of empirical and experimental studies.

In our research on sustainability indicators, we examined what it would mean for emitting countries to compensate countries adversely affected by climate change for their current or cumulative CO_2 emissions. We found that future payment increases and the present value of future capital gains on transfers would affect sustainability. This underscores the importance of designing effective transfer and funding schemes, such as the loss and damage fund.

In addition, in collaboration with Projects 1 and 2, we initiated research to decompose the damages caused by climate change and GHG emissions in the 21st century into those related to inter- and intragenerational equities. The results revealed that, under a high GHG emission scenario, the damages related to intergenerational equity will be greater than the damages related to intragenerational equity. Consideration of intergenerational equity is indispensable. Under a low GHG emission scenario, the damages related to intragenerational equity became comparable to the damages related to intergenerational equity. This highlights the importance of focusing on future intragenerational equity with a sustainable path.

Co-design Approach for Local Sustainability Research Program

By working with local governments, local residents, and other local stakeholders as the implementing entities to create a sustainable society, we intend to build ways of developing co-creative and sustainable local communities by using human, social, and scientific knowledge. We will also examine ways to support the implementation of these measures.

This Research Program will address the following four issues:
Project 1: Research on sustainable society implementation through regional collaboration
Project 2: Proposal and evaluation of eco-efficient technologies and systems in collaboration with local communities
Project 3: Development of a regional evaluation tool to simultaneously solve regional and lifestyle issues and achieve sustainability goals
Project 4: Construction of measures for creating sustainable local communities and support for introducing these measures into local communities.

Through these efforts, we will collaborate with local governments and other local stakeholders in local communities in Japan to co-create problem-solving measures that will create sustainable local communities by using scientific knowledge. We will clarify how support should be provided, with the aim of establishing these measures as feasible systems in local communities. Our aim is to promote the creation of a sustainable society in the region.

Project 1. Research on sustainable society implementation through regional collaboration

We continued research on decarbonization support through forest resource utilization, focusing primarily on woody biomass, in the town of Mishima in Fukushima Prefecture. We provided ongoing insights to the Mishima Town Regional Circular Symbiosis Promotion Council. We advanced the development of methods to evaluate forest value from the perspective of local residents by utilizing a “Social Impact Assessment Methodology.” Specifically, we held prototype workshops targeting a small core group of key town stakeholders involved in forest utilization, collecting data to develop programs for the broader resident population. As outreach activities, we exhibited at the town’s cultural festival and conducted environmental learning activities for elementary school students and their parents. This created opportunities for us to gather opinions from a range of residents within the town.

Shiga Prefecture has developed 13 “Mother Lake Goals” (MLGs) for conserving Lake Biwa and creating a sustainable society around it by 2030. One of the 13 goals is “Goal 2: Restore bountiful seafood (‘lake food’) resources.” At the request of the prefecture, we have evaluated the achievement of this goal every year. In addition,

to help with goal achievement, we have accumulated data on the spawning ecology and migration range of the native fishes used as food. This year, we used a survey of the distribution of eggs laid in rice paddy areas to clarify the upstream migration range for spawning, and we made conservation recommendations to the prefectural government.

In a study of Lake Biwa's water quality, we integrated phytoplankton species-composition data into a dataset combining fish-assemblage distribution and general water-quality data, and we analyzed the relationships among these variables. Statistical analyses showed that differences in the fish-assemblage distribution could be explained by the water temperature and the diatom abundance. We continued our collaboration with the Shiga Prefectural Fisheries Experiment Station to apply wastewater treatment technologies to challenges in freshwater pearl aquaculture. Drawing on analyses of last year's experiments, we conducted a demonstration study that implemented measures to suppress the accumulation of ammonia and nitrate. These outcomes are expected to help achieve multiple sustainable development goals.

We also aim to provide balanced solutions for multiple environmental issues. In FY 2023 we performed the following activities in the island city of Goto, in Nagasaki Prefecture. The CO_2 reduction diagnostic tool developed in Project 3 was used to analyze the effectiveness of each of the measures and policies designed to achieve decarbonization by 2050. The tool was improved by using feedback from Goto, including the incorporation of the use of renewable energy sources such as offshore wind power and solar power generation, which the city of Goto is promoting. Moreover, a field survey for seaweed bed restoration has been initiated and model analysis is underway. The plan is to select priority areas for seaweed bed preservation and restoration. In addition, buoys were installed for coral protection and use in sustainable tourism. Future projections were made for wastewater treatment, waste disposal, and local traffic. A questionnaire survey was conducted with the cooperation of local government in Goto to investigate the inhabitants' awareness of the natural and living environment and their vision for the future.

Project 2. Proposal and evaluation of eco-efficient technologies and systems in collaboration with local communities

As a measure to contribute to carbon neutrality in the chemical and paper industries, we have proposed a system (LCCN: Life Cycle Carbon Neutral) in which low-grade waste that is difficult to recycle (and is currently mainly incinerated) is collected in industrial areas that use large amounts of steam for material production (such as chemical complexes). It is then burned in a newly constructed large incinerator to supply steam, instead of fossil-fuel boilers being used. The CO_2 in the exhaust gas is reacted with green hydrogen to recycle carbon back into chemical raw materials. We evaluated the CO_2-reduction effect and economic feasibility of LCCN, and we held discussions on commercialization with stakeholders from multiple chemical

complexes and the surrounding local governments.

To address the imbalance between wastewater management services and needs due to changes in social structure, such as a declining birthrate and an aging population, we developed a quantitative assessment model (Nitrogen Inventory based on Municipal Population for Sewage into Sanitation Facilities: NIMPO-SISF) for each municipality across Japan. Aiming to apply this model to specific regional issues, we focused on remote islands (e.g., the city of Goto) to identify regional issues and needs related to wastewater management and develop an island-specific model. Furthermore, we collected and analyzed data on the treatment performance and operational status of wastewater treatment facilities in Tokushima and Kochi prefectures, which have low wastewater treatment population coverage. Our aims were to gather knowledge to help with the sustainable operation of these facilities and to provide insights focused primarily on technical solutions. We found that many facilities were operating with excessive power consumption because of insufficient wastewater volume. In addition, in response to the deterioration of sewage treatment facilities, we proposed operational methods to stabilize water quality in the Yoshino River Basin Sewerage System in Tokushima Prefecture, thus helping to optimize wastewater treatment in the region.

From the perspective of sustainable regional waste management, we estimated the amount of used disposable diapers generated in light of future population decline and aging. We found that, in some areas in Japan, the proportion of used disposable diapers in combustible waste will increase to approximately 20%. In such areas, where there is concern about a decline in the lower heating value of waste, separating and recycling food waste and used disposable diapers is considered an effective solution. By focusing on the waste recycling efforts of the town of Osaki in Kagoshima Prefecture, we created a logic model for waste disposal and considered proposals for evaluation indicators related to regional capital and value creation. For example, having elderly people take on some of the role of sorting and collecting waste increased their sense of mission and vitality.

With the aim of achieving sustainable regional transportation, we conducted interviews with the relevant departments of local governments regarding the regional transportation policies they are promoting, issues specific to the region, and responses to people with mobility issues. In response to the national government’s promotion of bicycle use, many local governments are promoting the introduction of bicycle rentals, but these are limited to tourists. Bicycle use by island residents has not progressed because of regional characteristics such as steep slopes and the inconvenience of transporting shopping. In response to these findings, we are collaborating with local stakeholders to develop highly durable personal mobility that can accommodate users at all life stages.

Project 3. Development of a regional evaluation tool to simultaneously solve regional and lifestyle issues and achieve sustainability goals

By targeting two or three regions common to the Research Program, we intend to develop detailed socioeconomic, energy, environmental, and other data and analyze regional characteristics to determine the current and future state of the regions, taking into account national scenarios. In addition, this Project will study how to provide support from a scientific perspective to solve regional issues and create policies to achieve sustainability goals in collaboration with the public and other stakeholders in specific regions.

A municipal climate citizen assembly is a tool that is widely recognized for revealing the measures that are most acceptable for decarbonizing our society. We created a detailed design for the city of Tsukuba to develop the best climate citizens' conference in Japan today, with consideration of the problems encountered in other domestic cases.

By promising in advance that the recommendations would be reflected in policy, and by increasing the financial incentive, we were able to attract a large number of potential participants to build a mini-public. By providing opportunities to obtain a broad and diverse range of opinions, and by simultaneously considering changes in actions and changes in institutions, we obtained recommendations that were based fully on the opinions of the citizens. These recommendations will be organized into a roadmap that indicates the timing of implementation and will be reflected in the Action Plan for Global Warming Countermeasures and other related documents. The Environmental Policy Division's willingness to actively implement the recommendations underlines its efforts to fulfill its prior commitment to reflect policy at a high level, and the collaboration is working well so far.

We have developed a prototype regional diagnostic tool that is based on a methodology for regional decarbonization scenario analysis. A graph of the results is arranged at the top of the web page, and the types of measures and policies and their implementation intensity settings are listed at the bottom. The graphs display energy consumption and CO_2 emissions, as well as electricity demand, renewable energy use, and other data. The options are set up as a group of options related to energy demand, a group related to local energy projects and renewable energy, and a group related to energy supply, such as grid electricity and hydrogen production. These options can be set up together for each group, and any unnecessary options can be closed. Prototype versions were developed for a total of 34 municipalities, including the city of Goto in Nagasaki Prefecture, which is often the focus of this Program; the city of Tsukuba in Ibaraki Prefecture, where the Climate Citizens' Conference was held; and the city of Kitakyushu in Fukuoka Prefecture. Improvements were made to the tool in response to feedback received on its use and screen display. We also improved the analytical methods, such as the calculation logic and assumptions of measures and policies, through discussions with the

municipal policymakers in charge of decarbonization measures.

Project 4. Construction of measures for creating sustainable local communities and support for introducing these measures into local communities

We have identified and analyzed issues that are common in several regions in Japan. People are aware of global warming and the gradual decline in population in this country. However, it is difficult for them to find solutions on a local level, because these problems are country-wide and global, not area specific. Under a declining population, it is a big challenge for small local governments to maintain their social infrastructure, such as waste and wastewater treatment or public transport. In our analysis of decarbonization, we found issues related to grid connection and low household penetration. We also analyzed the requirements for a sustainable society, which are to maintain the regional working population; ensure a sufficient number of people in each occupation; secure the local municipality's budget; downsize excessive infrastructure facilities; and maintain local communities. These are difficult tasks because each local government has limits on its budget and on its existing implementation plan. In addition, small local governments often suffer from a shortage of human resources, so that a single person is often responsible for many tasks at once.

Environmental Emergency and Resilience Research Program

This relatively new program will engage in research and technological development to help address the environmental issues associated with disasters and accidents. Specifically, regional collaborative research will be promoted to help revitalize and manage the regional environment of Fukushima Prefecture and create an environment that utilizes regional resources in collaboration with regional stakeholders, taking into consideration the results of past efforts. Moreover, the program will build a resilient waste treatment system and an emergency response system for chemical risk management in the event of a large-scale disaster by accumulating, utilizing, and systematizing the experience and knowledge gained from past disasters, including the Great East Japan Earthquake. Through these efforts, the program will support the construction of a sustainable local environment that meets social needs in affected areas, including the zone of Fukushima Prefecture in which the evacuation order has been lifted. The program will also use our efforts in Fukushima to help improve the environmental disaster resilience of local communities in preparation for other large-scale disasters.

In this fourth year of the program, the following efforts were made in each project, mainly from the perspective of technological development. The goal is to implement the results of each project socially to help revitalize the environment of Fukushima and prepare for future disasters.

Project 1. Technical systems research for reconstruction and environmental recovery in areas of Fukushima where residents are returning

1) Development of technology and systems for volume reduction of removed soil and radioactively contaminated waste with the aim of final disposal

To achieve final disposal outside Fukushima Prefecture, we have developed several scenarios that combine characteristic volume-reduction methods and corresponding disposal systems. As the parameters of the disposal system, such as the disposal facility structure and the nature of the solidified product, vary depending on the chosen technology combination, we created a disposal model for each scenario. We then evaluated the leachate and leakage water concentrations at the lower edge of a modeled disposal facility to assess the overall safety of the system. The analysis revealed that the concentrations of leachate and leakage water were below the limit of 90 Bq/L in all disposal systems. This study successfully demonstrated a method for evaluating the safety of specific disposal systems to achieve final disposal outside the prefecture. It is important to ensure the system's safety while also making it flexible, efficient, and fail safe. This involves considering both the leaching characteristics of the stabilized material and the radioactive cesium (r-Cs) absorption by components such as filler materials and reinforced concrete.

In addition, we started full-scale outdoor large-column tests (using three test cells) to confirm the environmental safety of molten slag, as part of joint research with

JESCO (the Japan Energy Service Corporation).

2) Development of biomass utilization technology and systems as countermeasures

We investigated the behavior of r-Cs in woody power generation facilities. By using a mass-balance analysis of r-Cs, we clarified the ratio of r-Cs concentration to residue (e.g., biochar from the feedstock in power generation facilities). In addition, we determined the leachability of hazardous heavy metals, as well as of r-Cs, from the residues with the aim of recycling them. We found that biochar from a downdraft gasifier can be utilized as a soil amendment to control the level of r-Cs to less than 400 Bq/kg. This utilization can be regarded as a type of carbon storage. These results will be useful in similar facilities under construction in Fukushima Prefecture.

In collaboration with Project 4, we proposed the most feasible biogas method for generating power from local waste biomass, such as the grass cuttings from highway maintenance, which are currently disposed of. Furthermore, we designed a combined system employing the biogas method and a downdraft gasifier using woody biomass as an advanced biomass power generation system. The system's energy and mass balances, as well as the carbon storage capacity, were estimated.

Project 2. Research into environmental impacts and management in the disaster areas of Fukushima

We conducted research in response to a request stated in the "13th Proposal for Accelerating Recovery from the Great East Japan Earthquake," issued by Liberal Democratic Party in August 2024. The proposal noted: "From the perspective of restoring the blessings of the mountains, we request the implementation of measures such as verification of the appropriateness of current standards regarding regulations on food and other items." Currently, Fukushima Prefecture continues to impose shipping restrictions on wild game animals, wild vegetables, and freshwater fishes. By using the village of Iitate in Fukushima Prefecture as a model, we estimated the additional radiation exposure doses from the collection and consumption of wild vegetables. For this estimation we needed accurate data on wild vegetable intake levels and the reduction effect of cooking. Previous studies had confirmed that cooking reduces the r-Cs content by 40% to 90%. To estimate the wild vegetable intake, we developed a food frequency questionnaire and used it to conduct interviews. The results showed that the combined per-person intake of wild vegetables with high concentrations of r-Cs, such as *Chengiopanax sciadophylloides* (*Koshiabura*), *Pteridium aquilinum* (*Warabi*), and *Aralia elata* (*Taranoki*), was less than 2 kg/year at its peak before the accident. The internal radiation dose from wild vegetable consumption was calculated by multiplying the 2021 r-Cs concentration in wild vegetables by the maximum intake and the reduction effect of cooking, resulting in an estimated annual dose of 0.2 to 32 μSv (Fig. 1). The external exposure dose, calculated from the time required for

collection of wild vegetables and related factors, ranged from 0 to 28 μSv. These results suggest that the additional exposure dose is sufficiently small, corresponding to a maximum of 6% and a median of less than 1% of the target additional exposure dose of 1 mSv/year. We also found that about 80% of the internal exposure originated from the consumption of *Koshiabura*.

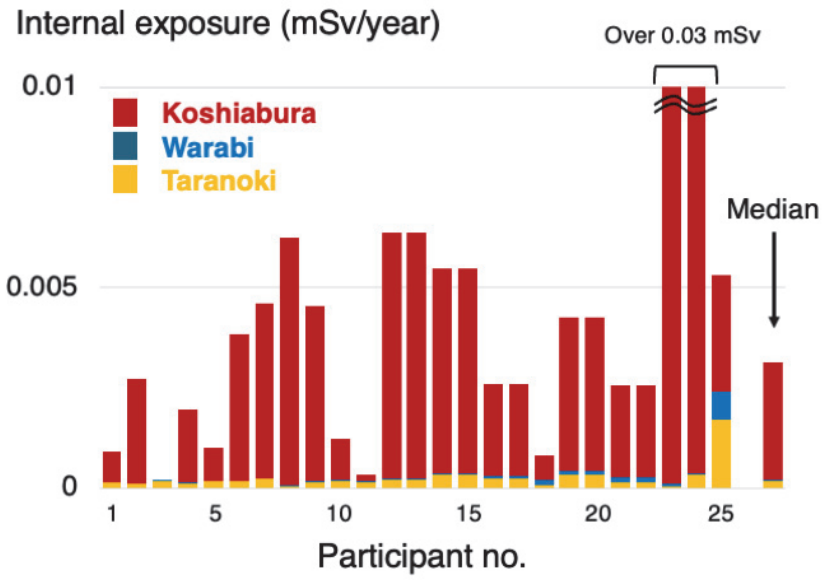


Fig. 1 Estimated internal radiation doses from three types of wild vegetables consumed by 25 individuals in the village of Iitate. Radioactive cesium concentrations of wild vegetables were obtained from 2021 data published on the Iitate Village website. The effect of cooking was derived from the results of our experimental study.

Project 3. Evaluation and analysis of regional revitalization and sustainable town reconstruction and development

We continued to update the previously collected statistical information as a reconstruction database and compiled forest area by age class and tree species to evaluate forest carbon accumulation and biomass supply potential. To construct future scenarios, we promoted discussions of the direction of reconstruction and development utilizing the regional capital framework. By using information from previous reconstruction projects, we set up two axes that focused on the main type of capital used and on intra- and extra-regional relationships. We then constructed four future scenarios to fit each quadrant—"calm," which emphasizes residential areas; "active," which emphasizes industrial locations; "lively," which emphasizes exchange populations; and "abundant," which emphasizes agricultural revitalization. We performed quantitative calculations by using a model constructed with FY 2023 data to map future factors (e.g., main industries, number of residents, extra-regional commuting relationships, land use, and renewable energy development) to the aforementioned four scenarios. Subsequently, we conducted future projections for the four scenarios, focusing primarily on Okuma and Futaba, where interim storage facilities are located. Next, we noted differences in the resident population and employment.

As part of research into development of a regional analysis system, we refined a

model simulating energy management by using demand response and electric vehicle batteries, and we used real-world data from the town of Shinchi's combined heat and electricity supply area for verification. We then expanded on these results. For example, we examined the expansion of the supply area of the current regional energy project. During this study we conducted simulation evaluations under the assumed implementation of scenarios of revitalization-enabled energy and electric vehicle charging and of smart control, including demand response, on top of the current scenario. We estimated the effects of these introductions. We were able to quantify the annual CO_2 emissions, revitalization-enabled energy power generation, and revitalization-enabled energy self-consumption rate for the assumed scenarios. However, despite the importance of the development of this quantification method, the evaluation results cannot be generalized because they depend on the assumed scenario. We need additional evaluation cases if we are to obtain generalized data. The previous series of results achieved in Shinchi have been compiled and submitted as an academic paper, and details of the overall research project, the prototype evaluation system, and the energy management subsystem have been published in several academic journals.

In another study, we used a local meteorological model in an evaluation of the potential of wind power. We used tower observation data from the Hamadori region to validate a four-dimensional wind database developed previously for a reference year. We then used this database to conduct a supply and demand balance simulation that incorporated wind power generation forecasts, linking the revitalization of potential energy generation in a reference year with fluctuations on the energy demand side.

Project 4. Studies of the emergence of regional resources and systems in Hamadori, Fukushima, after lifting of the evacuation orders

The main theme of Project 4 is the recovery and reconstruction of natural and social systems after the Fukushima Daiichi Nuclear Power Plant accident. Subtheme 1 addresses research on regional resources and environmental technologies, including the management process for utilizing these resources from a natural science perspective. Subtheme 2 aims to identify local characteristics and develop methods of applying the scientific findings of Subtheme 1 to society. This fiscal year's main research results were as follows.

Subtheme 1: In the town of Okuma we elucidated a consultative framework for achieving an RE100 industrial base (100% renewable energy industrial complex), a conceptual design of which had been completed during the previous fiscal year. On the basis of this work, we established a study group and developed a system for collaborating with the relevant parties for a feasibility study to be conducted next fiscal year. In doing so, to foster collaboration among diverse stakeholders from the perspective of local development, we referred to the results of an advanced case study survey and a stakeholder survey conducted up to last fiscal year under

Subtheme 2. We used our findings to design an implementation system based on dialogue and collaboration to ensure business feasibility and improve social acceptability and multifaceted value.

Subtheme 2: We created a platform to communicate the knowledge gained in regions that are practicing sustainable community development (hereinafter referred to as "advanced regions") to other regions. Specifically, we promoted the provision of knowledge based on a database on advanced cases that had been established the previous fiscal year in the towns of Okuma, Tomioka, and Naraha in the Hamadori region of Fukushima Prefecture. With the cooperation of local stakeholders who were headquartered in Tomioka and were involved in many projects related to reconstruction town planning, we convened a study meeting to apply the knowledge database to the Tomioka Station and Yonomori Station areas in Tomioka, Fukushima Prefecture, and analyzed the results. We confirmed that applying the knowledge gained from the community development processes used by the advanced regions enabled us to obtain an effective social systems perspective on revitalization of the region. We were also able to use the advanced regions' patterns to share the district's challenges and the urban development processes needed to overcome them with local stakeholder.

Project 5. Making a resilient material cycle and waste management system at the local level to tackle mega-disasters

We conducted case studies targeting the municipalities within Fukushima Prefecture that had experienced multiple disasters within a short period. This process validated the conceptual model of disaster waste governance that we developed last year. We also conducted interviews focusing on pioneering initiatives by municipal governments, with the aim of achieving effective resident collaboration on disaster waste management. The results were categorized and summarized as a guidebook for municipal governments. Furthermore, we collaborated with municipalities to explore ways of using the online tools we developed in previous years to support disaster waste management. Collaboration with the government of Aichi Prefecture revealed that use of a self-assessment tool for local government staff named *Sai-hai* was more effective when the assessment results were shared and discussed with staff from different municipalities, compared with when they were used individually.

We also conducted field surveys on the current status of river waste generation in Jakarta. We found that organic matter and plastics (mainly HDPE) were the major constituents. We organized location information for river waste-collection points and temporary storage sites in preparation for an analysis of the geographical distribution of river waste.

As a strategy for disposing the large amounts of concrete debris anticipated from a future Shuto Chokka Mega Earthquake (a major earthquake expected to strike the

Kanto region, including Tokyo, directly from below), we conducted life-cycle cost analysis and life- cycle CO_2 analysis for three different scenarios of disaster debris/concrete treatment: the conventional method of recycling as roadbed materials, and two new methods of use as material for mound-reef construction or for marine depression filling. We also examined the optimal allocation of these methods by using a linear programming model aimed at minimizing total treatment costs. The linear programming model analysis, which used three Tokyo wards as a case study, showed that about 87% of concrete rubble generation would be reused in new marine applications under the optimal scenario. This scenario reduced the treatment costs by about 7% compared with using the concrete only as roadbed material, and it shortened the processing period from 8.8 years to 2.4 years.

Project 6. Strategic chemical risk-management research in emergencies

We advanced the analysis of a tabletop exercise held for staff of regional environmental research institutes and local government officials. The exercise was aimed at strengthening response capabilities for chemical substance releases into the environment during disaster incidents. The exercise involved group work in which each team developed accident scenarios and discussed investigation methods and countermeasures (Fig. 2). We used each team's findings to systematize the accident response process by determining which scenarios to set from among the diverse chemical substance accidents in which participants could potentially become actual responders, as well as by organizing how the response actions evolved in response to changing circumstances (Imaizumi et al., 2025). Through the desktop exercise, we were able to enhance the foundational system (D.Chem-Core: Chemical Risk Assessment and Management Resource Core for Disaster and Emergency), which systematizes the information needed during disasters and accidents, making it more practical. Furthermore, as well as improving the system, we strengthened our comprehensive disaster and accident response capabilities, including the design and training of exercises for local government officials.

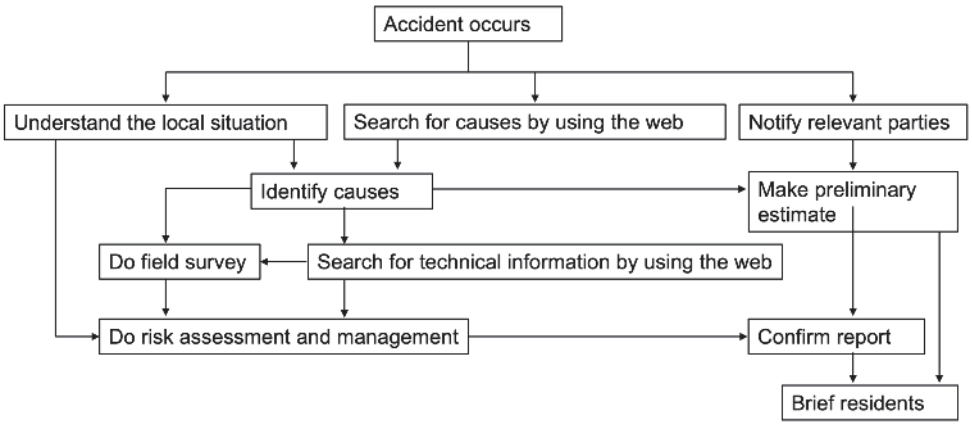


Fig. 2 Systematization of the incident response process in group work

Reference:

Imaizumi Y., Koyama Y., Nakajima D., Takazawa Y., Suzuki N. (2025) Usability evaluation of a web-based information system to support response to the release of

chemical substances into the environment during disasters and accidents. *Journal of Environmental Chemistry* 35, 39–46

Climate Crisis Research Initiative

1 About

The Climate Crisis Research Initiative ("the Initiative") is responsible for coordinating four climate-change-related Strategic Research Programs (Climate Change and Air Quality Research Program, Climate Change Adaptation Research Program, Decarbonized and Sustainable Society Research Program, and Co-design Approach for Local Sustainability Research Program). It also collaborates with Harmonization with Nature Research Program, Material Flow Innovation Research Program, and other divisions, and it consolidates and disseminates findings that are relevant to public concerns (Fig. 1).

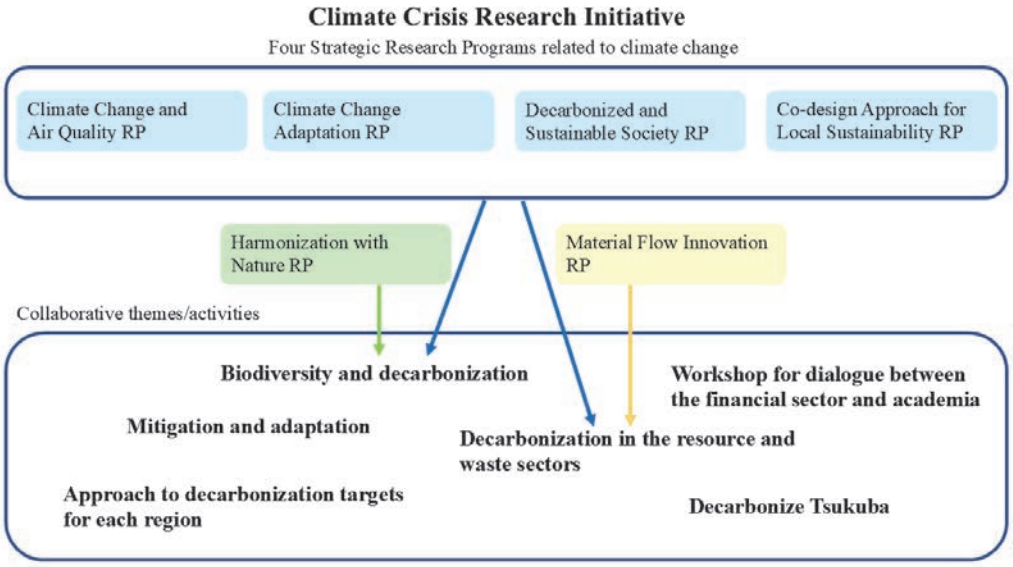


Fig. 1 Structure of the Climate Crisis Research Initiative and the four Strategic Research Programs related to climate change (Climate Change and Air Quality Research Program, Climate Change Adaptation Research Program, Decarbonized and Sustainable Society Research Program, and Co-design Approach for Local Sustainability Research Program)

2 Activities in FY 2024

2.1 Monthly meetings

The research directors of the four climate-change-related Strategic Research Programs, along with the project leaders, the research directors of the Harmonization with Nature Research Program and Material Flow Innovation Research Program, the directors of Earth System Division, and other members, including the president of NIES, the vice president for research, and the leader of the Initiative, held monthly briefings on the progress of each Research Program and discussed shared issues for collaboration, as described in section 2.2. In addition, efforts were made to discuss other topics to give us a new perspective on the issue of climate change, as described in section 2.1.1. We also created two maps that provide a bird's-eye view of NIES's climate-change-related research activities. One of the maps summarizes the Initiative-related research activities performed by the four Strategic Research Programs, and the other summarizes related external research funding projects.

2.1.1 Free discussion of cross-disciplinary issues based on topics presented by young to mid-career researchers

In our monthly meeting, with the aim of broadening participants' perspectives and insights, and serving a reference for considering the next Mid-and-Long Term Plan (FY 2026–2030) of NIES, we launched a project to encourage younger researchers to raise and discuss research-theme issues that are difficult to deal with within the framework of existing research domains and programs, as well as issues and challenges that are often overlooked but are potentially important. We conducted this project from the second half of FY 2024 onward and received presentations from two young and mid-career researchers on the following topics, which were freely discussed:

- a social science perspective on solar radiation management
- a multifaceted and comprehensive study of the nitrogen waste issue

We plan to continue this project in the upcoming year and to consider topics such as Loss and Damage, the economic impacts of climate change, IPBES (Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services) Values Assessment, and new uses for satellites.

2.2 Collaborative themes

The Initiative has identified six cross-disciplinary issues as collaborative themes that are discussed at our monthly meetings: (1) Biodiversity and decarbonization, (2) Workshop for dialogue between the financial sector and academia, (3) Mitigation and adaptation, (4) Decarbonization in the resource and waste sectors, (5) Approach to decarbonization targets for each region, and (6) Decarbonize Tsukuba.

2.2.1 Workshop for dialogue between the financial sector and academia

Since the "Workshop between Academia and the Financial Community on the Global Environment," held in FY 2021, we have had individual dialogues with some financial communities. In FY 2024, discussions were held with a private asset management company regarding the needs of financial institutions, as well as with the Financial Services Agency of Japan regarding the handling of Tipping Points. In addition, we invited a lecturer from Keio University to conduct a seminar on sustainable finance. To discuss the future approach of the NIES to this issue, we also exchanged opinions with the Sustainable Finance School of University of Tokyo (a recurrent education program) and Future Earth (an international research platform).

2.2.2 Decarbonize Tsukuba

To replace the current aging NIES building as part of the decarbonization of NIES,

discussions have continued with the aim of making the new building a ZEB (Net Zero Energy Building). This year, additionally, the discussions have progressed to cover compatibility with wellbeing. Last year, the green space within NIES was registered as a National Certified Sustainably Managed Natural Area, and discussions were held to ensure that the new building, together with the green space, will be visible and familiar to local residents. To properly manage the green space, last year we cut down the dense Japanese white oak. This year we burned the cut wood to fix the carbon in it and distributed the charcoal to participants of the seminars about the green space. To save electricity at NIES, we discussed an electricity billing system in which the beneficiary bears the burden.

To further the decarbonization of the city of Tsukuba, the Climate Assembly TSUKUBA was held in FY 2023. It started with a carbon-negative study meeting we had with the mayor, and we then participated in an executive committee to plan and organize the conference. At the end of the conference, the participants submitted 74 recommendations to the mayor, which were summarized as "Zero Carbon, Livable Tsukuba City." We also advised Tsukuba City as it developed to the roadmap. We have also advised the mayor that, when the prefectural Doho Park is changed to a municipal park, the city government should apply for the park to become a National Certified Sustainably Managed Natural Area.

2.3 Public webinar

A webinar on the ISIMIP (Inter-Sectoral Impact Model Intercomparison Project), "How to Understand the Uncertainty of Future Projections of Climate Impacts: Now and in the Future of Global Impact Projections Focusing on International Model Comparison Assessments," was hosted jointly by the Climate Change Research Project Cooperation on Scenarios Initiative (represented by the University of Tokyo) and research project SII-11 of the Environment Research and Technology Development Fund. ISIMIP is an international project that uses multiple climate change impact models for multiple sectors to compare impact assessments under the same conditions and to discuss uncertainties in the models. In this webinar, model developers who had participated in ISIMIP, including five external experts, introduced their sectors of agriculture, water, terrestrial biodiversity, and fire, and they discussed the treatment of climate scenario data sets and user needs. The webinar had approximately 290 registrants and 165 attendees, confirming the high level of interest in this topic.

Fig. 2 Seminar on "How to Understand the Uncertainty of Future Projections of Climate Impacts: Now and in the Future of Global Impact Projections Focusing on International Model Comparison Assessments"

Research Domains

Earth System Domain

The surface of the Earth is covered with the atmosphere, oceans, and land, and preserving this surface environment is indispensable for creating a sustainable human society. However, human activity has caused changes in the climate, including not only rising average temperatures but also an increase in extreme weather events, rising sea levels, and damage to ecosystems and food production. Countries and regions are required to take further measures to reduce greenhouse gas (GHG) emissions under the Paris Agreement, an international framework for climate change countermeasures. There is growing concern about the climate crisis in the world, and Japan has pledged to achieve net-zero GHG emissions by 2050.

Researchers in NIES's Earth System Domain will, in collaboration with scientists in Japan and overseas, work on a variety of research issues, such as the prediction of future changes in the global environment, assessment of risks, and development of the advanced measurement technologies and models needed for their research. The intellectual research infrastructure (e.g., long-term monitoring and databases) will continue to be maintained by the CGER (Center for Global Environmental Research), established in 1990. We will also work closely with the Satellite Observation Center, which is responsible for the "IBUKI" (GOSAT) series of GHG observation satellites. We will disseminate our research results more quickly and widely than has been possible before. Scientific knowledge and data will be actively transmitted to international frameworks such as the UNFCCC (United Nations Framework Convention on Climate Change) and the IPCC (Intergovernmental Panel on Climate Change). We hope that, through the above activities, we can help to achieve a sustainable global environment and society.

1. Foresight and Advanced Basic Research

Evaluation of cloud microphysics and vertical velocity through combined analysis of next-generation active sensor satellite data

We improved the cloud and aerosol retrieval algorithms for the Japan–Europe joint Earth satellite observation mission EarthCARE (Earth Cloud Aerosol and Radiation Explorer), which was launched at the end of May 2024 and will operate for the next 3 years. To improve the algorithms, we used a state-of-the-art ground-based lidar and cloud radar combined observation system that was jointly developed in 2021 with Kyushu University, the National Institute of Information and Communications Technology, and others and operated successfully on a regular basis. By using the database constructed by the system, estimation procedures, as well as thresholds for the identification of cloud and aerosol layers, were improved, and we were able to successfully identify these layers (Fig. 1) and to estimate particle types and optical properties. In addition, initial validation of EarthCARE products by using the above ground-based observation system was conducted in the latter half of this fiscal year,

and the results were adopted as an indicator in the review process for the public release of the products from JAXA (the Japan Aerospace Exploration Agency). The ground validation will continue, and the results will be used to continue to improve the algorithm.

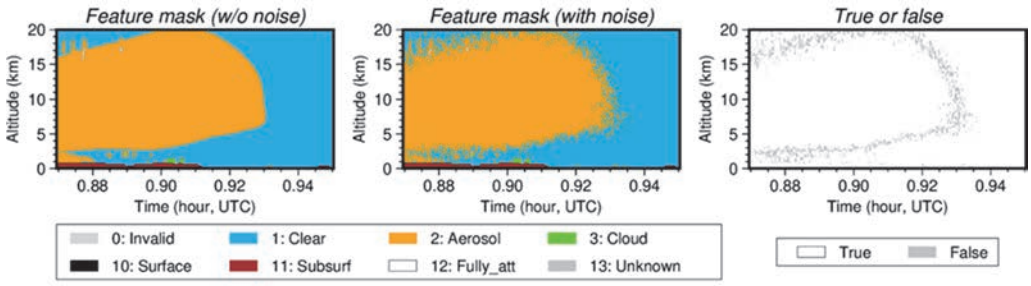


Fig. 1 Layer identification from lidar onboard EarthCARE satellite products by using pseudo-signal data (true values, left; retrieved values, middle; true/false, right). An example of an atmospheric field with clear skies and a dominant aerosol layer is shown. The layers of clean air (sky blue), aerosols (orange), and clouds (green) are well identified (from Nishizawa et al., 2024).

Reference:

Nishizawa T., Kudo R., Oikawa E., Higurashi A., Jin Y., Sugimoto N., Sato K., Okamoto H. (2024) Algorithm to retrieve aerosol optical properties using lidar measurements on board the EarthCARE satellite. *Atmospheric Measurement Techniques Discussions*. https://doi.org/10.5194/amt-2024-100, in review.

2. Policy-oriented Research

The Arctic region is the area most affected by global warming, and early detection of the progress of this warming and its impacts on Arctic nature and society is important in the effort to support Japan's science and technology diplomacy. As part of research collaboration under a Memorandum of Cooperation between NIES and the Finnish Environment Institute (SYKE), we have co-authored a review paper with two SYKE researchers comparing observations of essential biodiversity variables at the national scales in Japan and Finland, and the paper was published in Ecological Research. As part of our black carbon (BC) research, we analyzed Arctic BC by using the Nordic emission inventory developed by SYKE and the chemical transport model developed by NIES.

3. Intellectual Research Infrastructure Development

Latitudinal differences in the increase in atmospheric methane (CH_4) mole fraction over the Pacific Ocean

NIES has continued to observe atmospheric GHGs by using voluntary observation ships in the western Pacific since 1994, in the North Pacific since 1995, and in Southeast Asia since 2007. In this study, we analyzed data obtained from the western and northern Pacific regions. We plotted variations in the annual mean atmospheric CH_4 mole fraction at 16 latitudes from 50°N to 35°S (Fig. 2; Umezawa et al., 2025). The CH_4 mole fraction was larger in the northern high latitudes and decreased gradually to the south. The long-term trend showed persistent increases at all latitudes between 50°N and 35°S. Growth rates were relatively small from

1994 to 2006 (except for a large increase from 1997 to 1998), but they increased from 2006 onwards with superimposed interannual variations. The recent annual increases differed by latitude and year. In 2020, the annual increase was the largest, at 18.2 ± 2.0 ppb at 25°N, but it was lower in the Southern Hemisphere. However, after 2021, we observed larger annual increases in the Southern Hemisphere than in the Northern Hemisphere.

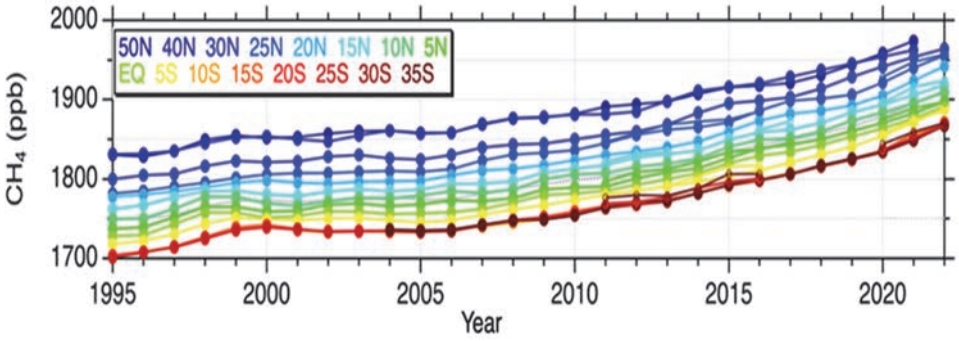


Fig. 2 Time series of annual mean CH_4 mole fraction over the Pacific Ocean from 50°N to 35°S

Reference:

Umezawa, T., Tohjima, Y., Terao, Y. et al. (2025) Long-term and interannual variations of atmospheric methane observed by the NIES and collaborative observation networks. *Progress in Earth and Planetary Science* 12 (39). https://doi.org/10.1186/s40645-025-00711-9

Material Cycles Domain

As part of our **Foresight and Advanced Basic Research**, we are conducting two main research activities. One is sustainability assessment and design of a future vision of resource utilization. The other is advanced science and engineering for material cycles.

As part of our **Policy-Oriented Research**, we have been conducting three main research activities. The first is research on social systems in material cycles and waste management. The second is impact assessment of hazardous substances in material cycles measurement, testing, and evaluation of hazardous substances in the resource-recycling process. The third is advancement and implementation of waste management technologies for social adaptation and improvement of waste treatment and disposal technologies.

In addition to the main research activities mentioned above, we launched an international project with overseas academic institutions to strengthen international joint research. As participants in several technical committees of the International Organization for Standardization (ISO), we also helped to issue standard documents and scientific findings.

As part of the ongoing development of intellectual research infrastructure, we have begun not only to visualize international resource flows and Japanese municipal waste data but also to improve the user interface for data visualization.

Details of the abovementioned research activities are given below.

1 Foresight and Advanced Basic Research

1.1 Sustainability assessment and design of a future vision for resource utilization

How can we decarbonize the global steel industry? Growing expectations are being placed on green-hydrogen-based steel for decarbonizing this industry. However, the scale of the expected demand is currently dispersed across numerous case studies, resulting in a fragmented picture.

In FY 2024, with a focus on green hydrogen (hydrogen produced without CO2 emissions in the manufacturing process), we analyzed 28 existing scenarios and compiled data on the future production scale of green-hydrogen-based steel in an effort to clarify the extent to which it could meet steel demand (Fig. 1). We found that the supply of green-hydrogen-based steel would be limited in the short term and would likely remain at about 2% of total steel production by 2030. Its rapid growth is likely to begin in about 2040, and our analysis suggests that it could

account for over 35% of total production by 2050. To cope with this increase, the necessary green-hydrogen-related infrastructure, such as electrolyzer capacity, would need to increase more than 1000-fold by 2050. These results provide basic information to clarify the role of green-hydrogen-based steelmaking in decarbonization plans. In other words, in decarbonization plans in which the key is the reduction of cumulative emissions, it is essential to reduce these emissions immediately through options that are already feasible (enhanced recycling and improved resource efficiency). We propose that green-hydrogen-based steelmaking should be considered as merely one of the many options to support the long-term transition towards decarbonization.

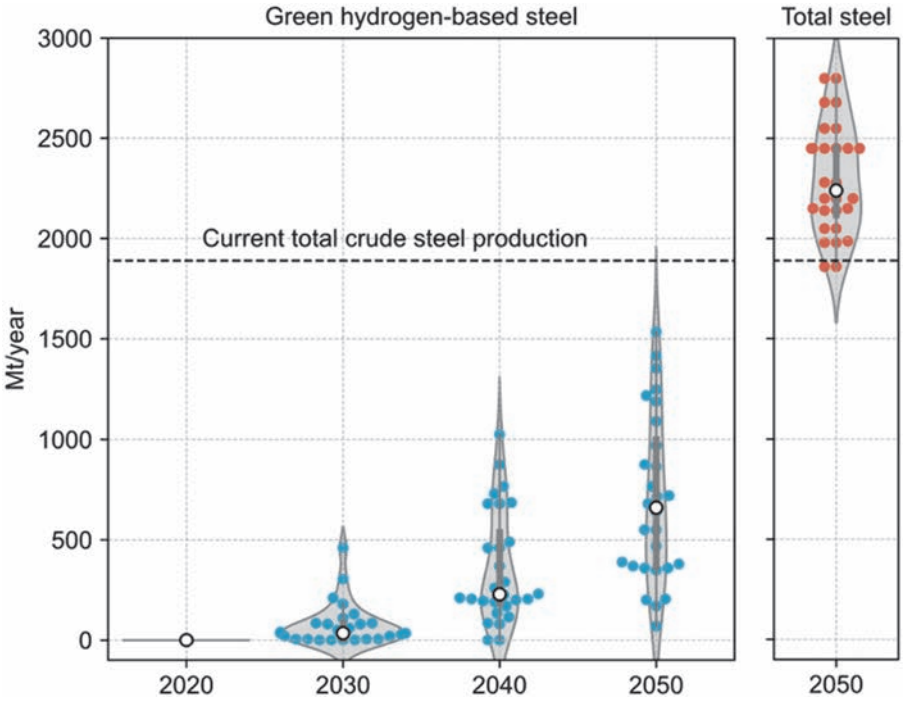


Fig. 1 Expected global demand for green-hydrogen-based steel, as determined from 28 scenarios. White symbols represent medians of the data and thick gray bars represent the interquartile ranges. The light gray areas show the distribution of the data, as determined by using kernel density estimation.

1.2 Advanced science and engineering for material cycles

The dynamics and environmental risks of micro- and nanoplastics (MNPs) are of substantial concern. An accurate method for the quantitative analysis of NPs is needed so that we can assess their environmental pollution. An understanding of the mechanism of plastics fragmentation in the marine environment is also essential for the prediction of MNP generation. Furthermore, resource recycling technologies that consider decarbonization in the regional circular and ecological sphere are needed. Therefore, we conducted studies focusing on plastics of different sizes and on the resource recycling of waste biomass considering decarbonization.

In research on the dynamics and risks of NPs, we developed a highly accurate method for quantitatively analyzing NPs by preparing isotope-labeled standard NP particles and using them as surrogate materials (standard materials to correct errors

in pre-analysis treatment and analysis). Previous studies had developed a method to recover NPs from environmental samples, such as water, by ultrafiltration and then quantify them by Pyr-GC/MS (pyrolysis gas chromatography – mass spectrometry). Our studies have so far revealed that NP losses are particularly large in the process of ultrafiltration (filtration using a membrane to recover particles as small as a few nanometers), and that the recovery rate of NPs in this process is sometimes about 30% to 50%. Our study found that, by introducing isotope-labeled NP particles as surrogates into this analytical method, errors in the pre-analysis treatment process, including losses in the ultrafiltration process, could be corrected, and the recovery of NPs could be corrected to 80% or more (Fig. 2). Surrogates have never been applied to the analysis of NPs in the past, but they are an essential technology for improving the accuracy of quantitative analysis of NPs and ensuring the quantitative quality. We expect that they will become widely used as a basic technology for the risk assessment of NPs and elucidation of their environmental dynamics in the future.

In research on the mechanism of plastic fragmentation, we improved the fragmentation test method to reproduce physical actions (such as the collision of waves and sand) in the coastal environment and established a method to detect MPs of 1 μm minimum using a scanning electron microscope and analyze the particle size distribution. In addition, by continuing the outdoor plastic exposure test which started in FY2022, we were able to obtain deteriorated plastic test pieces which had been exposed outdoors for about two years at 10 locations nationwide. We applied these samples to the above fragmentation test method and quantitatively evaluated regional differences in the fragmentation speed of plastics degraded in the outdoor exposure environment. As a result, there was a positive correlation between the UV intensity and the fragmentation speed, and the UV index (an index representing the UV intensity) was about 1.6 times and the fragmentation speed was about eight times higher than in the region where the difference was especially large. In addition, by comparing the fragmentation speeds of plastics with different additives, we clarified that the UV absorber suppressed the fragmentation speed.

In research on resource recycling technology considering decarbonization, we evaluated the inhibition of the bioplastic conversion technology by grouping sampling sources for sampling under the hypothesis that the inhibition of oil extracted from brown grease against microorganisms depended on the management method of grease traps (interceptors to separate brown grease from wastewater) at the sampling sources. We confirmed that at the sampling source where oil and fat were collected and cleaned every week, the oil and fat concentration at which the activity of microorganisms was reduced by 50% (IC50) was less than 1/3 of that compared with other sampling sources and that shortening the residence time in the grease trap was effective in reducing the inhibitory effect. In joint research with a private enterprise, we aimed to develop a system for the rapid evaluation of food waste for biomethane production. To achieve this, we developed a database of near-infrared (NIR) light absorption characteristics, nutrients, and methane production

potential for food residue from restaurants, department stores, and other establishments and constructed a model to predict the concentrations of nitrogen, oil and fat, and other substances as well as methane production potential, which could cause operational problems in anaerobic digestion, from NIR spectra (a series of data showing the absorbance for each wavelength in the NIR wavelength region). The errors between the measured and predicted values for moisture and methane potential were within 10% on average over the whole range, but those for lipids exceeded 25% in the low concentration range below 0.01 g/g, suggesting the necessity of verifying the applicable concentration range of the calibration curve.

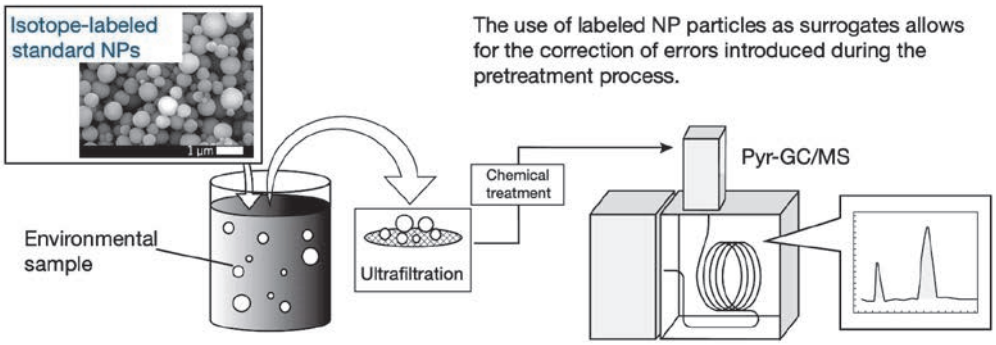


Fig. 2 Schematic overview of quantification of nanoplastics (NPs) by using isotopically labeled NP particles. Pyr-GC/MS, pyrolysis gas chromatography – mass spectrometry

2 Policy-Oriented Research

2.1 Research on social systems in material cycles and waste management

2.1 Research on social systems in material cycles and waste management

In FY 2024, we upgraded the operability and other functions of our municipal waste model by making some macroscopic improvements. We also conducted a multiple regression analysis by using a long time series with the amounts of municipal waste discharged and sorted as objective variables and such indicators as taxable income and number of single households as explanatory variables for living and working. A weak correlation was observed between the explanatory variables and the objective variables. It is likely that 3R measures will have greater impacts than indicators related to living and working on the amounts of waste discharged and sorted. We closely examined the integration algorithm that we are developing for municipal waste treatment facilities and presented a paper on it.

We investigated the effects of the joint collection of waste plastic containers and packaging and other waste plastic products aiming for recycling (hereafter referred to as “joint collection”) on the collection and sorting processes of plastic waste, as well as the effects of measures taken to mitigate the potential adverse effects of joint collection. Interviews with municipal staff and mechanical recycling operators revealed that joint collection may have several adverse effects on the

collection and sorting processes operated by these stakeholders (especially those operated by mechanical recycling operators), such as damage caused to shredders by plastic products containing metals and fires caused by products containing batteries. To reduce these adverse effects, municipalities have implemented countermeasures such as restrictions on the products to be collected and changes in the sorting process; however, we inferred that these measures lead to trade-offs, such as a decrease in the amount of plastic waste collected and an increase in the operational costs. It is essential to develop an appropriate collection system from multiple perspectives, including the amount of plastics recycled and the expenditure.

In an examination of circular economy indicators, we collected 20 years of data on circular flows in Japan and developed a new method for overcoming the drawbacks of recycling rates. Although the recycling rate in Japan has increased by about 5% over the past 20 years, the amount of waste generated, as well as the rates of final disposal and proper treatment, has decreased markedly. This means that waste prevention has advanced more than recycling without contravening the waste management hierarchy. In addition, data from the Ministry of the Environment showed that Japan's reuse rates are low, at about 0.3%, because the coverage of data on reused items is limited; we therefore attempted to estimate the genuine reuse amount.

To determine the impact of the COVID-19 pandemic on waste, which had a major impact on medium- to long-term socioeconomic activities, we used the results of the Survey on General Waste Disposal conducted by the Ministry of the Environment to look at trends in the amount of waste nationwide since FY 2012. The largest impact was on collection organized by communities. Before COVID-19, there had already been concerns that the impacts of population decrease and aging would weaken local communities—mainly neighborhood children's associations (a community-based organization for local children)—and reduce the volume of collective collection, but the rapid decline in the volume of collective collection during the spread of COVID-19 indicated that the weakening of local communities was accelerating.

In a study of policy design, we investigated the extended producer responsibility scheme in France, which is highly ambitious. From among 22 items, we selected toys, chemical products, unused medicines, medical sharps, and tobacco, which are not subject to Japanese recycling acts, and we explored the features of the schemes that could be applied to products in Japan in future.

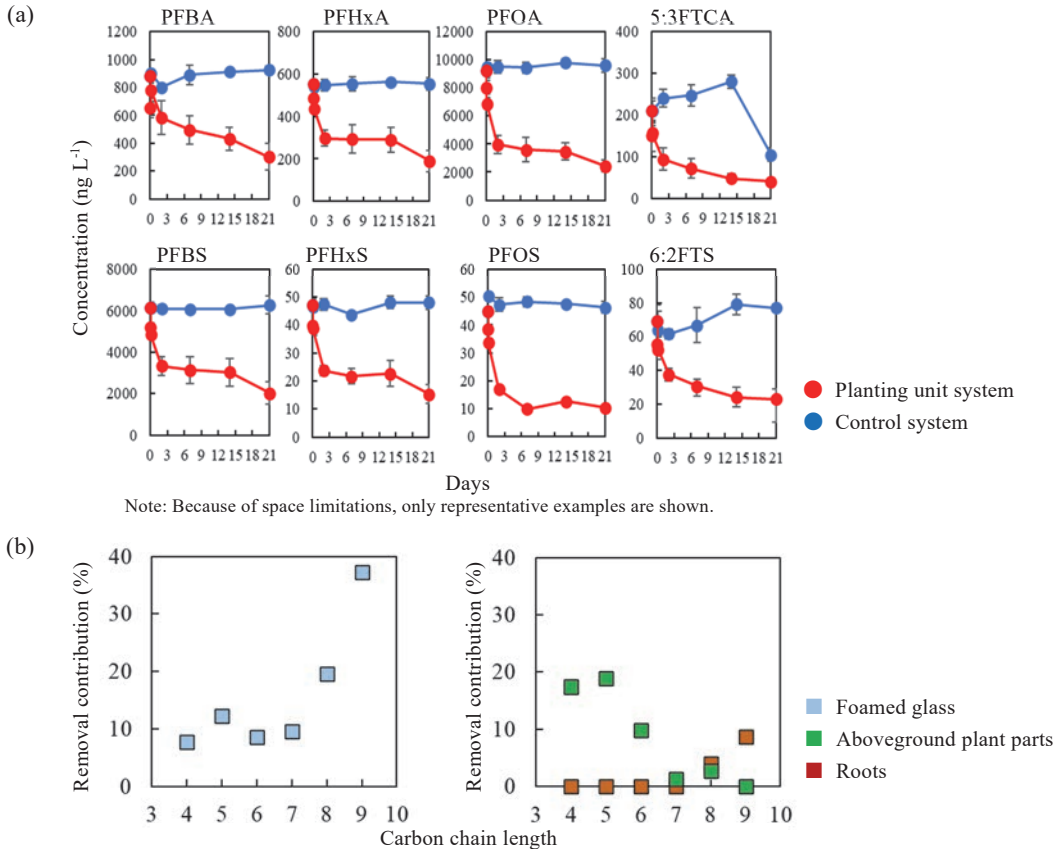
In a safety evaluation of the material cycle process, we collected and evaluated information on ignition accident prevention measures in local government incombustible waste treatment facilities, and we compiled a set of technical data guidelines.

2.2 Impact assessment of hazardous substances in material cycles

We developed planting units that utilize the interaction between recyclable resources (foamed glass), plants, and microorganisms to develop a green infrastructure technology that utilizes the natural environment and recyclable resources. We also confirmed the efficient removal of organic substances and nutrient salts from wastewater by using this system. We filed a patent application for this achievement, and this led to joint research with a private enterprise for demonstration.

To evaluate the applicability of the abovementioned technology to the removal of per- and polyfluoroalkyl substances (PFAS), we conducted a treatment performance test of planting units by using contaminated water containing PFAS. We confirmed the removal of 13 PFAS with short- and long-carbon chains (Fig. 3). A mass balance analysis showed that most of the removal of 6:2 FTS (6:2-fluorotelomersulfonic acid) was due to foamed glass accumulation. For the other PFAS, the contribution of other removal processes in addition to foamed glass accumulation and plant adsorption/uptake was demonstrated. In the case of long-chain PFAS (carbon chain lengths eight and nine), the contribution of foamed glass accumulation and plant adsorption/uptake increased, whereas the contribution of these decreased in the case of short-chain PFAS, for which transfer to the upper parts of plants was confirmed. We therefore found that the carbon chain length of PFAS affected the removal mechanism of the planting units. These results should provide an option for cost-effective PFAS treatment technology, in addition to existing treatment technologies such as adsorption and pyrolysis.

As a whole, the planting units that we developed in the fifth term by utilizing the interaction between recyclable resources (foamed glass), plants, and microorganisms, with the goal of implementing green infrastructure, resulted in patent applications and joint research with private enterprise. Furthermore, as a new development, we evaluated the PFAS removal performance of the planting units and the effects of biological reactions (plants and microorganisms) on PFAS removal, and we accumulated basic knowledge for PFAS decontamination by planting units. These results should help to elucidate the behavior of PFAS in the environment and to develop cost-effective PFAS treatment technologies.



Note: Because of space limitations, only representative examples are shown.

Fig. 3 Removal of PFAS by planting units (a), and the effect of PFAS carbon chain length on the removal mechanism (b)

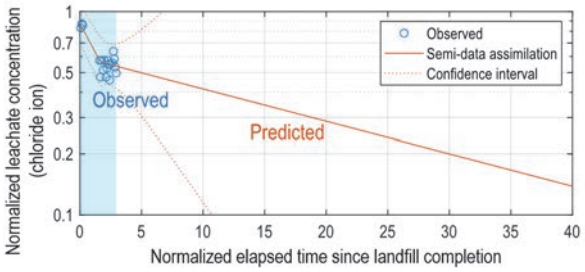
2.3 Advancement and implementation of waste-management technologies for society

We have been conducting a multifaceted evaluation of final waste-disposal sites in Japan; developing appropriate waste treatment and resource-recovery technologies based on an assessment of waste characteristics in Asian cities; and studying the establishment of a Johkasou management technology system to adapt decentralized wastewater treatment technology to Southeast Asia.

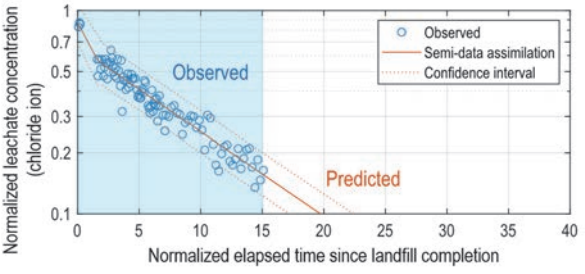
In our research on disposal sites, we hosted a seminar for local government officials engaged in inspection work, along with personnel from testing and inspection institutes, to confirm the effectiveness of our procedure manual. We also examined a simple and alternative investigation method for application to disposal sites with insufficient investigation systems.

In landfills, water flows preferentially through particular gaps in porous media. For this reason, we proposed a regression equation (a bilinear interpolation equation of the relationship between the logarithmic concentration of leachate and elapsed time) that could approximate a solution to this physical model by considering water flows. We also proposed an algorithm to obtain a regression equation that minimized the prediction error by adding measured data as needed, with reference to the idea of data assimilation (Fig. 4). A bilinear interpolation

equation was used as a regression equation, and its two coefficients were determined as the first half-life (before tailing occurred [when washing efficiency was high]) and the second half-life (after tailing occurred [when washing efficiency was low]). The tailing phenomenon refers to the situation in which the easily flowable parts of a contaminated porous medium are preferentially washed away when flow is applied, while leaving contaminants in the less flowable parts. This results in a low-concentration state that continues over a long period. In addition, the two coefficients were related to various quantities at the final disposal site (final disposal site capacity, landfill area, depth, landfill start year, and landfill period). By using this relationship, the first and second half-lives could be estimated from the quantities at the final disposal site, and reliable future predictions of leachate concentrations could be made for final disposal sites without actual measurement data. To collect real-life measurement data that were essential for the above predictions, and to help working-level personnel who had these data to understand the value of the data in management, we started providing a web application for these personnel to view, analyze, and predict the measurement data themselves. We are now reaching a situation in which this system is close to implemented.

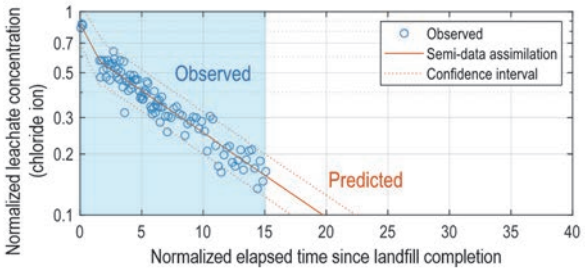


(a) When not enough data are available yet



(b) When data accumulate over time

Fig. 4 Leachate concentrations (tracer: chloride ion), based on observed data and future predictions by using semi-data assimilation



(c) Accurate prediction via continuous data accumulation

In the research on countermeasures against infectious diseases, we set the frequency or time of occurrence of work situations with infection risks during a day's work in the collection of general waste. For this, we used by a questionnaire survey, as well as literature surveys and experiments, to determine infection rates and as well as the transmission of sources of infection sources included in garbage and infection rate by literature surveys and experiments. These results are expected to be usedtilized for the safe collection of waste.

We performed In the research on waste management in developing countries, as part of the international joint research with King Mongkut's University of Technology and Kasetsart University (both in Thailand). The aim was to strengthen anthe international network for establishing the realization of waste management schemes in responseding to disasters and climate change. We , we held the dialogue with the local community in Chiang Rai, which were is considerably vulnerable tofor natural disasters such as flooding and landslidesing. We have communicated with a community leader and community members of communities, to identify the status of evacuation the warning systemsituation for evacuation during at disasters situation, and to implement the appropriate disaster waste disposal practices during on disaster waste disposal under emergency responses. We agreed to secure the a temporary waste storage site in the community and to design athe plan to operate and manage it.

As part of research on decentralized household wastewater treatment systems in Southeast Asia, at the 10th World Water Forum, as well as at a Johkasou seminar in Sri Lanka and an international workshop in Tokyo, we discussed the dissemination of performance test methods and the standardization of operation and maintenance procedures for decentralized systems.

2.4 International Waste Management Research Administration Office

We intend to support the proposal and implementation of international joint research by integrating research interests in multiple fields, with the resource-recycling field as the core. We will promote the efficient social implementation of research results and policy recommendations by promoting cooperation with academic institutions and local governments overseas and by quickly identifying needs. In addition, we

support the reflection of research results through international organizations and international activities.

We concluded an MoU (Memorandum of Understanding) with the National Institute of Environmental Research of Korea regarding the promotion of comprehensive waste recycling. Mutual visits were conducted to exchange opinions and explore possibilities for joint research. We also supported an international inter-laboratory comparison for measuring plastics containing persistent organic pollutants, as well as a seminar on mercury management in artisanal and small-scale gold mining.

To promote international collaborative research, we supported applications for external funding in cooperation with overseas institutions (e.g., the Royal Society and the British Council), and we supported the hosting of international researchers. As part of a project run by Thailand's Office of the National Higher Education Science Research and Innovation Policy Council (NXPO) to strengthen international scientific and technological networks, an on-site training program was conducted in local communities, with a focus on disaster waste management.

Furthermore, a series of three international seminars were co-organized with Thai University to prevent the environmental leakage of plastic waste. To share information and develop human resources within this feld of research, we have promoted the social implementation of research outcomes through involvement in international standardization activities, and we have facilitated interdisciplinary networking among international researchers. As part of international outreach, a science communication workshop was held with an invited lecturer from the University of Tsukuba.

3 Intellectual Research Infrastructure Development

We developed an interactive data browsing and comparison Web system by using "Tableau" to compare data on the status of municipal solid waste management at the prefectural and municipal levels in Japan. The system makes it possible to make comparisons among similar municipalities nationwide. The website in Japanese language was published and drew attention of waste management experts and citizens who are interested in waste and recycling issues (https://www-cycle.nies.go.jp/jp/db/file01/visualize00.html).

We also released the NIES Global Trade of Materials (https://gtm.nies.go.jp), a tool for visualizing the import, export, consumption, and social stock of metal resources in each region of the world (Fig. 5). The platform provides time-series data from 1995 to 2016 on the global trade volumes of 15 types of materials, including rare metals. Users can explore each country's contribution to global exports and imports, as well as the significance of major traded items. In addition, the tool offers insights into per capita consumption, social stock, and gross domestic product (GDP) for each country.

Fig. 5 Screenshot of the NIES Global Trade of Materials

Health and Environmental Risk Domain

In the field of health and environmental risk, we aim to promote foresight and advanced basic research and policy-oriented research to help protect human health and preserve ecosystems from environmental stressors such as chemical substances.

Our foresight and advanced basic research includes: (1) predicting the chronic toxicity of pharmaceuticals to *Daphnia* and evaluating their efficacy on the basis of the presence of target orthologs; (2) developing a highly sensitive simultaneous analysis method for trace levels of 95 pesticides in honey; (3) co-hosting the 21st International Symposium on Toxicity Assessment (ISTA21) in Fukuoka City, attended by 135 participants from 21 countries; (4) developing a highly sensitive mass spectrometry system capable of measuring five mercury isotopes; (5) establishing a method for degradation of nanoplastics particles in the gas phase and detection of cytotoxicity in exposure experiments; (6) confirming some mechanisms by which bisphenol-S (BPS) exposure suppresses pulmonary inflammation in senescence-accelerated mice (SAMP8); (7) conducting behavioral analysis of hypothyroidism model mice; (8) analyzing the pharmacokinetics of phthalates and other compounds in samples collected during interventional studies; and (9) publishing a paper on the impact of environmental changes on natural resource utilization and food intake in developing countries.

In our policy-oriented research, we intend to promote regulatory science research to help protect human health and preserve ecosystems from hazardous chemicals by using the latest scientific findings, including the results of our foresight and advanced basic research and our comprehensive environmental risk research program. We intend to contribute to environmental policy through these results and will promote our efforts as a reference laboratory.

Below are brief accounts of some of the important results of our research in FY 2024.

1. Foresight and Advanced Basic Research

1.1 Development and optimization of a pre-concentrated gaseous mercury (Hg) analytical system by using triple quadrupole ICP-MS

Understanding the redox reactions and transformation rates of mercury (Hg) species in the environment is important for predicting future gaseous elemental Hg (Hg^0) levels and assessing the impacts of anthropogenic Hg emissions on human health. Utilization of a stable Hg isotope tracer is a promising technique to estimate those production rates in the atmospheric and aquatic environments, but it must be measured by mass spectrometry rather than atomic spectrometry, which is widely used for Hg analysis. We therefore developed and evaluated a custom-made thermal desorption unit coupled directly to a triple quadrupole inductively coupled plasma-

mass spectrometer (ICP-QQQ) for the quantification of Hg^0 pre-concentrated on Au traps (Fig. 1). The performance of the developed system was validated by multiple measurements of Hg standard gas and pre-concentrated Hg^0 generated from aqueous Hg standards. The system demonstrated ultra-trace Hg quantification and precise Hg isotope measurements, with analytical errors of less than approximately 3.5%. Superb linearities of the calibration curves in a range of 0 to 300 pg of Hg were obtained (r^2 = >0.999), and the method detection limit was approximately 0.01–0.03 pg of Hg. Moreover, the performance of the Agilent 8900 ICP-QQQ, which has a newly developed desorption unit, was far superior to that of the previous model (the Agilent 8800 ICP-QQQ). Its sensitivity was approximately five times that of the Agilent 8800, and five Hg isotopes could be precisely measured simultaneously in the time-resolved analysis (Fig. 1).

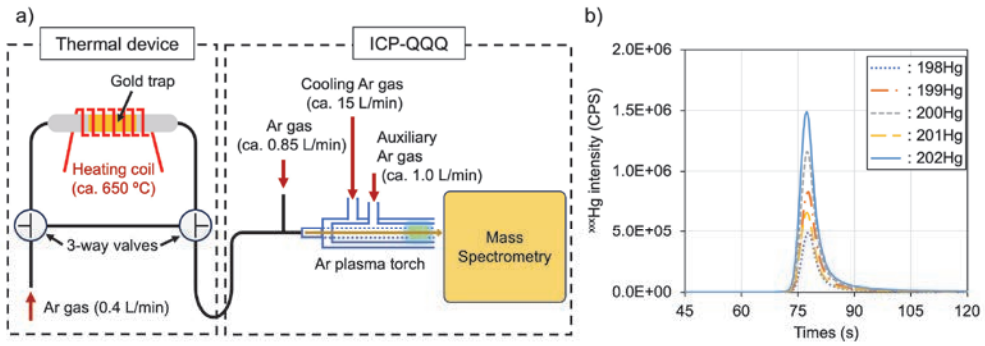


Fig. 1 (a) Schematic illustration of the ICP-QQQ coupled with the thermal desorption unit developed in this study (TD-ICP-QQQ), and (b) time-resolved measurements of Hg isotopes by using TD-ICP-QQQ (modified from Shintani and Takeuchi, 2024)[1)]

1.2 Establishment of toxicity assessment methods and toxicological evaluation of airborne nanoplastics particles

Nanoplastics (NPs), defined as plastic particles smaller than 1000 nm in diameter, have been detected in ambient air, raising concerns about their potential health effects through inhalation exposure (Fujitani et al., 2024)[2)]. Various exposure scenarios are being studied to evaluate the health effects of NPs, with the aim of obtaining fundamental toxicological data, including information on their organ accumulation and toxicity depending on material type and particle size.

In this study, we began with the aerosolization of NPs and developed an online measurement method by using an aerosol mass spectrometer for polystyrene particles to evaluate the exposure dose during toxicity assay or animal inhalation studies. Furthermore, we established a direct exposure method using air–liquid-interface cell exposure systems, allowing for the assessment of airborne NP toxicity. In addition, we evaluated the effects of NPs whose surfaces were modified by the adsorption of atmospheric pollutants. In 2024, we further advanced this work by establishing a method to treat commercial 500-nm polystyrene particles (used as model NPs) with OH radicals, ozone, and UV radiation in a flow-through reactor (Fig. 2). This represents the development of an experimental system that simulates the degradation of NPs during atmospheric transport.

We first examined the physicochemical differences caused by degradation. Each type of particle was collected and observed by using transmission electron microscopy, but no apparent differences in morphology were observed. However, when exposed to an electron beam at an accelerating voltage of 200 kV, undegraded NP particles remained unchanged, whereas degraded NP particles exhibited deformation. Furthermore, comparison of the mass spectra obtained from a mass spectrometer revealed that the degraded NP particles contained a greater abundance of oxygen-containing compounds, whereas the presence of styrene-related molecules such as $C_8H_8^+$ ions was reduced. These results confirmed that degradation led to observable changes in particle characteristics.

We then compared cell viability by collecting airborne NP particles with an electrostatic sampler, suspending them in a culture medium, and exposing the cells to the resulting solution. To ensure accurate exposure assessment, the particle-collection efficiency of the sampler was independently evaluated, and the exposure dose was quantified before we exposed the cells. Approximately 4–7 μg of particles per plate was collected. On the basis of this information, a suspension containing 4 μg mL^{-1} was used for cell exposure. There was virtually no difference in cell viability between exposures to degraded and undegraded NPs. We found that polystyrene particles at this exposure level had no detectable effect.

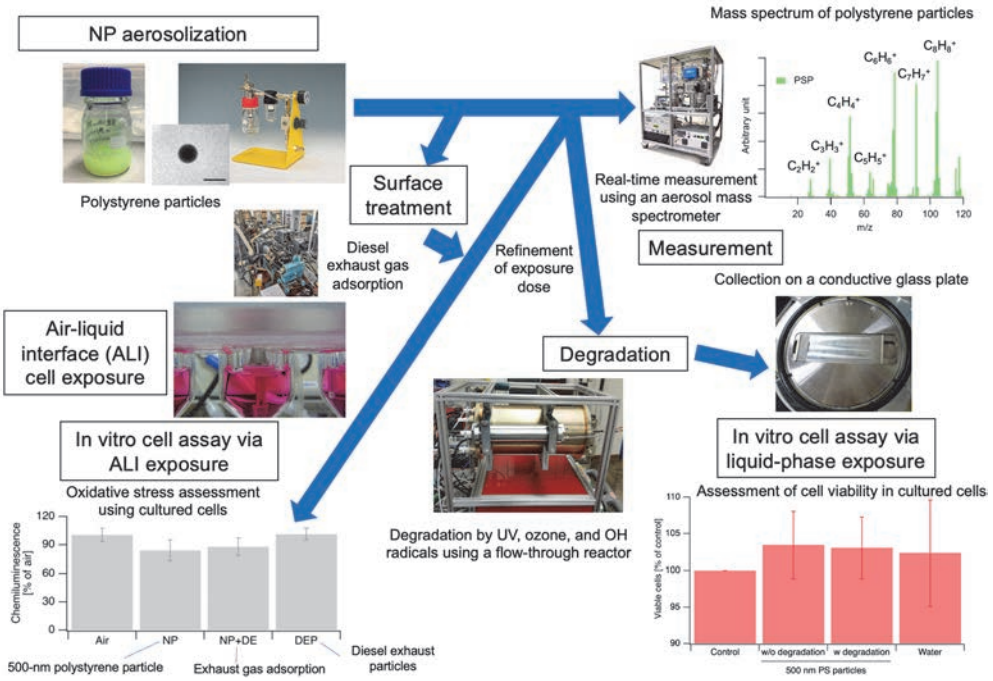


Fig. 2 Framework for nanoplastics toxicity assessment, from exposure method development to toxicological evaluation

1.3 Intervention study of the pharmacokinetics of chemical substances in foods and personal care products

In the estimation of human exposure to chemical substances, two primary methods

are commonly used: (1) calculating the sum of the products of chemical concentrations in various exposure media—such as air, water, soil, and food—and the intake amounts of those media; and (2) estimating exposure levels on the basis of the concentrations of chemicals in biological samples. A challenge with the former method is the lack of data on the usage amounts of personal care products, which makes it difficult to estimate the exposure from such products. With the latter method, a key issue is that pharmacokinetics models have been established for only a limited number of chemicals, making it difficult to estimate exposure from internal concentrations.

To address these challenges, we have developed usage data for products to construct pharmacokinetic models, through the following three studies:

1. An intervention study in which diet and personal care product use were controlled,
2. Research on biomonitoring methods for chemical substances, and
3. Development of survey tools to assess personal care product usage.

In Study 1, we provided 100 participants with personal care products that did not contain the target chemicals and instructed them to use only those products. Additionally, participants were served identical meals which were then analysed for target compounds. This intervention aimed to limit exposure to the target chemicals during the study period and to model the dynamics of internal chemical doses.

In Study 2, a self-blood-collection kit was developed and tested in a pilot survey. A method for the trace and rapid measurement of alcohols in blood was also developed and used to analyze blood alcohol levels in preterm infants for the first time.

In Study 3, a web-based questionnaire was created that showed images of various types of personal care products (foam, liquid, cream) placed on the palm of a hand to estimate the quantities used, and the validity of the tool was evaluated.

We used the outcomes of these studies to analyze samples from the intervention study for additional chemicals (i.e., bisphenols and triclosan), and we examined their pharmacokinetics (Fig. 3). Following the intervention, some participants showed decreased urinary concentrations of bisphenol F and S—substitutes for bisphenol A. However, complete control over bisphenol A exposure could not be achieved. For triclosan and benzophenones (UV filter compounds), the intervention effects were observed only in some participants. These findings suggest the need to provide meals free from these substances and to conduct longer-term interventions. For participants who showed intervention effects, we estimated the pharmacokinetic parameters, including half-lives (Nguyen et al., 2024)[3)].

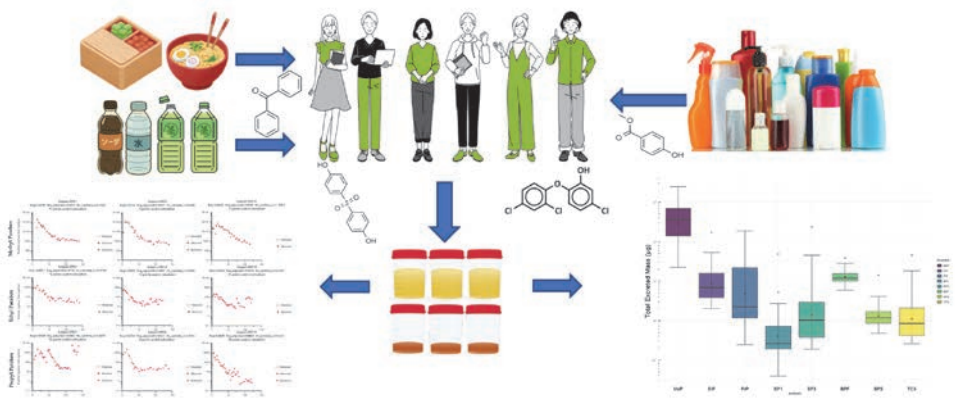


Fig. 3 Intervention study to estimate the pharmacokinetics of chemicals from the diet and personal care product use (created with data from Nguyen et al., 2024)[3)]

References:

1) Shintani T., Takeuchi A. (2024) Development and optimization of a triple quadrupole ICP-MS-based system for the quantification of pre-concentrated gaseous elementary mercury. *Analytical Sciences* 40, 531–540

2) Fujitani Y., Ikegami A., Morikawa K., Kumoi J., Yano T., Watanabe A., Shiono A., Watanabe C., Teramae N., Ichihara G., Ichihara S. (2024) Quantitative assessment of nano-plastic aerosol particles emitted during machining of carbon fiber reinforced plastic. *Journal of Hazardous Materials* 467, 133679

3) Nguyen H.T., Isobe T., Iwai-Shimada M., Takagi M., Ueyama J., Oura K., Tanoue R., Kunisue T., Nakayama S.F. (2024) Urinary concentrations and elimination half-lives of parabens, benzophenones, bisphenol and triclosan in Japanese young adults. *Chemosphere* 349, 140920. doi:10.1016/j.chemosphere.2023.140920

2. Policy-Oriented Research

2.1 Contribution to the "Report from the Survey of Exposure Assessment Models Used in a Regulatory Context" conducted by the OECD

Researchers from the Health and Environmental Risk Division of NIES have continuously participated in Organisation for Economic Co-operation and Development (OECD) Working Parties on chemical risk assessment and management, such as hazard assessment, exposure assessment, and quantitative structure–activity relationships (QSAR), representing Japan in the field of environmental risk issues. Within the Working Party on Exposure Assessment, a project has been conducted to collect information on exposure assessment models used for regulatory purposes by OECD member countries and international organizations and to compile this information into a "Report from the Survey on Exposure Assessment Models Used in a Regulatory Context" (OECD, 2023)[1)]. Researchers from the Environmental Risk and Health Division of NIES, together

with the US Environmental Protection Agency, served as leads for the project, contributing to data analysis and drafting parts of the report.

The survey was designed to provide information on the regulatory use of exposure models, including which regulatory bodies incorporate the models into their regulatory schemes and how the estimation results are used for decision-making and risk communication (OECD, 2023)[1)].

Two examples of analyses conducted for the report are presented here. The first concerns the environmental media targeted by the exposure assessment models (Fig. 4). For general chemicals, multimedia and air were the most common target media. For pesticides, many models focused on water, but a substantial number also addressed other media. Models targeting water are often used to assess biological effects, whereas models for the others frequently address direct exposure of agricultural workers and the general population to pesticides.

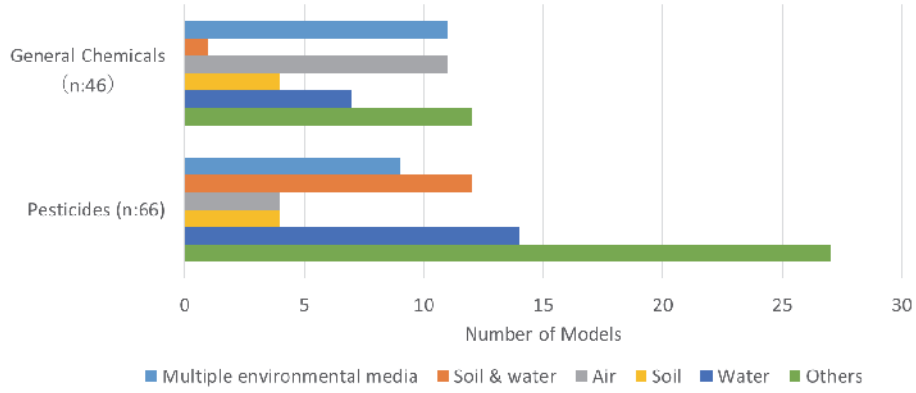


Fig. 4 Environmental media targeted by the exposure assessment models (created from Table 3.5 of OECD, 2023)[1)]

We summarized how the models were applied in regulatory contexts (Fig. 5). Among the models collected in this survey, their regulatory use followed a sequence: screening assessment, higher tier assessment, and assessment for substance registration by manufacturers and importers.

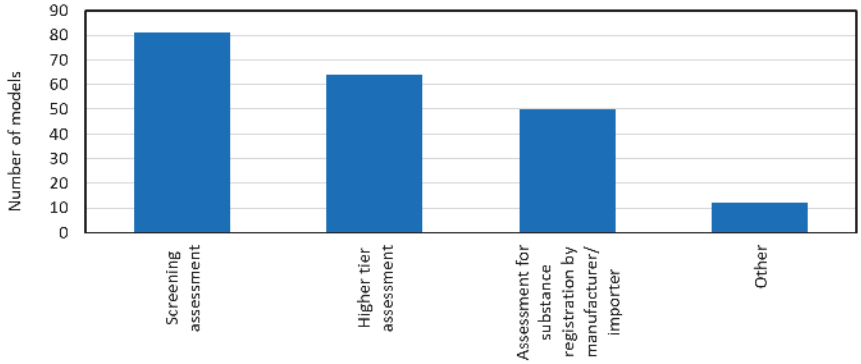


Fig. 5 Distribution of models by regulatory use (OECD, 2023)[1)]

2.2 Proposal and validation of international standard ecotoxicity test methods in the OECD

In preparation for the adoption of a revised version of the OECD Test Guideline

(TG) No. 201 (Algal Growth Inhibition Test), which is being led by NIES, we have compiled the results of international ring tests, prepared a final validation report, and prepared a revised guideline. In addition, since 2016, we have validated the Juvenile Hormone Activity Screening Assay (JHASA), which uses the production of juvenile hormone active substances in male *Daphnia magna* in 21 days as a detection method that simplifies Annex 7 of the existing confirmatory test, OECD TG211 (Daphnia Reproduction Toxicity Test). In response to comments made by experts from OECD member countries, we tested the impacts of environmental factors other than chemical substances (e.g., temperature, density, and photoperiod) (Watanabe et al., 2024)[2]. Validation using standard substances has also been completed by the use of interlaboratory ring tests in collaboration with domestic and international institutions. JHASA was adopted at the OECD meeting in April 2024 as the world's first test for detecting substances with endocrine disrupting effects by using invertebrates, and it was published in July as OECD TG253 (Fig. 6).

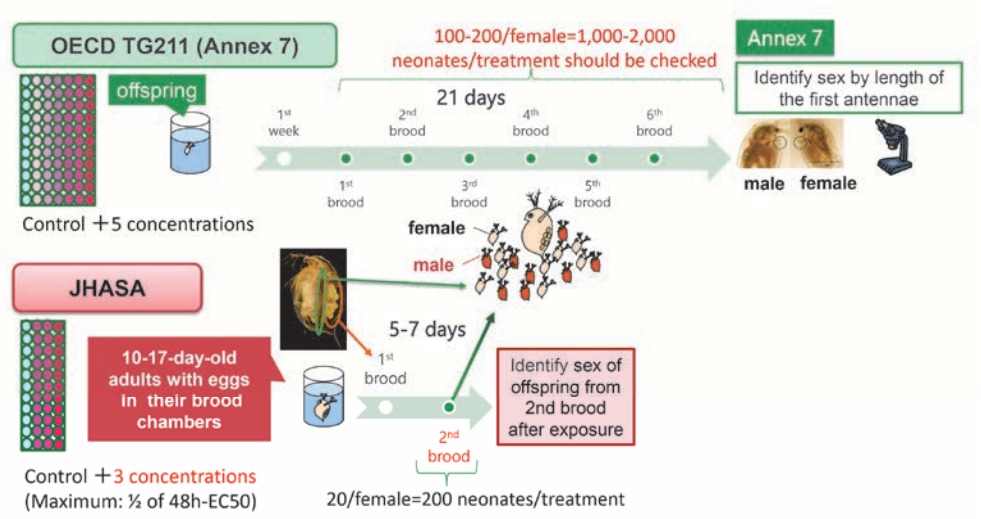


Fig. 6 Comparison of the existing juvenile hormone activity confirmation test using *Daphnia magna* (top: OECD TG211 Annex 7) with the juvenile hormone activity detection test (bottom: OECD TG253, JHASA)

References:

1) OECD (2023) *Report from the Survey of Exposure Assessment Models Used in a Regulatory Context, Series on Testing and Assessment No. 389*, ENV/CBC/MONO 38.

2) Watanabe H., Abe R., Tatarazako N., Yamamoto H. (2024) Non-chemical stresses do not strongly induce male offspring in *Daphnia magna* ascertained using the short-term juvenile hormone activity screening assay. *Journal of Applied Toxicology* 44, 1914–1923

Regional Environment Conservation Domain

Human activities have a substantial impact on both human life and ecosystems through environmental media such as the atmosphere, water, and soil. To minimize the environmental impacts of human activities, the Regional Environment Conservation Division has been studying the dynamics and effects of substances in each medium; developing new measurement and analysis methods; and investigating environmental restoration, regeneration, and conservation technologies at various spatial scales, from cities to Asia-wide. Furthermore, in cooperation with Japanese local environmental research institutes, we are promoting research on environmental management technologies suitable for each region. Our aim is to achieve comprehensive regional environment conservation.

This Division consists of six sections (Regional Atmospheric Modeling, Regional Atmosphere Research, Lake and River, Marine Environment, Soil Environment, and Environmental Management and Technology) and has one Principal Researcher.

In FY 2024, we implemented many research projects covering a wide range of regional environmental issues. Most of the projects are collaborations with other NIES divisions. Our main research projects in **Foresight and Advanced Basic Research** were as follows:

- Impacts of climate change and load reduction on hypoxia in Tokyo Bay and Ise–Mikawa Bay
- Understanding the drivers of land subsidence in semi-arid regions: A time-series SBAS-InSAR analysis at the Oyu Tolgoi Mine, Mongolia.

We have also developed an air-pollution-simulation support system and measured oxygen consumption in the bottom layer of Lake Biwa as part of **Policy-Oriented Research**. Additionally, there are two long-term monitoring programs as part of **Intellectual Research Infrastructure Development**, namely the Regional Atmospheric Monitoring Program, which monitors the air quality in East Asia at Okinawa and Nagasaki, and the Global Environment Monitoring System (GEMS)/Water Program in Lake Kasumigaura, which is a collaboration with the Biodiversity Division. In the following section, we briefly describe some of our important results in FY 2024.

1 Foresight and Advanced Basic Research

1.1 Impacts of climate change and load reduction on hypoxia in Tokyo Bay and Ise-Mikawa Bay

To clarify the climate change impacts on the effect of nutrient management in semi-closed sea areas, numerical experiments in Tokyo Bay and Ise-Mikawa Bay were conducted by using the integrated river basin – coastal ocean hydro-environment

assessment model under the climate conditions of the present (the end of the 20th century) and the future (the end of the 21st century) Representative Concentration Pathway (RCP) scenarios. The simulations projected that, under RCP 8.5 (the high emission scenario), sea surface temperature would be 3–4 °C warmer than in the present climate. As a result, primary production of phytoplankton would decrease during summer and autumn owing to elevated temperatures. The decline in primary production would be most pronounced in Tokyo Bay, followed by Ise Bay and Mikawa Bay, corresponding to the relatively high water temperatures in these bays. Bottom-layer dissolved oxygen (DO) was influenced by both a decrease, resulting from enhanced stratification and reduced oxygen solubility associated with rising water temperatures, and an increase, resulting from the decline in primary production. Although the volume of hypoxic water tended to increase in Tokyo Bay and Ise Bay, it showed a decreasing trend in Mikawa Bay, where the decline in primary productivity was particularly pronounced (Fig. 1). The effects of load reduction under the future climate under RCP 8.5 were evaluated for Tokyo Bay and Ise Bay, where the volumes of hypoxic water were predicted to increase. Hypoxic water masses with DO < 3 mg/L in Tokyo Bay could be suppressed to a scale similar to those in the present climate by reducing domestic wastewater loads by approximately 10%–20%. However, for hypoxic water masses with DO < 4 mg/L, there would be extensive areas in both Tokyo Bay and Ise Bay where suppression through load reduction alone would be difficult.

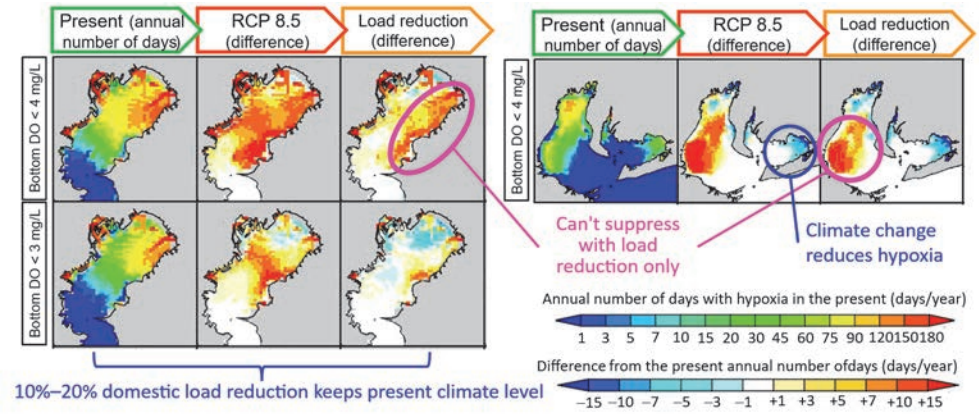


Fig. 1 Effects of climate change and load reduction on annual number of days with hypoxia in Tokyo Bay and Ise-Mikawa Bay (Higashi et al., 2024)

Reference:

Higashi H., Koshikawa H. (2024) Climate change impact on hypoxia and nutrient management in Tokyo Bay and Ise–Mikawa Bay. *Japanese Journal of JSCE*, 80 (16) (in Japanese with English abstract). doi.org/10.2208/jscejj.23-16137

1.2 Understanding the drivers of land subsidence in semi-arid regions: A time-series SBAS-InSAR analysis at the Oyu Tolgoi Mine, Mongolia

Mongolia's vast mineral resources have fueled rapid economic growth, with the Oyu Tolgoi (OT) copper and gold mine serving as a key driver. However, continued large-scale mining activities in this arid region have raised serious environmental

concerns, particularly about land subsidence, which poses risks to operational safety and may trigger geological hazards. This study investigates land subsidence at OT by using the small baseline subset interferometric synthetic aperture radar (SBAS-InSAR) technique, which enables the precise detection of ground deformation by analyzing phase differences in satellite-acquired synthetic aperture radar (SAR) images. A total of 120 Sentinel-1A satellite scenes from 2018 to 2022 were used to generate a time-series analysis of surface displacement.

The results revealed a maximum cumulative subsidence of −742.01 mm and a peak annual rate of −158.11 mm/year. The most severe subsidence occurred near active mining infrastructure and groundwater extraction points (Fig. 2). Three primary drivers were identified: (1) substantial groundwater depletion—up to 46 m in some wells—leading to soil compaction; (2) continuous mineral excavation disturbing subsurface stress conditions; and (3) shifting surface loads and geomechanically stress. The reliability of the SBAS-InSAR analysis was validated through cross-comparison with persistent scattered InSAR (PS-InSAR) results.

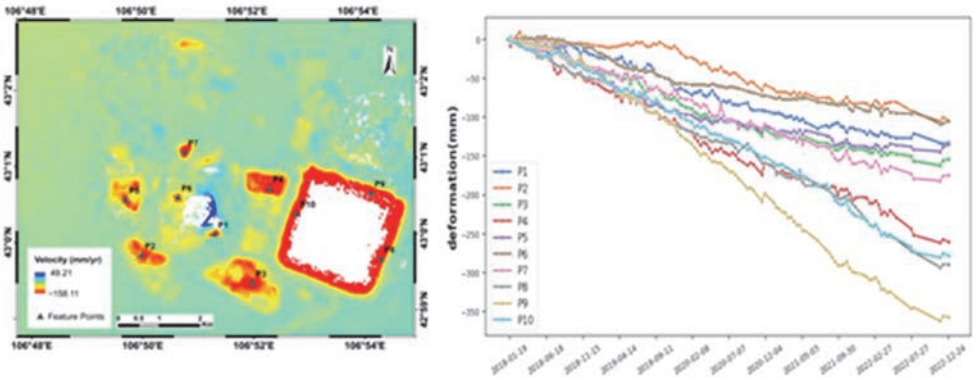


Fig. 2 Annual average surface deformation rate (units: mm/year) and time-series subsidence at points P1 to P10, which represent 10 characteristic subsidence locations selected for detailed time-series analysis (Xie et al., 2024)

This study highlights the pressing need for integrated monitoring of geotechnical risks and groundwater use in mining regions. The findings provide scientific evidence to support safer mining practices and more sustainable groundwater management. Additionally, the SBAS-InSAR framework demonstrated here offers a transferable tool for monitoring land deformation in other resource-extraction regions facing similar subsidence risks.

Reference:

Xie Y., Bagan H., Tan L., Te T., Damdinsuren A., Wang Q. (2024) Time-Series Analysis of Mining-Induced Subsidence in the Arid Region of Mongolia Based on SBAS-InSAR. *Remote Sensing* 2024(16), 2166. https://doi.org/10.3390/rs16122166

2 Policy-Oriented Research

2.1 Transmission of information and support for numerical simulations to local governments related to air pollution forecasting

The Air Pollution Forecast System VENUS is a system that has been under development by NIES and has received budgetary support from the Ministry of the Environment under contract since FY2014. In addition, the Air Pollution Simulation Support System, which was developed from FY 2019 to FY 2021 under Environment Research and Technology Development Fund 5-1903, is a tool that makes it easier to conduct numerical simulations and provides the emissions data necessary for simulations by region, industry, and substance. It can automatically generate the emissions data required for simulations, and it can set increases and decreases by region, industry, and substance.

This research was conducted with two main objectives: to update and maintain the Support System of the latest version of the numerical model, including conducting training sessions and providing support for users, and to develop and maintain a system to disseminate and process the additional information that is important for local air pollution managers to make administrative decisions. In addition, the project was conducted in collaboration with the research subgroups of Type II Joint Research on air pollution with other regional environmental research institutes.

In FY 2024, we improved and updated the Support System developed under the Environment Research and Technology Development Fund 5-1903, and we held three workshops on its use, which were attended by many participants. Questionnaires were sent to the participants to collect their requests for the Support System, workshops, and VENUS. Furthermore, in cooperation with the Administrative Support Study Group (a research subgroup of Type II Joint Research), we studied information that is considered important for local air pollution managers to make administrative decisions and developed a prediction method for spatial concentration distribution (the “Regression Kriging” (RK) method) for the purpose of relocating measuring stations and reviewing areas to issue air pollution warnings. We developed analysis scripts (RKscripts) for the RK method and a support tool (RKsupport) that semi-automates the generation of input data required for the analysis. In addition, we developed a method for estimating the spatial concentration distribution of air pollutants by using the RK method on the basis of observed data. We provided these tools to personnel at regional environmental research institutes and conducted training sessions on the RK method using the tools. This made it possible to use the RK method to study the effects of increasing or decreasing the number of measuring stations or changing the location of measuring stations from the perspective of optimal station placement, and it enabled local governments to conduct rational studies on the relocation of measuring stations.

In addition, analysis and administrative proposals were promoted by the staff of local environmental research institutes on the basis of the methods and findings of various analyses centered on the RK method. These efforts are expected to make it possible for local governments to conduct numerical simulations similar to those of VENUS on their own. In addition, through the development of tools related to the RK method, it will be possible to study the spatial distribution of air pollutants and other substances by using both numerical simulations and observation data, and to consider the optimal placement of observation stations (Fig. 3).

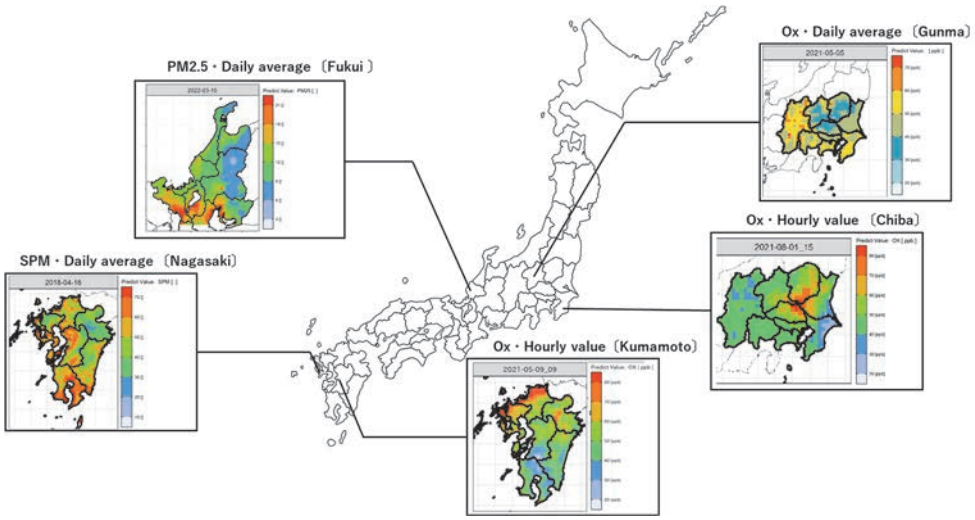


Fig. 3 Spatial distributions of air pollutant concentrations in each area, as determined by using the RK method. The pollutant name, the variable, and the name of the prefecture that conduct analysis are shown on each concentration map.

Biodiversity Domain

We intend to conduct surveys and research on the structure, functions, and relationships of ecosystems, which consist of diverse organisms on the Earth and their surrounding environment, and on the benefits that humans receive from ecosystems. We will also clarify and evaluate the impacts and risks that human activities impose on biodiversity and ecosystems at various spatial and temporal scales.

In our **Foresight and Advanced Basic Research**, we conducted a survey on the impact of policies on consumer behavior. A nationwide survey in Japan found that younger males who consumed Japanese eels (*Unagi*) were the most likely to be prone to illegal consumption. Promoting marine conger eel (*Anago*) as a substitute, as well as targeted education, can support sustainable conservation. As part of our **Policy-Oriented Research**, we developed a model to calculate the probability of mongoose extinction on Amami Island. The result of our calculation was used as the basis for the Ministry of the Environment's declaration of mongoose eradication on the island. As part of our **Intellectual Research Infrastructure Development**, we developed a layered gel aseptic method to efficiently obtain bacteria-free microalgal strains at the Microbial Culture Collection at NIES, producing 21 axenic strains and supporting research on harmful algal blooms and microalgae-based carbon capture, storage and utilization.

1 Foresight and Advanced Basic Research

Japanese eel (*unagi*; *Anguilla japonica*) is an important part of Japanese cuisine and culture. However, there is substantial evidence that global eel populations have declined dramatically. To ensure the sustainable use of fishery resources, many countries and international organizations have implemented management measures for eel conservation, such as including eels in CITES listings. In Japan, several prefectures have issued regulations to control eel harvesting. However, if eel populations continue to decline, the government may need to implement stricter management strategies, including restrictions on eel consumption. To assess the potential impact of future regulations, we conducted a nationwide questionnaire survey in Japan to identify individuals who may be prone to illegal purchasing behavior and to explore possible alternatives to Japanese eel consumption. Our results suggest that younger males who consume eel at least once a year are more likely to engage in illegal behavior. As alternative options to eel consumption, the marine whitespotted conger eel (*anago*; *Conger myriaster*) emerged as the most preferred substitute (Fig. 1). On the basis of these findings, we recommended that the government enhance public education efforts targeting potential illegal groups before introducing related regulations. Additionally, evaluating the sustainability and development of alternative food industries will be crucial.

Reference:

Mameno, K., Hsu, C.H., Tsuge, T., Onuma, A., Kubo, T. (2024). Who is likely to have illegal eel products after the market regulations? A best-worst scaling approach. *Marine Policy* 169, 106373

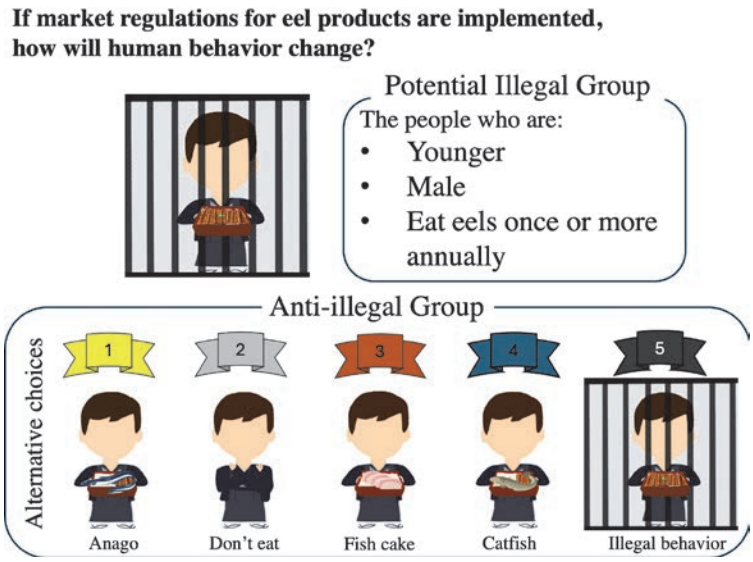


Fig. 1 Graphical abstract of an eel regulation evaluation article (Mameno et al., 2024)

2 Policy-Oriented Research

Evaluating the eradication success of the small Indian mongoose

In the long-term eradication of an invasive species, conservation practitioners are faced with the decision of when to declare that eradication has been achieved and that the eradication campaign has finished. Integrating various data obtained during the eradication process to quantitatively demonstrate the certainty of eradication will provide strong support for this challenging decision-making process.

In the case of the control of the small Indian mongoose (*Urva auropunctata*) on Amami Island, despite the capture count reaching zero in FY 2018, capture and search efforts continued at the same level as before until FY 2023. By integrating parameters obtained to date on the status and life history of mongooses, two eradication probability calculation models were developed to clarify the eradication probability of this species: an area-based eradication probability calculation HBM (harvest-based model) and an individual-based eradication probability calculation REA (rapid eradication assessment) (Fig. 2). The results of REA were utilized as one of the bases for the Ministry of the Environment's declaration of eradication of the small Indian mongoose on Amami Island.

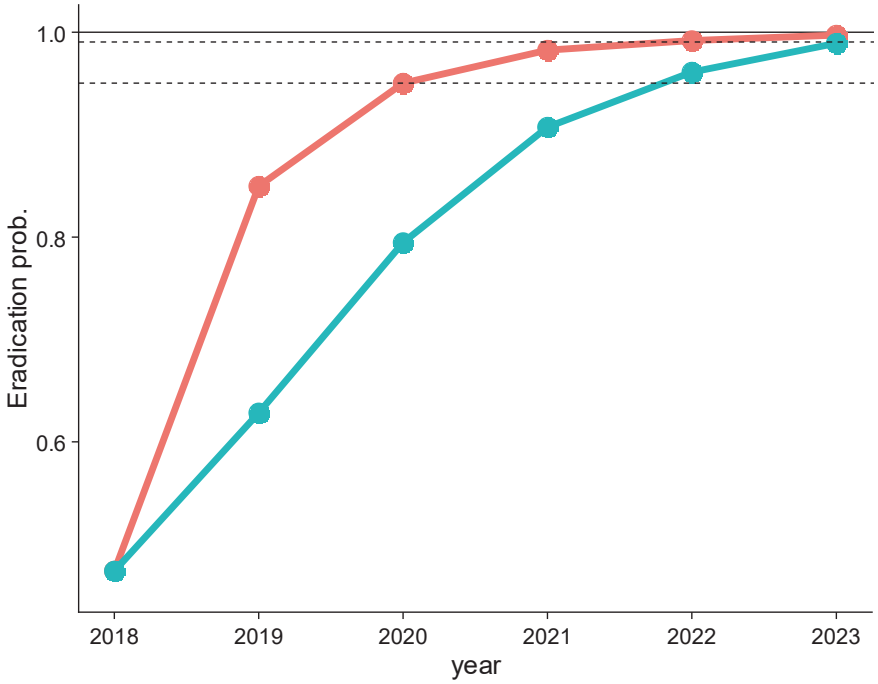


Fig. 2 Eradication probability of the small Indian mongoose on Amami Island, as calculated by using two methods: HBM (blue) and REA (red)

3 Intellectual Research Infrastructure Development

Since 1983, we have been running a microbial culture collection under the Microbial Culture Collection at NIES (MCC-NIES). We are committed to the collection, preservation, and global distribution of diverse microbial strains to advance scientific research. We are also engaged in the *ex-situ* conservation of endangered species of freshwater macrophytes. One of the major challenges in the sustainable preservation of microalgal strains is maintaining cultures free from contamination. Most microalgal strains are not axenic and are often contaminated with bacteria that can affect the preservation of algae. For researchers using MCC-NIES strains, a bacteria-free culture is also desirable because the coexisting bacteria can affect the reproducibility of experiments. Since the establishment of MCC-NIES, ongoing efforts have been dedicated to the sterilization of microalgal strains. However, even with the specialized techniques of experts, this remains a difficult task. To improve the efficiency of sterilization of microalgal strains, we have developed a new method called the layered gel aseptic (LGA) method. By passing cells through a special gel polymer, algae cells can be quickly and efficiently obtained as pure cultures (Fig. 3). Applying this method to our strains resulted in the successful production of over 21 axenic strains, including some previously considered difficult to sterilize. We expect that this method will contribute not only to improvement of the quality of our microalgae strains, but also to the advancement of environmental research related to microalgae, such as studies of harmful algal blooms and microalgae-based carbon capture, storage, and utilization.

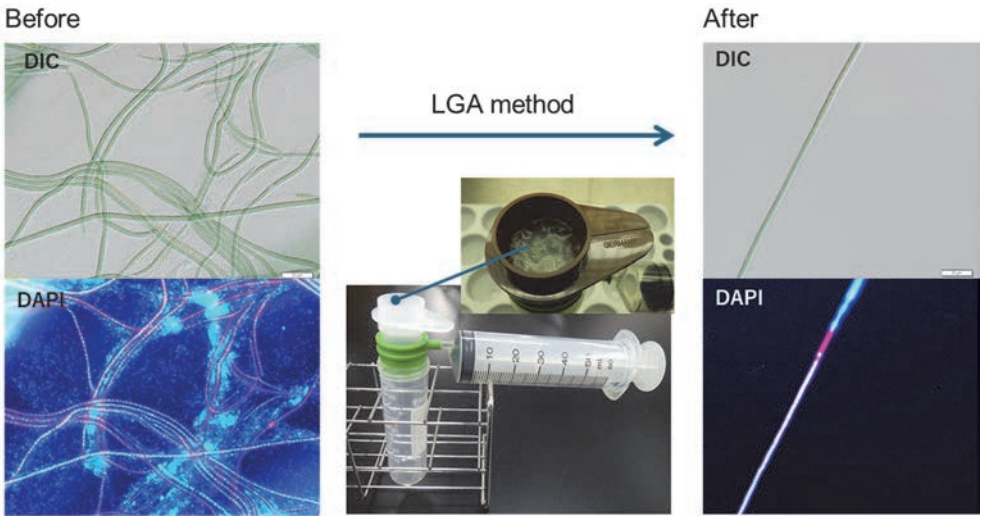


Fig. 3 Application of layered gel aseptic (LGA) methods to the filamentous cyanobacterium *Oscillatoria laetevirens* NIES-31. The original culture contains numerous bacterial contaminants, which are indicated in blue signals in the DAPI image. The LGA method successfully eliminated this bacterial contamination, as evidenced by the absence of blue signals in the DAPI image after LGA treatment. (DIC, differential interference contrast image.)

Social Systems Domain

The Social Systems Domain addresses the challenges of social systems to achieve the future vision that human socioeconomic activities—the root cause of our environmental problems—will be sustainable for both the environment and human society. We are conducting research to support the transition to sustainable social systems, including developing theories and methodologies such as those related to mathematical models. We are also performing social surveys that take an integrated approach to examining the relationship between socioeconomic human activities and various environmental issues. Moreover, we are developing scenarios and roadmaps to achieve a vision for a sustainable society that harmonizes the environment and the economy, and we are proposing specific measures and policies in collaboration with stakeholders.

The Social Systems Domain consists of the following five research sections:
Global Sustainability Integrated Assessment Section: Develops integrated models to assess various comprehensive issues on a global scale to achieve global sustainability for society and the environment.
Decarbonization Measures Assessment Section: Develops models and databases for assessing decarbonization initiatives to tackle climate change problems.
System Innovation Section: Studies the sustainable use of energy and resources, including the development of measures to substantially improve their utilization efficiencies.
Regional Planning Section: Studies lifestyle and regional planning to balance the environment and quality of life in urban and rural communities.
Economics and Policy Studies Section: Performs environmental policy assessments and theoretical research on environmental evaluation and methodological developments in the field of economics.

Researchers in the Social Systems Domain are engaged mainly in the Decarbonized and Sustainable Society Research Program and the Co-design Approach for Local Sustainability Research Program.

1 Foresight and Advanced Basic Research

In FY 2024, the Social Systems Domain set the following research areas as **Foresight and Advanced Basic Research:** (1) research for development and application of the integrated assessment model, (2) research for environmental planning support, and (3) research for economic analysis and environmental policy support.

1.1 Research for development and application of the integrated assessment model

(1) Study of changes in electricity prices considering demand flexibility

In a future decarbonized society, hydrogen will play a key role as an energy source in end-use sectors, such as the industrial sector and transportation sector. As hydrogen production leads to increased electricity demand, the price of electricity will rise. Here, we analyzed the impacts of additional electricity demand resulting from hydrogen production in 2050 on electricity prices in Japan by using the Asia-Pacific Integrated Model / Multi-regional Optimal Generation Planning Model (AIM/MOGPM), which can analyze hourly plant operation, as well as capacity and grid planning by region (e.g., Hokkaido, Tohoku, Tokyo). The study set two cases for analysis: (1) a fixed schedule case and (2) a flexible schedule case. In the fixed schedule case, the hourly production levels of hydrogen by region are given. In contrast, the flexible schedule case assumes that the annual amount of hydrogen production is given, but the hourly hydrogen production will be determined in the optimization process of the model, under the condition that the capacity factor of the hydrogen production plant is maintained at greater than 60%. The results show that the hourly electricity price in the flexible schedule case will decrease compared with the price in the fixed schedule case. For example, in the Hokkaido area (Fig. 1), the maximum electricity price in the fixed schedule case reaches 26.5 JPY/kWh and the annual demand-weighted average electricity price will be 22.0 JPY/kWh. In the flexible schedule case, the maximum hourly electricity price falls to 21.0 JPY/kWh and the average price falls to 18.8 JPY/kWh. Although these prices are higher than the reference price in 2015, flexible hydrogen production will suppress the increase in electricity prices.

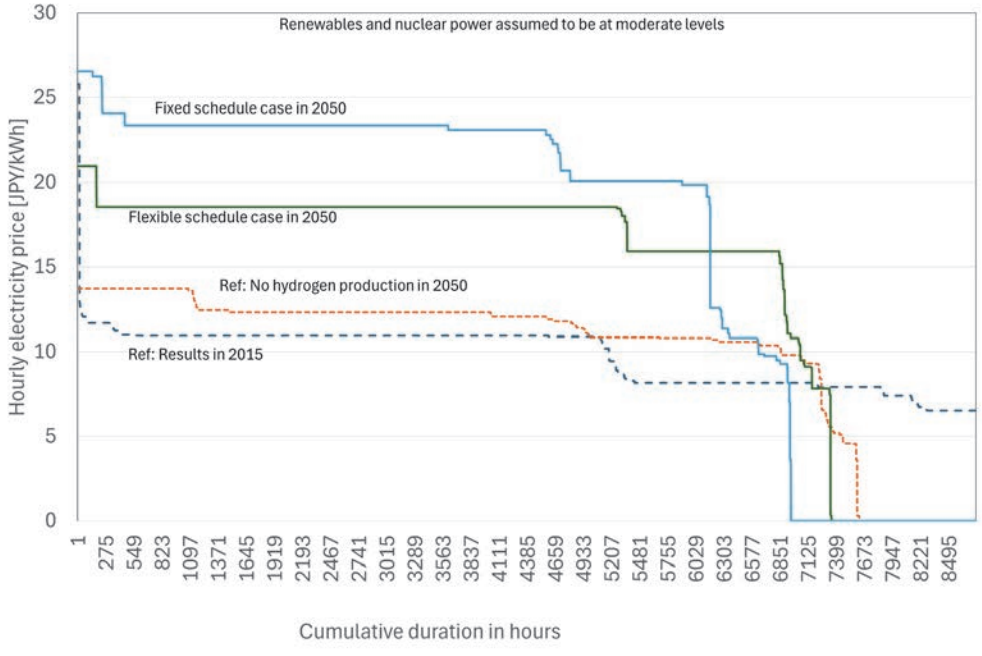


Fig. 1 Electricity prices in the Hokkaido area in 2050, sorted by descending order

(2) Analysis of the impact of pets on household energy consumption

The transition to a decarbonized society will require lifestyle changes. In this research, we analyzed the impacts of pet ownership on household energy consumption by using statistical results from the "Survey on the Actual Conditions of Carbon Dioxide Emissions from the Residential Sector" of the Ministry of the Environment, Japan. A multiple regression analysis was conducted, with summer and winter electricity consumption as explanatory variables, and number of households, household income, floor space and type of houses, and pet ownership and air-conditioning (cooling and heating) services for pets as response variables. The regression model was constructed for 10 regions, including Hokkaido, Tohoku, and Kanto. The results showed that, on average, households that provided cooling services to pets would consume 0.23 GJ/household more electricity than households with pets but no cooling. This additional electricity consumption is almost equal to 17% of the national average monthly electricity consumption during cooling periods: 9% in the Hokkaido area and 17% to 19% in the other nine areas. In terms of heating periods, electricity consumption would be 0.31 GJ/household greater in households with heating services for pets than in households with pets but no heating; this corresponds to 17% of the average monthly electricity consumption during heating periods. However, unlike the case in the cooling period, the changes in electricity consumption during heating periods would differ largely by region: there would be a 16% increase in the Kyushu area, but a 26% increase in the Chugoku area—about 1.6 times that in Kyushu.

1.2 Research for environmental planning support

(1) Estimation of CO_2 emissions from passenger cars by municipality in Japan

To reflect regional characteristics in the creation of carbon neutral and livable communities, we have continued to estimate and improve carbon dioxide (CO_2) emissions data for the residential and transportation passenger sectors by municipality throughout Japan.

Vehicle inspection certificate data were used to estimate the number of light passenger cars and passenger cars owned, the amount of driving, and CO_2 emissions by municipality throughout the country. The per capita CO_2 emissions are high in Ibaraki/Fukushima, the eastern part of Hokkaido, and southern Nara, as well as in inland areas throughout Japan. They are low in Sapporo, Atami, Nagoya, Otsu/Kusatsu, Hiroshima, Matsuyama, Fukuoka, and Nagasaki, as well as in the Kanto region, Keihanshin, Nara, and island areas (Fig. 2).

Decarbonization measures were examined according to regional characteristics, and we found that conversion to small, lightweight electric vehicles is more likely to take place in regions with a high percentage of light passenger car use and short driving distances. The estimated data were published in the NIES repository,

available at https://doi.org/10.34462/0002000048.

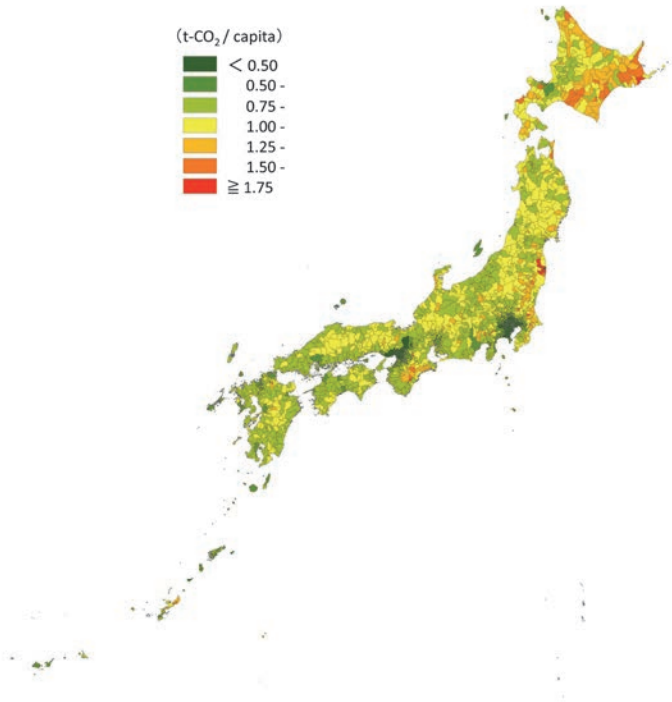


Fig. 2 Per capita CO_2 emissions from light passenger cars and passenger cars by municipality in Japan

(2) Clothing color effect as a target of the smallest-scale climate change adaptation

In previous research, we observed the surface temperatures of polo shirts of the same material and design but different colors. The shirts were placed in unshaded and well-ventilated outdoor open spaces on sunny summer days. The maximum difference between dark green or black and white shirts was more than 15 °C during calm, sunny weather and was greatest when the solar radiation was strong. If the transmission of solar radiation energy through a shirt were ignored in the calculation of the absorption by the shirt, the absorption of solar radiation accounted for 24% of the temperature difference among colors. If the transmission was considered, we concluded that an absorption difference of 34% led to a temperature difference of 15 ℃ (Fig. 3). When we compared the brightness of the colors, we found that the albedo of both the visible and near-infrared (NIR) bands explained why the red and green colors were so different from each other with respect to the surface temperatures we observed. The reflection in the NIR bands was also an important determinant of the surface temperature.

In FY 2024, we made observations of the influence of wind speed on color effects on the rooftop of the NIES campus building, which has no shade. We used a white and a black urethane mask for the observations. We attached them to an electric fan and positioned them so that wind at the same speed hit them from behind (Fig. 4). After confirming that there was no temperature difference between the two colors

indoors, we took the masks outside, where we found a temperature difference between them. During the experiment, the solar radiation intensity was extremely stable, and the reason for the temperature difference could be explained by wind speed alone. Although the temperature depended on the material and structure of the surface of the mask, the temperature difference between white and black was almost eliminated at a wind speed of 3 m/s in this experiment.

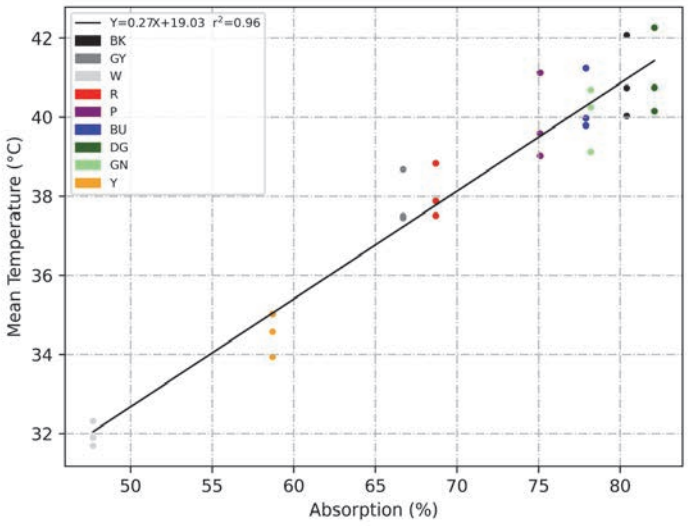


Fig. 3 Relationships between percentage absorption and mean temperature in a rectangle superimposed on the chest area of the mannequin's shirt. BK: black; GY: gray; W: white; R: red; P: purple; BU: blue; DG: dark green; GN: green; Y: yellow

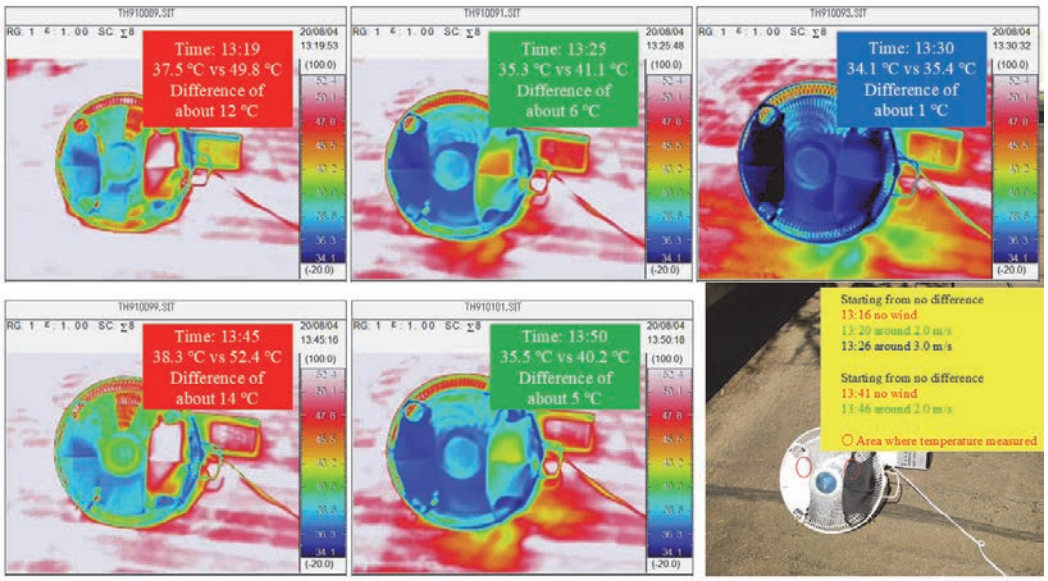


Fig. 4 Influence of wind speed on color effects

1.3 Research for economic analysis and environmental policy support

(1) Environmental awareness survey to determine the relationship between the awareness of the seriousness of climate change impacts and knowledge/political ideology

The results of an online questionnaire survey of Japanese citizens' perceptions of

climate change revealed that the more right-wing the ideological attitude, the more likely respondents were to perceive the effects of climate change less severely and be skeptical of anthropogenic causes (Fig. 5). Greater knowledge of climate change (measured by a quiz score) indicated a tendency to perceive the effects of climate change more seriously, irrespective of ideology (Fig. 5, left). On the other hand, greater subjective knowledge (measured by self-reporting) of climate change was associated with a tendency to view the impacts as more severe by the left-wing group and less severe by the right-wing group (Fig. 5, right). In addition, each group of respondents that agreed with statements about "climate change denial" and "skepticism about anthropogenic causes" had distinctive patterns of association with various factors, including the degree of knowledge and socioeconomic variables. These results suggest that it is important to respond to the values and political views of information recipients when communicating about climate change.

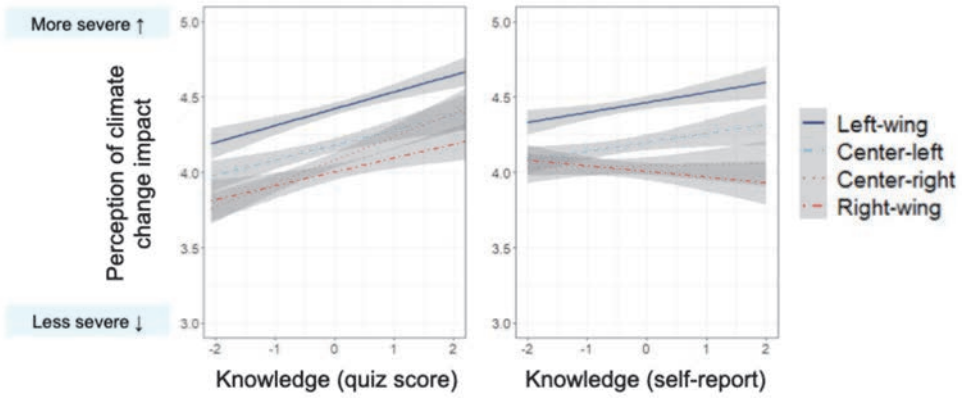


Fig. 5 Associations of climate change impact perceptions and knowledge, as measured by quiz score (left) or self-report (right), according to the respondent's ideological stance

(2) Examination of the history and future of IPCC Special Reports focusing on the dual role of politicization and normalization

In FY 2024, we critically examined the role of the Intergovernmental Panel on Climate Change (IPCC) through the preparation of Special Reports from three perspectives: their history, function, and future. Because Special Reports focus on timely and policy-relevant themes, they have been found to play a dual role in the relationship between science and policy: politicization and normalization. In addition to the fact that IPCC scientific assessments themselves are the subject of political controversy (politicization), Special Reports have the dual function of normalizing politically controversial issues and providing policy justification through IPCC scientific assessments. This dual function is an inherent institutional feature of the IPCC and implies an inherent tension behind the principle of policy neutrality that the IPCC upholds. Given their history and functions, the future status of the Special Reports in IPCC assessments will require a reconsideration of their roles in three areas: their priority relative to the assessment reports of each IPCC Working Group, their response to the political needs of the United Nations Framework Convention on Climate Change, and the selection and definition of the themes they will address.

2 Policy-Oriented Research

2.1 Capacity development for realization of a sustainable society in Asia

In collaboration with the Institute for Global Environmental Strategies (IGES) and Ministry of the Environment, Government of Japan, the AIM and LoCARNet Peer-to-Peer Meeting for Sharing Experience and Lessons was held at NIES in August 2024. The main participants were policymakers in Asia and researchers in each country who use AIM, and the main purposes of this meeting were to provide the information needed to properly apply models to climate policy and to foster collaboration among Asian countries using AIM. Policy dialogue meetings were also held in some countries, such as Bangladesh. NIES researchers also attended the AIM meeting to support their greenhouse gas mitigation policies and actions.

A training workshop on AIM/MOGPM was conducted in May 2024. At the workshop, participants from Thailand, China, and Taiwan learned the model structure and data preparation methods. In addition, training sessions on ExSS (Extended SnapShot tool) for policymakers in developing countries were conducted in July 2024, and January and February 2025 at the request of the Japan International Cooperation Agency.

The 30th AIM International Workshop (Fig. 6) was held at NIES on 28 and 29 August 2024 as a hybrid face-to-face/online meeting, with more than 120 participants discussing the status of AIM development and policy contributions in Asian countries. Recent AIM activities to support climate mitigation policies in Japan and global-scale analyses, and their results, were shared with the participants.

Fig. 6 Group photo at the 30th AIM International Workshop at NIES

3 Intellectual Research Infrastructure Development

3.1 Development and open sourcing of a sensor module to record people's ambient conditions and activities

Various factors need to be considered in the assessment of scenarios for global

decarbonization and a sustainable society. For example, we need to understand the effects of climate change on human behavior and health in different regions and climate zones of the world. For this purpose, we are developing a sensor module to record exposure to the thermal environment and behavior in daily life for use in modeling studies. The sensor module developed in this study (Fig. 7), including hardware design information, will be open source to enable researchers around the world to procure and use equivalent sensor modules at low cost.

The sensor module is capable of measuring temperature, humidity, air pressure, three-axis accelerations, and illuminance. It is small enough to be used as a wearable device, and most manufacturers are able to produce it easily.

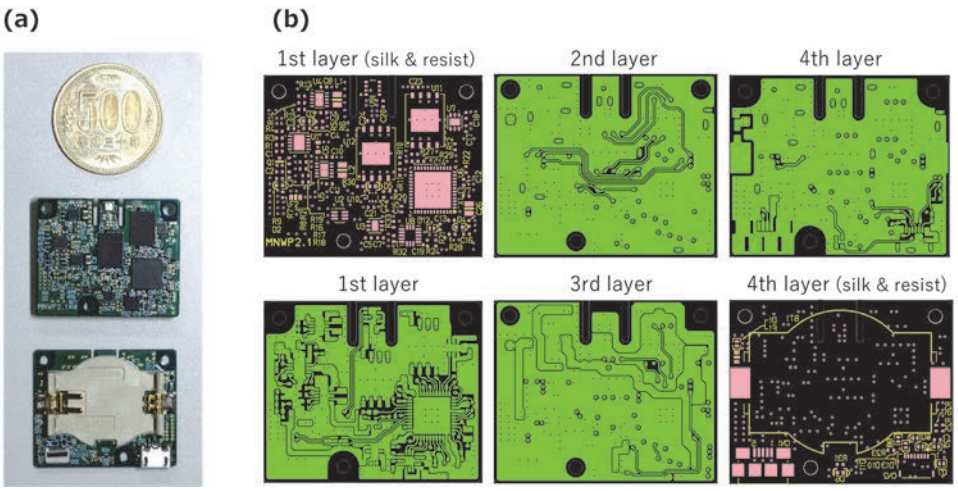


Fig. 7 The sensor module that we developed. (a) appearance, (b) module design information, which will be open source

Environmental Emergency and Resilience Research Domain

Much empirical knowledge has been obtained from large-scale disasters such as the Great East Japan Earthquake, including the accident at TEPCO's Fukushima Daiichi Nuclear Power Plant (FDNPP). We intend to use the knowledge gained from studying environmental emergencies and resilience to promote research and surveys. This will help us to understand and evaluate the medium- and long-term environmental impacts in disaster areas. We will also conduct practical research for post-disaster environmental reconstruction in collaboration with the local community, as well as other research that will build strong and sustainable communities in preparation for future large-scale disasters. Specifically, in continuing on from NIES's Fourth Five-Year Plan, we aim to solve technical issues such as disaster waste disposal and establish a technical support framework to further improve disaster environmental management capabilities. Similarly, we will further investigate and gain an understanding of the process of environmental recovery from nuclear disasters, and we will conduct strategic monitoring research that will resolve the issues that have become obstacles to revitalization. As a new initiative of the Fifth Five-Year Plan, we intend to establish a comprehensive environmental management approach to prepare for future nuclear disasters from certain environmental perspectives. Similarly, we aim to support local governments in Fukushima Prefecture in formulating environmental policies. Furthermore, we will build a system to promote regional cooperation and thus foster environmental revitalization and sustainable regional development in Fukushima.

1 Foresight and Advanced Basic Research

1.1 Construction of a reference genome sequence for an indicator species, the large Japanese field mouse

The large Japanese field mouse (*Apodemus speciosus*) is an endemic rodent widely distributed across Hokkaido, Honshu, Shikoku, Kyushu, and the surrounding islands. Owing to its broad distribution, high abundance, ease of sampling, and short generation time, it is a useful indicator species for continuously monitoring physiological and genetic responses to diverse environmental changes within Japan. To support these applications, we generated a high-quality reference genome assembly as a foundational resource for impact assessment. We captured *A. speciosus* in Tsukuba and Kagoshima prefectures. From the Tsukuba specimen, high-molecular-weight (HMW) DNA was extracted from muscle tissue by using a Macherey-Nagel HMW DNA extraction kit (Duren, Germany). From the Kagoshima specimen, primary cultured cells were established, and HMW DNA was subsequently extracted by using the phenol–chloroform method. For each HMW DNA sample, we performed whole-genome sequencing with Oxford Nanopore Technologies' PromethION (long reads) (Oxford, UK) and Illumina NovaSeq (short reads) (San Diego, CA). Genome size was estimated by applying Jellyfish

software to the short-read data from each specimen, yielding ~2.5 Gb for Tsukuba and ~2.3 Gb for Kagoshima. Hybrid genome assemblies were generated by using WENGAN to combine the long- and short-read data. For the Tsukuba specimen, additional scaffolding was performed by using the house mouse (*Mus musculus*) reference genome, and this assembly was designated as the reference genome for the eastern lineage of *A. speciosus*. For the Kagoshima specimen, scaffolding was performed against the eastern-lineage reference, yielding the reference genome for the western lineage. *Ab initio* gene prediction was performed on both reference genomes by using the Helixer tool, followed by annotation with the mouse reference protein dataset. Assembly completeness and structure were evaluated with BUSCO and dot-plot analyses were generated by using D-GENIES. The assembled reference genomes comprised 1172 contigs totaling 2.45 Gb for the eastern lineage and 2228 contigs totaling 2.25 Gb for the western lineage (Table 1). High BUSCO scores and large N50 values (an indicator of long-sequence genome assembly) indicated high completeness and contiguity for both assemblies. Consistent with the Jellyfish estimates, the eastern lineage genome was ~0.2 Gb larger than the western lineage. Because karyotypic differences between eastern and western lineages have been reported, it will be important to determine whether this size discrepancy reflects differences in the chromosome number. Dot-plot analyses further showed extensive synteny between the eastern and western assemblies at large genomic scales (Fig. 1). The high-quality reference genomes established here are expected to serve as foundational resources for impact assessments of environmental change in Japan.

Table 1 Evaluation of reference genome assemblies of the large Japanese field mouse (*Apodemus speciosus*)

	Eastern lineage (Tsukuba)	Western lineage (Kagoshima)
No. of contigs	1172	2228
Genome size	2,446,332,326 bp	2,245,345,086 bp
N50	119,829,018 bp	112,053,478 bp
BUSCO score	C: 96.0% [S: 95.2%; D: 0.8%] F: 0.9%; M: 3.1%	C: 94.9% [S: 94.1%; D: 0.8%] F: 1.2%; M: 3.9%

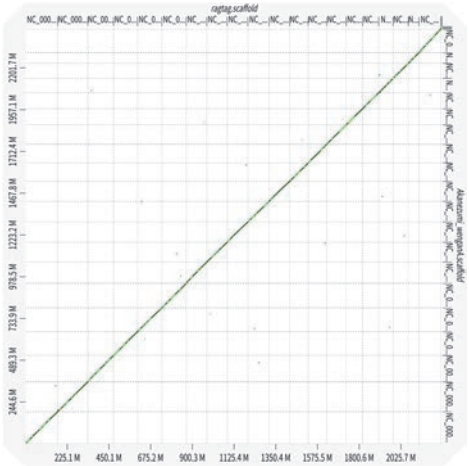


Fig. 1 Whole-genome dot plot comparing reference genomes of the eastern and western lineages of the large Japanese field mouse (*Apodemus speciosus*)

2 Policy-Oriented Research

2.1 A survey of municipal environmental plans and environmental policies in Fukushima Prefecture

This study aims to help with environmental recovery and creation following the FDNPP accident. In addition, it aims to provide knowledge that will contribute to the environmental policies implemented by municipalities in Fukushima Prefecture. Data on policy infrastructure, administrative plans formulated by municipalities, and local community stakeholders involved in environmental and reconstruction policies will be collected and analyzed to help with recovery in the affected areas. These analyses will be used to make recommendations for formulating the environmental plans and environmental policies of municipalities.

In one of the most notable achievements this fiscal year, a questionnaire survey was administered to organizations involved in the Fukushima Innovation Coast Initiative, which seeks to establish an industrial base in 15 municipalities in the Hamadori region. Of the 289 organizations targeted, 166 responded (response rate: 57.4%). The analysis identified the policy needs and policy networks of these organizations and clarified both the structure of the policy network associated with the Fukushima Innovation Coast Initiative and the challenges of building a broad collaborative network among participating organizations. We found that the policy network of this initiative was characterized by organizations that had previously formed a “nuclear village” before the Fukushima nuclear disaster played a central role in this initiative, and the structure of the network was biased toward industry–government–academia collaboration. Additionally, the organizations participating in the initiative were numerous and diverse, with varying trends across policy fields, and power and influence were dispersed.

The findings of our analysis of the policy network related to the Fukushima Innovation Coast Initiative were reported at the 49th Conference of the Japan Association of Regional and Community Studies. Through these academic reports and discussions, insights were provided to researchers, government officials, members of industry, and engineers involved in Fukushima reconstruction research. This will help with municipal policy formation and with the activities of various organizations in the Hamadori area of Fukushima.

2.2 Study of major technical aspects of the development of local disaster-waste-management policies

We systematically compared the predictive accuracy of multiple statistical models to develop an optimal model for estimating the amount of disaster waste in future disasters. In an evaluation of the models from the perspective of point prediction and interval prediction, we identified several candidates, including Bayesian hierarchical regression models with different probability distributions (log-normal, gamma, and Weibull). To help prepare suitable sites in normal times for temporary waste storage in times of disaster, a database structure for candidate sites was studied in collaboration with the Toyama Environmental Science Center.

An attempt was made to quantitatively evaluate the physical workload of the task of manual waste sorting. Specifically, by monitoring workers wearing biosensors, we studied the construction and implementation of quantitative evaluation methods for the labor intensity, physical activity levels, and muscle load of manual sorters, and we investigated both conscious and unconscious fatigue. We found that the maximum sorting speed for manual workers was approximately 480 pieces per 5 min. Additionally, after about 1.5 h of manual sorting, no clear fatigue was observed in either subjective or objective fatigue assessments.

The development and refinement of an AI model continued for rapid asbestos measurement technology for disaster response. By using training data from multiple institutions, the model achieved a reproduction rate and conformity rate of approximately 70%–85% for fiber counting accuracy on real atmospheric samples from general air or air near demolition sites. The time required for fiber detection was about 1 s per image—sufficiently faster than that of a skilled analyst. Development of a trial version is underway, and an automatic detection program that handles difficult-to-count fibers is pending.

2.3 Environmental Emergency Management Office

We supported national and municipal governments in formulating disaster waste management policies and plans, as well as in designing and implementing training programs. Furthermore, we continuously updated our Disaster Waste Information Platform. During FY 2024, 54 disaster waste management plans, one disaster waste management action plan, 10 proceedings from the annual conference of the Japan Waste Management Association, and 22 contributed or edited articles were newly posted on the platform.

To advance discussions on the role that branch offices of prefectural governments should play in providing effective technical support to affected municipalities needing disaster waste management, we surveyed the actual and expected roles of these branch offices in the prefectures' disaster waste management system. We

found that branch offices are expected to handle matters beyond the capacity of prefectural headquarters or municipal governments (such as collecting local disaster damage information and assessing temporary storage site conditions). Challenges identified included insufficient staff knowledge and experience, staff shortages, and undefined roles during disasters. The survey summary is publicly available on the Disaster Waste Information Platform.

Our staff conducted a field survey in July after the 2024 Noto Peninsula Earthquake. One member accompanied an asbestos exposure survey at the request of the Ministry of the Environment and Ishikawa Prefecture to address asbestos countermeasures. Additionally, staff provided expert advice during joint patrols related to publicly funded demolition following the earthquake. At a training session on asbestos dispersion prevention measures for publicly funded demolition, hosted by the Ministry of the Environment and Ishikawa Prefecture, a staff member gave a presentation on asbestos dispersion prevention measures during disasters, thus helping to promote asbestos dispersion prevention measures in the disaster-affected areas.

To enhance collaboration with related organizations, we provided information on our activities, including our response to the Noto Peninsula Earthquake, at the 26th Tsukuba Science City Exchange Council. We will continue collaborating with Tsukuba's research institutions to share the status of responses to the Noto Peninsula Earthquake.

3 Intellectual Research Infrastructure Development

3.1 Estimated amount of r-Cs that has migrated with industrial waste in Fukushima Prefecture

To avoid unnecessary or harmful public misinformation and promote proper recycling of industrial wastes in the wake of the nuclear power plant accident, it is important to show the public and waste professionals how to appropriately recycle wastes according to the degree of radioactive contamination. Contaminated wastes were derived from materials located mainly outdoors at the time of the nuclear accident; most were construction wastes resulting from the demolition of buildings and civil engineering structures. We estimated the amount of industrial waste and the r-Cs migration associated with the treatment and disposal of construction waste in Fukushima Prefecture. At the same time, we took into account the effect of decontamination performed sequentially since the accident in reducing the surface contamination density of buildings and other structures.

Industrial waste manifest information for Fukushima Prefecture from FY 2011 to FY 2015 was used to estimate the amounts of waste transferred. The amount of waste transferred after the disposal of external building components was estimated for each type of construction waste (e.g., wood and concrete) by analyzing the

names of business sites, the percentage of wood waste generated, and representative building structure blueprints in the manifest data. The amount of r-Cs transferred with these wastes was estimated from the air dose rate at the place of waste generation.

We conducted a survey to measure the surface contamination density of buildings, roads, and other structures in Fukushima Prefecture, and we determined the relationship between air dose rate and contamination density for each type of component and each horizontal and vertical installation direction. The surface contamination density of the exterior surfaces of buildings that had not been decontaminated in the difficult-to-return zone was measured for 2 years and 3 months. The decrease in surface contamination density over time due to washing away by precipitation or to environmental attenuation was determined in relation to the amount of precipitation measured at the site. The surface contamination density at the time of measurement was corrected to the value at the end of each year when the waste was generated by environmental and physical decay. Furthermore, we assumed that the surface contamination density was reduced by decontamination in the case of waste generated from areas with air doses of 0.23 μSv/h or higher, which is the standard for the designation of priority contamination investigation areas. By using information on the progress of decontamination in Fukushima Prefecture, we calculated the decontamination progress rate as the percentage of houses, public facilities, and roads that had been decontaminated by fiscal year. The reduction in surface contamination density due to decontamination was assumed to follow the reduction in air dose rates at residences or schools and parks resulting from decontamination by municipalities and the national government.

We attempted to determine the amount of r-Cs transferred by multiplying the concentration of r-Cs by waste type (concrete waste and asphalt concrete waste) by the amount of waste (concrete waste and asphalt concrete waste) and by the place of generation, obtained above.

We then estimated the amount of r-Cs that migrated from the treatment and disposal of concrete waste, asphalt concrete waste, plastic waste, and wood waste generated from construction and demolition work. The analysis showed that, in 2015, approximately 5.8 GBq of r-Cs was transferred from the treatment and disposal of concrete waste. For asphalt concrete waste, the amount was 498 GBq; for waste plastics, 45 GBq; and for wood waste, 41 GBq. The study showed that, in Fukushima Prefecture, most of the waste (with the exception of wood waste in 2011) has been intermediately processed and subsequently recycled.

3.2 Monitoring of r-Cs behavior in a multimedia environment

To determine the long-term persistence of r-Cs contamination in forest environments, we investigated the temporal changes in exchangeable ^{137}Cs concentrations in surface soils from the forest at Mt. Tsukuba (Fig. 2). Over the 10

years after the accident, the concentration of exchangeable ^{137}Cs decreased to approximately half of its initial level. This was likely due to the progressive fixation of exchangeable ^{137}Cs by soil minerals. However, a certain amount of exchangeable ^{137}Cs remained, even after 10 years; this likely resulted from continuous replenishment through the decomposition of plant material within the soil–plant cycling system.

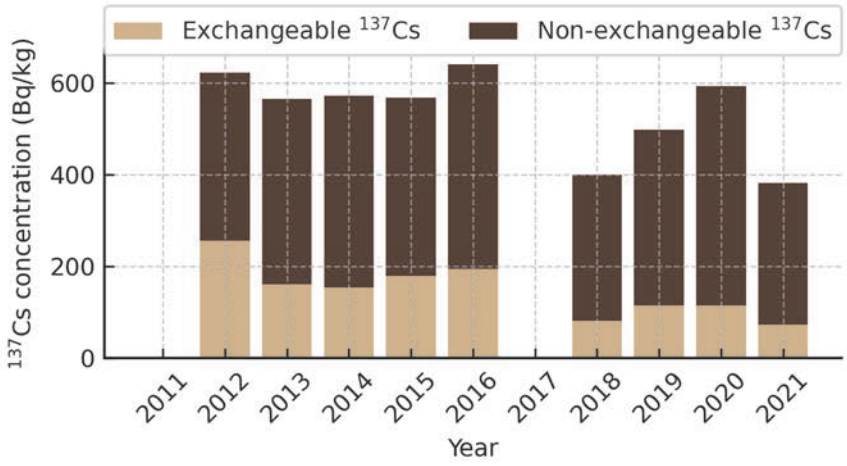


Fig. 2 Temporal changes in the mobility of ^{137}Cs in forest soils at Mt. Tsukuba. Soil samples were collected each spring from the surface to a depth of 10 cm by using a two-stage soil core sampler (Watanabe et al., 2025) and were sieved through a 0.5-mm mesh to remove plant debris prior to analysis. All data were decay-corrected to the sampling date. The concentration of exchangeable ^{137}Cs was corrected for changes during sample storage. The concentration of non-exchangeable ^{137}Cs was calculated as the difference between total ^{137}Cs and exchangeable ^{137}Cs.

Reference:
Watanabe M., Koshikawa M.K., Takamatsu T., Takahashi A., Nishikiori T.N., Morita D., Watanabe K., Hayashi S. (2025) Two-stage soil core sampler to collect a less-compressed core from forested areas. *Ecological Research* 40(3), 377–384. https://doi.org/10.1111/1440-1703.12450

3.3 Biodiversity and ecosystem monitoring for regional collaboration

Monitoring of terrestrial biodiversity (mammals, birds, frogs, and insects) in and around the evacuation area was conducted in FY 2024, continuing the work from the previous year. Furthermore, we participated in the "Snapshot Japan 2023" project in 2023, in which wildlife monitoring was conducted in autumn by using camera traps with a standardized protocol, and the integrated dataset was published in the form of data paper (Fukasawa et al., 2025). In the Fukushima sub-project, still images from 11 camera traps were collected, and 12 mammal species (excluding domestic cats) and five bird species were identified to species level.

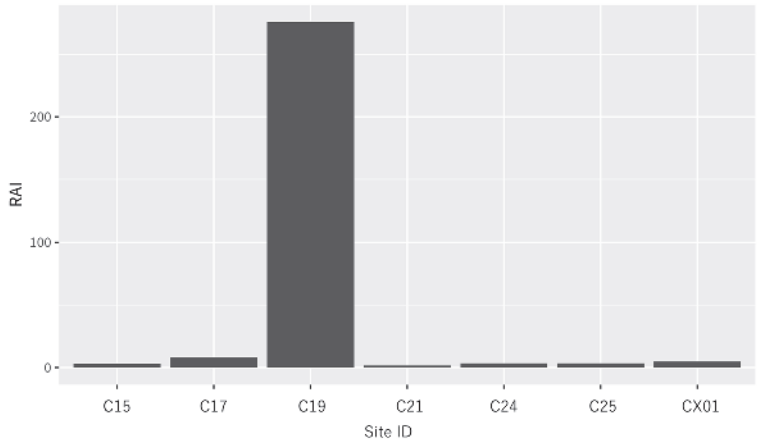


Fig. 3 Relative abundance index (RAI) of wild boars from each camera trap deployed in Fukushima as part of the Snapshot Japan 2023 project. Note that data from the sites where no wild boars were detected were omitted.

Wild boar (*Sus scrofa*) was considered to have increased in abundance in the evacuation zone and was of interest during the project. The relative abundance index (RAI, independent photographic events per 100 trap nights) for wild boar was as high as about 275 at one site in the evacuation zone (Fig. 3)—the second-highest value among the camera traps deployed for sub-projects in the Snapshot Japan 2023 project. However, RAIs from the other camera traps in Fukushima were not as high (the mean RAI in Japan was 41.84), and the spatial heterogeneity may be high.

Notably, the Snapshot protocol is following the Snapshot USA initiative (https://www.snapshot-usa.org/), making it possible to analyze the wildlife dataset of Fukushima in comparison with data from a broader area.

Reference:

Fukasawa K. et al. (2025) Snapshot Japan 2023: the first camera trap dataset under a globally standardised protocol in Japan. *Biodiversity Data Journal* 13, e141168

3.4 Promotion of regional collaboration

To further promote research in collaboration with the local community, we conducted public relations activities, dialogues with the local community, and research in collaboration with the community in an integrated manner. As part of efforts to build relationships with local stakeholders, a collaborative initiative was advanced, centering on the mountain farm—an environmentally conscious, welfare-oriented agricultural project—operated by the nonprofit organization (NPO) Shinsei in the city of Koriyama, as part of its agriculture–welfare integration program. In the context of the experiential program titled “Mountain School,” which is conducted at a farmstead, researchers from our institute were responsible for the environmental education component. The content delivered by the researchers utilized the farmstead’s natural setting, incorporating themes such as radiation monitoring and climate change. To further enhance the endeavors of the Mountain School, Shinsei, Fukushima Prefectural Asaka Kaisei High School, and NIES concluded a tripartite agreement in October 2024, thereby establishing a “Partnership for the Realization of a Sustainable Regional Coexistence Society” (Fig. 4).

Fig. 4 Signing ceremony for the "Partnership for the Realization of a Sustainable Regional Coexistence Society" between Shinsei (an NPO), Fukushima Prefectural Asaka Kaisei High School, and NIES

Environmental Measurement Research and Affairs

Environmental measurement research and affairs are managed by the Center for Environmental Standards and Measurement. In this center, two laboratories, namely the Environmental Standards Section and the Environmental Measurement and Analysis Section, are responsible for fundamental measurement work in a cross-disciplinary manner, as well as for advanced measurement research in cooperation with other research domains. In addition to performing analyses on request by using chemical measuring instruments, the Center prepares and provides environmental reference materials that meet international standards in response to social needs. We also add certified values and reference values to existing environmental reference materials in order to increase their usefulness. In addition, to improve our understanding of the status of chemicals in the environment, we are promoting a long-term preservation project for environmental samples, including the collection, long-term preservation, and analysis of bivalve mollusks from the coast of Japan.

Below are brief accounts of some of the important results of our research in FY 2024.

1. Foresight and Advanced Basic Research

1.1 Isotopic Characterization of Atmospheric Mercury at Mauna Loa Observatory, Hawaii

Mercury (Hg) is a globally distributed atmospheric pollutant with long-range transport potential owing to the persistence of its elemental form (Hg^0). An understanding of how Hg^0 is oxidized and removed from the atmosphere is essential to closing critical gaps in the global mercury cycle. However, processes operating in the free troposphere remain poorly constrained because of limited observational data. To address this, we conducted the first long-term isotopic analysis of total gaseous Hg (TGM) at the Mauna Loa Observatory (MLO, 3397 m elevation) in Hawaii, a remote high-altitude site well suited for capturing background atmospheric signals (Yamakawa et al., 2024)[1]. Over the period from January to September 2022, TGM was sampled every 48 h by using gold traps and analyzed for mercury isotopes ($\delta^{202}Hg$, $\Delta^{199}Hg$, $\Delta^{200}Hg$, $\Delta^{201}Hg$) via cold vapor multi-collector inductively coupled plasma mass spectrometry (MC-ICP-MS), following a protocol established by Yamakawa et al. (2017)[2].

The $\delta^{202}Hg$ values ranged from –1.86‰ to –0.32‰, while $\Delta^{199}Hg$ values varied narrowly from –0.27‰ to 0.04‰. Comparison with the values reported at other high-altitude sites suggested that at MLO there was mixing of free-tropospheric background Hg with ocean-derived Hg^0. The unique upslope (daytime) and downslope (nighttime) wind regimes at MLO likely facilitate this mixing. A representative plot of $\Delta^{199}Hg$ vs. $\delta^{202}Hg$ (Fig. 1) shows that the MLO samples

occupies a compositional space between previously reported marine and continental sources.

Continuous monitoring revealed a negative correlation between gaseous elemental Hg (GEM) and gaseous oxidized Hg (GOM), particularly during the summer months. This supports the hypothesis that *in situ* oxidation of Hg^0 occurs in the free troposphere, potentially via OH or O_3. Furthermore, negative $\Delta^{200}Hg$ anomalies—although rarely reported—suggest photo-oxidation of Hg^0 in the upper troposphere or lower stratosphere. Temporal patterns observed in September showed that the gas–particle partitioning of oxidized Hg was influenced by the relative humidity and particle number concentration, highlighting the role of meteorological factors in atmospheric Hg cycling.

This study demonstrates the value of isotopic analysis in disentangling the complex sources and transformations of atmospheric Hg. The data provide new insight into the processes controlling Hg speciation at high altitude and contribute to a better understanding of its global environmental behavior.

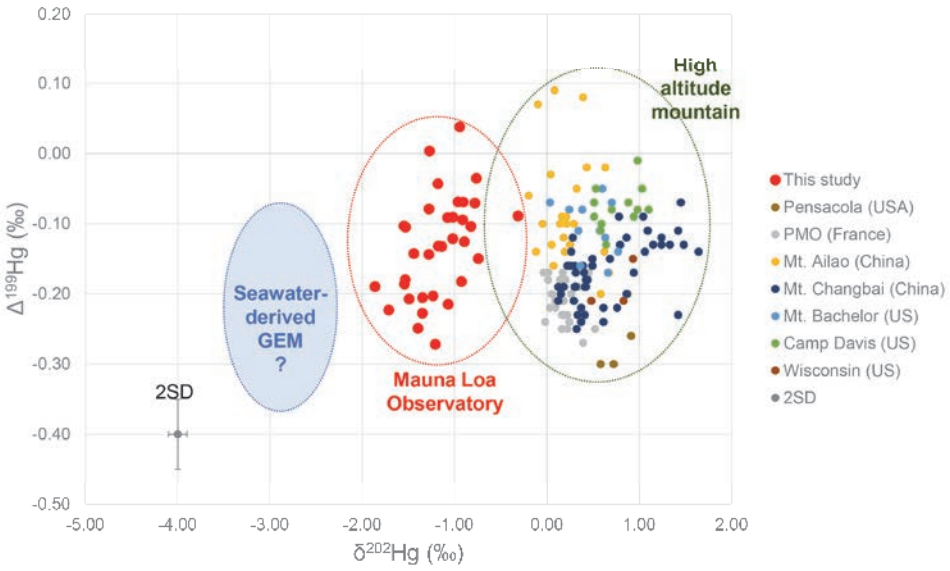


Fig. 1 $\Delta^{199}Hg$ vs. $\delta^{202}Hg$ in GEM/TGM samples collected at Mauna Loa Observatory. For comparison, data from other high-altitude sites are shown: Pic du Midi Observatory (PMO; Fu et al., 2016[3]), Mt. Ailao and Mt. Changbai (Fu et al., 2019[4]), Mt. Bachelor and Camp Davis (Kurz et al., 2020[5]), and Wisconsin (Demers et al., 2013[6]). (Adapted from Yamakawa et al., 2024[1], licensed under CC BY-NC 4.0). SD, standard deviation

References:

1) Yamakawa A., Luke W., Kelly P., Ren X., Iaukea-Lum M. (2024) Unraveling atmospheric mercury dynamics at Mauna Loa through the isotopic analysis of total gaseous mercury. *Ecotoxicology and Environmental Safety*, 284, 116993; licensed under Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/)

2) Yamakawa A., Moriya K., Yoshinaga J. (2017) Determination of isotopic composition of atmospheric mercury in urban-industrial and coastal regions of Chiba, Japan, using cold vapor multicollector ICP-MS. *Chemical Geology* 448, 84–92

3) Fu X., Marusczak N., Wang X., Gheusi F., Sonke J.E. (2016) Isotopic composition of gaseous elemental mercury in the free troposphere at the Pic du Midi Observatory, France. *Environmental Science & Technology* 50, 5641–5650

4) Fu X., Zhang H., Liu C., Zhang H., Lin C.-J., Feng X. (2019) Significant seasonal variations in isotopic composition of atmospheric total gaseous mercury at forest sites in China caused by vegetation and mercury sources. *Environmental Science & Technology* 53, 13748–13756

5) Kurz A.Y., Blum J.D., Gratz L.E., Jaffe D.A. (2020) Contrasting controls on the diel isotopic variation of Hg^0 at two high elevation sites in the western United States. *Environmental Science & Technology* 54, 10502–10513

6) Demers J.D., Blum J.D., Zak D.R. (2013) Mercury isotopes in a forested ecosystem: implications for air–surface exchange dynamics and the global mercury cycle. *Global Biogeochemical Cycles* 27, 222–238

2. Intellectual Research Infrastructure Development

2.1 Encouragement of Environmental Specimen Banking

Predicting future environmental issues and new pollutants in advance is not an easy task. Additionally, once environmental pollution occurs, it becomes impossible to collect uncontaminated samples. The Environmental Specimen Banking program conducted by NIES aims to systematically collect environmental samples and store them in a stable condition for decades, or more, as valuable fragments for tracing pollution history in the future by using advanced analytical techniques (Takazawa, 2024). In the fifth phase of NIES, bivalves were collected at fixed sampling sites in the Kyushu region, Okinawa, Hokkaido, Tohoku region, Tokai region, Kinki region, and Hokuriku region (Fig. 2). Samples were frozen, ground, and homogenized for liquid nitrogen storage. By systematically implementing this long-term environmental sample preservation project, we are helping to maintain and improve the quality of environmental monitoring. We also expect that the continued accumulation of data through the analysis of preserved samples—including quality control—will provide foundational information for analyzing the effects of various policies and the impacts of changes in industrial structures.

Fig. 2 (Left) Sample collection scene in FY 2024. (Right) The mussel *Septifer virgatus* attached to rocks

Reference:

Takazawa Y. (2024) Environmental Specimen Banking in NIES, Japan. *GMP and GCG meeting 2024*, United Nations Environment Programme (Invited lecture)

Research Projects

Satellite Observation Project

The Satellite Observation Project contributes to improved scientific understanding of the global carbon cycle, more accurate prediction of the future climate, and climate-change-related policymaking by the Ministry of the Environment (MOE) through activities that use data from satellites of the GOSAT Series, namely the Greenhouse gases Observing SATellite (GOSAT), launched in 2009; GOSAT-2, launched in 2018; and the Global Observing SATellite for Greenhouse gases and Water cycle (GOSAT-GW) to be launched in FY 2025. Activities include developing and operating data-processing systems for the GOSAT Series. These systems are being used to calculate the concentrations and fluxes of greenhouse gases (GHGs) and to verify, archive, or distribute GOSAT Series products. The GOSAT Series projects are jointly promoted by MOE, the Japan Aerospace Exploration Agency (JAXA), and NIES.

NIES's Satellite Observation Center (SOC) is responsible for implementing the Satellite Observation Project. Major achievements of the Satellite Observation Project in FY 2024, including a study of GOSAT-GW follow-on, were as follows.

1 GOSAT

Operational data processing for GOSAT, which has been in space for more than 16 years, continued, as did the generation, validation, and distribution of GOSAT products, such as the concentrations and fluxes of carbon dioxide (CO_2) and methane (CH_4). Concentration products up to February 2025 (V03.00), CO_2 flux products up to October 2022 (V02.10), and CH_4 flux products up to September 2021 (V01.08) are freely available from the GOSAT Data Archive Service (GDAS; https://data2.gosat.nies.go.jp). Concentration products were validated by using ground-based observation data. Maintenance and operation of the GOSAT Data Handling Facility (a computer system necessary for these activities) were also conducted. Moreover, we have continued to provide GOSAT FTS (Fourier Transform Spectrometer) Level 2 CO_2 data to the World Data Centre for Greenhouse Gases, which is operated by the Japan Meteorological Agency under an agreement with the World Meteorological Organization.

According to GOSAT XCO_2 data through December 2024, the annual increase of the whole-atmosphere mean concentration of CO_2 (i.e., average concentration throughout Earth's atmosphere) from 2023 to 2024 was 3.5 ppm—the largest annual increase since GOSAT began providing annual increase data in 2011 (Fig. 1). The following conditions may have contributed to the large increase: high temperatures and droughts caused by the El Niño of 2023–2024; increased CO_2 emissions and decreased areas of terrestrial vegetation and rates of photosynthesis due to forest fires; and increased anthropogenic emissions of CO_2. To clarify the causes of the increase, a detailed analysis will be conducted by using not only the GOSAT data obtained during 2024 but also the entire GOSAT Series data.

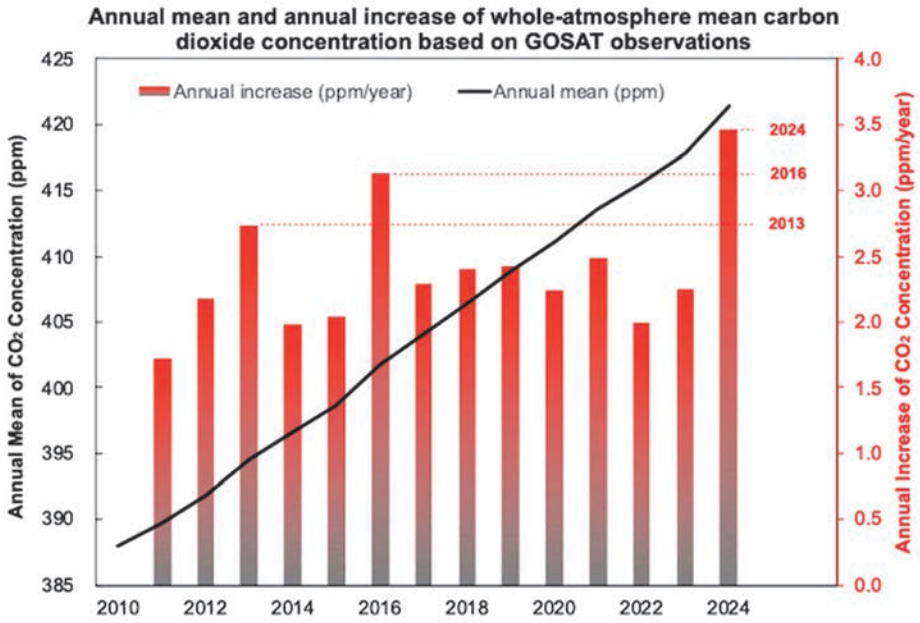


Fig. 1 Annual mean (black line) and annual increase (red bars) of whole-atmosphere mean carbon dioxide concentrations, based on GOSAT observations. The annual mean concentration is the simple average of the monthly whole-atmosphere concentrations over a 12-month period. The annual increase is the increase of the annual mean concentration from one year to the next. Annual mean concentrations are available only for 2010 and subsequent years, and annual increases are available for 2011 onward, because observations by GOSAT began in April 2009.

2 GOSAT-2

GOSAT-2 data have been distributed by the GOSAT-2 Product Archive (https://prdct.gosat-2.nies.go.jp) since 2019. Concentration products up to January 2024 (CO_2, CH_4, carbon monoxide (CO), and solar-induced chlorophyll fluorescence (SIF); V02.10) and CO_2 flux products from October 2019 to October 2020 (V01.02) are freely available from the GOSAT-2 Product Archive. Concentration products were validated by using ground-based observation data. One GOSAT-2 Science Team Meeting was held in FY 2024 to discuss issues such as data quality, validation analysis, and releases of standard products.

A paper on the estimation of GHG emissions from megacities by using GOSAT-2 data was published in November 2024 (Ohyama et al., 2024). In this paper, a method was developed to calculate the enhancement ratios among CO_2, CH_4, and CO concentrations in megacities by using data from GOSAT-2—the only satellite observing all three gases simultaneously. Furthermore, the accuracy of emission databases was evaluated, and CH_4 and CO emissions for approximately 40 cities around the world were estimated and plotted as calculated 4-year average ratios to the EDGAR (Emissions Database for Global Atmospheric Research) values (Fig. 2). This study will help to improve the emission database for megacities and foster the reduction of their emissions of GHGs and air pollutants.

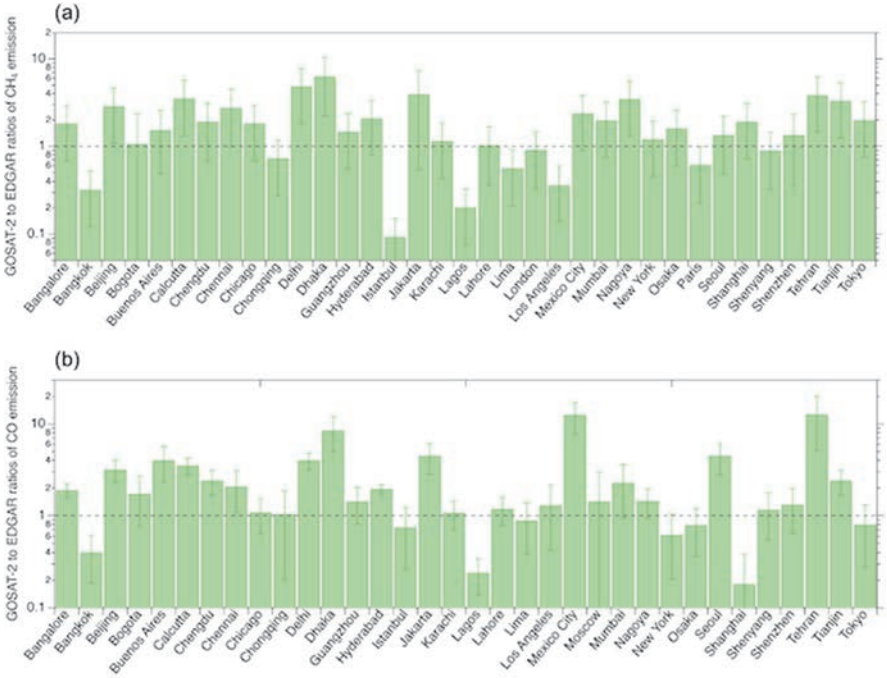


Fig. 2 GOSAT-2 (a) CH_4 and (b) CO emissions for each city as 4-year average ratios to the EDGAR (Emissions Database for Global Atmospheric Research) values. The EDGAR values used for comparison are from v7.0 (2019) for CH_4 and v6.1 (2018) for CO. The error bars were calculated from the uncertainty of the emissions estimated from GOSAT-2 data. Values greater (smaller) than 1 indicate that EDGAR was underestimating (overestimating) emissions compared with those from GOSAT-2.

3 GOSAT-GW

In December 2024, the postponement of the launch of GOSAT-GW from FY 2024 to FY 2025 was announced owing to a delay in the development of the spacecraft.

In FY 2024, the system tests of the Total Anthropogenic and Natural emissions mapping SpectrOmeter-3 (TANSO-3) and related ground systems, including NIES's GOSAT third-generation Data Processing/operating System (G3DPS) and the GOSAT-GW Nitrogen dioxide (NO_2) Data Processing System (GNDPS), were continued by JAXA, NIES, and their contractors. Installation of the GOSAT Operational and research Computing Facility (GOCF) at the University of Tsukuba was completed, and TANSO-3 data processing was tested on GOCF. Observations with the ground-based instruments installed by FY 2023 for validation of the TANSO-3 products were continued at all sites. In addition, ground-based GHG observations at Suburb Tokyo became operational.

4 GOSAT-GW Follow-on

The fourth generation of GOSAT (i.e., the GOSAT-GW follow-on) has been under consideration at NIES since FY 2023. In FY 2023, we examined the scientific requirements and proposed three observation concepts. On the basis of these results, we organized information from scientific, policy, and business perspectives to discussions on further mission objectives and investigate the mission's feasibility in FY 2024. GHG flux errors associated with the satellite's product qualities were evaluated by using a GHG flux inversion system, with consideration of the scientific aspects. Additionally, hardware systems based on the proposed observation concepts were investigated. We had discussions with

scientists and administrative officers to better understand the intended purposes of satellite data use. We also investigated the availability of future GHG satellite data for commercial use. On the basis of the three aspects, we organized the results to define mission objectives and determine satellite specifications. We proposed several options for political and commercial availability, along with the observation concepts raised in the FY 2023 discussion, for the future mission.

5 Collaboration with Other Organizations

Research Announcements on the GOSAT Series have been issued jointly by MOE, JAXA, and NIES three times since 2018 to solicit research proposals covering GOSAT and GOSAT-2 from around the world. Proposals that are evaluated as appropriate by the GOSAT Series Research Announcement Selection and Evaluation Committee are adopted to conclude joint research agreements. In total, 41 joint studies have been conducted and seven studies are ongoing.

In response to agreements concluded with the US National Aeronautics and Space Administration (NASA), the European Space Agency, le Centre national d'études spatiales, and the German Aerospace Center (das Deutsches Zentrum für Luft- und Raumfahrt), several informal meetings were held virtually and in person. The agreement with NASA was renewed in November 2024.

6 Hosting of Meetings

NIES, with support from MOE and JAXA, will host the 21st International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-21) in Takamatsu in June 2025. NIES hosted IWGGMS-18 in 2022, mostly as an online meeting because of COVID-19. IWGGMS-21 will be the first face-to-face meeting to be held in Japan in 6 years, since IWGGMS-15 in Sapporo in 2019.

7 Participation in International Events

In November 2024, SOC participated in the 29th session of the Conference of the Parties (COP29) to the United Nations Framework Convention on Climate Change (UNFCCC) in Baku, Azerbaijan, by means of an official exhibit, an on-site seminar at the Japan Pavilion, and participation in the Virtual Japan Pavilion (Fig. 3). The official exhibit presented how Japanese satellites, including the GOSAT series, had revealed the effects of climate change on our planet, including changes in GHGs, rainfall, forests, and other land uses. The Japan Pavilion seminar "New Developments of GOSAT Series – Japanese GHG Center and Use of Satellite Data for Business" was hosted jointly by NIES, MOE, and the Japan Agency for Marine-Earth Science and Technology. This seminar provided an overview of the preparation status of GOSAT-GW (the third satellite of the GOSAT series) and the Japan Greenhouse Gas Center, a new information center designed to disseminate advanced GHG observation data and the latest scientific insights from GOSAT

series satellites and other sources to the international community. Speakers from the private sector, academia, and government shared their expectations for utilizing high spatial resolution GHG data from satellites such as GOSAT-GW in business applications and policymaking as well as climate science research.

Fig. 3 Left: UNFCCC COP29 official exhibit by NIES, JAXA, and the Remote Sensing Technology Center of Japan. Right: Speakers at the Japan Pavilion Seminar

8 Press Releases

SOC issued the following two press releases in FY 2024:

1) "Signing of the Implementing Arrangement to Continue Collaboration on Satellite Data Comparison of Trace Gases among National Institute for Environmental Studies, Ministry of the Environment, Japan Aerospace Exploration Agency, and NASA" (December 2024)
   See https://www.nies.go.jp/whatsnew/20241212/20241212-e.html
2) "Annual increase of whole-atmosphere mean concentration of carbon dioxide in 2024 was the largest in the past 14 years: preliminary results from the "IBUKI" (GOSAT) satellite" (February 2025)
   See https://www.nies.go.jp/whatsnew/20250214/20250214-e.html

Reference:

Ohyama H., Yoshida Y., Matsunaga T. (2024) CH_4 and CO emission estimates for megacities: deriving enhancement ratios of CO_2, CH_4, and CO from GOSAT-2 observations, *Environmental Research Letters* 19(12), 124025. https://doi.org/10.1088/1748-9326/ad89e0

Japan Environment and Children's Study

The Japan Environment and Children's Study (JECS) is a large-scale birth cohort study that aims to investigate the impact of the environment on children's health and development. NIES serves as the JECS Program Office, supporting the Regional Centers that conduct surveys in 15 study areas throughout Japan in cooperation with the Medical Support Center, which is located in the National Center for Child Health and Development and provides medical expertise.

1 Aim

The aim of JECS is to identify environmental factors that affect children's health in order to develop better environmental risk management policies. Specifically, JECS focuses on the effects of exposure to chemical substances during the fetal period or in early childhood. JECS gives priority to five major health domains: reproduction and pregnancy complications; congenital anomalies; neuropsychiatric or developmental disorders; allergy and immune system disorders; and metabolic and endocrine system dysfunction. The environment is defined broadly as the global or ambient environment (including chemical substances and physical conditions), the built environment, behaviors and habits, socioeconomic factors, family and community support, and genetic factors.

2 Study Design and Subjects

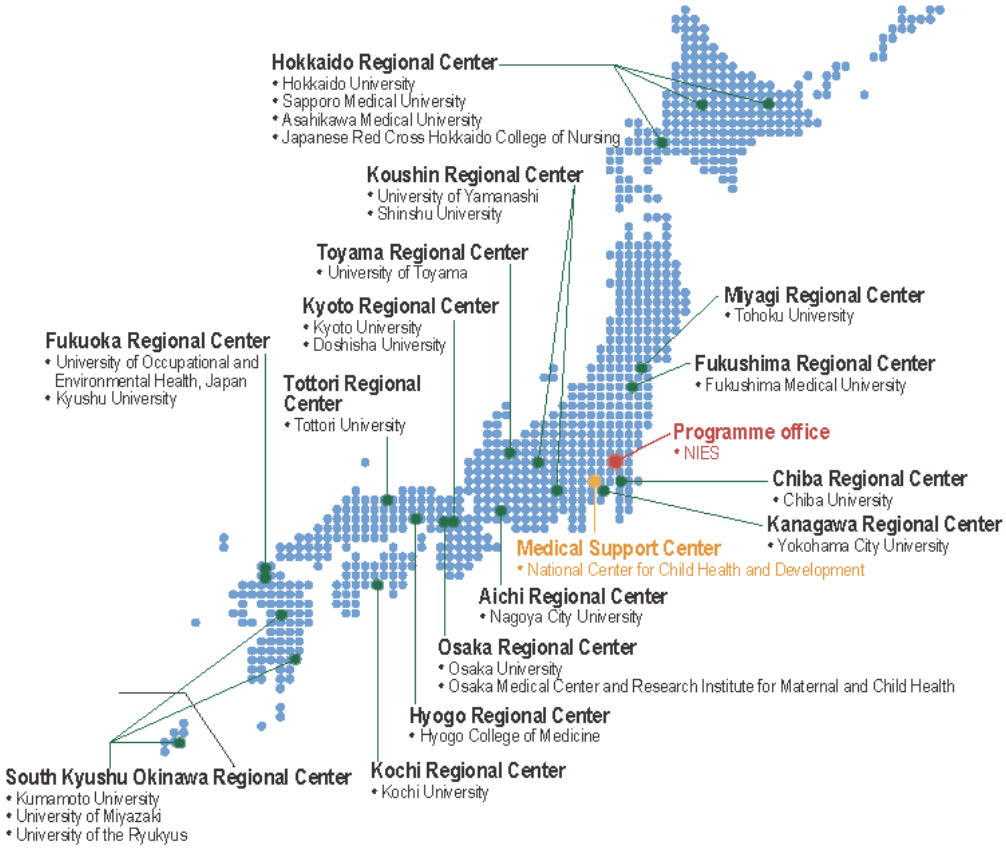
We started recruiting participants in January 2011, and recruitment continued until March 2014, by which time the number of participating mothers had reached 103,099. Recruited participants were pregnant women and their partners (when accessible). JECS began to collect data when the mothers were pregnant and planned to follow their children until they reached 13 years of age. The study protocol has now been updated to keep following the children until they reach at least 40 years of age. For the Main Study, JECS acquires information about participant health and development and potentially relevant environmental factors by administering questionnaires twice a year. A Sub-Cohort Study, which involves 5000 children selected randomly from among participants in the Main Study, is also being conducted to investigate environmental factors and outcome variables more thoroughly. It includes extensive assessment through home visits, ambient air measurements, psycho-developmental testing, and examinations by pediatricians.

3 JECS Study Organization and Role of the Program Office

The Program Office plays key roles in ensuring appropriate data collection and analysis, including developing standard operation procedures, accumulating the data collected by the 15 Regional Centers (Fig. 1), operating the data management system, maintaining a repository of biological and environmental specimens, performing exposure and environmental measurements (including chemical

analyses of biological samples), and administering questionnaires. The Office also performs administrative tasks, provides administrative and technical support for Regional Centers, and is responsible for risk management and public communications. The Office strives to play a leadership role in facilitating collaboration among the different research groups conducting environmental birth-cohort studies in both Japan and other parts of the world, working as a platform for information exchange among researchers.

Fig. 1 JECS organization



4 Study Protocols

Details of the study protocols of JECS can be found in the following literature:

Kawamoto T., Nitta H., Murata K. et al. (2014) Rationale and study design of the Japan environment and children's study (JECS). *BMC Public Health* 14, 25. doi:10.1186/1471-2458-14-25

Michikawa T., Nitta H., Nakayama S.F. et al. (2018) Baseline profile of participants in the Japan Environment and Children's Study (JECS). *Journal of Epidemiology* 28(2), 99–104. doi:10.2188/jea.JE20170018

Sekiyama M., Yamazaki S., Michikawa T. et al. (2022) Study design and participants' profile in the Sub-Cohort Study in the Japan Environment and Children's Study (JECS). *Journal of Epidemiology* 32(5), 228–236. doi:10.2188/jea.JE20200448

5 Activity Report for FY 2024

The children participating in the Main Study reached the ages of 10 to 13 years in FY 2024. We continued to administer questionnaires to participants to collect a wide range of information on the children's health and development and their exposure to environmental factors. We analyzed 5000 children's blood samples for per- and polyfluoroalkyl substances (PFAS) and 38,000 DNA samples extracted from maternal blood for whole-genome single nucleotide polymorphisms (SNPs). As part of the Sub-Cohort study, about 1400 ten-year-old participants were tested developmentally and examined by pediatricians. Blood and urine samples were also collected and tested.

Promotion of Climate Change Adaptation

Center for Climate Change Adaptation

Under the Climate Change Adaptation Act enforced in December 2018, NIES is designated as the core information platform for climate change adaptation in Japan. NIES established the Center for Climate Change Adaptation (CCCA) in the same month. It is tasked with collecting, organizing, analyzing, and providing information on the impacts of climate change and climate change adaptation, as well as supporting local governments and Local Climate Change Adaptation Centers (LCCACs) by providing technical advice for efforts on climate change adaptation (Fig. 1). Some of the activities of the Center in FY 2024 are described below.

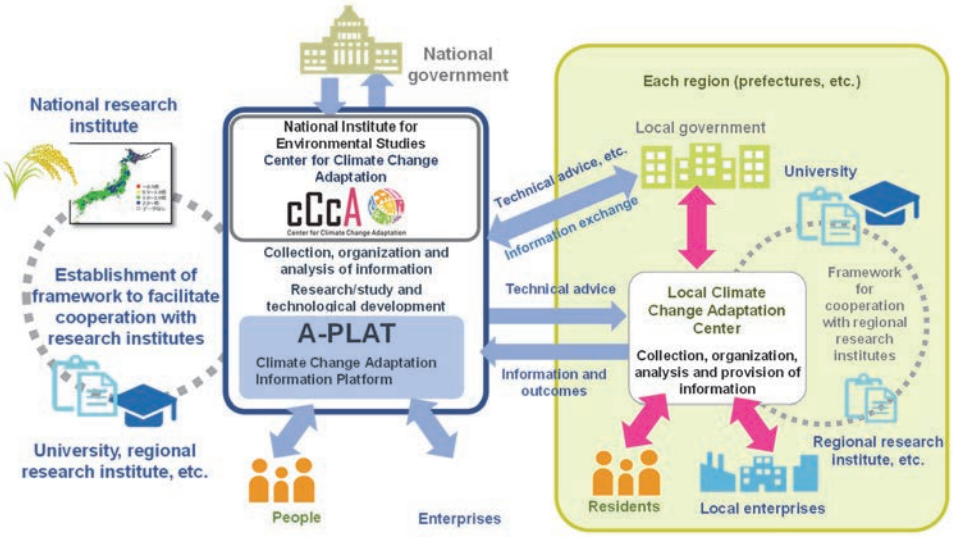


Fig. 1 Role of the Center for Climate Change Adaptation

1 Promotion of Climate Change Adaptation

1.1 Technical support for local governments

We provided various forms of technical advice and help to prefectures, municipalities, and LCCACs to promote the development of regional climate change adaptation plans and adaptation measures by local governments. Some of the specific activities are summarized below.

We conducted an e-learning training program for newly appointed local government officials from April to July 2024. In August 2024, we co-hosted a training course for local government officials with the Ministry of the Environment, with about 160 participants, to provide basic information for formulating regional climate change adaptation plans. We held regular online meetings once every 2 months and an in-person meeting in December with LCCACs across Japan (Fig. 2) to share knowledge of the activities of LCCACs and to exchange information and opinions.

We gave lectures at various meetings at the request of local governments and other entities and provided information on climate change adaptation to a total of about 11,400 people in FY 2024, thereby contributing to human resource development in local communities. In addition, as part of the development of environmental research and technical help to local communities, we conducted “Joint Research on Climate Change Adaptation with LCCACs” on seven themes.

We held a symposium and umbrella meetings of the Study Group on Climate Change Adaptation in December 2024, with the participation of national research institutes of various ministries and LCCACs, to discuss the feasibility of tangible collaboration (e.g., social implementation) among national research institutes on the basis of local needs.

Fig. 2 LCCAC discussion meeting in 2024

As a result of our continued support for local communities, the numbers of local adaptation plans and LCCACs have been increasing (Fig. 3). As of 31 March 2025, local adaptation plans have been formulated in all 47 prefectures, and regional adaptation centers have been established in 46 prefectures. In FY 2024, based on the five-year review conducted by the Central Environmental Council following the enforcement of the Climate Change Adaptation Act (interim summary published in August 2024) and related findings, we compiled the “Local Climate Change Adaptation Center Operations Guidebook.” This guidebook clarifies the medium- to long-term vision, roles, functions, and strategic direction of local climate change adaptation centers, aiming to support the practical implementation of climate change adaptation efforts in each region.

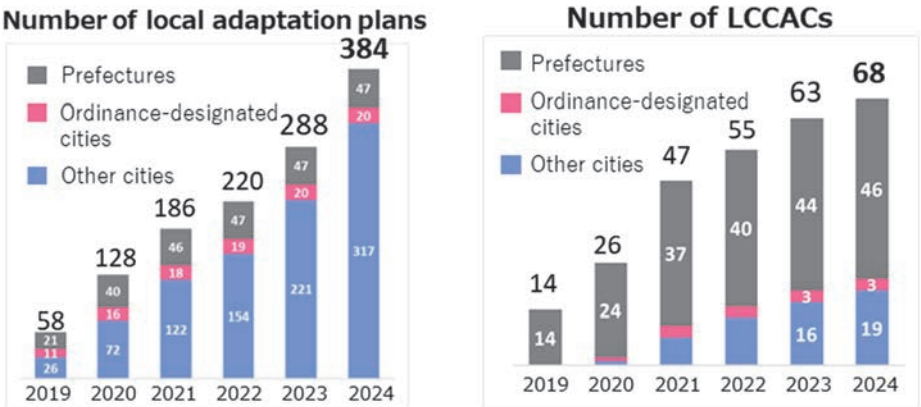


Fig. 3 Numbers of local adaptation plans (left) and LCCACs (right) . A "ordinance-designated" city is a large Japanese city granted special administrative powers by the national government, allowing it to handle functions usually managed by prefectures.

1.2 Collecting, organizing, analyzing, and providing information related to climate change adaptation

The Climate Change Adaptation Information Platform (A-PLAT), which provides comprehensive information on adaptation to the effects of climate change, has disseminated information on various events and initiatives of government ministries and agencies, national research institutes, local governments, LCCACs, businesses, and others. Following renovations last fiscal year, we continued to enhance the entire website in FY 2024. We improved usability by reviewing the site structure with a CMS (a software platform called a content management system) and redesigning the overall layout. Additionally, we released chapters 2 to 6 of the educational material "Climate Change and Adaptation" on the website, expanded the available scientific information in WebGIS format, added videos targeted at children, and published tools for public awareness and outreach. In FY 2024, the number of web page views was approximately 1.30 million (target: over 500,000), and there were 654 SNS (social networking service) transmissions (X, Facebook, Instagram, LinkedIn, and Twitter) (target: more than 100). Both of these figures substantially exceeded the target values.

To monitor the status of public awareness of climate change adaptation, we have conducted a web-based questionnaire survey annually since FY 2021. The survey covers items such as awareness of climate change effects and adaptation, sufficiency of the information provided, and areas of interest in each of the seven regions of Japan.

To enhance public awareness of climate change adaptation, we developed and loaned out educational tools (e.g., *Gacha*, a capsule toy machine, and *Sugoroku*, a board game). We also created a video for children in A-PLAT Kids titled "Hello, Adaptation Measures," and established a photo material database. Additionally, we facilitated information dissemination and opinion exchanges through the ESD (Education for Sustainable Development) for 2030 Learning Together Project in the Kanto and Kyushu regions.

To promote the utilization of climate change data, we promoted the activities of the Roundtable on Scenarios and Data for Climate Change Risk and Opportunity Assessment, which was established by the relevant ministries and agencies (including NIES) for the purpose of close exchange of information and opinions between data providers and users. In FY 2024, we compiled the activities of the networking meetings held so far and updated the Climate Change Risk Analysis Information Site.

1.3 International contributions to the development of an information platform for the Asia-Pacific region

The Asia-Pacific Platform for Climate Change Adaptation (AP-PLAT) (Fig. 4), which is being developed as an information platform to support adaptation measures in developing countries in response to the Paris Agreement, developed, implemented, and released an Adaptation Database, which collects and organizes information on good practices, case studies, and organizations related to adaptation.

To strengthen international cooperation for AP-PLAT, we held the 5th International Climate Change Adaptation Platformers Meeting, an international conference on the Climate Change Adaptation Information Platform. We collaborated with international organizations such as the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) and gave presentations on AP-PLAT and scientific tools at training workshops hosted by the PCCC (Pacific Climate Change Center) and JICA (Japan International Cooperation Agency). Through these activities, we helped to promote climate change adaptation in the Asia-Pacific region.

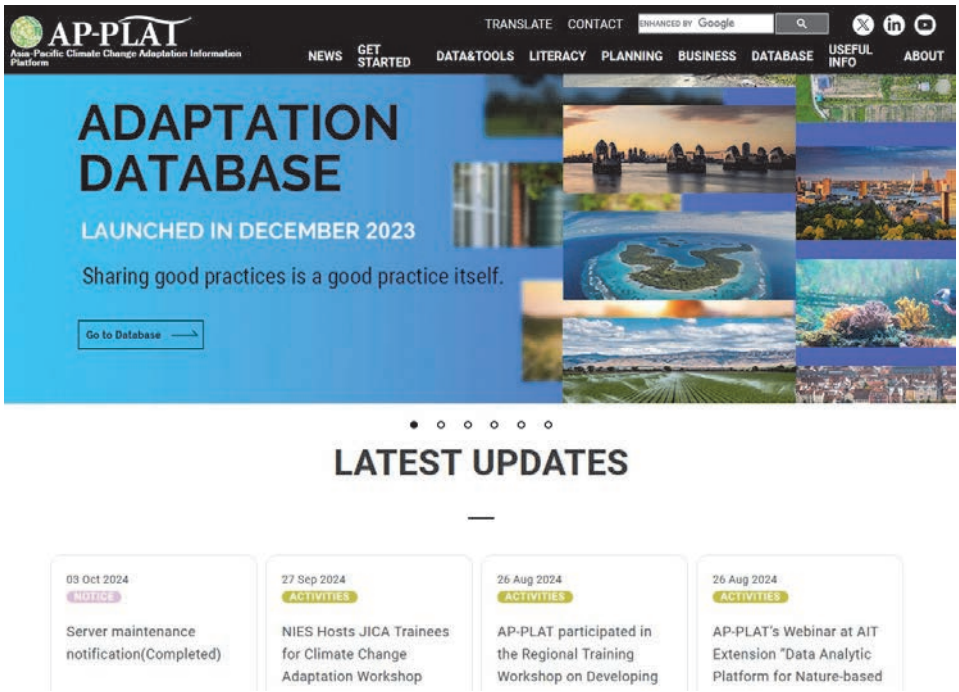


Fig. 4 Screenshot of the home page of the AP-PLAT website (https://ap-plat.nies.go.jp/)

1.4 Contribution to climate change policy

We contributed to discussions on climate change risks and adaptation measures and promotion of the government's adaptation-related projects by sending staff to 82 committees and working groups. This included working with the Subcommittee on Climate Change Impact Assessment and Adaptation (part of the Global Environment Committee of the Central Environment Council, an advisory council to the Minister of the Environment) and sectoral Working Groups. We also held monthly exchanges of opinions with the Climate Change Adaptation Office of the Ministry of the Environment. In particular, we contributed to the Subcommittee's discussion on the implementation status of the Climate Change Adaptation Act in its fifth year of implementation by responding to its hearings and reporting on achievements and challenges, as well as on the future direction of our research and technical support activities.

2 Climate Change Impact and Adaptation Research

To promote adaptation-related research throughout the country, NIES takes the lead in managing liaison councils and study groups consisting of research institutes from various ministries and agencies, and we work closely with these research institutes.

To promote important adaptation measures, NIES conducts research on various fields and items, including ecosystems, the air and water environments, and health impacts such as heat stroke. We aim to detect and predict the effects of climate change, evaluate the effects of adaptation measures to reduce the impacts, and develop policy research and the methods needed to formulate and implement adaptation measures on the basis of our findings. These studies are largely divided into "Strategic Research Program" and "Basic Research and Research Infrastructure Development." Figure 5 summarizes the main topics for FY 2024 in the three research projects that comprise the Strategic Research Program: PJ1, impact assessment; PJ2, improvement of assessment methods; and PJ3, adaptation strategies.

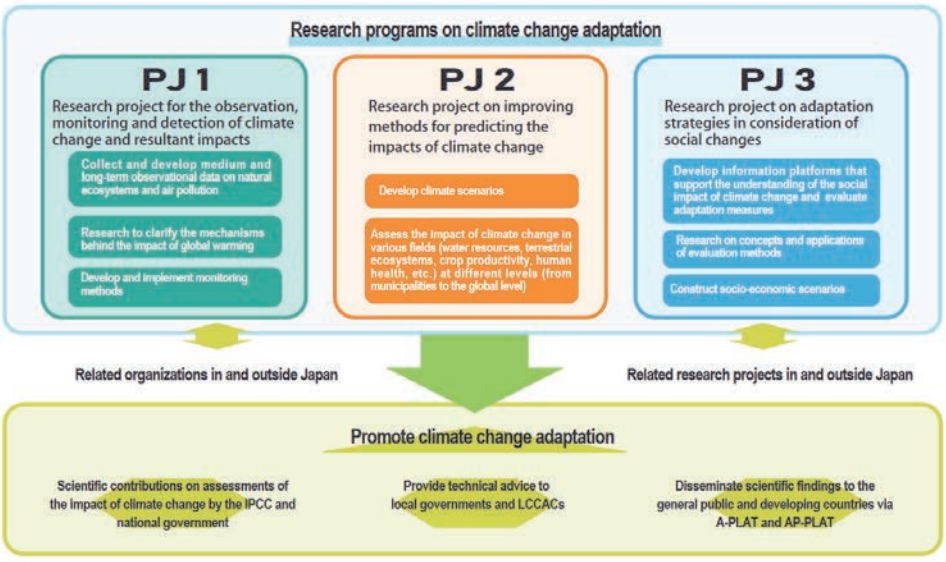


Fig. 5 Structure of our research projects

2.1 Observation, monitoring, and detection of climate change and resultant impacts (PJ1)

In this project, we elucidate the impacts of climate change on terrestrial, terrestrial–water, and coastal ecosystems, as well as on inland bay environments, heat, and health by using observation data in priority target areas. We also provide useful information for planning and promoting adaptation measures. Information on detected climate change impacts, as well as monitoring data that are useful for detecting climate change impacts, will be made public through A-PLAT and AP-PLAT, with the aim of helping to plan and promote regional and local adaptation measures.

In FY 2024, building on past achievements, we gained more concrete and detailed insights about the impacts of climate change in various fields, enriching the foundational information for climate change impact projections. For example, in a study of lake and pond ecosystems (PJ1-3b), a model was developed to explain fish density in the survey target, Lake Yunoko, on the basis of factors such as water temperature and dissolved oxygen. The model predicted changes in fish habitat suitability due to rising water temperatures and decreasing dissolved oxygen levels.

2.2 Improving methods for predicting the impacts of climate change (PJ2)

In PJ2, we are conducting climate change impact assessments by using the latest climate scenarios and socioeconomic scenarios. We are also evaluating impacts with and without adaptation measures by upgrading future climate change impact assessment methods for multiple sectors and scales (global, Asia-Pacific region, and Japan). The purpose of this project is to help advance climate change impact assessment methods and the consideration of adaptation measures, such as the identification of priority areas. The project also aims to contribute to our understanding of climate change risks in society by publishing the climate scenarios that are developed, as well as the results of the impact assessments obtained from them through A-PLAT and AP-PLAT.

In FY 2024, many achievements were made across 12 sub-projects, but two points are particularly noteworthy. First, in a mangrove impact assessment study (PJ2-2b), past and future evaluations were conducted and published as part of the Red List of Ecosystems by the international organization IUCN. The results showed that 50% of mangrove forests are at risk of extinction, and 30% may be submerged because of future sea level rise. Secondly, in a study predicting the distribution changes of biological species due to climate change (PJ2-3f), changes in pollination function distribution under climate change were predicted by using data from Tohoku University's Hanamaru Bumblebee Census and a distribution estimation model developed last year. The results indicated that, under the business-as-usual scenario (RCP8.5), functional diversity would decline across a wide area of the lowlands by the 2090.

2.3 Adaptation strategies in consideration of social changes (PJ3)

In collaboration with PJ1 and PJ2, this project aims to identify gaps and impediments among climate change impact projections, adaptation planning, and adaptation practices, as well as to develop models and methods to ameliorate them. The topics for 2024 included results on the challenges of promoting adaptation in local communities.

In FY 2024, we developed a method to assess regional differences in climate change risk by combining classifications of Japanese regions based on climate change impacts with those based on exposure and vulnerability indicators. By focusing on local governments in eastern Japan, we evaluated how climate affects domestic water use. Our findings showed that, in areas along the Sea of Japan and in highland regions, both summer heat and winter cold lead to increased domestic water consumption. Additionally, we proposed climate change adaptation measures for coral conservation and aquaculture that were based on scientific knowledge of climate change impacts. In our assessment of the promotion of climate change adaptation, we found that small and medium-sized enterprises have less awareness of transition risks than of physical risks.("Transition risks" include risks related to policies and regulations, technology, markets, and reputation, while "physical risks" include acute risks (such as an increase in extreme weather events) and chronic risks (such as sea level rise).) We also demonstrated that certain indicators, such as adaptation goals and the use of scientific knowledge, have improved following revisions to local climate change adaptation plans.

Environmental Information Division

Environmental Information Division

The Environmental Information Division provides information technology (IT) support for research and related functions at NIES and collects, processes, and disseminates environmental information to the general public.

In the fifth Medium- to Long-Term Plan, NIES formed the Portfolio Management Office (PMO), which is responsible for IT project management within the organization. Additionally, with the goal of leading data utilization and data-driven science in the environmental research field in the future, as well as establishing an internal IT infrastructure and a team to support the use of information and data in research activities, a substantial reorganization of the division was considered and implemented. In 2021, the Information System Strategy Working Group was established to discuss the efficient use of computational resources and a new research data infrastructure. In 2022, the public affairs team in the Division was transferred to the Public Relations Office in the Planning Division. In October 2023, the Information Management Office was reorganized into the IT Infrastructure Office, and both the Planning Office and the Database Office were reorganized into the Research Information Office. The work content was also revised to further strengthen the system for supporting research activities and enhancing the dissemination of environmental data.

1 IT Support for Research and Related Activities at NIES

The Division manages and operates the computers and related systems at NIES, uses IT to improve the work efficiency of NIES, and runs a library service.

1.1 Management and operation of computers and related systems

The first NIES supercomputer, an NEC SX-3, was installed in 1991 to elucidate phenomena related to global environmental change and to project future phenomena. The NIES computer system has been updated several times, and in March 2020 the computing performance and storage capacity were vastly improved by the installation of a new system consisting of the following three main elements:

- a vector-processing computer (NEC SX-Aurora TSUBASA A511-64; 256-vector engine, total 2048 CPU, peak performance 622.8 TFLOPS) (Fig. 1)
- a scalar-processing computer (HPE Apollo 2000; 28 nodes, total 1120 cores, peak performance 86.0 TFLOPS)
- a large-capacity file system (Data Direct Networks [DDN] SS9012 etc., total about 22 PB).

A local area network (LAN) called NIESNET was established at NIES in 1992.
In March 2025, NIESNET's network service devices were replaced with a more resilient system.

We are improving user convenience by expanding wireless LAN coverage and enhancing authentication security to support new cloud services.

Fig. 1 The NEC SX-Aurora TSUBASA supercomputer

1.2 Use of IT to improve work efficiency at NIES

The Division provides IT support to the administration and planning divisions of NIES with the aim of increasing work efficiency. It also provides NIES researchers with processed research data and helps them to disseminate their data through the NIES website. In FY 2024, the Division supported:

- development of an electronic application and registration system at NIES
- operation of a thin-client PC management system for the administrative section
- development of the NIES research information database
- modification and operation of a database of basic information on each staff member at NIES.

1.3 Preparation for next-generation research computing infrastructure

We started planning to upgrade to the next computer system for research, and the upgrade should be completed by February 2026. On the basis of discussions by the Working Group and a survey of opinions across the Institute, a committee to consider the next research computing infrastructure was launched in 2023. As the Working Group and committee secretariat, the Division compiled opinions on specifications and conducted hearings with IT vendors.

As a result of the review of the next research computing infrastructure, we newly adopted a virtualization computational infrastructure to meet user needs broadly. For the feasibility study of this infrastructure, we started using “mdx”, a platform for building a data-empowered society (https://mdx.jp/en), and we are working to resolve technical issues and consider operating rules.

1.4 Library services

As of March 2025, the NIES Library (Fig. 2) held 76,572 books, 7489 journals (including electronic resources), and various other technical reports and reference materials. These materials can be searched by using the Online Public Access Catalog (OPAC) and a link resolver via the Intranet. We have also introduced a web-scale discovery service, Primo (Ex Libris). It has the capacity to more easily connect researchers with the library's vast amount of information held in physical holdings, digital collections, and various repositories.

In addition to these resources, researchers at NIES can use abstracts and full-text articles through scientific and technical information databases such as Web of Science (including Essential Science Indicators and Journal Citation Reports).

Library facilities include separate rooms for reading books, journals, and reports. We have two PCs for accessing electronic materials.

Fig. 2 The NIES Library

1.5 Promoting open science

To facilitate the use and application of research resources, prevent the loss of research results, and assure permanent accessibility, we have started attaching digital object identifiers (DOIs) to research data and papers written by our researchers. Accordingly, we have set up a system for publishing URLs (metadata) associated with DOIs on the NIES website, as well as an institutional repository.

The Japanese government's 5-year Science and Technology Basic Plan calls for efforts to promote open science. A working group was established at NIES, and we examined the introduction of an archiving system (i.e., an institutional repository) to be operated and constructed by NIES. As a result of the Group's discussions, we joined the Japan Consortium for Open Access Repository (JPCOAR), and in May 2022 we started to operate JAIRO Cloud, a cloud-based service that provides an institutional repository environment. It is now possible for us to release articles and assign DOIs in response to requests from our researchers. In February 2023, the repository module was changed to the WEKO3 data publishing program to enable the registration of various content types.

In addition, NIES is using the CHORUS Institution Dashboard Service to monitor and understand the status of our researchers' products and activities. In response to the monitoring results, we made improvements to our library systems, including the web-scale discovery service. We are continuing discussions on the information infrastructure required to support the promotion of open science.

1.6 Collection, processing, and dissemination of environmental information

One of NIES's major tasks is the collecting, processing, and disseminating of environmental information. The Division provides various kinds of environmental information to the public through websites. It also processes and manages environmental information databases and provides environmental information via geographic information systems (GIS).

1.6.1 Environmental Observatory (Information Platform for Environmental Outlook)

The Environmental Observatory (Information Platform for Environmental Outlook) is a multimedia site providing integrated environmental information to promote wider involvement of the public and relevant institutions in environmental conservation. It gives users broad access to a range of systematically organized environmental information aimed at creating a sustainable society. The site offers a quick search facility to access news updates on environmental issues in Japan and across the globe; descriptions of key environmental technologies; environmental information via GIS; and other content to aid environmental learning.

1.6.2 Processing and management of environmental information databases

Various environmental data are needed for research, policy decisions, and policy enforcement. We compile and process air-quality data collected by local governments. These processed data can be accessed through the database on the NIES website. A lending service is also available.

1.6.3 Provision of environmental information via GIS

The Division, in cooperation with the Ministry of the Environment (MOE), has been using GIS to develop an environmental data provision system. By displaying data on environmental quality and other information on maps, this system helps users to easily understand the status of the environment. The system has been publicly available through the Internet since July 2010 and has since been updated as needed in response to user requests. The cloud-based GIS data platform can also be linked to the integrated GIS infrastructure system promoted by MOE, and we plan to share mutual data in the future.

Inquiries:
International Coordination Office
Facsimile:＋81-29-851-2716
E-mail:international@nies.go.jp

National Institute for Environmental Studies
16-2 Onogawa, Tsukuba, Ibaraki 305-8506, JAPAN
https://www.nies.go.jp/

NIES Publications
https://www.nies.go.jp/kanko/index-e.html

Editorial assistance: MAEDA Printing Co., Ltd.