

NIES Annual Report

2026

AE - 32 - 2026



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

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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 2025 (FY2025: April 2025 to March 2026) which marked the final year of our Fifth Five-Year Plan (FY2021-FY2025). This report marks an important milestone that not only summarizes our efforts to date but also lays the foundation for our next Five-Year Plan.

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 have also steadily developed *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.

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 have been 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. The third GOSAT was successfully launched and preparations were made for the release of its observation data, and the birth cohort study to children aged 13 years and older has also been continued. As for climate change adaptation, we are conducting research and providing technical assistance to local governments to promote adaptation.

As Japan's core institute for environmental research, NIES will continue to work closely with related organizations and contribute to the society. Through collaborative research with leading research institutions both domestically and internationally, we address a broad range of environmental challenges. In collaboration with local governments, communities, and citizens, we are also advancing diverse initiatives to tackle climate change, promote nature restoration, and support the transition to a circular economy.

This Annual Report aims to inform the public of our research activities. Moving forward, we will remain committed to addressing environmental challenges through policy support grounded in scientific knowledge and meaningful engagement with society. We would greatly appreciate your candid feedback and perspectives as we shape our future activities.



Yoshito OSHIMA
President
September 2026

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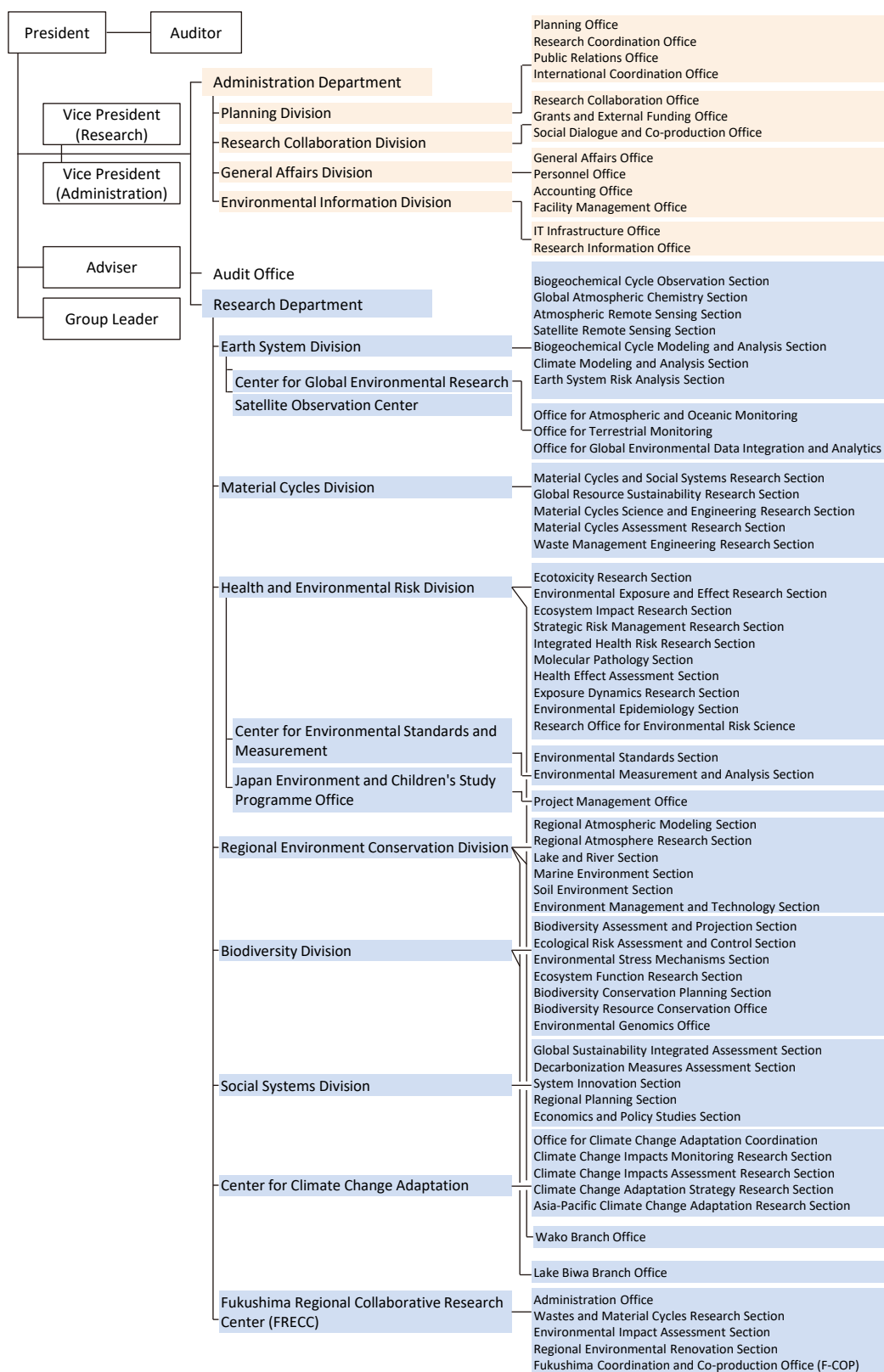
During the 1950s and 1960s, Japan experienced serious environmental pollution problems accompanying rapid economic growth. The Environment Agency was established in 1971 as part of the Japanese government to develop measures to counteract serious problems associated with environmental pollution, such 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, 2025, there are 310 NIES permanent staff and 626 contract staff (Table 1; Figs. 2 to 5). The total budget for FY2025 was 21,475 million yen (Table 2).

Table 1
Numbers of
permanent
staff

(As of April 1, 2025)

Administration Department	76	
Research Department	228	(2)
Audit Office	1	
Executives and Advisers	5	
Total	310	(2)

Table 2
Budget for
the Fifth
Five-Year
Plan

(Unit: million yen)

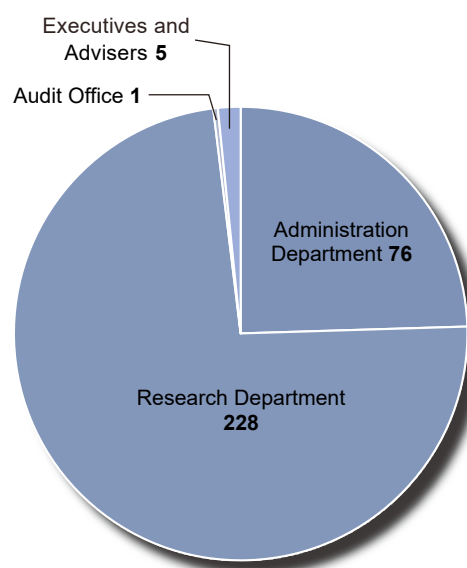
	Category	2021-2025 Budget (5 years)	Fiscal Year 2025 Budget
Revenue	Grants for Operating Costs	85,277	17,177
	Subsidies for Facilities	2,003	662
	Commissioned Work	18,428	3,636
	Total	105,708	21,475
Expenditure	Project Costs	66,315	13,241
	Facility Improvements	2,003	662
	Expenses for Commissioned Work	18,179	3,636
	Personnel Expenses	17,069	3,533
	General Administrative Expenses	2,141	402
	Total	105,708	21,475

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	:	76	
Research Department	:	228	(2)
Audit Office	:	1	
Executives and Advisers	:	5	
Total		310	(2)

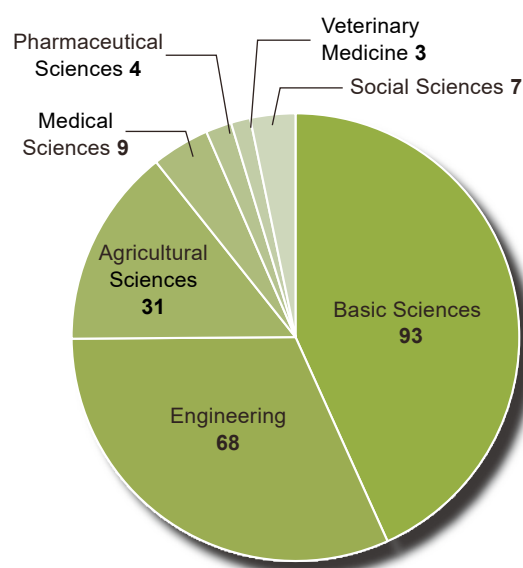
Notes:

1. Data is as of April 1, 2025.
2. Figures in parentheses indicate number of foreign nationals.

Fig. 2 Permanent Staff breakdown


Basic Sciences	:	93	43.26%
Engineering	:	68	31.63%
Agricultural Sciences	:	31	14.42%
Medical Sciences	:	9	4.19%
Pharmaceutical Sciences	:	4	1.86%
Veterinary Medicine	:	3	1.39%
Social Sciences	:	7	3.25%
Total		215	

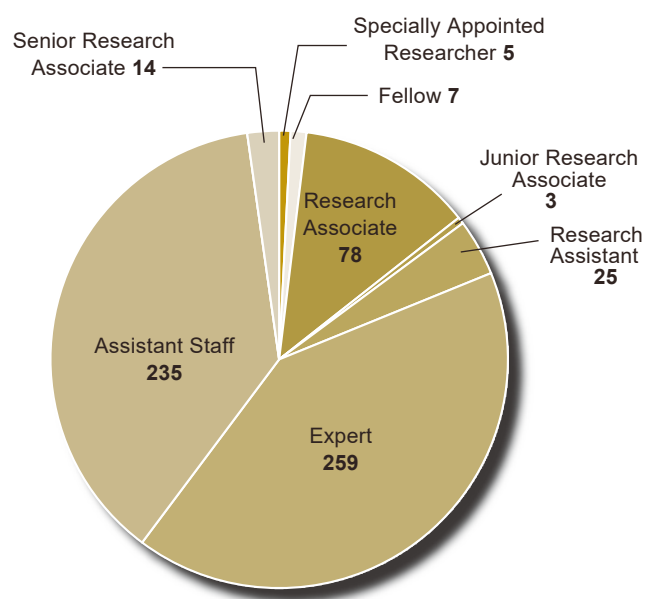
Note: Data is as of April 1, 2025.

Fig. 3 Fields of expertise (Researchers holding doctorates (98.6%))


Fellow	:	7	
Research Associate	:	78	(50)
Junior Research Associate	:	3	
Research Assistant	:	25	(9)
Senior Research Associate	:	14	(2)
Expert	:	259	(11)
Assistant Staff	:	235	
Senior Staff	:		
Specially Appointed Researcher		5	
Total		626	(72)

Notes:

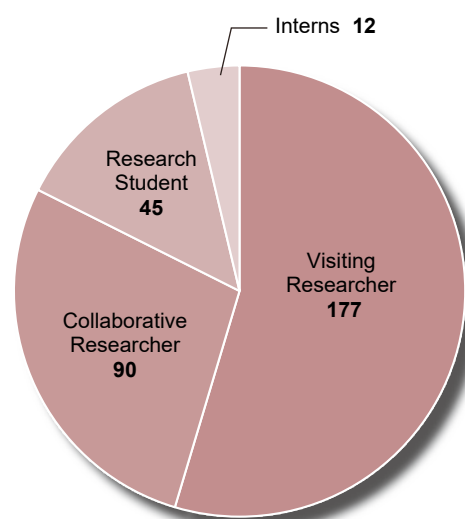
1. Data is as of April 1, 2025.
2. Figures in parentheses indicate number of foreign nationals.

**Fig. 4** Contract Staff Breakdown

Visiting Researcher	177	(17)
Collaborative Researcher	90	(12)
Research Student	45	(13)
Interns	12	(9)
Total	324	(51)

Notes:

1. Data is the total number accepted in FY2025.
2. Figures in parentheses indicate number of foreign nationals.

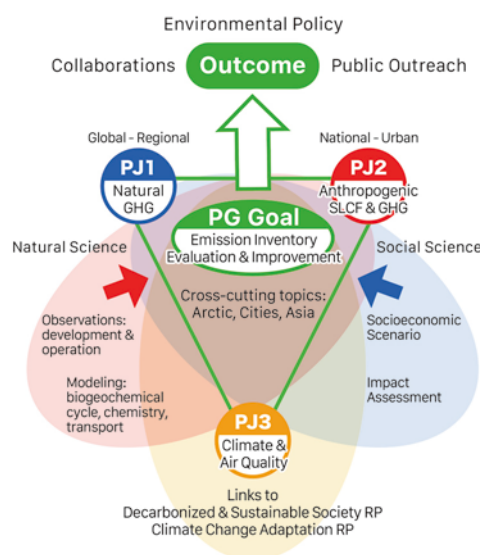
**Fig. 5** Visiting and Collaborative Researchers, Research Students, and Interns

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 at 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



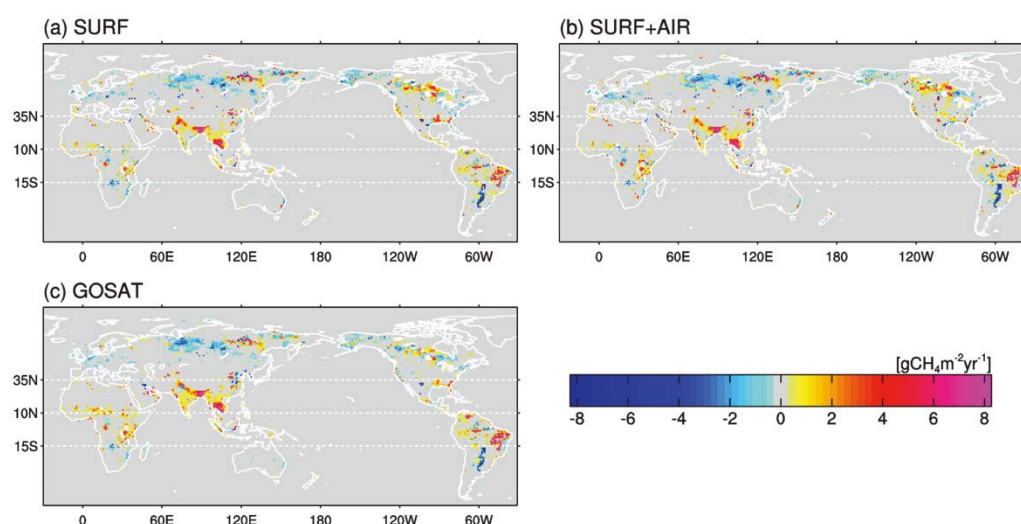
Project 1. Quantitative evaluation of natural/anthropogenic GHG sources and sinks on the global scale

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.

To identify the main drivers of the recent rapid increase in atmospheric methane (CH₄) growth rates, we have used an inverse model to estimate regional and sectoral

emission changes for the period 2016–2022. Three inverse estimates were based on different sets of atmospheric CH₄ observations: surface observations only, “SURF”; surface and aircraft observations, “SURF+AIR”; and GOSAT (Greenhouse gases Observing SATellite) observations, “GOSAT.” From 2016–2019 to 2020–2022, the spatial patterns of CH₄ emission increases were consistent in the three inversions. In a comparison of the differences in CH₄ emissions from the 2016–2019 mean, defined as $\Delta f\text{CH}_4$ (Fig. 2), the areas with notable positive $\Delta f\text{CH}_4$ values ranged from the tropics to the northern high latitudes. The increase in the northern low latitudes (10°N–35°N) was particularly noteworthy. The three inversions consistently estimated that northern South Asia (Bangladesh and northern India) and mainland Southeast Asia were major contributors to the increase. In the northern high latitudes (35°N–90°N) and tropics (15°S–10°N), areas with large emissions increases were also consistently estimated, but their magnitudes differed, especially between the SURF or SURF+AIR inversions and the GOSAT inversion. For example, emissions in the northern North America and African Sahel regions were estimated as smaller and larger, respectively, in the GOSAT inversion.

Fig. 2 Spatial patterns of total net CH₄ emissions increases ($\Delta f\text{CH}_4$) from 2016–2019 to 2020–2022 in the SURF (a), SURF+AIR (b), and GOSAT (c) inversions (taken from Fig. 4 of Niwa et al., 2025). SURF, surface observations; SURF+AIR, surface and aircraft observations; GOSAT, Greenhouse gases Observing SATellite



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 CH₄ for 2020–2022. *Atmospheric Chemistry and Physics* 25, 6757–6785, <https://doi.org/10.5194/acp-25-6757-2025>

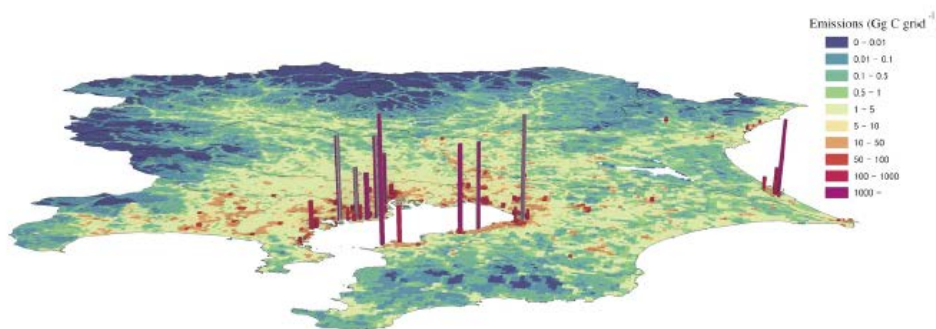
Project 2. Quantitative evaluation of anthropogenic SLCF and GHG emissions on regional, national, and city scales

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.

Subnational climate actions, such as the decarbonization of cities, require timely and spatially granular GHG information. However, commonly used emissions datasets often do not capture subnational variations, because such differences are masked by national-level aggregation. We have developed the National Emissions Modeling System for GHG emissions in Japan (NEMS-GHG), a framework for modeling monthly emissions at 1×1 -km spatial resolution. It enables us to estimate FFCO₂ (fossil-fuel CO₂) emissions for eight sectors, with sector-specific spatiotemporal variations derived from publicly accessible socioeconomic statistics (Fig. 3). Annual FFCO₂ emissions from NEMS-GHG closely matched those reported in Japan's National Greenhouse Gas Inventory. At the subnational scale, NEMS-GHG reproduces regional variations reasonably well, although noticeable discrepancies appear in electricity generation and industry and commerce when compared with a widely used global dataset. Comparisons of 1-km emissions distributions show differences exceeding 100% for about 4% to 8% of grid cells with emissions ≥ 10 Gg C year⁻¹. With further refinement to improve sector-specific spatial distributions, NEMS-GHG should provide a transparent and detailed bottom-up framework capable of estimating recent emissions from local socioeconomic sources at the municipal and prefectural scales. This will support the development and evaluation of subnational mitigation strategies by identifying locally relevant emission sources.

Fig. 3 Distribution of annual FFCO₂ (fossil-fuel CO₂) emissions (Gg C grid⁻¹) in the Tokyo Metropolitan area in 2015 at a spatial resolution of 1 km (taken from Fig. 2 of Saito et al., 2026)



Reference:

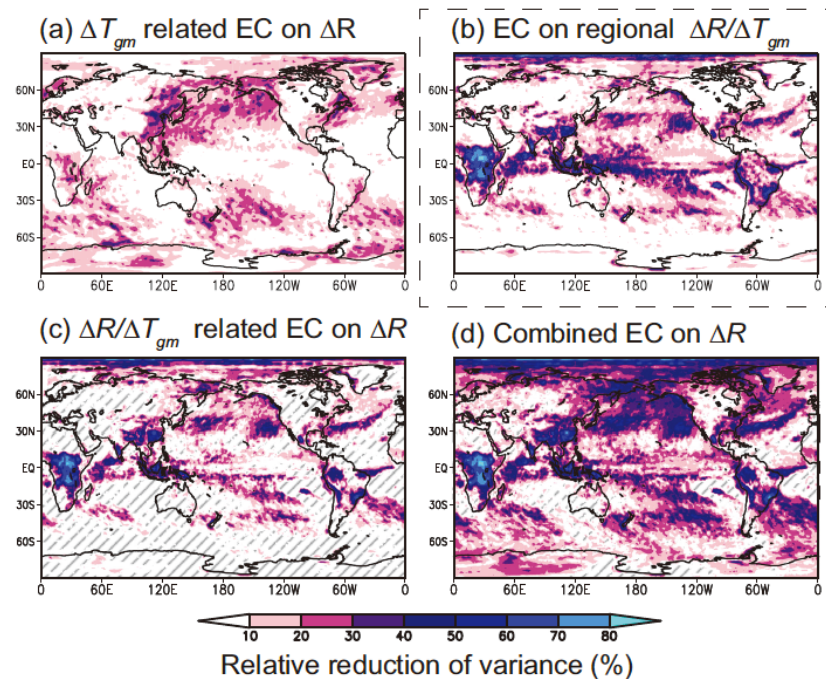
Saito, M., Yamada, H. and Oda, T. (2026) A 1×1 km spatially explicit framework for modeling fossil fuel CO₂ emissions across Japan to support subnational climate mitigation actions. *Mitigation and Adaptation Strategies for Global Change* 31, 42, <https://doi.org/10.1007/s11027-026-10313-5>

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.

Recent studies have shown that the observed global warming trend over recent decades provides efficient constraints not only for future global mean temperature increases (ΔT_{gm}) across Earth system models but also for changes in several climate variables that include significant ΔT_{gm} -related uncertainty. However, ΔT_{gm} -related emergent constraints (ECs) cannot reduce the uncertainty unrelated to ΔT_{gm} . To overcome this limitation, we have developed an EC method and are applying it to future changes in the annual maximum daily precipitation in order to reduce uncertainty in the modeling. An EC for precipitation sensitivity based on historical extreme precipitation biases is combined with the constrained ΔT_{gm} . This combined EC decreases the variance of the global mean precipitation by 42%—an improvement from using only temperature (resulting in 26% reduction). Moreover, it decreases the variance in regional precipitation by $\geq 30\%$ in 24% of the globe; in contrast, $\geq 30\%$ reduction is seen in only 2% of the globe with the temperature-related EC) (Fig. 4).

Fig. 4
Reduction in the variance of the regional extreme precipitation change (ΔR). Shading shows the relative reduction in variance (RRV, %) in the regional ΔR (2051–2100 minus 1851–1900) based on (a) the temperature-related emergent constraint (ΔT_{gm} -related EC); (b) the RRV of $\Delta R/\Delta T_{gm}$; (c) the sensitivity-related ($\Delta R_{gm}/\Delta T_{gm}$ -related) EC; and (d) the combined EC. Gray hatching in panels (c) and (d) indicates where the RRV becomes negative (taken from Fig. 4 of Shiogama et al., 2025). ΔR_{gm} , global mean extreme precipitation change; ΔT_{gm} , global mean temperature increase



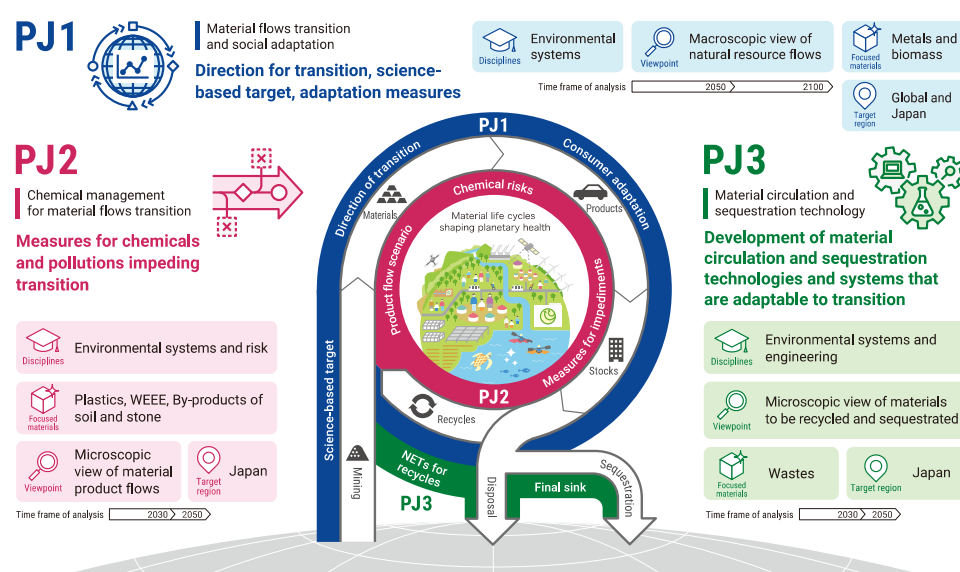
Reference:

Shiogama, H., Hayashi, M., Hirota, N., Ogura, T., Kim, H., and Watanabe, M. (2025), Combined emergent constraints on future extreme precipitation changes. *Nature Communications* 16, 5293, <https://doi.org/10.1038/s41467-025-60385-1>

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 the 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



Throughout the 5-year research period, in addition to the research plans for each project, we have steadily implemented collaborative initiatives across projects. While building a body of academic research, we have conducted outreach activities—including engagement with UNEP (the United Nations Environment Programme), the media, and public forums—to enhance the social impact of our findings. We have also entered into joint research agreements with multiple companies to facilitate the practical implementation of our results in society. Our self-assessment of the results indicates that we have achieved the three project-specific end-of-project goals: “PJ1: Launch material flow management based on scientific targets for producers and consumers”; “PJ2: Contribute to harmonious material cycle and chemical management policies compatible with the realization of a new material cycle”; and “PJ3: Systematize waste treatment and disposal systems suitable for a decarbonized society.” Overall, the project concludes that it has created the starting point for a trend toward “a long-term innovation strategy for material flows” by returning scientific insights—which serve as the foundation for material flow innovation—to society. The following is a summary of the results for each project.

Highlighted research findings

Project 1: Material flows transition and social adaptation

Transitioning to a circular economy is inherently complex because it involves a diverse array of stakeholders adopting different practices at various temporal levels that lead to emergent macro-level behaviors. This complexity presents the dual challenges of overcoming limited consumer acceptance, interest, and awareness while ensuring sustainability gains and addressing concerns associated with rebound effects (e.g., unintended emissions resulting from increased production or transport associated with circular business models).

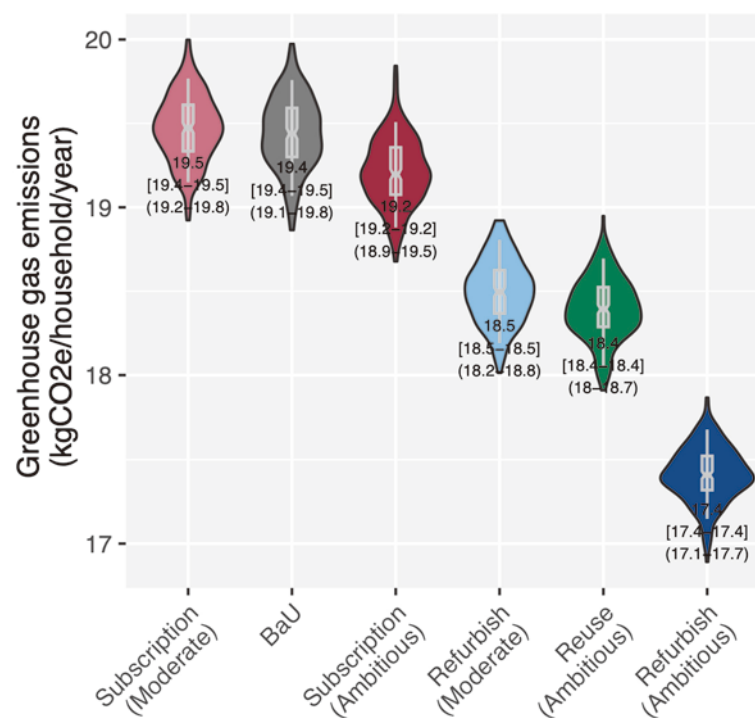
In a previous project year, we developed an agent-based model for circular business models. However, a substantial remaining challenge lay in its empirical basis—particularly for consumer decision-making. Although some existing studies have utilized survey or census data, a robust methodology for mapping survey data to agents' decision-making rules within agent-based modeling frameworks and the circular economy has not yet been established.

This study evaluated the circularity and environmental impacts of circular business models over a 30-year period. It used an empirically grounded agent-based model coupled with life-cycle assessment and material flow analysis. We developed a methodology to parameterize agents' decision-making by using data from demographically representative surveys and to prospectively assess the sustainability impacts of circular strategies. The case study examined three circular business models, namely, reuse, refurbishment, and subscription of refrigerators and laptops in Japan. Simulation experiments using an agent-based model with six scenarios were conducted to evaluate the contributions of circular business models toward enhancing circularity and reducing greenhouse gas emissions over the next 30 years.

Results from the global sensitivity and scenario analyses revealed that manufacturer-led refurbishment could reduce the emissions of society as a whole by 10% to 12% (see Fig. 2 for laptop results) and extend product lifetimes by 30% to 33%. In contrast, the subscription model showed minimal benefits, with improvements of only 0% to 3%, primarily because of consumer preferences for new products. The most important driver of emissions reductions was the decreased need to manufacture new products. These reductions were primarily due to increased product circulation (from refurbished and reused items) and extended product use. Conversely, the limited impacts of subscription services could be attributed to consumer preferences for brand-new products and the cannibalization of other circular business models, such as traditional reuse. These findings imply that the effects of circular business model configurations are largely dependent on each other. Therefore, a mixed policy approach is advisable, rather than the implementation of strategies in isolation.

Compared with conventional methods, including life-cycle assessment, material flow analysis, and discrete event simulation, our model advances sustainability assessment in three ways: by representing the national-scale market, explicitly modeling heterogeneous consumer decision-making within a socio-technical system, and dynamically assessing product lifetime and circularity. Our consequential approach extends beyond technical strategies to evaluate the effectiveness of strategies targeting consumer behavior, including pricing, advertisements, and improvements in repair and collection services. The findings highlight the need for combining synergistic circular and diffusion strategies and suggest the need to reorient policy efforts from end-of-life material recovery to refurbishment, reuse, and repair, supported by intensive campaigns and substantial price reductions in circular offerings.

Fig. 2 Life-cycle greenhouse gas emissions by circular business models for laptops in Japan during years 21 to 30 of the simulation.¹⁾ BaU, business as usual



Reference:

- 1) Koide, R., Murakami, S., Yamamoto, H., Nansai, K., Quist, J., Chappin, E. Prospective life cycle and circularity assessment of circular business models using an empirically grounded agent-based model. *Journal of Industrial Ecology* 2025, 29(5), 1897–1911

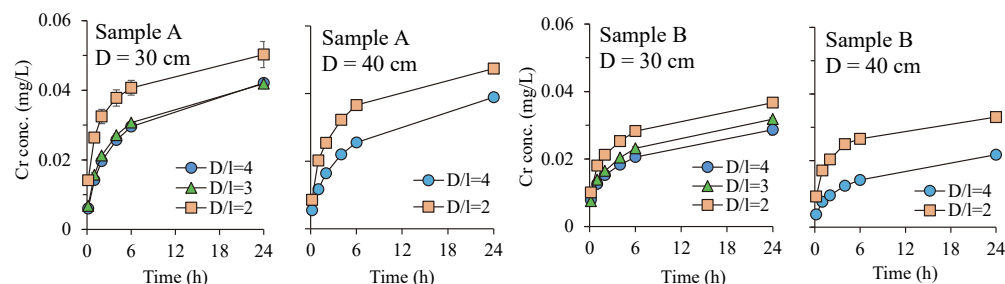
Project 2: Chemical management for material flows transition

Waste concrete—one of the major types of construction wastes in Japan—is predominantly reused as recycled concrete aggregate (RCA) in road base applications. Because trace amounts of hexavalent chromium derived from cement may leach from RCAs, the acceptability of this material's reuse has been conventionally assessed with reference to Japan's soil environmental quality standard (leaching criterion: 0.05 mg/L). With the recent tightening of the drinking water standard and the environmental quality standards for public water bodies and groundwater for hexavalent chromium (to 0.02 mg/L), a corresponding revision of the soil standard is anticipated. Under these circumstances, hexavalent chromium leaching exceeding the revised standard could substantially hinder the continued use of RCAs in road base applications. By FY 2024, we had demonstrated that introducing an evaluation approach based on a test method that better reflects the actual reuse conditions of RCAs, such as the as-is stirring test, could enable the continued effective use of RCAs while ensuring environmental safety, even under a stricter soil environmental quality standard.

In FY 2025, with the aim of establishing practical and reliable testing conditions for the as-is stirring test, we conducted leaching tests within the range of conditions specified in Japanese Industrial Standard (JIS) K 0058-1 (Leaching test methods for slags) and examined the effects of the test conditions on the concentration of hexavalent chromium in the leachate. Comparable results were obtained for sample masses of 3 kg (tank diameter: 40 cm; water volume: 3 L) and 1 kg (tank diameter: 30 cm; water volume: 1 L), suggesting that the influence of sample masses on reuse acceptability judgments based on the reference criterion is limited. These findings indicate that the test can be scaled down while maintaining practical applicability. In terms of apparatus conditions, the effect of tank diameter on the concentration of hexavalent chromium in the leachate was limited, whereas longer mixing blades resulted in higher concentrations (Fig. 3).

In addition, the concentration of hexavalent chromium in the leachate increased markedly during the 6-h test period specified in the JIS and continued to increase gradually thereafter. The initial rapid increase was attributed to wash-off from particle surfaces, whereas the subsequent gradual increase was attributed to diffusion within the solid phase. These findings suggest that, under field conditions where groundwater is flowing, the initial increase in chromium leaching is the most relevant process to consider. Therefore, the 6-h test specified in the JIS appears sufficient for evaluating chromium leaching from recycled crushed concrete under real-world reuse conditions.

Fig. 3 Effects of tank diameter (D) and mixing blade length (l) on chromium concentration in the leachate during the propeller stirring test



To propose a framework for managing chemicals and environmental pollutants in harmony with material circulation, we synthesized the findings from case studies conducted over the course of the 5-year project. The analyses revealed two major categories of barriers to recycling: (i) the presence or leaching of hazardous substances in recycled materials; and (ii) environmental releases or accidents occurring during recycling processes. Correspondingly, effective mitigation measures can be grouped into three approaches: preventing the entry of hazardous substances through source separation; controlling releases and accidents during recycling processes; and implementing appropriate decision-making checkpoints based on actual reuse conditions.

The first approach is particularly effective when only a small fraction of the waste stream contains problematic substances, as demonstrated by the cases of chemical additives in plastic recycling streams and lithium-ion batteries mixed into municipal waste streams. The second approach applies to situations where environmental releases or accidents occur during recycling processes—such as microplastic releases from recycling processes and battery-related ignition and fire incidents. The third approach is important when hazardous substance content or leaching constrains recycling, as observed in the case of chemical additives in plastic recycling streams and heavy metals leaching from recycled construction materials. In such cases, recycling suitability should be evaluated by using test methods and decision criteria that reflect actual reuse conditions, thereby placing management checkpoints at appropriate stages of the recycling chain. In some cases, this approach can be combined with the removal of hazardous substances during recycling processes.

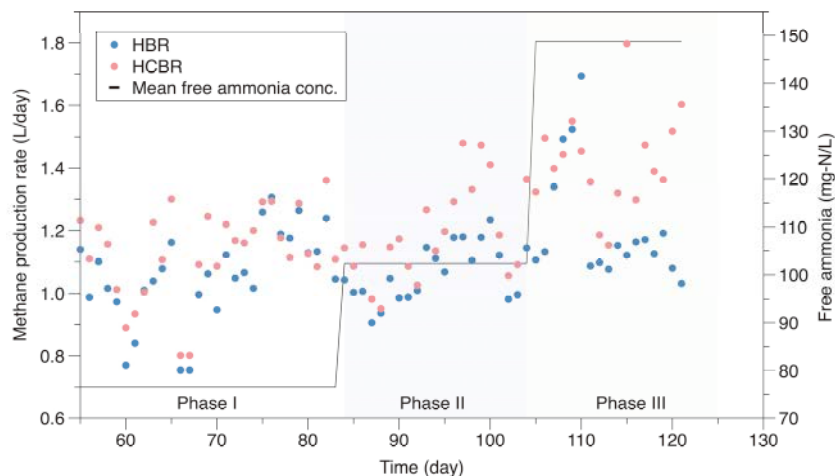
These findings suggest that the management of chemicals and environmental pollutants in harmony with material circulation can be achieved by using the following strategies: keeping problematic chemicals and pollutants within closed loops; preventing exposure and damage; and implementing appropriate checkpoint-based management. The framework provides a basis for identifying effective measures for a wide range of waste streams and pollutants. It supports the development of chemical and environmental pollutant management approaches that are aligned with the transition to a circular economy.

Project 3: Material circulation and sequestration technology

We investigated the effects of biochar addition on the operational performance of an in-situ biomethanation system (CO_2 to CH_4 conversion), in which hydrogen was externally supplied to a continuous anaerobic digestion process using food waste as the substrate. The system combining hydrogen supply and biochar addition, referred to as HCBR, exhibited a performance superior to both a hydrogen-added reactor without biochar, referred to as HBR, and a conventional anaerobic digestion reactor, referred to as BR. This superiority was observed in terms of CH_4 (methane) production, CO_2 consumption efficiency, hydrogen utilization efficiency, and tolerance to operational fluctuations. Under normal operation without hydrogen addition (in BR), the methane yield was approximately 371 to 377 mL/g-VS (volatile solids). Hydrogen addition (in HBR) increased the methane yield to approximately 577 to 606 mL/g-VS. Furthermore, in the HCBR system, where hydrogen addition was combined with biochar supplementation, the methane yield ultimately reached 722 ± 60 mL/g-VS, representing a 95% increase compared with conventional anaerobic digestion without hydrogen addition.

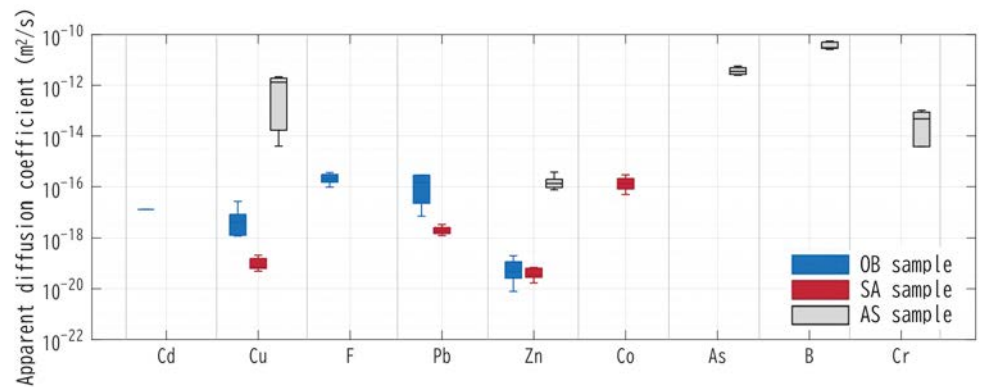
Clear differences were also observed in the response of each system to changes in operating conditions. During Period III (see Fig. 4), in which the hydrogen supply rate was increased and the gas circulation rate was further varied, CO_2 consumption in the liquid phase caused an increase in pH, which in turn led to an increase in free ammonia concentration. In the HBR system, the methane concentration decreased to below 50%, residual hydrogen accumulated, and the process became unstable. In contrast, the HCBR system maintained a methane concentration of approximately 65%, indicating that stable gas conversion performance was retained even under conditions of high hydrogen partial pressure (Fig. 4). In the liquid phase, both systems showed risks of pH elevation and increased free ammonia concentration associated with hydrogen addition. However, correlation analysis suggested that biochar mitigated inhibition of methane production without substantially altering the liquid-phase characteristics, while promoting hydrogen utilization and CO_2 -to- CH_4 conversion. In addition, cost evaluation indicated that the total profit of the system incorporating HCBR reached 50.5 USD/m³-fed, which was 47% higher than that of BR and 20% higher than that of HBR. These findings demonstrate that biochar addition in hydrogen-assisted anaerobic digestion of food waste is not merely an auxiliary amendment; it is also an effective strategy for simultaneously improving CO_2 conversion efficiency, operational stability, and economic performance.

Fig. 4 Relationship between free ammonia concentration and methane production rate from the bioreactor during in-situ CO_2 methanation of food waste. Control, hydrogen-added reactor without biochar (HBR); Biochar addition; hydrogen supply and biochar addition (HCBR)³⁾

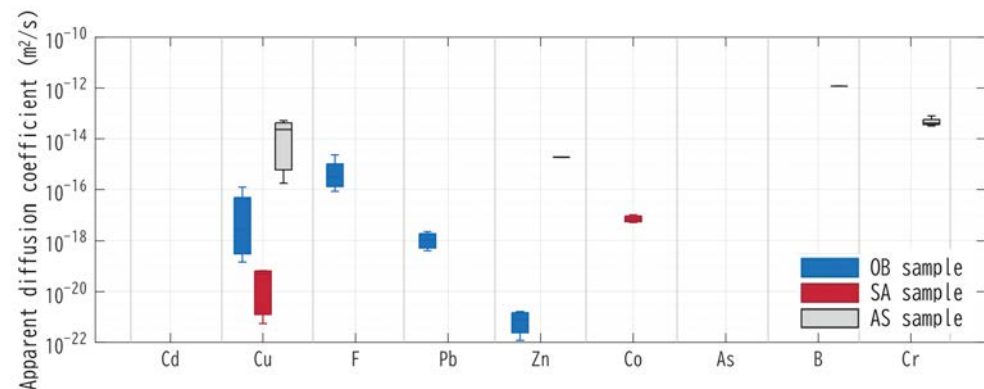


We also investigated long-term environmental safety in response to the risk of the functions of isolated-type landfills being compromised by aging or earthquakes. The effectiveness of solidification treatment using cement-based materials or magnesium oxide (MgO) in suppressing the migration of hazardous substances was evaluated. Test results using actual, specially controlled waste revealed that the strength development of a blast-furnace slag cement (Type B) was inhibited by lead and organic matter, making it difficult to achieve the requirement of 0.98 MPa compressive strength. Although the MgO-solidified specimen did not develop strength, it maintained a weakly alkaline environment (pH approximately 10.5) and markedly suppressed the leaching of most substances, except for arsenic and boron. We compared the effects of containment in terms of the apparent diffusion coefficient, which was reduced to less than one-thousandth of the self-diffusion coefficient in free water, for metals of Cd, Cu, F, Pb, Zn and Co in all solidified samples tested (Fig. 5). Future research on retardation of the leaching of arsenic and boron should focus on physical methods of delaying leaching, such as increasing density through compaction or enhancing flexibility by adding fly ash, rather than on approaches that rely on chemical binders or adsorbents.

Fig. 5 Apparent diffusion coefficients of hazardous wastes solidified with blast-furnace slag cement or $\text{MgO}^{(4)}$: “OB sample” refers to residue generated during open blasting using iron grit; “SA sample” refers to residue generated during paint removal using a stripping agent; and “AS sample” refers to residue generated during the removal of plating under strongly alkaline conditions.



(a) Solidified by blast-furnace cement



(b) Solidified by MgO

We then developed a mathematical model usable in spreadsheet software to estimate the long-term risk regarding isolation facilities, to enable landfill operators and local authorities to conduct assessments. The model takes into account the deterioration (cracking) of the containment facility and combines the leaching rate of hazardous substances (the apparent diffusion coefficient) with the adsorption delay in the subsurface (the distribution coefficient) to provide a simple prediction of changes in leakage and groundwater migration over time. This provides a scientific basis for forecasting long-term safety in the design of isolation schemes.

As a technical document to serve as a guideline for ensuring the long-term environmental safety of hazardous waste isolation facilities, we have compiled five key indicators: stability of the isolation structure, surface treatment of the structure, solidification treatment of hazardous waste, natural barriers (adsorption layers), and exposure assessment. Our findings provide a foundation for operators, local authorities, and residents to discuss safety on the basis of a shared understanding of potential risk. This will help to improve the reliability and transparency of future hazardous waste isolation schemes.

Reference:

- Li Y., Kobayashi T. (2025) Impacts of biochar addition on anaerobic digestion

of food waste with hydrogen. *Bioresource Technology* 438, 133245

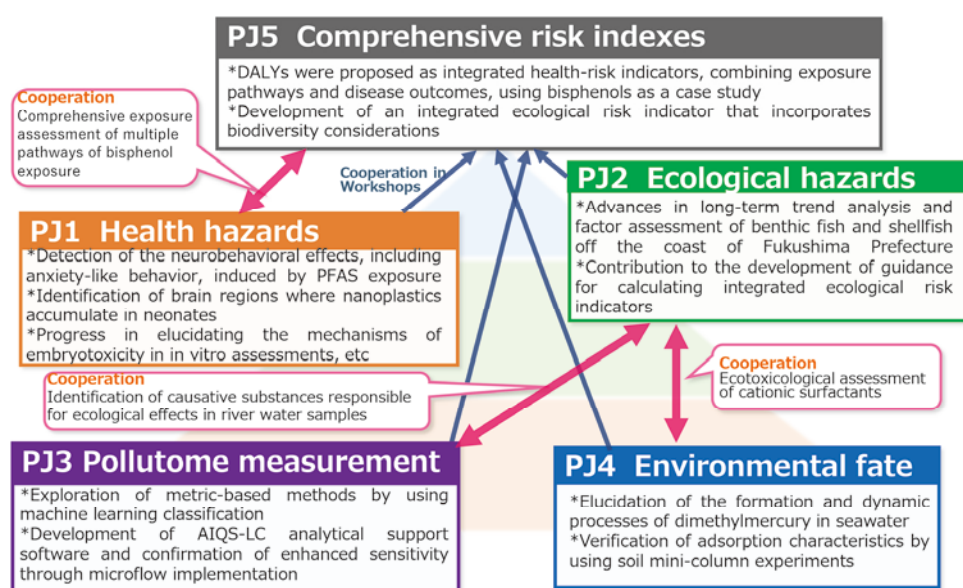
4) Ishimori H., Nagamoto K., Ishigaki T., Yamada K., Yamada M. (2025) Effectiveness on decreasing leaching rates by solidifying hazardous incineration ash and sludges using cement and MgO. *Journal of the Japan Society of Material Cycles and Waste Management* 36, 34–48, 10.3985/jjsmcwm.36.34

Comprehensive Environmental Risk Research Program

In this program, we conducted five projects to accomplish our annual goals (Fig. 1). We aimed to more comprehensively investigate the environmental risks of most chemicals of concern and to consider the susceptible groups and life stages of humans (Project 1) and of other organisms and ecosystems (Project 2). We also upgraded our comprehensive measurements of the pollutome (Project 3) and performed further studies to better understand the environmental fate and transport of chemicals (Project 4), as well as the effects and risks that have been hard to quantify. As a result of these efforts, we have proposed and established a few comprehensive health risk indexes and ecological risk indexes (Project 5).

Through the continuous implementation of this 5-year research program, Projects 1 through 5 were successfully implemented as originally planned (Fig. 1). We obtained substantial outcomes that will contribute to a comprehensive understanding of the risks posed by chemicals of concern, including those that are unknown, insufficiently characterized, or currently unregulated. In particular, the human health-hazard information selected through the collection and organization of experimental data and literature in Project 1 was effectively utilized in Project 5 to develop health-hazard indicators. In addition, collaborative efforts between Projects 2 and 3 enabled us to identify the substances responsible for causing ecotoxicity in river waters. This research will continue under the Safety Assurance Project in the upcoming sixth Five-Year Medium- to Long-Term Plan starting in FY 2026. Furthermore, the findings from this program—particularly those related to per- and polyfluoroalkyl substances (PFAS), plastics, and antimicrobial agents—have made important contributions to the formulation of one of the cross-cutting research programs in the sixth plan, namely the “Cross-Media Understanding and Solution Program.”

Fig. 1 Overview of inter-project cooperation and major progress in the Comprehensive Environmental Risk Research Program in FY2025. PFAS, per- and polyfluoroalkyl substances; AIQS-LC, liquid chromatography with automated identification and quantification systems; DALY, disability-adjusted life year. One DALY represents a loss equivalent to one year of life, combining losses from premature death and disability.

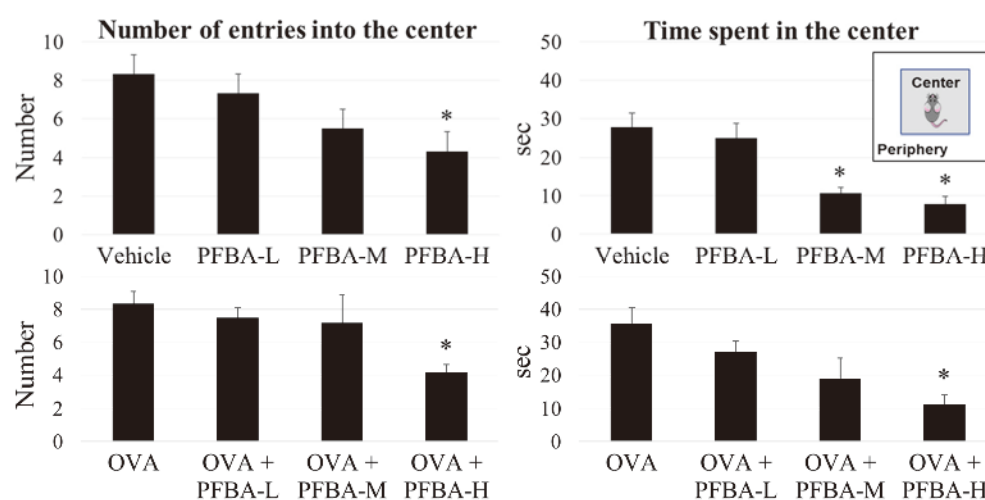


Project 1. Health hazard assessment considering the real-life environment and vulnerabilities

We developed methodologies to assess the human health hazards of chemicals, considering exposure in the general environment and among vulnerable populations. We investigated the impacts of chemical exposure on disease, aging, and future generations. Our major findings in immunotoxicity, neurodevelopmental toxicity, aging, and the development of novel *in vivo* and *in vitro* evaluation systems are summarized below.

To elucidate the mechanisms by which oral exposure to perfluorobutanoic acid (PFBA) exacerbates allergic asthma, we analyzed the gut microbiota, neuroimmune parameters, and related factors. PFBA altered the relative abundance of inflammation-associated bacteria. It also induced anxiety-like behavior regardless of allergen sensitization (Fig. 2), accompanied by corresponding gene expression changes in the prefrontal cortex. Additionally, perfluorooctanoic acid induced anxiety-like behavior in senescence-accelerated mouse prone 8 (SAMP8) mice.

Fig. 2 Oral PFBA exposure induces anxiety-like behavior in an open field test. Animals with lower anxiety typically spend more time in the center area; however, PFBA exposure at high concentrations significantly reduced both the number of entries into the center and the time spent there. Similar trends were observed when PFBA exposure was combined with allergen (OVA; ovalbumin) exposure. Data are expressed as means $\pm$ SE for six animals per group. * $P < 0.05$ versus the Vehicle group (upper panels) or the OVA group (lower panels). PFBA-L: 2 ng/kg/day; PFBA-M: 20 ng/kg/day; PFBA-H: 200 ng/kg/day



In our cell-based model, we examined the neurotoxic effects of various isocyanates and found that isophorone diisocyanate exhibited a strong toxic effect on neuronal cells. In an animal model, fluorescently labeled polystyrene nanoplastic particles were orally administered to neonatal subjects, and the localization of nanoplastics in the brain 24 h later was examined by using light-sheet fluorescence microscopy. Accumulation was observed in specific brain regions—particularly in the periventricular area.

In parallel, we pursued three additional approaches to develop sensitive methods for evaluating the effects of chemical exposure. First, a refined behavioral analysis method in mice was established to reduce experimental noise. Second, we investigated factors in infant formula that strongly stimulate the secretion of a gut hormone deeply involved in the regulation of metabolism. Thirdly, we used

preimplantation embryo culture systems. Comparative analyses by using pesticides with relatively well-defined mechanisms of action suggested the existence of candidate pathways underlying embryonic growth suppression.

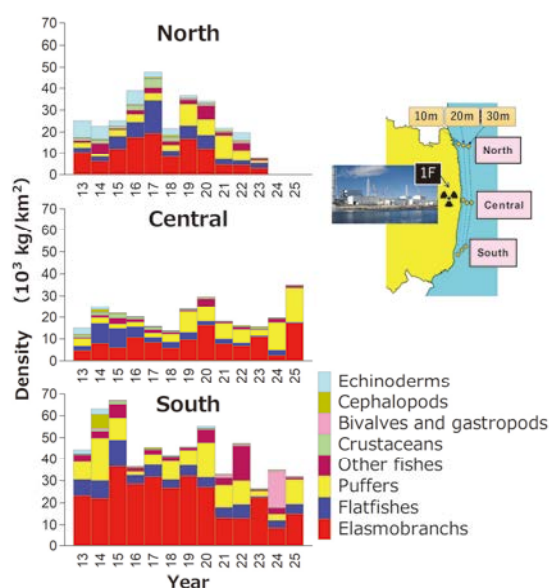
Project 2. Ecological hazards and factor analysis considering vulnerabilities

We continued regular field surveys in Tokyo Bay and the coastal waters off Fukushima, Japan. In Tokyo Bay, surveys were conducted twice, in August and November. The results showed that the densities of small- to medium-sized fishes and shellfishes remained low, whereas the increased densities of large elasmobranchs persisted. By using our field survey data, we also developed a prototype mathematical model to describe density fluctuations of major fish species through food-web interactions, and we began examining how predator–prey relationships influence these fluctuations.

In the coastal waters off Fukushima, we continued our fisheries-independent bottom-trawl and environmental surveys to clarify the long-term changes in megabenthic communities after the 2011 Tohoku earthquake, tsunami, and nuclear disaster. Surveys were conducted at nine fixed stations established at depths of 10, 20, and 30 m in the northern, central, and southern areas. Analyses of the 13-year dataset up to 2025 revealed long-term changes in the density and taxonomic composition of fishes, crustaceans, molluscan taxa, and echinoderms. Although the density of some species, including elasmobranchs, puffers, black cow-tongues (flatfishes), dragonets and gurnards (other fishes), increased in 2025, other fishes, crustaceans, bivalves and gastropods, and echinoderms generally showed decreasing trends. These results indicate that the megabenthic community has become less diverse and increasingly dominated by a limited number of fish species (Fig. 3). Seawater temperature in the coastal waters off Fukushima has shown an increasing trend in recent years, and further detailed studies are needed to clarify its relationship with the observed community changes.

3. Comprehensive Environmental Risk Research Program

Fig. 3 Temporal changes in the biomass density of megabenthic organisms in the coastal waters off Fukushima, Japan. Data are shown for the northern area from 2013 to 2023 and for the central and southern areas from 2013 to 2025.



In addition, as a preliminary step toward laboratory experiments to evaluate the effects of radiation exposure on the density fluctuations of major fish species, we examined rearing conditions by using individuals collected in the field. Puffers, flatfishes, and rays were successfully maintained for several months in a 15-t titanium aquarium and were fed fish and shrimp meat during the rearing period. Acclimated individuals were subsequently used to perform preliminary exposure experiments with a few elements in 90-cm glass aquaria.

Project 3. Comprehensive pollutome measurement

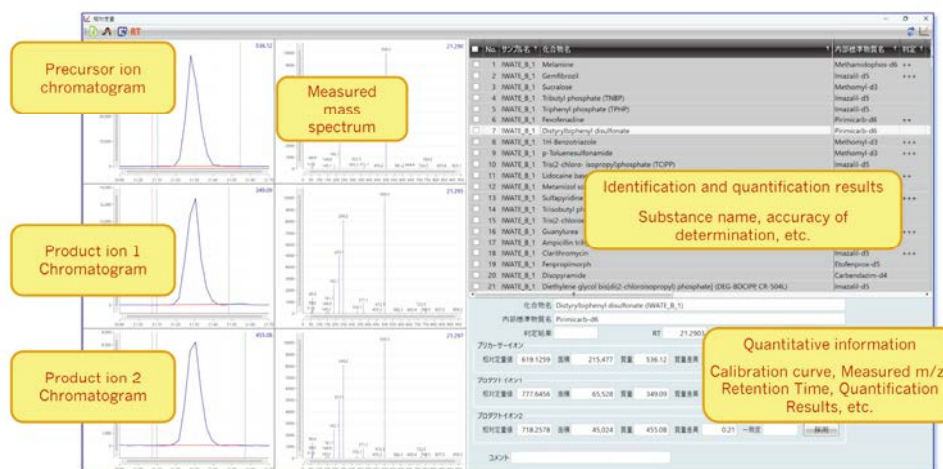
In FY 2025, we aimed to comprehensively measure substances of concern and advanced the development of mass spectrometry methods for non-target analysis, support software for automated identification and quantification systems—liquid chromatography (AIQS-LC), and analytical techniques for PFAS.

Comparison of similarity metrics for classifying unknown mass spectra: In liquid chromatography–mass spectrometry (LC-MS) and gas chromatography–mass spectrometry (GC-MS) non-target analyses, numerous unknown spectra are detected, and classification based on similarity to known patterns offers an alternative to structural prediction. By using open-access mass spectrometry libraries, we compared the multiple metrics employed in classification to calculate similarity. Among the evaluated metrics, Spearman showed the best robustness to intensity variation and spectral shifts, whereas fast-feature (FF) and dynamic time warping (DTW) were also effective for nonlinear distortions, albeit with higher computational cost. We need to perform further optimization and validation with larger datasets to establish an automated classification framework.

Development of software for rapid AIQS-LC data analysis: AIQS-LC, which is a multi-target liquid chromatography with quadrupole time-of-flight mass

spectrometry (LC-QToFMS) method for hydrophilic compounds, enables the identification and semi-quantification of hundreds of compounds in a single run. However, data processing has been a major bottleneck because of its time demands. Here, we developed analysis-support software to streamline and accelerate processing (Fig. 4). The software integrates functionalities established over the past 4 years, including (1) retention-time correction, (2) system performance check with automated report generation, and (3) support for measurements in negative ion mode. Application of this software reduced the analysis time per sample from approximately 4 h to about 30 min.

Fig. 4 Development of analysis-support software for the practical implementation of automated identification and quantification database system for liquid chromatography (AIQS-LC)



Enhancement of AIQS-LC sensitivity by using a microflow system: In addition to improving AIQS-LC sensitivity, we investigated a microflow system by reducing the column inner diameter from 2.1 mm to 0.3 mm. When the flow rate was reduced from the conventional 200 $\mu\text{L}/\text{min}$ to 3 $\mu\text{L}/\text{min}$, the peak area reached its maximum, increasing approximately 2- to 28-fold compared with that in the conventional system.

Comprehensive PFAS characterization by using combined analytical approaches: For PFAS analysis, we evaluated the total oxidizable precursor (TOP) assay for identifying the emission sources of regulated and emerging PFAS, such as perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), and we optimized the oxidation conditions. By using National Institute of Standards and Technology (NIST) house dust standard reference material (SRM) 2585, we combined five analytical approaches—target analysis, TOP assay, total hydrolyzable precursor assay, methanol-extractable organofluorine analysis, and total fluorine analysis (the latter two in collaboration with Yokohama National University)—to comprehensively assess PFAS occurrence. The results clarified the presence of regulated PFAS, their potential precursors, and other organofluorine compounds in SRM 2585.

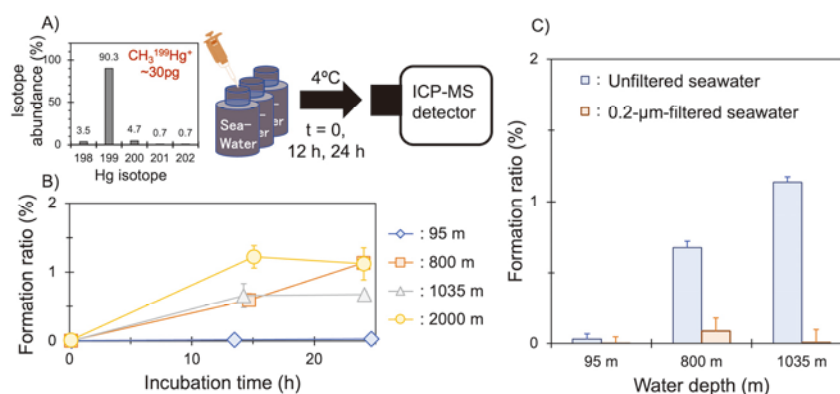
Project 4. Modeling the environmental fate of the pollutome

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.

We explored the extent to which “unknown” substances (i.e., substances lacking ecotoxicity data or emission factor data, or both) contribute to an aggregated risk indicator based on the production volume, emission factor, and ecotoxicity of individual substances for freshwater ecosystem impacts from global chemical discharges. About 99% of roughly 45,000 substances with production volume data fell into this category, and missing parameters were estimated from the available data distributions. Our analysis suggests that these “unknown” substances may account for a substantial share of this indicator.

In another study, by using outputs from our global multimedia models, food balance statistics, and modeled trophic magnification factors, we estimated the national exposure to polychlorinated biphenyls (PCBs) and brominated diphenyl ethers (BDEs) through seafood consumption. Future projections suggested that PCB and BDE exposure will decline toward 2050. As part of efforts to improve our global model for mercury, laboratory experiments on North Pacific seawater revealed that highly toxic dimethylmercury (Hg) forms in deep water from monomethyl-Hg, with formation ratios increasing with the presence of particulates in seawater (Fig. 5).

Fig. 5 A) Experimental and analytical methods; B) Formation ratios of dimethyl-Hg in monomethyl-Hg-amended seawater at different depths; and (C) Dimethyl-Hg formation ratios in filtered and unfiltered seawater amended with monomethyl-Hg



The soil column chromatography–mass spectrometry method introduced previously as part of Project 4 was further developed to enable the use of nonvolatile salts in the eluent. Flow dilution and splitting allowed us to investigate PFAS sorption under environmentally realistic conditions in soils containing inorganic ions such as Na^+ and Ca^{2+} . In addition, we observed the respiratory bioaccumulation kinetics of PFAS in a sandworm species; these kinetics differed from those reported in other aquatic animals. This behavior can be explained by membrane permeability to only a limited extent, suggesting that other factors related to chain length and functional

group may play more important roles.

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

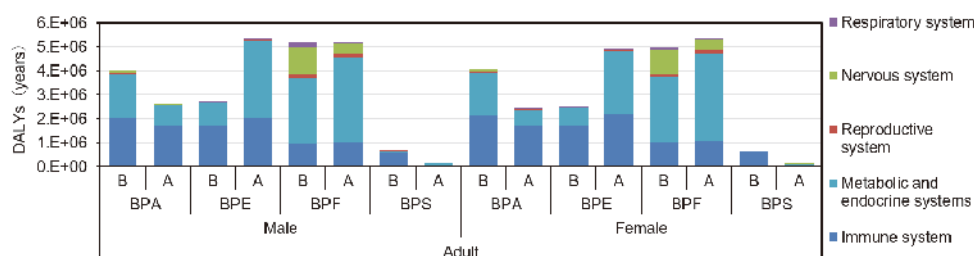
In this research project, we have continued to hold periodic workshops for the Program staff, including the leaders of other projects in the Comprehensive Environmental Risk Research Program. In these workshops, we have discussed the proposal of comprehensive environmental risk (i.e., health risk and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

For comprehensive health risk assessment, we conducted a case study using bisphenol A (BPA) and its alternatives as target substances, and we attempted a quantitative assessment based on disability-adjusted life years (DALYs) as a comprehensive risk index. Exposure levels were estimated by deriving the distributions of estimated daily intake based on urinary concentration measurement results obtained in Japan. In the hazard assessment, effects on the immune, metabolic and endocrine, reproductive, nervous, and respiratory systems were evaluated as adverse-effect endpoints relevant to disease development. The assessment was based on key studies cited in European Food Safety Authority (EFSA) assessment reports and on our literature review of hazard data conducted as part of this research program. For effects on the immune system, experimental data obtained in Project 1 of the program were also used. For each adverse effect, the lowest observed adverse effect level (LOAEL) or benchmark dose lower confidence limit (BMDL) identified from these data sources was converted to a human equivalent dose (HED), and the resulting HED was used as the point of departure (POD). For alternative substances for which relevant toxicity data were not available, the corresponding POD for BPA was applied. This substitution represents a major source of uncertainty in the risk assessment. Next, each adverse effect was linked to relevant diseases, and the DALY per case of each disease was calculated for the Japanese population by age group and sex. The above information was then used to calculate the DALYs caused by BPA and its alternatives for adults, separately for the periods before and after 2010 (Fig. 6).

The results indicated that exposure to BPA decreased after 2010, whereas exposure to some of the other bisphenols tended to increase (data not shown). Estimated DALYs decreased for BPA and BPS, showed no major change for BPF, and tended to increase for BPE. By type of adverse effect, effects on the immune system and on the metabolic and endocrine systems accounted for more than 90% of the total DALYs. As noted above, these results involve substantial uncertainty, including the use of BPA-derived PODs for alternative substances for which toxicity data were unavailable, as well as the assumption that disease occurs among individuals exposed to levels exceeding POD. Further detailed study will therefore be necessary. At present, this method has high uncertainty, and it is difficult to compare the resulting risks quantitatively with different types of risks such as climate change

and biodiversity loss. However, this type of comprehensive risk assessment method is likely useful as a tool for conducting risk assessments of substance groups, including alternatives, and for discussing chemical management approaches for multiple chemical substances with similar properties.

Fig. 6 Calculation results for health risks from bisphenols, obtained by using DALYs as an index (example comparing adult men and women before and after 2010 by substance). The letters B and A in the figure indicate “Before” and “After” 2010, respectively.



For comprehensive ecological risk assessment, we advanced the development of diversity indexes that reflect species evenness by taking into account not only the number of species but also the number of individuals of each species. Hill numbers were adopted for the analysis of biological community diversity. Hill numbers are indexes in which the parameter q , representing the viewpoint of diversity, can be used to control whether greater emphasis is placed on rare species or on the evenness of the community as a whole. When $q = 1$, the Hill number corresponds to the exponential form of the Shannon-Weiner entropy, and when $q = 2$, it corresponds to the inverse of the Simpson index. We set four levels, $q = 0, 1, 2$, and 10 , and conducted multifaceted diversity assessments, including evaluation of community evenness and bias in species composition. This method made it possible to comprehensively understand the effects of chemical substances and to obtain information useful for predicting the effects of environmental improvement. The decrease in diversity indexes associated with environmental chemical exposure was estimated for each q , and the magnitude of the decrease was presented as a new diversity index.

We also translated into English the review sections of the “*Compendium of Reference Materials on the Basis for Establishment of Environmental Quality Standards in Japan*” developed in this project. We published the review sections in the English version of the NIES website (<https://www.nies.go.jp/eqsbasis/en/index.html>).

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 2025 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

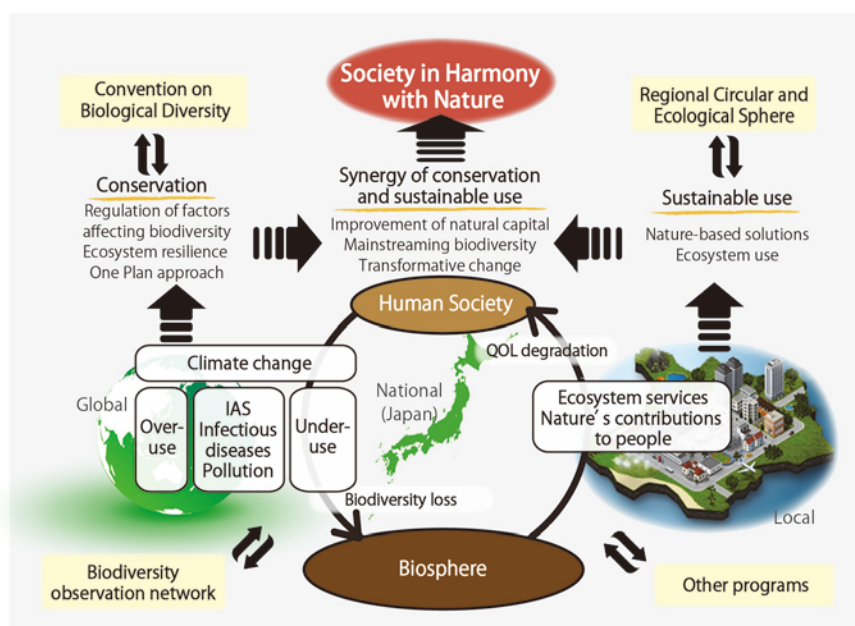
Project 3: Biological responses, acclimations, adaptations, and resiliencies to environmental changes

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

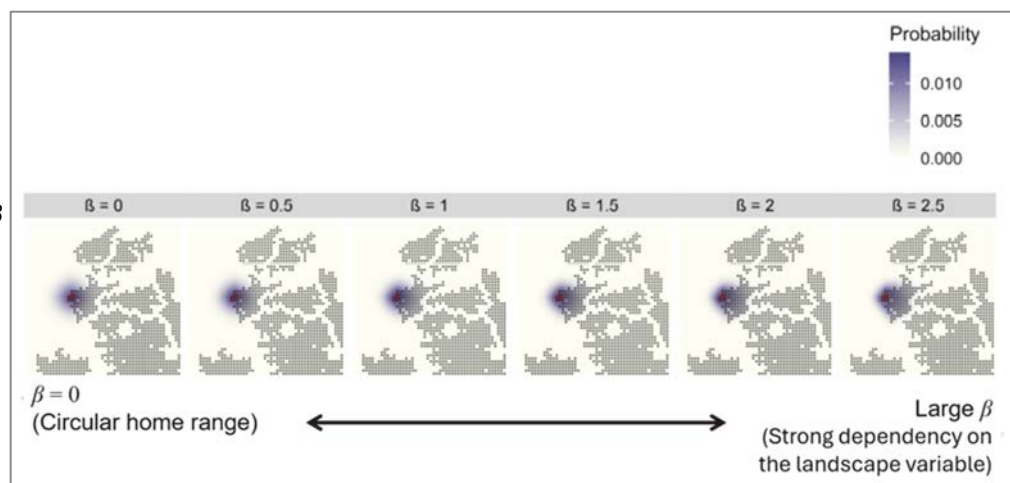


Project 1. Sustainable ecosystem management strategies for a society with a declining population

A new spatial capture–recapture model incorporating landscape permeability

We developed a new statistical framework, the advection–diffusion capture–recapture model (ADCR; Fukasawa and Higashide, 2025), to estimate animal population density and landscape connectivity from capture–recapture data. Traditional spatial capture–recapture (SCR) models often assume simple home-range structures and have difficulty incorporating realistic animal movement processes, particularly in heterogeneous landscapes with barriers. To address this limitation, we integrated mechanistic home-range formation (Fig. 2) into SCR by using advection–diffusion equations, which represent both directed movement toward an activity center (site fidelity) and random diffusion influenced by landscape permeability. The probability distribution of individual space use (utility distribution) is a steady-state solution of the advection–diffusion equation.

Fig. 2 Examples of simulated utility distributions under a heterogeneous landscape. The red dot indicates the activity center. The parameter β controls the effect of a landscape feature on the animal's landscape permeability. Licensed under CC BY 4.0



We evaluated the performance of ADCR through simulation experiments and found that it provided unbiased estimates of population density and landscape effects on movement across a wide range of conditions. We showed that, compared with basic SCR and SCR with least-cost paths, ADCR more accurately predicts home range shapes and captures spatial variation in home-range size.

We also applied ADCR to a dataset of Asiatic black bears in Japan and found that it successfully identified rivers as barriers and agricultural lands as movement corridors, consistent with previous ecological studies. In contrast, alternative models produced less interpretable or biased results.

Overall, we demonstrated that ADCR provides a flexible and powerful framework that links individual movement processes with population-level patterns, enabling more realistic ecological inference and improved conservation planning in fragmented landscapes.

Reference:

Fukasawa, K., Higashide D. (2025) Mechanistic home range capture–recapture models for the estimation of population density and landscape connectivity. *Ecology* 106(2), e70046. <https://doi.org/10.1002/ecy.70046>

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

Development of chemical control technologies for invasive social insects

In Japan, preventing the introduction and spread of highly invasive social insects, including the red imported fire ant, little fire ant, Argentine ant, and yellow-legged hornet, has become an important challenge. We advanced chemical control technologies targeting these invasive alien insects.

1. Evaluation of the efficacy of novel control agents against the red imported fire ant through contact toxicity bioassays

The red imported fire ant (*Solenopsis invicta*) was first detected in Japan at Kobe Port in 2017. Since then, repeated introductions associated with international cargo have frequently been reported at ports throughout the country, raising concerns regarding the ant's future establishment and spread into inland areas. To achieve complete eradication within port environments, we screened insecticides with potential efficacy, in addition to the conventionally used fipronil, through laboratory-based acute toxicity assays. The median lethal dose (LD₅₀) values of three candidate insecticides—metaflumizone, spinosad, and pyriprole—were determined for individual fire ant workers and compared with that of fipronil. Among the three candidate compounds, pyriprole exhibited LD₅₀ values comparable to those of fipronil at both 48 h and 72 h after treatment. In contrast, metaflumizone had LD₅₀ values similar to those of fipronil and pyriprole only at 72 h post-treatment. On the basis of the acute toxicity data, pyriprole is expected to possess insecticidal activity against *S. invicta* equivalent to that of fipronil. Furthermore, because its unit cost is lower than that of fipronil, pyriprole has strong potential as a practical alternative insecticide. Although metaflumizone exhibited a slower mode of action, it also demonstrated high insecticidal activity and is therefore expected to be useful in the development of alternative bait formulations.

2. Evaluation of insecticidal efficacy and validation of bait effectiveness against the little fire ant (*Wasmannia auropunctata*)

The little fire ant (*Wasmannia auropunctata*) is an extremely small insect with a body length of only about 1.5 mm, making conventional topical application bioassays, in which insecticide solutions are applied directly to the body surface, difficult to perform. To address this limitation, we developed a novel filter paper contact toxicity bioassay and used it to determine the LC₅₀ values of four candidate insecticides—fipronil, pyriprole, thiamethoxam, and imidacloprid—for comparison

of their efficacy against the little fire ant. We found no significant differences in LC_{50} values among the four insecticides. However, at 72 h after treatment, fipronil exhibited the lowest LC_{50} value. On the basis of this result, a field evaluation of the attractiveness of a fipronil bait formulation was conducted in the city of Changhua, Taiwan, where the little fire ant has become established. A granular fipronil bait formulation, which has been used successfully for the control of invasive ants such as the red imported fire ant and Argentine ant, was applied in areas inhabited by the little fire ant. Within a few minutes after bait application, numerous workers were observed aggregating around the bait granules and feeding on them, indicating a strong feeding preference for the bait. These findings suggest that granular fipronil bait is a highly suitable tool for the emergency control of little fire ant infestations.

3. Collection of information on environments at high risk for the introduction and establishment of invasive social insects

Over a 3-year period from 2023 to 2025, field surveys were conducted in 11 prefectures in Japan where the occurrence and nesting of four invasive ant species and one invasive hornet species designated as Specified Invasive Alien Species under the Invasive Alien Species Act had been confirmed (Fig. 3). The target species included the red imported fire ant (*Solenopsis invicta*), tropical fire ant (*Solenopsis geminata*), electric ant (*Wasmannia auropunctata*), Argentine ant (*Linepithema humile*), and yellow-legged hornet (*Vespa velutina*). Nesting and establishment environments were investigated at each site, and the environmental conditions associated with the establishment of these invasive species were documented (Table 1). For the Argentine ant, which is already widely established in Japan, highly humid environments—particularly areas adjacent to rivers—were identified as high-risk habitats. For the yellow-legged hornet, which has established populations in the city of Tsushima, in Nagasaki Prefecture, forested habitats were identified as having a high nesting risk, whereas apiaries were identified as high-risk locations for damage. For the red imported fire ant, tropical fire ant, and little fire ant, all of which in Japan have thus far been detected nesting only within port environments, asphalt cracks were commonly utilized as nesting sites. In addition, when vegetation was present, the bases of weeds were frequently utilized as nesting sites. These findings provide a scientific basis for identifying priority inspection points for the early detection of nests and for developing environmental management strategies aimed at suppressing nest establishment and colony persistence.

Fig. 3 Sites visited for alien invasive social insect control and surveys

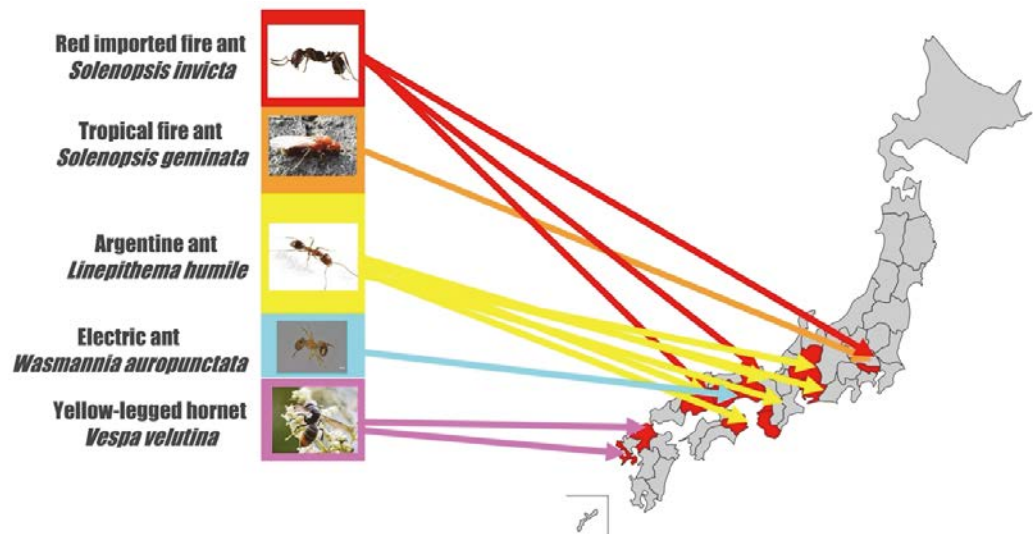


Table 1 High-risk environments for the establishment of alien invasive social insects

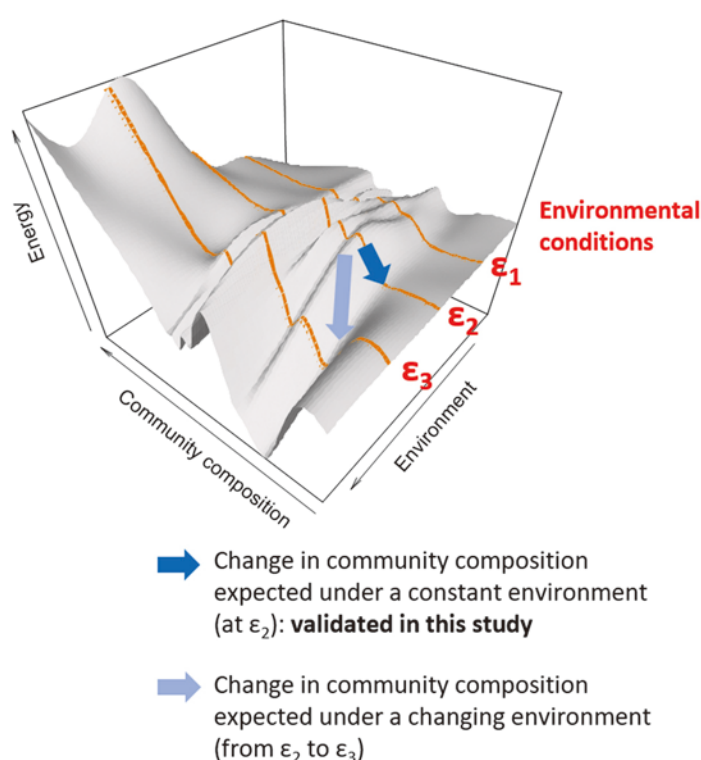
Species	Detection location	Nesting and/or establishment habitat
Red imported fire ant <i>Solenopsis invicta</i>	Shinagawa, Tokyo	Port area (cracks in asphalt pavement, weed-covered ground)
	Kobe, Hyogo	Port area (cracks in asphalt pavement, weed-covered ground)
	Fukuyama, Hiroshima	Port area (cracks in asphalt pavement)
	Fukuoka, Fukuoka	Port area (beneath a container support plate)
Tropical fire ant <i>Solenopsis geminata</i>	Shinagawa, Tokyo	Port area (cracks in asphalt pavement, weed-covered ground)
Argentine ant <i>Linepithema humile</i>	Itami and Amagasaki, Hyogo	Residential area, Disturbed vacant land, River embankment, Industrial green space
	Settsu and Ibaraki, Osaka	Residential area, Park, River floodplain
	Nara, Nara	Residential area, Agricultural land, River embankment
	Tokushima, Tokushima	Residential area, Disturbed vacant land, Apiary, River floodplain
Electric ant <i>Wasmannia auropunctata</i>	Kurashiki, Okayama	Port area (cracks in asphalt pavement), Disturbed vacant land
Yellow-legged hornet <i>Vespa velutina</i>	Fukuoka, Fukuoka	Forest
	Tsushima, Nagasaki	Forest, Apiary, Residential area

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

Energetic instability predicts temporal biodiversity change

The possible states of an ecological community may help us anticipate how its composition will change after disturbances if the available long-term observations include relevant disturbances and alternative community compositions. However, such long-term data are rarely available in ecology. Here, we proposed an energy landscape analysis to approximate the likelihood of compositional shifts (Fig. 4). The analysis showed that instability measures derived from the resilience of the current state of community composition greatly improved the predictability of biodiversity change. Specifically, we applied energy landscape analysis to the community compositions of both simulated and natural ecosystems of distinctive regions and taxa (birds, fishes, mollusks, and phytoplankton) and estimated the resilience of those systems. We found that a metric of local instability, which represents how current community states are inflated from local optima, explained well the magnitude of species turnover and energy changes from the current to future states for both simulated and real communities. A metric of global instability, which represents a community's tendency to cross over ridges (i.e., thresholds) of local basins of attraction (i.e., the range of the same stable state) to alternative stable states, served as a weaker, yet important, index of such changes. Our energy landscape analysis results suggest that quantifying the resilience of real ecosystems is essential for understanding the mechanisms of community dynamics in an effort to improve the prediction of biodiversity change (Kadoya et al., 2025).

Fig. 4 Concept of the energy landscape of species composition. By sampling community compositions under different environmental conditions (e.g., ϵ_1 , ϵ_2 , and ϵ_3), energy landscape analysis can approximate stability landscapes unique to the environmental conditions (orange lines). Dark and light blue arrows represent the changes in community composition expected under constant and changing environments, respectively.



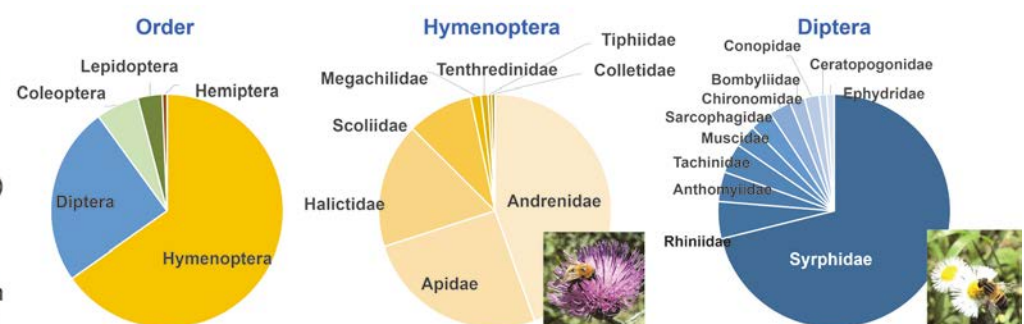
Reference:

Kadoya, T., Suzuki, K., & Terui, A. (2025). Linking energetic instability to compositional changes in biological communities. *Proceedings of the National Academy of Sciences* 122(17), e2422701122

Project 4. Research on problem solving by using ecosystem functions**Urban green spaces contributing to pollinator supply**

Robust pollination ecosystem services can be maintained in agricultural landscapes by enhancing the ecological functions of urban green spaces. We investigated flower-visiting insect assemblages in urban green spaces and identified the pollen species carried on their bodies to examine the ecological linkages with surrounding agricultural ecosystems. Flower-visiting insects were surveyed in grassland patches at 17 urban green spaces in the city of Tsukuba and neighboring areas. Across all surveys, 515 individuals representing 84 species were recorded, with Hymenoptera and Diptera accounting for 90% of all observations. The dominant hymenopteran and dipteran families contain important agricultural pollinators (Fig. 5). Metabarcoding analysis of insect-carried pollen revealed the frequent occurrence of plant species common in urban green spaces, as well as several crop taxa, including *Malus* (apple), *Pyrus* (pear), and *Allium* (onion). These results indicate that individual pollinators utilize both urban green spaces and surrounding agricultural fields, thereby linking the two ecosystems. They further suggest that conserving and managing urban green spaces can help to maintain the pollinators essential for agricultural production.

Fig. 5 Taxonomic composition of flower-visiting insects recorded in urban green spaces. Ants and microarthropods (e.g., thrips, aphids, and mites) were excluded from the survey. Most hymenopteran and dipteran taxa observed in the study are recognized as pollinators, although some taxa with uncertain pollination roles were also recorded.

**NbS for watershed management: output- and input-control approaches**

Under the Watershed subtheme, 61 abandoned paddy fields and farm ponds within the Lake Kasumigaura watershed were surveyed to evaluate their potential as nature-based solutions (NbS). The assessment focused on water purification, water storage, methane regulation, damselfly richness, native fish richness, and resistance to exotic fish invasion. Synergies were observed among water purification, water storage, and damselfly richness, particularly in water-retaining abandoned paddy fields and farm ponds with slow flows. In contrast, a trade-off was identified with

the risk of non-native-fish invasion, which increased under such conditions. Methane regulation could be enhanced by improving dissolved oxygen conditions, whereas native fish richness could be promoted by maintaining diverse aquatic and riparian vegetation. These findings suggest that the multifunctionality of abandoned paddy fields and farm ponds as NbS can be enhanced through improved water retention and flow conditions, invasive fish control, improved oxygen availability, and diversification of vegetation. Furthermore, an NbS map identifying priority areas for management and restoration was developed (Matsuzaki et al., 2025). As part of an input-control approach, an Internet-based survey of 211 crop farmers revealed that approximately half were willing to reduce their chemical fertilizer use. However, various barriers to implementation were identified, and for some farmers, financial incentives alone may be insufficient to encourage such changes.

Reference:

Matsuzaki, S.-i.S., Kohzu, A., Watanabe, M., Nakanishi, K., Tsuchiya, K., Kondo, N.I. and Sueyoshi, M. (2025) Spatial variation of multifunctionality among abandoned rice paddies and irrigation ponds: potential roles of hydrological and environmental factors. *Restoration Ecology* 33, e70161.
<https://doi.org/10.1111/rec.70161>

Community-based coastal restoration and environmental education

Under the Coastal subtheme, our efforts were focused on enhancing local vibrancy and community engagement by utilizing coastal ecosystems as natural capital. On the Yamaguchi Bay tidal flats, a community-based Japanese short-neck clam (*Ruditapes philippinarum*) enhancement technique (the Hiroshima-Ono method), involving the rearing of juvenile clams in mesh bags followed by their release and cultivation beneath protective nets, increased adult clam yield approximately tenfold while maintaining relatively low management costs. The approach is also expected to promote citizen participation and sustained involvement in tidal-flat restoration activities. To support long-term restoration, the adjacent nature observation park was divided into four functional zones: a juvenile clam collection zone, a juvenile clam rearing zone, a *Satoumi* experience zone, and a biodiversity observation zone. This zoning created a “Mini Yamaguchi Bay” within the park, providing opportunities for *Satoumi*-based environmental education and hands-on learning. In addition, corporate-sponsored collaborative events on “Support for Artificial Tidal-Flat Development” and “Public-Participation Ecosystem Restoration Experiences” were held. Aligned with the CEPA (Communication, Education, Participation, and Awareness) framework of the Ramsar Convention, these activities demonstrated an effective approach to fostering the next generation of environmental stewards for the conservation of tidal flats and other coastal ecosystems.

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

Mapping ecosystem-specific biodiversity by using indicator species

To support biodiversity conservation under the restraint of limited monitoring capacity, we developed a data-driven framework for identifying plant indicator species and mapping ecosystem-specific biodiversity patterns by using large-scale vegetation survey data.

Biodiversity assessments are often constrained by the difficulty of comprehensive species identification, making indicator species a practical tool for large-scale monitoring. Another challenge of biodiversity assessments is that conventional approaches typically combine all species into a single measure of diversity, which can obscure important ecological differences among regions and ecosystem types. Such aggregated assessments tend to emphasize regions with inherently greater species richness, such as those in warmer climates, while underrepresenting the conservation value of ecosystems with fewer species. As a result, biodiversity unique to specific vegetation types or climate zones may be overlooked, potentially leading to bias in conservation priorities. The development of indicator species that reflect both ecosystem specificity and biodiversity characteristics within each ecosystem can provide a solution to this limitation.

However, conventional approaches to indicator species selection rely largely on expert judgment or computationally intensive statistical methods such as randomization tests or hierarchical Bayesian modeling, thus limiting their applicability to national-scale datasets. To support conservation planning and monitoring that reflect the biodiversity unique to vegetation types and climate zones under limited monitoring capacity, we developed a framework to identify plant indicator species on the basis of large-scale vegetation survey data with small computational burden. Selection is based on a combination of simple statistical models that evaluate the ecological representativeness of species and their relevance to local species richness, while remaining computationally efficient for large-scale application. By cross-validation, we found that the number of indicator species in a site was strongly correlated with the total number of species at the site. This showed that our method could provide an indicator species set with a quality similar to that of the existing method but with a much smaller computational burden.

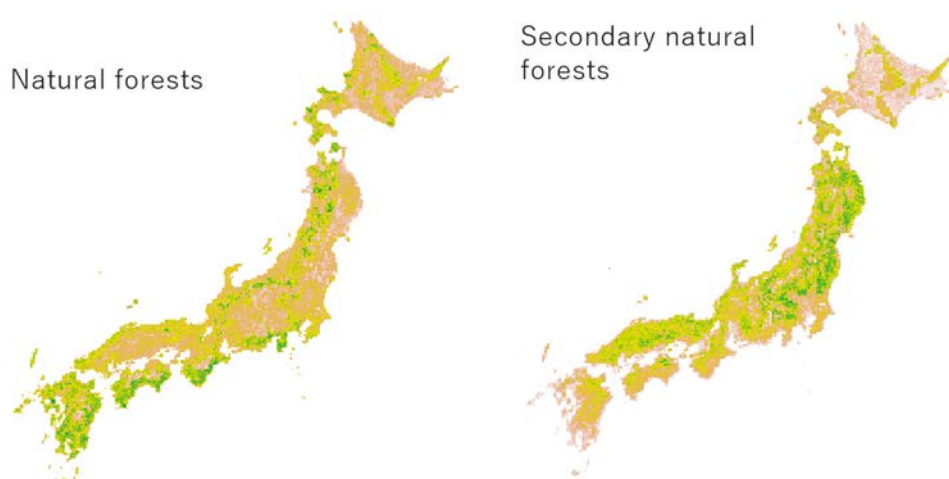
This framework provides a robust basis for extracting indicator species in a reproducible and scalable manner, and it will help to develop quantitative biodiversity assessment tools. It also facilitates ecosystem-specific monitoring approaches, particularly in situations where complete species identification is not feasible.

By using the selected indicator species, we constructed maps that represented biodiversity separately for each ecosystem type (Fig. 6). The ecosystem-specific indicator species maps facilitate the identification of areas that are important for

4. Harmonization with Nature Research Program

conservation within each ecosystem type. They also provide a practical tool for supporting decision-making aimed at harmonizing biodiversity conservation with sustainable land use, while maintaining attention on the diversity and uniqueness of individual ecosystems.

Fig. 6 Examples of maps of the biodiversity of each ecosystem, estimated by using indicator species



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 identified 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 identified 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 (IAM) to evaluate the necessary measures 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 developed a suite of global mitigation assessment models centered on a technology-based bottom-up framework. The subtheme examines pathways for reducing the emissions of greenhouse gases (GHG) and short-lived climate forcers (SLCFs) while assessing their implications for sustainability and the achievement of the Paris Agreement goals.

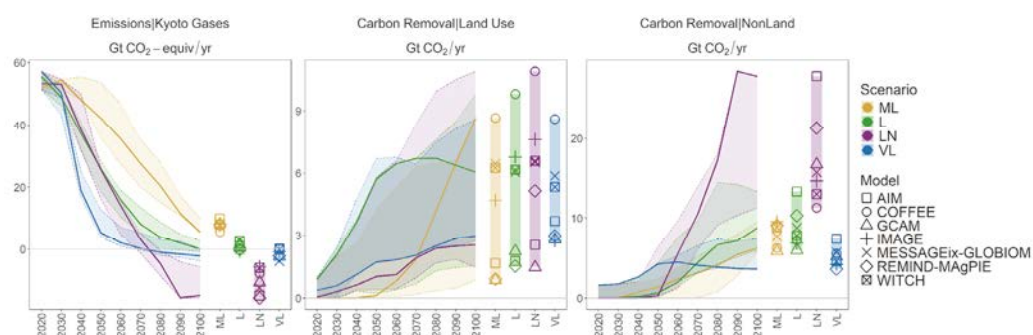
In FY 2025, we contributed to the Scenario Model Intercomparison Project (ScenarioMIP), an international model comparison project supporting climate research for the Intergovernmental Panel on Climate Change's Seventh Assessment Report (AR7). By using the AIM/Hub model in collaboration with six other IAMs, we quantified future pathways of GHG emission, land use, and carbon dioxide removal (CDR). In particular, AIM/Hub provided the Low-to-Negative (LN) scenario as a marker scenario representing a pathway that temporarily but markedly exceeds the 1.5-°C target before returning below it by the end of the century. We also participated in

a comparative assessment of CDR deployment and feasibility indicators, including hunger risk, agricultural productivity, and biodiversity impacts.

The results highlighted substantial differences in CDR portfolios across mitigation pathways (Fig. 1). Whereas low-overshoot pathways rely primarily on afforestation–reforestation and biomass energy with carbon capture and storage (BECCS), large-overshoot pathways require the extensive deployment of technological CDR options such as direct air capture with CCS (DACCS) and BECCS. These findings provide important insights into the feasibility and sustainability implications of alternative pathways toward the Paris Agreement targets.

Fig. 1 Greenhouse gas emission pathways and carbon dioxide removal (CDR) deployment across ScenarioMIP scenarios.

Comparisons of low- and high-overshoot pathways illustrate differences in the timing and scale of technological and land-based CDR required to achieve the 1.5-°C target. ML, medium-low; L, low; LN, Low-to-Negative; VL, Very Low



Subtheme 2 developed an integrated sustainability assessment framework based on a global computable general equilibrium model. The research examines the interactions among climate mitigation, human well-being, food security, biodiversity conservation, and other dimensions of sustainability under pathways consistent with the Paris Agreement.

In FY 2025, we advanced our integrated assessments of the sustainability outcomes associated with climate mitigation strategies. By building on previous work examining the health benefits of replacing red meat consumption with small pelagic fish consumption, we investigated the implications of international fish trade for global health. The analysis showed that prioritizing domestic fish consumption in net-exporting countries could further reduce mortality from ischemic heart disease—particularly in low- and middle-income countries. We also developed a framework for identifying strategic afforestation and reforestation locations that simultaneously support carbon sequestration and biodiversity conservation. The analysis revealed spatial trade-offs between carbon removal potential and biodiversity impacts, highlighting the importance of location-specific planning.

In addition, we led an international model comparison study evaluating the contributions of ozone pollution reduction to food security under climate mitigation pathways. The results indicated that improvements in air quality could substantially offset adverse food-security impacts associated with mitigation measures, demonstrating the broader sustainability benefits of climate action.

Subtheme 3 developed an integrated Earth–human system model that links an Earth system model with representations of human activities, including land use, agriculture, water management, and climate mitigation measures. The model is used to investigate long-term interactions between human societies and the Earth system beyond the end of the 21st century.

In FY 2025, we further developed the MIROC-INTEG-ES Earth–human system model and analyzed long-term Earth system projections, with a particular focus on the Amazon rainforest. By using simulations from multiple state-of-the-art Earth system models, we investigated the mechanisms responsible for large-scale Amazon forest degradation (dieback) under future climate change. The analysis showed that many models project substantial declines in photosynthetic carbon uptake in the Amazon, although the timing and spatial extent of dieback vary considerably among models.

The results suggest that Amazon dieback could begin this century under a wide range of warming levels exceeding 1.5 °C. Projected increases in temperature, reductions in precipitation, and land-use change were identified as key drivers of forest degradation. This work provides new insights into climate-related tipping elements and helps to improve our scientific understanding of long-term Earth system stability under future climate change.

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 major Asian countries excluding Japan (subtheme 2). Through this project, future scenarios for decarbonized and sustainable societies in Japan and other Asian countries were quantitatively assessed by using the AIM (Asia-Pacific Integrated Model) framework. Consistent with global pathways for achieving the 1.5-°C targets under the Paris Agreement, this project aimed to propose measures, policies, and systems for achieving net-zero GHG emissions, as well as to develop sustainable short- and medium-term national roadmaps. It takes into account the diversity of countries and the economic, technological, and institutional constraints associated with enhancing the formulation of each country’s Nationally Determined Contribution (NDC) and long-term strategy, which indicate the country’s individual climate action plan under the 2015 Paris Agreement.

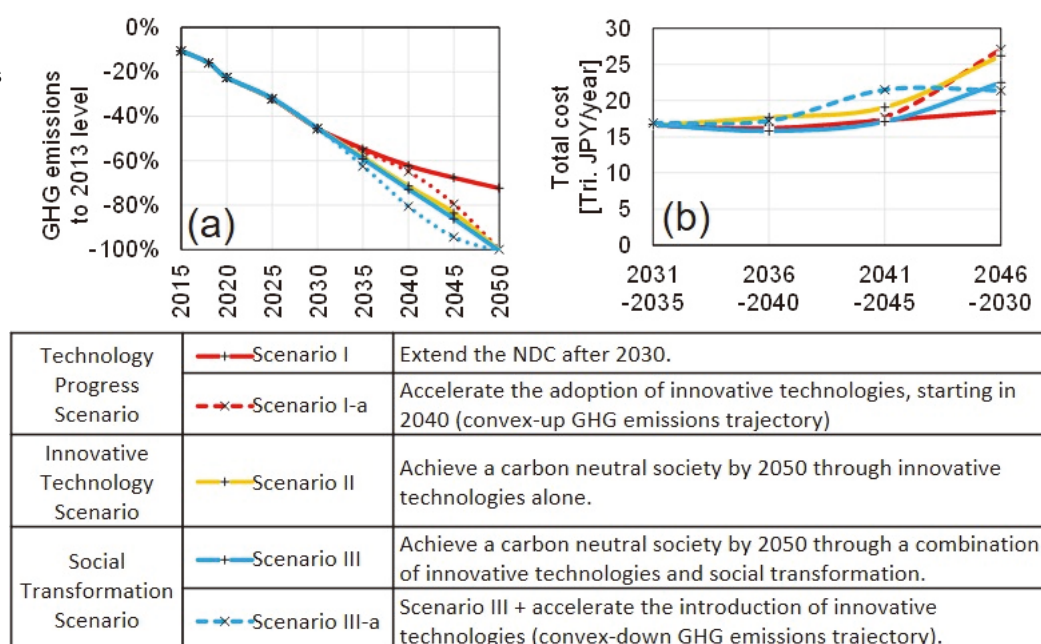
In **subtheme 1**, future scenarios toward achieving a decarbonized and sustainable society in Japan have been quantified by using the AIM/Enduse model, a power system model, and the AIM/CGE (computable general equilibrium) model. The analyses demonstrated that extending the current efforts to achieve Japan’s 2030 NDC alone would not be sufficient to realize net-zero GHG emissions by 2050. To achieve a decarbonized society, the large-scale deployment of renewable energy, hydrogen and synthetic fuels, and innovative technologies such as BECCS and CCS is indispensable. In addition, social transformation measures that reduce energy service demand through

the use of information and communications technologies, circular economy approaches, and behavioral change are also essential.

In FY 2025, we analyzed several emission pathways toward achieving a decarbonized society by 2050 (Fig. 2). The analyses compared a pathway with accelerated early mitigation measures (Scenario III-a) and a pathway with delayed mitigation efforts (Scenario I-a). Earlier introduction of innovative technologies could reduce cumulative GHG emissions but increase mitigation costs, because large-scale deployment would be required before sufficient cost reductions through learning effects could be achieved. Conversely, the delayed mitigation pathway increased cumulative emissions and required rapid large-scale deployment of technologies and continuing demand for synthetic fuels after 2040, resulting in higher costs. These analyses revealed that, with the limited amount of time remaining before 2050, effective and timely implementation of mitigation measures is critical. In addition, we developed sector-specific roadmaps for realizing a decarbonized society, including measures for residential energy efficiency improvement, electrification, heat pump deployment, and the implementation of demand response systems.

The analyses also clarified the regional disparities within Japan by developing an inter-prefectural carbon emission and removal model. Because renewable energy potential and forest carbon sinks differ among prefectures, regions with large metropolitan areas and energy-intensive industries face greater challenges in achieving deep emission reductions. A survey of the GHG reduction plans of each prefecture revealed that the mechanisms for addressing disparities in mitigation burdens are currently limited among prefectures.

Fig. 2 (a) GHG emission trajectories and (b) their cost in Japan under various scenarios. NDC, Nationally Determined Contribution



In **subtheme 2** we have been conducting future scenario analyses for sustainable and decarbonized societies in major Asian countries. These analyses take into account the diversity of the socioeconomic conditions and environmental challenges in each country. For example, in FY 2025, we analyzed decarbonization measures aimed at achieving Thailand's 2050 carbon neutrality (CN) and NDC targets. As delays in mitigation policies could hinder early reductions in GHG and SLCF emissions, we quantified future CO₂ and black carbon (BC) emission pathways and evaluated the impacts of delayed mitigation measures in the household cooking and transport sectors. The results demonstrated that decarbonization measures could substantially reduce both CO₂ and BC emissions. However, delays in implementing mitigation measures would substantially weaken the near-term climate benefits associated with BC reductions and increase the overall socioeconomic costs, even though the long-term CO₂ emission pathways would remain largely unchanged. Furthermore, an economic assessment comparing the cost of action and cost of inaction showed that the increase in impact costs caused by delayed mitigation would far exceed any savings in mitigation costs. These findings indicate that delays in introducing cleaner cooking and vehicle mitigation measures would undermine early climate benefits and reduce the overall cost-effectiveness, even if long-term CO₂-reduction targets were maintained. Therefore, if we are to achieve effective and economically efficient decarbonization pathways, it is essential that we overcome any barriers to policies that simultaneously reduce CO₂ and BC.

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

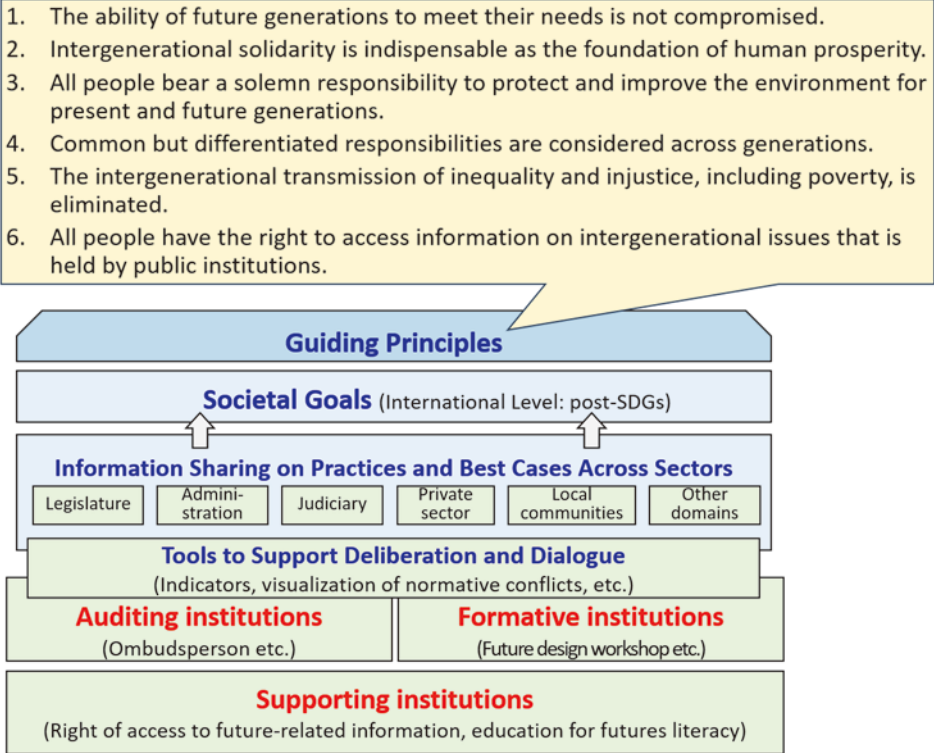
Project 3 aims to establish a regime that will help to improve intergenerational equity and enable future generations to inherit a better world. It consists of two subthemes, with four elements of the regime: norms, indicators, institutions, and perception

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 held an expert workshop to analyze normative issues in renewable energy by using the evaluation matrix developed in the previous year. With a focus on mega-solar projects, key issues for current stakeholders were identified across four value axes, namely increased disaster risks such as landslides, increased local tax revenues, inequitable distribution of profits, and environmental degradation such as deforestation. For future generations, major issues included reduced future energy costs and increased remaining carbon budgets through decarbonized energy. We also developed a framework to incorporate natural resource-use efficiency into national sustainability indicators. Although efficiency has improved, its contribution to sustainability was found to be limited. Furthermore, we proposed a framework to evaluate fossil fuel stocks and depletion as natural capital—including the social cost of carbon (SCC)—on the basis of the CO₂ emission responsibilities of oil-producing countries.

In **subtheme 2**, we conducted a case study of the town of Yahaba, in Iwate Prefecture, which has established a Future Strategy Division, and we identified drivers of institutional reform that promote decision-making that takes into account future generations. Finally, building on findings from the last 5 years of research, we proposed a regime inclusive of future generations, consisting of three types of institutions (those with auditing, formative, or supporting functions), six guiding principles, and tools (Fig. 3).

Fig. 3 Proposed regime inclusive of future generations.



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 in Japan.

Project 1. Research on sustainable society implementation through regional collaboration

We aim to work with diverse stakeholders in three regions of Japan to identify and assess the goals that each region seeks to achieve, as well as the challenges and obstacles to their realization. Based on existing objectives and institutional frameworks, the project seeks to support the introduction of systems that contribute to sustainable regional societies. It also aims to develop guidelines for region-specific governance structures and roadmaps for community development, thereby contributing to target setting, planning, and social implementation that incorporate sustainability considerations.

In the town of Mishima, in Fukushima Prefecture, one of the region's key issues is forest management. The project supported the formulation of a zero-carbon vision focusing on forest utilization. It helped to establish the Mishima Town Regional Circulating and Ecological Sphere Promotion Council, where local stakeholders examined possibilities for using woody biomass. Building on discussions within the council, the project developed methods to assess and visualize forest values from residents' perspectives by adapting social impact assessment approaches. This resulted in the creation of a forest-utilization logic model in consultation with local

stakeholders. A workshop for residents was held to update the model, and substantial evaluation work has begun.

In Shiga Prefecture, ecological surveys of native lake fish were conducted to accumulate data on spawning and migration, which were then used to provide policy recommendations to the prefectural government. In collaboration with local stakeholders, the project performed research on water environment conservation, contributing to the Shiga-specific Sustainable Development Goals framework “Mother Lake Goals” (MLGs). Public awareness surveys were also conducted to assess how research dissemination influences interest in Lake Biwa and its native fish. Recommendations were made to the MLGs, with a focus on ayu (sweetfish), the declining catches of which have recently become a major concern. Furthermore, focusing on *nigorobuna* (round crucian carp)—a vital local resource and the basis of the traditional food *funazushi*, an ancient Japanese type of sushi—the project examined the influence of habitat distribution and food resources. We found that individuals caught in areas with high chlorophyll-*a* concentrations and turbidity tended to grow larger, contributing to stock assessment.

In research on juvenile freshwater pearl oysters, introduction of the downflow hanging sponge (DHS) system enabled the first successful rearing of juvenile *Hyriopsis schlegelii* in indoor recirculating tanks in Japan.

In response to issues identified through hearings, the city government of Goto, in Nagasaki Prefecture, implemented some initiatives. These included “Decarbonization Plan Support,” “Examination of Measures for Seaweed Bed Restoration and Protection/Utilization of Natural Resources (Tourism Use) in Coastal Areas,” and “Planning for Infrastructure Maintenance Amid Population Decline.” The city also made some relevant recommendations.

We offered a CO₂ Reduction Diagnostic Tool to the city as part of decarbonization plan support, and energy projections were conducted considering regional characteristics such as offshore wind power generation. For balancing natural resource conservation and tourism promotion, we estimated suitable conservation sites by using high-resolution 3D flow simulations. We also collaborated with local stakeholders to select protected areas for *Osuribachi-sango* corals (species such as *Turbinaria* that form vase-shaped structures) and explored cooperation with the tourism industry.

As part of infrastructure maintenance, we conducted on-site surveys of wastewater treatment systems on secondary islands in Goto. We found that information sharing between workers and city officials is crucial. We also demonstrated that it is theoretically feasible to produce methane for use in the transportation sector by using waste-derived biomass under decarbonization scenarios. We conducted a review of local transportation in Goto based on needs and social conditions, and we proposed the reorganization of local bus routes. In response to interviews and

questionnaire surveys, we conveyed requests from the public to the city government as reference materials for formulating a future vision.

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

We conducted studies with the aim of presenting technological solutions to help address the challenges faced by regions experiencing population decline. Specifically, the project focused on three thematic areas: carbon-neutral transitions in the chemical and paper industries through efficient waste utilization; economically viable wastewater and waste treatment systems under reduced population densities; and the assurance of transport options for residents and tourists in depopulated areas. Our intention was to advance these topics through industry–government–academia collaboration.

In the waste management sector, the project proposed the Life-Cycle Carbon Neutral (LCCN) concept, which combines the incineration and steam supply of hard-to-recycle wastes with carbon capture and utilization (CCU). This integrated approach aims to achieve carbon-neutral performance by improving both energy efficiency and economic viability. A practical implementation pathway was presented to relevant stakeholders in which steam supply systems are introduced first, followed by a phased expansion of CCU as future green hydrogen prices decline. This framework has begun to facilitate concrete discussions on commercialization in several regions, both inside and outside Japan. In addition, research findings on waste treatment and resource circulation in regional cities experiencing substantial population decline were compiled into a guidance document titled *Guidance on Regional Co-creation Based on Food Waste Circulation*.

In the wastewater treatment field, the project addressed the downsizing and energy-reduction needs of existing sewerage facilities that face reduced influent volumes, increasing operational costs, and growing maintenance challenges due to population decline. Demonstrations were conducted on a wastewater treatment system developed by NIES and introduced in the city of Susaki, in Kochi Prefecture. Our results showed that electricity consumption could be reduced by 81% on an annual basis compared with consumption by existing facilities, and by 76% even in winter, when the load on biological filtration tanks is typically high. Moreover, from the results of analyses of current wastewater and night-soil treatment practices on remote islands, we developed a diagnostic tool to help local government officials assess operational soundness and determine whether facility restructuring is necessary. Application of this tool to 10 facilities in the cities of Gobo, in Wakayama Prefecture, and Shunan, in Yamaguchi Prefecture, revealed that nine required operational or equipment upgrades, for which tangible improvement measures were proposed.

In the field of regional transportation, continuous consultations were held with local stakeholders on Fukue Island in the city of Goto, in Nagasaki Prefecture. To support the development of a sustainable mobility system, three new bus routes considered to be efficient and feasible were proposed.

Through these efforts, this project successfully helped to develop sustainable regional models in a society facing population decline. By addressing regional infrastructure—including waste, wastewater, and transportation—cross-sectorally, and by proposing and demonstrating technologies and systems that balance environmental efficiency with economic viability, the project advanced practical pathways for resilient and sustainable community development.

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

We aim to establish a framework for qualitatively and quantitatively examining visions of sustainable regional societies, as well as pathways for the transformation of these societies. This project explored desirable regional futures on the basis of sustainability requirements and the opinions and needs of stakeholders. It also analyzed lifestyles and behaviors in light of regional characteristics and individual attributes, and it examined the feasibility of transitions, ultimately presenting actionable transformation pathways.

Specifically, the project first clarified age–period–cohort effects in population dynamics at the prefectural, municipal, and urban-district scales, thereby identifying the demographic trends that shape long-term regional sustainability. In addition, by drawing on national and international reviews of climate citizens' assemblies, the project designed and facilitated an assembly in the city of Tsukuba. The recommendations resulting from the assembly were compiled and reflected in municipal plans, demonstrating a practical model for participatory climate governance.

The project also advanced the development of a Regional Decarbonization Navigator, which is a diagnostic tool designed to support municipalities in examining pathways toward regional carbon neutrality. To enhance the tool's analytical foundation, comprehensive datasets covering all municipalities in Japan were compiled, and methods for calculating local energy balances and CO₂ emissions were newly developed or improved. These enhancements enabled more robust and location-specific assessments of mitigation potentials and policy options.

By using this framework, the project evaluated reduction measures in selected municipalities and quantified their expected impacts. It also performed normative analyses to explore feasible CO₂ reduction rates for each municipality across Japan for 2030 and 2040. These analyses provided insights into the scale and speed of transformation required under ambitious climate targets, and they helped to identify

the structural factors that influence local decarbonization capacities.

Furthermore, the project investigated the potential for simultaneous solutions to multiple sustainability challenges, such as the harmonization of climate mitigation policies with biodiversity conservation. This included integrated assessments of land uses, renewable energy deployment, nature-positive practices, and lifestyle shifts that contribute to both emission reductions and ecological restoration. By incorporating these multidimensional perspectives, the Regional Decarbonization Navigator offer municipalities a means to avoid trade-offs and pursue co-benefits in their planning processes.

Through these combined efforts, this project generated a comprehensive analytical platform that supports local governments in envisioning and realizing sustainable regional futures. By integrating demographic insights, participatory governance processes, detailed energy and emissions modeling, and cross-sectoral sustainability evaluations, the project contributed practical methodologies that local governments can use to design credible, inclusive, and transformative pathways toward long-term sustainability.

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

To build a sustainable society in the local region of Japan, we have identified, analyzed, and evaluated regional issues. Requirements for a sustainable society include maintaining the working population, securing personnel for various occupations, securing budgets within each municipality, optimizing infrastructure facilities, preserving local communities, and addressing external factors such as decarbonization. Constraints include low resident levels of interest, annual budget planning by each municipality, the need to retain young and mid-career staff, and the need to balance tourism with existing industries like fishing.

As an example, the town of Mishima in Fukushima Prefecture supports the use of wood biomass to achieve decarbonization, but constraints include competition for wood biomass resources and low resident interest. As another example, the city of Goto in Nagasaki Prefecture has implemented migration policies, achieving overall population growth. However, outside the urban center, population decline continues, making it difficult to sustain local communities. Support for migrants has sometimes created friction with existing residents, presenting a challenge for the municipality to maintain overall balance.

Regional circumstances vary widely, making it difficult to solve community issues in general manners. However, providing tools such as the Regional Decarbonization Navigator that allow city officials to easily access research findings online can offer effective support for local decarbonization efforts.

Overall, we conducted qualitative assessments as planned in terms of identification

of the challenges and proposal of solutions in each region, the essential components of a sustainable society, and the nature of support for local governments and other entities. This enabled us to achieve our objectives of developing ways to achieve sustainable local communities and support the introduction of systems to solve local issues by themselves at the regional level.

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 fifth 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

We refined technology implementation scenarios for final soil and waste disposal outside Fukushima Prefecture. As key component technologies, we advanced studies of a two-stage chemical coprecipitation process for the maximum volume-reduction scenario and of the direct cement solidification of molten fly ash for the non-concentration scenario. As part of the scenario assessment, we estimated material flows, radionuclide concentrations, costs, and life-cycle CO₂ (LCCO₂) emissions. The non-concentration scenario resulted in the highest CO₂ emissions because of its extensive cement consumption. In particular, for the treatment of highly contaminated removed soil, the scenario combining thermal treatment with direct cement solidification of molten fly ash was estimated to generate the largest carbon footprint, reaching approximately 8 Mt-CO₂.

Melting furnace fly ash presents several technical challenges because it contains higher concentrations of zinc and lead than conventional incineration fly ash. These elements retard cement hydration and strength development. To mitigate these effects, we employed a calcium aluminate-based accelerator and investigated mix designs that satisfied multiple performance requirements, including minimizing

volume increase by cement addition, maintaining workability, achieving adequate compressive strength, and suppressing the leaching of cesium and heavy metals. In collaboration with JESCO (Japan Environmental Storage & Safety Corporation), we successfully developed a mix design that satisfies these performance criteria for contaminated molten fly ash from real-world treatment facilities. Future work will focus on evaluating the applicability of this approach to a broader range of molten fly ash compositions.

Furthermore, as part of our ongoing collaborative research with JESCO, we continued full-scale outdoor large-column experiments using three test cells to verify the long-term environmental safety of molten slag.

2) Development of biomass utilization technology and systems as countermeasures

In woody biomass gasification power generation, slag formation caused by ash remains a challenge for utilizing feedstocks. We investigated the effects of ash composition on ash melting behavior by using Japanese cedar. Ash fusion temperatures of blends containing heartwood, sapwood, and bark were measured, and ash melting behavior, mineral phases, and chemical compositions were analyzed by TG–DTA (thermogravimetry – differential thermal analysis), XRD (X-ray diffraction), and XRF (X-ray fluorescence). Thermodynamic equilibrium calculations were performed under a CO₂ atmosphere that simulated gasification conditions.

Heartwood ash showed a low melting temperature and foaming behavior, likely due to CO₂ release during the decomposition of K–Ca carbonates. In contrast, bark addition increased the Ca to K ratio and raised the ash melting temperature. When the molar ratio of CaCO₃ to (CaCO₃ + K₂CO₃) exceeded 83%, the melting temperature increased to above 1420°C, indicating the suppression of liquid phase formation. Thermodynamic calculations and XRD analysis showed that K–Ca carbonates, including the rare double carbonate minerals Fairchildite and Bütschliite, played a key role in controlling ash melting behavior. These findings demonstrate that biomass blending can suppress slag formation and improve gasification performance and reliability, while underutilized bark can serve as an additive for the stable gasification of biomass feedstocks.

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

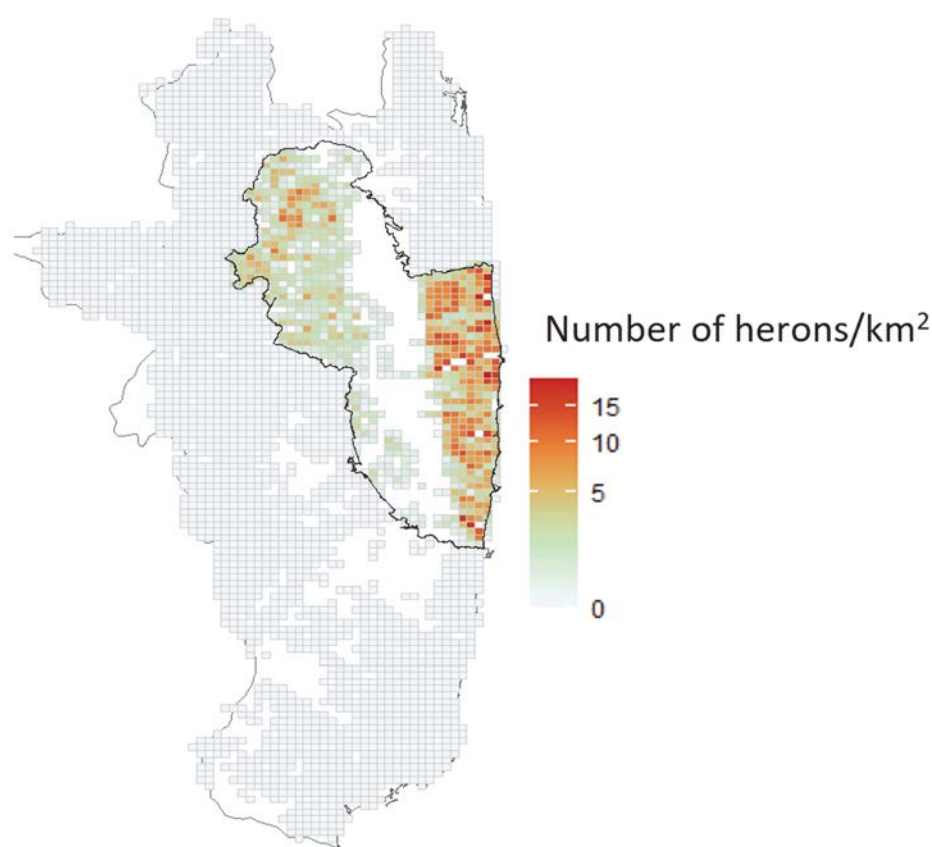
We conducted a study to estimate the population density of egrets and herons—indicator species of biodiversity-friendly rice paddy ecosystems—both inside and outside the evacuation zones during 2014–2016 (Kumada et al., 2025). The analysis was based on data collected by using GPS-equipped vehicle-mounted cameras and used a distance sampling method. The results suggested that bird densities were lower in evacuation zones where rice cultivation had ceased, with about 2650 fewer

individuals compared with the estimated density under conditions where rice farming was assumed to be practiced (Fig. 1). In areas where evacuation orders have since been lifted, restoration and expansion of rice paddy fields are expected to help to increase these bird populations.

In addition, an analysis of pollinator insects suggested that the taxonomic diversity index of long-tongued bees (Apidae and Megachilidae) was higher in areas where evacuation orders had been lifted than in areas that were not subject to evacuation orders. In the areas where evacuation orders had been lifted, a greater abundance of resources available to bees, including floral resources and nesting sites, may have been present.

Furthermore, we analyzed a dataset obtained from an event held in the city of Fukushima in 2024 to promote “Tori-Tore,” a quiz-based online training tool designed to improve the birdsong identification skills of beginner birdwatchers (Ogawa et al., 2025). Even over a short period (half a day), participants demonstrated improved accuracy during training, as well as increased interest in birds.

Fig. 1 Map showing the difference between two estimated values of heron density (individuals per square kilometer): one based on actual conditions (i.e., rice cultivation had ceased) and the other based on a counterfactual scenario in which the evacuation zone had not been established. Reprinted from Kumada et al. (2025) Fig. 8, <https://www.sciencedirect.com/journal/science-of-the-total-environment>. Copyright © 2025 with permission from Elsevier



References:

Kumada N., Fukasawa K., Yoshioka A., Tsuda N., Ouchi H. (2025) Vehicle-

mounted cameras reveal negative impact of the Fukushima Daiichi nuclear power plant accident on large-bodied bird abundance via paddy field abandonment. *Science of the Total Environment* 1005, 180813

Ogawa Y., Fukasawa K., Nagato M., Masubuchi S., Terayama K., Kumada N., Yoshioka A. (2025) Birdsong training tool popularization event: toward promoting citizen science in acoustic monitoring. *Bird Research* 21, A11–A25 (in Japanese with English Abstract)

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

Information on renewable energy facilities was collected and incorporated into the NIES reconstruction database, thereby extending its coverage to more recent years. Future scenarios were constructed by using a regional resource framework. Discussion of reconstruction and development pathways was informed by an analysis of information from past reconstruction projects. To facilitate this analysis, two axes were established, focusing primarily on the types of capital utilized and the relationships between stakeholders within and outside the target region in Fukushima. We used these axes to develop four scenarios corresponding to four quadrants: “Calm,” which emphasizes residential living; “Active,” which emphasizes industrial locations; “Vibrant,” which emphasizes the visitors to the region; and “Prosperous,” which emphasizes agricultural revitalization. These four scenarios were subsequently quantified by using a previously developed regional integrated assessment model. Future elements (e.g., major industries, resident population, commuting relationships with outside areas, land use, and renewable energy development) were assigned to the four scenarios above. The towns of Okuma and Futaba, where interim storage facilities are located, were the primary focus. In addition, land-use structures and activities in the area after the future completion of interim storage operations were defined. Afterwards, future projections under the four scenarios, including ripple effects, were made, and indicators such as resident population, employment, gross regional product, and renewable energy supply were estimated. To analyze the reconstruction process and the development of future scenarios, these results were linked with the findings of studies conducted up to the previous fiscal year. Analysis of the factors behind population recovery demonstrated that regions with particularly long evacuation periods experience overwhelming delays in the recovery of socioeconomic activities, even after adjustment for other contributing factors. Furthermore, for areas that remain under evacuation orders, including those containing interim storage facilities, a methodology for comparing and examining different directions for reconstruction was developed, and a sample application of that methodology was presented. These achievements enabled us to provide useful information for discussions on reconstruction.

As part of the development of a regional analysis system, simulations of energy management were conducted for a specific community power utility that had been

the subject of ongoing discussions with business operators. The smart-grid area of the Fukushima village of Katsurao, where large-scale solar power generation and battery storage systems have been introduced, was selected this fiscal year as the evaluation target as a result of discussions with multiple municipalities and business operators. Discussions concerning this regional energy supply project had been underway with Katsurao Sosei Electric Power, which is the operating company, and studies of supply–demand efficiency improvement and decarbonization have been conducted on the basis of actual operational performance. This fiscal year, actual operational data from 182 contracted customers were used to conduct analyses, including a long-term supply–demand balance evaluation, a temperature sensitivity analysis, and a simulation-based assessment of battery operation optimization. Several new deployment scenarios were considered as measure-implementation cases relative to the conventional facilities scenario. They included the introduction of decentralized regional energy supply systems, enhanced renewable energy deployment, and the use of electric vehicle batteries. Energy-saving effects and CO₂ reduction effects under each scenario were then quantified. Coupled with these efforts, the findings from ongoing discussions that had continued with business operators across multiple specific regions since the previous fiscal year were integrated, resulting in the completion of a prototype regional analysis system. The system was advanced into an evaluation platform incorporating fluctuations in electricity market trading prices and the FIP (feed-in premium) scheme (a scheme in which producers sell electricity on the spot and are given a guaranteed premium payment on top of the fluctuating market price). These results were subsequently used as a basis for promoting social implementation initiatives. This was done by proposing improvements in the efficiency of local production and consumption of energy, as well as in regional energy management, primarily for decarbonized reconstruction-oriented community development planning in the Hamadori region of Fukushima.

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 since 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.

In Subtheme 1, NIES actively supported the RE100 industrial base (100% renewable energy industrial complex) concept in the town of Okuma. Following Okuma’s commissioning of a feasibility study and basic design project, NIES participated as a member of the advisory board, providing advice and support aimed at solidifying and commercializing the concept. Specifically, NIES facilitated

discussions among local electric power companies, biomass fuel suppliers, local energy users, and manufacturers and operators involved in woody biomass gasification CHP (combined heat and power) systems and methane fermentation technologies. Through these activities, the basic design of the energy system and business framework was clarified, and technical and institutional challenges to implementation were identified and organized.

In Subtheme 2, a workshop was conducted with municipal officials to examine the future directions of community development in Hamadori by utilizing knowledge patterns collected from regions that have advanced environmentally sustainable community development practices through FY 2024. Ten officials from various departments of the Okuma Town Office participated. Discussions emphasized the importance of “developing plans aligned with the community’s actual capacities” and linking current initiatives to the “development of next-generation human resources.” Workshop participants envisioned scenarios in which the town could be revitalized by attracting new residents from outside the town and encouraging collaborative engagement between newcomers and existing residents. Post-workshop questionnaires indicated that participants gained a deeper understanding of the current regional situation and were able to share medium- to long-term perspectives on future initiatives across municipal departments.

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

We examined the institutional arrangements supporting disaster waste governance (DWG) in Japan by analyzing DWG-related documents published since 2011 through thematic coding. The results showed that Japan has institutionalized nationwide networks of personnel and organizations in response to accumulated disaster experience and pressure on local administrative resources. We also developed a DWG guidebook to support municipal waste departments in preparedness planning with the relevant actors, including a visual tool to explain DWG and assess coordination status. The guidebook was reviewed by government, private-sector, and academic experts and is available online at <https://dwasteinfo2.nies.go.jp/page/page000569.html>.

In another study, we analyzed the geographical and temporal distribution of river waste in Jakarta by using GIS. The results suggested that an upstream river waste-collection facility established in 2023 reduced waste at major river traps in central Jakarta by approximately 60%. Field surveys and thematic analysis further indicated that river waste generation is linked to household waste management practices, which are shaped by collection service capacity, governance arrangements, and community perceptions of waste collection systems.

We used previous findings to examine recycling strategies for disaster concrete debris generated by the 2024 Noto Peninsula Earthquake, focusing on marine

applications such as artificial reefs and structures supporting fisheries and coastal ecosystem restoration. In the four Oku-Noto municipalities, we assessed the potential supply by surveying current management and reuse plans. We also examined the demand potential by using information from fisheries-related departments in Ishikawa Prefecture and from recovery projects. A project concept was developed, covering quality control, life-cycle CO₂ analysis (including carbon capture effects), life-cycle cost analysis, and stakeholder collaboration.

To clarify strategies for disaster woody debris from future mega-floods, we compared three treatment scenarios in the Tama region: municipal incineration with energy recovery, biomass power generation, and combined material recycling with biomass power generation. Municipal incineration was the most cost effective, at about one-third the cost of the other options, whereas biomass power generation performed better in CO₂ emissions. These results suggest that measures to promote biomass power generation and recycling should be considered during non-disaster times.

Project 6. Strategic chemical risk-management research in emergencies

A third joint tabletop exercise was conducted under Subtheme 1 the basis of an analysis of previous exercises. Discussions and survey results from the second exercise confirmed the effectiveness of multi-team approaches to similar scenarios, as well as exercises tailored to participant characteristics. The usability of the NIES web-based information platform D.Chem-Core (Chemical Risk Assessment and Management Resource Core for Disaster and Emergency) was enhanced by improving accessibility to frequently used functions, strengthening mapping capabilities, creating a new FAQ page and adding supplementary explanations. Under Subtheme 2, development began on a drone for gas analysis and sample collection at disaster and accident sites. Test flights were performed with a large drone that had a wingspan of 1.8 m and was equipped with gas sensors (for hydrogen sulfide, carbon monoxide and methane), a particle counter, GPS and communication devices. Following verification by the Cabinet Office's Cybersecurity Centre, the system was found to enable full data encryption, real-time ground transmission and data recovery in the event of a crash.

In our ongoing prediction of coastal ecosystem changes, fixed-point surveys continued at Gamo Tidal Flat in the city of Sendai, in Miyagi Prefecture, and benthic organism surveys were conducted at Same River Estuary Tidal Flat in the city of Iwaki, in Fukushima Prefecture. The Ministry of the Environment's "Monitoring Site 1000" survey was performed by the field representative at Matsukawa-ura Tidal Flat, in Fukushima. A paper summarizing the results of the Gamo Tidal Flat survey up to 2023 (Kanaya & Suzuki, 2024) was published in the *Japanese Journal of Benthology*. These findings supported the revision of the Nature Restoration Plan. To estimate the origin of oil spills and assess the impacts of oil pollution, joint research with Mitsui O.S.K. Lines involved analyzing the hydrocarbon composition

of 340 samples in detail, confirming that there were significantly higher PAH (polycyclic aromatic hydrocarbon) concentrations in VLSFO (very-low-sulfur fuel oil) than in HFO (conventional high-sulfur fuel oil). Following the Noto Peninsula Earthquake, sediment surveys at Suzu Fishing Port detected lower hydrocarbon contamination levels than those in Kesenuma Bay after the 2011 Great East Japan Earthquake. Under Subtheme 3, development and updating of our disaster epidemiology exposure assessment tools and questionnaires progressed. This included discussions on collaboration with universities and local governments regarding health impact assessments and preparations for the release of the Japanese-language version.

Reference:

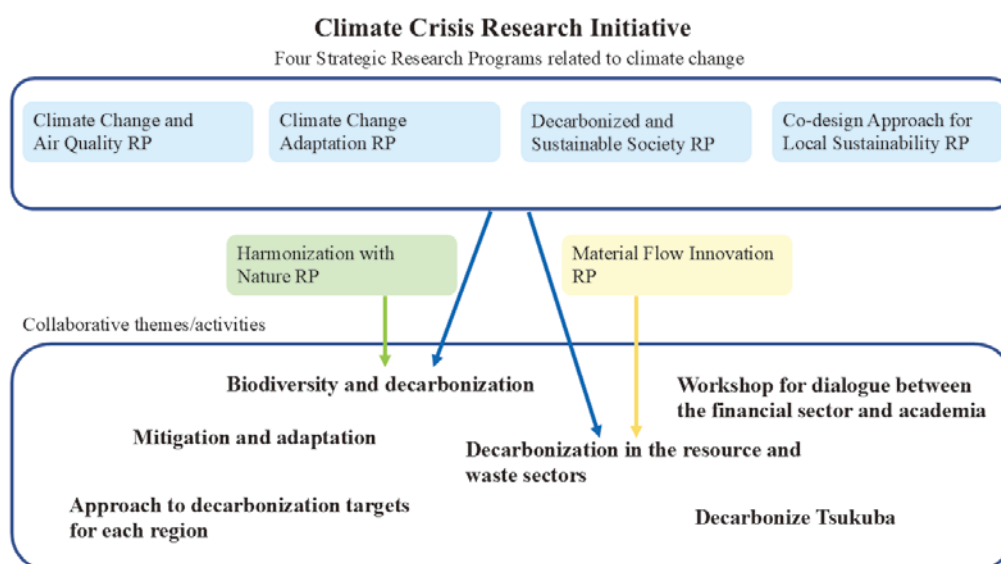
Kanaya G., Suzuki, T. (2024) Changes in topography, vegetation, sediment characteristics, and benthic invertebrates of coastal ecotones in Gamo Lagoon (Miyagi Prefecture, Japan) after the disturbance of 2011 Great East Japan Earthquake. *Japanese Journal of Benthology* 79, 26–38

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



2 Activities in FY 2025

2.1 Monthly meetings

The research directors of the four climate-change-related Strategic Research Programs, along with the project leaders, the research director of the Material Flow Innovation Research Program 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 as 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 have conducted this project since FY 2024 and received presentations from seven young and mid-career researchers on the following topics, which were freely discussed:

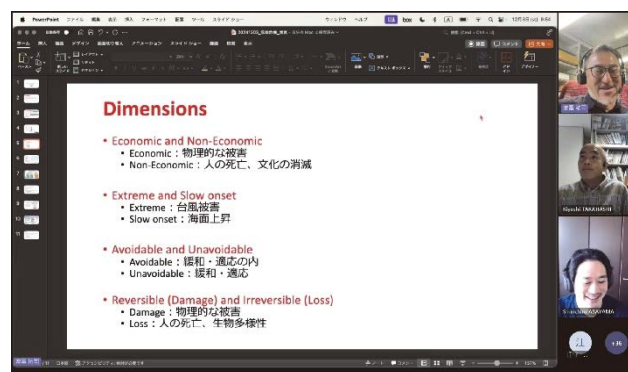
FY 2024:

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

FY 2025:

- Loss and Damage
- the linkage between IAM (Emissions & socio-economic scenarios), CM (Climate projections), and IAV (Impacts, adaptation & vulnerability)
- the economic impacts of climate change
- IPBES (Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services) Values Assessment
- new uses for satellites

Fig. 2 The “Loss and Damage” session of the free discussion of cross-disciplinary issues was based on topics presented by young to mid-career researchers.



In the session on “Loss and Damage” (Fig. 2) it was reported that, although the term is frequently mentioned at international conferences in the Asia-Pacific region, a clear definition has yet to be established. The concept of “residual impacts” (defined as unavoidable and remaining impacts after mitigation and adaptation have been implemented) was also introduced, and we outlined future research plans aimed at quantifying these impacts. After the meeting, research related to this topic was adopted and is being performed as Environment Research and Technology Development Fund project No. 2-2502.

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 Biodiversity and decarbonization

In recent years, concerns about the negative impacts on biodiversity associated with the development of renewable energy sources such as solar and wind power have been increasing. To address this issue, this theme involves collaboration with Harmonization with Nature Research Program to examine suitable sites for domestic renewable energy development while taking biodiversity conservation into account.

Since FY 2023, research under this theme has been conducted under Environment Research and Technology Development Fund project No. S-21. Project members share the results of conflict analyses among biodiversity, renewable energy, and disaster prevention. This fiscal year, through collaboration with other institutions under the project, a framework was created that maps conflicts among agrisolar and wind power potential, areas of high and low biodiversity value, and landslide disaster risk, serving as a useful tool for identifying suitable sites.

2.2.2 Decarbonize Tsukuba

We have been conducting research and outreach activities in Tsukuba Science City, where NIES is based. Discussions are held about once a month at a meeting of about 15 volunteers, in addition to the regular meetings of the Initiative. We have identified the following three pillars and conducted the following activities within each pillar:

(1) Decarbonization of NIES

- We continued to explore decarbonization options for the construction of the new building and discussed the potential for a PPA (Power Purchase Agreement, a model in which a third party owns the power generation facilities).

(2) Decarbonization through research institution collaboration

- At another research institution in Tsukuba, conflicts with nature arose when the installation of solar panels on the campus was planned, so one of our members was invited to give a lecture at a colloquium.

(3) Decarbonization of Tsukuba City

- At the “Science Café”—an event held at a commercial facility in Tsukuba where members of the public can easily participate—we gave a presentation on the

Climate Assembly TSUKUBA, which we organized as one of the host organizations in FY 2023.

- We discussed the planned construction of a data center in Tsukuba and the anticipated high energy consumption and large emissions. We confirmed, in our meeting, the importance of the data center itself procuring decarbonized electricity, disclosing the information on corporate activities in accordance with the TCFD (Task Force on Climate-related Financial Disclosure), and assessing the Scope 3 emissions (the greenhouse gases generated indirectly across a company's whole upstream and downstream value chain) of the tenants operating within the facility.

2.3 Public webinar

A webinar on CDR (Carbon Dioxide Removal) titled “Challenges and Potential of CDR Technologies: Toward Achieving the 1.5°C Target” was co-hosted with researcher under the Fund for Environmental Research and Technology Development project No. 1-2401 (Fig. 3).

It's said that reducing greenhouse gas emissions will not be enough to achieve the 1.5°C target, and that CDR—which involves the large-scale absorption and removal of CO₂ from the atmosphere—is necessary. However, the public does not fully understand what technologies are available for CDR, as well as the costs, benefits, potential, and feasibility of each technology and the constraints on large-scale CDR implementation. While existing research has often focused solely on afforestation and the use of biomass resources, the project also addresses DAC (Direct Air Capture) and examines combinations of multiple CDR technologies. Furthermore, the webinar explained that the project evaluates not only impacts of rapid mitigation with CDR measures on climate change, biodiversity, and air pollution, but also the social and economic impacts, such as poverty, hunger, health, economic growth, and inequality.

The webinar had approximately 290 registrants and 185 attendees, confirming the high level of interest in this topic. We uploaded the first half of the recorded video, which explains the basics of CDR, to YouTube, at https://www.youtube.com/watch?v=YSLKeg17_yo

Fig. 3 Seminar on “Challenges and Potential of CDR Technologies: Toward Achieving the 1.5°C Target”



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.

In collaboration with scientists in Japan and overseas, researchers in NIES's Earth System Domain 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 also work closely with the Satellite Observation Center, which is responsible for the "IBUKI" (GOSAT) series of GHG observation satellites. We are disseminating our research results more quickly and widely than has been possible before. Scientific knowledge and data are 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

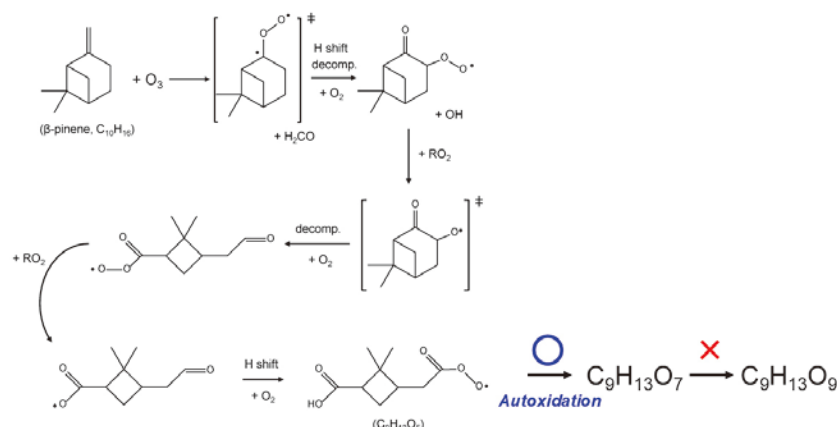
First detection of highly oxygenated organic molecules in newly formed particles with diameters less than 10 nm

We conducted a chemical analysis of new particles with diameters less than 10 nm, generated from β -pinene ozonolysis. The particles were collected on a filter by using a 1-nm scanned mobility particle sizer spectrometer and analyzed by using an electrospray ionization high-resolution mass spectrometer. Our findings confirmed the presence of $C_9H_{14}O_5$ to $C_9H_{14}O_7$ in the new particles, suggesting the occurrence of autoxidation from $C_9H_{13}O_5$ to $C_9H_{13}O_7$ (Fig. 1). Subsequent autoxidation from $C_9H_{13}O_7$ to $C_9H_{13}O_9$ was not observed. To our knowledge, this is the first report of the detection of a highly oxygenated organic molecule, $C_9H_{13}O_7$, in newly formed particles with diameters less than 10 nm.

Among monoterpenes, α -pinene is globally the most emitted compound and β -pinene is the second. We are going to apply this method to α -pinene ozonolysis next.

In addition, we collected particles with diameters less than 10 nm on the filter to accumulate particle nuclei. To identify the particle nuclei more clearly, it might be better to analyze particles which are as small as possible.

Fig. 1 Mechanism used to obtain the highly oxygenated extremely low volatile organic compound $C_9H_{13}O_7$ from experimental β -pinene ozonolysis (modified from Inomata et al., 2025)



Reference:

Inomata S., Fukuyama D., Sekimoto K. (2025) Chemical analysis of new particles with diameters less than 10 nm, generated from beta-pinene ozonolysis. *Chemistry Letters* 54, upaf061. <https://doi.org/10.1093/chemle/upaf061>

2. Policy-oriented Research

The Arctic is the region most affected by global warming, and early detection of the progress of global 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 visited SYKE, the Finnish Meteorological Institute (FMI), and the Ministry of the Environment to exchange information on the latest air quality and the Arctic environment, and to discuss future collaborative studies. One NIES researcher was also hosted at SYKE as a visiting researcher from September 2025 to January 2026, where she conducted remote sensing research on vegetation phenology. During this period, she also participated in five seminars, which were jointly organized with researchers from SYKE and FMI and focused on carbon cycling and biodiversity monitoring of terrestrial ecosystems.

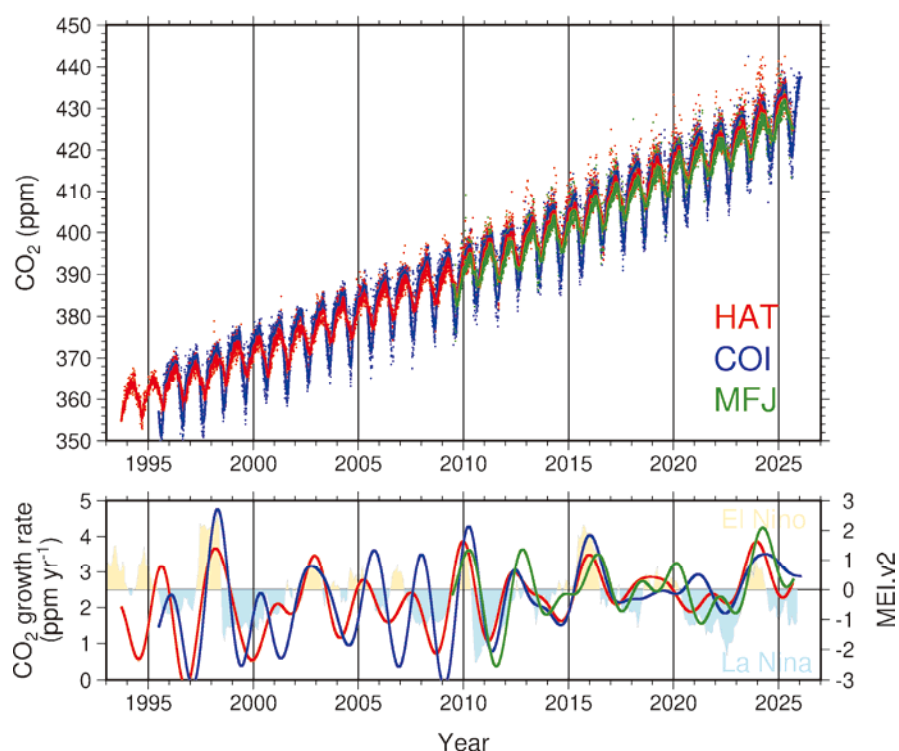
3. Intellectual Research Infrastructure Development

Long-term changes in atmospheric carbon dioxide observed at Hateruma Island, Cape Ochiishi, and Mt. Fuji

NIES has continued to observe atmospheric CO_2 concentrations at Hateruma Island (Okinawa), Cape Ochiishi (Hokkaido), and the summit of Mt. Fuji with high precision and temporal resolution (Fig. 2). The annual average CO_2 concentrations

in 2024 were 427.18 ppm at Hateruma, 426.79 ppm at Ochiishi, and 425.49 at Mt. Fuji. The rate of increase of CO₂ reached between 3 and 4 ppm/year during the strong El Niño events before 2020, whereas it fell to below 2 ppm/year during the strong La Niña events. However, during the strong La Niña event spanning autumn 2021 through the winter of 2022–23, the rate of increase remained between 2 and 3 ppm/year. A relatively strong El Niño occurred from around June 2023 to May 2024, driving the rate of increase up to between 3.5 and 4 ppm/year, but the rate declined following the onset of La Niña in June 2024. The annual increase in CO₂ at Ochiishi was 3.44 ppm in 2024, but it decreased to 3.00 ppm in 2025.

Fig. 2 (Top) CO₂ concentrations and (bottom) CO₂ growth rates and the El Niño–Southern Oscillation index (Multivariate ENSO Index Version 2) observed at Hateruma Island (red), Cape Ochiishi (blue), and the summit of Mt. Fuji (green)



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 and 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 are conducting some international projects with overseas academic institutions to strengthen international joint research. As participants on 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 visualized international resource flows and released a new tool to support local governments in examining future waste management strategies and facility development plans.

Details of the abovementioned research activities are given below.

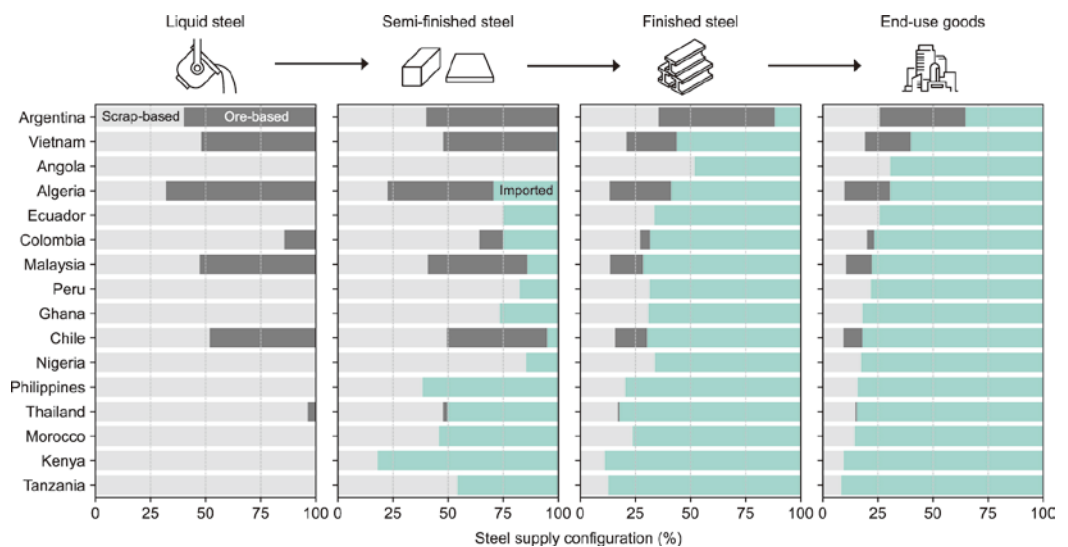
1 Foresight and Advanced Basic Research

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

Steel is a fundamental ingredient in modern economies worldwide. Yet, detailed insights into how steel is produced, traded, and accumulated across the Global South remain limited. In FY 2025, we tried to fill this gap by analyzing how steel is produced, traded, and accumulated in 16 countries across South America, Africa, and Asia. We found that, despite their regional differences, all countries share key characteristics—namely, limited domestic steelmaking and a persistent reliance on imports. On average, only about one-third of finished steel products (e.g., sheets) and one-fourth of steel embedded in end-use goods (e.g., cars) originate from domestically produced liquid steel (Fig. 1). This trend is not limited to iron-ore-poor countries. Even major iron ore exporters depend on imports for fabricated steel products, highlighting unequal participation in global value

chains. We also found that half of these countries have not yet reached the minimum in-use steel stock required to support decent living standards, and none has exceeded the levels compatible with a well-below 2-°C carbon budget. This situation underscores both a need for further infrastructure development and an opportunity to do so within a finite global carbon budget, provided that a fair budget allocation and international support are ensured. Our findings collectively indicate that the advancement of steel recycling and decarbonization in the Global South must be pursued as a shared global agenda, rather than left as something for these countries to solve alone.

Fig. 1 Supply configuration of liquid steel, semi-finished steel, finished steel, and steel embedded in end-use goods in 2019. The share of domestically produced liquid steel, whether scrap-based or ore-based, decreases along the supply chain because of international trade.



1.2 Advanced science and engineering for material cycles

The environmental behavior and risks of nanoplastics are of substantial concern. An accurate method for the quantitative analysis of nanoplastics is needed so that we can assess their environmental pollution and risks. An understanding of the mechanism of plastic fragmentation in aquatic environments is also essential for predicting the generation of microplastics and nanoplastics. Furthermore, resource recycling technologies that consider decarbonization in the regional circular and ecological sphere are needed. Therefore, in FY 2025, we conducted studies focusing on the analytical methods and environmental behavior of nanoplastics, the fragmentation and degradation of plastics in aquatic environments, and the resource recycling of waste biomass considering decarbonization.

In research on the environmental behavior and risks of nanoplastics, we developed techniques to remove matrix components that interfere with the quantitative Pyro-GC/MS (pyrolysis gas chromatography – mass spectrometry) analysis of nanoplastics in environmental water, biological samples, and other matrices. One of the key elements was extraction by using solvents in which the target nanoplastics are selectively dissolved. For example, polyethylene and

polypropylene nanoplastics can be dissolved in heated xylene, whereas plankton-derived chitin—one of the major interfering components in environmental and biological samples—is not dissolved under these conditions. Use of the new solvent technique enabled us to separate nanoplastics from interfering biological components. In addition, we developed a clean-up technique using silica gel column chromatography. By passing solvent extracts containing nanoplastics through a column packed with silica gel, polar components that are derived from biological materials and have strong interactions with silica gel can be removed. Previous analytical methods have generally analyzed nanoplastics as particles. In contrast, the method developed in this study is novel because it dissolves nanoplastics and separates them from interfering components on the basis of their chemical properties. We expect that this method will be widely used as a fundamental technology for reliable nanoplastics analysis and risk assessment and elucidation of their environmental behavior.

In research on the mechanism of plastics fragmentation, we improved the fragmentation test method established in the previous fiscal year, which reproduced physical actions in the coastal environment, such as the collision of waves and sand, and established a new fragmentation test method assuming seabed environments. We also obtained plastic samples with shapes similar to those detected in actual seabed environments, such as in films and ropes, and prepared degraded plastic test pieces by accelerated ultraviolet exposure. By applying the seabed fragmentation test method to these degraded plastic test pieces, we quantitatively evaluated the effects of plastic shape and material type on fragmentation speed. The results showed that the fragmentation speed under simulated seabed conditions was markedly lower than that under coastal conditions, indicating that plastic litter deposited on the seabed may persist for a long period while gradually generating microplastics and nanoplastics. Furthermore, we investigated the degradation status of plastic litter collected from seabed and river environments. By using differential scanning calorimetry, we clarified differences in degradation trends depending on plastic type and sampling region.

In research on resource recycling technologies with consideration for decarbonization, we continued collaborative research with a private company on the development of a support system for anaerobic biogas-production-based resource recycling. In this project, we continuously collected data on the near-infrared characteristics, nutrient composition, and methane production potential of food residues generated by restaurants, department stores, food factories, and other sources. As a result, we improved the accuracy of the prediction model and developed a model capable of predicting methane yield with a mean absolute error of less than 5%. We also developed an online platform for future practical application.

We also investigated the relationship between the degradation and biodegradability of the biodegradable materials that are increasingly being introduced as collection

bags for food waste in biogas plants. The results showed that both mechanical strength and the biodegradation rate during digestion were strongly correlated with the changes in average molecular weight caused by degradation. By material type, PHBH [poly(3-hydroxybutyrate-co-3-hydroxyhexanoate)] showed substantial changes in both mechanical strength and biodegradation rate as its molecular weight decreased to approximately half of the initial value. In contrast, PBS (polybutylene succinate) showed a similar trend in mechanical strength to PHBH, but its biodegradation rate tended to increase rapidly only after its molecular weight had decreased to approximately 1/300th or less of the initial value. These findings indicate that, for PHBH, even degradation within the range expected during actual use can substantially affect biodegradability.

2 Policy-Oriented Research

2.1 Research on social systems in material cycles and waste management

We investigated how municipalities collect and recycle plastic products other than packaging plastics (hereafter referred to as “non-packaging plastics” respectively). We found no significant difference in collection or recycling volumes between municipalities that collect non-packaging plastics together with packaging plastics and those that collect them separately. On the other hand, in municipalities that conduct material recycling or chemical recycling of non-packaging plastics, a large share of the collected plastics is excluded at the sorting stage and not recycled. We also found that municipalities that do not charge fees for the disposal of non-packaging plastics or combustible waste tend to have lower collection and recycling volumes of non-packaging plastics.

A web-based questionnaire survey on material cycles of residential photovoltaic (PV) panels revealed that fewer than 40% of households prioritize reuse and recycling. These households tended to have prior experience with, or intention to undertake, inspections and maintenance. They were also more likely to have been exposed to information on end-of-life PV panels. However, they placed emphasis on management costs and the trustworthiness of service providers, suggesting that these factors may act as constraints to material cycles.

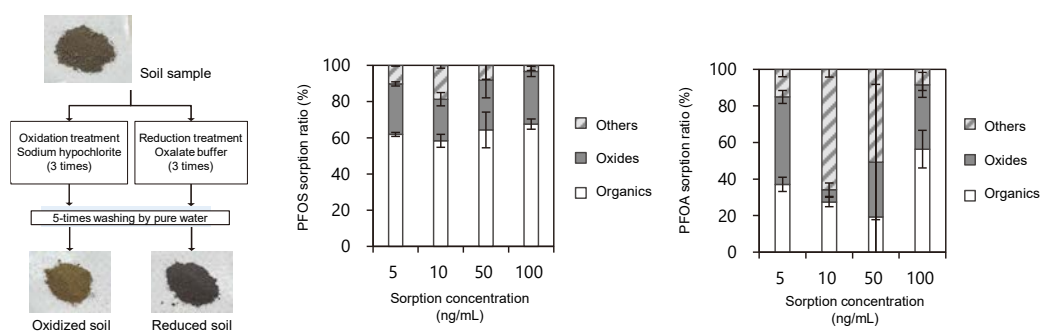
In ongoing research on circular economy indicators, we continued estimating total reuse flows by incorporating transaction quantities from secondhand housing and from reuse shops, because data from the Ministry of the Environment captured only a low reuse rate. The domestic reuse flow was estimated to be approximately 200 million tonnes. We also joined in discussions on the Global Circularity Protocol led by the WBCSD (World Business Council for Sustainable Development) and helped to standardize corporate information disclosure in the circular economy.

In policy research, we continued investigating France's extended producer responsibility (EPR) system, and we highlighted features for items not covered by Japan's system, such as used medicines, medical sharps, chemicals, tobacco, and toys. These features include consultative approaches to system operation and the securing of financial resources, including costs to raise awareness.

2.2 Impact assessment of hazardous substances in material cycles

To identify per- and polyfluoroalkyl substances (PFAS) behaviors in soil and groundwater, we investigated how the sorption and desorption of perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) changed between before and after the chemical removal of organic matter and iron/aluminum oxides from soil. By using soils from which these components had been selectively removed, we quantitatively clarified the respective contributions of organic matter and iron/aluminum oxides to the sorption and desorption of PFOS and PFOA. Removal of organic matter reduced the sorption capacity of the soil for both PFOS and PFOA (Fig. 2). In contrast, the removal of amorphous iron and aluminum oxides did not result in as great a decrease in sorption as did the removal of organic matter. The contribution of organic matter to sorption was greater for PFOS than for PFOA, whereas the contribution of amorphous iron and aluminum oxides was greater for PFOA than for PFOS (Fig. 2). In addition, the desorption of PFOS from soil was suggested to occur primarily from PFOS associated with organic matter. The results are expected not only to advance our understanding of PFAS behavior in contaminated soil and groundwater but also to contribute to the development of more effective washing and decontamination measures in the future.

Fig. 2 Soil treatment method and the contribution ratios of organic matter and amorphous iron oxides, among other components, to the sorption of PFOS and PFOA with mean and standard deviation of three samples.



As a contribution to the international standardization of methods for obtaining leaching parameters such as partition coefficients, we submitted a first draft of a guidance standard that was approved as a New Work Item at ISO/TC 190 Soil Quality.

To assess metal occurrence in thermal treatment residues from waste, we established a method to separate residue samples into crushed fractions and uncrushable metal particles. We analyzed the former by X-ray fluorescence and wet digestion using hydrofluoric acid and other acids, and we analyzed the latter by wet

digestion using aqua regia. By using these methods, we determined the contents of valuable and hazardous metals not only in municipal solid waste incineration bottom ash and fly ash, but also in the incinerated ash of organic wastes that can serve as a heat source for melting treatment, including sewage sludge, night soil sludge, cattle manure, swine manure, and poultry manure. In sewage sludge and night soil sludge of human origin, we detected not only hazardous metals but also gold, silver, and palladium at average concentrations of 1 mg/kg or higher. At the same time, hazardous metals such as chromium, arsenic, selenium, and lead were detected at levels on the order of several tens of mg/kg or higher. In contrast, the concentrations of these elements in the ash of cattle manure, swine manure, and poultry manure were extremely low. We also found that the ash of sewage sludge and swine manure often contains phosphorus at levels exceeding 10 wt.%, indicating its high potential for use as a phosphorus fertilizer resource. These results were obtained through joint research with private companies, and they are expected to be applicable to future melting treatment processes.

2.3 Advancement and implementation of waste-management technologies for society

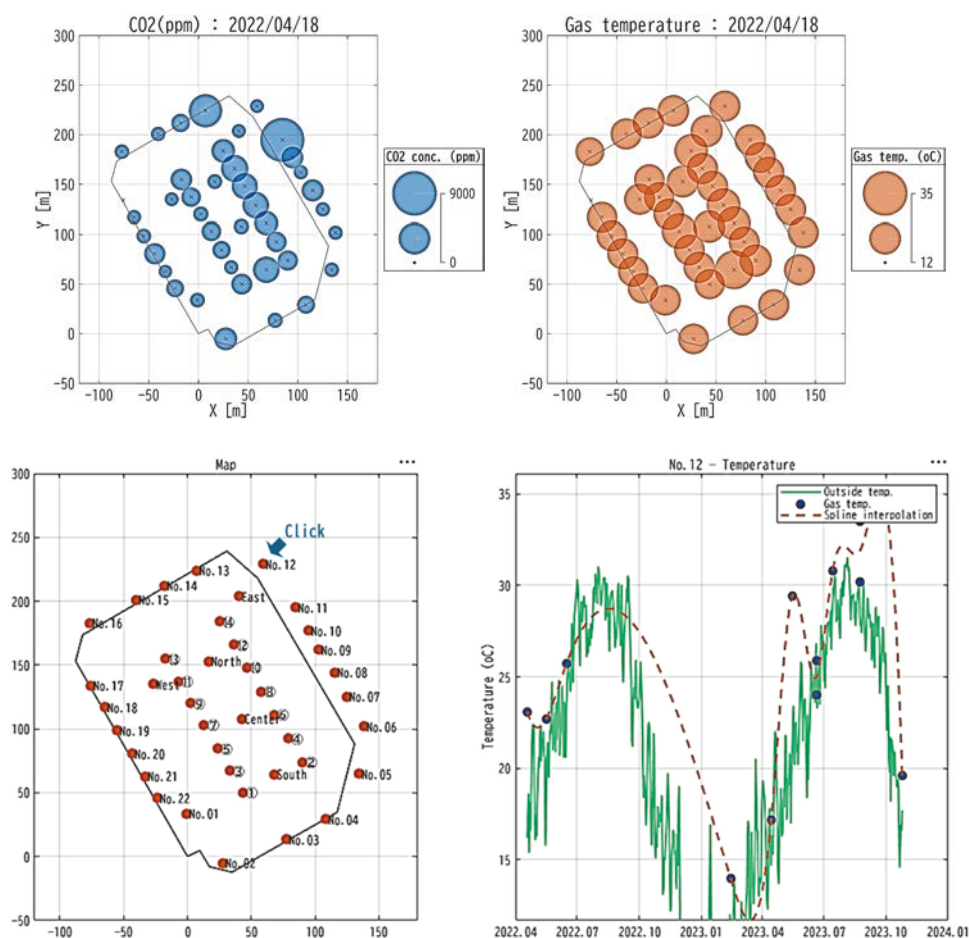
We conducted a survey of gas emission behavior at landfill sites that were under consideration for their end-of-post-closure-care period. Although the sites did not meet the required criteria for the end of post closure care, we advised that ongoing monitoring should be performed, and we provided guidance on the locations for installing observation wells for long-term monitoring. We held training sessions for local authority officials involved in inspection work, as well as for staff from testing and inspection bodies. This training session confirmed the effectiveness of the standardized monitoring procedures developed in this study by comparison of measurement accuracy. We also examined alternative, simplified survey methods for use at disposal sites where the survey infrastructure is inadequate.

We are developing a web application to help landfill operators to utilize maintenance and management records. Our goal is to predict the operational lifespan of final disposal sites from a data science perspective. Although we have previously made future projections based on time-series analyses of leachate concentrations, this fiscal year we expanded our scope to include gas emissions and internal temperatures of landfills. As these emissions and temperatures are measured at multiple points on the landfill surface, we expanded our functionality to support spatial distribution analysis in addition to time-series analysis. Specifically, we visualize data from multiple observation points by using bubble charts and display time-series changes in video format to provide an overview of maintenance conditions. Users can use the application to click on any observation point to view the time-series analysis results for that location (Fig. 3). Our efforts were recognized at the Special Technical Seminar held by the Landfill System Association (a specified nonprofit organization) in February 2026; this should lead to strengthened future collaboration between practitioners and researchers. Our goal

2. Material Cycles Domain

is to accelerate and expand the use maintenance and management records while introducing data-driven maintenance and management support at actual landfills. The maintenance and management data collected over the past 5 years cover 85 municipal solid waste landfills and 19 industrial waste landfills.

Fig. 3 Web application for long-term landfill management: (Top left) Spatial map of CO₂ concentration on April 18, 2022. (Top right) Spatial map of landfill gas temperature on April 18, 2022. (Bottom left) Interactive map with monitoring points for selecting target locations (e.g., No. 12). (Bottom right) Time-series plot of gas and outside temperatures with spline interpolation for the selected point.



In an international collaborative project with King Mongkut's University of Technology, Thonburi, and Kasetsart University (both in Thailand), we conducted a survey of waste management facilities in Japan and Thailand to develop an evaluation framework for the multiple environmental impacts of waste management. The aim was to strengthen the networks of waste management schemes to be more resilient to disasters and climate change. This involved gathering information on GHG emissions, energy consumption and production, economic and human costs, and trends in plastic waste management. As part of this initiative, two postgraduate students from Thailand stayed at NIES to deepen mutual understanding regarding the resilience of waste management systems. A workshop for local authorities was held in Thailand to consider the renewal of the country's waste management systems. Information was exchanged on the importance of redundancy in waste management systems as a public service, as well as on the level of acceptance of this concept in Thailand. The actual conditions of waste collection by individual settlements, as well as of waste incineration in small-

scale furnaces and dumping in the mountainous regions of Chiang Rai, Thailand, were investigated as part of a study of community-level waste management in Southeast Asia. Although the direct impact of air and water pollution on residential areas was not significant, emissions of hazardous substances cannot be ignored from the perspective of wide-area environmental management. There are also concerns about the potential health effects on workers at these sites. Because this issue is closely linked to the autonomy of ethnic minorities, decentralized management was proposed as a more reasonable option in terms of transport efficiency. In addition, relevant local authorities should respond by providing appropriate advice and budget support for conducting monitoring. In a study of waste recycling in Yogyakarta, Indonesia, it was revealed that facility capacity is not being fully utilized because of instability of the waste collection system. Additionally, fluctuations in waste volume and quality caused by tourism-related activities and the impact of natural disasters are factors hindering appropriate management. Technical advice is required to ensure the effective operation of the recycling facility, along with improvements in the accuracy of waste generation forecasts.

As part of our research on decentralized domestic wastewater treatment systems in Southeast Asia, we participated in an international workshop organized by the Ministry of the Environment, and in the ISO/TC224/WG8 meeting, to discuss performance testing methods and the standardization of operation and maintenance procedures for decentralized systems.

2.4 International Waste Management Research Administration Office

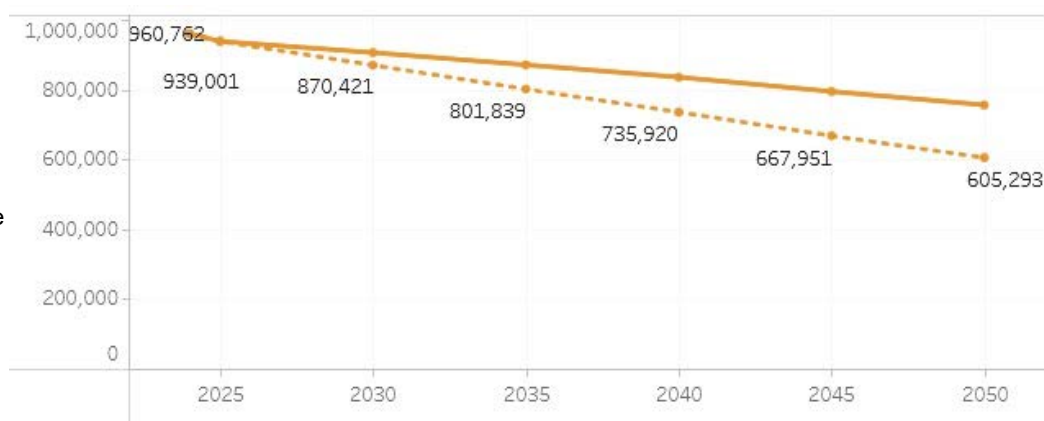
As part of a joint research project with the National Institute of Environmental Research in Korea, we collected and analyzed statistical data to compare the current situations regarding waste recycling and management in both countries, and we published a data book containing this information. In response to a request from the Korea Waste-to-Energy Association, we hosted a PhD student as an intern. This involved facilitating visits to relevant industries and local authorities in Japan, as well as exchanges of views and interactions with young researchers in this field. A liaison between the JICA Global Environment Department and our division was established, and regular information-exchange sessions were held to raise topics and issues that contribute to international cooperation and research. We also coordinated and arranged meetings with relevant researchers, including research discussions with visiting delegations from the Abu Dhabi Environment Agency and the Chinese Academy of Sciences, and we responded to a request for advice from the city of Agadir in Morocco. Building on the previous fiscal year's work, we continued to promote the societal implementation of research outcomes through involvement in international standardization activities. We also continued to foster cross-disciplinary exchanges for foreign researchers as part of information sharing and human resource development within the division.

3 Intellectual Research Infrastructure Development

We made an annual update to the material flow database (NIES Global Trade of Materials) for data on six elements (Fe, Cu, Ni, Au, Co, and Nd) through 2021, and we calculated the amount of material transfer associated with international trade and apparent consumption and stocks for nine elements (Fe, Al, Cu, Zn, Pb, Hg, Au, Ni, and Co) through 2023.

We released the Future Simulator of Municipal Waste, a new tool equipped with current and future projection data on the generation, recycling, and treatment of municipal solid waste. It is designed to support local governments in examining future waste management strategies and facility development plans. Figure 4 is an example of waste estimates generated by the simulator. The Future Simulator is intended to support municipalities across Japan in addressing the challenges posed by depopulation. It enables users to examine future scenarios for waste treatment, resource circulation, and facility development for both individual municipalities and groups of municipalities with a view to promoting inter-municipal cooperation and the consolidation of waste treatment facilities.

Fig. 4 Screenshot of the Future Simulator projecting the future generation of municipal waste in Ibaraki Prefecture. The vertical axis represents the estimated annual waste generation (tons).



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 encompassed studies of the following: (1) calculation of the ecological risk rankings of pharmaceuticals in Japan across different biological groups, including algae and daphnids; (2) quantitative analysis of pesticide residues in honey samples, based on improved pretreatment methods and enhanced analytical sensitivity and precision; (3) assessment of changes in ecosystem conditions through continued experimental bottom trawling and environmental surveys in Tokyo Bay and along the coast of Fukushima Prefecture; (4) use of a global mercury model to examine the impacts and contributing factors of climate warming and climate modes on mercury cycling; (5) assessment of the failure to detect oxidative stress induction when cells were exposed to oxidatively degraded nanoparticles at the air–liquid interface; (6) investigation of the potential for perfluorooctanoic acid to contribute to different pathological conditions in senescence-accelerated mouse prone 8 (SAMP8) mice depending on exposure dose, and confirmation of the involvement of DNA methyltransferase expression in the mechanism of arsenic-induced inhibition of muscle differentiation; (7) confirmation that human immortalized neural stem cells (ReNcell) internalize nanoplastic particles following exposure to fluorescently labeled polystyrene nanoparticles; (8) development of a blood biomarker analytical method by exploring biomarkers applicable to the assessment of exposure to green spaces, focusing on terpenes emitted by coniferous and broadleaf trees; and (9) confirmation that plantation development increases the risk of infectious disease pathogen spillover in local communities and that elderly individuals living with companion animals have a reduced risk of developing health disorders. The findings on (1) pharmaceuticals, (6) arsenic-induced inhibition of muscle differentiation, and (9) companion animals are presented and summarized below as representative results.

In our policy-oriented research, we conducted regulatory science studies that were aimed at contributing to environmental policy and were based on foresight and advanced basic research. This fiscal year, we specifically (1) performed continuous monitoring of atmospheric mercury concentrations over a larch forest stand to characterize their seasonal and diurnal variations, and (2) identified the blue substance responsible for water quality incidents at drinking water sources, following the relocation of the Wako Branch of the Drinking Water Quality Research. Furthermore, as part of the development of an intellectual research infrastructure, we updated WebKis-Plus (NIES's comprehensive chemical substance database) with the latest information, improved its usability through site modifications, and maintained and provided biological resources to support research both within and outside the institute.

Below are brief accounts of some of the important results of our research in FY 2025.

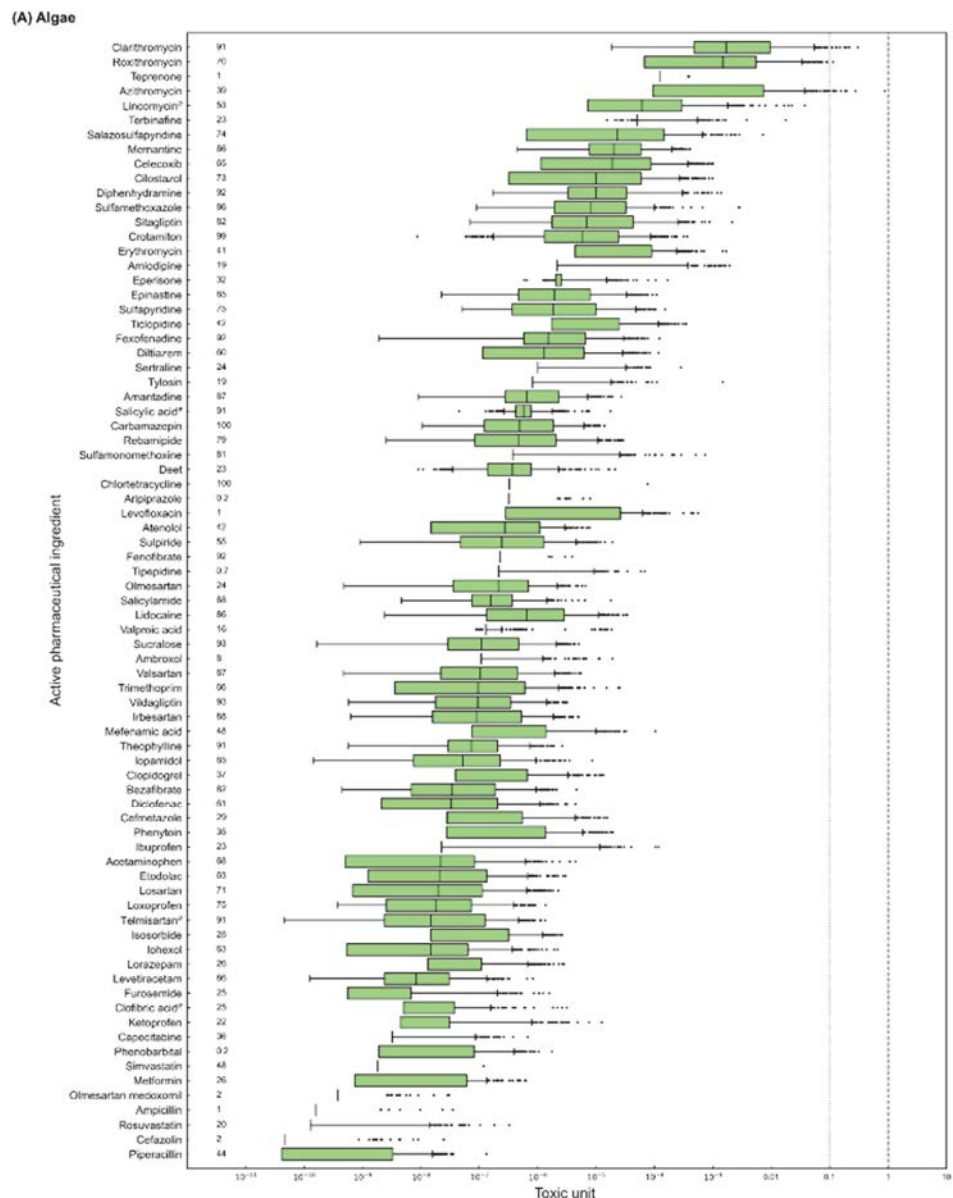
1. Foresight and Advanced Basic Research

1.1 Ecological risk ranking of pharmaceuticals for human use in surface waters in Japan

We continued conducting ecological risk assessments of human pharmaceuticals cooperatively with the National Institute of Health Sciences (NIHS). In this project, the NIES ecotoxicity research team newly conducted (sub-)chronic toxicity tests for more than 40 pharmaceuticals. The NIHS group continued its ongoing work on developing and refining environmental risk assessment guidance, in addition to its simultaneous monitoring of nearly 100 pharmaceuticals, development of an ecotoxicity database for the pharmaceuticals, and validation of the current action limits based on Predicted Environmental Concentrations for further risk assessment.

The (sub-)chronic toxicity tests conducted by our research team include an algal growth inhibition test using a green alga (*Raphidocelis subcapitata*), a daphnid reproduction test using *Ceriodaphnia dubia*, and short-term toxicity tests with early-life stage (embryo and sac fry stage) zebrafish (*Danio rerio*). By combining these newly obtained data with data collected in a literature search, we were able to compile (sub-)chronic toxicity data for over 70 pharmaceuticals detected by a monitoring campaign of approximately 600 samples of surface water from all over Japan in 2018–2021 (Kobayashi et al., 2026)¹⁾. Toxic unit (TU) values were determined for each species (alga, daphnid, and fish) from the individual measured concentrations divided by the no-observed effect concentration (NOEC) for these pharmaceuticals. After sorting the TU values of individual pharmaceuticals for algae, daphnid, and fish, we found that the TU exceeded 0.1 only for three macrolide antimicrobials (clarithromycin, roxithromycin, and azithromycin) in algae, whereas no pharmaceuticals exceeded a TU of 0.1 for daphnid and fish, although we need to keep in mind that some hormonal agents (e.g., the contraceptive pill) were not measured. We also calculated the sum of the TU values for each sampling site and found that the maximum value exceeded 1 and the 95th percentile exceeded 0.1 (the trigger value for further risk assessment and management) (Fig. 3; Ninomiya et al., 2026)²⁾.

Fig. 1 Ecological risk ranking of human pharmaceuticals in algae in Japan, evaluated by toxic unit and arranged in descending order based on the median. In each boxplot, the left whisker, middle line, and right whisker represent the 5th percentile, median, and 95th percentile (box represents 25th and 75th percentile), respectively. The number displayed on the left side indicates the detection frequency (created with data from Ninomiya et al., 2026²), licensed under CC BY-NC 4.0).



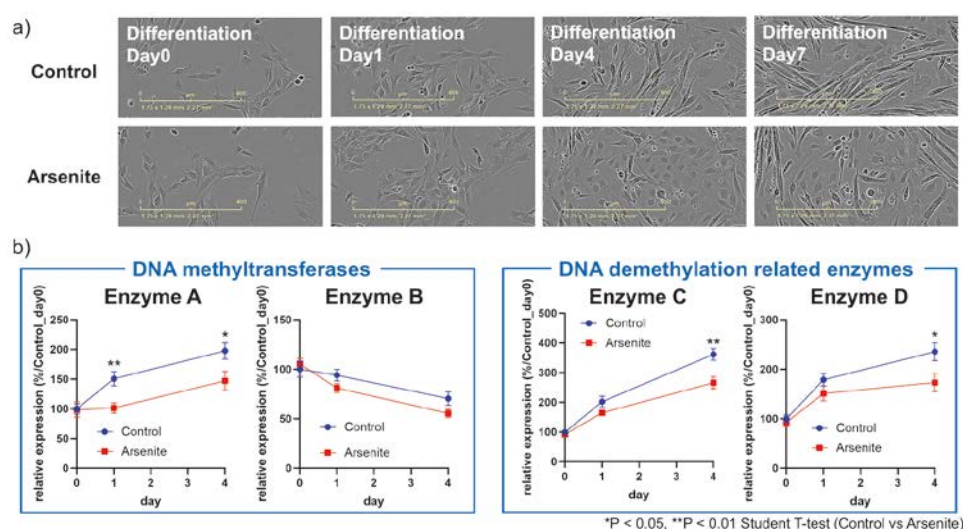
1.2 Investigation of the mechanisms by which arsenite exposure inhibits muscle differentiation

Arsenic is a known environmental toxicant affecting more than 100 million people worldwide, primarily through chronic exposure to contaminated drinking water, and it has been closely linked to cardiovascular diseases. However, the underlying pathogenic mechanisms for these increased health risks remain largely unclear. Declines in muscle quality, together with impaired metabolic function, contribute to increased cardiovascular disease morbidity and mortality, partly through their effects on metabolic regulation and physical function. Previous *in vivo* and *in vitro* experiments have shown that arsenic exposure inhibits muscle regeneration and differentiation. Therefore, clarifying the mechanisms by which arsenic exposure inhibits muscle differentiation is important for preventing and treating arsenic-

induced cardiovascular diseases. However, little is known about the mechanisms underlying arsenic-mediated inhibition of muscle differentiation. As epigenetic modifications—particularly DNA methylation—are known to play a critical role in cell differentiation, we investigated whether arsenic exposure alters the expression of DNA-methylation-related genes during this process.

We confirmed that arsenite (the trivalent form of inorganic arsenic) exposure inhibits cell differentiation. Clear morphological changes were observed after 4 days of differentiation in C2C12 cells, a mouse myoblast cell line (Fig. 1a). The mRNA expression of a DNA methyltransferase gene (Enzyme A) was markedly increased in the control group following differentiation stimuli, suggesting that its induction plays an important role in the progression of differentiation (Fig. 1b). On the other hand, arsenite exposure suppressed gene expression from day 1 of differentiation, preceding the morphological changes observed on day 4. The gene expression levels of DNA demethylation-related enzymes (Enzyme C and Enzyme D) were also induced by the differentiation stimuli, and arsenite exposure suppressed their expression (Fig. 1b). However, the effect of arsenite exposure was observed only on day 4, and not on day 1, suggesting that the changes in gene expression occur downstream of changes in the DNA methyltransferase gene expression. Our study elucidated the time-dependent change of gene expression of DNA methylation-related enzymes during myoblast differentiation, revealing that arsenite exposure inhibits the induction of methyltransferase before the appearance of visible morphological changes. This inhibition may be involved in the inhibition of muscle differentiation.

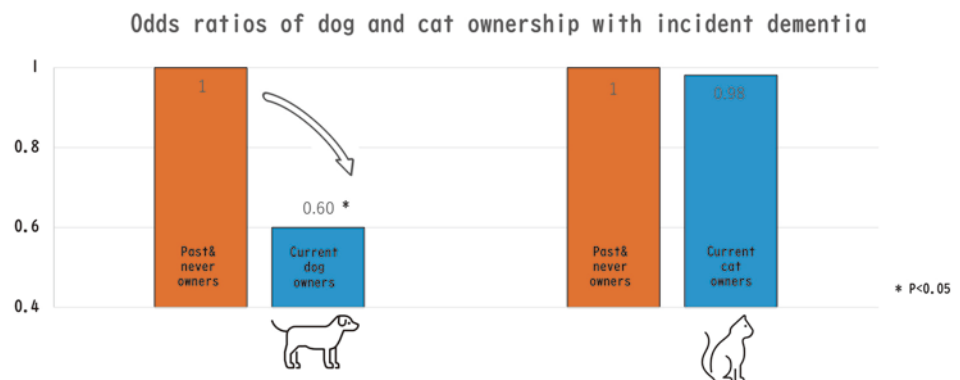
Fig. 2 (a) Morphological changes in C2C12 cells following differentiation stimuli in control and arsenite-exposed groups. (b) Time-dependent changes in the expression levels of DNA-methylation-related genes



1.3 Elderly people who live with dogs have a 40% lower risk of developing dementia

In an epidemiological study that was conducted by the Tokyo Metropolitan Institute of Gerontology and tracked over 11,000 elderly individuals, we analyzed the impact of living with dogs and cats on the onset of disabling dementia³⁾. Dog/cat ownership was defined as “current” or “past or never”. Disabling dementia was defined according to physicians’ ratings in the long-term care insurance system in Japan during the 4-year follow-up period. Current dog owners had an odds ratio of 0.60 of having disabling dementia compared with past or never owners (Fig. 2). For cat ownership, the corresponding odds ratio was 0.98. After adjustment for background factors, dog ownership had a suppressive effect on incident disabling dementia. Specifically, dog owners with an exercise habit and no social isolation had a significantly lower risk of disabling dementia. Our joint research with the Tokyo Metropolitan Institute of Gerontology has also shown that elderly people who live with dogs have a lower risk of onset of disability and mortality⁴⁾, but the mechanisms remain largely unknown. Further research at NIES will elucidate the mechanisms of the health benefits that companion animals have on humans.

Fig. 3 Associations between experience with dog or cat ownership and dementia incidence



References:

- 1) Kobayashi N., Tsuchiya Y., Kosugi Y., Suzuki T. (2026) Occurrence and fate of pharmaceuticals and personal care products in river water, lake water, sewage effluent, tap water, and groundwater in Japan, *Environmental Toxicology and Chemistry* 45(1), 45–56. <https://doi.org/10.1093/etjnl/vgaf261>
- 2) Ninomiya Y., Oda Y., Watanabe H., Yamagishi T., Kobayashi N., Yamada T. Hirose A., Yamamoto H. (2026) A comprehensive ecological risk assessment of pharmaceuticals in Japan with newly obtained chronic toxicity, *Environmental Toxicology and Chemistry*, 45(6), 1636-1652. <https://doi.org/10.1093/etjnl/vgag080>
- 3) Taniguchi Y., Seino S., Ikeuchi T., Hata T., Shinkai S., Kitamura A., Fujiwara Y. (2023) Protective effects of dog ownership against the onset of disabling dementia in older community-dwelling Japanese: A longitudinal study.

- 4) Taniguchi Y., Seino S., Headey B., Hata T., Ikeuchi T., Abe T., Shinkai S., Kitamura A. (2022) Evidence that dog ownership protects against the onset of disability in an older community-dwelling Japanese population. *PLoS One* 23, 17(2):e0263791

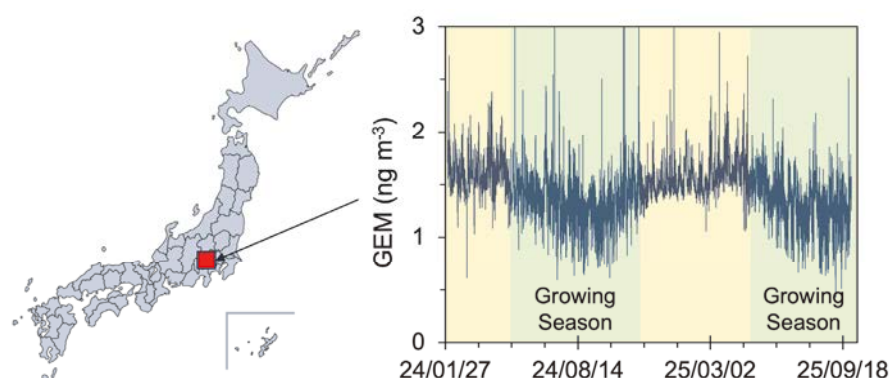
2. Policy-Oriented Research

2.1 Atmospheric mercury monitoring and natural variability analysis to evaluate the effectiveness of the Minamata Convention

In FY 2025, continuous observations of atmospheric mercury (Hg) concentrations were conducted above a larch forest canopy at the northern foot of Mt. Fuji (Fig. 4) to investigate the influence of terrestrial ecosystems on atmospheric mercury levels.

The observed mean concentration of gaseous elementary Hg (GEM) above the canopy was $1.5 \pm 0.2 \text{ ng m}^{-3}$ —a value that is comparable to the background level in the Northern Hemisphere and indicates the absence of local emission sources at the study site. A pronounced seasonal variation was nevertheless observed. The average GEM concentration during the growing season was $1.4 \pm 0.2 \text{ ng m}^{-3}$ —about 14% lower than that during the non-growing season (Fig. 4). This seasonal pattern is consistent with previous studies suggesting that terrestrial ecosystems act as a sink for atmospheric mercury. In particular, the reduced GEM concentrations during the growing season likely reflect enhanced uptake by vegetation through physiological processes such as stomatal assimilation.

Fig. 4 Location of the monitoring site (left) and seasonal variation of gaseous elementary mercury (GEM) concentrations (right)

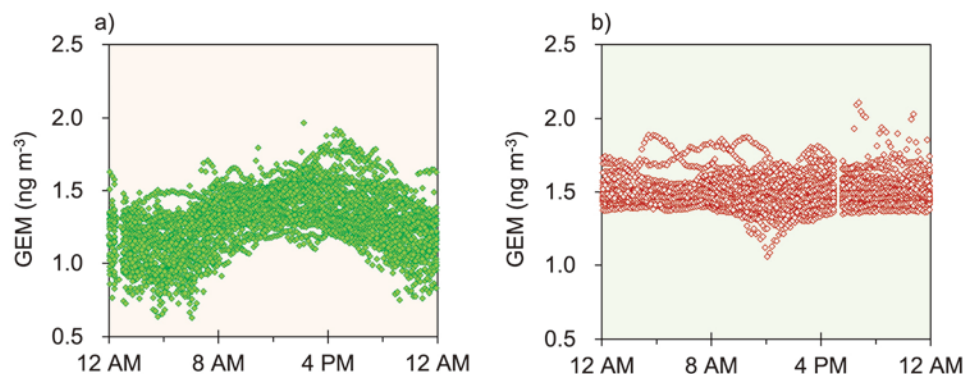


Analysis of diurnal variability revealed that, during the growing season, GEM concentrations tended to be lower at night than during the daytime, whereas no substantial diurnal variation was observed during the non-growing season (Fig. 5). These findings suggest that the larch forest may influence both seasonal and diurnal variations in GEM concentrations.

The findings of this study provide important insights into atmospheric Hg

variability, contributing to evaluations of the effectiveness of the Minamata Convention and supporting the assessment of future international Hg mitigation strategies.

Fig. 5 Diurnal GEM variations in the (a) growing and (b) non-growing seasons



2.2 Identification of the chemical causing the blue water quality incident

Water quality incidents caused by human activities that affect drinking water quality are a major concern for water utilities and people. Blue water was observed in an agricultural water channel in the city of Ikeda, in Osaka Prefecture, in March 2025¹⁾ (Fig. 6). The blue water flowed into the Inagawa River, and water intake at a downstream drinking water treatment plant was suspended about 4.5 h after the blue water was observed upstream in the river. Water samples were obtained from the water channel during the incident by staff of the Ikeda City Waterworks and Sewage Department and were analyzed by using liquid chromatography with photodiode array and high-resolution mass spectrometry (LC-PDA-HRMS).

The PDA spectrum of the peak in the water samples exhibited a maximum absorption wavelength at 628 nm, corresponding to the blueness. The PDA spectrum, HRMS spectrum, and retention time of the peak of the sample during the incident corresponded to a commercial blue food coloring product having brilliant blue FCF (BB-FCF) as the blue component and to a BB-FCF reference standard. Thus, BB-FCF was identified as the causative chemical during the incident. BB-FCF is a synthetic food coloring approved for use as a food additive in Japan. The treatability of BB-FCF by using powdered activated carbon was also evaluated, as were the BB-FCF loads into the water environment during the incident.

Information related to BB-FCF was provided to the water utility and to the Ministry of the Environment. Also, this information was provided to the Regional Development Bureau of the Ministry of Land, Infrastructure and Transport via the water utility.

3. Health and Environmental Risk Domain

Fig. 6 Water in the Inagawa River during the blue water incident (provided by the Ikeda City Waterworks and Sewage Department)



Reference:

- 1) Kinki Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan (2025). Blue-colored water has been observed near an agricultural water channel that flows into the Inagawa River, part of the Yodo River System (Furuemachi, Ikeda City, Osaka Prefecture). No reports of any impact have been received at this time (March 9, 2025, 7:00 p.m.). (in Japanese)
<https://www.kkr.mlit.go.jp/news/top/press/2024/20250309-1inagawa.html>

Regional Environment Conservation Domain

Human activities have substantial impacts 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). It also has a Lake Biwa Branch Office in Shiga Prefecture.

In FY 2025, 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:

- Analysis of source sensitivities of surface ozone concentrations in Japan at multiple timescales
- Estimating internal dissolved methane loading in rivers by using a mass balance approach.

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 2025.

1 Foresight and Advanced Basic Research

1.1 Analysis of source sensitivities of surface ozone concentrations in Japan at multiple timescales

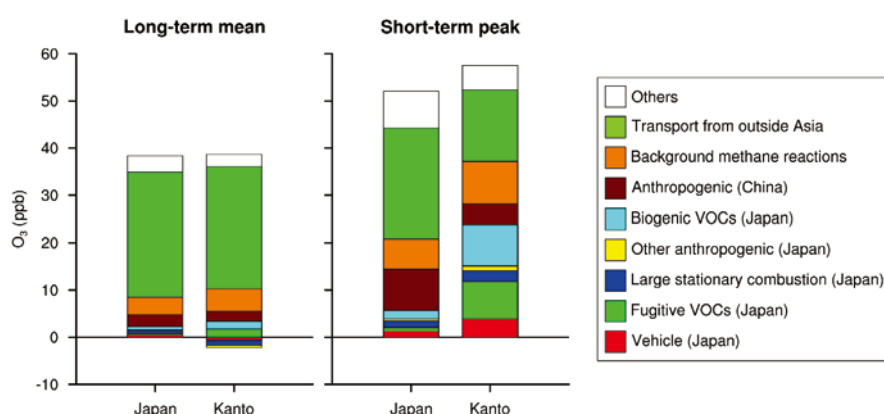
Source sensitivities—defined as changes in ambient pollutant concentrations in response to variations in precursor emissions—are useful for identifying key

4. Regional Environment Conservation Domain

contributors to ambient pollution levels and for predicting the effectiveness of emission-reduction strategies. The Japanese environmental quality standards for photochemical oxidants (primarily ozone) have recently been revised by the government, with two distinct criteria established for short-term peak and long-term mean concentrations. In this study, the source sensitivities of both short-term peak (defined as the annual mean of the top 10 daily maximum 8-h average concentrations) and long-term mean (defined as the annual mean of daily maximum 8-h average concentrations) surface ozone concentrations in Japan were analyzed by using air quality simulations (Chatani and Shimadera, 2025). These simulations incorporated long-term emission inventories developed in the study, which provided useful insights for mitigating both short-term peak and long-term mean surface ozone concentrations.

There were evident differences in the source sensitivities of long-term mean and short-term peak surface ozone concentrations (Fig. 1). Long-term mean concentrations were highly sensitive to transport from outside Asia and to background methane reactions, whereas short-term peak concentrations were more sensitive to anthropogenic sources in Japan and transboundary transport from China. Short-term peak concentrations in urban areas were more sensitive to sources of volatile organic compounds (VOCs), whereas those in other areas were more sensitive to sources of nitrogen oxides (NO_x), reflecting differences in ozone formation regimes. The results imply that the emission controls implemented in Japan are effective to some extent in suppressing short-term peak concentrations, whereas international cooperation is essential for reducing long-term mean concentrations.

Fig. 1 Source sensitivities of short-term peak and long-term mean surface ozone concentrations throughout Japan and in the Kanto area



Reference:

Chatani S., Shimadera H. (2025) Analysis of source sensitivities of surface ozone concentrations in Japan in multiple timescales. *Journal of Japan Society for Atmospheric Environment* 60(5), 101–114. doi.org/10.11298/taiki.60.101

1.2 Estimating internal dissolved methane loading in rivers by using a mass balance approach

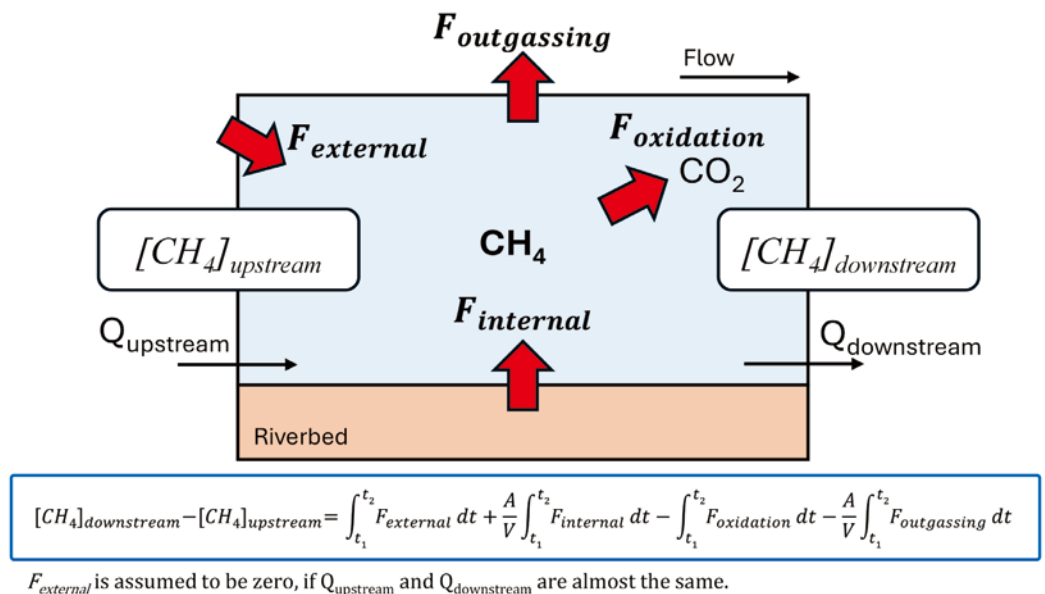
Rivers and streams are important sources of methane (CH_4) released to the atmosphere, but the mechanisms controlling riverine CH_4 emissions remain insufficiently quantified. Methane in rivers is supplied by both internal production within riverbed sediments and external inputs from groundwater, wetlands, soils, and tributaries. Because these two pathways require different mitigation strategies, separation of internal and external CH_4 loading is essential for understanding and managing riverine greenhouse gas emissions.

In this study, we developed a simple mass balance approach to estimate the internal dissolved CH_4 loading from riverbed sediments (Fig. 2). The method uses the difference in dissolved CH_4 concentration between upstream and downstream sites within a short river reach where tributary inflow and discharge changes are negligible. Under these conditions, external loading can be assumed to be small, allowing internal loading from the riverbed to be estimated while accounting for CH_4 oxidation and outgassing to the atmosphere.

We applied this approach to two reaches of the Kokai River, Ibaraki, Japan, including sections affected by the operation of the Fukuoka Weir for agricultural irrigation. The estimated net CH_4 flux from the riverbed sediment to the water column ranged from -33 to $160 \mu\text{mol m}^{-2} \text{h}^{-1}$ (Tsuchiya et al. 2025). This range was comparable to values reported by previous studies using benthic chambers, porewater-based model simulations, isotope-based approaches, and other mass balance methods. These results indicate that the proposed method provides realistic reach-scale estimates of internal CH_4 loading with less intensive fieldwork than in conventional approaches.

The study also revealed clear spatial and seasonal variations in internal CH_4 loading. Internal loading was generally higher in summer and lower in winter. During the

Fig. 2 Schematic illustration of the reach-scale mass balance approach used to estimate internal dissolved CH_4 loading in rivers. Changes in dissolved CH_4 concentration between upstream and downstream sites are controlled by internal loading from the riverbed, external loading, microbial oxidation, and outgassing to the atmosphere. In short reaches with negligible discharge change, external loading can be assumed to be small, allowing internal loading to be estimated from the mass balance.



latter half of the irrigation period (July to August), internal CH₄ loading was significantly higher upstream of the weir than downstream. This difference suggests that weir operation modifies local hydrological conditions by increasing the water depth and reducing the flow velocity. Such conditions can promote sediment deposition and create favorable conditions for CH₄ production near the sediment–water interface.

These findings demonstrate that hydraulic structures can substantially modify CH₄ dynamics in agricultural river systems. The proposed mass balance approach is useful for identifying river sections with high internal CH₄ loading and for evaluating how river management practices influence greenhouse gas emissions. Because the method is simple and can be applied across multiple reaches, it has potential for large-scale assessments of internal CH₄ loading and for informing practical mitigation strategies for riverine CH₄ emissions.

Reference:

Tsuchiya, K., Miura, S., Kohzu, A. (2025) Estimating internal dissolved methane loading in rivers using a mass balance approach. *PeerJ* 13, e20238.

2 Intellectual Research Infrastructure Development

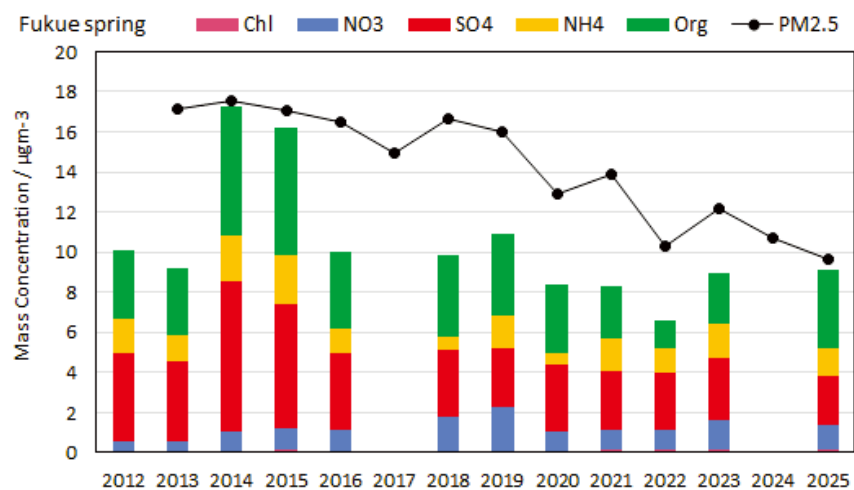
2.1 Long-term monitoring of air pollutants for the purpose of monitoring air quality in East Asia at Cape Hedo and Fukue Island

Long-term monitoring of atmospheric pollutants, including aerosols and gaseous species, has been conducted by our division at the Cape Hedo Atmosphere and Aerosol Monitoring Station (CHAAMS, 26.9°N, 128.3°E) on Okinawa Island and at the Observatory of Atmospheric Environment on Fukue Island (33.4°N, 130.4°E) in Nagasaki, Kyushu. These observations aim to capture changes in the atmospheric environment over the East Asian region. Observations of the optical, physical, and chemical properties of aerosols—including scattering coefficients, chemical composition, mass concentrations, and vertical distributions—have been conducted since spring 2004 at CHAAMS and since autumn 2008 on Fukue Island.

Figure 3 shows the results of aerosol chemical composition observations on Fukue Island during the spring season from 2012 to 2025 (excluding 2017 and 2024). During spring, Fukue Island is frequently affected by long-range transport of transboundary air pollutants originating from mainland China via the seasonal monsoon. From 2013 to 2019, sulfate concentrations decreased, whereas nitrate concentrations exhibited an increasing trend. In 2020, when economic activity declined significantly owing to COVID-19 mitigation measures, PM_{2.5} concentrations decreased markedly. Correspondingly, nitrate concentrations also decreased, whereas no substantial change was observed in sulfate concentrations. These trends likely reflect changes in the emissions of sulfur dioxide (SO₂) and nitrogen oxides (NO_x) from the Asian continent. Although SO₂ emissions in China have shown little change since 2019, NO_x emissions decreased substantially in 2020

because of COVID-19-related restrictions; however, the rate of decline has since slowed, or may even have reversed, with the recovery of economic activity. These results highlight the importance of continued long-term observations to track changes in air quality in the East Asian region.

Fig. 3 Long-term trends in aerosol chemical composition and PM_{2.5} mass concentration observed on Fukue Island during spring (Chl: chloride; NO₃: nitrate; SO₄: sulfate; NH₄: ammonium; Org: organics)



Biodiversity Domain

We 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 are also clarifying and evaluating 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 developed an autonomous surface vehicle to improve the monitoring of aquatic macrophytes. Tests in Lake Nojiri showed that the vehicle gave efficient GNSS (global navigation satellite system)-based autonomous navigation and clear observations of submerged aquatic vegetation. We used the captured images to create orthomosaics and an AI method to map submerged vegetation, thus enabling rapid and effective lake monitoring. As part of our **Policy-Oriented Research**, we released the Lake Biwa Fish Egg Distribution Database. This database compiles egg-distribution records from our studies and displays DNA-based species identification results on an interactive map. It enables users to visualize the recovery of spawning sites for native fishes, thereby helping to evaluate conservation measures and guide future restoration efforts.

As part of our **Intellectual Research Infrastructure Development**, we preserve the genetic resources of endangered species through cryobanking. By using these materials, we compared the antiviral responses of *RIG-I* (*retinoic acid-inducible gene 1*) and *MDA5* (*melanoma differentiation-associated gene 5*) in somatic cells from domestic cats and the Iriomote wild cat (*Prionailurus bengalensis iriomotensis*) exposed to an RNA virus analog. We found similar gene expression between the two species, providing the first insights into innate immune responses in the critically endangered Iriomote subspecies.

1 Foresight and Advanced Basic Research

Aquatic macrophyte surveys in lakes are essential for the assessment and conservation of aquatic environments and ecosystems. Conventional survey methods include diver-based observations, aerial imaging by drones, and visual inspection or video recording using remotely operated vehicles (ROVs) and underwater cameras. However, aerial drone surveys are affected by surface reflection and wave action, which hinder the accurate identification of submerged plant species. ROV surveys also present practical limitations, including the risk of vegetation entanglement in propellers and the difficulty of precisely identifying survey tracks and image-acquisition points because many platforms lack GNSS. Diver-based surveys also require greater cost and labor, making routine monitoring difficult.

To overcome these limitations, we developed an autonomous surface vehicle (ASV) equipped with GNSS-based autonomous navigation and an underwater camera. By using continuous subsurface imaging during autonomous navigation, we established a novel method for observing submerged vegetation by integrating remote-sensing techniques, including Structure from Motion (SfM) and orthomosaic image generation (Fig. 1).

Field experiments conducted in Lake Nojiri in Nagano Prefecture produced georeferenced and scaled orthomosaic images of submerged vegetation and underwater topography. Deep learning was applied to these orthomosaic images to generate a broad-area distribution map of aquatic vegetation (Fig. 2). The ASV enabled simple and rapid mapping of submerged vegetation. This study was conducted in collaboration with Shimane University.

Fig. 1 Exterior view of the autonomous surface vehicle (ASV)

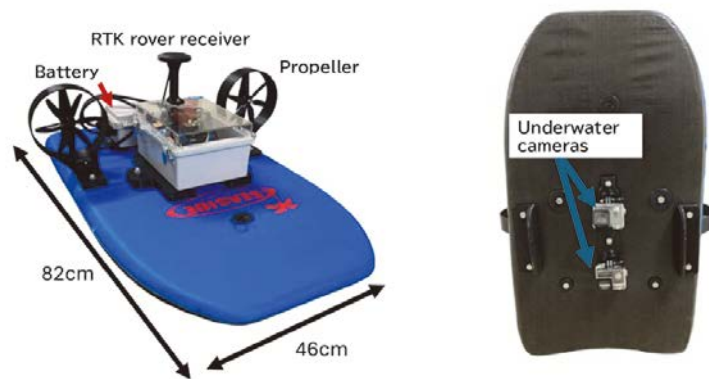
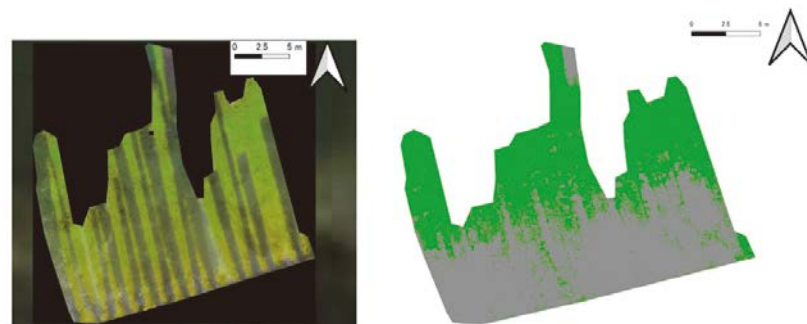


Fig. 2 Underwater orthomosaic image of the survey area (left) and aquatic vegetation distribution map generated by using deep learning model (right). Green indicates the presence of aquatic vegetation, whereas gray indicates its absence.



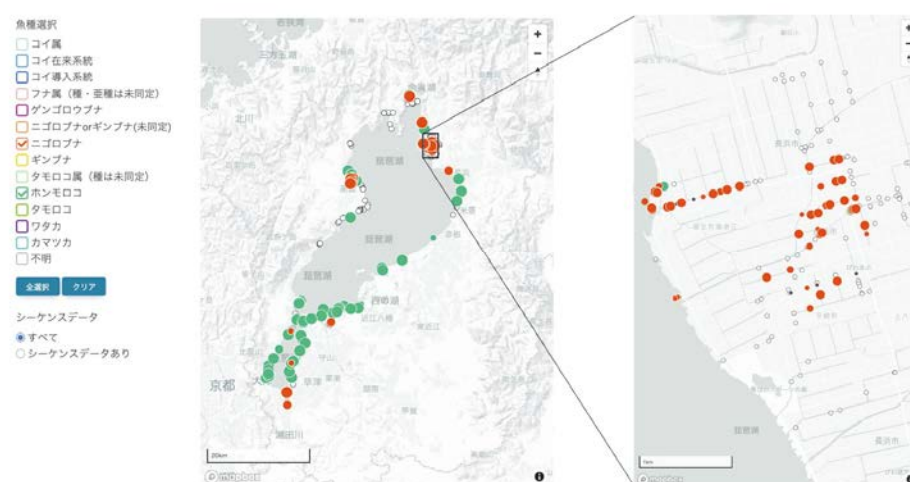
2 Policy-Oriented Research

Shiga Prefecture, which encompasses Lake Biwa—the largest lake in Japan—aims to realize and restore a society in which people and a lake-centered ecosystem coexist. As a symbol of this effort, the prefecture is working to restore stocks of the native cyprinid fishes that have been consumed since ancient times. During the spawning season, these native fishes migrate from offshore areas to lakeside reed zones, rice fields, and waterways to spawn. However, the construction of lakeside embankments and the modernization of rice paddy irrigation systems between the 1970s and 1990s resulted in the loss of many spawning grounds, leading to a drastic decline in native fish populations.

To address this issue, Shiga Prefecture has been creating new reed zones along the lakeshore and promoting the installation of fish passages in waterways to facilitate the upstream migration of native fishes into rice fields. However, the effectiveness of these measures has not been fully understood.

To help evaluate and improve these conservation efforts, the NIES Lake Biwa Branch Office has been investigating the current state of native fish breeding ecology by collecting spawning eggs and conducting DNA-based species identification. Building on these investigations, we have also taken steps to support the conservation and restoration of spawning habitats more broadly. This year, we released the Lake Biwa Fish Egg Distribution Database, which compiles the deposited-egg distribution records previously reported in our scientific publications (Fig. 3). The database displays species identification results for collected eggs on an interactive map, enabling users to observe the recovery of *honmoroko* (*Gnathopogon caeruleus*) spawning sites along the lakeshore (green circles), as well as the upstream spawning activity of *nigorobuna* (*Carassius auratus grandoculis*) in rice-field waterways (red circles).

Fig. 3 Map interface of the Lake Biwa Fish Egg Distribution Database

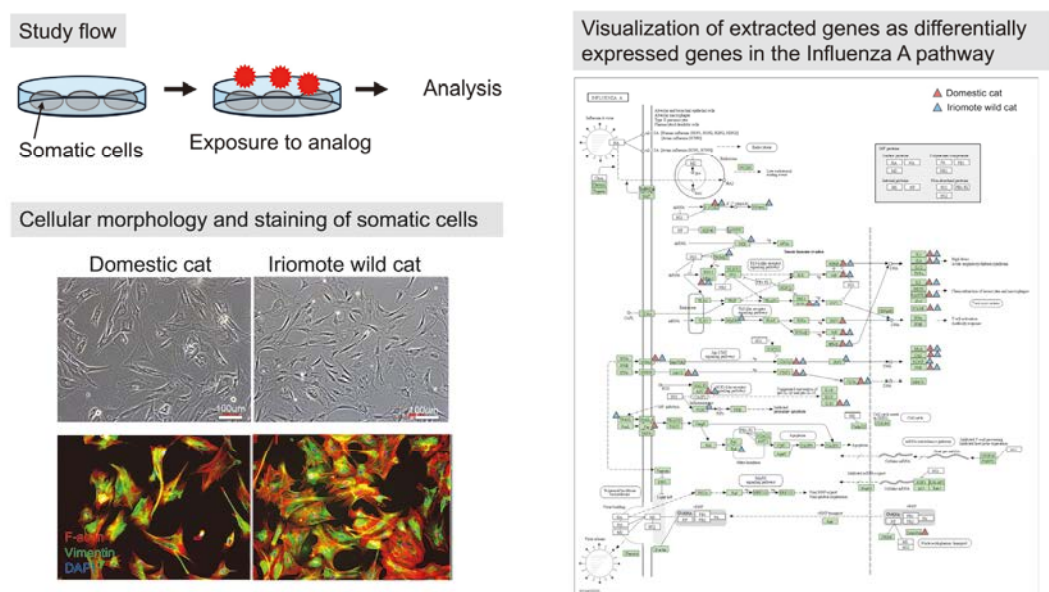


3 Intellectual Research Infrastructure Development

Somatic cells, germ cells (e.g., sperm, eggs, and fertilized eggs), and tissues of endangered species are cryopreserved as genetic resources in the Environmental Specimen Time Capsule Building of NIES. Cryopreservation of genetic resources in the so-called genetic resource bank is one of the options for *ex situ* conservation. These genetic resources are additionally used for research activities such as reproductive biology, genetic diversity evaluation, bioresource development, and infectious disease ecology. Here, we present one example of how these cells were used in endangered species research.

The Iriomote wild cat (*P. bengalensis iriomotensis*) is an endemic subspecies of Iriomote Island. The total population of the Iriomote wild cat is only 100; therefore, these cats are listed as critically endangered on the IUCN Red List. Infectious disease is listed as a risk factor for further reducing the population. RIG-I and MDA5 are important sensors that recognize host viral defense responses, and their gene-derived signals have a critical effect on the exacerbation of viral infections in animals. In this study, we tried to compare the *RIG-I* and *MDA5* responses of domestic cat- and Iriomote wild-cat-derived somatic cells after exposure to the analog of an RNA virus. A comprehensive gene expression analysis revealed that the molecular responses of cells derived from domestic cats and those derived from Iriomote wild cats to exposure to the analog were similar. To the best of our knowledge, this is the first study to compare the *RIG-I* and *MDA5* responses of Iriomote wild cats and domestic cats after such exposure. This study provides valuable insights into the cellular response mediated by RIG-I and MDA5 in the Iriomote wild cat (Fig. 4).

Fig. 4 Comparison of *RIG-I* and *MDA5* responses after exposure of domestic cat- and Iriomote wild cat-derived somatic cells to the analog of an RNA virus. (Upper left) The study flow. (Lower left) The morphology of somatic cells of the domestic cat and the Iriomote wild cat, and the staining of these cells for representative markers of the nucleus (DAPI), cytoskeleton (F-actin), and intermediate filaments (Vimentin). (Right) The extracted genes as differentially expressed genes (DEGs) in the Influenza A pathway



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; this includes the development of 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 2025, the Social Systems Domain set the following research areas as **Foresight and Advanced Basic Research:** (1) research for development and application of an 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 an integrated assessment model

(1) Quantifying the carbon footprint of Japan's healthcare system by using a capital-endogenized input-output model

This study used a capital-endogenized input-output (IO) model based on the 2020 Japanese IO table to quantify the carbon footprint of Japan's healthcare system. The analysis covered medical services, long-term care, public health and hygiene, and household pharmaceutical products. It included emissions associated with buildings, vehicles, machinery, and other fixed capital used directly or indirectly through supply chains. The results showed that the healthcare system in Japan induced emissions of 74.1 Mt-CO₂e in 2020, equivalent to 6.4% of the country's total greenhouse gas emissions. Compared with a conventional model, the capital-endogenized model attributed an additional 13.5 Mt-CO₂e to the healthcare sector. These findings emphasize the necessity for decarbonization strategies that address both operational activities and capital-related supply chains.

(2) Impact of partner behavior differences on eco-friendly actions by newly married couples

The objective of this study was to analyze how individuals who have lived with different values influence each other's eco-friendly behaviors when they begin cohabitating upon marriage, and to thereby obtain insights that will help to promote effective climate change mitigation measures. In January 2025, an online questionnaire survey was conducted targeting individuals who had been married for 5 years or less and resided in the municipal areas of four prefectures. The survey focused on accessible daily climate change mitigation measures practiced at home, categorized into appliance purchases and routine conservation behaviors. For three major types of appliances, the survey investigated the methods used to acquire replacements and the points considered during purchase. The levels of implementation of routine conservation behaviors both before and after cohabitation were examined to analyze the changes in behavior resulting from living together. The findings revealed that, for example, regarding cooling temperature settings, women significantly lowered the set temperature after marriage but set it higher as the duration of marriage increased. Furthermore, choices regarding accessible mitigation measures vary depending on the type of behavior. Therefore, understanding these distinct characteristics is necessary to design tailored approaches for promoting energy-saving behaviors.

1.2 Research for environmental planning support

(1) Analysis of the transportation sector

To reflect regional characteristics of the creation of carbon neutral and livable

communities, we have continued to estimate and improve CO₂ emissions data for the residential and transportation passenger sectors, by municipality, throughout Japan.

In FY 2025, we evaluated a carbon tax with carbon dividends based on regional passenger vehicle mileage and CO₂ emissions. In the context of gasoline price increases, policies counter to achieving a decarbonized society—such as the introduction of subsidies for regional economies and low-income households, and discussions to eliminate the temporary tax rate—were considered by policymakers. We therefore examined a policy that would eliminate the tax burden on low-income and low-emission households by allocating part of the carbon tax revenue as dividends.

Specifically, we conducted a simulation in which the amount of carbon tax and related costs borne by vehicle owners with annual mileage at the median level would be returned via a dividend to all owners through automobile tax reductions or similar measures. Figure 1 shows the number of vehicles owned, by annual mileage, in Ibaraki Prefecture, and Figure 2 presents the estimated results for the carbon tax and carbon dividend in Ibaraki Prefecture. If the tax burden were reduced—such as by eliminating it entirely for owners with mileage below the median—the policy would become more socially acceptable. Furthermore, if the revenue that exceeded the carbon tax burden of low-mileage vehicle owners were reserved, it could be allocated toward supporting carbon neutrality initiatives or covering municipal fiscal shortages. Additionally, the study indicated that distributing carbon dividends on a regional level could mitigate regional disparities, because it would reduce the tax burden in areas where annual mileage tends to be higher, such as in Ibaraki Prefecture.

Fig. 1 Number of vehicles owned, by annual mileage range (Ibaraki Prefecture)

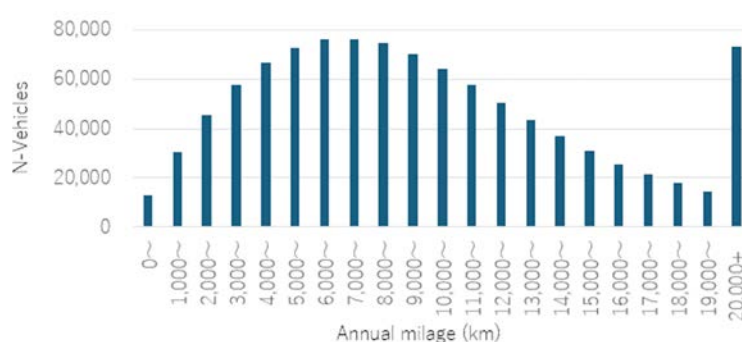
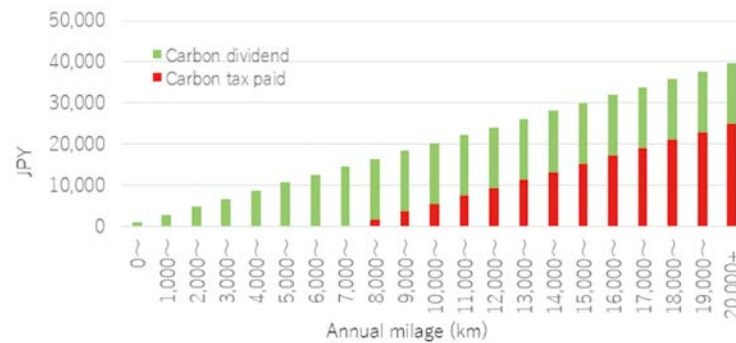


Fig. 2 Carbon tax and carbon dividend (Ibaraki Prefecture)



(2) Collaboration between field scientists and artists

The Fundamentals Program (2021–present; fundamentalz.jp) aims to reconnect science, art, and society to form a new culture. Here, the results of exchanges between scientists and artists have been announced through events such as the Fundamentals Festival and online activities such as video streaming. A NIES researcher, Toshiaki Ichinose (the author) has participated as a field scientist (urban environmentalist) since the first year and has collaborated with the following artists.

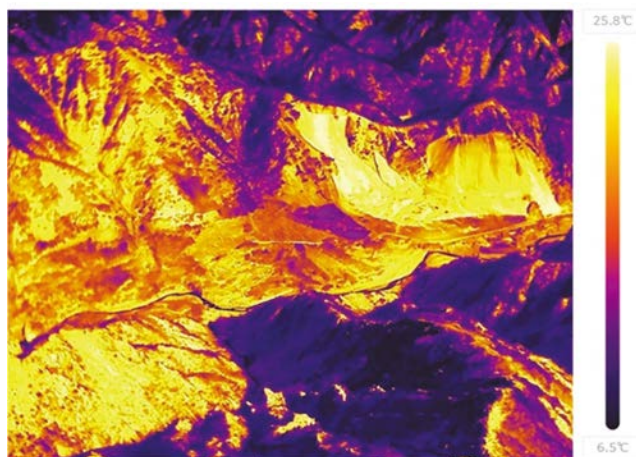
Filmmaker Dr. Kenichi Sawazaki: “Multimodal Co-Creation/Emotion in the Research Process” (2021–)

Ichinose was featured in short films such as “Records of Dialogue: On the Scientist’s Research by Toshiaki Ichinose and Kenichi Sawazaki” (Sawazaki, 2022: 75 minutes). In this work, he walks around Tokyo Station with a thermo camera in hand, interpreting the urban structure, natural environment, geography, and history of the area through the spatial distribution of surface temperature.

Photographer Dr. Yuiga Otsuki: “Landscapes and Social Issues” (2022–)

In 1990, Ichinose served as Chief of the Ashio Erosion Control Office at the Forestry Agency, Ministry of Agriculture, Forestry and Fisheries, and was engaged in erosion control projects for the Ashio Wasteland (Ashio, Nikko City, Tochigi Prefecture). Since 2019, Dr. Otsuki has been photographing the Ashio Wasteland under the theme of “Life and Death.” By comparing these newer photos with photos taken in 1990 and collecting new unmanned aerial vehicle aerial footage (visible and thermal-infrared) of the area where Ichinose was in charge of construction in 1990, the effects of the nature restoration project were confirmed by Ichinose himself (Fig. 3).

Fig. 3 Thermal infrared aerial image from the Ashio Wasteland area (noon, 31 October 2023). Some slopes are covered with clouds, and there are areas where vegetation has recovered and areas where rocks and sediments are exposed. There are several types of surface temperatures that can be distinguished with a thermal camera (low-temperature areas are purple, high-temperature areas are yellow).



Mixed Media Writer Ms. Kumi Hiroi: “Environmental Future Prediction” (2023–) Ichinose and Prof. Dr. Itaru Yasui (Ichinose and Yasui, 2004) summarized environmental future predictions up to 2050 by dozens of Japanese environmental scientists in the mid-1990s. Now Ichinose and Hiroi reviewed the difference between the predictions and the actuals, and they prototyped a card game with the theme of environmental future prediction.

Through these activities, we are able to highlight the differences between field sciences (such as geography) and other academic disciplines, as well as the characteristics of an artist’s perspective and the potential for collaboration between art and science.

Reference

Ichinose, T., & Yasui, I. (2004). Future scenarios: Predicting our environmental future. In Y. Himiyama (Ed.), *Area studies – Regional sustainable development: Japan* (pp. 28+). In L. D. Kiel (Ed.), *Encyclopedia of Life Support Systems (EOLSS)*. UNESCO–EOLSS Publishers.

1.3 Research for economic analysis and environmental policy support

(1) Comprehensive evaluation of lithium production technologies for the transition to a decarbonized society

In FY 2025, we conducted a comprehensive assessment of technologies for the production of lithium from brine resources, focusing on the Atacama Salt Flat in northern Chile. Lithium is a critical mineral for the transition to a decarbonized society, and increasing attention is being paid to the environmental and social implications of its production.

The study compared three lithium extraction and refining technologies—evaporation ponds, adsorption columns, and solvent extraction—not only in terms of private costs and benefits, but also in a broader social cost–benefit framework.

Environmental and social impacts, including water consumption, ecosystem degradation, reductions in tourism value, and carbon emissions associated with electricity consumption, were incorporated into the analysis by using the social cost of carbon (SCC).

The results revealed substantial trade-offs among the technologies. Evaporation ponds exhibited relatively high economic efficiency but had a huge ecological impact, whereas solvent extraction required substantial energy inputs and produced substantial greenhouse gas emissions. Adsorption columns gave a more balanced performance across economic and environmental dimensions. These findings provide evidence for designing sustainable resource policies and evaluating the critical mineral supply chains required for global decarbonization.

(2) Generational differences in environmental concern among Japanese citizens

In FY 2025, we analyzed the long-term trends in concern about global environmental issues among members of the Japanese public by using data from public opinion surveys conducted by the Cabinet Office between 2001 and 2023. The study aimed to clarify the factors underlying relatively low levels of environmental concern among younger generations.

By using an age–period–cohort analytical framework, we statistically separated the effects of historical period, age, and birth cohort on level of environmental concern. The results showed that public concern peaked in about 2007, declined during the 2010s, and has increased again in recent years. Level of environmental concern was also found to increase with age. In addition, birth cohort effects indicated that individuals born in the 1940s exhibited the highest levels of concern, whereas successive younger cohorts showed progressively lower levels of concern.

These findings suggest that the relatively low level of concern observed among younger people today is associated with both their current age and their membership of more recent birth cohorts. The study provides new evidence on generational differences in environmental awareness and contributes to future research on promoting behavioral change toward decarbonization and sustainability.

2 Policy-Oriented Research

2.1 Developing capacity for realizing a sustainable society in Asia

In collaboration with the Institute for Global Environmental Strategies (IGES) and the Ministry of the Environment, Government of Japan, the AIM (Asia-Pacific Integrated Model) and LoCARNet (Low Carbon Asia Research Network) Peer-to-Peer Meeting for Sharing Experience and Lessons was held at NIES in July 2025. The main participants were policymakers in Asia and researchers in each country

who use AIM. The main purposes of the 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 and Indonesia. NIES researchers also attended the dialogue meeting to support the greenhouse gas mitigation policies and actions of the other countries.

Training sessions on ExSS (Extended SnapShot tool) for policymakers in developing countries were conducted in February and July 2025 at the request of the Japan International Cooperation Agency.

The 31st AIM International Workshop (Fig. 4) was held at NIES on 22 and 23 July 2025 as a hybrid face-to-face/online meeting, with more than 140 participants discussing the status of AIM development and policy contributions in Asian countries. Recent AIM activities to assess the pathways achieving net-zero greenhouse gas emissions in Japan, as well as global-scale analyses and their results, were shared with the participants.

Fig. 4 Group photo at the 31st AIM International Workshop at NIES



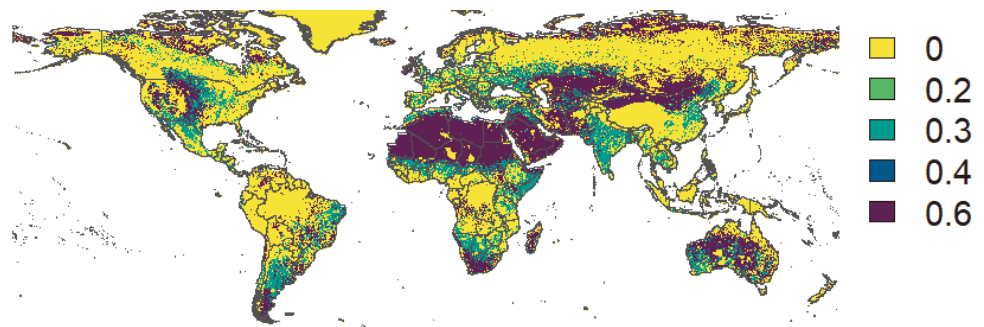
3 Intellectual Research Infrastructure Development

3.1 Database for assessing the availability of global renewable energy resources

During FY 2025, activities aimed at developing a global dataset of the land available for installing utility scale renewable energies, such as solar photovoltaic (PV) and wind power systems, were conducted. This dataset is fundamental for assessing the global availability of energy resources (also called energy potential) while also considering land availability at a high spatial resolution. The dataset combines data on elevation, slope, protected areas for nature conservation, and land cover. These

data, which have different spatial resolutions and extents, were consolidated into a single dataset with a spatial resolution of 100 m. The dataset assumes the following restrictions on the availability of land: maximum elevation (2000 m), maximum slope (3% for solar PV and 20% for wind power), complete exclusion of protected areas, and exclusion of certain land cover types (water bodies, permanent ice/snow, forests, urban/built-up). It is also assumed that a fraction of the area of selected land cover types (croplands, grassland/savanna, shrubland, desert/barren) is excluded. The dataset was applied to assess the effect of siting restrictions on the global energy potential of airborne wind energy systems (AWES), a novel type of wind power technology that uses flying aircraft that are tethered to a power generator in the ground. Figure 5 shows the land availability results in our assessment of the energy potential of onshore AWES.

Fig. 5 Global distribution of land availability for installing onshore airborne wind energy systems (AWES). Values indicate the fraction of land that is available for installing onshore AWES (yellow means not available, 0.6 means 60% of land area is available). (Silva Herran, D. Proceedings of the 42nd Conference on Energy, Economy and Environment. Tokyo, Japan. 2026).



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 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 Seasonal testicular regression and male germ cell apoptosis in the large Japanese field mouse (*Apodemus speciosus*) as baseline information for environmental monitoring

The large Japanese field mouse (*Apodemus speciosus*) is an endemic rodent widely distributed throughout Japan. Because of its abundance, ease of sampling, and short generation time, it may serve as a useful wild-animal model for monitoring environmental stressors such as radiation and chemical toxicants. Reproductive function—particularly spermatogenesis—is a sensitive indicator of environmental effects. However, this species is a seasonal breeder, and its testicular activity changes markedly throughout the year. Therefore, these normal seasonal changes must be clarified before the mouse can be used for environmental monitoring.

In this study, we examined the relationship between male germ cell apoptosis and seasonal testicular regression by using TUNEL (terminal deoxynucleotidyl transferase dUTP nick-end labeling) staining and a detailed classification of spermatogenic activity. Twenty-five adult or sub-adult males were captured in Toyama and Aomori prefectures during 2013–2014. Spermatogenic activity was classified into nine phases on the basis of paired testicular weight and histological

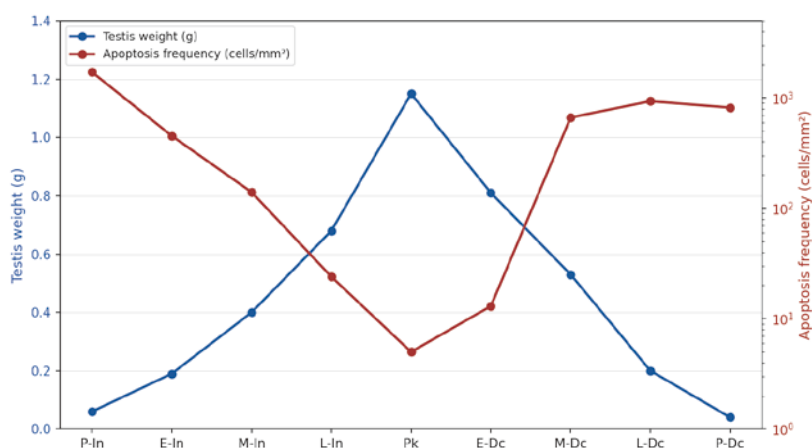
observations. Morphological changes in the seminiferous tubules and epididymides were also investigated.

Paired testicular weight, epididymal weight, and seminiferous tubule diameter were strongly positively correlated and changed significantly among phases. In contrast, apoptosis frequency was negatively correlated with testicular weight (Fig. 1). Apoptosis was low during the late-increasing, peak, and early-decreasing phases, but high during the pre-increase, mid- to late-decreasing, and post-decrease phases. Elevated apoptosis during the early- and mid-increasing phases suggests that it has a role in eliminating surplus or abnormal germ cells.

Spermatocytes were the main apoptotic cell type in most phases. During the mid-decreasing phase, both spermatocytes and spermatids underwent apoptosis, and live round spermatids were occasionally observed in the seminiferous tubule lumens, suggesting that cell desquamation may accelerate testicular regression. Apoptosis persisted even in the non-breeding season, possibly contributing to regulation of the germ cell – Sertoli cell balance.

The nine-phase classification revealed detailed apoptotic changes that were not detectable by using broader classifications. These findings provide baseline information on the normal reproductive physiology of *A. speciosus* and may help us to identify the possible pathological changes associated with environmental stressors such as radiation and chemical toxicants.

Fig. 1 Paired testis weights (blue, left axis) and male germ cell apoptosis frequencies (red, right axis) in *A. speciosus* across nine spermatogenic phases. Apoptosis frequency is expressed as TUNEL-positive cells per mm² cross-sectional area. Phases are shown on the x-axis: In, increasing; Dc, decreasing; P, pre-; E, early; M, mid; L, late; Pk, peak



2 Policy-Oriented Research

2.1 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 FY 2025, we began a qualitative social survey of the process of introducing hydrogen policies, focusing on the case of the town of Namie in Fukushima Prefecture. Specifically, on the basis of administrative documents issued by the Ministry of Economy, Trade and Industry (METI), Fukushima Prefecture, Namie Town government, the New Energy and Industrial Technology Development Organization (NEDO), and other government agencies involved in hydrogen policy in Fukushima Prefecture and Namie, we organized the process of introducing hydrogen policy in chronological order.

Furthermore, as a theoretical study summarizing this research project for all of Phase 5 of the Environmental Emergency and Resilience Research Domain, we conducted a narrative review of “policy entrepreneurs” (PEs) and “honest brokers” (HBs)—who mediate the formation of networks in today’s environmental policy—and clarified the roles and capabilities required of mediators addressing environmental issues. Specifically, we found that some PEs and HBs possess the capacity to build and manage policy networks, and some PEs were identified as playing a central role in networks focused on climate change mitigation and environmental policy. Furthermore, the study indicated that the orientation of PEs toward policy change, along with their diverse human and social capabilities, has the potential to help establish multi-stakeholder partnerships that transcend the boundaries between the scientific, political, and social spheres.

For FY 2025 and throughout Phase 5 of the Environmental Emergency and Resilience Research Domain, we were successful in gathering and analyzing policy information that directly contributes to the environmental policies of local governments in Fukushima Prefecture.

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

We advanced our research on the estimation of disaster waste amounts in future disasters. To develop a simple statistical model capable of producing both point and interval predictions, we systematically compared 21 candidate models by using hierarchical Bayesian regression. The results showed that the model using the number of damaged houses as a predictor, assuming either a lognormal or Weibull distribution and stratified by disaster type and degree of urbanization, achieved the highest predictive performance. This model is expected to support disaster waste-management planning during normal times, as well as initial waste-generation

estimations immediately after disasters.

For the manual sorting of disaster wastes, we attempted to acquire images of waste moving on a conveyor belt at an actual treatment site by using a visible-range hyperspectral camera. The results showed that digital data on reflected light from waste could be obtained through the simple installation of a hyperspectral camera, enabling the quantitative analysis of visual sorting work by operators. Further adjustments to the hyperspectral camera and image-processing methods will be made to obtain more detailed information on target materials.

In collaboration with AI model developers and environmental analysis companies, we improved an AI model for recognizing asbestos fibers through image analysis with the aim of disaster application and commercialization. By using 98 labeled datasets (77 for training and 21 for evaluation) created from air sample images provided by five analytical companies, we replaced the model with a state-of-the-art semantic segmentation model, ConvNeXtV2-nano-Unet. The results showed a recall of 95% and precision of 71%, compared with 90% and 68%, respectively, for the previous model using the same dataset. Inference time without a GPU (graphics processing unit) was also greatly reduced from about 30 s to approximately 2.3 s on a laptop and 1.2 s on a desktop computer. These improvements will enable the development and commercialization of an automated detection program covering the process from image acquisition to counting. The technology has attracted international attention through our journal and conference presentations.

2.3 Environmental Emergency Management Office

From records of past disaster waste management, we collected and organized quantitative data that had not been systematically managed or utilized to date. Specifically, we utilized the records published by the Ministry of the Environment (MOE) in its annual Survey of Municipal Solid Waste Management since FY 2011 and linked them with disaster information collected separately from disaster records. As a result, we developed a municipality- and disaster-level database consisting of 977 cases over the 13-year period from FY 2011 to FY 2023. We evaluated the quality of the database in terms of accuracy, comprehensiveness, and consistency. The results suggested that the data are of sufficient quality to understand the average nationwide situation of disaster waste treatment. By visualizing disaster waste generation and using the database to estimate parameters for disaster waste estimation models, the database is expected to contribute to national and municipal disaster-waste-management preparedness actions.

We also continued to support national and municipal disaster waste policy making by providing expertise to MOE committees, municipal disaster waste management planning, and training programs at national and municipal levels. In particular, we helped to improve preparedness for a future mega-earthquake in the Tokyo area by supporting the revision of the disaster waste management guidelines for Tokyo's

special wards, as well as the design and implementation of specialist training programs organized by the Tokyo Metropolitan Government and a preparedness workshop conducted by the Kanto Regional Block Council.

Furthermore, we continued to manage and operate the Disaster Waste Information Platform on the NIES website and added new content. Specifically, we newly uploaded 50 disaster waste-management plans, including revised versions, 10 papers from the Japan Waste Management Association's annual conference, and 22 contributed or edited original articles.

As this fiscal year marks the 10th anniversary of the Office's establishment, we compiled a record of activities in cooperation with relevant organizations. The resulting document will serve as a useful reference for the national government's ongoing efforts to develop a specialized support institution for disaster waste management.

3 Intellectual Research Infrastructure Development

3.1 Summarizing and visualizing the budget and migration of accident-derived r-Cs in Fukushima Prefecture

The objective of this study is to quantify and visualize the inventory and migration of accident-derived radioactive cesium (r-Cs) deposited across Fukushima Prefecture following the FDNPP accident. Our previous work focused on industrial waste streams—particularly construction-related wastes—to evaluate the transfer of r-Cs through waste treatment and disposal processes. For FY 2015, the amount of r-Cs transferred through the treatment and disposal of concrete waste was estimated at approximately 5.8 GBq. Corresponding estimates were 498 GBq for asphalt concrete waste, 45 GBq for waste plastics, and 41 GBq for wood waste.

In addition, we used tag information from approximately 12.97 million flexible container bags to estimate the amount of r-Cs transported to the Interim Storage Facility (ISF) through decontamination activities. Data from FY 2014 to FY 2021, when large-scale decontamination was conducted, revealed that the total inventory transported to the ISF was approximately 191 TBq (at the time of transport).

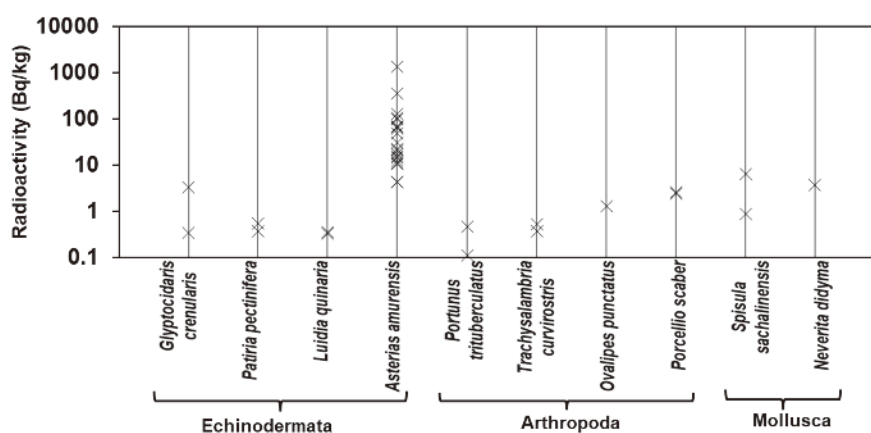
Although estimates of total fallout have been reported for eastern Japan as a whole, no corresponding estimate had been available specifically for Fukushima Prefecture. To address this gap, we extracted prefecture-specific fallout data through image processing of fallout maps published by MEXT (the Ministry of Education, Culture, Sports, Science and Technology). The total fallout within Fukushima Prefecture was estimated at approximately 1910 TBq. This indicates that environmental remediation activities have recovered approximately one-tenth of the accident-derived cesium deposited within Fukushima Prefecture.

Under the next medium-term research plan, we will further quantify the transport of r-Cs through drainage systems and riverine processes to evaluate long-term losses from the terrestrial environment due to natural weathering and runoff.

3.2 Biodiversity and ecosystem monitoring for regional collaboration

To expand our knowledge of the accumulation of strontium-90 (^{90}Sr) in marine ecosystems, we measured the concentrations of ^{90}Sr in calcified tissues of various invertebrates (echinoderms, arthropods, and mollusks) collected in 2013 and 2014 from coastal areas of Fukushima Prefecture. ^{90}Sr was detected in 10 of the 15 species measured. Among those 10 species, the starfish *Asterias amurensis* had high concentrations of ^{90}Sr (4.42 to 1362 Bq/kg), whereas the concentrations in the other species were below 10 Bq/kg (Fig. 2). Relatively high ^{90}Sr concentrations among *A. amurensis* was mainly detected in individuals with an arm length of ≤ 9 cm. Individuals of this size are reported to be less than 2 years old (Hatanaka et. al., 1959), indicating that these individuals were exposed at an early life stage to the contaminated water released from FDNPP. Because their growth rate may be high during the early life stages and the uptake rate of inorganic components is also likely high, a relatively large amount of ^{90}Sr may be incorporated into their calcified tissues.

Fig. 2 Concentrations of ^{90}Sr in various invertebrates (reprinted from Kintsu et al., 2026, with permission from Elsevier). Radioactivity of ^{90}Sr was normalized by whole wet body weight.



We estimated the maximum absorbed dose rate of ^{90}Sr in the soft tissues of *A. amurensis*. It was approximately 170 $\mu\text{Gy/day}$ —below the dose rate reported by the International Commission on Radiological Protection (ICRP, 2008) to have adverse effects on organisms. Therefore, ^{90}Sr did not accumulate in invertebrates at concentrations that were high enough to adversely affect them.

In addition, in FY 2025 we monitored the terrestrial biodiversity (mammals, birds, frogs, and flying insects) in and around the evacuation area, continuing our work from the previous fiscal year.

Reference:

Hatanaka, M., Kosaka, M. (1959) Biological studies on the population of the starfish, *asterias amurensis*, in Sendai Bay. *Tohoku Journal of Agricultural Research* 9, 15.

International Commission on Radiological Protection. (2008). Environmental protection: the concept and use of reference animals and plants. *Annals of the ICRP* 38(4-6), 1-242. ICRP Publication 108.

Kintsu, H. Kodama, K., Horiguchi, T. (2026) The uptake and persistence of radioactive strontium in the calcified tissues of marine organisms of the Fukushima coastal region. *Journal of Environmental Radioactivity* 296, 107979. <https://doi.org/10.1016/j.jenvrad.2026.107979>

3.3 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, the tripartite partnership between the NPO (non-profit organization) Shinsei in the city of Koriyama, Fukushima Prefectural Asaka Kaisei High School, and NIES has enabled the collaborative initiation of biological monitoring with the aim of recovery of biodiversity in the area surrounding a mountain farm operated by Shinsei. This initiative involves the revitalization of abandoned paddy fields. In addition, we are working to establish a regional community that will contribute to preparedness for future disasters. This objective will be accomplished by helping elderly individuals in the Nishinouchi district of Koriyama with their refuse collection. We have initiated the creation of a framework that will be led by local residents with disabilities and high school students. With the guidance of the NIES, high school students have successfully initiated several projects. These have included participating in local events and organizing roundtable discussions. The objective of these initiatives is to gather and organize information on the activities and needs of stakeholders who can actively participate in support activities. The initiatives will also promote the formation of networks. As a result, a consensus was reached among a diverse range of local stakeholders regarding specific measures for waste-collection support in the coming year and beyond.

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 2025.

1. Foresight and Advanced Basic Research

1.1 Introduction of informatics into environmental monitoring

Chemical substances that reach the environment and ecosystems are becoming increasingly diverse, but no method has been established that can simultaneously detect all possible substances. Mass spectrometry (MS) is commonly used to measure emerging contaminants in the environment because of its high versatility and sensitivity and the large amount of information it provides. Moreover, the combination of MS with time-of-flight mass spectrometry (ToFMS) offers mass-resolving power of several tens of thousands or more and enables the simultaneous detection of an enormous number of components.

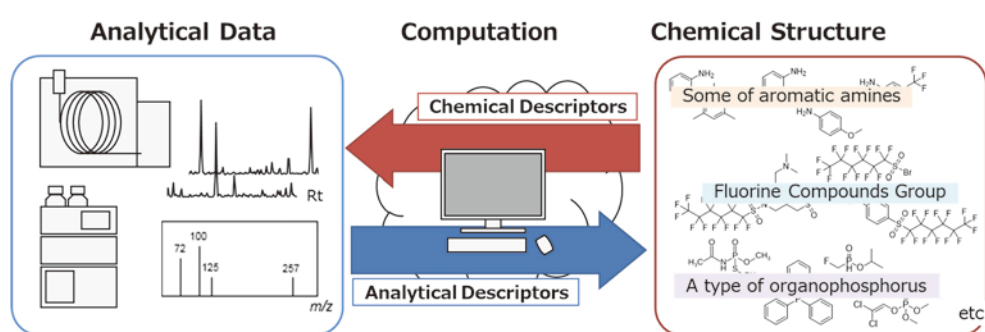
In recent years, information-processing technologies and informatics, including artificial intelligence (AI), have begun to be introduced for the interpretation of massive datasets. The development and application of machine learning, a type of AI, have been remarkable, and we have been benefiting from such technologies in our daily lives, even if we are not consciously aware of these benefits. The introduction of AI and computational science into the field of chemistry has by no means lagged behind this broader trend. Their application to toxicology, analytical chemistry, and environmental chemistry is likely to bring about breakthrough advances in research.

In the fields of drug discovery and functional chemical substances, AI was introduced early on for chemical design, thus promoting efficient and effective

small-lot, high-mix production of chemicals. This has accelerated the diversification of chemical substances. Consequently, increasing attention is being paid to attempts to apply similar computational-science approaches to research investigating the negative impacts associated with this increased diversification.

The introduction of informatics into environmental analytical chemistry can be broadly classified as leading in two directions. One is predicting or optimizing analytical conditions from substances or their structures, and the other predicting the partial structures, physicochemical properties, or biological activities of substances from analytical data (the right and left sides, respectively, of Fig. 1).

Fig. 1 Classification by information flow of the utilization and development of computational science in analytical chemistry. One direction infers or optimizes analytical conditions from the substance (structure) (right to left in the figure), and the other predicts the (partial) structure, physical properties, or biological activity of a substance from analytical data (left to right in the figure). Suspect screening and NTA are classified in the latter direction.



Data-mining approaches, such as the search for unknown substances by non-target analysis (NTA), which has been developed and applied rapidly in recent years, and the comprehensive detection of arbitrary groups of substances by suspect screening, or sub-data extraction, fall into the latter category.

In the area of prediction and optimization of analytical conditions from chemical substance data, active research is being conducted on topics such as the prediction of retention times in liquid and gas chromatography, automated peak detection, prediction of ionization efficiency in MS, and prediction of mass spectra from molecular structures.

In contrast, in the area of estimation of structures, physicochemical properties, and toxicity from analytical data, as well as the exploration of unknown substances, areas attracting attention include the estimation of physicochemical properties from measurement data, structural elucidation from mass spectra, prediction of physicochemical properties from molecular descriptors, suspect screening, and the exploration of unknown substances.

The number of unknown substances identified through NTA is rapidly increasing, but the preparation of reference standards cannot possibly keep pace. Nevertheless, a quantitative understanding of related compounds, including newly identified substances, is essential for risk management and the creation of countermeasures. Therefore, there is a gradual shift from classical quantitative analysis based on comparison with reference standards toward virtual or *in silico* analysis.

As analytical tools for high-resolution MS data, we have been developing numerous software programs. These include so-called *in silico* cleanup tools designed to extract accurate mass spectra consisting of specified elements from measurement data, or to selectively retrieve information for which the isotopic composition and accurate mass spectra are consistent with a user-defined molecular formula. They also include tools for resolving, or deconvoluting, chromatographically co-eluting components on the basis of accurate mass measurements.

2. Policy-Oriented Research

2.1 Global Monitoring Plan for persistent organic pollutants

The Global Monitoring Plan (GMP) for persistent organic pollutants (POPs) is a key tool for evaluating the effectiveness of the Stockholm Convention. It provides a structured approach for collecting comparable monitoring data on POPs across all regions, thereby allowing countries to track changes in the concentrations of POPs over time and to better understand their regional and global environmental transport. Monitoring, capacity building, and the preparation of regional monitoring reports are performed by regional organization groups in each of the five United Nations regions. A global coordination group oversees the overall implementation of the GMP, supports coordination among regions, and leads the preparation of global GMP reports. To date, three GMP reports have been submitted to the Conference of the Parties to the Stockholm Convention. The first GMP report established baseline information on concentrations of the 12 initial POPs. The second GMP report provided early indications of trends for the 12 initial POPs and baseline data for newly listed POPs. The third GMP report focused on improving data comparability across monitoring programs, enabling better assessment of time trends and the regional and global transport of POPs. Currently, one researcher from the Health and Environmental Risk Division of NIES serves concurrently as a member of the Global Coordination Group and the Asia-Pacific Regional Steering Committee. Working in collaboration with the United Nations Environment Programme (UNEP) Secretariat and committee members representing other regions, this researcher has prepared and updated the following materials to support the implementation of GMP Phase 4 (GMP-4) in 2025:

- guidance on the global monitoring plan for POPs¹⁾
- regional strategies for implementing GMP-4
- recommendations to the COP for implementing GMP-4.

As part of the development of guidance on global monitoring, the researcher authored a report chapter covering topics such as long-term sample storage methods and ensuring regional representativeness. This chapter was written with reference to implementation details at NIES and the methodologies of the International Environmental Specimen Bank Group, specifically regarding environmental specimen banking as a complement to environmental monitoring.

Reference:

- 1) UNEP/POPS/COP.12/INF/43 (joint authorship; Takazawa Y.) (2025) *Guidance on the Global Monitoring Plan for Persistent Organic Pollutants*, 84–92

3. Intellectual Research Infrastructure Development

3.1 Development and certification of human hair certified reference material

Accurate assessment of human exposure to mercury (Hg) is a critical component of public health and environmental safety. Monitoring the human hair levels of Hg—particularly methylmercury (MeHg), which remains fixed in the hair matrix once incorporated—serves as a valuable, noninvasive method for long-term biomonitoring. To support global Hg exposure assessments and ensure the reliability of analytical data, NIES has developed a new certified reference material (CRM), NIES CRM No. 13-a (Fig. 2) by using scalp hair from East Asian females.

Fig. 2 Bottle containing NIES CRM No. 13-a



The preparation involved large-scale processing of 5 kg of hair, which was washed, dried, and finely milled to a particle size of less than 74 μm to ensure optimal homogenization. A total of 806 bottles were produced and sterilized via gamma-ray irradiation at 20 kGy. Stability tests demonstrated that the CRM remains stable for at least 10 years when stored at 5 °C in a dark environment. The certification was achieved through an extensive collaborative analysis involving 20 laboratories using multiple independent techniques, such as CV-AAS, GC-ECD, and ICP-MS (Table 1)¹⁾, and following international guidelines for value assignment.

The certified values were determined for total Hg (1.06 ± 0.07 mg/kg) and MeHg (0.858 ± 0.075 mg/kg), along with other trace elements, including arsenic, cadmium, lead, selenium, and zinc (Table 1)¹⁾. Notably, NIES CRM No. 13-a uniquely incorporates information values for stable Hg isotope ratios, which are increasingly utilized as tracers for identifying Hg exposure pathways²⁾. Additionally, reference values were provided for several other elements, including calcium, magnesium, and copper, to enhance the material's versatility. This new CRM offers a substantially broader scope of certified and reference values

compared with existing materials, thus helping to improve the accuracy of Hg speciation and toxicological studies globally.

Table 1 Certified values for NIES CRM No. 13-a (human hair).

Element	Mass fraction			Analytical method *
	Unit	Certified value	Uncertainty	
Methyl Mercury (as Hg)	mg/kg	0.858	0.075	GC-CV-AFS, GC-ECD, ID-GC-ICP-MS, LC-ICP-MS
Total Mercury (THg)	mg/kg	1.06	0.07	CV-AAS, ICP-MS, ID-GC-ICP-MS, TD-CV-AAS
Arsenic (As)	mg/kg	0.255	0.016	HG-AAS, ICP-MS
Cadmium (Cd)	mg/kg	0.165	0.012	ICP-MS
Lead (Pb)	mg/kg	7.42	0.62	ICP-MS
Selenium (Se)	mg/kg	0.463	0.052	HG-AAS, ICP-MS
Zinc (Zn)	mg/kg	337	22	ICP-MS, ICP-OES

All certified values were determined on the basis of dry mass.

CV-AAS, cold vapor atomic absorption spectrometry; GC-CV-AFS, gas chromatography – cold vapor atomic fluorescence spectrometry; GC-ECD, gas chromatography – electron capture detector; HG-AAS, hydride generation – atomic absorption spectroscopy; ICP-MS, inductively coupled plasma – mass spectrometry; ICP-OES, inductively coupled plasma – optical emission spectrometry; ID-GC-ICP-MS, isotope dilution – gas chromatography – inductively coupled plasma – mass spectrometry; LC-ICP-MS, liquid chromatography – inductively coupled plasma – mass spectrometry; TD-CV-AAS, thermal decomposition – gold amalgamation – cold vapor atomic absorption spectrometry

References:

- 1) Yamakawa A., Nagano K., Onishi K., Ukachi M., Ieda T., Kobayashi M., Sano T., Iwai-Shimada M., Iwai K., Inamasu K., Amouroux D., Tessier E., Horvat M., Alilović A., Klemenčič P., Begu E., Hudobivnik M. J., Matthew R., Haraguchi K., Li P., Rodríguez-González P., Suárez-Criado L., Hu L., Takeda N., Li Y. F., Uchida K. (2025) Human hair certified reference material for total mercury, methylmercury, and trace element analyses. *Accreditation and Quality Assurance* 30, 277–290
- 2) Yamakawa A., Takeuchi A., Shibata Y., Berail S., Donard O. F. X. (2016) Determination of Hg isotopic compositions in certified reference material NIES No. 13 Human Hair by cold vapor generation multi-collector inductively coupled plasma mass spectrometry. *Accreditation and Quality Assurance* 21, 197–202

R esearch 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) launched in June 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.

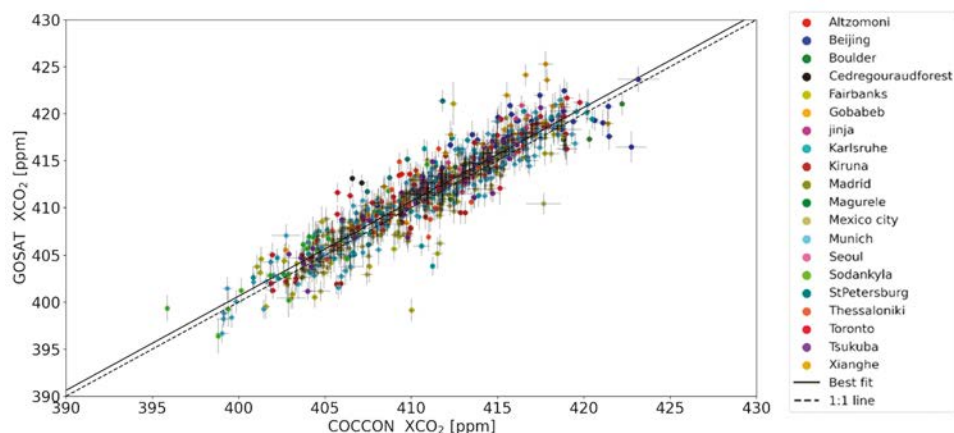
NIES's Satellite Observation Center (SOC) is responsible for implementing the Satellite Observation Project. Major achievements of the Project in FY 2025 were as follows.

1 GOSAT

Operational data processing for GOSAT, which has been in space for more than 17 years, continued, as did the generation, validation, and distribution of GOSAT products, such as the concentrations and fluxes of carbon dioxide (CO₂) and methane (CH₄). Concentration products up to February 2026 (V03.00), CO₂ flux products up to October 2022 (V02.10), and CH₄ flux products up to September 2021 (V01.08) are freely available from the GOSAT Data Archive Service. 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 CO₂ 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.

Validation of column-averaged GHG concentrations from the GOSAT series has been performed by using ground-based high-resolution FTSs observing direct solar radiation. Although validation has traditionally relied on large and expensive FTSs, recent efforts have explored the use of the Collaborative Carbon Column Observing Network (COCCON), a network of more portable and low-cost FTSs. An international study (Sha et al., 2025) involving 53 authors from 18 countries conducted a large-scale validation of satellite products by using COCCON data, suggesting that COCCON can complement existing networks of large FTSs and improve validation coverage (Fig. 1).

Fig. 1 Validation results of GOSAT CO₂ product (V03.05) by using 766 COCCON data. The mean difference (standard deviation) between GOSAT and COCCON was 0.65 (± 2.01) ppm.



2 GOSAT-2

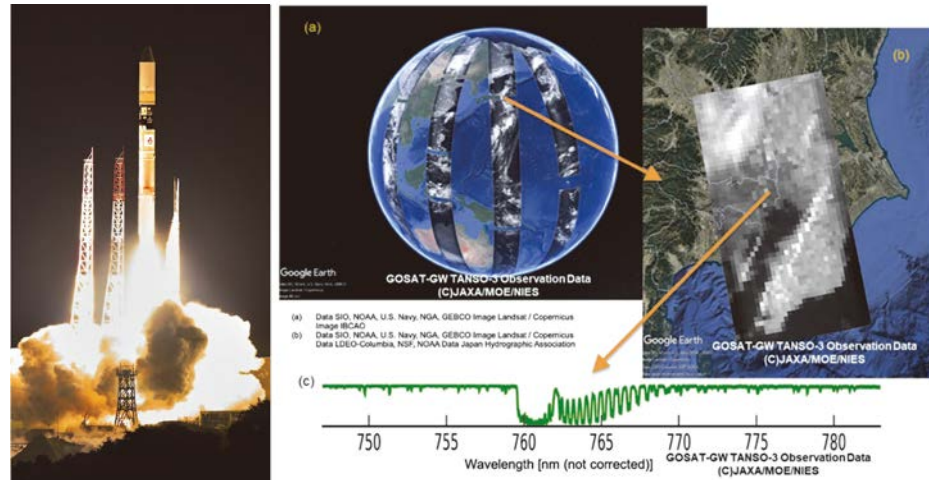
GOSAT-2 data have been distributed by the GOSAT-2 Product Archive since 2019. Concentration products up to September 2025 (CO₂, CH₄, carbon monoxide (CO), and solar-induced chlorophyll fluorescence; V02.20/V02.21), CO₂ flux products from October 2019 to October 2020 (V01.02), and CH₄ flux products from May 2019 to October 2022 (V01.01) are freely available from the GOSAT-2 Product Archive. Concentration products were validated by using ground-based observation data. Three GOSAT-2 Science Team Meetings were held in FY 2025 to discuss issues such as data quality, validation analysis, and releases of standard products.

Methane emission estimates by sectors using the global high-resolution inversion model have traditionally been derived from GOSAT data since 2009. With the accumulation of GOSAT-2 observations, a consistent inversion analysis was newly conducted for 2019–2022, when both GOSAT and GOSAT-2 data were available, to compare their respective estimates under identical conditions (Janardanan et al., 2025). Differences in global annual means by emission sector were within approximately −3% to +5%, indicating high consistency. Anthropogenic emissions for the five largest methane-emitting countries showed differences of approximately −13% to +6%. These discrepancies were comparable to the inherent uncertainties of the inversion analysis.

3 GOSAT-GW

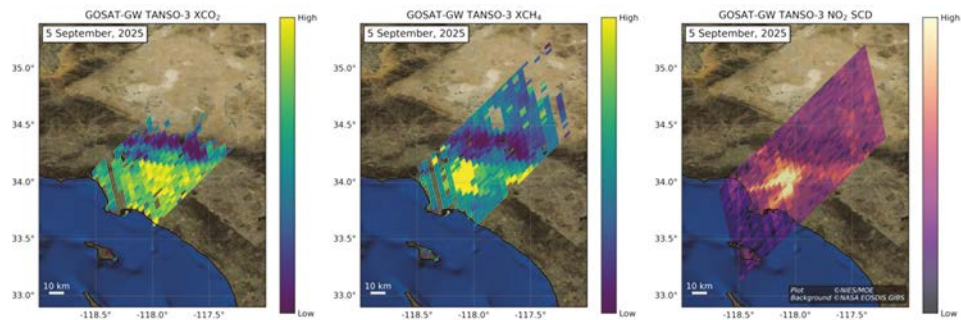
GOSAT-GW was successfully launched by an H-IIA rocket from JAXA Tanegashima Space Center on 29 June 2025. The first images of Total Anthropogenic and Natural emissions mapping SpectrOmeter-3 (TANSO-3) onboard GOSAT-GW were acquired 2 weeks after the launch, confirming that TANSO-3 is functioning normally (Fig. 2).

Fig. 2 (Left) Launch of H-IIA rocket carrying GOSAT-GW on 29 June 2025; (Center) TANSO-3 first Wide mode image acquired in 1 day; (Right) TANSO-3 first Focus mode image acquired over east Tokyo and west Chiba; and (Bottom) TANSO-3 Band 2 spectral data acquired for east Tokyo



The SOC finished developing two ground data processing systems for GOSAT-GW, namely the GOSAT third-generation Data Processing/operating System (G3DPS) and the GOSAT-GW Nitrogen dioxide (NO_2) Data Processing System (GNDPS). These systems started nominal operations in December 2025. As of March 2026, G3DPS was receiving provisional TANSO-3 Level 1 products from JAXA on an operational basis and distributing them to a limited number of domestic and overseas users. These systems are also being used to generate Level 2 products, including CO_2 and CH_4 concentrations. The provisional Level 2 products (Fig. 3) look promising, although further elaboration and validation are necessary.

Fig. 3 Analysis results of TANSO-3 data acquired around Los Angeles, US, on 5 September 2025. (Left) Column-averaged CO_2 concentration (XCO_2), (Center) column-averaged CH_4 concentration (XCH_4), and (Right) slant column density (SCD) of NO_2



To obtain validation data for the TANSO-3 products, NIES, the Ministry of the Environment (MOE), the Japan Agency for Marine-Earth Science and Technology, and the US National Aeronautics and Space Administration conducted the Tokyo Field Campaign (TOKYO-FC), a joint international operation, in March 2026. During TOKYO-FC, flights by Japanese and US aircraft equipped with observational instruments over major emission sources in Japan were coordinated.

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 previous work, we examined the scientific

requirements and proposed three observation concepts. This year, we conducted investigations to quantify the relationships between radiance spectra (Level 1B), CO₂ and CH₄ concentrations (Level 2), and their fluxes (Level 4) on the basis of simulations. We developed a retrieval simulator to evaluate the relationship between Level 1B and Level 2 product qualities. Assuming certain sensor characteristics, we investigated the differences in retrieval performance in megacity areas. We also evaluated the impact of the horizontal resolution and measurement noise of the Level 2 product on flux estimates in the Kanto region by using data from an observation system simulation experiment. Additionally, we assessed the error sources of CO₂ lidar observations for two types of lidar system.

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, 48 joint studies have been conducted and three studies are ongoing.

In response to agreements concluded with NASA, the European Space Agency, le Centre national d'études spatiales (France), and the German Aerospace Center (das Deutsches Zentrum für Luft- und Raumfahrt), several informal meetings were held virtually and in person. In addition, new agreements were concluded with the Space Research Organisation (Netherlands) and the Royal Belgian Institute for Space Aeronomy in 2025.

6 Hosting of Meetings

NIES, with support from MOE and other organizations, hosted the 21st International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-21) in Takamatsu in June 2025 (Fig. 4). IWGGMS is an annual international expert meeting focusing on GHG measurement from space. A total of 275 researchers and experts (including 60 online-only participants) from 19 countries participated in IWGGMS-21 to exchange the latest information and innovative ideas on GHG observation from space. Over the 3 days of the workshop, there were 82 oral and 57 poster presentations. In addition, the 21st Committee on Earth Observation Satellites Atmospheric Composition Virtual Constellation meeting and the Working Group on Calibration & Validation Atmospheric Composition Subgroup meeting were held in conjunction with IWGGMS-21.

Fig. 4 Group photo of participants at the International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-21) in Takamatsu, June 2025



7 Participation in International Events

In May 2025, SOC participated in the Group on Earth Observation (GEO) Global Forum 2025 in Rome, Italy, and contributed to Japan's GEO exhibit by providing posters and movies on the GOSAT Series. Achievements of the GOSAT Series and the expectations for GOSAT-GW were also introduced during Japan GEO Short Lectures.

In November 2025, SOC participated in the 30th session of the Conference of the Parties (COP30) to the United Nations Framework Convention on Climate Change (UNFCCC) in Belém, Brazil, with an official exhibit and an on-site seminar at the Japan Pavilion (Fig. 5). The official exhibit showed how Japanese satellites, including the GOSAT series, monitor climate change impacts. It also showcased international collaboration and the newly launched GOSAT-GW. The Japan Pavilion seminar on “Promoting Use of GOSAT Data for Climate Science Outreach and Business Applications” was hosted jointly by NIES and MOE. It provided an overview of the current status of GOSAT-GW and the Japan GHG Center, as well as prospects for private-sector use of GOSAT data. Speakers from domestic and international research institutions, United Nations agencies, space agencies, and private companies presented the achievements of Japan's GOSAT series satellites and prospects for utilizing satellite data to promote decarbonization efforts. Japan's efforts to establish frameworks for next-generation education in climate science and GHG studies were also introduced.

Fig. 5 (Left) UNFCCC COP30 official exhibit by NIES, JAXA, and the Remote Sensing Technology Center of Japan in November 2025. (Right) Speakers at the Japan Pavilion Seminar



8 Press Releases

SOC issued the following five press releases in FY 2025:

- 1) “Estimation of methane and carbon monoxide emissions in megacities by using simultaneous greenhouse gas and air pollutant observations by “IBUKI-2” (GOSAT-2) – Satellite observations enable megacity-level emission estimates -” (May 2025)
See <https://www.nies.go.jp/en/pr/news-and-updates/2025/20250529/20250529.html>
- 2) “GOSAT-GW (“IBUKI GW”) Successful Launch and Completion of Critical Operations Phase” (July 2025)
See <https://www.nies.go.jp/en/pr/news-and-updates/2025/20250701/20250701.html>
- 3) “First observations by the Total Anthropogenic and Natural emissions mapping SpectrOmeter-3 (TANSO-3) onboard the Global Observing SATellite for Greenhouse gases and Water cycle “IBUKI GW” (GOSAT-GW)” (August 2025)
See <https://www.nies.go.jp/en/pr/news-and-updates/2025/20250826/20250826.html>
- 4) “Initial analysis results of focus-mode observation data from the Total Anthropogenic and Natural emissions mapping SpectrOmeter-3 (TANSO-3) onboard the Global Observing SATellite for Greenhouse gases and Water cycle (GOSAT-GW, “IBUKI GW”)“ (January 2026)
See <https://www.nies.go.jp/en/pr/news-and-updates/2026/20260122/20260122.html>
- 5) “NASA–Japan Joint Observations for GOSAT-GW Data Validation – Airborne Observation of Greenhouse Gas Emissions in Metropolitan Tokyo –” (March 2026)
See <https://www.nies.go.jp/en/pr/news-and-updates/2026/20260302/20260302-e.html>

References:

Janardanan, R., Maksyutov, S., Wang, F., Nayagam, L., Yoshida, Y., Lan, X., Matsunaga, T. (2025) High-resolution inversion of

GOSAT-2 retrievals for sectoral methane emission estimates during 2019–2022: A consistency analysis with GOSAT inversion. *Remote Sensing* 17, 2932. <https://doi.org/10.3390/rs17172932>

Sha M. K et al. (2025) Fiducial Reference Measurements for Greenhouse Gases (FRM4GHG): Validation of satellite (Sentinel-5 Precursor, OCO-2, and GOSAT) missions using the COllaborative Carbon Column Observing Network (COCCON), *Remote Sensing* 17, 734, <https://doi.org/10.3390/rs17050734>

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

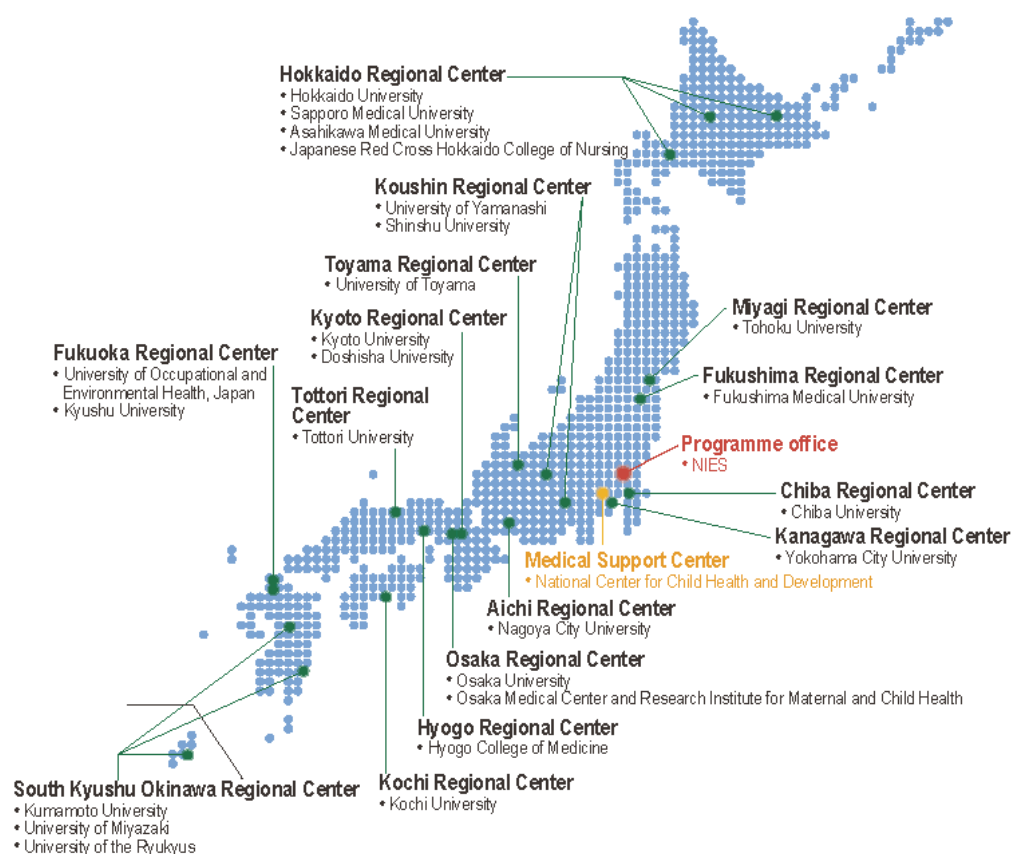
We started recruiting participants in January 2011, and recruitment continued until March 2014, by which time the number of participating mothers had reached 103,099. Recruited participants were pregnant women and their partners (when accessible). JECS began to collect data when the mothers were pregnant and planned to follow their children until they reached 13 years of age. However, 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 2025

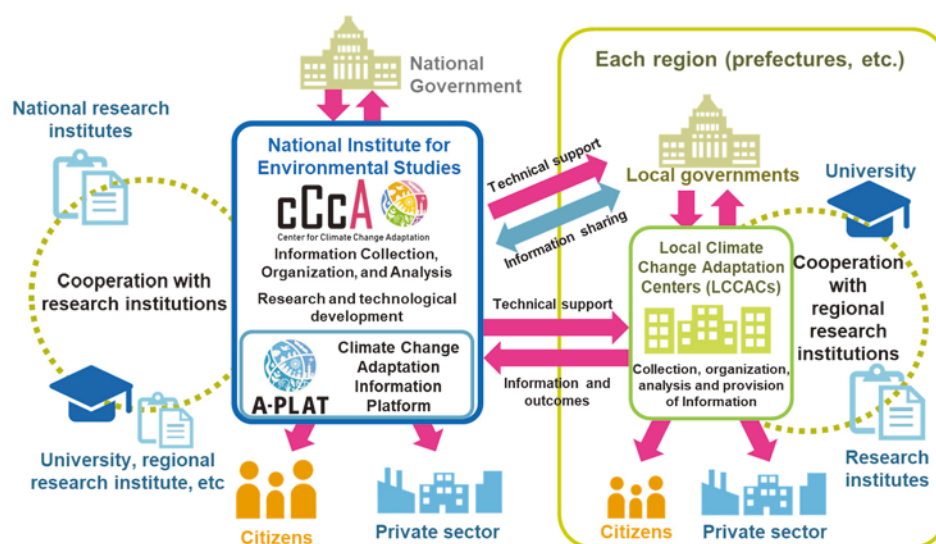
The children participating in the Main Study reached the ages of 11 to 14 years in FY 2025. We continued to administer questionnaires to participants to collect a wide range of information on the children's health and development and their exposure to environmental factors. We analyzed 5000 maternal blood samples for synthetic musk. Furthermore, elemental analyses were conducted on approximately 12,431 blood samples collected from children. In addition, DNA samples extracted from about 6809 maternal and 48,379 paternal blood specimens were analyzed for genome-wide SNPs (single nucleotide polymorphisms). As part of the Sub-Cohort study, about 3600 twelve-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 2025 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 and the private sector

We provided various forms of technical advice and help to prefectures, municipalities, LCCACs, and private-sector entities to promote the development of regional climate change adaptation plans and adaptation measures by local governments, as well as to encourage climate change adaptation efforts by the private sector. 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 2025. In July 2025, we co-hosted a training course for local government officials with the Ministry of the Environment, with about 140 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 to share knowledge of the

activities of LCCACs and to exchange information and opinions (Fig. 2). In addition, we provided support for the formulation of local adaptation plans by publishing a “Manual for Formulating Local Climate Change Adaptation Plans” and “Guidelines for Climate Change Impacts Assessment and Adaptation Planning Considering Regional Characteristics,” both prepared by the Ministry of the Environment, on the Climate Change Adaptation Information Platform (A-PLAT). We also developed a Support Tool for Formulating Local Climate Change Adaptation Plans.

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 11,200 people in FY 2025, 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.

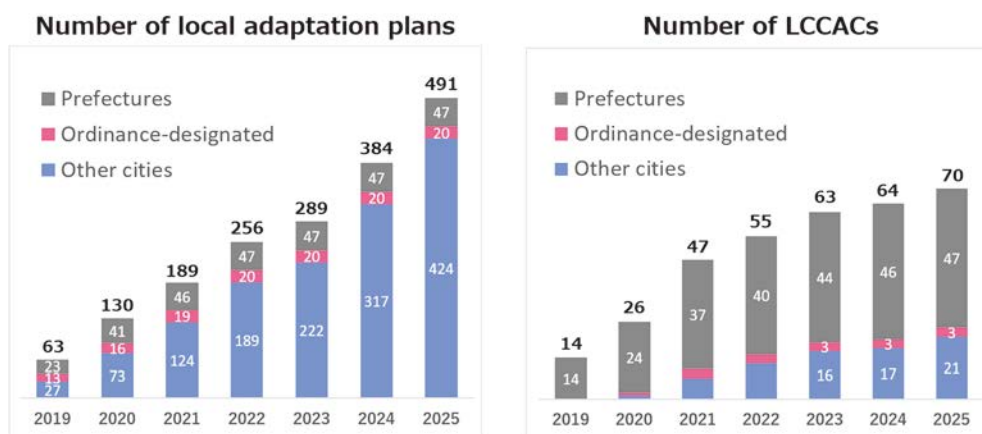
We held a symposium and umbrella meetings of the Study Group on Climate Change Adaptation in December 2025, with the participation of national research institutes of various ministries and LCCACs, to discuss the feasibility of tangible collaboration (e.g., social implementation) among national research institutes on the basis of local needs.

Fig. 2 LCCAC discussion meeting in 2025



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 2026, local adaptation plans have been formulated in all prefectures and designated cities, and regional adaptation centers have been established in 47 prefectures.

Fig. 3 Numbers of local adaptation plans (left) and Local Climate Change Adaptation Centers (LCCACs) (right). An "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.



In September 2021, a Climate Risk Public–Private–Academia Collaboration Network was established in partnership with the Ministry of the Environment, the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Land, Infrastructure, Transport and Tourism, and the Financial Services Agency. This network serves as a platform for exchanging opinions and collaborating with companies that provide consulting services on climate change, impact forecasting, and TCFD (Task Force on Climate-related Financial Disclosures) compliance, aiming to promote climate change adaptation among business operators. Under this framework, study groups and seminars were held, alongside public symposiums designed to deepen businesses' understanding of adaptation.

Since 2023, NIES has participated as one of the research and development institutions in the Construction of a Smart Disaster Prevention Network, which is a Strategic Innovation Promotion Program (SIP project). NIES has developed an e-learning system and corporate training programs that reflect the needs of business operators regarding adaptation. Through these initiatives, efforts are underway to foster human resources with high climate change adaptation capabilities.

1.2 Collecting, organizing, analyzing, and providing information on climate change adaptation

The Climate Change Adaptation Information Platform (A-PLAT) provides comprehensive information on adaptation to the effects of climate change and has disseminated information on various events and initiatives of government ministries and agencies, national research institutes, local governments, LCCACs, businesses, and others. Following Website renovations last fiscal year, we continued to enhance the entire website in FY 2025. 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 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 2025, the number of web page views was approximately 1.30 million (target: over

500,000), and there were 857 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 among each of the seven regions of Japan.

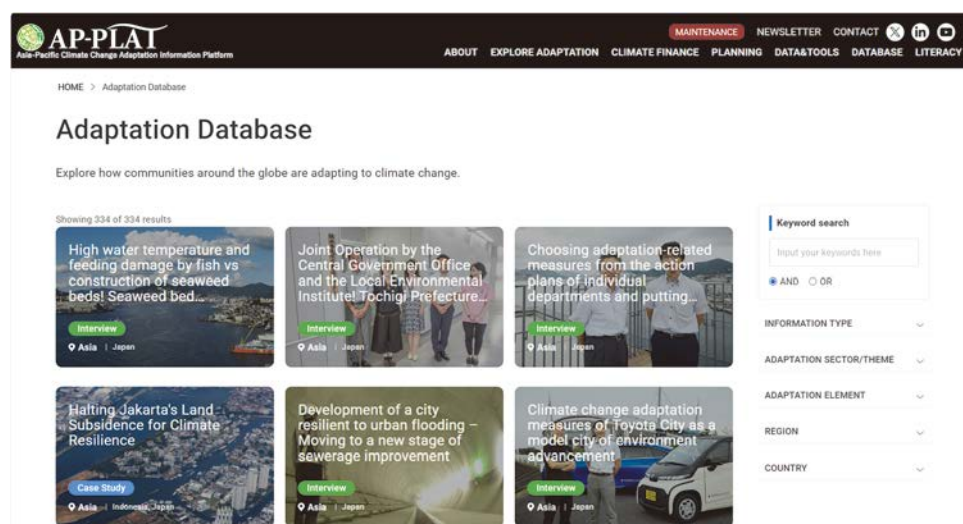
To enhance public awareness of climate change adaptation, we developed and loaned out educational tools (e.g., *Gacha*, a capsule toy machine, and *Sugoroku*, a board game). We also initiated the “#Let's Adapt” promotional campaign aimed at further enhancing public recognition and understanding of climate change adaptation.

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. In addition, we have officially released a webpage to support the preparation of Green Climate Fund (GCF) concept notes.

To strengthen international cooperation for AP-PLAT, at the 8th international Adaptation Futures Conference in New Zealand in 2025, we conducted a thematic session focused on scientific tool. 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

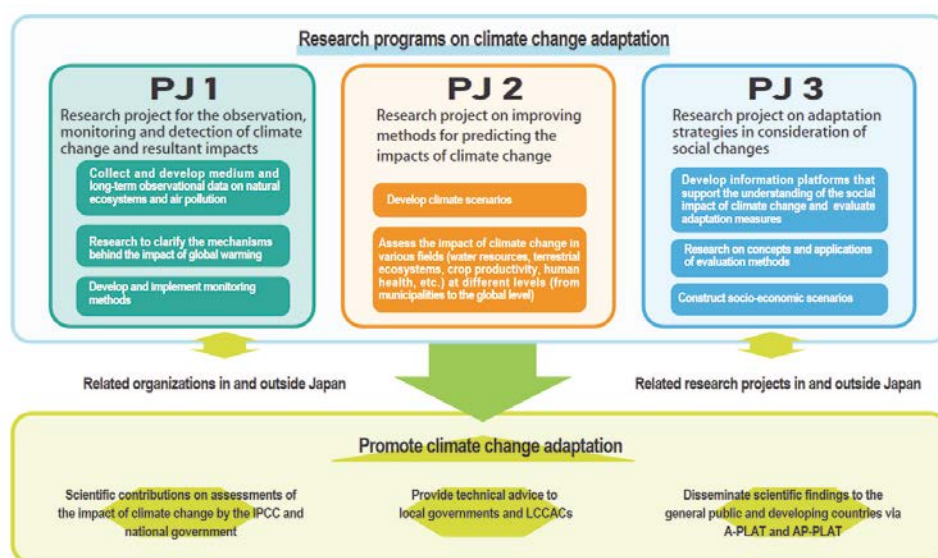
We contributed to discussions on climate change risks and adaptation measures and promotion of the government's adaptation-related projects by sending staff to 131 committees and working groups. This included working with the Subcommittee on Climate Change Impact Assessment and Adaptation (part of the 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. Especially within the Adaptation Subcommittee of the Central Environmental Council, we participated in hearings to revise the Climate Change Adaptation Plan on the basis of the Third Climate Change Impact Assessment Report. We contributed to the discussions by compiling and reporting on the outcomes, challenges, and future directions of our research and technical support initiatives to date.

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 from the research institutes of 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 2025 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 are elucidating 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 2025, research continued to focus on detecting the impacts of climate change and elucidating their underlying mechanisms. Studies on natural ecosystems were conducted to clarify the status of tree species transition in deciduous broad-leaved forests and temperate coniferous forests; the impacts of whole-lake turnover on benthic fish communities; the mechanisms of the impact of sea-level rise and rising water temperatures on the respiratory costs of mangrove plants; and the characteristics of coral distribution expansion toward higher latitudes. For paddy rice, the factors influencing the suppression of chalky grain development were identified. In the area of heat and health issues, research verified the superiority of an index (RelTemp) that accounts for the effects of heat acclimation in predicting the number of emergency transportations required for victims of heatstroke. Furthermore, in a study examining basin-scale climate change risks and nature-based adaptation measures, the effectiveness of wetland restoration for flood control, water purification, and biodiversity conservation was demonstrated; locations for effective mitigation measures were also successfully mapped out.

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 2025, research continued to focus on advancing methodologies for climate change impact assessment. Notably, the effects of nitrogen fertilizer on the ozone sensitivity of paddy rice, which were clarified through the activities of PJ1, were incorporated into our model. The results suggested that ozone impacts may be

overestimated in countries with high fertilizer inputs, such as China, while being underestimated in many other developing countries with low fertilizer inputs.

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.

In FY 2025, PJ3-1 proposed a novel Adaptation Urgency Index that quantitatively demonstrated the timing when adaptation measures would become necessary for 1847 municipalities nationwide. It utilized yield projections for 67 crop cultivars. By defining threshold-exceedance years on the basis of multiple general circulation models and climate scenarios, the project created urgency maps that visualized how the optimal timing for implementing adaptation measures varies by region.

PJ3-2 advanced high-resolution environmental analysis and vegetation monitoring targeting coastal ecosystems and the Southwest Islands (i.e., the Nansei Islands) to deliberate on conservation and adaptation strategies. The project compiled administrative documents and local perceptions regarding corals and seaweed beds, and it revealed gaps in current conservation measures. Additionally, through resurveys and long-term monitoring of vascular plants, it evaluated the impacts of climate change and anthropogenic pressures on ecosystems. Furthermore, the project analyzed green infrastructure functions and institutional challenges in terms of the implementation feasibility of ecosystem-based adaptation, highlighting the synergies and trade-offs among different policy measures.

PJ3-3 quantitatively evaluated the effectiveness of revisions made to local government adaptation plans. It analyzed how the inclusion of scientific knowledge and socioeconomic factors influenced the revised content. Focusing on LCCACs, the project conducted a survey using resilience indicators, clarifying the weaknesses in monitoring capabilities and the challenges faced by municipal centers. Furthermore, through field surveys in Fiji, it identified complex challenges and governance issues surrounding relocation and in-situ adaptation.

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)
- 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 SS9012, etc., total about 22 PB).

This seventh-generation computer system operated without major problems for 6 years and was retired in November 2025.

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.

1.2 Upgrading of the research computing infrastructure

After discussions by the Working Group and a survey of opinions across NIES, a committee was launched in 2023 to consider the next research computing infrastructure. As the secretariat of both the Working Group and the committee, the Division compiled opinions on system specifications and consulted with IT vendors. As a result of the review, we adopted a virtualization infrastructure to meet diverse user needs. A request for proposal was issued in December 2023 and a request for information in September 2024, and the constructor was selected in June 2025. The system consists of a virtualization infrastructure with 20 GPUs and 1328 CPU cores, computing nodes equipped with vector processors (628 TFLOPS of peak performance), and 18 PB of disk storage. In parallel, we used the “mdx” system, which is operated by nine universities and two research institutions in Japan, to assess the technical challenges of operating the virtualized infrastructure. The installation of NIES’s 8th-generation research computing system was completed and operations began in March 2025 (Fig. 1).

Fig. 1
NIES Environmental
Research Computing
Facility



1.3 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 2025, 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 NIES staff member.

1.4 Library services

As of March 2026, the NIES Library (Fig. 2) held 77,423 books, 9219 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. Anticipating the growth of electronic resources, we conducted an evaluation for the implementation of Alma Starter, a streamlined ERM (electronic resource management) system for libraries.

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. The rooms are equipped with 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 published 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 recent years, escalating journal publication fees have been making it more difficult for researchers to publish their work. Since 2025, we have concluded transformative agreements with electronic journal publishers (e.g., Springer Nature and the Microbiology Society) to reduce the financial burden on researchers when publishing their papers.

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 results of monitoring, we made improvements to our library systems, including the web-scale discovery service, and we held a seminar on academic publishing for our researchers. 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 to collect, process, and disseminate environmental information. The Division provides various kinds of environmental information to the public through websites. We also process and manage environmental information databases and provide 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(<https://tenbou.nies.go.jp/>) offers a quick search facility to access archived news content on environmental issues in Japan and across the globe; descriptions of key environmental technologies; and environmental information via GIS, including updated datasets and newly released thematic indicators.

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 GIS-based environmental data provision system displays environmental quality data and other relevant information in a map-based format, making it easy and intuitive for users to understand the current status of the environment. The data are collected and created through research activities and environmental administration. The system has been publicly available via the internet since July 2010 and has been continuously updated in response to user feedback and operational needs. In addition, the cloud-based GIS data platform “Environmental GIS plus” can integrate GIS content from other organizations. Initiatives aimed at mutual data sharing with MOE and their GIS data infrastructure are planned for the future.

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Editorial assistance: MAEDA Printing Co., Ltd.

