Research Overview in 2006

Research Overview in 2006

Research Organization

- President
  - Vice President
  - Auditors
  - Principal Research Director
    - Research Planning Office
    - Research Coordination Office
    - Public Relations and Information Office
    - Experimental Farm Management Division
    - Coordinator for Research Information Systems
  - Principal Administrative Director
    - Administrative Services Office
    - Accounting Office
  - Audit Office
  - (Research Divisions)
    - Agro-Meteorology Division
    - Carbon and Nutrient Cycles Division
    - Soil Environment Division
    - Organochemicals Division
    - Biodiversity Division
    - Environmental Biofunction Division
    - Ecosystem Informatics Division
  - Principal Research Coordinators

(Research Projects)

- Risk Assessment of Organic Chemicals
- Risk Management of Heavy Metals
- Ecological Impact Assessment of Invasive Alien Species
- Ecological Impact Assessment of Genetically Modified Organisms
- Biodiversity in Paddy Fields
- Biodiversity in Upland Soils
- Ecological Functions of Semiochemicals
- Factors Affecting Crop Production Changes
- Mitigation of Greenhouse Gas Emissions
- Carbon and Nitrogen Budget in Regional Scale
- Environmental Risk Assessment of Nutrients
- Global Warming Monitoring
- Spatial Information in Agriculture
- Agro-Environmental Risk Indicators
- Classification and Information of Environmental Resources

Summary of NIAES Research Projects

The National Institute for Agro-Environmental Sciences emphasizes the following research themes in three research fields during the new medium-term research period (2006 to 2010) as it provides for the specialization and prioritization of basic studies and research meant to assure the security of agricultural production environments.

A. **Assessing and managing agro-environmental risks**
B. **Elucidating and managing the structure and function of agro-ecosystems to maintain and enhance the function of natural circulation**
C. **Basic study to support elucidation of the agro-ecosystems functionality**

A. Assessing and managing agro-environmental risks

1) Development of risk management technology for hazardous chemical substances in agro-ecosystems

(1) Development of assessment methodology and management technology for agro-environmental risks by hazardous chemical substances

Amid rising concerns about the burdens of chemicals from farmland and other non-point sources spreading outside of agro-ecosystems, and about the diffusion of such pollutants over wide areas, researchers are faced with the challenge of developing methods to assess the risk of ecosystem disruption by chemicals and other pollutants, and technologies to prevent their diffusion over wide areas. For that reason, we will develop methods to assess the ecological risk of hazardous chemicals and technologies to manage ecological risks.

Research Plan for 2006–2010

To reduce the risk of pollution by chemicals and substances in agricultural environments, such as cadmium, arsenic, radioactive materials, and persistent organic pollutants (POPs) including drin family pesticides, we will elucidate their dynamics and develop technologies to reduce their risks. For pesticides and other organic chemicals, this will involve developing models to predict behavior in the environment, and also developing environmental risk assessment methods using means including exposure experiments with aquatic arthropods and other organisms. Also, we will develop technologies for remediating soil contaminated with hazardous chemicals by such means as chemical washing and bioremediation, as well as technologies for using cultivars that have low absorption of these substances.

Summary for 2006

In the area of pesticides and other organic chemicals, we developed a model to predict the concentrations of not only the parent compounds of rice field pesticides, but also their metabolites. We found that the rate at which chlorinated organic pesticides disappear from the soil depends on Kow, the octanol/water partition coefficient indicating a substance's hydrophobicity, and on soil carbon content. Additionally, researchers chronologically analyzed and predicted the distribution of these pesticides in Japanese farmland. The tendency of sensitivity to various insecticides was determined with the caddisfly (*Cheumatopsyche brevilineata*) as an indicator organism, and it was found that, depending on pesticides, sensitivity was far different from that of the water flea, which is the OECD indicator organism.

Our laboratory was first in the world to successfully isolate and identify a bacterium (*Nocardioides* sp. PD653) that can aerobically mineralize hexachlorobenzene (HCB). To investigate the remediation effect of a high-absorption plant (zucchini) on dieldrin-contaminated soil, pot experiments were conducted, and it was found that in soil where zucchini had been grown, young cucumber plants absorbed far less dieldrin than in the soil where zucchini had not been grown.

In situ investigations of cadmium-contaminated soil confirmed that the cadmium removal rate of chemical washing is higher if rice paddy water is deep. A search for cultivars with low cadmium absorption determined that, in the case of eggplant, turkey berry (*Solanum torvum*) rootstock is capable of holding the cadmium concentration in eggplant fruit down to about 30% of that resulting with other rootstocks.

2) Development of risk management technology for invasive alien species and genetically modified organisms in agro-ecosystems

(1) Assessment of ecological impact and development of risk management technology for invasive alien species and genetically modified organisms

Amid increasing concerns about the escape of alien species (those that invaded and those introduced) and GM organisms, and their impacts on ecosystems, we are faced with the challenge of developing technologies to assess the risk of ecosystem disruption by the organisms and technologies to prevent them from diffusing over wide areas. For that purpose, we will develop methods to assess the ecological risks of alien species and GM organisms, and technologies to manage their ecological risks.

Research Plan for 2006–2010

To prevent the disruption of and damage to agro-ecosystems by alien species (those which invaded and those introduced), we will elucidate the characteristics of the proliferation, allelopathy, and other effects of alien species, and we will determine the state of damage by alien species, and predict their colonization and the diffusion of, and damage caused by those organisms. We will also determine where alien species originate, and estimate their probability of invasion. Further, by analyzing the impacts of alien species such as alien natural enemy insects on closely related native species from aspects including competition and hybridization, we will assess the risks that alien species present to agro-ecosystems and will develop technologies using molecular markers and other means for the early detection and monitoring of alien species that are hard to identify. To appropriately assess the impacts of GM organisms on ecosystems, we will develop technologies that use DNA markers and other means to detect hybridization between GM crops and closely related species, such as GM soybeans and wild soybeans, and shed light on the ecosystem impacts of hybridization. To provide for the coexistence of GM and non-GM crops, we will develop models to predict hybridization rates and technologies to suppress hybridization through cultivation methods that, for example, assure isolation distance.

Summary for 2006

Work proceeded on understanding the growth and breeding characteristics of alien species and on determining the extent of actual damage; analyses were performed on the relationship between the frequency of alien plant appearance and the type of plant community. Results showed that it is easy for alien species to invade plant communities that have been heavily disrupted by human activities. We also found that the star cucumber (*Sicyos angulatus*) suppresses native species and that parrotfeather (*Myriophyllum brasiliense*) and Nuttall's waterweed (*Elodea nuttallii*) suppress endangered species; these plants heavily impact biodiversity. A few alien plants produce large quantities of allelopathic substances, and among those identified were mimosine from the lead tree (*Leucaena leucocephala*), tartaric acid from Japanese laurel (*Aucuba japonica*), and rosmarinic acid from comfrey (*Symphytum officinale*).

To understand the impacts of alien species on native species, we worked on the development of DNA markers to distinguish between alien natural enemy insects (*Torymus sinensis* and *Chrysoperla carnea*) and native species, and between the invasive alien plant fungus *Phytophthora cinnamomi* and closely related native species. We studied the distribution in Lake Kasumigaura of the golden mussel (*Limnoperna fortunei*), which was designated as an invasive alien species for its harmful impact on the operation of water utilization facilities and native ecosystems. Our investigation found the mussel had expanded its distribution to about one-half of the lake shore, and that it would have invaded the lake in 2004.

To assess the ecosystem impacts of GM crops, we grew wild soybeans so they would entwine themselves around GM soybeans, and so that their full-flowering period would coincide with that of GM soybeans, then checked for hybridization between the GM and non-GM plants. Out of 32,502 wild soybean seeds, we found one that was a natural hybrid. The airborne pollen quantity measured with an automatic pollen counter correlated well with the count obtained with the standard pollen counting method. Techniques tested for limiting hybridization were to put a water-spray curtain or sorghum windbreak next to corn, which succeeded in decreasing the hybridization rate 10 m from the pollen parents.

B. Elucidating and managing the structure and function of agro-ecosystems to maintain and enhance the function of natural circulation

1) Elucidation and evaluation of the structure and function of agro-ecosystems

To provide for the appropriate management of agro-ecosystems and create sustainable production technologies that make use of ecosystem functions, it is essential to build a store of knowledge on ecosystem structure including the makeup and the temporal and spatial distribution of the living and non-living resources that constitute agro-ecosystems, as well as on ecosystem functions including the interrelationships between species, the interrelationships between species and non-living resources, and material transport. We will elucidate the ecological niches of species and interspecies relationships, and with developing objective methods of assessing biodiversity. By these means, we shall shed light on the structure of agro-ecosystems by understanding the composition, dynamics, and functions of species in agro-ecosystems.

(1) Elucidation of synecological dynamics and biodiversity in agro-ecosystems

Research Plan for 2006–2010

To conserve the biota that supports agriculture, and that biota's diversity, we will investigate the dynamics of the plants, birds, insects, nematodes, microorganisms, and other organisms living in and around farmland, and then determine the impacts on the makeup and diversity of these organisms caused by the tilling of farmland and the use of chemicals, by switching crops, fallowing, and changes in management methods for peripheral vegetation and irrigation ponds, and by changes in rice paddies and their surrounding landscape structure. Using the results obtained, we will build a model to predict the dynamics of populations, such as those of indicator insects, occurring in conjunction with changes in agricultural activities, such as land use, and use the model to determine what factors stabilize populations.

Summary for 2006

To gain an understanding of how irrigation pond management affects biodiversity, we typed ponds according to the makeup of dragonfly species living in each, and chose a dragonfly indicator species group for each pond group. We also determined the main environmental factors that influence the dragonfly species makeup from the correlations between environmental factors and the results of ranking all the ponds.

To discover how changes in the management methods for landscape structures and rice field periphery vegetation influence biodiversity, we surveyed birds in the monitoring zone of the "Rural Landscape Information System (RuLIS)," a rural landscape database that our institution developed, found the land cover characteristics that correlate strongly with the residence of certain bird types, and built a model that estimates the number of birds from the landscape structure. We also confirmed that RuLIS is effective for assessing the residence potential of various species groups. A survey of vegetation along the edges of forests by valley rice fields found that cutting the weeds around the rice fields was important for conserving plant community diversity.

To investigate the influence of farmland management methods on soil organism dynamics without the use of culturing, we directly extracted DNA from soil, looked for the optimum analytical conditions (such as polymerase chain reaction (PCR) protocols and primers, and electorophoresis conditions) using PCR-DGGE (amplify with PCR, then analyze with denaturing gradient gel electrophoresis (DGGE)) to efficiently detect soil biota, specifically bacteria and molds, and wrote the results into a manual as a standard procedure.

(2) Elucidation of semiochemicals affecting the function of agro-ecosystems

Research Plan for 2006–2010

To make a contribution to maintaining and improving agro-ecosystem functions, we will elucidate the functions of substances including those involved in the interactions between organisms, such as the physically active substances produced by Rosaceae plants and others, and the semiochemicals involved in the propagation of Pyraustinae moths and other insects, as well as substances that control the expression of genes in bacteria groups such as *Burkholderia* sp. for decomposing chemicals such as persistent aromatic chlorinated compounds.

Summary for 2006

We worked on elucidating the semiochemicals involved in the interactions between organisms; quantitatively assessed the total activity of plant growth inhibitors that emerge from leaves and roots, such as 53 species of medicinal Rosaceae plants (dried leaves) and 65 species of Rosaceae plants (fresh leaves); and found that plants such as *Prunus zippeliana* have strong allelopathetic active. Analysis and assessment of the constituent ratio of the *Ostrinia zaguliaevi* moth's sex pheromone found that there are large variations in the ratio within populations, and that this ratio is strongly controlled by genes.

Research on the NK8 strain *Burkholderia* sp., soil bacteria, determined that the expression of two promoters of the gene cluster related to the decomposition of persistent aromatic compounds is induced by different aromatic compounds for each promoter. Through our research on fungi that break down biodegradable plastics, we isolated for the first time, from insects that eat lignin and other substances, a true fungus that simultaneously decomposes the major biodegradable plastics PBS and PBSA.

2) Elucidation of mechanisms causing changes in agro-ecosystems and development of mitigation technology against the changes

Amid rising expectations for ensuring security of land and water resources, it has become difficult to maintain and manage farmland and other lands due to factors including the dwindling vitality of domestic agriculture; there are increasing worries about matters such as the soundness of the water and material cycles. Internationally, solutions are needed for worldwide food shortages and environmental problems, and in that context there are increasing concerns about widening weather-caused disasters and the destabilization of agricultural production due to global warming. Thus, it is necessary to build a store of knowledge about matters including the interaction of agricultural activities with changes in agro-ecosystems and the global environment. For this reason, we seek to understand the interaction of climate change and other global environmental change with agro-ecosystems, and to determine how changes in agricultural activities affect the functions of natural cycles, and then develop technologies for appropriate management.

(1) Impact assessment of global environmental changes on agro-ecosystems and risk assessment of the change on crop production

Research Plan for 2006–2010

To assess, on the scale of individual fields, the changes in rice harvest yield caused by global warming and weather extremes, we will develop a comprehensive rice field ecosystem response model that includes water, soil, rice cultivars, and cultivation management conditions. We will also develop a simple regional-scale yield model to predict the changes in rice yield mainly in Japan and other Asian countries around the middle of this century judging from yield and water resources, and will develop a method for wide-area assessment on a regional scale of the risks of rice yield decline. Based on the results, we will build a scenario to predict the impact of climate change on food production.

Summary for 2006

As a rice field ecosystem response model, we designed a system configuration for a model that consists of three elements: dynamics of soil carbon and nitrogen, rice plant growth, and canopy hydrothermal balance. By combining the DNDC (DeNitrification-DeComposition) model, which indicates the dynamics of soil carbon and nitrogen, and a growth model that takes nitrogen nutrients into consideration, we succeeded in reproducing the effects on growth and yield by the continuous use of organic materials and by nitrogen fertilizer. Verification at eight sites throughout Japan demonstrated that the growth model is effective in analyzing the meteorological and cultivation technology factors that affect changes in crop conditions.

To illuminate crop response to global warming and high atmospheric CO_2 under field conditions for the purpose of predicting changes in rice yield, we built a database of growth, yield, and meteorological components from a free-air CO_2 enrichment (FACE) experiment conducted at Shizukuishi, Japan and Jiangsu Province, China.

(2) Elucidation of effects of agricultural activities on carbon and nutrient cycles

Research Plan for 2006–2010

To help solve regional and global environmental problems relating to greenhouse gases, nitrogen, and other agricultural emissions, we will illuminate the impacts of agricultural activities on material cycles and find ways to mitigate environmental burdens. With respect to greenhouse gases, we will propose a technological system to efficiently mitigate environmental burdens by quantitatively assessing the efficacy of limiting the generation of greenhouse gases with cultivation and soil management technologies. At the same time, by using soil-related databases to examine and improve models that describe soil carbon dynamics, we will predict changes in soil carbon storage occurring in conjunction with climate change and changes in the management of Japan's farmland soil. Nitrogen flow and stock in agro-ecosystem that result from food production, imports, exports, and other factors will be estimated on the basis of information including an acidic material dynamics model and statistical data. The wide-area cycle of nitrogen and its environmental burden will be elucidated for the entire East Asian region or on the country level, and predictions will be made. On the watershed level, research will ascertain the runoff dynamics of nitrate nitrogen, phosphorus, and other substances in the pedosphere, including shallow groundwater, and develop methods of assessing vulnerability to water pollution.

Summary for 2006

Tests of technologies to suppress the generation of greenhouse gases conducted on farmland in China showed the effectiveness, in terms of cost as well, of managing organic materials in rice-wheat cropping systems and of using nitrification inhibitors in upland field cultivation. We built and analyzed a database on N_2O generation from Japanese farmland, proposed corrected emission factor values for each emission category, and included them in the report on Japan's greenhouse gas inventory (Table 1). Further, the 2006 IPCC revised guidelines adopted our new calculation method and default values for methane generated by the world's rice fields.

We performed the basic design for a carbon and nitrogen flow model that comprises a wide-area carbon and nitrogen balance model and an integrated organic material dynamics model. We verified the model with respect to soil organic material dynamics on the basis of soil data, and used a scenario assuming that rice straw is removed

Table 1 Emission factor for N_2O from cropland soil in Japan

Emission source type*	Crop	Emission factor (kgN_2O-N/kgN)	Uncertainty (kgN_2O-N/kgN)	Source or authority
Synthetic and organic fertilizer	Paddy rice	0.31%	±0.31%	Citations 1), 2)
	Tea	2.90%	±1.8%	
	Other crops	0.62%	±0.48%	
Crop residue		1.25%	±0.25–6%	IPCC default values
Indirect emissions (atmospheric deposition)#		1.00%	±0.5%	IPCC default values
Indirect emissions (leaching, runoff)##		1.24%	±0.6–2.5%	Citations 1), 3)

* We proposed emission factors for plowing of organic soils using the IPCC default values (emission factor: 8 kg N_2O-N ha^{-1} $year^{-1}$, uncertainty: 1-80 kg N_2O-N ha^{-1} $year^{-1}$).

\# Indirect emissions (atmospheric deposition): N_2O emitted when nitrogen applied as fertilizer volatilizes into the atmosphere and then settles again to earth.

\## Indirect emissions (leaching, runoff): N_2O that arises through the transport process from streams to the ocean through the groundwater.

1) Akiyama et al., Soil Science and Plant Nutrition, 52, 774-787(2006)
2) Akiyama et al., Global Biogeochem. Cycles, 18, GB2012 (2005)
3) Sawamoto et al., Geophys. Res. Let., 32, L03403 (2005)

and organic amendments applied to calculate the changes in the carbon storage of fields in Japan, and to show that using organic amendments is effective for building carbon storage (Fig. 1). To throw light on the temperature response of organic material decomposition, we developed a method for soil heating experiments on farmland. Additionally, we collected and compiled information from China including national and regional statistics, and soil carbon data.

Research on nitrogen runoff in watersheds found that soil layers with high denitrification activity in field systems using tea and rice fields are distributed in limited areas near the boundaries between diluvial and alluvial soils. Investigating the runoff of phosphorus through the subsoil found that most of the phosphorus runoff through culverts from clay upland fields converted from paddy fields occurs when suspended phosphorus that has stagnated in the boundary between the plow layer and plow sole is carried out through cracks, but that in yellow soil tea fields almost all runoff phosphorus is in a dissolved state.

C. Basic study to support elucidation of the agro-ecosystems functionality

1) Long-term monitoring researches of environment in relation to agriculture

(1) Long-term monitoring researches of agro-environment and development of simple and accurate methods for analysis

To assess environmental changes due to global warming, sudden disasters, and other causes, and to properly assess and manage agricultural resources, it is necessary to continuously collect ecosystem data over long terms at representative sites, and to build useful databases. For that purpose we will develop methods for the simple but highly precise measurement of agro-environments, and perform long-term monitoring.

Research Plan for 2006–2010

To detect changes in agro-environment resources at an early date, we will perform long-term monitoring of the physical environment, which is the baseline of agro-ecosystems. We will also monitor greenhouse gas fluxes including carbon dioxide and methane, and monitor ^{137}Cs, ^{210}Pb, and other isotopes in crops and the soil. We will develop a method to analyze organic arsenic and other trace chemicals in the environment, which includes crops, and a simple but highly precise measurement method for chemicals in the environment.

Summary for 2006

We used a standardized method to analyze the monitoring data, including that on carbon dioxide flux, obtained from the five sites in farmland and grassland ecosystems in the Monsoon Asia program, which NIAES runs for the Asia Flux network. We then determined the characteristics of the carbon dioxide balances between ecosystems and between sites. In addition to these flux observation sites, we started observations at new sites including Bangladesh, thereby enhancing our observation system.

Monitoring of radioactive substances found that the concentrations of ^{90}Sr and ^{137}Cs in the rice and barley produced in 2005 in radiation reference fields throughout Japan, and the concentrations in the soils in those fields were the same as in 2004. We performed a rush study in conjunction with North Korea's nuclear testing, but detected no artificial radioactive nuclides in leafy vegetables. Long-term monitoring data indicated that the decrease rate of radioactive Sr in the plow layer of upland fields' soil is determined by the soil's cation exchange capacity.

We developed a method to quantify organic arsenic compounds in soil contaminated with organic arsenic, and in the rice straw and unpolished rice grown in that soil (Fig. 2).

2) Collection, classification, and digital archive of environmental resources

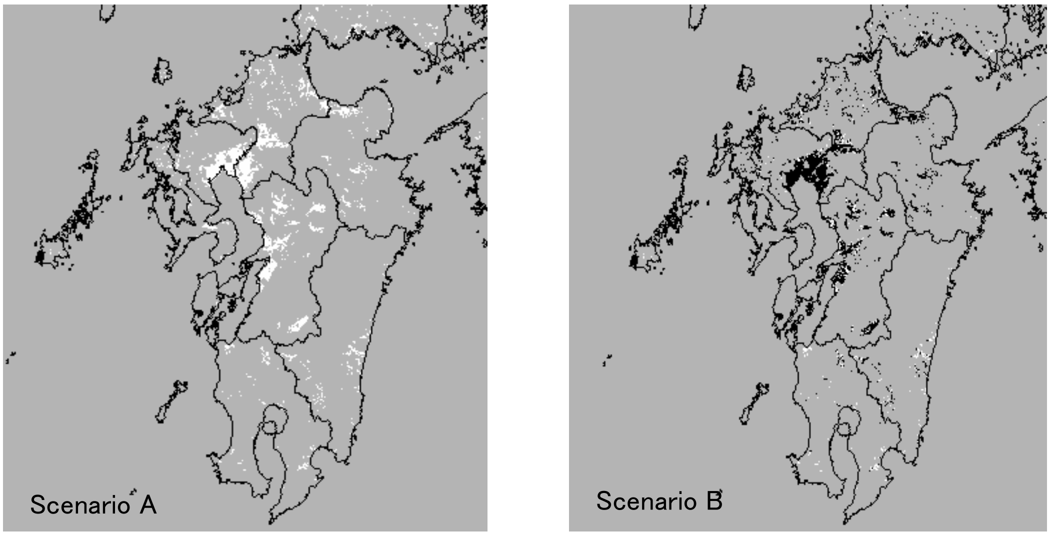

Fig. 1 Spatial distribution of changes in organic carbon stock in paddy soil, in Kyushu (white cells represent places with decreases over a period of 20 years, and black cells are places where there were increases)

Initial conditions: Soil carbon stock distribution determined on the basis of a basic soil fertility conservation survey and a representative soil profile database.
Scenarios: Taken from a 2004 report on studying and analyzing management by farmers who practice eco-compatible farming (rice cultivation).
A: Straw removed, only stubble and roots (67 kg C/ha) incorporated into soil.
B: Organic amendments, rice straw, stubble, roots (174 kg C/ ha), and compost (32 kg C/ ha).

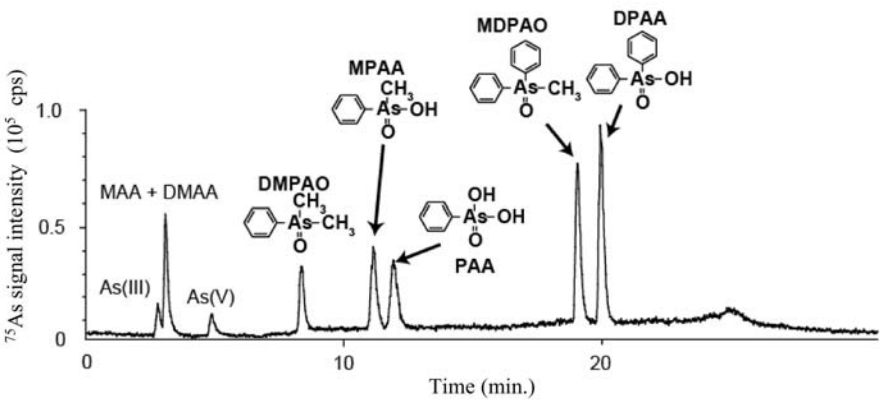

Fig. 2 Simultaneous determination of various arsenic compounds. The detection limits were 0.5–5.0 pg as As.

(1) Development of natural resources inventory and its utilization

As advances are made in field research such as studies and analyses of environmental resources and various ways of monitoring them, it is important to accelerate research by efficiently using assets such as the specimens and information obtained from such research, and to take the initiative in research at home and abroad. For that purpose, we will develop ways to build and use a comprehensive inventory of environmental resources.

Research Plan for 2006–2010

To comprehensively assess agro-environments, we will develop technologies to analyze remote sensing data from sources including microwave measurements and the Moderate Resolution Imaging Spectroradiometer (MODIS). By using the Geographic Information System (GIS) and other means, we will develop new methods of ascertaining the state of agricultural land use, and indicators relating to organism habitats. We will develop a method for linking individual databases that have the GIS as their shared platform, and develop a new information recording and collection system, thereby contributing to the formulation of agro-environmental indicators. Furthermore, we will expand individual environmental resource databases, publish a tentative soil classification that includes functional assessments of deep soil, and build a comprehensive soil database of cropland and non-cropland. To efficiently use inventory data and other information, we will develop a basic statistical method, a method of visualizing its results, and other tools, and also cooperate as a sub-bank of the gene bank run by the National Institute of Agrobiological Resources.

Summary for 2006

We collected and processed time-sequenced satellite images, mainly from MODIS, data on cultivation history and from on-site surveys, and other information, then chose as our region for analysis the Mekong Delta, whose land use type is a simple large rice field district. We then developed an algorithm to identify wide-area changes in flooded areas, rice-cropping types, and land use by using high-frequency observation data. To help formulate agro-environmental indicators, we completed a general-purpose spatial information platform that performs the integrated accumulation and management of spatial information that forms the basis for assessing the ecological roles and environmental burdens of farmland, and performs assessments and predictions. Additionally, for the development of indicators showing changes in organism habitats, we gathered data on the Japanese macaque (*Macaca fuscata*) and integrated them into the GIS. By making efficient use of inventory data and other information, we prepared soil erosion risk indexes while referring to sources including past research, and created a risk map with a 1-km grid using the indexes.

We developed a system that prepares thematic maps by linking individual databases on soils, insects, and other subjects. Additionally, GIS data on insects and other subjects for which geographical coordinates had been generated from place names were additionally registered to the agro-environmental inventory. For the purpose of expanding and enhancing data on environmental resources, we databased 1300 items from soil series surveys, and published soil survey-related materials on the web. Our work on microorganisms included registering to the inventory another 133 strains that decompose persistent substances, 30 strains of 2,4-D decomposers, and 30 strains closely related to *Burkholderia cepacia*, while for insects we registered another 1800 butterfly specimens, 1600 ground beetle (Carabidae) specimens, and more.

For the gene bank project, we prepared data sheets on the history and handling of 67 microorganism strains and data sheets on a total of 1243 characteristics of 244 strains. We bred 100 strains of bacteria and transferred them to the central gene bank, while for insects we performed characteristic assessment studies for 13 items in five species, and sustaining characteristic studies for 13 items in eight lines.

Special Research Projects

1. Japan–Korea Cooperative Research Project on Water Quality Conservation in Agro-Ecosystems and Assessment of Risk to the Environment

Both Japan and Korea are located in monsoon Asia, and they have similar agro-ecosystems that depend on rice production. In addition, there are many points of similarity between Japan and Korea, not only in terms of their agro-ecosystems but also in socioeconomic features such as their high population densities, high levels of dependence on food supplied from overseas, and advanced states of industrialization. Accordingly, both countries have various problems with the water quality of their agro-ecosystems—including contamination by nitrate-nitrogen, heavy metals, and dioxins—and they face the common challenges of evaluating indirect emissions of greenhouse gases, assessing the impact of farm chemicals on aquatic organisms, and developing technologies to reduce contamination by these chemicals.

In this cooperative research project, we therefore aimed at the conservation of water quality in agro-ecosystems and elucidation of the influence of agricultural activities on water quality in Japan and Korea. In addition, we planned to verify reduction technologies that have been developed here in Japan—including a model that predicts water quality, a water balance model, technology to reduce nitrogen loads by using natural circulation, and methods for monitoring toxic substances—in Korea, where the ecosystem is similar. For a total of 4 years (from FY 2003 to FY 2006), researchers worked together to tackle the following three major challenges:

1. assessment of the effects of agricultural activities on the water quality in agro-ecosystems
2. development of a PC-based model to predict water quality and development of promising technologies for water quality conservation
3. elucidation of the toxic substance loading of arable lands and development of a methodology for risk assessment in agro-ecosystems.

Our major achievements can be summarized as follows:

1. Discharge of suspended matter and associated phosphorus to tile drains in a clayey field with subsurface cracks (NIAES Annual Report 2005, p. 51)

We found that discharge of water to the tile drains was initiated soon after the pressure potential at the topsoil–plowsole boundary became positive, and we presumed that subsoil cracks can be major pathways for the discharge of suspended soil particles and associated phosphorus from clayey ex-paddy fields.

2. Database system for estimating the nutrient balance associated with agricultural production in administrative districts (NIAES Annual Report 2004, pp. 57–58)

We established a database system in which we estimated the nutrient balance in arable lands on the basis of statistical information collected in administrative districts such as prefectures, cities, and towns.

3. Origin of nitrous oxide in the shallow groundwater under upland fields (NIAES Annual Report 2005, p. 52)

Changes in the stable-isotope ratio of nitrogen to oxygen suggested that, in the ground water lying under the upland fields of Ibaraki Prefecture on which farmers had disposed of livestock excreta, nitrogen oxides have originated from different sources (such as chemical fertilizers and the livestock excreta), which may have mixed together through leaching and horizontal migration.

4. Easy detection of the herbicide susceptibility of diatoms from the rate of growth of their native colonies (NIAES Annual Report 2006, pp. 46–47)

We developed a method for easily detecting the herbicide susceptibility of native colonies of diatoms, which are the dominant producer organisms in Japanese rivers. The newly developed method can be widely utilized in the ecotoxicological assessment of the producers in our rivers.

5. High susceptibilities of the aquatic fern *Salvinia natans* to sulfonylurea herbicides (NIAES Annual Report 2006, p. 37)

We found that the threatened free-floating fern *S. natans* had the highest susceptibility to bensulfuron-methyl, a kind of sulfonylurea herbicide, among the plants tested. The susceptibility of this species was much higher than that of *Pseudokirchneriella subcapitata*, the species recommended by the OECD guidelines for use in testing chemicals.

2. POPs and Related Compounds in Agricultural Fields in Japan: Contamination Status and its Future Trend

Persistent organic pollutants (POPs), such as dioxins, PCBs, DDT, dieldrin, and chlordane, are transferred across borders and are accumulated in organisms such as polar bears and seals. This means that POPs cause contamination on a global scale. The Stockholm Convention on Persistent Organic Pollutants entered into force in May 2004 with the aim of encouraging cooperation among countries worldwide to minimize or prevent the global environmental contamination caused by these compounds. After the limits set by the Convention begin to take effect, it should be possible to manage some of the issues associated with POPs, such as prohibition of use and reduction of emissions to the environment, and to predict future changes in contamination levels.

The purposes of this project were to elucidate the status of contamination by POPs and related compounds in the agricultural soils of Japan from the 1960s up to the present, and to predict future trends in the levels of these compounds, by the analysis of archived agricultural soils collected from all over Japan since the 1960s. We are also developing a multimedia model that will consider the diffusion and outflow of these substances to the atmosphere and the aquatic environment. The project ran from FY 2004 to FY 2006.

The temporal changes in the levels of POPs and related compounds in agricultural soils (Fig. 1 and Fig. 2) reflected changes in the use of pesticides. DDTs, dieldrin, and HCHs were used as insecticides until they were banned in the early 1970s. The concentrations of DDTs, dieldrin, and HCHs began to decrease dramatically at the end of the 1960s. Chlordane was used as an agricultural pesticide until 1968 and for the treatment of domestic pest insects until 1986. The concentrations of chlordane in agricultural soils increased from the 1970s through to the 1980s. Thereafter, concentrations have decreased continuously. This pattern suggests that chlordane was transported via the atmosphere and (or) water during the entire period in which it was used.

In order to estimate the mass balance of POPs and related compounds in agricultural fields during the last half century and to predict their future contamination status, we estimated the half-lives of these compounds in terms of their disappearance from agricultural soils. These half-lives during the initial 10 years (from the year in which they were detected at the highest concentration through the following 10 years) and after the initial 10 years were estimated to be 1.7 to 12.1 years and 5.3 to 35 years, respectively. We found that the total carbon content (T-C) of the soil is an important factor in the disappearance of these compounds from agricultural soils. Therefore, the mass balance of POPs and related compounds in agricultural fields was calculated by using the half-lives and T-C as key parameters. Although over 90% of the total amount of POPs and related compounds used on Japanese agricultural soils has disappeared over the last half century, the concentrations of the remaining compounds will decrease very gradually over time.

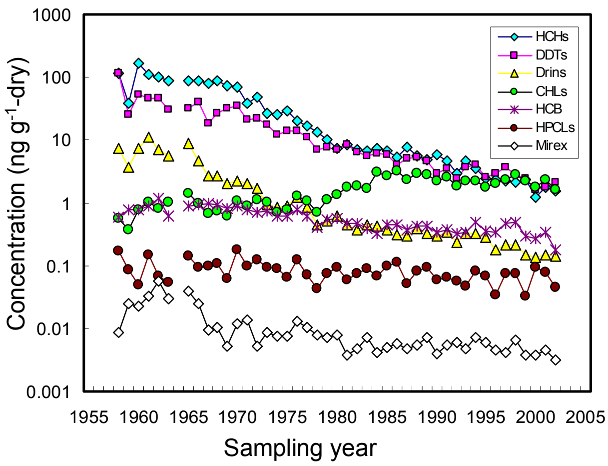

Fig. 1 Temporal changes in OCP concentrations (geometric mean of 14 sites, ng g^{-1} -dry) in Japanese paddy soils

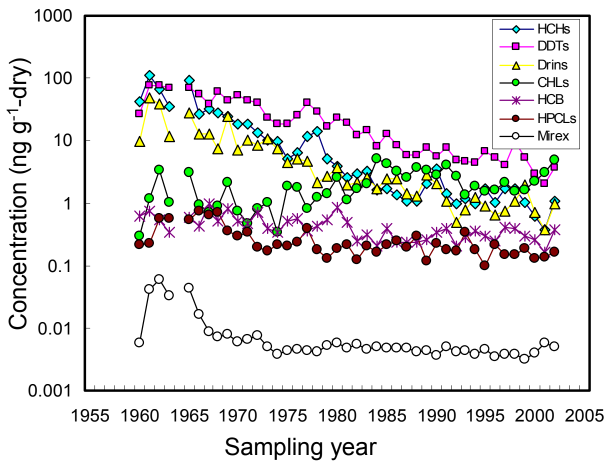

Fig. 2 Temporal changes in OCP concentrations (geometric mean of 10 sites, ng g^{-1} -dry) in Japanese upland soils

3. Development of a System for the Analysis of Soil Biodiversity by Using Environmental DNA

Extremely diverse microorganisms and micro-fauna live in the soil, and they have important roles in the cycling of various elements through the soil. Their activities affect not only soil fertility but also the occurrence and suppression of disease by soil pathogens. Therefore, the characteristics of soil microorganisms and soil fauna—otherwise commonly known as "soil biological properties"—are considered to be important soil indexes. We have been conducting various studies in this research area to explore new technologies for maintaining soil fertility and suppressing soil disease. However, our current technologies enable us to cultivate less than 1% of soil microorganisms. Furthermore, because the identification of soil fauna is extremely difficult for those who are not well trained as taxonomists, our current knowledge of their function is scant. Recent advances in molecular biology have made it possible to examine DNA extracted directly from the soil. By analyzing the DNA (environmental DNA, eDNA) from soil, we have been investigating "soil biological properties" without the cultivation of microorganisms (see Annual Report 2005, pp. 41–42).

We have therefore started on a new project, "Development of a System for the Analysis of Soil Biodiversity by Using Environmental DNA ", which is supported by the Agriculture, Forestry, and Fisheries Research Council of the Ministry of Agriculture, Forestry, and Fisheries. This 5-year project has three major themes: 1) development of a method of analyzing soil organisms by using eDNA; 2) analysis of soil biological properties and crop production, and the development of new indices for these properties; and 3) development of a database of soil eDNA and its utilization methods. The project is led by NIAES and is conducted by NIAES, several institutes from the National Agriculture and Food Research Organization (NARO), and several universities.

4. Research Project on Assurance of Safe Use of Genetically Modified Organisms

The second term (2006 to 2010) of the above project, which is entrusted to NIAES by the Ministry of Agriculture, Forestry and Fisheries as part of its "Comprehensive Project on Securing the Safety of Genetically Modified Organisms", aims to investigate the appropriate use of recombinant DNA techniques. The four major research subjects are: I. Collection of scientific knowledge on the effects of living modified organisms (LMOs) on biodiversity; II. Development of management measures that will assure the safe use of GM crops; III. Development of measures for the coexistence of GMOs with conventional crops; and IV. Collection and analysis of overseas research into techniques for securing the safety of GM crops (Fig.1). Details of each research subject are as follows.

I. Collection of scientific knowledge on the effects of LMOs on biodiversity, focusing on the development of methods for appropriate biodiversity risk assessment under the Cartagena Law (law concerning the conservation and sustainable use of biological diversity through regulations on the use of living modified organisms; came into force February 2004) and on research into satisfying public concerns. Types of LMOs include crops (clover, bentgrass, sweet potato, strawberry, soybean, and canola), fishes (salmon, killifish, and zebra fish), insects (silkworm, bee), trees (Japanese cedar), and microbes. Examples of the information to be collected are the degree of pollen dispersal, degree of generational change, the possibility and degree of introgression, unintended changes in biochemical characteristics, and adverse effects of substances produced by the expression of transgenes.

II. Development of management measures that will assure the safe use of GM crops. These include biological containment by the use of sterile male lines and lodicule-size dwindles in crops (cleistogamy), and the development of techniques for the detection of new GMOs.

III. Development of measures for the coexistence of GMOs with conventional crops, such as the prevention of crossing and contamination.

IV. Collection and analysis of overseas research into techniques for securing the safety of GM crops. To help us in our own research project we plan to collect and analyze European research into techniques of securing the safety of GM crops.

(V. Census project to survey public opinion) for comprehensive project on GMOs.

By gathering data on public opinion we intend to gain an understanding of the public's view on GM crops. This will help us to promote mutual communication and to disseminate comprehensive research results and other GM information.

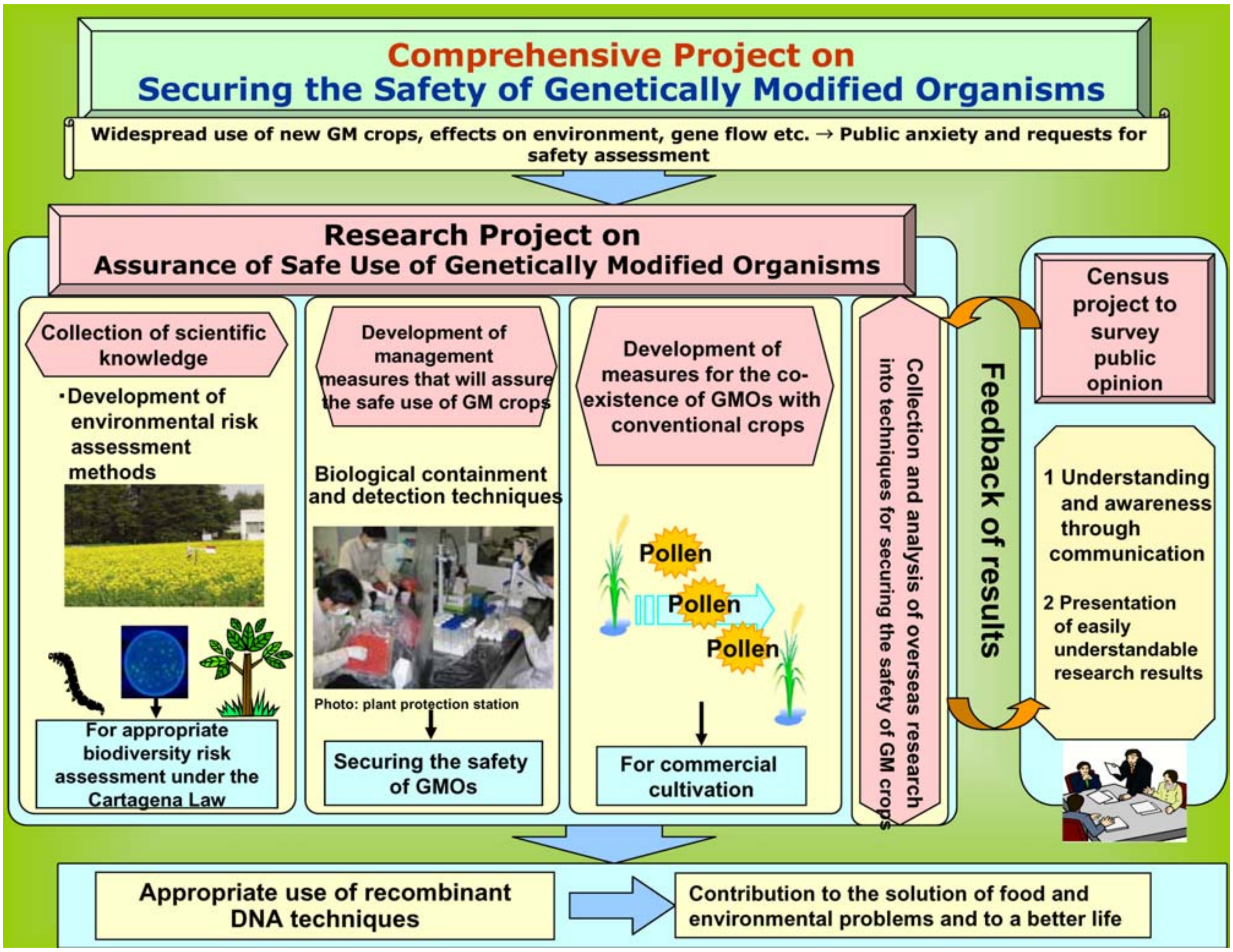

Fig. 1 The Main Structure of Comprehensive Project on Securing the Safety of Genetically Modified Organisms

5. Modeling Rice-based Agro-Ecosystem Responses to Climate Change for Risk Assessment in Rice Production

Ongoing climate change will have significant impacts on future agricultural production. To ensure the food supply under changing environments, we need to assess these impacts on staple food production and to develop agricultural technologies that can adapt to future conditions. We have therefore initiated this project to develop a model that enables us to analyze and predict the effects of climate change on rice production and the interaction of these effects with soil and crop management factors. Both field- and regional-scale impact assessments will be necessary, the former for directing future agricultural technology and the latter for addressing the risks of rice production variability under future climates. At a field level, predictions of the rice production response to climate change will need to take account of soil and crop management factors. The field-scale model will therefore include soil carbon and nitrogen metabolism, a mechanistic presentation of the crop age- and nitrogen-dependent CO_2 fertilization, and the effects of abiotic stresses such as extreme temperatures under elevated CO_2 conditions. We will use various experimental results obtained from chamber and field experiments, including free-air CO_2 enrichment studies, to develop and test the model. At a regional scale, we aim to evaluate climate change impacts on rice production, taking into consideration the temporal and spatial variations in environmental and technological changes. We will address variations in both crop harvestable area and yield under changing climates. Constraints on these components can differ from region to region, depending on soil, water, and climatic resources. For this study, we have chosen to target three regions in which these conditions differ greatly: Japan (where irrigated and comparatively uniform management is practiced), the Mekong River Basin (mostly rain-fed lowland, with large spatial variations in precipitation and in soil and hydrological conditions), and China (mainly in Heilongjiang Province, where large-scale land-use change is occurring). By modeling the impacts of water resource changes on the plantable or harvestable area and combining this modeling with a simple regional rice yield model that takes into account water and nitrogen use, we will attempt to answer the question of how vulnerable these different rice production systems will be in response to global climate change. Our goal is to quantify the effects of technological and climatic factors on rice production under different ecosystems at different scales.

6. Evaluating Environmental Vulnerability to Water Pollution by Gaining a Better Understanding of Nutrient Fates in Soil and Water Systems

The threat of surface and ground water pollution by excess nutrients discharged from arable fields is still increasing. To introduce appropriate strategies that will prevent the degradation of water quality at a watershed scale, it is prerequisite to develop a suitable method for evaluating the vulnerability of different areas to water pollution. In a newly launched collaborative research project, "Evaluating Environmental Vulnerability to Water Pollution on the Basis of a Better Understanding of Nutrient Fates in Soil and Water Systems" (FY 2006–2010), we are investigating the discharging processes of excess nutrients in soil, shallow groundwater, and surface water systems to better define environmental vulnerability and to develop a method for evaluating water pollution risk at a watershed scale.

Particular attention is paid to quantifying denitrification at a watershed scale. Our previous research has shown that there are considerable gaps between the nitrate loads estimated from the surface balance of nitrogen in arable fields and those observed downstream. Part of this difference has been ascribed to denitrification (the loss of nitrate under anaerobic conditions), a process that should reduce the vulnerability of the areas to nitrate pollution. However, not very much is known about the spatial distribution of denitrification activity at a watershed scale. A collaborative study is in progress to elucidate the nitrate transport and denitrification processes in shallow groundwater in an attempt to identify the key factors governing the denitrification activity. We are also attempting to define the vulnerability of areas with different soil and topographic conditions to nitrate pollution.

Phosphorus discharge from arable fields is of critical concern because of its potential for eutrophication of surface water. In addition to the surface runoff of phosphorus during rainfall events, there has been increasing evidence that, in clayey fields, discharge of dissolved and particulate phosphorus to tile drains can be a major pathway of phosphorus export to surface waters. Field monitoring studies are being performed to elucidate the processes of phosphorus discharge in a clayey ex-paddy field that has subsurface cracks and in sloping fields with highly water-dispersible soil.

The environmental vulnerability of areas as defined above with respect to nitrate and phosphorus pollution will then be incorporated into a watershed-scale nutrient dynamics model that combines detailed topographical and land-use information. The model should be able to produce risk assessment maps of water pollution by excess nutrients in selected areas characterized by different topographical, soil, and land-use conditions.