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.

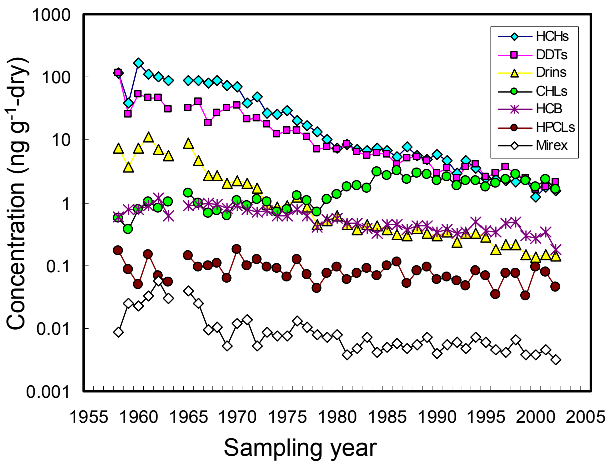

Fig. 1 Temporal changes in OCP concentrations (geometric mean of 14 sites, ng g^{-1} -dry) in Japanese paddy soils

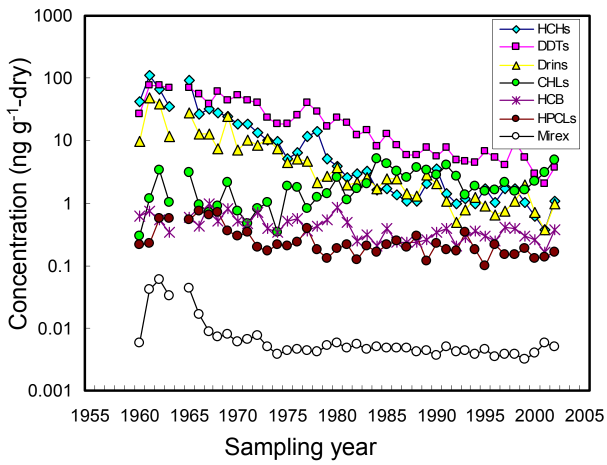

Fig. 2 Temporal changes in OCP concentrations (geometric mean of 10 sites, ng g^{-1} -dry) in Japanese upland soils

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.

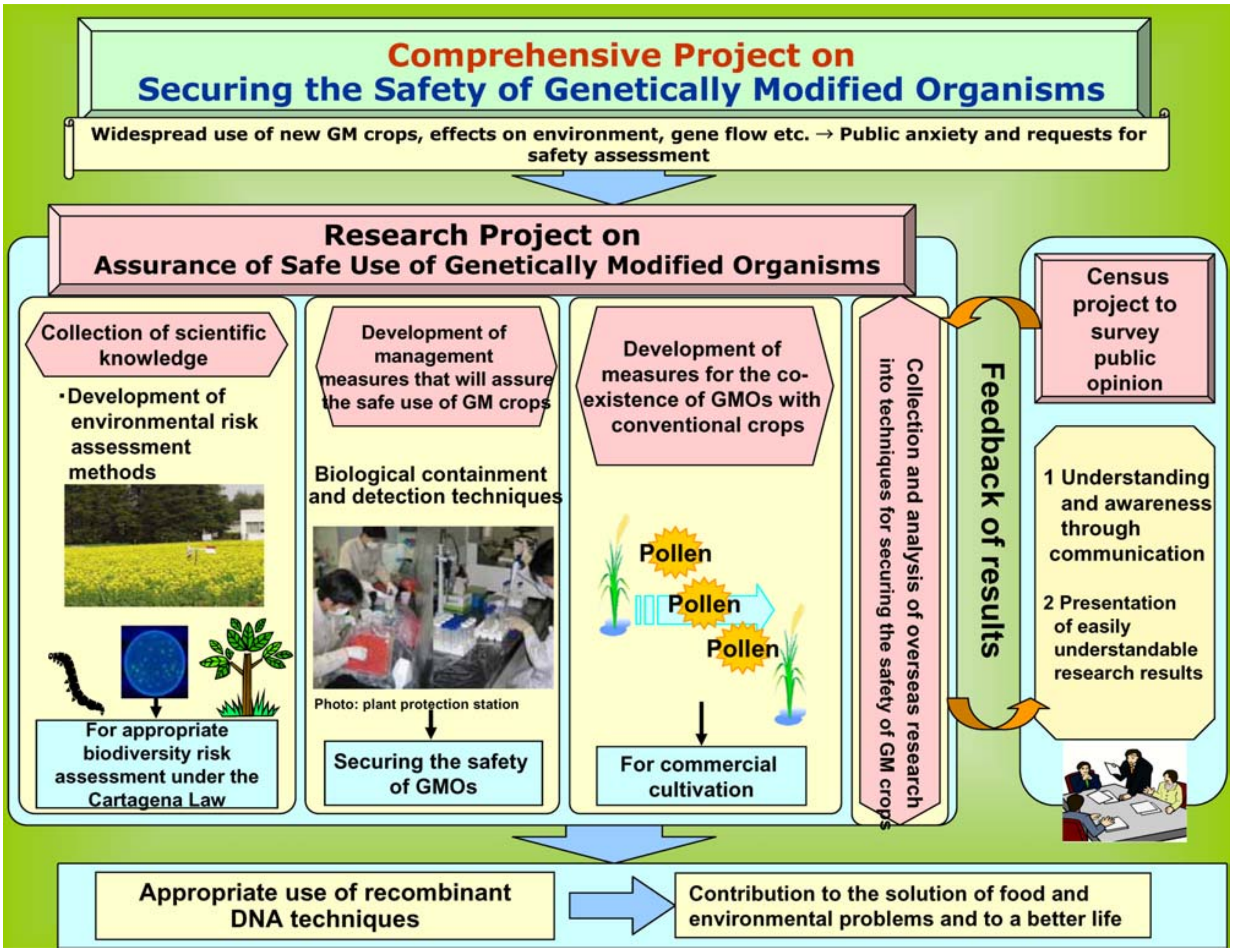

Fig. 1 The Main Structure of Comprehensive Project on Securing the Safety of Genetically Modified Organisms

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.