Special Research Projects

1. Selection of Functional Biodiversity Indicators and Development of Assessment Methods

To promote sustainable agriculture in which agricultural productivity is compatible with conservation of biodiversity, environment-friendly (environment-preserving) farming systems have been developed and propagated in Japan. Little is known, however, about the effect of these farming systems on biodiversity in agro-ecosystems. Over the period from FY 2008–2012, NIAES has been conducting a research project on "Selection of functional biodiversity indicators and development of assessment methods" with the support of a Grant-in-Aid from the Ministry of Agriculture, Forestry and Fisheries of Japan. The objectives of the project are to develop indicators that can help evaluate the effects of environment-friendly farming on the conservation and enhancement of agrobiodiversity. The project focuses on the investigation of indicator organisms beneficial to agriculture, such as predators and parasitoids of agricultural pests. Essentially, the research compares the species and abundance of organisms in fields where environment-friendly farming and conventional farming are practiced; organisms abundant in the environment-friendly farming systems are selected as candidate indicator organisms.

The project includes the following two research subjects:

(1) Selection of organisms as indicators of functional agrobiodiversity

We expect that some indicator organisms will be vulnerable to differences in management (e.g., pesticide application) in each cropping field; thus their abundance will differ among plots. Other indicator organisms, however, may not be vulnerable to changes in management, but their populations may fluctuate at the landscape level because they move over wide areas or use different sites in a landscape as habitats. Hence, agrobiodiversity is to be analyzed at a crop field level and at a landscape level.

(2) Development of simple methods of evaluating agrobiodiversity by using indicator organisms

The evaluation methods that are developed need to be simple so that they can be applied at the farm level. The research will therefore establish simple methods of identifying indicator organisms and will develop efficient ways of monitoring these organisms. In addition, we will develop a system for applying the results of research subject (1) to the entire agro-ecosystem in order to predict changes in agrobiodiversity in Japan.

2.Research project for developing risk mitigation technologies for POPs in vegetables

The concept of risk analysis has only recently been introduced to domestic food safety administration in Japan. It is therefore essential that we build a scientific and technical basis for risk mitigation of farm/marine products and livestock.

Twelve chemicals were selected as persistent organic pollutants (POPs) by the Stockholm Convention in 2001, and nine chemicals have been newly assigned in 2009. Fourteen of these POPs have been used as pesticides. They include drins and heptachlor, which were recently detected in fruits of cucumber and pumpkin in amounts exceeding Japanese maximum residue levels (MRLs), even though their use was banned in the early 1970s.

We have studied these chemicals in past research projects, but we still have limited practical information on the risk analysis of POP residues in agricultural products.

This project has the following three study components, targeting mainly vegetables: (1) development of risk assessment technologies for POP exposure in the food chain; (2) development of risk management technologies for POP contamination; and (3) development of basal technologies for risk assessment and management of POPs.

The goal of the project is to develop and validate preventive (minimization of absorption by crops) and curative (remediation of soils) technologies for those POPs that were used domestically as pesticides in the past. We aim to keep POPs residues in crops at levels lower than the MRLs. By using these newly developed methods, together with good field practices, we hope to achieve risk mitigation of POPs. This project is divided into three large issues, composed by 21 action plans as a whole, and they are conducted by about 22 researchers from 13 organizations.

This project is one in a sequence of seven known collectively as the "Research project for ensuring food safety from farm to table". The objective of the sequential project is to clarify the behavior of significant hazards, such as arsenic and cadmium (as described below), POPs, mycotoxins (nivalenol, deoxynivalenol), and pathogenic microbes, in order to develop simple and quick detection methods and methods of mitigating exposure risk in the journey of food products from arable lands and fishing waters to the table. The project began in FY 2008 and is scheduled to end in FY 2012. It is supported by the Ministry of Agriculture, Forestry and

Fisheries of Japan. The participants are not only NIAES, but also other non-designated independent administrative institutions, universities, prefectural agricultural experimental stations, and the private sector.

3. Development of risk mitigation technologies for arsenic and cadmium in crops

Arsenic is considered one of the most important toxic elements found in the environment because of its potential risk to human health. Food is a potentially important source of dietary arsenic intake. Rice (*Oryza sativa*) accumulates the highest amount of arsenic of all grain crops, largely because of the high plant availability of arsenic under reduced soil conditions. Rice is one of the world's major staple food crops, with daily intakes of up to 0.5 kg per head in Asian countries and 0.17 kg in Japan in 2002. Consequently, rice is a potentially major source of dietary arsenic for much of the world's population. The Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF) has analyzed arsenic contents of staple crops in Japan. The arsenic concentration in brown rice ranged from 0.04 to 0.33 mg kg^{-1} (average 0.16 mg kg^{-1}; n = 199) in 2003. The averages in other crops were wheat, 0.008, soybean, 0.005, and spinach 0.010 mg kg^{-1}. Chemical speciation of arsenic influences its toxicity to humans. Inorganic arsenic is generally considered to be more toxic than methylated arsenic compounds

Recently, the CODEX Alimentarius Commission of the FAO and the WHO proposed a new international standard for Cd concentrations in a variety of staple foodstuffs; for fruiting vegetables this level is 0.05 mg Cd kg^{-1} and for root vegetables it is 0.10 mg Cd kg^{-1}. In a field and market basket survey conducted by the MAFF in 1998–2001 in Japan , about 7% of 381 samples of eggplant (*Solanum melongena*), 22% of 165 samples of okra (*Abelmoschus esculentus*), and 10% of 302 samples of taro (*Colocasia esculenta*) contained cadmium at concentrations above these limits. We therefore urgently need to develop technologies to suppress cadmium absorption by crops.

This project has the following two study components: (1) development of risk mitigation technologies for arsenic in paddy rice; and (2) development of risk mitigation technologies for cadmium in upland crops. The project began in FY 2008 and is scheduled to end in FY 2012. This research project is supported by a grant from the MAFF and conducted by 27 organizations carrying 54 themes (Research project for ensuring food safety from farm to table).

4. Assessment and extension of technologies for mitigating greenhouse gas emissions from agricultural soil

Greenhouse gas (GHG) emissions from Japan's agricultural sector are estimated to be 27 million tons-CO_2. CH_4 emissions from rice paddies account for 21% of total agricultural sector emissions, and N_2O emissions associated with N-fertilizer use account for 9.5%. Japan did not select "cropland management" in the first commitment period of the Kyoto Protocol, but the Japanese government will choose "management to reduce GHG emissions from agricultural soil" in the second commitment period of the Kyoto Protocol. Therefore, the government is expected to promote the introduction of farming practices that reduce GHG emissions by the agricultural sector.

A research project, entitled "Assessment and extension of technologies for mitigating greenhouse gas emissions from agricultural soil" focuses on evaluation of the effects of reducing CH_4 emissions by implementing new water management practices (longer periods of mid-season drainage) in paddy fields and by carbon sequestration through intensive soil management based on organic matter application. The project is sponsored by the Agricultural Production Bureau of MAFF, and NIAES is supervising the project activities of the two national institutes, 47 prefectural institutes, and one incorporated foundation. The research project runs from FY 2008–2012.

In this project, we will estimate the CH_4-emission-reduction effects of water management at nine experimental paddy field sites in Japan. We will also confirm soil carbon sequestration factors for every region, soil type, and type of organic matter (e.g., plant residues, manure composts, and charcoals) at 68 sites in paddy fields, upland fields, greenhouses, and orchards. Moreover, we will evaluate soil carbon content to 30 cm depth at 3200 sites in farmers' fields by soil survey and will interview farmers about their soil management.

5. Assessment of Risks to Aquatic Ecosystems by Zinc and Other Heavy Metals Originating in Farming Areas

In recent years, to conserve aquatic organisms, an environmental quality standard for water and an effluent standard have been set for zinc. In rural districts there are concerns that emissions of zinc and other heavy metals from not only graywater but also buildings housing pigs and other livestock are sources of ecosystem pollution. The reason is that, because metals such as zinc and copper are essential elements for mammals, considerable amounts are used daily by humans and the livestock industry. In the livestock industry especially, these elements are added in large amounts to pig and chicken feed to promote growth, and they are present in high concentrations in livestock waste. However, nearly all research so far deals with efforts related to human health risks, such as accumulation of heavy metals in farmland soil, and absorption and transport into agricultural crops. One sees no research at all from the perspective of ecological toxicity or ecosystem conservation, and hardly anything is known about the burden on river systems by zinc and other heavy metals, or their dynamics.

Accordingly, through this research we will determine the flow in rural watersheds of zinc and other heavy metals whose ecological toxicity is perceived as a problem, and create a dynamics model. Additionally, we will develop a technology for treatment of the zinc and other heavy metals in effluent from livestock buildings, and throw light on the water remediation function of wetlands. Then we will integrate these and assess the risk to aquatic ecosystems by zinc and other heavy metals arising in farming areas. Specifically, we will investigate the following items and provide basic knowledge on aquatic ecosystems in rural areas.

1) Determining the state and intensity of emissions of zinc and other heavy metals from livestock farms

Mainly with regard to pig farming, in which high amounts of zinc and copper are added to feed, we will investigate the concentrations of zinc and other metals in effluent, find the amount of runoff through interviews and other means, calculate the runoff loads of zinc and other heavy metals in river systems, and find the load intensity with reasonable accuracy.

2) Determining the state of emissions and runoff dynamics of zinc and other heavy metals in agricultural watersheds

In agricultural watersheds where many livestock farms are found, we will determine the load of zinc and other heavy metals from non point sources such as fields on which composted livestock waste has been applied. Additionally, we will determine the process by which the load of zinc and other heavy metals emitted from non point sources and livestock operations arrive in public waters from emission channels via streams. Further, we will carry out a study of aquatic biota in the rivers of rural watersheds, and will analyze changes in biota and its relationship to the loading from livestock farming and river water quality.

3) Developing a technology to lower the concentration of zinc in livestock industry wastewater

We will investigate the wastewater treatment processes operating at pig farms and other facilities, and will verify the effectiveness with which zinc concentration in wastewater is lowered by reducing suspended matter. Additionally, with regard to those treatment processes for which reduction of zinc concentration is still insufficient, we will develop a method of lowering wastewater zinc concentration that can be used in livestock operations in order to stably keep the zinc concentration below the effluent standard.

4) Determining the function of wetlands in reducing loads of zinc and other heavy metals

We will quantify the effectiveness of wetlands and vegetation zones in reducing zinc, throw light on remediation processes such as soil adsorption and plant absorption, and explore ways of enhancing load reduction by artificial wetlands.

5) Assessing risks to aquatic ecosystems

For agricultural watersheds, we will create a GIS (Geographical Information System) model that expresses the emissions and dynamics of zinc and other heavy metals, and then we will assess the risk to public waters and ecosystems.

This project will be carried out in cooperation with National Institute for Agro-Environmental Sciences, National Agriculture and Food Research Organization/National Institute of Livestock and Grassland Science, Aichi Agricultural Research Center, and Nagoya Women's University; it is supported by the Minstry of the Environment from FY2008 to 2011.

6. Predicting acidification and nitrogen leaching in East Asian ecosystems with a catchment-scale model

Emission rates of acidic substances in East Asia are likely to increase over the next several decades owing to the expected increases in energy and food demand. Natural ecosystems in the area are thus likely to be chronically exposed to atmospheric acidic deposition. The effects of chronic input of acidic substances on tropical ecosystems are not well known, because investigations of the effects in these ecosystems are quite limited compared with those in temperate and boreal areas. The objectives of our 3-year research project in collaboration with The University of Tokyo and the Acid Deposition and Oxidant Research Center are therefore to 1) clarify the changes in soil and stream water chemistry, such as acidification and nitrogen leaching, caused by atmospheric deposition in tropical ecosystems; and 2) predict the temporal trends in these changes under future emission scenarios.

Small catchment study sites have been established in a tropical rain forest in the Danum Valley area of Malaysia and in a tropical dry evergreen forest at Sakaerat Silvicultural Research Station, Thailand, and catchment-scale monitoring of atmospheric depositions and soil and stream-water chemistry has begun in order to evaluate material cycles. Numerical models of soil chemistry changes and the nitrogen cycle are being developed on the basis of these data. The results of the first year of research indicate that there are prominent seasonal changes in soil and stream-water chemistry in response to the periodic dry and rainy seasons in Sakaerat. The model also shows similar changes in soil pH and in the concentrations of some soil elements. Various GIS data and statistical data on, for example, agriculture and households in the divisions or provinces containing the study sites are being collected, and nitrogen budgets are being evaluated to estimate the contribution of agriculture to acid deposition and the future trend in this contribution until 2030.

The research project has been conducted during FY2008-2010 period supported by the Global Environment Research Fund (C-082) of Japan's Ministry of the Environment.

7. Study of Changes in Chemical Form and Plant Uptake of Aromatic Arsenicals in Agricultural Soils

In 2002, the inhabitants of the Kizaki area of the town of Kamisu in Ibaraki Prefecture exhibited uncommon clinical symptoms of the central nervous system. In 2003, diphenylarsinic acid (DPAA), and phenylarsonic acid (PAA) were detected in groundwater drunk by the inhabitants. In 2004, DPAA was detected in groundwater used for irrigation in Kamisu. DPAA and methylphenylarsinic acid (MPAA) were also detected in harvested paddy rice. There is therefore a need to measure the extent of pollution of the soil, water, and farm products, but there has been little research on plant uptake of aromatic arsenicals from soil.

We investigated methods of quantifying aromatic arsenicals in soil and in rice, which is widely cultivated in the Kizaki area. DPAA, PAA, MPAA, dimethylphenylarsine oxide (DMPAO), and methyldiphenylarsine oxide (MDPAO) in soil and rice were extracted, separated by reverse-phase chromatography, and quantified by ICP-MS. For extraction of arsenicals from rice grain and straw, hot trifluoroacetic acid at 2.0 mol/L or hot 68% HNO_3 gave better extraction efficiency than 50% MeOH. For extraction from soil, hot 68% HNO_3 gave a better result than 1.0 mol/L H_3PO_4 or NaOH. We also investigated the unknown arsenic species formed in the course of incubation of DPAA-amended soil under flooded conditions. The results of HPLC-TOF/MS analysis strongly suggested that some of the unknown species were dimethylphenylarsine sulfide and methyldiphenylarsine sulfide.

In an incubation study, we investigated the biogeochemical changes in DPAA in two types of agricultural soil, Kamisu soil and Tsukuba soil, under flooded or upland conditions. In flooded soils, DPAA can be converted to MDPAO by methylation; some of the DPAA can be converted to PAA, which is subsequently converted through MPAA to DMPAO. The concentration of DPAA in the Kamisu soil clearly decreased after 24 weeks' incubation. In sterilized soils of both types, the DPAA content was close to stable during the 24-week incubation, although small amounts of PAA were produced.

We investigated the uptake by rice of aromatic arsenicals from contaminated soil and from unpolluted soil amended with DPAA, PAA, MPAA, DMPAO, or MDPAO. In the contaminated soil, PAA and MPAA concentrations decreased and the DMPAO concentration increased under flooded conditions; however, their concentrations remained unchanged under upland conditions. DMPAO and MDPAO absorbed by the shoots were retained; MPAA absorbed by the shoots was translocated to the grain more easily than DMPAO and MDPAO.