Research Overview in 2009

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
Coodrinator for Safety Management

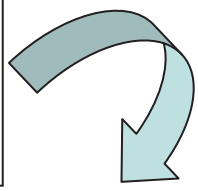
Principal Administrative Director

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
Natural Resources Inventory Center



(Research Projects)

- Risk Management 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
- Ecological Functions of Semiochemicals
- Climate Change Impact Assessment
- Mitigation of Global Warming
- Environmental Risk Assessment of Nutrients
- Global Warming Monitoring
- Chemical Analysis and Monitoring
- Spatial Information in Agriculture
- Agro-Environmental Risk Information and Indicators
- Classification of Environmental Resources

Principal Research Coordinators

Summary of NIAES Research Projects

During the Medium Term Plan period (2006 – 2010), the National Institute for Agro-Environmental Science (NIAES) has focused its research activities on the following three areas, emphasizing the specialization and prioritization of basic surveys and studies to ensure a sound environment for agricultural production.

A. Assessing risks to agro-environments, and developing technologies manage them
B. Determining the structures and functions of agro-ecosystems and developing management technologies to elicit the functions of natural cycles
C. Basic research to help elucidate the functions of agro-ecosystems

The following sections outline the particulars of the five-year Medium Term Plan and the research projects which have been carried out during the 2009 fiscal year.

A. Assessing risks to agro-environments, and developing technologies manage them

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

(1) Development of assessment methods and management techniques for agro-environmental risks from hazardous chemical substances

Medium Term Plan:

We plan to identify the dynamics of chemical substances in the agricultural environment — such as cadmium, arsenic, radioactive substances, and persistent organic pollutants (POPs) which include drin compounds — in order to reduce the risks of contamination by them, and develop risk reduction techniques. With respect to organic chemical compounds, such as agrochemicals, we plan to develop a prediction model for their behavior in the environment, and at the same time, develop techniques for environmental risk assessment through exposure tests on aquatic arthropods. We plan to develop technologies using chemical cleaning and bioremediation techniques to rehabilitate the soil contaminated by toxic substances, as well as techniques using cultivars with low-absorbance of these substances.

Research Overview:

1. Development of environmental assessment methods and risk reduction techniques for agrochemicals

(a) Development of risk reduction techniques for organic chemical substances
(Outcome ready for practical use: Fine activated charcoal powder tablets for water purification)

We carried out a validation of the soil extraction method which uses 50% methanol and water (a 2008 outcome ready for practical use) on four varieties of cucumbers grown in five dieldrin-contaminated farms having different soil characteristics (i.e. grey lowland soil, brown forest soil, and andosol). We obtained a strong correlation between the concentrations of dieldrin in the soil and in the fruit for all varieties. This demonstrated the usefulness of the method. The validation test also indicated a range of concentrations depending on variety, cropping type, and fruiting node.

We isolated a filamentous mold which aerobically breaks down dieldrin from the soil of sweet potato fields to which insecticide endosulfan (a compound having a structure similar to that of dieldrin which is one of the POPs) had been applied for a prolonged period. This mold was identified as closely related to *Mucor racemosus*. The mold was mixed with the soil to which dieldrin was added to simulate contamination. After seven days of cultivation, the dieldrin concentration in the soil decreased to below the detection limit. This result indicates that this method has a potential for application to the bioremediation of crop lands.

An offshoot developing from this seed research is a fine activated charcoal powder tablet which is designed to purify water.

(b) Development of risk assessment method for organic chemical substances

We studied median effective concentrations of insecticides used for rice and their degradation products on aquatic organisms, and found that the toxicity of the degradation products of some of the insecticides did not necessarily decrease. We also analyzed variations in the toxicity of agrochemicals to different aquatic organisms as well as regional variations in agrochemical concentrations in rivers, and established a technique to calculate a scale of environmental risks posed by agrochemicals.

2. Development of risk assessment methods for heavy metal contamination and technologies for the remediation of contaminated soil

(a) Using highly cadmium-absorbent rice varieties to clean cadmium-contaminated rice paddies (phytoremediation).
(Outcome ready for practical use)

We cultivated two to three crops of highly cadmium-absorbent rice with an early drainage method (i.e. the paddies are flooded after transplanting and kept flooded until the peak of the active tillering stage, after which the water is drained) and successfully reduced cadmium concentrations in the soil by 20 to 40%. The brown-rice cadmium concentrations of food crop rice cultivated in the paddies after the treatment were 40% to 50% lower than in adjacent untreated paddies. We also developed a low-cost method for disposing of the above-ground portion of the cadmium-absorbed rice by "separate harvesting of unhulled rice and straw plus on-site drying". With this method the unhulled rice is first harvested from the plant and the sun-dried straw is harvested and baled in rolls later. This outcome is an advanced level of the basic technology which was developed by NIAES in the first term of the Plan. It may be adopted as a low-cost and widely applicable technique for the remediation of cadmium-contaminated soil. Among the numerous techniques for phytoremediation being researched around the world this method is considered to be at the closest stage to commercialization. We published the outcome in an international journal as well as in a press release. The project was selected as one of the ten most exciting topics for 2009 in the fields of agriculture, forestry, and fishery research.

(b) Understanding the mechanisms of cadmium and arsenic absorption

Using rice varieties and some plants of the eggplant family with different abilities to accumulate cadmium in their above-ground parts, we analyzed physiological factors that determine the differences in cadmium accumulation and found that differences in the ability of their conduits to transport cadmium were a factor. In addition, we identified the quantitative type locus (QTL) involved in the cadmium accumulation in brown rice on the short arm of chromosome 7. Furthermore, we found that this QTL was not involved in the accumulation of the essential heavy metals, such as copper, iron, manganese, and zinc, in brown rice, but specifically increased the cadmium concentration. These findings should contribute to the development of new risk reduction measures through genetic and physiological explanation of cadmium accumulation in crops.

Existing methods to reduce cadmium in brown rice include flooding paddies about the time of the first heading of the rice. The effect, however, of this method on arsenic concentration in brown rice is not clear. In order to understand the effect of water control on arsenic and cadmium concentrations in rice plants and paddy soil, we analyzed rice plants and paddy soil for the presence of different chemical forms of arsenic. We found that water control at the time of the first heading had a significant effect on the arsenic concentration in brown rice. The concentration of organoarsenic (dimethylarsinate) increased when the paddies were flooded for three weeks after the first heading. A negative correlation was found between total arsenic concentration and total cadmium concentration in brown rice. These findings are important in discussions of countermeasures in regions where both cadmium and arsenic contamination risks exist.

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

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

Medium Term Plan:

In order to prevent alien species (invasive and introduced species) from disrupting or damaging agro-ecosystems, we plan to elucidate the growth, reproductive, and allelopathic characteristics of the alien species; at the same time identify the actual damage caused by alien species and project their rates of establishment and dispersal and the degree of damage caused. We plan to identify the regions from which alien species originate, and estimate the probability of their invasion. Analyze the impact of alien species, such as predatory insects, on their indigenous relatives from the points of view of competition and crossing to assess the extent of the risks they impose on the agro-ecosystems, and develop a technology using molecular markers for early detection and monitoring of the alien species that are not easily identifiable. In order to properly assess the ecological impact of genetically modified organisms, we plan to develop techniques using DNA markers for the detection of crossing of GMO crops with their relatives, such as GMO soybeans (*Glycine max*) with wild soybeans (*G. soja*), to shed light on the effects of their crossing on ecosystems. In order to allow GMO crops and non-GMO crops to co-exist side by side, we plan to develop techniques to suppress crossing by using models to project crossing rates and farming methods such as those that ensure distance for isolation.

Research Overview:

1. Assessment of ecological impact and development of risk management techniques for alien species

(a) Understanding of the characteristics of alien plant species and the prevention of disturbances in agro-ecosystems

With respect to the alien species rat-tail fescue (*Vulpia myuros*) used in orange orchards in western Japan for sod management, our research found that this species produced copious amounts of seeds and posed a risk of proliferation as weeds in farmlands and vacant lands. We also found that the rat-tail fescue had allelopathic activity, and detected the allelochemicals (–)-3-hydroxy-β-ionone and (+)-3-oxo-α-ionol. (See Fig. 1)

We studied the chemical and ecological characteristics of blindeyes (Papaver dubium), an alien plant species which has been rapidly spreading along roadsides and beginning to invade farmlands in recent years, as well as the risk of the species establishing itself as a weed, and found that it had a strong allelopathic activity. An assessment based on the improved FAO techniques indicates that it poses a significant risk of becoming a weed once it invades an area. It also indicates that the eradication of this plants before they flower is important as they can regenerate from immature seeds. (See Fig. 2)

(b) Risk management techniques for alien insects

Using a simulation model which incorporates the mate-hunting behavior of insects, we investigated the effectiveness of various methods to control invasive alien insects. We found that, at a low population density in the early stages of invasion, eradication would be easier than suggested by theoretical predictions used in the past. We also found that the choice of an effective control method would depend on the mating capacity and life expectancy of the target insect. This outcome is likely to lead to a discussion on technical strategies for the eradication of invasive alien insects.

With respect to the parasitoid wasp Torymus sinensis, which was introduced for the purpose of controlling the oriental chestnut gall wasp (*Dryocosmus kuriphilus*), an invasive insect pest for chestnuts, the ecological impact of crossing with its near relative, the indigenous predator *Torymus beneficus* is a serious concern. In order to understand the potential for the crossing, we developed a method using the aryl-specific PCR method that can distinguish minute differences in DNA base sequences for detecting individual crosses between *T. sinensis* and *T. beneficus*, which are, respectively, introduced and indigenous predators of the invasive insect pest *D. kuriphilus.*

Identification of allelopathy in rat-tail fescue, and its allelochemicals

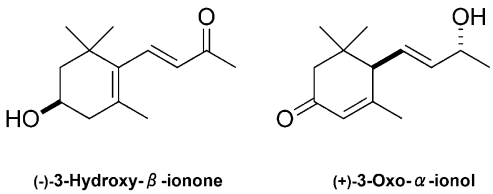


Fig. 1 Structural formulae of (–)-3-hydroxy-β-ionone and (+)-3-oxo-α-ionol
Both are derivatives of ionone which is a known aromatic ingredient of violets, and have structures that are similar to retinol (vitamin A) and carotenoid.

Blindeyes: Strong allelopathic activity and a significant risk of weedy proliferation

Fig. 2 Rosette leaves, flower, and immature pod of blindeyes (*Papaver dubium*)
One individual produces 150,000 seeds. Seeds in immature pods are also viable.

2. Assessment of ecological impact and the development of risk management techniques for genetically modified organisms

(a) Assessment of impact on biodiversity (a study of feralization and crossing ability)

In order to assess the impact of genetically modified crops on biodiversity, we developed an assessment method using a transition matrix model based on population viability in the field. In the 2009 fiscal year, we tested the validity of the transition matrix model using wheat, and confirmed that this model generally reflected the current state of the normal wheat population.

We surveyed the distribution of rapeseed populations near Kashima port in Ibaraki Prefecture, and found no sign that rapeseed plants originating from spilled seeds were expanding their range by displacing other plants. In order to verify this, we tested competition between rapeseed and weeds on a farm. The result of an analysis of the relationship between changes in the germinating population and growing population of rapeseed and

environmental factors (e.g. proliferation of other species, effective temperature for germination) using a generalized linear mixed model shows that the germinating population and growing population were strongly affected by the proliferation of other species.

(b) Study on co-existence (a study of control of crossing)

A study of potential for crossing between rice varieties was conducted with a pollen donor plot (*Nihonbare*: non-glutinous variety) and a pollen receptor plot (*Heiseimochi*: glutinous) which were separated by the very late-maturing fodder rice (*Leaf Star*: non-glutinous variety) planted as windbreak. The results suggested that windbreak planting may reduce the crossing rate to one-third. A numerical experiment for assessing the relationship between the position of windbreak netting and the crossing suppression effect indicated that windbreak netting placed in the center of the pollen donor field had a better suppression effect than netting placed between the pollen donor and pollen receptor plots, if the area of the pollen donor plot was small. This is believed to be due to the effect of the fact that the upwind section also benefited from the wind velocity being reduced by the windbreak netting. Placing the windbreak netting at the center of the pollen donor population reduced wind velocity on not only the downwind side but the upwind side as well, providing the most effective suppression of crossing as a result.

B. Determining the structures and functions of agro-ecosystems and developing management technologies to elicit the functions of natural cycles

1) Elucidation and evaluation of the structures and functions of agro-systems

(1) Understanding the synecological dynamics and biodiversity in agro-ecosystems

Medium Term Plan:

In order to preserve the biota and its diversity nurtured by agriculture, we plan to examine the dynamics of plants, birds, insects, nematodes, and microbes that live in farmlands and their surrounding areas to shed light on the impact on the composition of the species and diversity due to plowing and the use of chemicals as well as crop diversification and fallowing, changes in management methods for the surrounding vegetation and irrigation ponds, as well as variations in landscape structure of the paddies and their surrounding areas. Based on the results obtained in the above, we plan to develop a model to predict the dynamics of biological population, such as indicator insects, created by changes in agricultural activities, including land use, and identify the factors that stabilize the population.

Research Overview:

(a) Development and use of survey information system and identification of the relationship between landscape structure and biodiversity

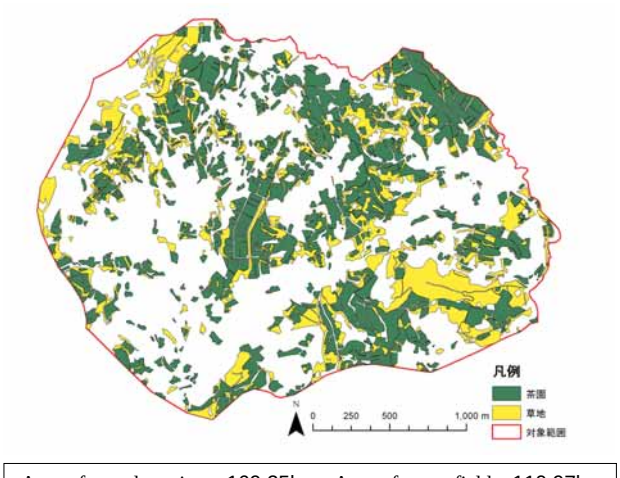
In order to assess the impact of management of rice paddies and the landscape surrounding the paddies on the composition and population of aquatic insect species, we investigated a number of aquatic insect species and their populations in paddy fields under different management methods: four sites in Tochigi Prefecture and two sites in Fukushima Prefecture. The number of aquatic insect species tended to be larger in organically controlled/low chemical load paddies than in the paddies managed by conventional farming methods. The extent of the difference varied from region to region. The results of the investigation also indicated the possibility for skimmer dragonflies (*Sympetrum* spp., a major species) to be used as an indicator for the differences in paddy farming methods. To allow comparison of the results of investigations similar to ours on a nationwide basis, we have enabled our Rural Landscape Information System (RuLIS) to collect and store site data.

In order to assess the impact of landscape structure surrounding paddy fields on the habitation of birds, we extracted spatial scales that affected the spatial distribution of the birds and also developed a technique for quantifying trends in changes in bird populations. We then carried out an analysis using a generalized linear model and the land use data around the RuLIS monitoring sites to explain the species richness of bird groups. As a result, we found that the spatial scale which was affected by the environmental elements varied considerably by group as well as by season.

(b) Impact of farming methods and management of lands surrounding farms on plant communities.

The tea producing areas in the Tokai Region employ a method of spreading pampas grass in the tea plantation in an effort to produce better quality tea. Large areas of grass fields are maintained in the region as a source for the pampas grass. We surveyed the vegetation in these grass fields and found that they were acting as precious semi-natural grasslands in which many grassland plants and endangered species lived. The diversity of indigenous plants has been strongly affected by past events, such as changes in land use, and management history. Semi-natural grasslands have declined dramatically in Japan. These semi-natural

Grass fields for tea production are a precious treasure trove of secondary nature



Area of tea plantations: 169.25ha Area of grass fields: 110.97ha

Fig. 3 Distribution of grass fields of tea plantations
The area of the grass fields at the survey site accounts for 65% of the tea plantations.

grasslands used to account for more than 10% of the total land area of the country and the decline has led to many animals and plants dependent on the grasslands facing extinction. The outcome of our survey should provide useful insights for long-term maintenance of the grass fields of tea plantations as a key to ensuring biodiversity. (See Fig. 3)

In order to understand the impact that farming using herbicides has on aquatic plants around rice paddies, we expanded our survey sites to include agricultural waterways in different landscape structures (i.e. paddy fields in valley bottoms and on flatlands) in southern Ibaraki Prefecture and recorded seasonal changes in the aquatic plant population and the herbicide concentrations. The environmental factors that had the strongest impact on the plant population in these waterways were the strength of herbicides and weed cutting. The strength of herbicides was found to be especially strongly affecting submerged plants while the weed cutting affected emergent plants.

(2) Research on semiochemicals affecting the functions of agro-ecosystems

Medium Term Plan:

In order to help maintain and enhance the functions of agro-ecosystems, we plan to identify bioactive substances produced by plants of the family Rosaceae. We plan to identify the substances involved in the interaction of organisms, such as semiochemicals involved in the proliferation of insects, such as moths of the family Pyraustinae. And we plan to identify and the substances which regulate the expression of genes in bacterial groups, such as those of the genus Burkholderia which break down persistent chlorinated aromatic substances. We also plan to specify each of their functions.

Research Overview:

(a) Understanding the functions of bioactive substances produced by the family Rosaceae

Thunberg's meadowsweet (*Spiraea thunbergii*) was selected from a process that had involved more than 100 species of the family Rosaceae by the end of fiscal year 2008. This species indicated that its *cis*-cinnamoyl glucosides had an extremely potent plant growth inhibiting activity, leading us to examine related compounds. In our examination, we introduced a substituent to the benzene ring of the *cis*-cinnamic acid and analyzed the changes in its activity to understand the differences in the expression of the activity among the different positions (*ortho*, *meta* or *para*) of the substituent. A result of our research led to the discovery of a compound which showed higher allelopathy than cis-cinnamic acid (patent pending). As the agent for the allelopathic activity in a Hardy orchid (*Bletilla striata*), which is a ground cover indigenous to Japan, we isolated militarin and identified its structure.

(b) Understanding the function of semiochemical substances involved in the proliferation of insects, such as moths of the family Pyraustinae

Based on the results of crossing tests carried out in the laboratory and the ecological verification of individuals collected in fields, we found that *fuki-nomeiga* (*Ostrinia* spp.) and *tsuwabuki-nomeiga* (*Adoxophyes* spp.) were crossing at a high rate. The sex pheromones of the hybrid individuals showed intermediate characteristics of the sex pheromones produced by the two species. This finding suggests that crossing of different species may reduce the efficacy of pest control using sex pheromones.

(c) Clarification of the functions of microorganisms that decompose biodegradable plastics

A particular mold (Strain 47-9) has a high activity to break down biodegradable plastics ("bioplastic"). By clarifying the conditions under which the mold can steadily produce a large amount of bioplastic-degrading enzyme, it is now possible to repeat the cultivation of the same strain more than ten times. The enzyme is found to maintain its activity at room temperature in

either liquid or freeze-dried powder forms for an extended period (patent pending). As we started experiments aimed at commercializing the enzyme, we found that moisture had a strong influence on the rate of breakdown.

Offshoots developing from this seed research include the following:

(d) Solid fermentation method for the production of bioethanol

We developed on a laboratory scale a new “solid fermentation method” for bioethanol production. With this method, low-moisture cellulose-based biomass which has been stored after harvest is saccharified and fermented to produce ethanol. It is suggested that, by using this method, which adds enzymes to saccharify biomass and yeast for ethanol fermentation, to freshly harvested grassy material before it is compressed/sealed in a container like silage, it is possible to produce bioethanol as well as feed from the entire fodder rice plant (the entire plant that include panicles, stems, and leaves).

2) Understanding mechanisms that cause changes in agro-ecosystems and the development of mitigation measures against the changes

(1) Prediction of the impact of global environmental changes on agro-ecosystems and assessment of the risks to crop production

Medium Term Plan:

In order to make a field-level assessment of the variations in the yield of rice crops under global warming conditions or abnormal weather patterns, we plan to develop a comprehensive paddy ecosystem response model which includes the conditions relating to water, soil, rice variety, and farm management. We plan to develop a simple regional-scale yield model for the prediction of variations in the yield of rice crop in Japan and other Asian countries in the middle of the 21 st century from the point of view of the crop yield and water resources, and develop a technique for a wide-area assessment of risk for rice yield reduction on a regional scale. Based on the results obtained from the above, we plan to develop scenarios for the prediction of impact of climate change on food production.

Research Overview:

(a) Impact assessment at a farm level (the development of a paddy ecosystem response model)
(Outcome ready for practical use: Forced ventilation tube that enables highly accurate temperature measurements at low cost)

With respect to the study of genetic variation in physiological and growth response to temperature and CO_2 concentrations, we analyzed the results of FACE (Free Air CO_2 Enrichment) and chamber tests which had been carried out to date. We found that there had been considerable inter-varietal differences among *Koshihikari, Akitakomachi, Akita No. 63,* and *Takanari* with respect to the yield responses to the CO_2 enrichment, nitrogen utilization rates during photosynthesis under high CO_2 conditions, and reduction of photosynthetic response.

To further develop and improve our impact prediction model to reproduce poor ripening due to high temperatures we developed a simple ripening model using grain growth period, growth rates, and the time sequence pattern during the flowering season as a function of temperature. The ripening model was verified by using the ripening results obtained under a wide range of temperature conditions in an environmentally controlled chamber; the model could generally reproduce the changes in grain weight distribution accompanying the rising temperatures. In addition, we developed a forced ventilation tube which can measure temperatures at a low cost and high accuracy as a part of the study.

(b) Impact assessment at a regional scale
(Outcome ready for practical use: Development of a method for accurate estimation of hourly amounts of insolation and the construction of a dataset covering the entire country)

Using the model-coupled crop–weather database (MeteoCrop DB), which is a product of the FY2007 project, we analyzed the impact of meteorological conditions during the summer of 2009 on the rice crop. We found that the crop had been reduced in the Sea of Japan side of the main island of Honshu, where sunlight was especially low, and that the crop was poor because of cold weather damage in Hokkaido, which suffered unseasonably low temperatures in July in addition to low levels of sunshine. Unlike cool summer damage in the past, the year 2009 saw a summer of record low levels of sunshine without cooler temperatures. An analysis of crops in such a year is important for assessing the impact of future climate change, including global warming. As part of this research project, we have developed a method for the accurate measurement of hourly insolation, which is being prepared for publication as a dataset. (See Fig. 4)

Development of a method for the accurate estimation of hourly insolation and the construction of dataset covering the whole of Japan

Insolation is one of the most important meteorological elements for crop growth. However, only 67 ground-based meteorological observation stations across the country collect insolation data. In order to improve data collection, we developed a method of estimating hourly insolation with a high degree of accuracy using the hourly sunshine data measured at a number of locations, and constructed a dataset for hourly insolation for all AMEDAS observation points across Japan for 1991 onward. This allows an accurate assessment of the crop production environment by region.

$$S/S_0 = A_1(n/N)^2+A_2(n/N)h+A_3h^2+A_4(n/N)+A_5h+A_6$$

S: Estimated insolation (hourly integration); S_0: Solar irradiance at the upper limit of the atmosphere;
n: measured sunshine hours (0–60 minutes); N: Possible duration of sunshine (0–60 minutes);
h: Solar elevation angle (0 to $\pi/2$); A_1 – A_6: Factors dependent on daily precipitation, presence of snow cover, and sunshine hours (cumulative daily value and values 1 hour before and after the datum).
(Note) If the air pollution and amounts of water vapor are to be considered, use solar irradiance value on fair day (S_f) instead of S_0.

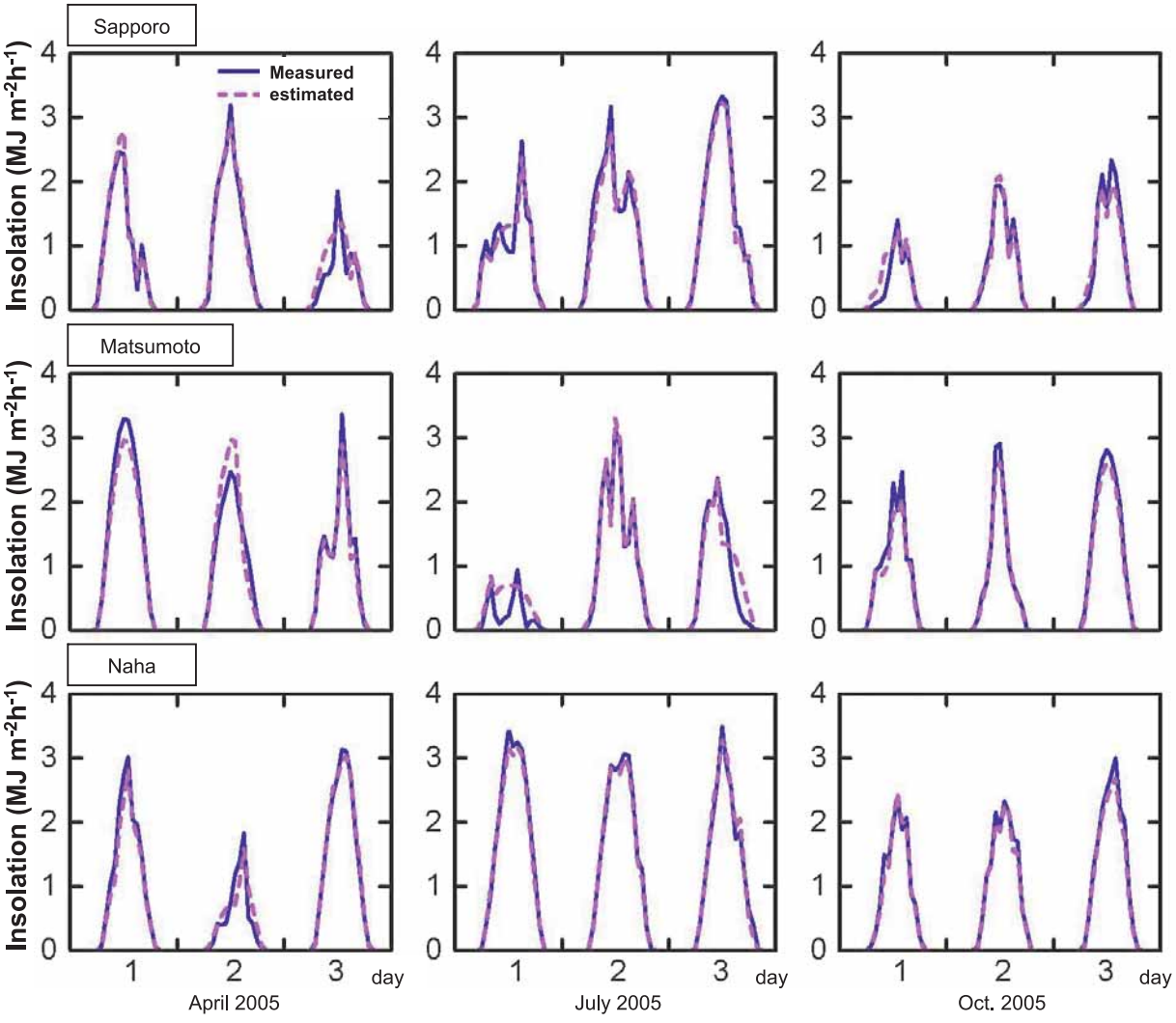


Fig. 4 Comparison of estimated and measured insolation in Sapporo, Matsumoto, and Naha

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

Medium Term Plan:

In order to help solve regional and global environmental problems relating to agriculture-derived greenhouse gases (GHGs) and nitrogen emissions, we plan to specify the impact of agricultural activities on material circulation, and establish load reduction measures. With respect to GHGs, we plan to quantitatively assess the effectiveness of GHG emission control through improved cultivation and soil management practices and propose efficient load reduction techniques and systems by. At the same time, by making effective use of soil-related databases, we plan to verify and improve our model that describes the dynamics of carbon in soil and predict changes in soil carbon accumulation in the soil of crop lands in Japan that might occur during climate change and under different management practices. We plan to estimate the nitrogen stocks and flows in food production and imports/exports based on a dynamic model of acidifying substances and statistical data to shed light on and make future predictions of wide-area circulation and environmental loads of nitrogen on a catchment- or nation-wide scale in East Asia. On a catchment level, we plan to shed light on the dynamics of nutrient runoff, such as nitrate-nitrogen and phosphorus, into the pedosphere which includes shallow groundwater, and develop a technique for the assessment of vulnerability to water pollution.

Research Overview:

1. Quantitative assessment of comprehensive global warming mitigation measures, including suppression of greenhouse gas emissions and accumulation of carbon in the soil

(a) Estimation of greenhouse gas emissions from farmlands and quantitative assessment of reduction techniques

(Outcome ready for practical use: Estimation of methane emissions from paddy fields around the world and their potential reduction)

Paddy fields are a significant man-made source of the greenhouse gas methane. The IPCC Guidelines used by governments around the world for the calculation of their GHG emissions were revised in 2006. The outcomes of NIAES research projects have been reflected in the revised Guidelines to make the calculation of methane emissions from paddy fields more accurate. Using this method and world statistical data for paddy farming, we calculated the methane emissions from paddy fields around world to be 25.6 million tonnes. We also found that the introduction of intermittent irrigation and improved management of rice straw could each reduce methane emissions by 4.1 million tonnes. This outcome should make a large contribution to the reassessment of the impact of methane emissions from paddy fields on global warming as well as to the development of rice farming techniques which mitigate global warming.

For a statistical analysis, we collected values from data in literature on farm experiments relating to techniques for the reduction of nitrous oxide emitted from farmlands. The results of the analysis indicated that the average reductions by those techniques relative to customary fertilizers were 38% for fertilizers with an added nitrification inhibitor and 35% for coated fertilizers. This study is the world's first quantitative assessment of the total reduction potential for nitrous oxide from farmlands.

(b) Wide-area assessment of dynamic model for soil organics, and nationwide estimation of changes in carbon accumulation in soil

We applied the Rothamsted Carbon Model (RothC) developed for the calculation of carbon dynamics in soil to the entire crop lands of Japan at a 1-km resolution level, and estimated the effectiveness for soil carbon accumulation on a national scale by means of hypothetical scenarios including the use of compost and double-cropping to increase the amount of crop residues incorporated into the soil. First, we prepared two realistic scenarios ("as is" and mitigation scenarios) for organic matter input during the period between 1970 and 2020 for each prefecture and land classification, and organized carbon input data by land use and prefecture for each of the scenarios. Each 1-km grid cell is represented by the soil or land classification accounting for the largest area in the grid cell. In order to increase the accuracy of the spatial resolution, we improved the 1-km mesh to make it usable for input into the model by dividing the grid cells into smaller sections by a combination of soil and land classification. These studies are important for the development of an accurate national estimation of changes in carbon deposits in Japanese crop lands based on realistic scenarios. (See Fig. 5)

National estimation of effects of organic fertilizers on carbon accumulation in farm soil

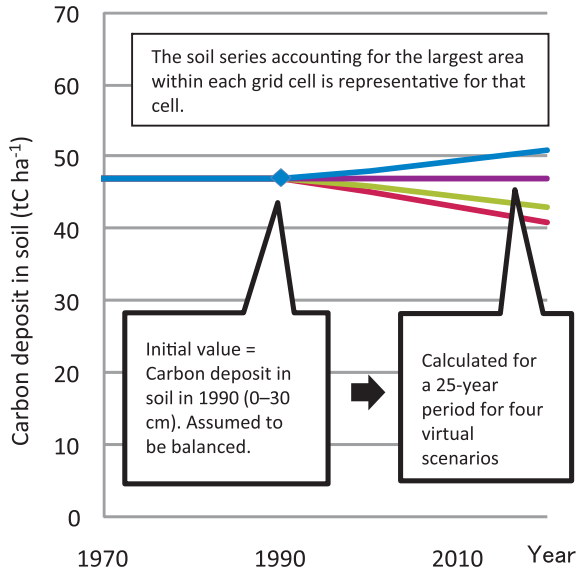


Fig. 5 Method for nationwide calculation at a 1-km resolution level
Three RothC models (paddy fields, andosol fields, and non-andosol fields) are used for the calculation of carbon accumulation in each 1-km grid cell. The results are aggregated for the calculation of a national value.

2. Development of techniques for assessment of water pollution risks based on the knowledge gained of efflux dynamics of nutrients from soil to water

(a) Assessment of environmental vulnerability to groundwater pollution by nitrate-nitrogen

In order to assess the environmental vulnerability to water pollution by nitrate-nitrogen (vulnerability to water pollution due to differences in climate, topography and soil factors), we developed a model and predicted the concentration and volume of groundwater efflux of nitrate-nitrogen under normal farming conditions and the effect of changes in annual precipitation on them for 104 sites in the Kasumigaura basin having different soil and topographical conditions. By supplementing the resulting values with the areal distributions of nitrate-nitrogen concentrations in groundwater predicted after taking into consideration the reductions in the concentration in each different soil type through the denitrification during underground flow or in waterfront areas, we were able to map the environmental areas vulnerable to groundwater pollution by nitrate-nitrogen. Groundwater concentrations of nitrate-nitrogen tended to be low in areas of light-colored andosol in which organic content concentration is low and on the Rokko Plateau where the water table is relatively deep. The waterfront areas (i.e. areas of moist soil, such as areas near rivers and lakes) showed a marked decrease in the concentrations regardless of the region.

C. Basic research to help elucidate the functions of agro-ecosystems

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

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

Medium Term Plan:

For early detection of changes in agro-environmental resources, we plan to carry out a long-term monitoring of baseline parameters in agro-ecosystems, such as physical environments, GHG flux including carbon dioxide and methane, as well as ^{137}Cs and ^{210}Pb levels in crops and soil. We plan to develop a method for analysis of trace chemicals, such as organoarsenic compounds found in crops and the environment, and develop a simple and accurate technique for measurement for use in monitoring.

Research Overview:

1. Advanced technologies for detection and monitoring of changes in the physical environment and gas fluxes relating to global warming

(a) Monitoring of greenhouse gas flux

We continued our monitoring activities at the existing flux observation sites in collaboration with other research institutions inside and outside Japan. Overall, new data collection progressed generally well during the year 2009.

Harvesting and incinerating crop residues is widely practiced in the rice-wheat double-cropping regions. We surveyed the carbon outflow from this practice as it is important for the assessment of carbon balance in ecosystems and analyses using a carbon dynamics model, and we estimated the carbon balance, including elements other than these gas fluxes, at both single-cropping and double-cropping paddy fields. A comparison of annual CO_2 balance showed that the difference between the single-cropping and double-cropping paddy fields was more evident with total photosynthesis than with ecological respiration (i.e. amounts produced by respiration of plants and breakdown of organic matter), with total photosynthesis accounting for most of the differences in net CO_2 sequestration (net ecological production; NEP) among the sites. At the single-cropping paddy fields, about a half of the planting season NEP flowed out during

harvest, with the remainder returning to the atmosphere through the breakdown of organic matter during the fallow period. As a result, the balance was at near equilibrium. In the double-cropping paddy fields, on the other hand, the NEP during two planting cycles was 1.5 to 1.7 times that of the single-cropping paddy fields, but due to the incineration of harvest residues, there was little difference in the amount which was plowed into soil.

We improved the method of filling in missing values in the process of separating observed CO_2 flux into total photosynthesis and ecological respiration. We also developed software for online flux monitoring. This software is capable of quickly evaluating the CO_2 absorption and water consumption by farms. It should be useful for network-based monitoring of crop growth and soil moisture management.

2. Long-term monitoring of radioactive substances in crops and soil, and the development of a simple and accurate method for measuring trace chemical substances

(a) Long-term monitoring of radioactive substances in the agricultural environment

(Outcome ready for practical use: Publication on the Internet of the analytical database of artificial radionuclides (^{90}Sr, ^{137}CS) in key grains and farm soil published)

We have been monitoring artificial radionuclides on a nationwide basis since the 1950s. The purpose of this monitoring is to understand the accumulation and persistence in crops and soil, as well as a degree of transition from soil to crops, of radioactive substances which have been released into the environment from nuclear weapons testing and nuclear reactor accidents. Based on monitoring at fixed-point radioactivity observation farms across Japan, we have developed a database of the concentrations of radioactive strontium (^{90}Sr) and radioactive cesium (^{137}Cs) in rice and wheat and in the soil in which they were grown. The database has been published on the Internet. This monitoring information allows us to trace historical changes in the event of trouble, and is important for preparing a response for unforeseen situations.

As part of the procedures to take over the analysis of radioactivity in relation to livestock, we performed a crosscheck analysis of ^{90}Sr in milk samples with the National Institute of Livestock and Grassland Science. The correlation coefficient obtained from this analysis was more than 0.99.

(b) Development of a simple method for accurate analysis of trace chemical substances in the agricultural environment

(Outcome ready for practical use: Manual for analysis of toxic organic chemical substances in water)

We developed a GC/MS-based analytical method by which it is simple and quick to extract and refine oxon analogs of organophosphate agrochemicals (10 analogs). The analogs are in high demand for trace analysis of organophosphate agrochemicals in water systems. This study, together with the development in the fiscal year 2008 of multi-component analysis of persistent organic pollutants (POPs), has been carried out as part of a two-year international joint study for the development of efficient method for trace analysis of toxic chemical substances in water (e.g. agrochemicals, pharmaceuticals, and hormones). Other participants are: Orange Country Water District (OCWD) in the United States, Technology Center for Water (TZW) of Germany, and Korea Water Resource Corporation (K Water) and the National Institute of Environmental Research (NIER) of the Republic of Korea. The outcomes of the four-nation joint research project have been published worldwide as an analytical manual in the English language. Researchers in related fields should find the outcome of this study useful. (See Figs. 6 and 7)

2) Collection, preserving, and digital archiving of environmental resources

(1) Development of agro-environmental resources inventory and methods for its utilization

Medium Term Plan:

For the comprehensive assessment of the agricultural environment, we plan to develop techniques for analyzing remote sensing data, such as microwave measurements and MODIS (moderate resolution imaging spectroradiometer) measurements. At the same time, we plan to use a geographical information system (GIS) to develop new methods of identifying agricultural land use and habitat indicators. We plan to develop techniques for linking individual databases to the common GIS platform as well as a registration and collection system for new information to assist in the development of agro-environmental indicators. We plan to enhance the individual environmental resource databases, and propose a soil classification system that includes functional assessment of soil in deeper layers, and construct a comprehensive soil database for both crop lands and non-croplands. For efficient use of inventory data, we plan to develop fundamental statistical methods as well as techniques to graphically

Manual for analysis of toxic organic chemicals in water

Fig. 6 Cover and table of contents of Volume 2 of the Manual

The manual explains in plain language the methods for trace analyses of organophosphate agrochemicals, short-chain chlorinated paraffins, polychlorinated naphthalenes, and pharmaceuticals, all of which require urgent attention in society.

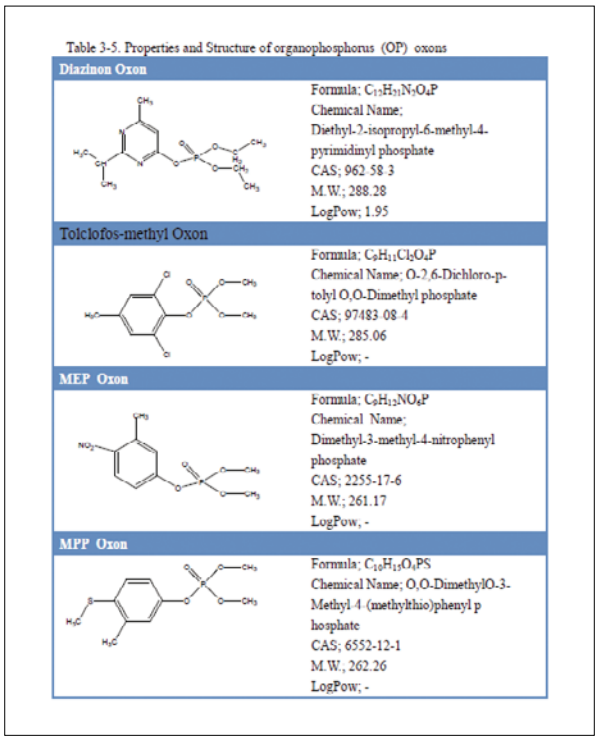


Fig. 7 Oxon analogs of organophosphate agrochemicals

The manual includes structural expressions, molecular weights, chemical names, and CAS numbers, making the properties of the chemical substances to be analyzed easily understood.

depict the results. We plan to cooperate with the National Institute of Agrobiological Sciences in its gene bank project by acting as a sub-bank.

Research Overview:

1. Digitalization and use of agro-environmental resources based on remote sensing/GIS systems

(a) Development of remote sensing/GIS techniques for the extraction and assessment of agro-ecosystem information

We developed a simple system for the field measurements of multi-spectral images in several visible /near-infrared frequencies which can be used for growth monitoring on a community scale.

Based on a hyper-spectral analysis, we found an accurate and highly versatile index for assessing the nitrogen content of a community. We also found a close relationship between the backscatter signals detected by the new X-band SAR satellite and the panicle weight of rice. This finding provided us with the possibility of developing a means for direct yield assessment. Application of a scatter component analysis model to all polarization data from the new C-band SAR satellite provided us with a possibility for extracting only the rice paddies from data for a single time period. In addition, we produced a historical map of the distribution of rice paddies in Heilongjiang Province of China, where land use has changed significantly, using time series data in the archive of high-resolution satellite images.

(b) Development of spatial structure indicators for assessment of biological habitats

In order to assess the spatial structural characteristics of land-use distribution and the configuration of land classifications from the point of view of their functions as biological habitats, we have established a technique (the cumulative cost method) for assessing habitat continuity which takes into consideration the mosaic nature of land use by using the cumulative cost index, an indicator of the difficulty of migration of organisms. Taking regions at different scales, we developed a cumulative cost map for deciduous forests where forest life forms were assumed to live, and another for waters assumed to be the habitat for the aquatic life and water birds. This technique makes it possible to visualize the

habitat continuity under a variety of conditions. By partitioning paddy fields throughout the whole of the Kanto region into 100-m strips, and comparing the gradient, amount of open sky, and the proximity to forest lands, we identified the distribution of valley-bottom paddy field landscapes, the conditions of their location, and the risk of their disappearance.

2. Construction of comprehensive inventory and development of its usage

(a) Construction and public release of a cropland information system
(Outcome ready for practical use: Construction and publication of Internet-based farm soil information system)

We produced a new farm soil map which corresponded to land use in 2001. We then systematically organized the information relating to farm soil across the country into an Internet-based system. The system has been available for viewing since April 2010 (http://www.niaes.affrc.go.jp/). This system contains digital farm soil maps (1:50,000), explanations of various soil types, and photographs of soils as well as schematic depictions (as reference for soil description), and instructions for recording cross-sectional descriptions which are necessary for field soil surveys and physiochemical analysis data (the standard soil cross-section database covers 7,115 survey locations across the country). This system is available to all. The soil maps should be useful for activities in both agricultural production and regional environment, including an assessment of farm soil for agricultural productivity and the ability to store carbon as well as water purification function. The standard soil cross-section database is useful for an assessment of the multiple functions of soil, as a tool for soil science education at universities, or as a support tool for soil survey projects.

(b) Draft development of a comprehensive soil classification system

In order to develop a draft proposal for a comprehensive soil classification system, a working group has been established with eleven researchers from outside NIAES (five from universities and six from the National Agriculture and Food Research Organization (NARO)) and six researchers from NIAES. Under the basic guideline that a draft comprehensive soil classification system should be developed through the amalgamation of the Crop Land Soil Classification (3rd edition, 1995) and the "Unified Soil Classification System for Japan – Second Proposal" (2002), the working group discussed and developed a first preliminary draft consisting of the diagnostic horizons, differentiating characteristics, and identification keys.

(c) Development of a database for the calculation of nitrogen and phosphate balances in prefectural farmlands

As nitrogen and phosphate balances in the Japanese farmlands are the fourth highest and the highest respectively among the OECD members, Japan needs to improve these balances by gaining knowledge of changes taking place over time, regional variations, and characteristics of various crops or livestock species. For this purpose, we calculated the nitrogen and phosphate balances every 5 years from 1985 to 2005 by prefecture, crop, and livestock species and constructed a database. The calculations were based on study results relating to manure management, amount of fertilizer production, and agricultural statistics relating to crop and livestock production. We also carried out an analysis using this database, and found that, although the overall balances are declining in Japan, the nitrogen balance in vegetables was excessive and unutilized livestock dung was increasing. This outcome may be used to improve the nitrogen/phosphate balances in the Japanese agricultural sector by designating the database as one of the agricultural environment risk indicators. The database will also be useful for estimating nitrous oxide generation by prefecture or improvements in water quality of groundwater, rivers, and lakes.

(d) Expansion of insect inventory

The "Mitsuhashi Notes" are a precious set of reference materials which cover almost all of the literature relating to entomological studies in Japan from the Meiji period to the late 1940s. From 135 books in this collection, we obtained 19,992 images of Coleoptera, a group that include numerous pests and beneficial insects and are especially relevant to agricultural and forestry sciences. We have made them available to the general public for viewing. This database will be a valuable source of information for those searching for literature on past Coleoptera events, including the distribution of various species, occurrence of pest species, and the use of beneficial species.

With respect to Asian moths, we made available to the general public type specimens from the Sugi Shigeo collection, one of the most prominent collections in Japan. It is now possible to browse images of a total of 379 specimens, including 178 type specimens, and their

species names, label data, and literature information . A type specimen is a single specimen which is designated at the time of reporting of a new species, and is recommended for management by an appropriate research organization under the International Code of Zoological Nomenclature (ICZN). This collection has been recently donated by Mr. Shigeo Sugi, and is expected to be used in taxonomical studies for an assessment of invasive pests and biodiversity.

(e) Gene bank project

Based on the 2009 Project Plan, twenty new MAFF registered strains and 420 properties were registered with the bacterial gene bank. A new line (*Bemisia tabaci*; Biotype Q) was introduced to the insect gene bank for which we carried out characteristics evaluations for nine items on two species.

Plans and Results of Research Projects with External Competitive Funding

1. Screening of Allelochemicals and Development of Novel Bioactive Chemicals

This research was accepted and started in 2008. It will continue for 5 years with support from the "Promotion of Basic Research Activities for Innovative Biosciences" program under the auspices of BRAIN (Bio-oriented Technology Research Advancement Institution).

Allelopathy is a biological phenomenon by which an organism produces biochemicals that influence the growth, survival, and reproduction of other organisms. These bioactive chemicals are known as allelochemicals. Allelochemicals are a subset of secondary metabolites not necessary for primary metabolism (i.e. growth, development, and reproduction) in organisms. However, it has recently become recognized that these allelochemicals might play an important role in plant defense or mutual communication for survival (allelopathy hypothesis).

There has only been one good example of the discovery of an allelochemical (leptospermone) leading to the development of a major class of herbicide (dubbed triketones by the American company that developed it). There are examples of allelopathic cover crops (such as velvet bean [*Mucuna pruriens*] and hairy vetch [*Vicia villosa*], research into which originated at NIAES) being used for weed management in other crops, as well as other cultural methods employing allelopathy. Our final goal is to 1) find novel agrochemicals derived from allelochemicals, and 2) find and utilize novel allelopathic cover crops for agriculture.

We will screen novel allelochemicals already contained in our database, and we will perform further screening of allelochemicals from around the world. We have already screened 4000 species of plants and have found some potent candidates. To discover phytotoxins and allelochemicals for use in pest management and to provide fundamental information on the modes of action, our project also includes the biosynthesis of natural bioactive chemicals and studies of the relationships between their structures and activities. Through cooperation with synthetic chemists, we will attempt the organic synthesis of chemical analogs and will try to determine the relationships between chemical structure and allelopathic activity.

2. Strategic Rainfed Rice Cultivation for Mitigating Greenhouse Gas Emissions

Rainfed rice fields in Southeast Asian countries are characterized by low productivity. On the other hand, these fields are recognized as an important source of atmospheric greenhouse gases (GHG), especially methane. Therefore, from the points of view of sustainable development and environmental conservation, improved methods of utilizing land and managing rainfed rice fields need to be developed.

A 3-year research project entitled "Strategic Rainfed Rice Cultivation for Mitigating GHG Emissions" was launched in July 2009 as a component of the project "Scenario Planning of Low Carbon Emission Energy System in Thailand," which is funded by the Asia-Africa Science and Technology Strategic Cooperation Promotion Program from the Special Coordination Funds for Promoting Science and Technology, Ministry of Education, Culture, Sports, Science, and Technology (MEXT).

The research project is investigating the effect on the net emissions of GHG that results from introducing a rotation of upland crops in the fallow period of rainfed rice. A portion of the harvested crop or their residues is utilized for bio-energy production. The effect of rotation system on mitigating GHG emissions is being quantitatively evaluated. This research is mostly being done in Thailand.

In 2009, the first year of the project, researchers from the National Institute for Agro-Environmental Science (NIAES) and the Joint Graduate School of Energy and Environment (JGSEE) at King Mongkut's University of Technology, Thonburi, discussed the preparation of field experiments and the GHG monitoring systems. As a result of these discussions, a field experiment started in January 2010 at Ratchaburi, Thailand. In 2010, parts of the area were converted to experimental plots. There are four treatments: control (no cultivation), lowland rice, corn, and sweet sorghum. Cultivation and collection of data began in January 2010. GHG emissions and soil carbon have been measured since then. In the second crop, rotations between lowland rice and corn and between lowland rice and sorghum will be used to investigate the effects of such cultivation practices on GHGs and soil carbon sequestration. Additional plots will be established from May 2010 to study the effects of manure and biochar application on soil carbon and greenhouse gas emissions.

Field experiments at the Ratchaburi site will continue, and monitoring data on soil carbon change and GHG emissions will be collected for different crop rotation systems. The data will be compiled and the net GHG emissions will be evaluated by life-cycle assessment for each cultivation system.

3. Multi-site Monitoring of Heat Stresses and Micrometeorological Conditions in Rice Plant Communities under Various Climates in the "Multilateral Research Exchange Project for Securing Food and Agriculture," funded by the Ministry of Agriculture, Forestry, and Fisheries

Rice yield can be reduced substantially when a crop is exposed to excessive heat, which will likely occur more frequently under future climates. However, despite much effort to determine temperature responses in closed environments, the magnitudes of yield losses under open-field conditions are still difficult to predict. To better understand heat stresses in the field, we need to determine the thermal conditions in the rice canopy, which can differ greatly from air temperature depending on other environmental factors. We have initiated a research project aiming to establish a network for monitoring the thermal environments of the rice canopy in paddy fields in various rice growing regions. The data thus collected will help to bridge the gap between chamber experiments and open-field measurements and allow us to better assess the potential impacts of climate change on rice production. As a part of this project, we hosted an international workshop on "Crop Production under Heat Stress," from 5 to 9 October 2009 in Tsukuba. The workshop, which attracted about 100 participants from 11 countries, was a forum to exchange information on the current status of heat stress in rice and to discuss methodologies for monitoring heat stress in the open field. The proceedings of the workshop are available online at http://www.niaes.affrc.go.jp/marco/marco2009/ws2proc.pdf.

We have also developed a stand-alone, forced-ventilation radiation shelter for monitoring air temperature and relative humidity in the rice canopy, utilizing a solar-powered ventilator equipped with rechargeable batteries. On sunny days, the ventilating airflow around the sensor is maintained at around 3 m/s, cooling both the sensor and the shields and thus minimizing error. We used these systems to measure temperature and humidity in the fields of the monitoring sites in China, India, Myanmar, the Philippines, and Sri Lanka. The susceptibility of these regions to climate change can be characterized by analyzing the relationship between above- and within-canopy thermal conditions at each site and across sites.

The project is an opportunity to improve the capacity of research in the area of agricultural meteorology, which is extremely important in studies of the impacts of climate change and our adaptation to it. The activities of this project will help detect signs of impact arising from climate change in various rice-growing regions around the world, and the information we gather will be shared with the international scientific community.

4. Assessment and Development of Mitigation and Adaptation Techniques to Global Warming in the Sectors of Agriculture, Forestry, and Fisheries

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) stated in its summary that "Warming of the climate system is unequivocal" and that "Most of the observed increase in global average temperatures since the mid-20 th century is *very likely* due to the observed increase in anthropogenic GHG [greenhouse gas] concentrations." Under the Kyoto Protocol, 37 industrialized countries, including Japan, have committed themselves to reducing their emissions of GHGs.

In consequence, we need to develop techniques to reduce emissions of GHGs and adapt to climate change in the sectors of agriculture, forestry, and fisheries. Over the period from FY2006 to FY2009, NIAES has been promoting and conducting a research project on "Assessment and Development of Mitigation and Adaptation Techniques to Global Warming in the Sectors of Agriculture, Forestry, and Fisheries," with the support of a Grant-in-Aid from the Ministry of Agriculture, Forestry, and Fisheries of Japan. NIAES has been managing the 94 subjects of the project and supervising project activities at 7 national institutes, 24 universities, 38 prefectural institutes, and 3 private institutes.

The main results of the project concerning NIAES are:

(1) Development of an agro-ecosystem carbon cycle model: The initial values and parameters of the model were determined by monitoring GHG flux in fields. The soil carbon content of Japanese farmland and amounts of plant residue or compost applied to farmland were estimated. The amount of carbon sequestration was predicted with the Roth C model for a number of scenarios involving different supplies of compost and changing land-use patterns in Japan.

(2) Development of mitigation techniques: Lifecycle

assessment of GHG emission revealed that alternating land usage between dry and flooded conditions, using minimum tillage, and supplying compost are effective means for reducing GHG emissions and increasing carbon sequestration. An improved Denitrification–Decomposition (DNDC) model was able to effectively assess the efficacy of rice field straw and fertilizer management methods in reducing CH_4 emissions over a wide area, and the results of the model were verified with experimental data.

(3) Evaluation of impact of global warming on agriculture: Rice yield increased by 20% at a rice free-air CO_2 enrichment (FACE) site (+200 ppm) under elevated water and soil temperatures (+2 °C). We developed a comprehensive rice field ecosystem response model that includes soil water temperature, soil properties, rice cultivars, and cultivation management conditions. Through this model we can assess the changes in rice growth, yield, and quality that arise under different scenarios of global warming and field management techniques.

5. Early detection and prediction of climate warming from long-term monitoring of alpine ecosystems on the Tibetan Plateau

The Qinghai-Tibetan Plateau is the highest plateau on Earth. Global warming and its impacts on ecosystems are likely more prominent at higher altitudes, and recent studies have provided evidences that the plateau is very sensitive to global warming. Because the alpine grassland ecosystem on the plateau is ecologically fragile and vulnerable to external changes, it is expected to show a more conspicuous response to global warming than grassland ecosystems of lower elevations at similar latitudes. The high elevation of the Qinghai-Tibetan plateau may provide us with a very important early warning system for understanding processes of climate change on both the regional and global scales. Over the period from FY 2005 to FY2009, NIAES and the National Institute for Environmental Studies conducted a research project entitled “Early detection and prediction of climate warming from long-term monitoring of alpine ecosystems on the Tibetan Plateau,” with the support of a Grant-in-Aid from the Ministry of Environment of Japan. The objectives of the study were to: (1) measure and examine climatic changes in typical alpine ecosystems of the Qinghai-Tibetan plateau, paying particular attention to changes in temperature at different altitudes through long-term observations conducted along two vertical, 1200-m transects; (2) monitor and analyze, through long-term observations, the ecological responses of the alpine grassland ecosystems at different altitudes, from ecological hierarchies arising from genetic structure and functions through to ecosystem functions; and (3) develop a model aiming at the early detection and prediction of global warming using the data from meteorological observations and current monitoring. NIAES was mainly responsible for the first of these objectives. To observe current climatic changes in the typical alpine ecosystems of the Qinghai-Tibetan plateau, we established two meteorological observation systems along two vertical transects, one at Dongxiong in the center of the plateau and another at Haibei in the north-eastern area. At the Haibei site we set six observatories along a transact from 3200 to 4400 m asl, and at the Dongxiong site we set 10 observatories along a transact from 4300 m to 5500 m asl to measure air temperature, air moisture, soil temperature, and soil water content at different depths. At each site, we set up a central meteorological observation system to monitor energy balances and all the other meteorological elements.

Our observations showed that in summer the lapse rate, the rate of decrease with height for air temperature along each transect was uniform at about 0.69 °C/100 m. However, in winter, because of the presence of a temperature inversion layer almost every day, there was a much lower lapse rate of about 0.09 °C/100 m in the lower section of each transect and a relatively large lapse rate of about 0.9 °C/100 m in the higher section. Precipitation data showed that there was a maximum precipitation belt in the middle section of each transect, with the amount of precipitation about twice that in the lower section. A horizontal grass line—the upper altitudinal boundary for the belt of closed alpine vegetation — passes through each transect. Even though the difference in altitude between the grass lines in the two transects is about 1000 m, our 4 years of observations show that the climate around the lines is almost the same during the growing season. This means that the grass line is controlled mainly by climate, and a change in the grass line would indicate a long-term change in climate.

6. Comparative study of nitrogen cycling and its impact on water quality in agricultural watersheds in Japan and China

A Strategic Japan-China Joint Research Project entitled “Comparative study of nitrogen cycling and its impact on water quality in agricultural watersheds in Japan and China” was conducted from December 2006

to March 2010 as a Strategic International Cooperative Program jointly sponsored by the Japan Science and Technology Agency (JST) and the Ministry of Science and Technology, China (MOST). The respective leading Japanese and Chinese institutes were the National Institute for Agro-Environmental Science (NIAES) and the Institute of Soil Science of the Chinese Academy of Sciences. The following Japanese institutes and universities also participated: the National Institute for Livestock and Grassland Science, Tohoku University, Hokkaido University, and Tokyo University of Agriculture and Technology.

The objectives of this study were to compare commonalities and differences in the characteristics of nitrogen cycling in typical Japanese and Chinese watersheds; to develop a new method to assess and predict the impact of non-point source nitrogen pollution on water quality; and to find mitigation options for agricultural non-point-source nitrogen pollution. To analyze the nitrogen budget and its relation to nitrogen discharged from agroecosystems to rivers, we conducted watershed-scale analyses in two watersheds in Japan and one in China. The study sites in Japan were the Shibetsu River watershed (SRW) in Hokkaido and the Upper Naka River watershed (UNRW) in Tochigi prefecture, and that in China was the Jurong Reservoir watershed (JRW) in Jiangsu province. The respective total areas of the watershed were 685, 1299, and 46 km^2, and the respective percentages of agricultural land use were 51%, 21%, and 55%. The main agricultural land use in SRW is grassland, whereas that in UNRW and JRW is cropland, with 11% and 31%, respectively, occupied by paddy fields.

The nitrogen inputs and outputs in the three watersheds were calculated for major land uses on the basis of statistics and actual measurements. Fodder crops in UNRW had the highest input of nitrogen (446 kg-N ha^{-1} $year^{-1}$), followed by paddy rice in JRW (418 kg-N ha^{-1} $year^{-1}$). The output from agricultural land uses ranged from 37 to 213 kg-N ha^{-1} $year^{-1}$, resulting in a farmland nitrogen surplus of 32, 145, and 390 kg-N ha^{-1} $year^{-1}$, for SRW, UNRW, and JRW, respectively. All watersheds exported food and imported feed, indicating the strong influence of livestock husbandry on regional-scale nitrogen flows. The proportion of discharged nitrogen from agroecosystems to rivers relative to net anthropogenic nitrogen input was calculated to be 21%, 23%, and 1.2% for SRW, UNRW, and JRW, respectively. It was suggested that the slow-flowing, comparatively shallow nature of the rivers in JRW, as well as the area's warmer climate, increased denitrification and resulted in a lower proportion of discharged nitrogen.

The results of the project were rated very highly in the final evaluation by the JST and MOST. As a consequence, it was decided that the project would be extended another 3 years for further research.