Summary of NIAES Research Projects

As the world pays more attention to environmental issues surrounding agriculture, and people are increasingly concerned about the safety of their food and environment, the basic philosophy of the National Institute of Agro−Environmental Sciences (NIAES) is to carry out high−level research activities aimed at achieving harmony among nature, society, and humans in order to help the world overcome its food and environmental issues. Our objective is to contribute to improving technologies relating to the preservation and enhancement of the environment in the habitats of the plants and animals that are the subjects of agricultural production through basic investigations and studies of technologies relating to habitat environment.

In order for us to achieve this objective, we established the following three goals focusing on basic investigations and research for the second medium−term plan period (five years covering 2006 through 2010) to secure the safety of the agricultural production environment:

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; and
C. Basic research to help elucidating the functions of agro-ecosystems.

We carried out our research projects with a clear sense of mission. The medium-term plan during the five -year plan period and the research projects carried out during FY 2010 are outlined below.

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, persistent organic pollutants (POPs) including 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 such as through exposure tests on aquatic arthropods. We plan to develop technologies using chemical cleaning and bioremediation techniques to rehabilitate soil contaminated by toxic substances, as well as techniques using cultivars having low-absorbance of these substances.

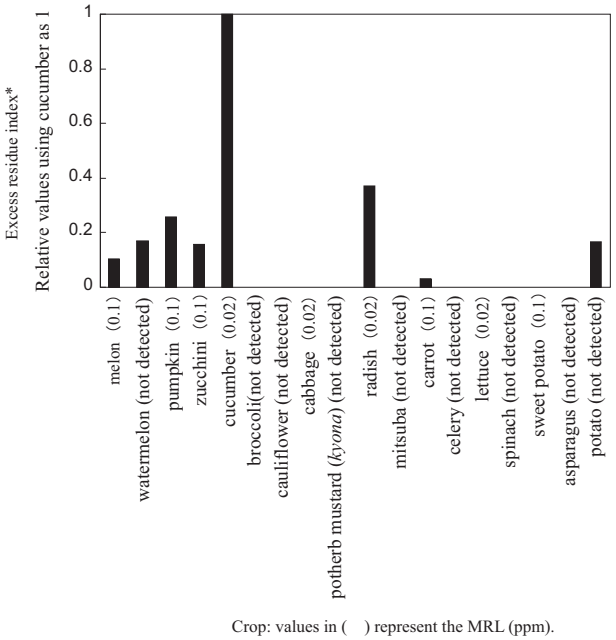
Research Overview:

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

(a) Development of risk reduction techniques for organic chemical substances

We cultivated eighteen crops from eight species in a dieldrin-contaminated field. An analysis of the edible

Cultivation of cucurbitaceous crops, root vegetables, and potatoes should be avoided in dieldrin-contaminated soil



Crop: values in ( ) represent the MRL (ppm).

Fig. 1 Excess residue index for dieldrin in various crops*

* Excess residue index = rate of migration MRL
(Note: If the MRL is set to "not detected", the calculation uses a value of 0.005 ppm, the lowest limit of determination for existing agrochemicals.)
The higher the index value, the higher the risk of the crop containing residues exceeding the allowable limit. As root vegetables and potatoes come in direct contact with the contaminated soil, and residues may be measured with the soil attached to them, crops with a particularly low MRL are not suitable as an alternative.

Development of a simulation model which predicts and maps changes in the concentration of paddy field pesticides in rivers

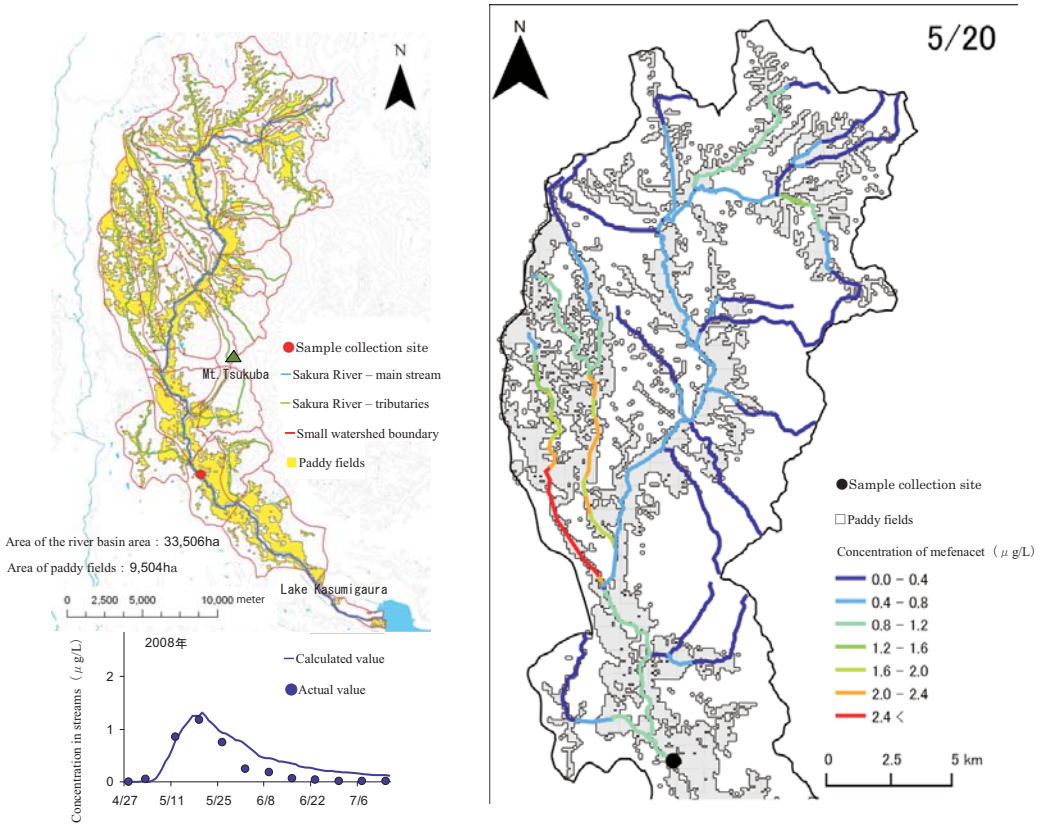


Fig. 2 River basin characteristics of the Sakura River by a GIS analysis (upper left); Changes in the concentration of the herbicide mefenacet in the river in a GIS-combined PADDY-Large model (lower left); and the distribution of concentrations (right)

Paddy fields account for 30% of the area of the Sakura River basin. When compared against the actual concentration of the herbicide mefenacet as measured in the midreaches of the Sakura River, our model satisfactorily reproduced the changes in the concentrations in the river. Displaying the model calculation results on a map makes the distribution of the aquatic mefenacet concentrations over the river basin area easily understandable.

parts and plant-foot soil of each of the crops found that the rate of migration to the edible parts (concentration in the edible part/concentration in the soil) was the highest among the crops of the Cucurbitaceous family. Other than the cucurbits, the rates tended to be high in radishes, carrots, and potatoes. The excess residue index value (the rate of migration to the edible parts divided by maximum residue limits (MRL)) calculated for radish and potato, as they have low residue limits, tended to be as high as those for pumpkin and zucchini. The results suggest that it is advisable to avoid crops of the Cucurbitaceous family as well as root vegetables (e. g. radish) and potatoes (e.g. potato), for which MRL are set low, as an alternative to cucumbers in dieldrin-contaminated farms.

Using three varieties of pumpkins cultivated in eight heptachlor-contaminated farms of different soil characteristics (immature soil of volcanic ejecta, grey lowland soil, and andosol), we tested the usefulness of the 50%-methanol-water extraction method and found a good correlation between the concentrations of heptachlor in the pre-cultivation soil and in the harvested pumpkin fruits. The validity of this soil extraction method was confirmed in FY 2009 for cucumbers grown in dieldrin contaminated soil. For POPs in vegetables of the Cucurbitaceous family, which is an issue at the moment, the usefulness of this method as a contamination prediction technique that can be applied prior to cultivation has been demonstrated.

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

With respect to pesticides used in paddy fields, we developed a simulation model (GIS-combined PADDY-Large model) using information relating to their physicochemical properties, environmental conditions, and drainage characteristics. This model can predict pesticide concentrations in river water with a high precision and display the distribution of concentrations

Practical soil cleaning technique for cadmium-contaminated paddy fields using iron chloride

Fig. 3a Flow of the processes of chemical cleaning of paddy soil

(1) Enclose the paddy with ridge boards, and fill it with an iron chloride solution and water; (2) Puddle the soil while keeping a constant depth of agitation. The water should be more than 40-cm deep to ensure a high removal efficiency; (3) Recover cadmium from the effluent using a treatment machine installed at the site; and (4) Fill the paddy with water only. Repeat the soil puddling and drainage processes two or three times to remove residual cadmium and chlorine.

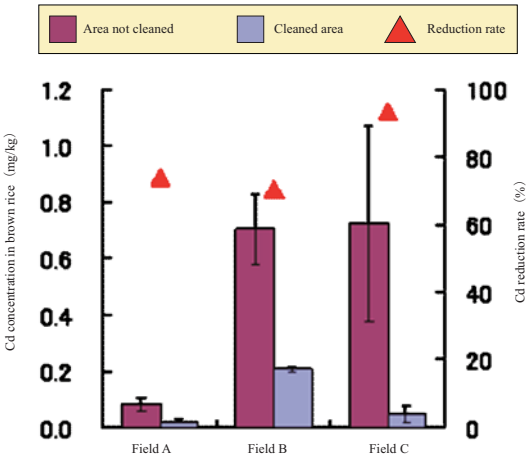


Fig. 3b Effective reduction of the cadmium (Cd) concentration in brown rice

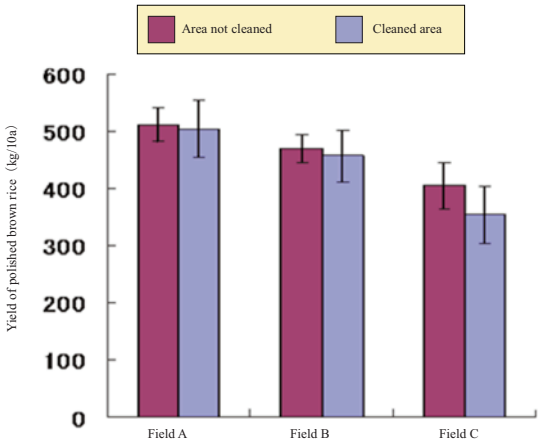


Fig. 3c Changes in the yield of brown rice

Cadmium concentration in produced rice was reduced by 70–90% compared to the rice produced in contaminated paddy fields. The yield of rice changed very little after the soil cleaning.

on a map. This model makes it possible to visually evaluate changes in the concentration of pesticides in rivers in different regions and seasons. It is also possible to use the model to evaluate scenarios with varied rates and methods of application when planning for control of pesticides use in river basin areas.

With respect to POP-like substances in the atmosphere (24 substances), we collected air samples from 106 sites in Japan, China, South Korea, and Taiwan using a passive sampler. The results of our analysis suggested the advection and diffusion of endosulfans in the atmosphere from the continent toward the regions of western Kyushu and Nansei Islands.

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

(a) Development of risk reduction techniques

(Outcome ready for practical use: Practical technique using iron chloride to clean soil in cadmium-contaminated paddy fields)

We established a real-scale on-site soil cleaning technique (chemical cleansing method) by which to supply water containing dissolved iron chloride to contaminated paddy fields and mix it with soil to elute and drain away cadmium. The cadmium concentration was reduced by 60–80% in soil and by 70–90% in brown rice produced in the soil. This technique causes very little change in the yield of brown rice and no significant changes in taste and nutritional values when the soil pH is corrected after it was cleaned and paddy rice is cultivated in the soil to replenish minerals. An environmental assessment using algae, water fleas, and fish indicated that the components, such as chlorine

Visualization of suppression of cadmium absorption by the roots of *Solanum torvum*

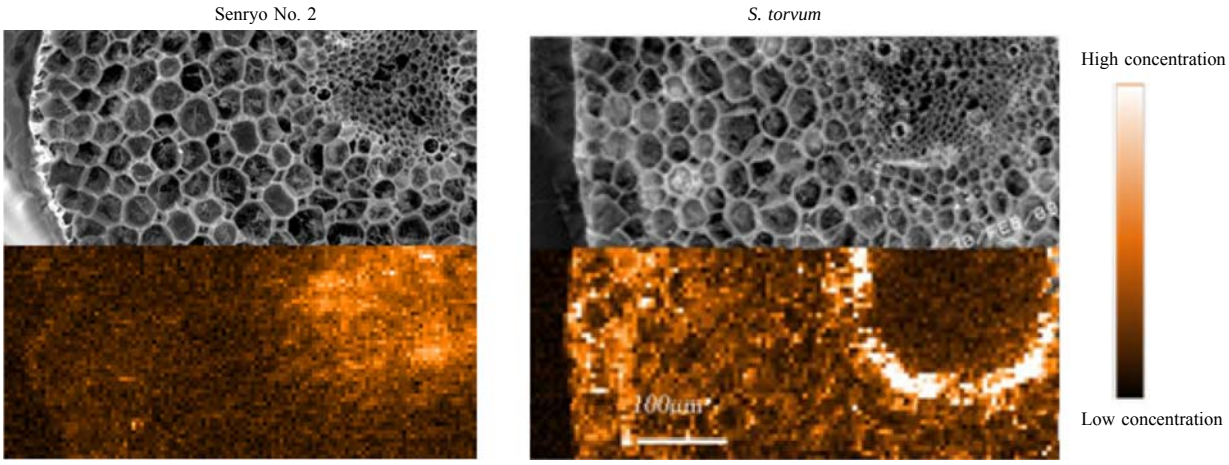


Fig. 4 Distribution of cadmium in the roots of "Senryo No. 2" variety and *S. torvum*

Cadmium is seen reaching the stele and ducts in Senryo No. 2. In *S. torvum*, on the other hand, cadmium could not reach the ducts and accumulated near the endodermis instead.

ions, dissolved in the water drained into agricultural drainage canals has no adverse effects on the ecosystem. The normal cost of applying the technique is about 3 million yen per 10 ares, which is equal to or less than the soil dressing treatment (3 to 6 million yen). In comparison with the phytoremediation, which was an outcome ready for practical use in FY 2010, we believe that this method is more likely to be adopted as a technique suitable for cleaning highly contaminated areas in a short period. This technique was selected as one of the ten most exciting topics for 2010 in the fields of agriculture, forestry, and fishery research.

As the Food Sanitation Act is expected to lower the allowable cadmium level in rice from the current "below 1.0 mg/kg" to less than 0.4 mg/kg starting at the end of February 2011, we published "Technologies for Reduction of Cadmium in Crops", a compilation the various techniques developed by NIAES including techniques to clean cadmium-contaminated soil, to absorb cadmium in soil, and to control migration of cadmium to crops. We expect that this publication will be useful for people involved in the planning and implementation of measures to reduce the risks of cadmium contamination in crops.

(b) Understanding the mechanisms of cadmium and arsenic absorption and the development of a risk assessment method

In FY 2010, we published the findings of our study of the reduction of cadmium concentrations in fruits of eggplants grafted onto a variety of *Solanum torvum* (eggplant) rootstock. Our study indicated that only a small amount of cadmium migrated from the root to the aboveground parts. Subsequently, a synchrotron radiation-sourced microbeam fluorescent X-ray analysis successfully visualized a high rate of cadmium accumulation near the endodermis of the root of the rootstock. This is an important finding for further elucidation of the mechanism of action in the technique using *S. torvum* as rootstock to reduce cadmium in eggplants (an outcome ready for practical use in FY 2008).

With respect to the understanding of the dynamics of organoarsenic in soil and crops, we showed that diphenylarsinic acid (DPAA) applied to soil changed its form through methylation and dephenylation by microbial action. We also showed that rice plants absorbed these arsenic compounds but only DPAA and MPAA migrated to brown rice. This outcome will contribute to solving the DPAA-related arsenic compound contamination at the township of Kamisu (the present city of Kamisu) in Ibaraki Prefecture, as well as to the risk evaluation of these toxic substances in the agro-environment.

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

Specified alien species *Altemanthera philoxeroides* (alligator weed) spreads by invading paddy fields

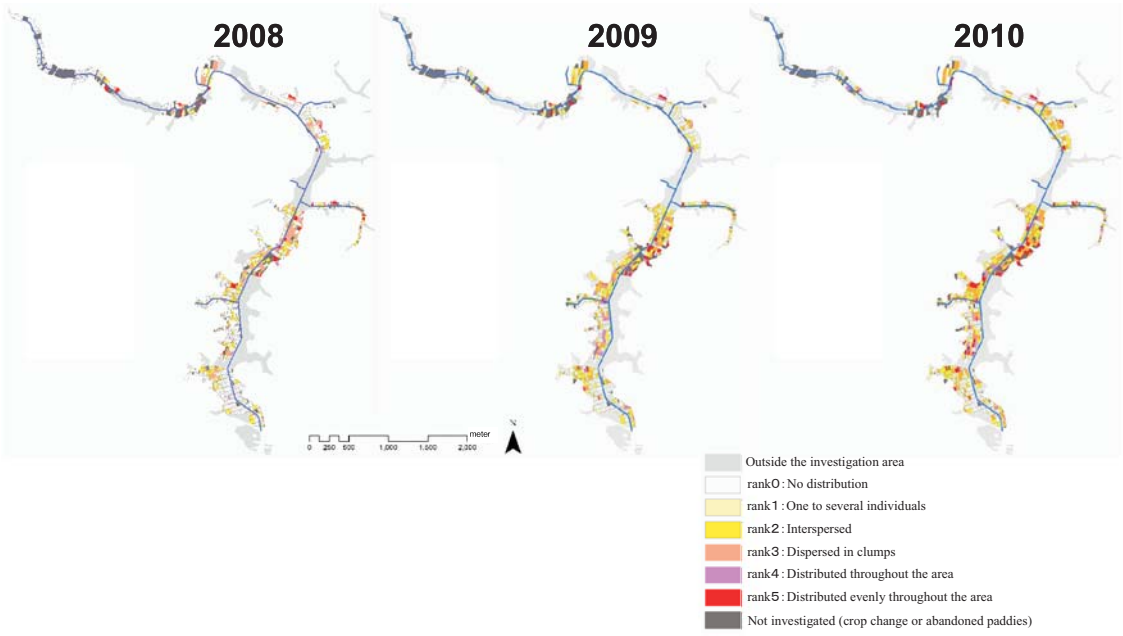


Fig. 5 Expansion of the distribution range of *A. philoxeroides* (alligator weed) in the Moroto River basin (2008–2010)

The range has expanded over the years with variations from area to area. The plants are also found distributed in "*yatsuda*", narrow paddy field areas deep within ravines.

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 we plan to identify the actual damage caused by alien species and project their rates of establishment and dispersal and the degree of damage caused. We also plan to identify the regions from which alien species originate, and estimate the probability of their invasion. Furthermore, we plan to analyze the impact of alien species, such as predatory insects, on their indigenous relatives from the point 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 genetically modified crops with their relatives, such as genetically modified soybeans (*Glycine max*) with wild soybeans (*G. soja*), to shed light on the effects of their crossing on ecosystems. Furthermore, in order to allow genetically modified crops and non-genetically-modified 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 the necessary 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 prediction of damage caused by them

Based on the results of the three-year on-site field study of the paddy fields near Inbanuma in Chiba Prefecture with respect to a specified alien species, *Altemanthera philoxeroides* (alligator weed), we established that the species was spreading in paddy fields influenced by its range of distribution in the previous year and the irrigation canal network. The growth was more robust along the levees than in the paddies. This finding suggests that this particular species spreads via irrigation canals and over adjacent paddies by crossing over the levees. As *A. philoxeroides* is seen to be spreading in rivers and lakes across Japan, this is a major finding in terms of preventing *A. philoxeroides* from invading irrigation canals and spreading to paddy fields thereby posing adverse effects on agricultural production and surrounding ecosystems.

As a result of a survey of weeds contained in imported grain, we confirmed the presence of seeds of a herbicide-resistant Lolium rigidum (ryegrass) for the first time in a wheat shipment from Western Australia. The herbicide to which the weed is resistant was found,

however, is not used or infrequently used in Japan, and therefore the potential for it becoming a hard-to-eradicate weed is believed to be low. This result, however, is an important finding which suggests the possibility that seeds of herbicide-resistant weeds may be mixed in large amounts of grains imported by Japan from around the world.

(b) Risk management techniques for alien plants

We developed a technique with which to acidify and reduce the nutrient content of soil in abandoned farmland dominated by *Solidago canadensis* (Canada goldenrod) by applying aluminum to the soil in order to reduce the growth of S. canadensis over a long period of time and return the land to grassland where indigenous plant species, such as *Imperata cylindrica* (Japanese bloodgrass) would thrive.

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

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

In order to gather information useful for an assessment of the impact of genetically modified oilseed rape on biodiversity, we surveyed the distribution of oilseed rape and the dynamics of its population at Kashima port in Ibaraki Prefecture where rapeseed is unloaded from ships. We also carried out an experiment in our field on the competitiveness of rapeseed against other grass species. We did not observe a trend for oilseed rape to invade and spread over surrounding plant communities. Except for sudden increases in populations on median strips in roads, the rapeseed population decreased generally as the indigenous community proliferated. This trend was similar to the results produced by a generalized linear mixed model which we had developed based on the results of the competition test in the field.

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

Soybean is an autogamous crop. While a few allogamous incidents are believed to be caused by pollinating insects, the possibility of wind pollination cannot be denied. Accordingly, we investigated the amount air-borne of soybean pollen over our open field, and detected very little air-borne pollen. An examination using a wind tunnel revealed that the dispersal distance was shorter than that which we had predicted from the size of the pollen, indicating that soybean pollen does not disperse widely. This finding should contribute to the development of a means by which to prevent cross-fertilization of genetically modified soybeans with non-modified soybeans.

To estimate the distribution of cross-fertilization instances of anemophilous crops due to the dispersal of pollen we developed a three-dimensional numeric model by taking into consideration daily fluctuations of pollen release rates and life expectancy of pollen during the flowering season. This model made it possible to carry out numeric simulations of the distribution of cross-fertilization instances under field conditions. The results of a simulation carried out in a test plot for corn

Oilseed rape tends to grow in roadside environments with frequent disturbances, such as mowing

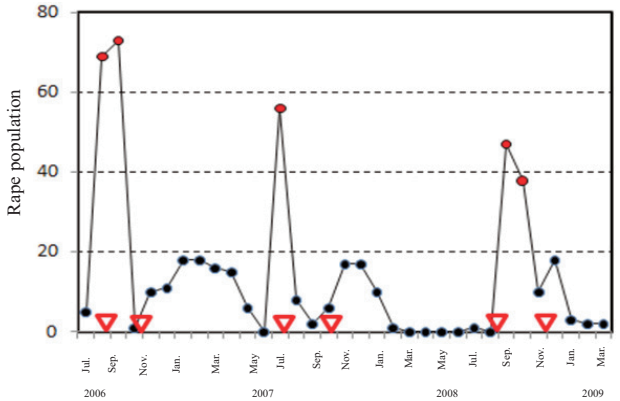


Fig. 6 Changes in the rape population on median strip

● Month in which a sudden population increase was observed, ▽ Month of survey in which mowing was confirmed (Aug. 23 and Oct. 25, 2006, July 23 and Oct. 18, 2007, Aug. 14 and Nov. 12, 2008)

Numeric model to evaluate the effectiveness of the use of windshield netting/windbreak plants in controlling cross-fertilization

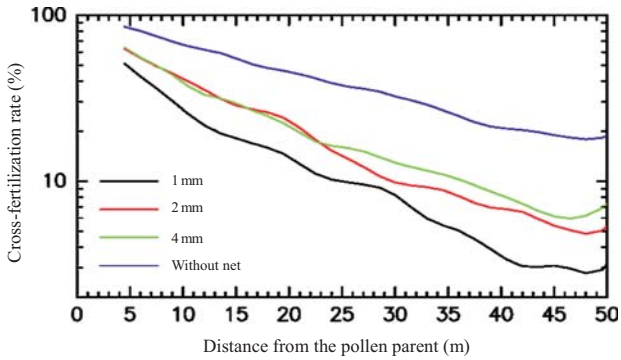


Fig. 7 Simulation of the effect of windshield netting on controlling cross-fertilization of corn

The use of 1-mm-mesh windshield netting reduced the cross-fertilization rate by 18–40% compared to the rates without the net, and by 14–25% compared to the use of 2-mm- and 4-mm-mesh windshield netting.

Web-based Rural Landscape Information System (RuLIS WEB) to collect, store, and provide biodiversity information

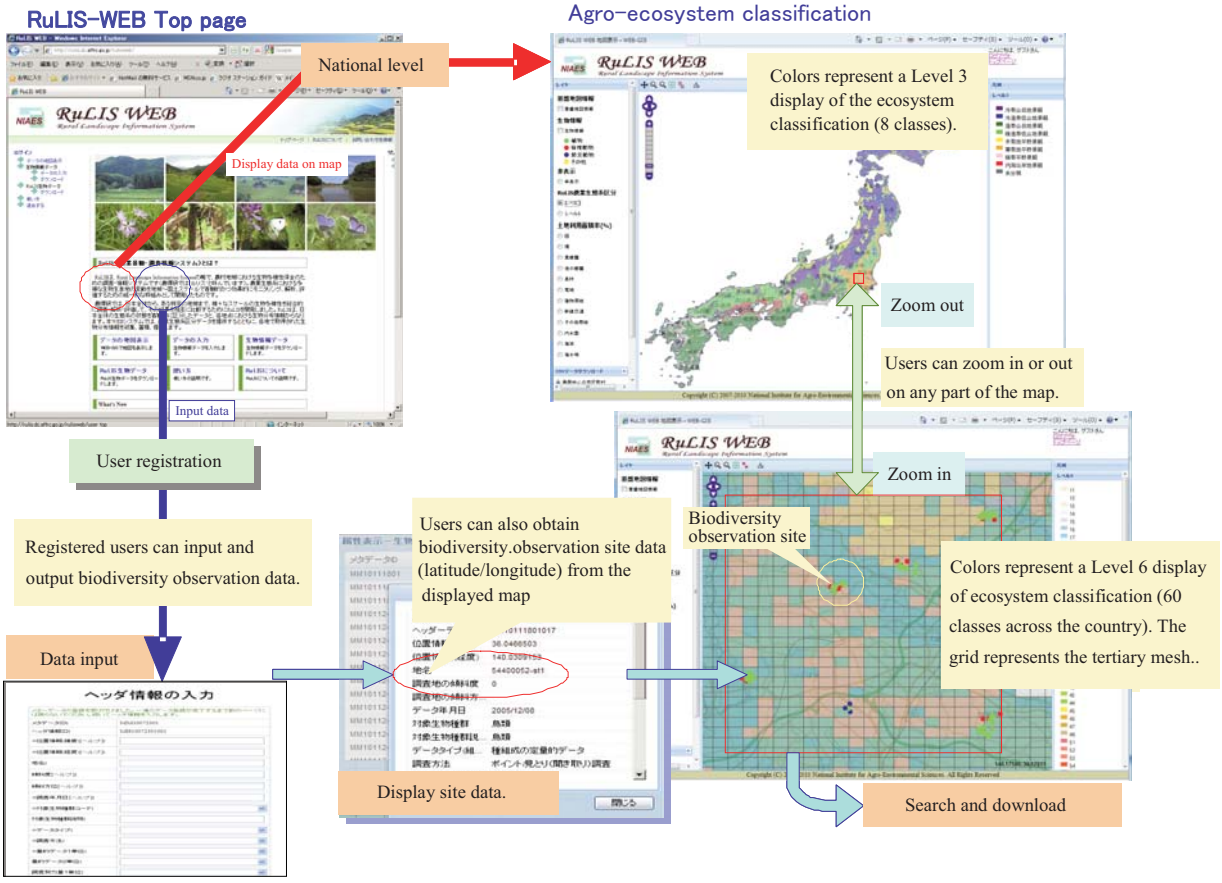


Fig. 8 Mapping of the agro-ecosystem classification and biodiversity data on RuLIS WEB

reproduced the decrease in cross-fertilization rates due to a distance from pollen parent, confirming the effectiveness of the use of windbreaks to control cross-fertilization.

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-ecosystems

(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 their impact on species composition 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 populations, such as indicator insects, created by changes in agricultural activities, including land use change, and identify the factors that stabilize the populations.

Research Overview:

(a) Development of a survey information system and the identification of the relationship between landscape structure and biodiversity
(Outcome ready for practical use: Web-based Rural Landscape Information System (RuLIS WEB) to collect, store, and provide information on biodiversity)

We have developed and published a system (web-based Rural Landscape Information System: RuLIS WEB) which displays on the Web-GIS (geographical information system) the national agro-ecosystem classification (60 classes) together with the biodiversity observation data for each of the observation sites. The data is downloadable. At present, the system contains

Cultivation with organic methods or with reduced agrochemicals has positive effects on aquatic insects in paddy fields. The effect varies according to the surrounding environment

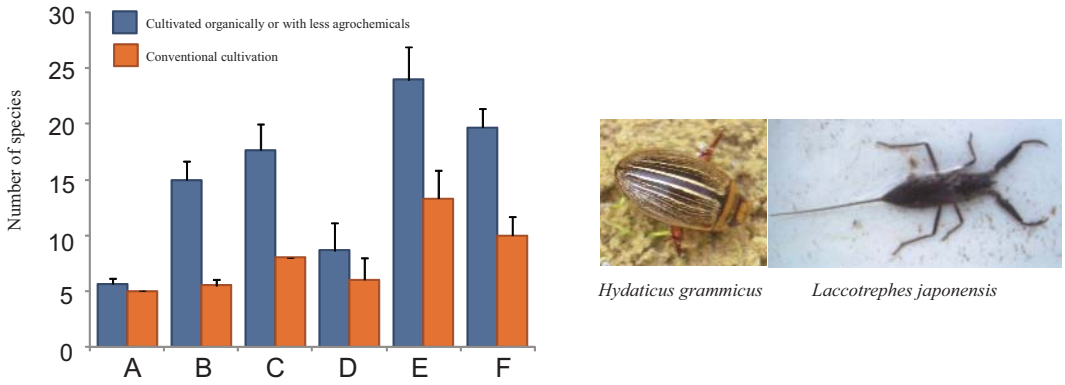


Fig. 9a Number of aquatic insect species in paddy fields managed under different cultivation methods

More species were found in paddy fields cultivated organically or with less agrochemicals than in paddy fields with conventional cultivation. The extent of this difference varied from region to region. Sizeable populations of *Hydaticus grammicus* (Coleoptera; diving beetle) and *Laccotrephes japonensis* (Hemiptera; water scorpion) were observed in paddy fields cultivated with organic methods or with less agrochemicals.

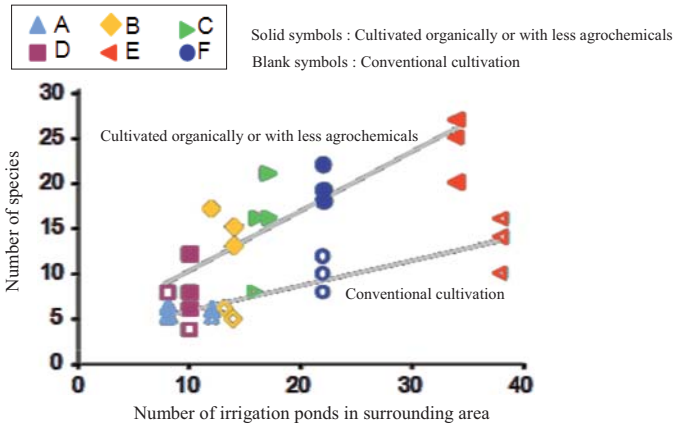


Fig. 9b Relationship between the number of irrigation ponds around paddy fields and the number of aquatic insect species

The graph shows that there are more aquatic insect species in regions with a large number of irrigation ponds. This tendency was more evident in the paddy fields cultivated with organic methods or with less agrochemicals.

data on the distribution of vegetation and birds in the RuLIS monitoring areas as well as nationwide data on the distribution of plants and small animals, which are available to anyone to obtain the information or input data. The accumulation of the observation data in this system will make it possible to carry out a comprehensive evaluation of the effectiveness of conservation oriented agriculture as well as the impact of changing human activities on biodiversity on a national scale.

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

We carried out a survey of the species and the populations of aquatic insects in paddy fields with varied cultivating controls in four regions in Tochigi Prefecture and two regions in Fukushima Prefecture. The results indicated that the number of aquatic insect species (of the Coleoptera, Hemiptera, and Odonata families) was significantly larger in the paddy fields cultivated organically or using fewer agrochemicals than in the paddy fields cultivated by conventional methods. The more irrigation ponds there were in areas surrounding the paddy fields, the more aquatic insect species were present, and there were large variations between different cultivation methods in the number of species. These findings indicate that conservation oriented agriculture, such as organic cultivation and the reduced use of agrochemicals, is effective in increasing the diversity of aquatic insect species, particularly in the regions which provide extensive habitats to a wide variety of species.

We developed a population dynamics model for

Volatile plant component used by predatory parasitoid wasp (*Cotesia zygaenarum*) in search for its host (*Plutella xylostella*)

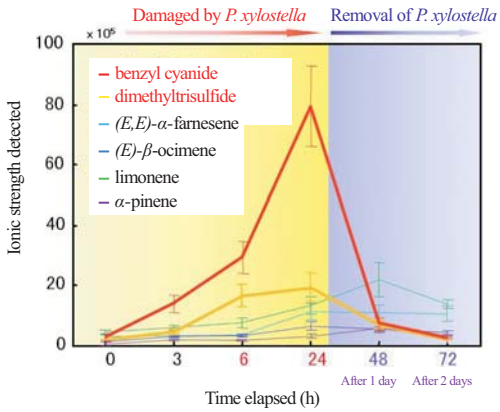


Fig. 10a Pattern of release of volatile component

The release of benzyl cyanide and dimethyltrisulfide increased as the plant was being eaten and decreased after the removal of *P. xylostella*.

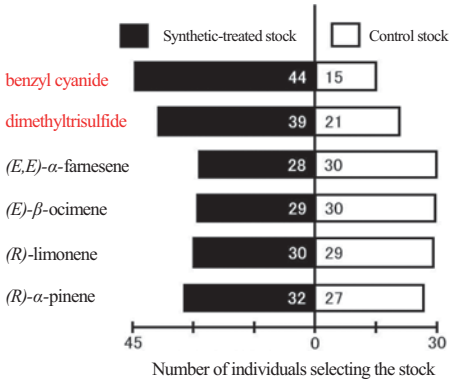


Fig. 10b Preferences of component by parasitoid wasps

A selection experiment using synthetic substances indicated that parasitoid wasps preferred two components which were released in quantity only when the plant was being eaten by moth larvae.
(Note: The figure on the left shows the selection made by 60 individuals released into cages containing synthetic-treated and untreated plants on either side of the datum line.)

Penthorum chinense — a near-threatened plant species growing mainly in paddy fields — incorporating the effects of a major herbicide for paddy rice (bensulfuron methyl), and evaluated the viability of this species in paddy fields, fallowed fields, and rivers. The population, which disappears from paddy fields after plowing and the application of the herbicide and disappears from fallowed paddies due to natural succession, was found to survive when the cultivation and fallowing are rotated at appropriate intervals. Concentrations of bensulfuron methyl in rivers were lower than the limit we had estimated to pose an extinction risk to this species, indicating that the effect of the herbicide in rivers was negligible. These findings indicate that farm management which takes the effects of plowing and herbicide use into consideration is effective for the preservation of hygrophytes in paddy field areas.

(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 and specify each of their functions. These substance include those produced by plants of the family Rosaceae; substances involved in the interactions between organisms, such as semiochemicals involved in the proliferation of insects, such as moths of the family Pyraustinae; 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,.

Research Overview:

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

We are currently conducting a study to synthesize a derivative of cis-cinnamic acid, which will act as a precursor to herbicide, from *Spiraea thunbergii* (Thunberg's meadowsweet) selected from numerous species of the family Rosaceae. We genetically analyzed its mechanism of action on plants, and estimated that the action was influenced by a group of genes involved in the absorption of phosphorus. We also isolated, refined, and identified isoforon and other substances, which are volatile allelochemicals acting as powerful germination inhibitors, from saffron and confirmed their herbicidal efficacy using potted plants. These bioactive substances are leading candidates for plant-derived herbicides.

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

We identified a volatile component which *Brassica rapa var. perviridis* (komatsuna) releases in large quantities only when the plant is being eaten by larva of a major pest, *Plutella xylostella* (diamondback moth), and found that a female parasitoid wasp (*Cotesia*

Predictions of yield and quality and the development of a model for evaluation of effectiveness of adaptive technologies

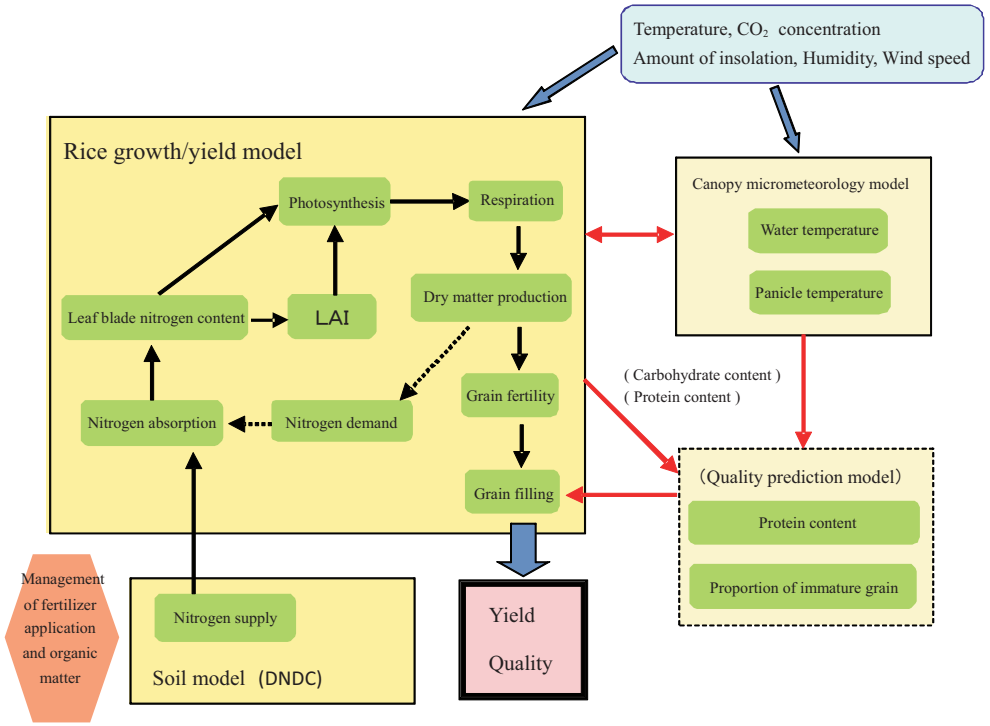


Fig. 11 Outline of the comprehensive rice model

By building a comprehensive model for the response of crop production in farmlands to climate change taking into consideration management of soil and fertilizer application, and characteristics of crop varieties, we can predict yield and quality based on a multiple climate scenarios. The model quantitatively evaluates the characteristics of varieties for acclimatization and the effectiveness of cultivation techniques.

zygaenarum), a predator to the diamondback moth, uses this component as a clue for locating the plants on which it would find a host. This is a major finding which will contribute to the development of predator-based pest control techniques.

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

We continued our work on the analysis of environmental factors involved in inducing microorganisms with a strong ability to break down biodegradable plastics, which were discovered by NIAES, to start breaking them down. We identified the importance of moisture and temperature on the action. We installed mulching films made of biodegradable plastic in a test field at the NIAES premises; mulching films sprayed with catabolic enzymes developed cracks which were significantly longer than were seen in mulch films not treated by the enzyme, indicating the effectiveness of the enzyme at the working level.

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 conditions of global warming 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 crops 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.

Stand-alone weather observation package to capture micrometeorological conditions within the canopy of rice plants (MINCER)

Fig. 12a Appearance and structure of MINCER

Air from within the canopy is drawn sideways into the unit through an intake vent ① by a solar fan ④ driven by a solar panel on the top of the unit and built-in rechargeable battery. A temperature and humidity data logger ⑦ (below), which is encased in a double-wall PVC tube wrapped in insulation matting ②, measures the temperature and humidity of the air. The air then passes through a PVC tube ③ to be exhausted from an exhaust vent ⑤ above the canopy. The height of the intake vent ① can be changed by adjusting the tripod mount ⑥. The temperature/humidity logger ⑦ is designed to take measurements and record them (15,000 records) by itself. The recorded data are transferred to a computer via a USB connection after the observation is completed.

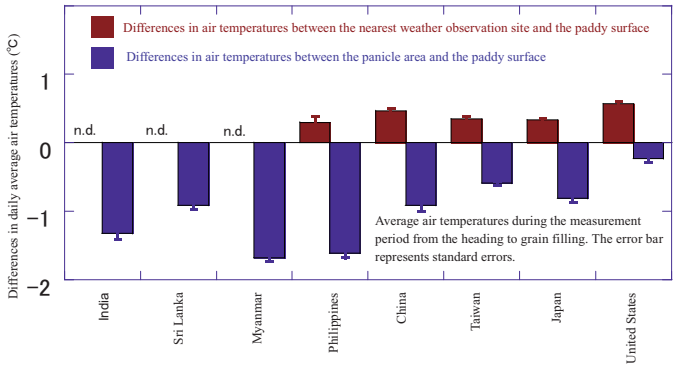


Fig. 12b Variance in data values between the paddy fields observed by MINCERnet and the nearest weather observation site

Generally, the nearest weather observation site produces temperatures higher than ones measured on the paddy surface. In addition, rice plants sense temperatures near the panicle which are lower than ones on the paddy surface. The graph shows that these differences vary from region to region.

Research Overview:

(a) Impact assessment at a farm level (the development of a paddy ecosystem response model)
(Outcome ready for practical use: MINCER — a stand-alone weather observation system that captures the micrometeorological conditions within the canopy of rice plants)

Based on previous experimental studies of environmental responses of rice plants carried out in a chamber and Free-Air CO_2 Enrichment (FACE) experimental facility, we constructed a paddy field ecosystem model consisting of three submodels: dynamics of soil carbon and nitrogen, growth of rice plants, and balance of water and heat in the canopy of rice plants.

We launched a research project at the Free-Air CO_2 Enrichment (FACE) experiment facility in Tsukubamirai, and the experiments during the first year yielded the following results: High CO_2 increased the yield of rice, but the yield increase varied among the varieties in a range of 3 to 36%; and high CO_2 reduced the sterility caused by abnormally high temperatures in summer on the average, but increased it in some varieties. With respect to the sterility due to high temperatures, the finding of the variety-specific responses to high CO_2 is significant. As it was the case in the past reports, although high CO_2 reduced the protein content of brown rice and increased eating quality as a result, the quality of appearance declined considerably in all varieties.

An analysis of yield response of each variety to high CO_2 in the FACE experiments carried out in Tsukubamirai and Shizukuishi indicated that the increases in yields of Akitakomachi and Koshihikari varieties varied with test site and cultivation year. While the increase in yield had been thought to be temperature-dependent, Akita No. 63 and Takanari showed a high rate of increase in yields regardless of test site location or cultivation year. We infer that these varieties possess important characteristics which produce a high CO_2 fertilization efficiency under a wide range of environmental conditions.

We developed MINCER (Multilayered Implementation for Natural Canopy-Environment Relations), an apparatus that allows for easy observation of air temperatures and humidity inside a plant community, factors which are strongly connected to heat stress of rice plants. We also constructed an international observation network (MINCERnet) through which to

shed light on the actual micrometeorological conditions of paddy fields and heat stress. Eight major rice-producing countries, namely India, Sri Lanka, Myanmar, China, Philippines, Taiwan, USA, and Japan are participating in MINCERnet. We expect that our efforts to carry out detailed analyses and clarify the causes of the heat stress in rice will make great strides under this multinational collaboration.

(b) Impact assessment at a regional scale

On a regional scale, we developed a simple yield model and a model which estimates changes in planted areas from moisture and salt conditions. Based on the output from several climate models, we evaluated regional yields and changes in production, as well as their uncertainties, in Japan, East Asia, and Southeast Asia. The results suggested that the changes in yields between the 1991–2000 period and the 2041–2050 period was estimated to be –10% to +10%, and the extent of impact was influenced by the growth characteristics of varieties adapted to the region and cultivation history.

(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 controlling GHG emissions through improved cultivation and soil management practices and to propose efficient load reduction techniques and systems. At the same time, by making effective use of soil-related databases, we plan to verify and improve our model which 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. At the 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 assessing vulnerability to water pollution.

Research Overview:

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

(a) Wide-area assessment of potential global warming mitigation in crop lands in Japan

We carried out a comprehensive assessment of the effectiveness of carbon accumulation in crop land soil by taking into account the trade-off with three greenhouse gases that are generated. We estimated changes in carbon content of soil in crop lands across the country and the amount of nitrous oxide generated from these lands as well as the amount methane emitted from paddy fields under two realistic organic-input scenarios (BAU: the trends in changes in the recent ten years are maintained; C-accumulation: input of compost and green manure is increased) which considered weather patterns, soil types, and data on land use change for different land uses and prefectures. According to our estimates, the total emissions of all gases converted to CO_2 equivalent were 13.7 Tg CO_2 eq in 1990, and 8.1 Tg CO_2 eq under the BAU scenario and 6.5 Tg CO_2 eq. under the C-accumulation scenario in 2020. The increases in methane and nitrous oxide are higher under the C-accumulation scenario than under the BAU but overall mitigation is achieved as CO_2 emissions will decrease considerably due to decreases in carbon content in the soil. When the differences in

Fig. 13 Front cover of the Manual for Water Management to Control Methane Emissions from Rice Paddies (in Japanese)

Rising CO_2 concentration and temperature during growth period of rice plants considerably increase methane emissions from paddy fields

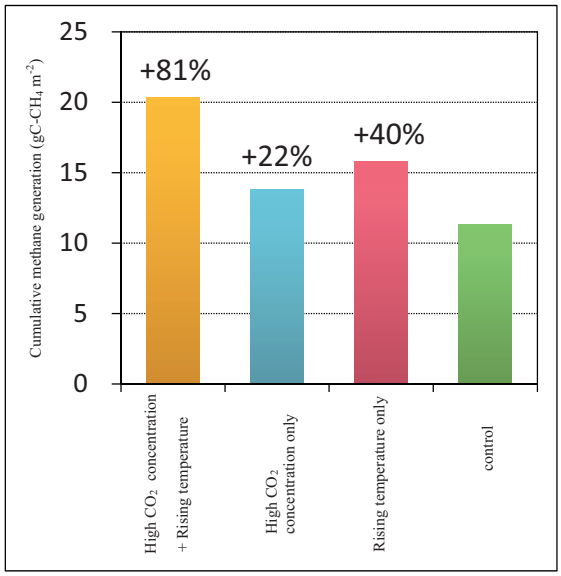


Fig. 14a Increase in methane emission due to high CO_2 concentration and rising temperature

Both high CO_2 concentration (+200 ppm) and rising water and ground temperatures (+2˚C) increased methane emission, together as much as 80%. Figures represent cumulative emissions per single growth period, and are the average for 2007 and 2008.

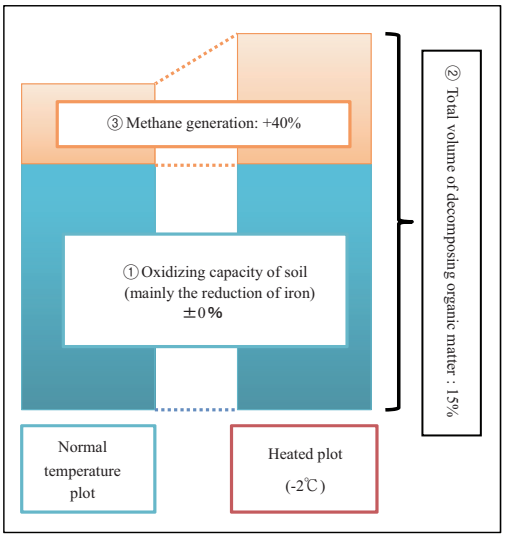


Fig. 14b How rising temperatures cause considerable increases in methane emissions

Methane is generated in an amount by which the reducing capacity of decomposing organic matter exceeds the oxidizing capacity of soil. Rising temperatures did not change the oxidizing capacity of soil (① in the Fig.) but increased the total volume of decomposing organic matter by about 15% (② in the Fig.). This was believed to be one of the reasons that methane generation increased by as much as 40% (③ in the Fig.).

absorbed amounts are compared between 2020 and 1990 (base year), the amount absorbed under the BAU scenario was 5.6 million tons CO_2 eq. per year and 7.3 million tons CO_2 eq. per year under the C-accumulation scenario. While the global warming mitigation measures adopted by Japan have already incorporated quantitative assessment methods and results of mitigation measures such as carbon storage in soil, we expect our findings to be useful for the implementation of more effective measures. Based on the results of verification tests carried out in FY 2008 and 2009 at nine sites across the country, we developed a manual for water management. This manual shows that a reduction in methane emissions from paddy fields can be achieved by extending midseason drainage. We hope it will be put into practice by farmers and agricultural extension centers.

We simulated emissions of methane over a two-year period from paddy fields under the scenario projected in 50 years from now: atmospheric CO_2 concentration (approx.. 580 ppm) and the warming environment (increases in water and ground temperatures by 2°C compared to the normal temperature plot). We estimated that methane emissions would increase by 80% compared to the present environment. This result clarified a part of the "positive feedback" effect in which climate change triggers further warming through the increased methane emissions from paddy fields. It is a useful finding for predicting methane emissions from paddy fields and future climate change.

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

We developed MacT (Mixing areal chemical Transport), a GIS-based regional chemical transport model for areal prediction of the mixing/attenuation and concentration distribution of environmental load substances originating from farms, including nitrate-nitrogen, through shallow groundwater. This model appropriately evaluates the flow direction of groundwater determined by topographical characteristics, such as an uplands-lowlands topographical chain, and concentration attenuation by dilution or denitrification due to the mixing of groundwater. When this model was applied to a small catchment area in a topographical chain, the estimated distribution agreed well with observed results.

By combining MacT and LEACHM, a model which describes morphological changes and movements of

Development of RealN, a system to assess the risk of groundwater contamination by farm-originated nitrate-nitrogen

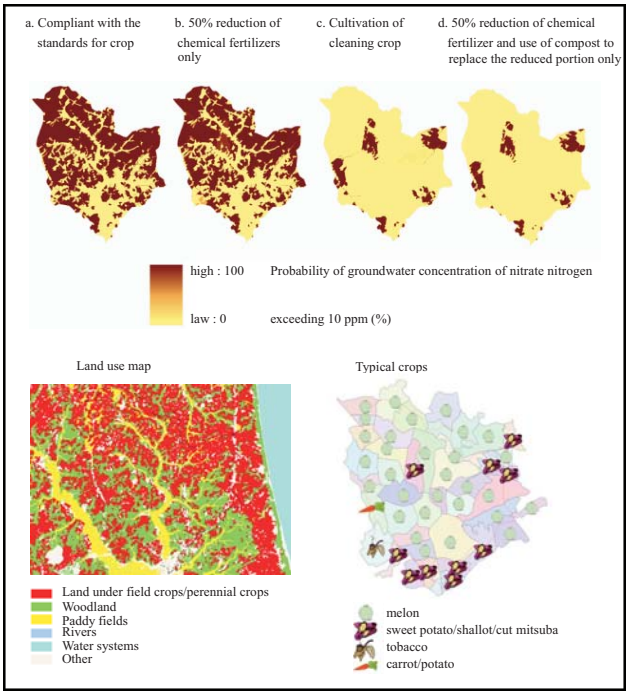


Fig. 15 Reduction of groundwater contamination risk predicted by RealN under a load reduction scenario

The system predicted that the probability of groundwater concentration of nitrate-nitrogen exceeding 10 ppm could be effectively lowered in the study area by cultivating a cleaning crop without fertilizers during the intercropping period or by reducing chemical fertilizer use by 50% and using compost to replace this portion only.

nitrogen in soil and absorption by crops (Hutson, 2003), we developed RealN, a system to assess the risk of groundwater contamination by farm-originated nitrate-nitrogen. From the soil and topographical characteristics of a region, this system can areally predict risks of groundwater contamination by nitrate-nitrogen efflux from farmlands.

We used RealN to predict the areal distribution of nitrate-nitrogen in groundwater based on the current planting patterns of major field crops and recommended rates of fertilizer application in the Kanto Region. The results were in good agreement with the actual measurements taken by local authorities. In the area of the study, it is highly probable for the groundwater nitrate-nitrogen concentration to exceed the environmental standard for groundwater of 10 ppm. Accordingly, when only chemical fertilizers are used, it is likely to be difficult to reduce the nitrate-nitrogen concentration to below the standard, even by a 50% reduction in the application rate.

However, on the other hand, the model predicted that the probability of the nitrate-nitrogen concentration exceeding the 10-ppm limit could be effectively lowered if the use of chemical fertilizers was reduced by 50% and only this portion is replaced by compost (to about 40% reduction in the rate of fertilizer application).

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 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 the analysis of trace chemicals, such as organoarsenic compounds found in crops and the environment, and develop a simple and accurate technique for measurement to be used in monitoring.

Research Overview:

1. Advanced technologies for detection and monitoring

Annual carbon balance in single-crop rice paddies and its interannual variations based on gas flux monitoring

Fig. 16 Interannual variations of carbon balance components in single-crop paddy fields (2002 – 2009)

The positive and negative values represent inflow to and outflow from paddy fields, respectively. The input of organic material and partial burning of crop residues occur irregularly.

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, including the paddy fields in Mase district of Tsukuba in Ibaraki Prefecture, and maintained the number of measurement items, measurement frequency and data quality at a level similar to previous years. At the Mase site, which is operated as the key measurement point, we improved the efficiency of observation and achieved labor-saving with the full operation of a remote management system and an information sharing wiki.

Observations at the paddy fields in the Mase district over the eight-year period (2002–2009) identified the key items of carbon balance in a single-crop paddy field to be carbon dioxide (CO_2) exchange between the paddy field and the atmosphere through photosynthesis and respiration of plants and the decomposition of organic matter in soil, as well as harvesting post-harvest processing of crop residues. Contributions from other components were small. Approximately one-half of the net amount of carbon absorbed during the cropping period (net ecosystem productivity, NEP) was removed at harvest time, and one-half of the remaining carbon was released into atmosphere through the decomposition of organic matter during the non-cropping period. As the result, the eight-year average of the annual carbon balance was –0.4±0.7 t-C ha^{-1} y^{-1} (negative value representing outflow), a near equilibrium. When the Global Warming Potential is taken into account, the methane emission was equivalent to 1.0 t-C ha^{-1} y^{-1} of CO_2 outflow, indicating the significance of methane as a greenhouse gas in paddy field ecosystems with carbon balance at equilibrium. These outcomes should be useful as basic information for the assessment of the carbon sink functions of farmlands.

In order to encourage the adoption of a series of techniques used in the data processing by the eddy correlation method, we developed and published a system for the easy processing of complex data for eddy correlation on the web and the immediate use of the results. As the system is compatible with the latest data correction and quality control methods, it is useful to specialists for confirmation of the effectiveness of various processing methods.

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

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

An analysis of radioactive strontium (^{90}Sr) and

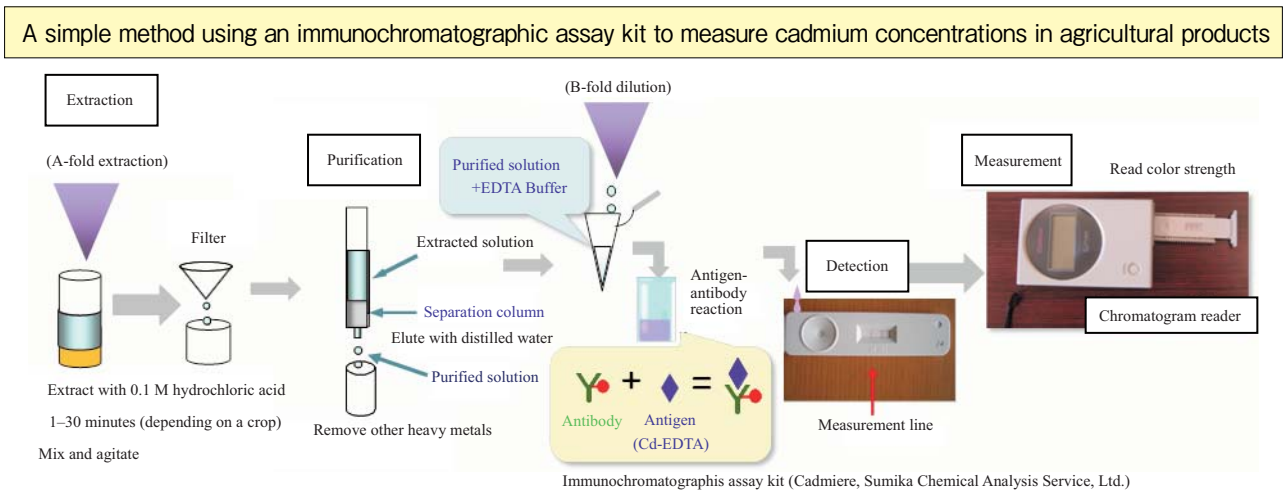


Fig. 17 Steps for a simple measurement of Cd concentrations in agricultural products using immunochromatographic assay kit

radioactive cesium (^{137}Cs) in the 2009 rice and wheat crops and soil from the reference fields indicated that there were no significant changes in their concentrations as they were the same as those in 2008.

According to a survey of land-use specific efflux of ^{137}Cs and ^{210}Pb from a field at Sakuragawa in Ibaraki Prefecture, the concentration of ^{137}Cs was approximately 2–7 Bq kg^{-1} and the ^{137}Cs flux was 10–10000 Bq month^{-1}. Both nuclides entered the system mostly through irrigation water, and very few seasonal changes were observed. On the other hand, the output from upland fields, although small, increased during the summer and decreased during the winter.

We used the ICP-MS method which we developed in collaboration with the private sector to collect analytical values of ^{129}I in the soil of Tokai Village where the background value of ^{129}I had been rising. The collected values were in good agreement with the values produced by an accelerator mass spectrometer (AMS) (primary coefficient of correlation r=0.999).

With respect to the March 2011 accident at Fukushima Daiichi Nuclear Power Plant of Tokyo Electric Power Company, the data from our monitoring of radioactive cesium concentrations in rice and wheat and their soil were used in the calculation of the "migration index for radioactive cesium from paddy soil to rice" (see attachment) in a document entitled An Approach to Rice Planting published by the Headquarters for Nuclear Emergency on April 8, 2011.

(b) Manual for development and analysis of analytical methods for chemical substances in the agro-environment

(Outcome ready for practical use: A simple method using an immunochromatographic assay kit to measure cadmium concentrations in agricultural products)

In order to apply the method of using an immunochromatographic assay kit to measure cadmium (Cd) concentrations in various agricultural products (e.g. wheat, soybean, spinach, taro, and eggplant), we developed pre-treatments and extraction methods appropriate for each item, and carried out a joint indoor test for validation. With international standards for cadmium concentrations in food, there is an increasing demand from agricultural extension agencies, which cannot afford expensive analytical instruments, for a simple measuring method to carry out tests on field crops for which the international Cd limits are lower than for rice and which contain a variety of contaminants. This technique is a response to that demand.

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

Role of branch stream paddies representing "*yatsuda*" as a spatial indicator of *yatsuda* distribution

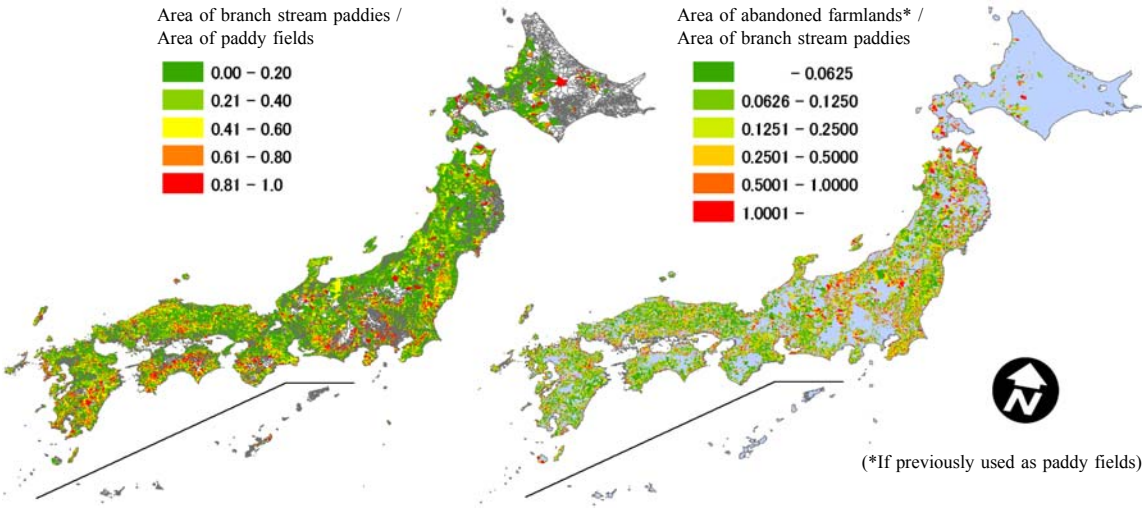


Fig. 18 Communities containing many branch stream paddies (left) and communities under a high pressure to abandon cultivation (right)

Rural communities containing a large number of branch stream paddies and those containing abandoned farmlands are found across the country.
(* Areas in colors not identified in the legend represent communities with no paddy fields (or, in the map on the right, no branch stream paddies).

to enhance the individual environmental resource databases, and propose a soil classification system that includes a 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 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. Digitization 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 technique with which to estimate stages of crop growth by using the seasonal change curve of the vegetation index which was developed from the daily observation data of the MODIS satellite sensor. Using as the reference the correspondence between the basic form of the multi-year seasonal change curve for each crop and region and ground-truthed survey data, this technique is designed to estimate the stages of crop growth in the current year from the deviation of the change curve for the current year from that of the base curve. A comparison with statistical data produced good results for estimation. Since this technique uses the shape of seasonal change curve, it is a simple and easy-to-use method in cases where there is little change in land use and crop varieties in the region.

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

Narrow paddy field areas called "*yatsuda*" (paddy field in ravines) are regarded as a key habitat that is well suited for the preservation of biodiversity. By defining narrow paddy field areas of less than 100 m in width as "branch stream paddies", we developed a GIS-based technique by which to extract the *yatsuda* from geographical data by applying a technique to detect the width of a double line. We used this technique to map out the branch stream paddies across the country from the paddy fields in the existing vegetation map of the Ministry of the Environment, and identified the rural communities rich in branch paddy fields from the communities marked as "rural" in the Agriculture and Forestry Statistics. Although branch stream paddies accounted for only 11% of the total paddy field area in Japan, in terms of the lengths of land use type sharing a boundary with paddy fields, we found that branch stream paddies account for about 33% of the total length of paddy field circumference, and about 44% of the total length of woodland–paddy field boundary. In

First Draft Proposal for Comprehensive Soil Classifications that can finely classify the entire land of Japan

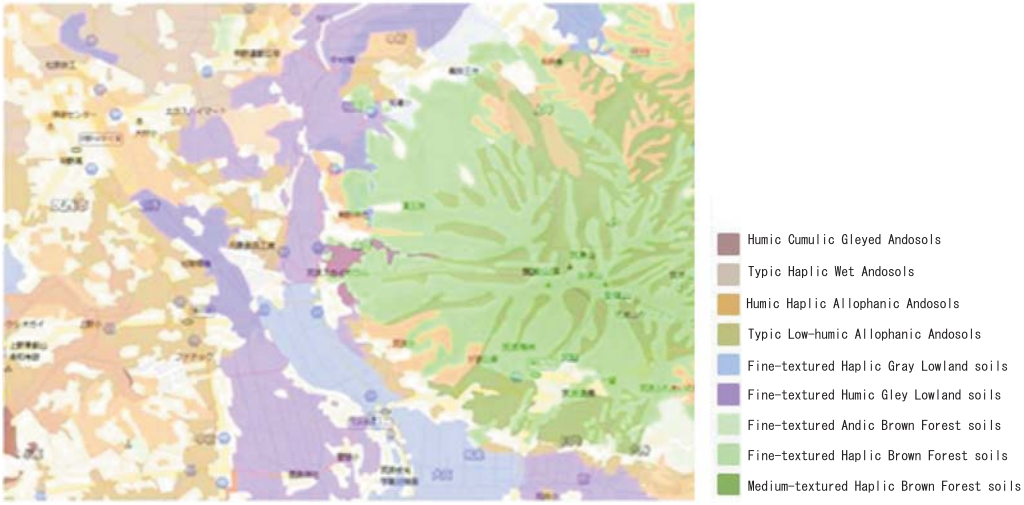


Fig. 19 Soil map of the area around Mt. Tsukuba according to the first draft proposal of the comprehensive soil classification

The first draft comprehensive classification makes it possible to map soil types without distinguishing farmlands from forest lands. (White sections represent urban areas, buildings and areas not surveyed.)

addition, as an indicator of the pressure to abandon cultivating the branch stream paddies, we calculated the ratio of the area of branch stream paddies to the area of abandoned farmlands (which were used previously as paddy fields) for all communities across the country. We expect a spatial indicator based on a GIS technique, such as this, will be used to prevent the abandonment of the cultivation of narrow paddy field areas, and to select the areas to be targeted for the implementation of measures to preserve rural landscape and biodiversity.

2. Construction of comprehensive inventory and development of its usage

(a) Draft development of a comprehensive soil classification system
(Outcome ready for practical use: First draft proposal for a comprehensive soil classification which finely classifies the entire land of Japan)

We drafted and published the First Draft Proposal for Comprehensive Soil Classifications based on the preliminary draft prepared in 2009. Japan has had separate soil classifications for farmland and for forest lands. The separate classifications posed problems with functional assessments for agricultural and environmental issues in regions where farmlands and forest lands are intermingled in complex patterns. The first draft proposal for the comprehensive soil classifications classifies soil types and provides soil maps that respond to the needs of environmental research and government administration by mapping the distribution of soil type for each soil series. For example, the combination of these soil maps and the typified and indexed results of carbon storage functions, water and air purification functions, soil contamination risks, or risks of invasion by alien species will make it possible to develop specific proposals relating to agricultural and environmental problems at the local level.

(b) Release of the Insect inventory
(Outcome ready for practical use: Integrated Insect Database Inventory System)

We developed an inventory framework for the purpose of promoting the use of the collection of insect information in the possession of NIAES and made it available to the public. The integrated system has made the information contained in the NIAES databases, including those of insect specimens, available for anyone to search and view. It also allows users to access information which will be useful for investigation and research of insects.

(c) Improvement and expansion of agro-environmental information inventory
(Outcome ready for practical use: A web-based system which offers information relating to weather, soil, farmland use, and greenhouses gases at one site (see note).)

Integrated Insect Database Inventory System

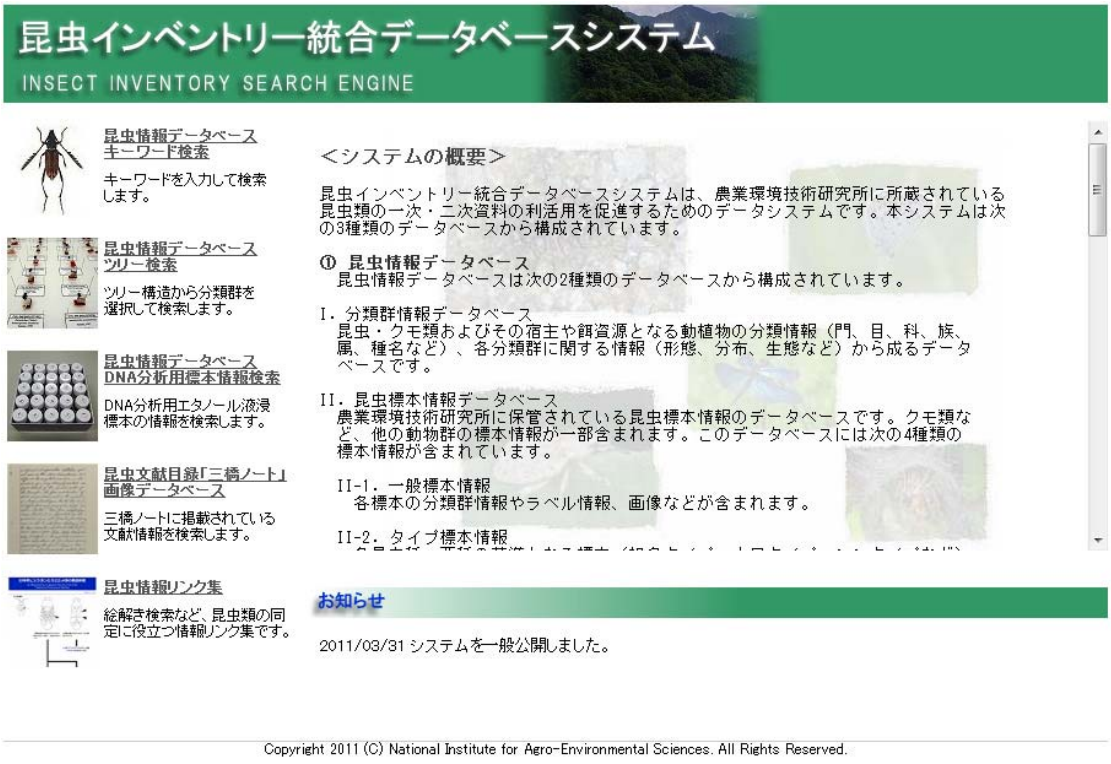


Fig. 20 Portal page of the Integrated Insect Database Inventory System (http://insect.niaes.affrc.go.jp/)

Web-based system to make information on weather, soil, farmland use, and greenhouse gases available together in one place

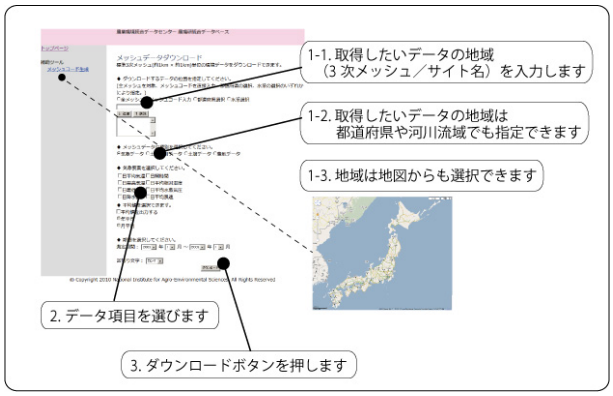


Fig. 21a Actual display and operation (in Japanese)

It is very simple to use. You can obtain all desired data just by checking the region and the items for which data are sought. If you do not know the name of the region, you can select it from the map.

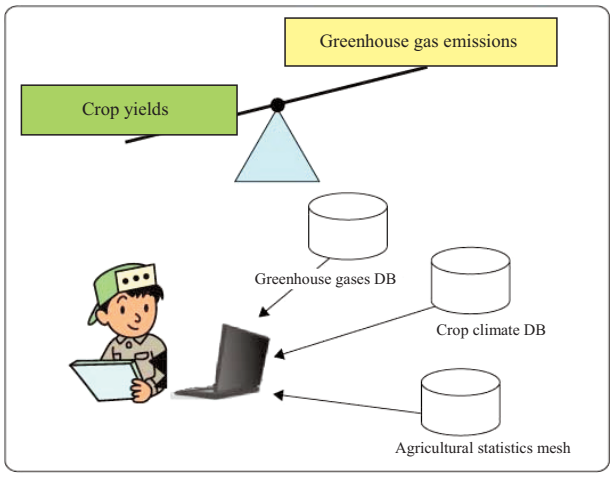


Fig. 21b Potential uses

This system will be useful in providing advice on farming practice that considers striking a balance between crop yields and greenhouse gas emissions. We are expecting active use mainly by research institutions, such as agricultural experiment stations and universities, agriculture surveyors, and analytical services in the private sector.

We developed the "eDNA Database for Agricultural Soils (eDDASs)" which contains information on the biological aspects of soil developed based on DNA (eDNA) directly extracted from soil as well as information on the physicochemical aspects of soil. With respect to the biological aspects of soil (types of microbes, fungi, and nematodes) which had been difficult to analyze in the past, the inventory contains information which was visualized in the form of eDNA barcodes by PCR-DGGE (denaturing gradient gel electrophoresis). Collecting data by an integrated analytical technique (Soil eDNA Analysis Manual) makes intercomparison of samples possible. This database is a system which can be viewed on the web by anyone, and its use by soil researchers around the country as well as the volume of information is expected to increase in future.

We also developed an inventory framework for the promotion of the use of primary and secondary information on insects in the NIAES archives. This system has made the information contained in the NIAES databases, including those of insect specimens, available for searching and viewing. It also allows users to access information which will be useful for investigation and research of insects.

We developed a web-based system from which users can obtain data on weather, soil, farmland use, and greenhouse gases which were collected and organized by NIAES at once and easily. Users can obtain desired information in a basic regional mesh (1-km mesh) or by measurement point. The system will be used in a variety of fields as it allows cross-disciplinary use of a multitude of agro-environmental information.

In order to expand the content of the Soil Information System, which we made available for public use in April 2010, we developed a database of the physical properties of soil (SolphyJ).