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.