# International Symposium on Paddy Soils

## New Challenges in Paddy Soils Research

# ABSTRACTS


**October 21, 2024**
**Nanjing International Youth Convention Hotel**
**Nanjing, China**
**14:00-17:30  Room729**

Paddy Soils Working Group
IUSS
International Union of Soil Sciences

中国土壤学会
SOIL SCIENCE SOCIETY OF CHINA

JSSSPN

JSSSPN 100th Anniversary 2027

# International Symposium on Paddy Soils

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|---|---|
| Opening address from moderators | 14:00-14:05 |
| Changes in fertility of paddy soils under crop rotation between irrigated paddy rice and upland soybean<br>Mizuhiko Nishida<br>Tohoku University, Japan | 14:05-14:25 |
| Optimizing Nitrogen Application for Sustainable Rice Production in China<br>Zhao Xu<br>Changshu National Agro-Ecosystem Observation and Research Station (CSAES), Institute of Soil Science, CAS, China | 14:25-14:45 |
| Soil phosphorus availability in paddy soils: a question of total P supply and water management"<br>Luisella Celi<br>University of Turin, Italy | 14:45-15:05 |
| Cadmium in Paddy Systems: How to Produce Safe Rice?<br>Wang Peng<br>Nanjing Agricultural University, College of Resources and Environmental Sciences, China | 15:05-15:25 |
| Impact of Selenium (Se) application to soil on the absorption of Se by plants and rice yield<br>Benito Heru Purwanto<br>Universitas Gadjah Mada, Indonesia | 15:25-15:45 |
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| Effect of biodegradable plastics on greenhouse gas emission and paddy rice growth under flooding conditions<br>Kazuyuki Inubushi<br>Tokyo University of Agriculture, Japan | 16:00-16:20 |
| Does organic matter application increase methane emission from the Andisol paddy field?<br>Chie Hayakawa<br>Utsunomiya University, Japan | 16:20-16:40 |
| Delema in organic matter management in rice paddy<br>Pil Joo Kim<br>Gyeongsang National University, South Korea | 16:40-17:00 |
| Discussion | 17:00-17:30 |

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# Changes in fertility of paddy soils under crop rotation between irrigated paddy rice and upland soybean

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The paddy field is dominant land use in Japan, which accounts for 54% of Japanese arable land area. Then, the fertility of paddy soil is very important for food production and food security in Japan. On the other hand, rice supply has exceeded domestic demand and so rice production has been adjusted accordingly over the past 50 years. A typical adjustment is the rotation of paddy rice (*Oryza sativa* L.) in paddy fields and upland crops in drained paddy fields (paddy-upland rotation), which has been promoted to improve upland crop self-sufficiency. Soybean (*Glycine max* (L.) Merr.) is a major crop in this rotation sequence. In recent years, soybean yields have been stagnated or declined. It was suspected that the productivity of the soil was altered by the conversion of paddy fields into upland fields. Studies were then carried out to identify the changes in paddy soils caused by converting paddy fields to upland fields including paddy-upland rotation.

In a field experiment of long-term upland conversion with application of rice straw compost, it was found that two types of field management, paddy and upland, brought the great difference in the accumulation and decomposition of organic matter in the soil. Long-term conversion from paddy to upland resulted in decomposition and reduction of soil organic matter, leading to a decrease in available soil nitrogen (mineralizable N), regardless of the application of rice straw compost. However, the application of rice straw compost mitigated the decrease in SOM and available soil N.

These results led to a study of soils from 22 fields belonging to five different farmers in Akita, north-eastern Japan. These fields had different profiles in terms of paddy-upland cycles, and applications of organic materials. Regardless of organic material application, a significant negative correlation was found between available soil N and an increase in the proportion of upland seasons in total crop seasons (upland frequency). However, fields with repeated applications of cattle manure compost had higher available soil N than fields with only crop residues. Soil total N and total C also tended to decrease with increasing upland frequency, suggesting that soil organic matter decomposition was enhanced by paddy-upland rotation. Thus, it was demonstrated that the conversion of paddy rice fields to upland soybean fields and the rotation of paddy rice and upland soybean induced a decrease in soil N fertility, as measured by available N.

Another large-scale field study of soil properties under different soybean cropping frequencies was conducted in Fukuoka, south-eastern Japan. In addition to soil N fertility, paddy-upland rotation also affected soil physical properties. The number of soybean croppings in the last 10 years was positively correlated with the proportion of solid phase and bulk density, and negatively correlated with the proportion of gas phase. These soil physical properties were related to soybean yield. The results indicated that the deterioration of soil physical properties by paddy-upland rotation induced a decrease in soybean yield.

The cycle of paddy-upland rotation (upland frequency) and the application of organic materials played a key role in determining the available soil N in paddy-upland rotation. To maitain available soil N above the minimum suitable level of 80 mg $kg^{-1}$, upland frequency should not exceed 60% where no organic material other than crop residues is applied. In contrast, the upland frequency can be increased with the application of cattle manure compost as it maintains the available soil N. The application of organic materials ensures diverse use of paddy fields.

**Key words:** available nitrogen, fertility, organic materials, paddy-upland rotation, upland frequency

# Optimizing Nitrogen Application for Sustainable Rice Production in China

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China's rice-based cropping systems, a pivotal component of global agriculture, have been identified as hotspots for reactive nitrogen (Nr) losses. Despite this, the nation has set an ambitious target to achieve rice self-sufficiency by producing 218 Mt annually by 2030. This dual challenge of ensuring food security and maintaining environmental integrity underscores the critical need for prudent and efficient nitrogen (N) management. However, China's small-scale farming and decentralized agricultural management present unique challenges for N use efficiency (NUE). The current approach to determining optimal N application rates, which involves soil and/or plant testing, is cumbersome, labor-intensive, and costly, hindering its large-scale implementation. Moreover, traditional yield-based N recommendation strategies prioritize economic returns without adequately considering environmental sustainability. Moreover, prior research has largely overlooked the intricacies of N management in smallholder-dominated agricultural regions, where yield performance varies substantially across different fields. This variability poses a considerable challenge to efforts aimed at reducing N fertilizer inputs among millions of small-scale farmers. A comprehensive risk analysis is therefore essential, assessing both the potential decline in productivity and the environmental implications of adopting N optimization strategies. Here, we introduce an optimized N rate strategy tailored to subregion-specific agricultural conditions, ensuring that the social, economic, and environmental benefits of fertilizer use are seamlessly incorporated into our analytical framework. Our comprehensive analysis leverages an extensive dataset from on-farm studies, assessing both the potential risks of yield losses for smallholder farmers and the practical challenges of implementing the proposed N management strategy. Our study indicates that achieving China's 2030 national rice production targets is feasible while implementing an optimal N rate strategy. This approach can reduce national N consumption by 10-27%, decrease Nr losses by 7-24%, and enhance NUE by 30-36%. Furthermore, it ensures that national Nr pollution from rice systems remains within proposed environmental thresholds, without adversely affecting soil N stocks or the economic viability of smallholder farms. To facilitate the implementation of this annually revised subregional N rate strategy, tailored to China's current rice cropping systems, we propose a multi-faceted approach. Firstly, we advocate for the establishment of a nationwide, large-scale monitoring network to assess crop yield responses to N application. This network would be complemented by an intelligent management system for informed "N control" decision-making. Additionally, we recommend the creation of a N fertilizer quota management system, complete with purchase quotas, use regulations, and financial incentives to encourage the optimization of nitrogen use among all farmers. The proposed optimal N rate strategy offers a viable pathway for China to achieve its rice production goals by 2030 in a manner that is economically beneficial, environmentally responsible, and socially equitable.

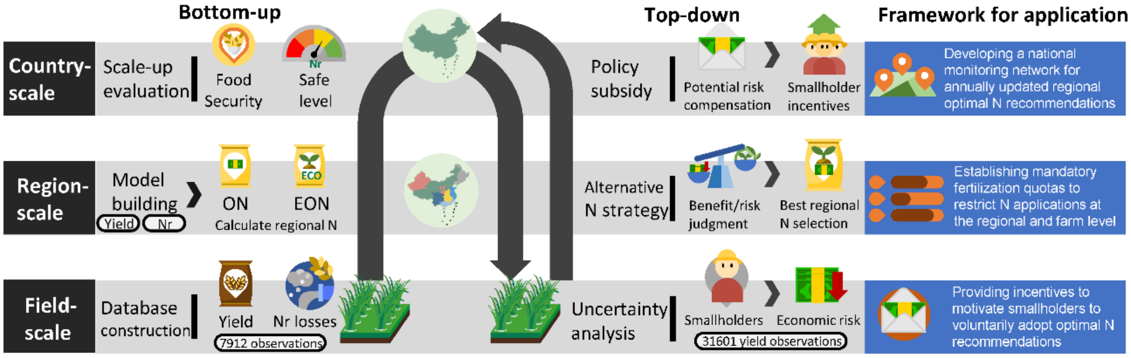


Fig. 1. Conceptual framework of rice region-specific fertilizer N optimization strategies.


**Key words:** Rice production, Environmental sustainability, Fertilizer optimization, Nitrogen threshold, Food security

## Soil phosphorus availability in paddy soils: a question of total P supply and water management


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Phosphorus cycling in soil is strongly controlled by abiotic processes, including adsorption, precipitation and coprecipitation, which lead the element to be the most inaccessible nutrient for most plants. All these abiotic processes determine the selective stabilisation of inositol phoshates with respect to the other organic P species, linked to their high affinity for iron oxide surfaces, which hamper their degradation and control their fate in soil. Thus, the proportion of different organic P species and the retention by the solid phase is governed by Fe cycling. However, in paddy soils, P compounds may be released into the porewater solution following microbial-driven reductive dissolution of Fe (hydr)oxides and easily migrate to the rhizophere replenishing the depletion zone determined by plant P uptake. On the other hand, aquatic plants can create a heterogeneous spatial distribution of O2 and cause the coprecipitation of Fe and P on root surfaces. The formed coprecipitates, the so-called Fe plaques, may retain both inorganic and organic P forms and their mineral composition is a function of P species, P/Fe ratio and O2 rate fluxes. Whether these plaques act as source or sink of P to plants is still matter of debate.

This presentation will show the most recent findings on the main factors that control inorganic and organic P coprecipitation/dissolution at both lab ad field scale and the chemical and mineralogical composition of the formed plaques. Furthermore, we will evaluate how the composition and mineralogy of coprecipitates control the release of P. Finally, the response of plants to utilize these plaques as source of P will be explored considering also the effects of changing water management techniques. These results will be then used to define new agricultural decision support systems to improve water and nutrient management technologies, fine-tune resource utilization and environmental protection for a greater sustainability of rice agrosystems.


Keywords: anaerobic soils, Eh, oxygen gradient, iron plaque, plant P availability, rice

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## Cadmium in Paddy Systems: How to Produce Safe Rice?


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Excessive cadmium (Cd) accumulation in rice grains poses a significant global threat to human health. During the grain filling period, the drainage of paddy soils leads to the remobilization of Cd, which contributes substantially to its accumulation in rice grains. The extent of Cd remobilization during drainage varies greatly among soils, but the mechanisms driving these variations are not well understood. This study reveals that Cd remobilization is primarily governed by the voltaic effect, free radical oxidation, and pH-dependent adsorption on Fe oxides. Applying Zn and Mn fertilizers mitigates CdS oxidative dissolution through the voltaic effect during soil drainage. Additionally, increasing soil pH reduces Cd solubility by limiting its release into the soil solution. Achieving Cd-safe rice grain production can be done by reducing Cd bioavailability, minimizing its uptake and translocation to grains, and removing Cd from soils. This research also presents a rice cultivar with high Cd accumulation potential, offering a viable phytoremediation approach to reduce Cd levels in contaminated soils.



**Key words:** Paddy field, cadmium, rice, phytoremediation, food safety

## Impact of Selenium (Se) application to soil on the absorption of Se by plants and rice yield


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Abstract

Up to 12.5 percent of global population do not get enough Se from their diets. For most people, plants are the main source of Se dietary that can help prevent Se deficiency. Conversely, overuse of Se-rich fertilizers and incorrect Se-biofortification may cause phytotoxic consequences in plants and be detrimental to human health. The study was carried out in Yogyakarta, Indonesia's rice fields to investigate the effect of soil-applied Se on plant absorption of Se and rice yield. Three levels of slow-release Se fertilizers, namely : $Se_0$ (without Se fertilizer), $Se_1$ (1 kg per ha), and $Se_2$ (2 kg per ha), and three levels of manure , namely : $M_0$ (without manure), $M_1$ (10 tons/ha of manure), and $M_2$ (20 tons/ha of manure) were used in this study. The randomized complete block design was employed in this study, and each treatment was duplicated by three replications. The result showed that Se fertilizers did not show a detrimental effect on rice yield. $Se_1$ dan $Se_2$ treatments increased uptake of Se in rice grain, and manure $M_2$ seemed to contribute to the distribution of $Se_1$ and $Se_2$ to rice grain. The findings suggested that adding Se fertilizer to the soil might significantly boost the amount of Se in rice and greatly alleviate human Se insufficiency.



**Key words:** rice grain, Se concentration, plant dry matter

## Effect of biodegradable plastics on greenhouse gas emission and paddy rice growth under flooding conditions


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Biodegradable plastics applied to soil stimulate the production of greenhouse gases and inhibit plant growth under aerobic conditions. In our previous study, some biodegradable plastics applied to soil can stimulate production of greenhouse gases, such as carbon dioxide ($CO_2$), due to the "priming effect" and significant amount of nitrous oxide ($N_2O$), an important greenhouse gas (IPCC 2021), can be produced by the amended biodegradable plastics, despite they contain only trace amount of nitrogen.  This study aimed to examine the effects of biodegradable plastics on paddy rice growth and greenhouse gas emission under flooding conditions in pot experiments and also on greenhouse gas production under flooding conditions in an incubation experiment. Two series of pot experiments were conducted with rice (*Oryza sativa*). First series as *immediate flooded* and 2nd series as *2 weeks nonflooding* before flooded, and both kept flooded until harvest. The following four kinds of materials were added to the sandy paddy soil, 1) *nonwoven fabric* sheets made of polylactic acid and polybutylene-succinate, 2) *laminate* sheets made of polybutylene adipate terephthalate and pulp, 3) *cellulose* filter paper, and 4) rice *straw*. Only soil was used as control. Methane ($CH_4$) emission, measured by chamber method followed by gas chromatograph, was significantly larger only in the *cellulose* treatment than *laminate* treatment in the *immediate flooded* series, indicating that biodegradable plastics had no significant impact on $CH_4$ emission from paddy rice soil. Rice growth and yield did not show significant difference among treatments in both series. Incubation experiment showed largest $CH_4$ production in *cellulose*-amended soil, followed by *straw*-amended and *laminate* amended soils, and least in *fabric*-amended soil, while $CO_2$ did not show significant differences among treatments. We need further examination with different biodegradable plastics for a longer period that test used in this study.



**Key words:** Methane, Polybutylene-succinate, Polybutylene adipate terephthalate, Polylactic acid, Anaerobic condition

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# Does organic matter application increase methane emission from the Andisol paddy field?


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**Introduction:** Application of organic matters is increasingly recommended for soil amendment or resource recycling in the paddy fields in Japan. The supply of organic substrates such as cow manure and rice straw residue risks increasing methane ($CH_4$) emission from paddy soils. Despite this, no significant differences in $CH_4$ emission were observed between manure- and chemical fertilizer amended Andisol soil. Application of organic matter is hypothesized to change $CH_4$ emission through effects on methane-producing/consuming microbial community as well as substrate availability in Andisol rich in organic matter. To test this, we compared $CH_4$ emission and microbial community involved in $CH_4$ production and oxidation in an Andisol paddy soil under different fertilizer management.

**Materials & Methods:** We compared three treatments (manure, chemical fertilizer, and no fertilizer application) in Andisol paddy fields at Utsunomiya University Farm. Gas samples were periodically collected using the closed chamber method to determine $CH_4$ flux in each plot. Regarding substrate availability for $CH_4$ production, the concentrations of dissolved organic/inorganic carbon (DOC/DIC) and acetic acid in the soil solution were measured. In addition, quantitative PCR was carried out to quantify the *pmoA* and *mcrA* genes as the indicators of soil methanogens and methane-oxidating bacteria, respectively. Soil Eh and rice plant growth were also monitored.

**Results & Discussion:** The $CH_4$ fluxes increased with decreasing soil Eh after flooding, while $CH_4$ fluxes decreased with increasing Eh after drainage. There was no significant difference in $CH_4$ fluxes between manure and chemical fertilizer plots. This indicates the prevailing importance of redox potential, rather than inputs of organic substrates, to control $CH_4$ emission in the Andisol paddy soil studied. The availability of direct substrate for $CH_4$ production (acetic acid and DIC) and abundance of $CH_4$ producers (methanogens) were consistently higher in the manure plot than in the chemical fertilizer plot. However, the abundance ratio of methanogens/methane-oxidating bacteria was lower in manure plot than in the chemical fertilizer plot throughout the year. This suggests that higher porosity (supported by lower bulk density) in manure plot is favorable for microbial $CH_4$ oxidation, compared to chemical fertilizer plot. We found that organic matter application increases substrate availability and $CH_4$ producers, but it does not always increase $CH_4$ emission. The changes in soil physical structure for microbial habitat, as well as substrate supply, need to be considered for optimizing fertilizer management for low methane emission.



**Key words:** Andisol paddy field, methane flux, methane-oxidating bacteria, methanogens, organic matter application

# Delema in organic matter management in rice paddy

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Soil can be a greenhouse gas (GHG) emission source and sink, and then the effect of soil management on global warming should be evaluated by net global warming potential (GWP) which is integrated by two GHG (methane-$CH_4$ and nitrous oxide-$N_2O$) fluxes and soil carbon (C) stock change with carbon dioxide ($CO_2$) equivalent. Application of organic amendments to rice paddies improve soil quality and sequester atmospheric carbon dioxide ($CO_2$). However, organic amendments can significantly increase methane ($CH_4$) emission, and then the influence of organic amendment application on net GWP is not clear in rice paddy yet. We compared the impact of organic amendments on net GWP by quantifying GHG fluxes and soil C stock changes in a rice paddy. Most organic amendments significantly increased seasonal $CH_4$ fluxes by 7–30 Mg $CO_2$-eq. $ha^{-1}$ compared with controls (no organic matter addition). However, the small increases in soil C stock (9–11 Mg $CO_2$-eq. $ha^{-1}$) were insufficient to reduce the net GWP in these treatments. In contrast, biochar decreased GHG emissions but highly increased the soil C stock, leading to a large decrease in net GWP with no effect on rice production. Given that rice paddies account for about 11% of anthropogenic GHG emissions, biochar can be an important negative emission technology (NET) in rice paddies.

Table 1. Comparison of organic amendment applications on net global warming potential (GWP) in rice paddies

| Treatment | No OA | Green manure | Rice straw + NPK | Livestock manure + NPK | | |
|---|---|---|---|---|---|---|
| | | | | Fresh | Compost | Biochar |
| GWP (Mg $CO_2$-eq. $ha^{-1}$) | | | | | | |
| $CH_4$ | 7.1c | 19.9ab | 14.0b | 36.3a | 27.6a | 15.8b |
| $N_2O$ | 1.9a | 2.5a | 1.5a | 3.7a | 2.9a | 1.2a |
| ∆SOC | 2.1a | -4.5b | -7.9b | -3.8ab | -9.3b | -17.1c |
| Net GWP | 11.1b | 17.9ab | 7.5b | 36.3a | 21.2b | -0.1c |

Note) No OA: no organic amendment application (NPK)

***Key words: greenhouse gas (GHG), methane ($CH_4$), nitrous oxide ($N_2O$), net global warming potential (GWP)***


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