Evaluation of the Nutritional Environment for Rice in Cianjur, Indonesia for Development of an Advanced Basin Model for Asia

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Abstract

Food production systems in tropical Asia face the following problems: 1) increased demand for production; 2) increasing environmental load; 3) water scarcity and 4) effects of climate change. To overcome these problems, strategies for better management of crop and environmental resources are recommended. Here, we describe our research in Cianjur, Indonesia under the project “Development and Practice of Advanced Basin Model in Asia – Toward Adaptation to Climate Change”. The study area, Cianjur, is one of the main rice production areas in Indonesia, and has water reservoirs that supply water to Jakarta. However, excess nutrients from agricultural land cause environmental problems. In this situation, evaluation of the nutritional environment for rice growth is necessary. We have begun to evaluate the nutrient concentrations in the irrigation water, soil and plants. The relationships of these nutrient contents to rice growth were analyzed using a rice growth simulation model. The simulation model and remote-sensing technologies were used in combination to evaluate the geographic distribution of rice growth and nutritional environment. The research produced baseline information for developing the Advanced Basin Model.

Keywords: environmental problem, irrigation water, remote-sensing, simulation model, soil solution

Introduction

Food production systems in tropical Asia face the following problems: 1) increased demand for production; 2) increasing environmental load; 3) water scarcity and 4) effects of climate change. To overcome these problems, strategies for better management of crops and environmental resources are recommended.

Since the green revolution, modern agricultural technology has increased land productivity and supported population growth. However, this technology tends to institutionalize agricultural management and reduce diversity. Previous studies reported that such institutionalized management increased the risk of disasters. Tsuno (1995) analyzed cold summer damage to rice production in Japan in 1993 and concluded that the simplification of management in cultivars and cultivation methods increased the extent of damage. Shiraiwa *et al.* (2002) analyzed the variability of rice production in Thailand and concluded that the annual variation was larger in an intensive high yielding area (the Central Plain) than in an extensive low-yielding area (the Northeast). Yoshino *et al.* (2000) analyzed the relationship between the Southern Oscillation Index and rice production in Indonesia and reported that the negative effect was largest in Java, which was the most productive area. These examples indicate that the present management is insufficient for coping with unfavorable conditions. Management variability may thus be the key to attaining production stability.

The high fertilizer input required by modern agriculture technology often exceeds an acceptable amount in the field and increases the environmental load. To optimize the input, the available nutrients in the soil and the requirements of the plant should first be evaluated. Because water scarcity is predicted in the future, the available water supply should also be evaluated.

The project "Development and Practice of Advanced Basin Model in Asia – Toward Adaptation to Climate Change"

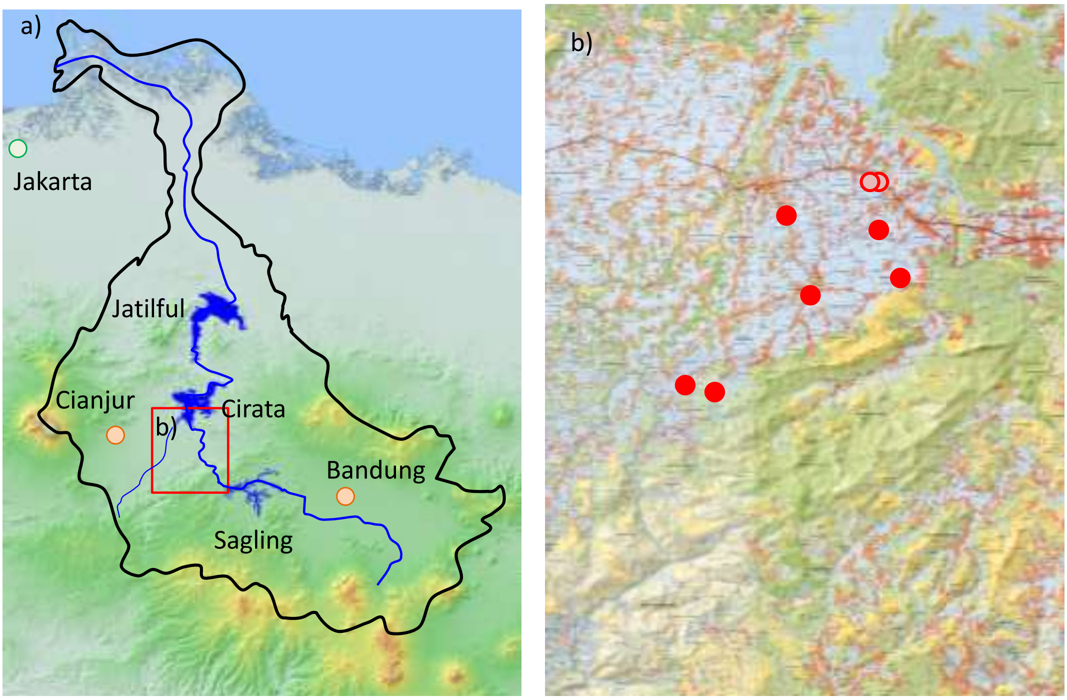
As mentioned above, the present situation demands not only a production increase, but also management optimization based on resource evaluation. Because the smallest water management unit is a basin and nearly all excess nutrients move with the water stream in the basin, a strategy to overcome these problems must be developed at the basin scale. Here, we established the project "Development and Practice of Advanced Basin Model in Asia – Toward Adaptation to Climate Change" supported by the Ministry of the Environment, Japan. The project includes the evaluation of environmental resources and crop production, proposals for better management and also the establishment of an environmental conservation community. The Citarum River in Indonesia and the Num Ngum River in Laos were selected as test sites (Oki, 2011). This manuscript describes one of the project activities in Indonesia, which were managed by the lead author. In the activities, the nutrient concentrations of the irrigation water, soil solution and plants are evaluated their relationships to rice growth will be analyzed using a rice growth simulation model. The relations in terms of rice growth would be analyzed by using rice growth simulation model. The simulation model and remote-sensing technologies will be used in combination to evaluate the geographic distribution of rice growth and then nutritional environment.

Overview of research area and activities

The research area is in the hydrographic basin of the Citarum River in West Java, Indonesia. The basin includes Bandung, the third largest city in Indonesia, and a total of 5 million people live in the area (Fig. 1a). Because the river is heavily polluted by human sewage and agriculture, the Asian Development Bank has called it the world's dirtiest river and approved a loan for clean-up in 2008. The river has 3 dams and one of 3 dams directly supplies water for Jakarta; thus clean-up of the river is of urgent concern.

Field observations have been conducted in the Bojongpicung and Ciranjang districts, Cianjur regency, West Java. The area is located between the Saguling and Cirata reservoirs and is downstream of Bandung. We selected 40 paddy fields, of which 30 were planted with rice and 10 were planted with soybeans in August 2011 (Fig. 1b). In addition to the chemical properties of the soil, the nitrogen and phosphate concentrations of soil solutions are periodically monitored. Because the nutrient concentrations in irrigation water are also measured along 3 points in the major channels, the nutritional environment for crop growth can be assessed in terms of nitrogen and phosphate levels.

Plant growth is nondestructively evaluated in terms of plant height and canopy cover using a digital camera. The spectral reflectance of the canopy is measured once a week with a reflectance-measuring instrument (MS-720, Eiko seiki Co. Ltd.). The plants are also destructively sampled once per month to determine the leaf area index (LAI), above-ground dry matter and root density. The grain yield and above-ground biomass will be measured at maturity.



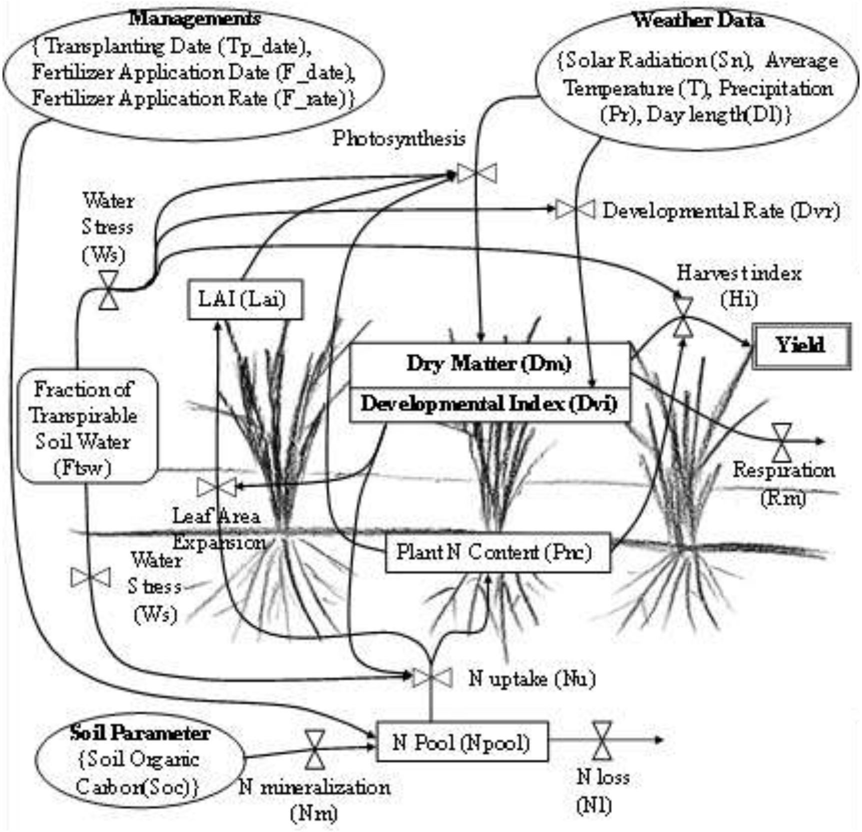
We selected 30 rice fields from 6 locations (●) and 10 soybean fields from 2 locations (o). Irrigation water is periodically monitored at 6 locations for rice fields.

Figure 1. Maps of the hydrographic basin of the Citarum River (a) and the field observation site (b).

Strategies for analysis and evaluation

To develop strategies for managing crop production in the hydrographic basin, the geophysical distribution of environmental resources and crop growth must be evaluated. However, the data we obtain are point-based. Accordingly, a method that scales up from point to area is needed. Satellite-based remote-sensing can be used for this purpose, and one of the co-authors of this paper had already developed a method that has been adapted in an agricultural area of Japan (Nuarsa *et al.* 2011). However, obtaining satellite images for analysis is difficult because the area often obscured by clouds.

To compensate for the missing data, we employed a simulation model. The authors developed the simulation model to predict rice growth and yield under rainfed conditions based on a field survey in Northeast Thailand, where the water and nutrients are quite limited (Fig. 2; Homma and Horie, 2008). Because the model was modified from SImulation Model for RIce Weather relations (SIMRIW), which has a good reputation for predicting the effects of climate change on rice production (Horie *et al.* 1995), the modified model may be able to handle climate change issues for the advanced basin model. We are now developing a simulation model to use in combination with remote-sensing (Fig. 3; Maki and Homma, 2011). The combined model will be used to evaluate the nutritional environment and predict rice yield by correcting the simulated data with satellite-based remote-sensing data. The combined model may also help to analyze the relationship between the remote-sensing data and field observations. The analysis will first be used for rice production and may be expanded to examine green soybean (edamame) production.



The basic concept of the model is derived from SIMRIW (SImulation Model for RIce Weather relations, Horie *et al.* 1995), and modified for rainfed rice production in Northeast Thailand (Homma and Horie, 2008).

Figure 2. Schematic illustration of the rice growth simulation model.

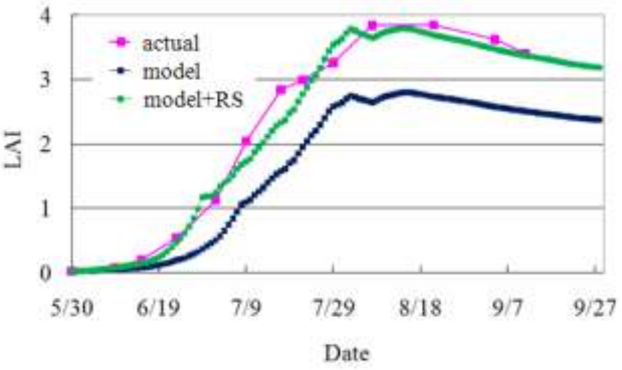


Figure 3. Examples of leaf area index (LAI) simulated by the rice growth simulation model and corrected by remote-sensing (Maki and Homma, 2011).

Conclusions

Here, we describe one of our activities in Cianjur, Indonesia. To develop better management practices for overcoming environmental problems and adapting to climate change, evaluation of the nutritional environment and rice growth are necessary. For this purpose, we have begun to evaluate the nutrient concentrations of irrigation water, soil solutions and plants. The relationship between these nutrient concentration and rice growth will be analyzed using a rice growth simulation model. The simulation model and remote sensing technologies will be used in combination to evaluate the geographic distribution of nutritional environment and rice growth.

Acknowledgement

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