Water Quality Model Development and BMP Evaluation for Paddy Rice Fields

○**Chun G. YOON*, Ji-Hong JEON*, and Jong-Hwa HAM***

Abstract: Water quality model applicable to paddy rice fields was developed using field experimental data during 1999 2002. The ponded water quality was influenced by fertilization dominantly and nutrient concentration was especially high during early cultural periods. Raising weir-height and shallow-irrigation methods were evaluated using the developed model as practical BMPs for loading reduction from paddy fields. The model demonstrated that these practices can substantially reduce loading from surface drainage. They are both suggested as paddy BMPs, but their application in field scale should be site specific considering field conditions.

Introduction

The hydrological and water quality characteristics of paddy fields are slightly different from other land-uses. The function of retaining water can reduce surface runoff, and drain-off can produce surface runoff without rainfall event. Nitrogen, phosphorus, and potassium are most commonly applied as fertilizer by farmers, and major portions of them are taken up by rice plants through the growth cycle. A significant portion of these nutrients could be lost from paddy field through surface drainage, seepage, and percolation. This might result in excessive nutrients supply to the receiving water body and cause eutrophication problems. A field experiment was performed during growing season of 1999 2002 to analyze water and nutrient balances in a paddy rice fields, and water quality model was developed to evaluate paddy BMPs.

Study Area

The field experiment was performed at two separate Korean sites. Site-1 is a Konkuk University agricultural research farm in Yojoo (37º14´N, 127º33´E) irrigated with groundwater, where the experiment was performed for 2 years (2001 2002). Site-2 is a field research farm in Jinan (35º37´N, 127º16´E) irrigated with surface water, where the experiment was performed for 2 years (1999 2000).

Model Development

Rice culture in the paddy field involves nutrient input and output, and theses activities are nearly cyclic and repeated each year. In the model development, nutrient balance in the paddy field is simplified as follows: (i) The paddy field is a completely mixed system, so that a continuously stirred tank reactor (*CSTR*) model can be applied; (ii) Water quality remains similar during a day, so that a daily continuous model can be used; and (iii) T-N and T-P are the main water quality parameters of interest.

The planning level model, PADDIMOD, was developed to predict water and nutrient balances in a paddy rice field. The inflow to the paddy field consists of irrigation, input from upper paddy field and rainfall, and the outflow consists of evapotranspiration, infiltration and surface runoff. Fertilization loading can be

* Dept. of Env. Sci., Konkuk Univ., 1 Hwayang-dong, Kwangjin-gu, Seoul 143-701, Korea, E-mail: chunyoon@konkuk.ac.kr

represented as *Dirac delta function* which can represent such an impulse loading.

Model Calibration and Validation

The model was calibrated and validated with two independent data sets from two separate sites. The simulation results are shown Figure 1. The ponded water depth generally varied with rainfall and irrigation. Nutrient concentration was mainly influenced by fertilization, and the T-N and T-P concentrations reached up to 50 mg/L and 5 mg/L, respectively. This result implies that control of surface drainage especially during May June can reduce non-point source loading substantially from paddy fields.

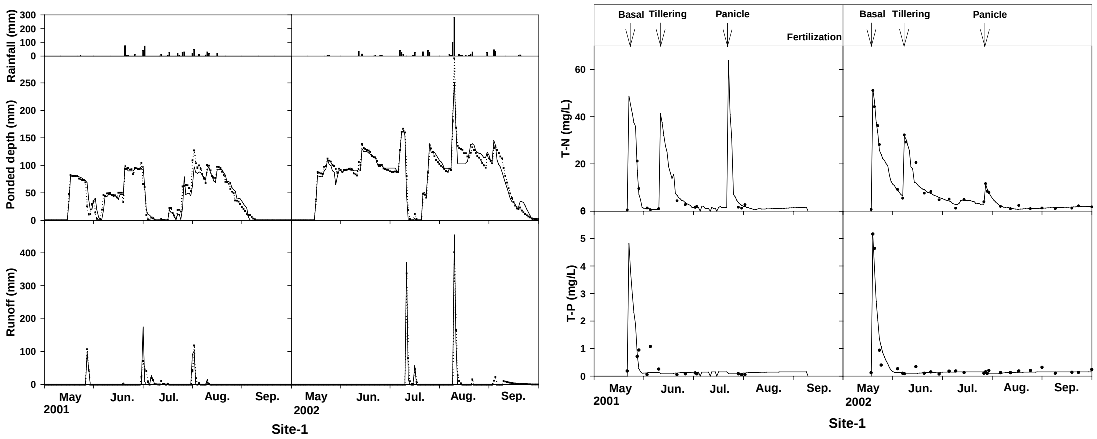

Fig. 1. Observed and predicted nutrient concentrations of ponded water and surface runoff in the paddy rice fields

BMP evaluation by PADDIMOD simulation

The increased weir height from 100 mm to 200 mm could retain more ponded water and reduce surface drainage especially during May, where high nutrient concentration resulted from fertilization, and resulting nutrient loading reduction of TN and TP surface loadings was about 78% and 49%. The ponded water depths of the field experimental sites were generally maintained as 100 mm, and shallow irrigation practice was simulated with conditions of 10 30 mm of ponded depth with 100 mm of weir height. Shallow irrigation could reduce TN and TP surface loadings about 74% and 53%, respectively, and the total irrigation depth from 296mm to130mm.

Conclusion

The PADDIMOD was developed using field data from two separate sites to simulate water and nutrient behavior in the paddy rice field system. Saving water by maintaining a shallow ponded depth and raising the drainage weir height in diked rice fields were evaluated as paddy BMPs by simulation of calibrated PADDIMOD. The increased weir height from 100 mm to 200 mm could retain more water, and contribute to reduction of TN and TP surface loadings about 78% and 49%, respectively. The shallow irrigation practice might also reduce TN and TP surface loadings about 74% and 53%, respectively, and lower the total irrigation depth from 296mm to130mm. It was demonstrated that the control of surface drainage during the initial stage might be the most critical factor in non-point source loading reduction from paddy rice fields, because its strength can be high due to the large amount of basal fertilization.