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Analysis of Nutrient Dynamics and Development of Model for Estimating Nutrient Loading from Paddy Field

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Abstract

To evaluate nutrient dynamics with different fertilization in paddy field and develop water quality model, mass balance analysis was performed during growing season of 2001-2002 in field experimental plots irrigated with groundwater. As a result of water balance analysis, most of outflow was surface drainage as about half of total outflow and about 500mm was lost by evapotranspiration. The water budget was well balanced. The runoff from paddy field was influenced by rainfall and forced drain. Especially runoff during early cultural periods more depends on the forced drain. As a result of mass balance analysis, most of nutrient was input by fertilization and lost by plant uptake. Significant amount of nitrogen were supplied by precipitation and input from upper paddy field, comprising 12% ~ 28% of total inflow. Nutrient loading by surface drainage was occurred showing about 15% ~ 29% for T-N and 6% ~ 13% for T-P. The response of rice yield with different fertilization was not significant in this study. Water quality model for paddy field developed using *Dirac delta function* and continuous source was calibrated and validated to surface water quality monitoring data. It demonstrates good agreement between observed and simulated. The nutrient concentration of surface water at paddy field was significantly influenced by fertilization. During early cultural periods when significant amount of fertilizer was applied, surface drainage from paddy field can cause serious water quality problem. Therefore, reducing surface drainage during fertilization period can reduce nutrient loading from paddy fields. Shallow irrigation, raising the weir height in diked rice fields, and minimizing forced surface drainage are suggested to reduce surface drainage outflow.

Keywords : Nutrient dynamic, Water balance, Paddy field, Water quality model

I. Introduction

Rice accounts for 21%, 14% and 2% of global energy, protein and fat supply, respectively. More than 90% of the world's rice is produced and consumed in Asia (Barker and Herdt 1983; IRRI 1989). Rice is a crop that requires ponded depth in paddy field during growing season. In

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some area, the amount of rainfall is sufficient to meet crop water requirements. At many other locations, rainfall is inadequate or poorly distributed and crop water requirements are supplemented by irrigation. More than 80% of the developed freshwater resources in Asia are used for irrigation purpose and of this, more than 90% of the total irrigation water is used for rice production (Khepar et al. 2000). Increasing attention is being paid to irrigation water management of paddy field both because of its importance for food production and its huge water use.

Nowadays many countries have increasingly emphasized watershed based assessment and integrated analysis of point and nonpoint source. Nonpoint source pollution is closely related with land use and rainfall events. Among the land use in Korea, paddy field is primary land use performed human activity as about 11% of total land use so the drainage water from paddy fields is suspected as a key pollution source due to the widespread use of chemical fertilizers. However, some studies have suggested that paddy fields can have beneficial effects, including water quality improvement, air cooling and refreshing, groundwater recharge, and soil erosion control (Eom, 2001). Simulation models are used extensively in water quality planning and pollution control, and applied to support watershed planning. However, it is limited to apply existing watershed model to Asia monsoon area. The hydrological and environmental characteristics of paddy field differ with those of other land-use type. The function of retaining water can reduce surface runoff and increase interflow, percolation and groundwater table, and drain off can produce surface runoff without rainfall event. The human controls such as dike height, drain off and fertilizer convert the pattern of hydrology and water quality of down stream.

To develop reasonable watershed management, the reactive mechanisms of hydrology and water quality in paddy field must be understood but are very complex. The quantitive analysis for paddy field needs much efforts and time. Some researchers analyzed the water balance (Kampen, 1970; Kitamura, 1988; Watanabe, 1992). Ha et al. (2001) studied the impacts of arochemical fertilizer on the aquatic environmental of paddy fields in Vietnam, and Cho and Han (2000) studied the nutrient losses from a paddy filed in Korea. Hwang et al. (2002) analyzed mass balance in paddy field, and Yoon et al. (2002) evaluated possibility of reuse of reclaimed water for irrigation on paddy rice culture and its effect. Developing models for water balance in paddy field were performed (Khepar et al., 2000; Odhiambo and Murty, 1996; Wu et al., 2001). Chung et al. developed GLEAMS-PADDY model, which modified GREAMS model, for estimating nutrient loading from paddy field. However, the studies about paddy field conducted recently, and the requirement of water quality model for paddy field is increasing to find out mechanism in paddy field and to evaluate the BMP for paddy field.

In this paper an attempt has been made to analyze water and nutrient balance components in paddy fields under a groundwater irrigation system during 2001 – 2002. A water quality model developed to predict the pollutant loading from paddy field was applied to an experimental site, and suggestions are made to reduce nutrient loading and its resulting water quality impacts.

Ⅱ. Materials and Methods

1. Site and Crop Management

Field experiments were carried out at experimental farm of the Konkuk University Agircultural Research, Yeoju (37°14′N, 127°33′E, 70 m elevation), Korea during growing season of 2001 to 2002. Fig. 1 shows the layout of study area and location of sampling station. Treatments included three fertilization rates, and the fertilization rate as recommended by the National Institute of Agricultural Science and Technology of Korea was applied to the excessive fertilization plot (SF; 165N kg ha^{-1}, 15P kg ha^{-1}), standard fertilization plot (EF; 110N kg ha^{-1}, 10P kg ha^{-1}), and reduced fertilization plot (RF; 77N kg ha^{-1}, 7P kg ha^{-1}). P and K were applied at transplanting, but N was applied at three different times (Table 1).

2. Measurements

Ponded water depth in each experimental plot

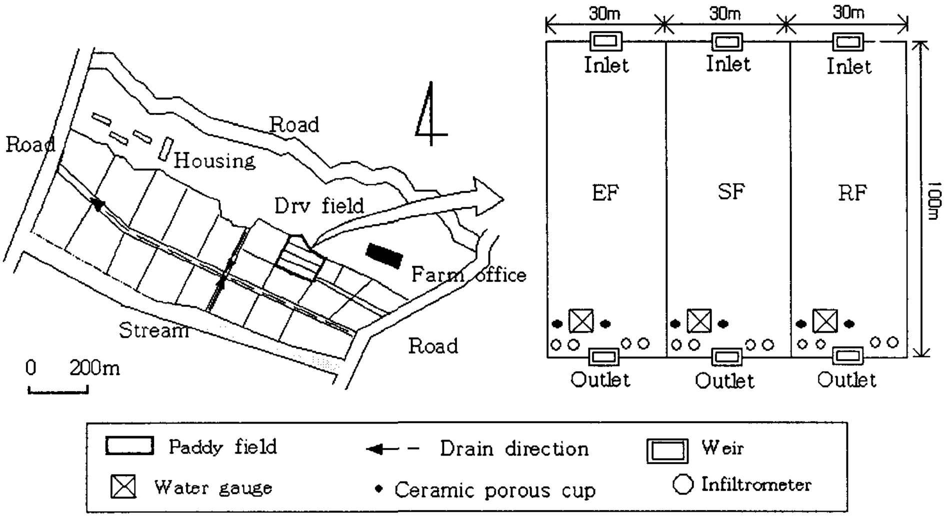


Fig. 1 Layout of the study area and location of sampling stations

Table 1 Agricultural activities during the study period.

2001	2002	Agricultural activity	Remark
May 20	May 17	Plowing and basal fertilization	Phosphorus, Nitrogen
May 29	May 27	Rice transplanting	15×30cm, four plants/hill
June 9	June 7	Tillering fertilization	Nitrogen
July 17	July 26	Panicle fertilization	Nitrogen
October 7	October 12	Harvest	-

was measured continuously by an automatic water level recorder, and inflow and outflow were measured using weirs installed at the inlet and outlet of each plot, respectively. The infiltration was measured by four infiltrometers, and percolation water was sampled via two ceramic porous cups. Water samples were conducted every two week, and analyzed by the Standards Methods (APHA, 1995). Rice plant samples were collected at harvest, and analyzed by the methods of Allen *et al.* (1986).

3. Mass Balance for Water and Nutrients

Water balance in paddy fields was estimated by the variation in ponded water depth (W), expressed in the form:

$$W_j = W_{j-1} + IR_{1j} + IR_{2j} + PR_j - (DR_j + ET_j + INF_j) \cdots\cdots (1)$$

where W_j is ponded water depth, W_{j-1} is ponded water depth on the previous day, IR_{1j} is amount of groundwater irrigation, IR_{2j} is amount of cascade inflow from upper paddy field, PR_j is rainfall, DR_j is surface drainage through weir, ET_j is evapotranspiration, and INF_j is deep percolation. The subscript j represents the j^{th} day and all parameters are expressed in millimeters.

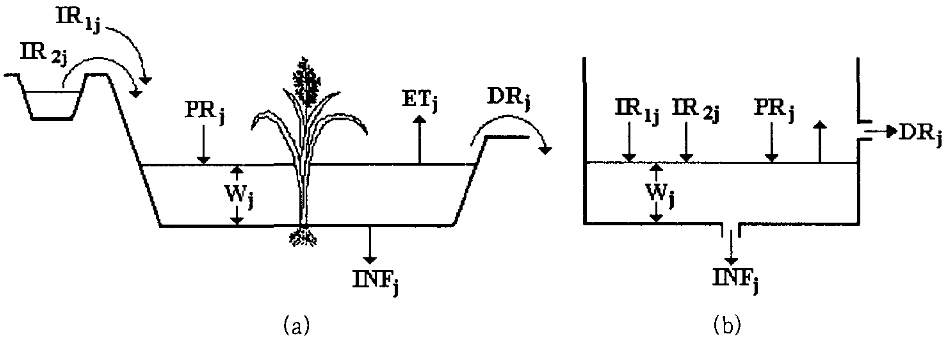
The nutrient inflow to the paddy fields was grouped into natural supply and fertilization, where natural supply included atmospheric deposition and irrigation water, and fertilization included mineral and organic sources. Nutrient outflow included surface drainage through the weir, deep percolation, and plant uptake. The general mass balance equation for both nitrogen and phosphorus was approximated in this study as:

$$I_{IR1} + I_{IR2} + I_{PR} + I_{FER} = O_{DR} + O_{INF} + O_{HRV} \cdots\cdots (2)$$

where I_{IR1} is inflow from groundwater irrigation, I_{IR2} is cascade inflow from upper paddy field, I_{PR} is inflow from rainfall, I_{FER} is inflow from fertilization, O_{DR} is outflow through surface drainage, O_{INF} is outflow through deep percolation, and O_{HRV} is outflow through plant harvest.

4. Model Development

The water balance concept in this model for paddy field was shown in Fig. 2. The inflow to the paddy field consists of irrigation, input from



(a) (b)

Fig. 2 Water balance concept in paddy field (a) and this model (b) upper paddy field and rainfall, and the outflow consists of evapotranspiration, infiltration and surface runoff.

Penman – Montheith equation and crop coefficient were applied for estimating actual evapotranspiration. Runoff and infiltration are calculated by ponded depth and coefficient function. Each equation is followed:

$$ET = PET \times K_c \quad \cdots\cdots (3)$$

$$DR = (W - D) \times a_1 \quad \cdots\cdots (4)$$

$$INF = W \times a_2 \quad \cdots\cdots (5)$$

Where, PET is potential evapotraspiration, K_c is a crop coefficient, D is depth of ridge, a_1 is coefficient for drainage and a_2 is coefficient for deep percolation.

Main nutrient loading in paddy field is fertilizer applied similar date and component, and retained water was drain off when the plant is harvested. This agricultural activity is recycle every year. To simulate water quality in paddy field in this study, assumptions of this model are followed;

- Paddy field is a completely mixed system, continuously stirred tank reactor (*CSTR*).
- Water quality concentration is same in daily (daily continuous model)
- Simulated water quality item is T–N and T–P
- Simulated pollutant sources in paddy field are fertilization and sediment release

5. Fertilization

Fertilization can be represented as impulse loading. Mathematically the *Dirac delta function* (or *impulse function*) δ(t) has been developed to represent such impulse loading (Chapra, 1997). The delta function can be visualized as an infinitely thin spike centered at t = 0 and having unit area. It has the following properties (Fig. 3): The particular solution for *Dirac delta function* is

$$c = \frac{m}{V} e^{-\lambda} \quad \cdots\cdots (6)$$

Where, c is concentration, m is quantity of pollutant mass, V is system's volume, λ is eigenvalue.

This solution indicates that the fertilizer is instantaneously distributed throughout the water body of paddy field, resulting in an initial concentration of m/V. Thereafter the result is identical to the general solution; that is, the

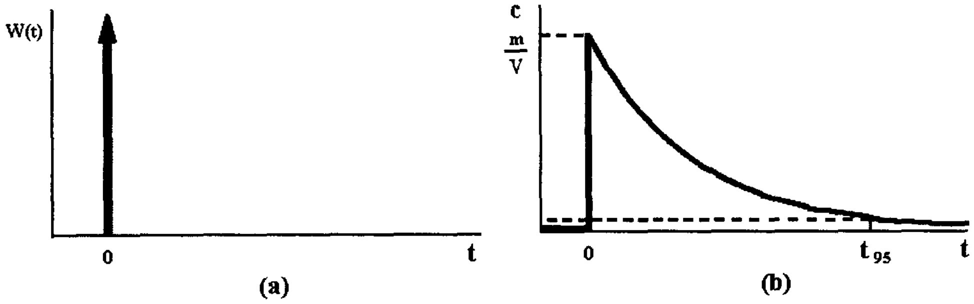


Fig. 3 Loading and concentration plot of impulse loading

concentration decreases exponentially at a rate dictated by the magnitude of λ.

6. Sediment Loading

If irrigation water inputs paddy field, nutrient concentration increase because of sediment release and reach certain concentration. Such behavior is given mathematical expression by the new continuous source (Chapra, 1997). The particular solution for this case is

$$c = \acute{c}\,(1 - e^{-\lambda t}) \cdots\cdots (7)$$

As depicted in Fig. 4 this solution starts at zero and then asymptotically converges on a new steady-state concentration.

Ⅲ. Results

1. Water Balance

Table 2 and Table 3 show the water balance

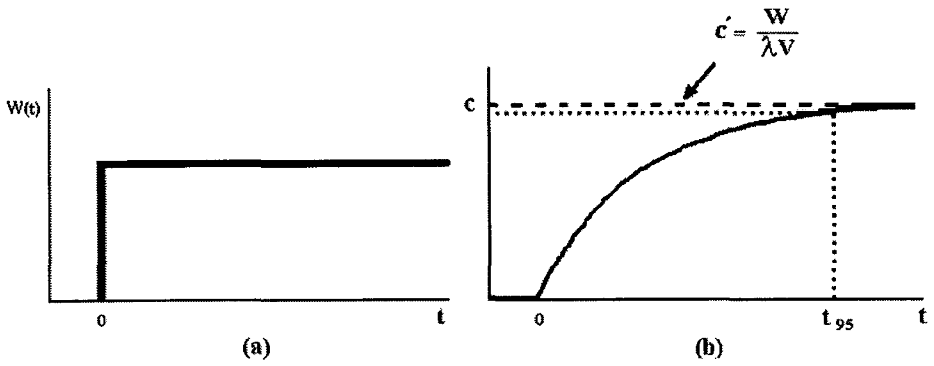


Fig. 4 Concentration plot of step loading

Table 2 Water balance summary in the treatment plots during study period

Plots		Inflow (mm)				Outflow (mm)			
		IR1	IR2	PR	Total	DR	INF	ET	Total
2001	EF	295.1 (29)	207.6 (20)	511.3 (50)	1,014.0 (100)	507.2 (44)	73.0 (7)	490.9 (46)	1,071.1 (100)
	SF	119.6 (11)	413.1 (40)	511.3 (49)	1,043.9 (100)	593.21 (51)	75.91 (7)	486.23 (42)	1,155.34 (100)
	RF	164.48 (15)	434.47 (39)	511.30 (46)	1,110.26 (100)	648.45 (53)	77.80 (6)	492.55 (40)	1,218.80 (100)
2002	EF	883.74 (46)	214.60 (11)	865.40 (43)	1,963.74 (100)	1,254.72 (70)	82.84 (4)	527.81 (26)	1,865.38 (100)
	SF	787.25 (42)	213.26 (11)	865.40 (46)	1,865.91 (100)	1,036.16 (63)	93.02 (6)	527.81 (32)	1,656.99 (100)

IR1 is irrigation, IR2 is input from upper paddy field, PR is precipitation, DR is surface drainage
INP is percolation, ET is evapotranspiration

Table 3. Monthly water balance summary in standard plot during study period

		Inflow (mm)				Outflow (mm)			
		IR1	IR2	PR	Total	DR	INF	ET	Total
2001	May	54.1	102.7	7.0	163.8	143.1	23.2	51.0	217.3
	Jun.	65.5	41.9	212.5	319.9	192.2	32.9	100.0	325.1
	Jul.	0.0	257.6	202.4	460.0	243.1	5.5	160.6	409.2
	Aug.	0.0	11.0	89.4	100.4	14.8	14.4	174.7	203.9
	Sep.	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
	Sum (%)	119.6 (25)	413.1 (40)	511.3 (46)	1,044.0 (100)	593.2 (51)	76.0 (7)	486.3 (42)	1,155.5 (100)
2002	May	151.7	0.0	7.0	158.7	0.0	23.1	58.6	81.7
	Jun.	61.6	0.0	61.4	123.0	0.0	33.8	111.9	145.7
	Jul.	0.0	461.6	217.2	678.8	452.9	13.8	137.1	603.8
	Aug.	0.0	325.6	531.6	857.2	583.3	14.9	135.0	733.3
	Sep.	0.0	0.0	48.2	48.2	0.0	7.4	85.2	92.6
	Sum (%)	213.3 (11)	787.2 (42)	865.4 (46)	1,865.9 (100)	1,036.2 (63)	93.0 (6)	527.8 (32)	1,657.0 (100)

for each treatment and monthly water balance for standard plot, respectively. Total water inflow ranged from 1,014~1,964 mm, about 43~50% supplied by rainfall and about 49~57% supplied by irrigation and input from upper paddy field. Total water outflow ranged from 1,071~1,865 mm and closed balanced with total water inflow. Infiltration and evapotranspiration were maintained regular amount about 80 mm and 500 mm, respectively. However, surface drainage runoff depended on amount of precipitation, and ranged from 507~1,255 mm (44~70%) during study periods.

2. Mass Balance

With a limited nutrient supply, there is maximum dilution of the nutrient in the plant, and uptake was replaced by other source such as rain or soil. Conversely, when the supply of a nutrient is large, the internal nutrient concentration is high, and there is maximum accumulation (Dobermann et al., 1998). In this study, because soil were still rich in these nutrients, and flooding was thought to increase their supply, yield responses to fertilizer N and P were small (Table 4). This situation was reported by other studies (De Datta and Mikkelsen, 1985). However, long-terms application of reduced fertilization can occurs nutrient deficiency, so plant uptake will sensitively respond to amount of fertilizer. The T-N inflow was mainly supplied by the three applications of fertilizer (67~92%). In addition, significant amounts were supplied by precipitation and from the upper paddy field, comprising 7~32 % of the total inflow. Groundwater irrigation did not contribute much to the nutrient loading because of its relatively clean water quality. Although most of the nutrient outflow was attributed to plant uptake (70~94%),

Table 4 Nutrient mass balance summary in the treatment plots during study period

Items			Inflow (kg ha^{-1})					Outflow (kg ha^{-1})			
			Fertilizer	IR1	IR2	Rainfall	Total	DR	INF	Harvest	Total
T-N	2001	EF	165.00 (92)	1.33 (1)	4.47 (2)	9.05 (5)	179.85 (100)	21.83 (15)	2.12 (1)	126.27 (84)	150.11 (100)
		SF	110.00 (86)	0.76 (1)	8.47 (7)	9.05 (7)	128.29 (100)	32.75 (21)	5.20 (4)	115.95 (75)	153.89 (100)
		RF	77.00 (78)	1.05 (1)	12.03 (12)	9.05 (9)	99.14 (100)	32.46 (23)	5.32 (4)	105.63 (73)	149.23 (100)
	2002	EF	165.00 (74)	1.37 (1)	41.94 (19)	15.32 (7)	223.64 (100)	51.61 (29)	2.29 (1)	122.66 (70)	176.58 (100)
		SF	110.00 (67)	1.36 (1)	37.70 (23)	15.32 (9)	164.38 (100)	33.21 (21)	2.21 (1)	125.95 (78)	161.37 (100)
T-P	2001	EF	29.46 (98)	0.10 (9)	0.43 (1)	0.20 (0)	30.20 (100)	1.13 (6)	0.00 (0)	18.49 (94)	19.62 (100)
		SF	19.64 (95)	0.06 (0)	0.67 (3)	0.20 (1)	20.57 (100)	2.00 (10)	0.00 (0)	17.56 (90)	19.56 (100)
		RF	13.75 (93)	0.08 (1)	0.78 (5)	0.20 (1)	14.82 (100)	1.27 (7)	0.00 (0)	16.81 (93)	18.08 (100)
	2002	EF	29.64 (90)	0.11 (0)	1.74 (8)	0.35 (2)	21.84 (100)	2.51 (13)	0.00 (0)	17.03 (87)	19.54 (100)
		SF	9.64 (91)	0.11 (0)	1.57 (7)	0.35 (2)	21.66 (100)	1.25 (7)	0.00 (0)	16.94 (93)	18.19 (100)

nutrient loss by surface drainage was substantial showing about 15~29 % for T−N, 6~13 % for T−P. However, we could not find remarkable responses of yield and drainage outflow to fertilization.

3. Model Calibration and Validation

The comparisons between observed and predicted ponded depth, runoff, nutrient concentration are shown as Fig. 5. The mean error (AE) of ponded depth, TN and TP concentration were 0.81 mm, −0.11 mg/L and −0.06 mg/L, and the model efficiencies (EF) were 0.93, 0.98 and 0.95, respectively (Table 7). The parameters of TN loading by fertilization (m_1, m_2, m_3) were 47 kg/ha, 34 kg/ha and 19 kg/ha, respectively, and these values are similar with actual TN fertilization, which is 55 kg/ha, 33 kg/ha and 22 kg/ha, respectively. However TP was smaller than actual fertilization. The TN decay rates of fertilization was little differ $\lambda_1$and λ_2 with λ_3 as 0.04, 0.03 and 0.17, respectively. It indicates that the TN decay during July more fast than during May−June, because high temperature stimulate ammonium volatization and more efficient plant uptake. In the $\hat{c}$ parameters, the background concentrations of TN and TP in paddy field were

Table 5 Monthly nutrient mass balance in standard plot during study period

			Inflow (kg ha^{-1})				Outflow (kg ha^{-1})		
			Fertilizer	Rainfall	IR1	IR2	DR	INF	Harvest
TN	2001	May	55.00	0.12	0.35	4.18	24.76	1.71	0.00
		Jun.	33.00	3.76	0.42	0.31	2.95	2.21	0.00
		Jul.	22.00	3.58	0.00	3.71	4.66	0.35	0.00
		Aug.	0.00	1.58	0.00	0.28	0.39	0.92	0.00
		Sep.	0.00	0.00	0.00	0.00	0.00	0.00	115.95
		Total	110.00	9.05	0.76	8.47	32.75	5.20	115.95
	2002	May	55.00	0.12	0.97	0.00	0.00	0.78	0.00
		Jun.	33.00	1.09	0.39	0.00	0.00	0.98	0.00
		Jul.	22.00	3.84	0.00	22.01	21.84	0.17	0.00
		Aug.	0.00	9.41	0.00	15.69	11.37	0.24	0.00
		Sep.	0.00	0.85	0.00	0.00	0.00	0.04	125.95
		Total	110.00	15.31	1.36	37.70	33.21	2.21	125.95
TP	2001	May	19.64	0.00	0.03	0.16	1.35	0.00	0.00
		Jun.	0.00	0.09	0.03	0.15	0.12	0.00	0.00
		Jul.	0.00	0.08	0.00	0.34	0.53	0.00	0.00
		Aug.	0.00	0.04	0.00	0.02	0.01	0.00	0.00
		Sep.	0.00	0.00	0.00	0.00	0.00	0.00	17.56
		Total	19.64	0.20	0.06	0.67	2.00	0.00	17.56
	2002	May	19.64	0.00	0.08	0.00	0.00	0.00	0.00
		Jun.	0.00	0.02	0.03	0.00	0.00	0.00	0.00
		Jul.	0.00	0.09	0.00	0.91	0.55	0.00	0.00
		Aug.	0.00	0.21	0.00	0.65	0.70	0.00	0.00
		Sep.	0.00	0.02	0.00	0.00	0.00	0.00	16.94
		Total	19.64	0.35	0.11	1.57	1.25	0.00	16.94

4.01 mg/L and 0.15 mg/L respectively.

As shown the Fig. 5 the nutrient concentration appeared high during early cultural periods, and was low when mainly outflow occurred by forced drainage and heavy rainfall. Some studies reported ammonia nitrogen concentrations in surface water of paddy field were as high as 25~100 mg/L during the initial periods of irrigation and fertilization (Takamura et al., 1977). Although fertilizer inputs in paddy field, high amount of nitrogen is loss by adsorption, volatilization and denitrification. A percolation rate less than 30 mm/day may sufficiently eliminate fertilizer nutrients from water by percolation and ammonia volatilization losses as high as 60% of applied nitrogen (Ghosh and Bhat, 1998; Ishikawa et al., 2002). The initial phosphorus flush is followed subsequently by a decrease from sorption or precipitation of Fe (II)-P compounds (Kirk et al., 1990). This result show the reducing surface drainage during fertilization period can abate non-point source loading effectively from paddy field, and explain the reason why we could not find the response

Table 6 The input parameter

Description	Symbol	Unit	Value
Water balance			
Infiltration coefficient	a_1	-	0.008
Runoff coefficient	a_2	-	0.80
Nitrogen			
Loading by fertilization (basal, tillering, panicle)	m_1, m_2, m_3	kg/ha	47, 34, 19
Decay rate of fertilization	λ_1, λ_2, λ_3	-	0.04, 0.03, 0.17
Concentration by sediment	ć	mg/L	4.01
Sediment loading coefficient	λ_s	-	0.01
Phosphorus			
Loading by fertilization	m	kg/ha	5.4
Decay of fertilization	λ	-	0.2
Concentration by sediment	ć	mg/L	0.15
Sediment loading coefficient	λ_s	-	0.13

Table 7 The statistics results of model performance for ponded depth, and surface TN and TP concentration

	Ponding depth (mm)	TN (mg/L)	TP (mg/L)
Mean error (AE)	0.81	-0.11	-0.06
RMS error (RMSE, %)	16.45	21.88	52.49
RMS (%)	11.48	1.99	0.24
Model fit efficiency (EF)	0.93	0.98	0.95

of nutrient drainage outflow to fertilization (Table 4).

Ⅳ. Discussion

Large amount of nutrient and water was consumed by rice culture, and substantial amount are lost through surface drainage without being used by rice plant. Nutrients lost with surface drainage water flows into a receiving water body and can cause eutrophication and excessive algal growth problems. Phosphorus and nitrogen are of more concern because they are essential plant nutrients, and often becomes a limits to algal growth. In these aspects, the rice culture is more focus on the water resource and watershed pollutant management recently. In this study we analyzed water and nutrient mass balance, and developed water quality model for paddy field drainage.

We can find from Table 2 that the surface drainage was over half the total water inflow loss, surpassing even evapotranspiration. The surface drainage was more influenced by rainfall and forced drainage, and the surface runoff at early agricultural periods in 2001 was caused by forced drainage although similar inflow with 2002 (Table 3). The obvious best management practices (BMPs) of paddy field area can be explained by Table 5 and Fig. 5. The key point of reducing nutrient loading is restraining surface runoff during early rice culture periods. Nutrient concentration of surface water was very high during

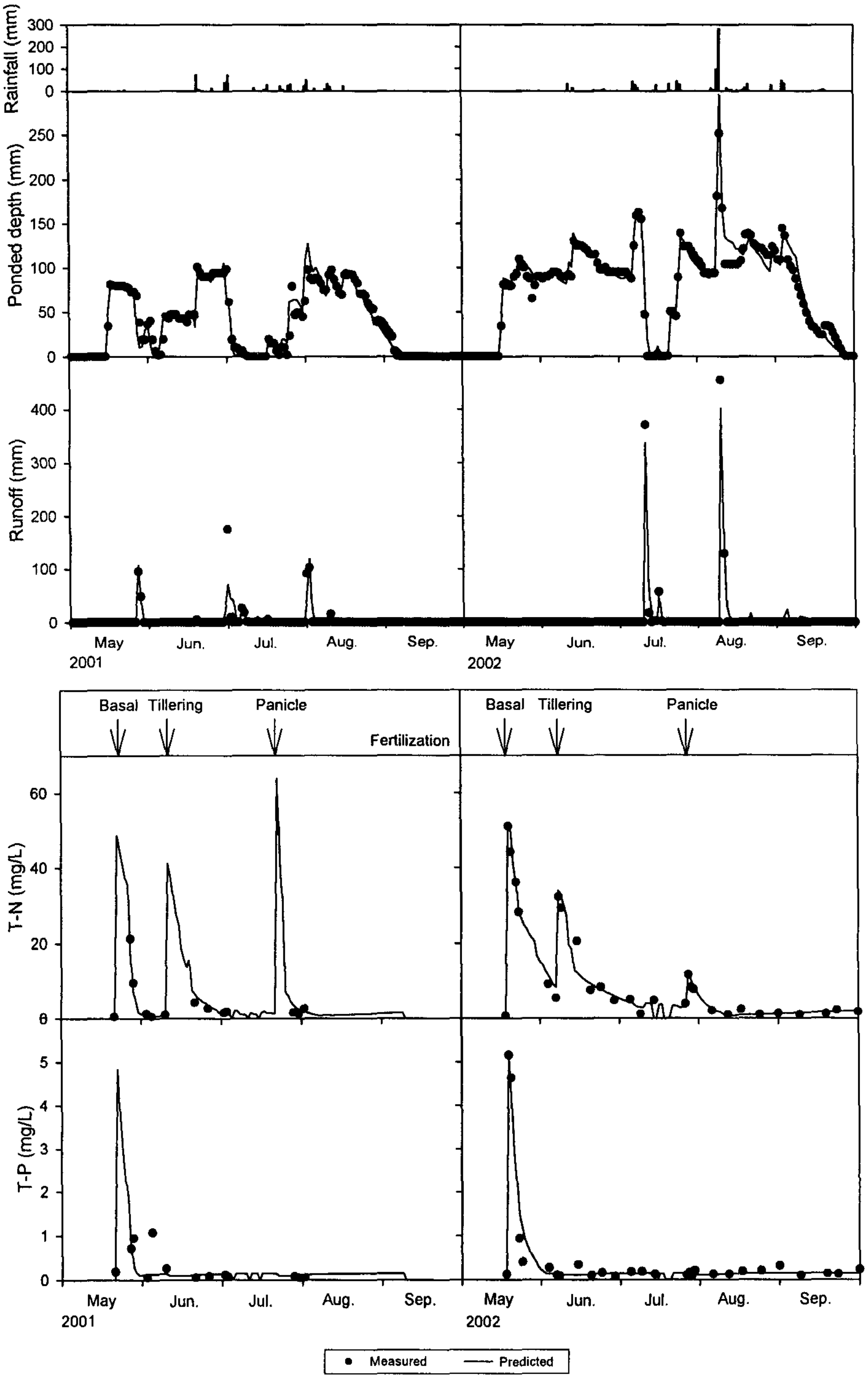


Fig. 5 Observed and simulated surface runoff and nutrient concentration in paddy field

May–June because of fertilization in paddy field. The surface runoff of high nutrient concentration and high nutrient loading occurred during May in 2001 caused by forced drainage so the impact of paddy field drainage on water body in 2001 is much more than in 2002.

Saving water by limiting inflow and restricting forced drainage can be a possible alternative to reduce surface drainage and nutrient loading if possible rice production is not significantly affected. Bouman and Tuong (2001) reported that increasing water productivity by reducing ponded water depth from 5(10 mm to the level of soil saturation did not reduce land productivity too much, where 23 % water savings caused 6 % yield reductions. Raising drainage weir height in diked rice fields can increase rain water storage by reducing excess flow from the field and reducing rainfall excess through surface drainage. A 3–years experimental study (Mishra et al., 1998) in India with weir heights of 6 and 30 cm at an interval of 4 cm revealed that about 56.75 % and 99.5 % of the rainfall could be stored in 6 cm and 30 cm weir height plots, respectively, without significant impact on grin yield. The weir height in this study varied, with 10 cm maintained most of time. It could be raised further to save rainwater and reduce surface drainage if necessary.

In the developing water quality for paddy field drainage, how can explain the change of nutrient concentration after fertilization is very important. However, the agricultural activity, such as irrigation – fertilization – forced drain – drain off – harvest, recycle every year, and past pollutant loading can not effect future water quality because of drain off before harvest. So water quality model for paddy field could be developed using simple react equation. In this study, the effects of fertilization and release from sediment were used by ***Dirac delta function*** and continuous source function, respectively, and the calibrated and validated model demonstrates good agreement with observed data and high modeling efficiency. So this model can be used to establish BMPs for paddy field area.

Ⅴ. Conclusion

The water quality of paddy field was influenced by fertilization, so high nutrient concentration appears early rice culture period from May to June. Surface runoff from paddy field depends on the rainfall and forced drainage. If the runoff occur in May, high nutrient loading may inflow water body, and cause eutrophication. However, the runoff at early rice culture period is more caused by human activity such as forced drainage because of low amount of rainfall. The high nutrient concentration loading from paddy field can be controlled by BMPs. water–saving irrigation, raising drainage weir height in diked rice fields, and minimizing forced surface drainage are suggested measures to reduce nutrient loading form paddy field. The possible benefits might include 1) reduced irrigation water use and more efficient water resources allocation, 2) increased storage of rainwater with resulting flood prevention and groundwater recharge effects, 3) reduced nutrient loss i.e. reduced nutrient loading and less water quality problems. Further study is recommended to examine possible impacts, nitrogen fixation by living biota for the inflow and volatilization and denitrification for the outflow, especially on land productivity of rice.

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