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Nitrogen and Phosphorous Movement Characteristic in Terrace Paddy Field Using Cascade Irrigation System in West Sumatra, Indonesia

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ABSTRACT

West Sumatra is one of Indonesian rice bowl. The landscape of this province dominated by mountainous area with beautiful terrace paddy field lied from the middle slope to the lowland. The most common rice cultivation management in this area is application of cascade irrigation system with blanked amount of chemical fertilizer application. This study intends to figure out, whether this kind of paddy field management sustains and friendly to the environment or not. The results showed that cascade irrigation system created some discrepancies in suspended solid (SS), dissolve organic matter (DOM) and the nutrient movement characteristic a long the slope. The SS and DOM load and discharge strongly influenced by land preparation activities, while total and available nitrogen (N) and phosphorous (P) affected by chemical fertilizer application. In the upper part, the amount of chemical fertilizer seemed sufficient, indicated by negative amount of nutrient balance, while lower terrace show some indication of excess nutrient input. To avoid some demerit of cascade irrigation system, chemical fertilizer application should be base on site specific characteristic and taking into account of natural source contribution.

Keywords: Cascade irrigation, chemical fertilizer, nutrient balance, terrace paddy field

INTRODUCTION

Indonesia is the third rice producing countries in the world after China and India. In 2007, China produced 185.5 million tons rice, followed by India (141.2 million tons) and Indonesia (57.1 million tons) (IRRI 2008). In case of Indonesia, rice is the major calorie intake for more than 230 million people which consume about 250 kg rice per capita per year (Indonesia Ministry of Agriculture 2010). To supply rice for such huge population, the food grain produced in 7.8 million hectare paddy field distributed in the whole country, including West Sumatra. Although total paddy field area in West Sumatra just about 250 thousand hectare, but due to the high productivity this province has been supplied rice to other province nearby.

West Sumatra lies in equator line and enjoys rain and sun shine whole year round. Since the landscape of this province dominated by mountainous area, cascade irrigation system has become the main choice to irrigate large amount of terrace paddy field in this region. Cascade irrigation system indicates by continuous water flow from upper to lower terrace pass-through paddy field. Agus *et al.* (2006) recorded that sediment gain in terrace paddy field in Indonesia ranged from 2 to 5.4 Mg ha^{-1} per cropping season. The flowing water is not just bringing the soil particle, but also some amount of nutrients as well. Sediment transported from upper terrace mostly deposited in the next few plots downward.

Rice, like other crops, needs 16 essential elements that must be present in optimum amounts and in forms available by rice plants for proper growth. Among these elements, nitrogen, phosphorus, and potassium are most commonly applied as fertilizer by rice farmers, and a major portion of these nutrients is taken up by rice plants as they grow to harvest size (Lee 2001; Lansing *et al.* 2001). An important question is whether or not cascade irrigation system brings substantive amounts of nutrients from upper terrace to the lower and whether these nutrients contributes to lake eutrophication and algal bloom problems. Some studies have suggested that paddy field can have beneficial effects, including water quality attenuation, air cooling and refreshing, groundwater recharge, and soil erosion control (Eom 2001; Kwun 2002).

Phosphorus (P) and nitrogen (N) are two kinds of nutrient which intensively added as chemical fertilizers in Indonesia. In order to support food security program, the Indonesian government urged farmers to plant rice in monoculture system and apply 200 kg Urea, 125 kg Triple Super-phosphate and 100 kg potassium chloride per hectare per cropping season (Lansing *et al.* 2001). Both phosphorous and nitrogen are essential elements for plant growth. High phosphate and nitrogen input in intensive agricultural area have been practice for several decades and resulted in enrichment of P and N in soil profiles (Sharpley *et al.* 1994). It is recognized that agricultural activities have contributed to the non-point pollution of inland waters, and constituted an important environmental issue.

Even though a number of study report about the loading of P and N from agricultural lands, but there is no any information discuss about the movement characteristic of these element in intensive paddy field occupied by cascade irrigation system (Tabuchi and Hasegawa 1995; Tabuchi and Takamura 1985; Kudo *et al.* 1995). The main purpose of this research was to study the characteristic of P and N movement in intensive terrace paddy field occupied by cascade irrigation in West Sumatra, Indonesia.

MATERIALS AND METHODS

Study Site Characteristic

This study was conducted in Solok district, one of rice production center in West Sumatra. The area located is about 80 km Southeast Padang, the capital of West Sumatra Province. This intensive old paddy field lies at 650 meter above sea level and receive about 3,500 mm precipitation which evenly distribute throughout the year. The original soil type is Inceptisols with pH 5.4 (1:2.5 soil water ratio) and particle size distribution of 3.2% sand, 45.7% silt and 51.1% clay with organic matter content 27 g kg^{-1}, total nitrogen 1.4 g kg^{-1}, available nitrogen (NO_3-N + NH_4-N) of 0.12 g kg^{-1}, total phosphorous 0.37 g kg^{-1} and available phosphorous 8.9 mg kg^{-1}. To examine the nutrient movement from upper to lower terrace, 10 x 4 m^2 plot were prepared on each terrace position with cultivation management follow farmer system.

Treatment and cropping

Five consecutive terraces from the closest to irrigation canal downward used as study plot and named as terrace I to V. To prevent the lateral water flow, plastic membrane was inserted in the soil to 25 cm depth at the edge of plots bund. Land prepared manually by using hoe three days before transplanting. Basal fertilizer applied in the transplanting day with dose of government recommendation. Irrigation water was supply every four days, except on the planting day, where irrigation stopped completely. To avoid the surface run-off in the end plot, irrigation stopped after the depth of standing water in the last plot was attained. Irrigation was also terminated in case of heavy rain to prevent the excess water supply. All land management method used in this study followed the local farmer's practices. Land preparation, transplanting, fertilization, weeding were done manually by man power. Soil plowed two times followed by top dressing fertilizer application. Fertilizers were applied according to practice for rice cultivation urged by the district government prior to ploughing at the rate of 200 kg Urea ha^{-1} (half applied at 52 day after planting), 125 kg Super-phosphate and 100 kg potassium chloride. Month-old rice seedlings (*Anak daro*, local variety) were transplanted 25 cm by 25 cm wide. Three days after transplanting, irrigation water was sent into paddy field up to the ponded level (about 5 cm). After that, each plot followed the treatment guide from 18 April to 30 July, 2009.

Sampling

Water sample was taken in the beginning, middle and the end of irrigation and drainage period at the water inlet and outlet, respectively; except for land preparation period. Sample for this period were taken within three days, when the land preparation is undertake. Therefore, all samples have three sub-samples. Then the sub-samples were mixed and treat as a single sample.
In order to calculate total nutrient and dissolve organic matter (DOM) movement, samples were divided into particulate (sediment load) and water sample by filtering them using Whatman 42 filter paper. The sum of them was calculated as a total movement of a parameter examined in this study.

Measurement and Samples Analyses

To study the characteristic of nutrient movement from the upper plot to the lower, irrigation water was supplied every 4 days. The water standing depth was monitored by using HOBO U-20 Water Level Logger. The water and suspended solid samples collected from the inlet (for irrigation) and outlet (for drainage) of each study plot in the beginning, middle and the end of irrigation period by using 500 ml plastic bottles. These samples were kept at cool storage for chemical analyses. To measure the amount of rain fall, PVC tank was set up in the middle of study plots. Four excess rain falls were occurred during the study period (12, 28, 68 and 100 days after transplanting). To avoid surface run-off, irrigation water was terminated in ach moment of heavy rain.

To measure the rate of infiltration, two lysimeters were set up in each study plots, close to water inlet and outlet. The rate of vertical water movement was very slow (less than 0.5 cm a day). Due to this condition, the amount nutrient loss through water infiltration was excluded from the nutrient movement calculation.

Laboratory Analyses and Calculation

All samples collected were divided into suspended solid and water by filtering them using Whatman 40 filter paper. The rate of suspended solid (SS) and water discharged calculated on hectare bases by multiply plot area (40 m^2) with 250. The suspended solid then air dried before proceed to another measurements. Total carbon and nitrogen in suspended solid examined by oven dried soil at 80°C for about 24 hours and then determined by dry combustion method (Nelson and Sommers 1982) using Yanaco CN Corder Model MT-700 (Yanagimoto MFG. Co. Ltd., Kyoto, Japan). Available nitrogen was analyzed by putting six grams of soil in a glass tube and submerged with distilled water and covered with rubber stopper. These tubes were incubated at 30°C for 28 days. After incubation, the inorganic nitrogen of soil was extracted with 2 M KCl and the content was determined by steam distillation method with MgO and Devarda alloy (JSSPN, 1986). Available P was extracted by Bray 2 method and the content was determined by colorimetry using UV/VIS Spectrophotometer (Jasco V-530) (Bray and Kurtz 1945). Total P was determined by extracted air dried soil with a H_2SO_4-NaOH method (Bowman 1989).

RESULTS AND DISCUSSION

The nutrient movement characteristic seemed influenced by irrigation water quality, land management activities and weather condition (Table 1 and 2). The rate of suspended solid (SS) load into study plot highly varied except for terrace I. Due to heavy rain, the irrigation channel in terrace I was closed at 12 day after planting (DAP+12), DAP+28, DAP+68, DAP+100 and DAP+112. The irrigation water into terrace I was totally terminated from DAP+104 as rice plant approach the drying period for harvest. Although the irrigation water was stopped at most upper terrace, small amount of SS was still found move downward by excess water into the lower terrace in every rain moment.

The seasonal amount of SS consignment into terrace I ranged from 46.1 to 54.5 kg ha^{-1} at DAP+38 and DAP+96, correspondingly. The disparity of SS load in this terrace was not as wide as recorded in the lower position. On the other hand, the rate of SS movement (exclude for rain moment) into terrace II, III, IV and V ranged from 44.9 to 56.2 kg ha^{-1}, 40.1 to 57.0 kg ha^{-1}, 37.5 to 61.9 kg ha^{-1} and 36.2 to 62.7 kg ha^{-1}, respectively, while in drainage water it was ranged from 20.8 to 63.7 kg ha^{-1}. Since terrace I received water directly from irrigation channel,

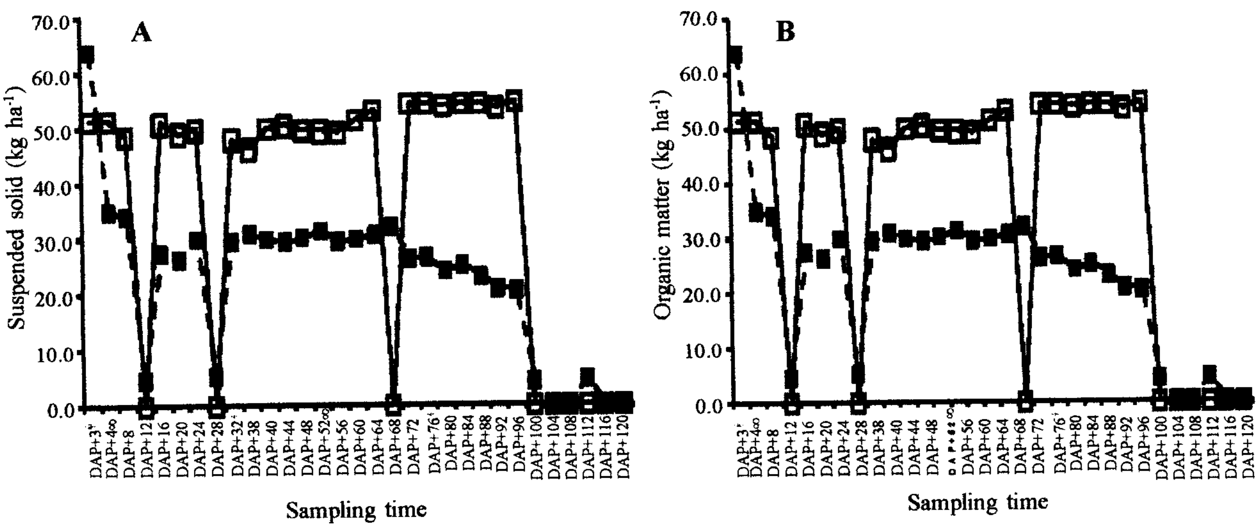

Figure 1. Seasonal transport of suspended solid (A) and organic matter (B) into and out of terrace paddy field through irrigation (IR = —□—) and drainage (DR = - ■ -) water (kg ha^{-1}) within a rice cropping season.

Table 1. Effect of cascade irrigation system on seasonal load and discharge of suspended solid (SS) and organic matter (OM) in irrigation and drainage water within a rice cropping season.

Sampling time	Suspended solid in irrigation and drainage water (kg ha^{-1})						Organic matter suspended solid in irrigation and drainage water (kg ha^{-1})					
	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage
DAP-3‡	51.4	55.3	57.0	61.9	62.7	63.7	1.90	2.00	2.11	2.29	2.32	2.36
DAP+4∞	51.4	49.1	46.5	46.0	45.5	35.0	1.91	1.82	1.72	1.71	1.69	1.30
DAP+8	48.5	48.2	47.3	46.2	44.4	34.1	1.80	1.79	1.75	1.71	1.64	1.26
DAP+12	IT	6.6	7.7	6.20	5.0	4.60	IT	0.25	0.28	0.23	0.19	0.17
DAP+16	50.8	48.4	47.4	41.8	39.7	27.4	1.47	1.55	1.75	1.79	1.88	1.01
DAP+20	49.0	48.2	46.7	45.6	44.2	26.5	1.64	1.69	1.73	1.79	1.81	0.98
DAP+24	49.7	49.1	48.1	47.0	45.1	30.0	1.67	1.74	1.78	1.82	1.84	1.11
DAP+28	IT	6.2	6.8	5.9	7.1	5.5	IT	0.22	0.25	0.23	0.21	0.20
DAP+32†	47.9	46.3	45.0	44.4	42.8	29.5	1.59	1.64	1.67	1.72	1.77	1.09
DAP+38	46.1	56.2	54.1	51.8	49.0	30.9	1.81	1.92	2.00	2.08	1.71	1.14
DAP+40	49.9	48.1	47.0	46.5	45.8	30.0	1.70	1.72	1.74	1.78	1.85	1.11
DAP+44	50.0	49.4	48.9	47.2	46.6	29.4	1.73	1.75	1.81	1.83	1.87	1.09
DAP+48	49.4	49.0	47.9	47.0	46.5	30.1	1.72	1.74	1.77	1.81	1.83	1.11
DAP+52∞	49.4	48.3	46.6	45.5	44.7	31.4	1.65	1.69	1.73	1.79	1.83	1.16
DAP+56	49.1	47.7	47.0	45.8	44.1	29.5	1.63	1.70	1.74	1.77	1.82	1.09
DAP+60	51.4	49.8	48.6	47.0	45.0	29.8	1.67	1.74	1.80	1.84	1.90	1.10
DAP+64	53.0	52.2	50.9	49.0	48.0	30.7	1.78	1.85	1.88	1.93	1.96	1.14
DAP+68	IT	22.6	25.0	27.8	29.7	32.0	IT	1.03	0.93	1.16	1.17	1.19
DAP+72†	54.2	44.8	42.8	42.5	40.5	26.4	1.50	1.57	1.59	1.66	2.01	0.98
DAP+76	54.2	47.8	46.2	43.4	40.9	26.6	1.51	1.61	1.71	1.77	2.01	0.98
DAP+80	53.8	47.4	45.0	42.6	40.6	24.1	1.51	1.58	1.67	1.76	1.99	0.89
DAP+84	54.2	47.4	44.3	42.2	40.5	25.2	1.50	1.56	1.64	1.75	2.01	0.93
DAP+88	54.2	45.2	40.0	38.8	36.3	23.1	1.35	1.44	1.48	1.67	2.01	0.86
DAP+92	53.5	45.5	40.2	38.5	36.2	21.0	1.34	1.43	1.49	1.68	1.98	0.78
DAP+96	54.5	44.9	40.1	37.5	37.3	20.8	1.38	1.39	1.48	1.66	2.02	0.77
DAP+100	IT	21.0	13.1	10.5	7.8	4.3	IT	0.39	0.49	0.78	0.79	0.16
DAP+104	IT	0.0	0.0	0.0	0.0	0.0	IT	0.00	0.00	0.00	0.00	0.00
DAP+108	IT	0.0	0.0	0.0	0.0	0.0	IT	0.00	0.00	0.00	0.00	0.00
DAP+112	IT	10.6	13.3	9.0	5.0	4.7	IT	0.33	0.49	0.39	0.31	0.17
DAP+116	IT	0.00	0.00	0.0	0.0	0.0	IT	0.00	0.00	0.00	0.00	0.00
DAP+120	IT	0.00	0.00	0.0	0.0	0.0	IT	0.00	0.00	0.00	0.00	0.00
Total	1126.0	1135.2	1093.5	1058.4	1021.0	706.1	35.74	39.16	40.50	42.40	44.42	26.15

IT = Irrigation Terminated, ‡ = land preparation, ∞ = fertilizer application, and † = weeding.

Table 2. Effect of cascade irrigation system on seasonal load and discharge of mineralized nitrogen in SS and in irrigation and drainage water within a rice cropping season.

Sampling time	Suspended solid in irrigation and drainage water (kg ha^{-1})						Organic matter suspended solid in irrigation and drainage water (kg ha^{-1})					
	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage
DAP-3‡	0.193	0.207	0.214	0.232	0.235	0.241	0.554	0.666	0.682	0.690	0.698	0.740
DAP+4∞	0.193	0.184	0.174	0.173	0.171	0.132	0.593	1.998	2.129	2.223	2.387	2.401
DAP+8	0.182	0.181	0.177	0.173	0.166	0.129	0.565	1.331	1.437	1.522	1.643	1.664
DAP+12	IT	0.025	0.029	0.023	0.019	0.017	IT	0.665	0.698	0.729	0.731	0.760
DAP+16	0.149	0.157	0.178	0.182	0.191	0.103	0.550	0.583	0.621	0.655	0.730	0.743
DAP+20	0.166	0.171	0.175	0.182	0.184	0.100	0.532	0.499	0.473	0.455	0.424	0.387
DAP+24	0.169	0.176	0.180	0.184	0.186	0.114	0.520	0.496	0.464	0.450	0.421	0.319
DAP+28	IT	0.022	0.025	0.023	0.021	0.021	IT	0.385	0.431	0.553	0.668	0.750
DAP+32†	0.161	0.166	0.169	0.174	0.179	0.112	0.500	0.474	0.429	0.395	0.370	0.305
DAP+38	0.184	0.194	0.203	0.211	0.173	0.117	0.543	0.458	0.441	0.442	0.396	0.316
DAP+40	0.172	0.174	0.176	0.180	0.187	0.113	0.541	0.624	0.695	0.715	0.773	0.805
DAP+44	0.175	0.177	0.183	0.185	0.189	0.111	0.506	0.622	0.649	0.675	0.745	0.769
DAP+48	0.174	0.176	0.180	0.184	0.185	0.114	0.537	0.506	0.485	0.461	0.435	0.371
DAP+52∞	0.167	0.171	0.175	0.181	0.185	0.119	0.573	2.045	2.070	2.105	2.194	2.213
DAP+56	0.165	0.172	0.176	0.179	0.184	0.112	0.534	1.163	1.203	1.232	1.315	1.420
DAP+60	0.169	0.176	0.182	0.187	0.193	0.112	0.517	0.775	0.741	0.781	0.829	0.903
DAP+64	0.180	0.187	0.191	0.196	0.199	0.116	0.510	0.620	0.540	0.514	0.498	0.426
DAP+68	IT	0.104	0.094	0.117	0.119	0.121	IT	0.585	0.607	0.633	0.651	0.720
DAP+72†	0.152	0.159	0.161	0.168	0.203	0.100	0.506	0.494	0.497	0.509	0.528	0.521
DAP+76	0.153	0.163	0.173	0.179	0.203	0.100	0.506	0.483	0.469	0.442	0.382	0.314
DAP+80	0.152	0.160	0.169	0.178	0.202	0.091	0.503	0.480	0.458	0.436	0.409	0.363
DAP+84	0.152	0.158	0.166	0.178	0.203	0.095	0.506	0.480	0.462	0.439	0.412	0.346
DAP+88	0.136	0.145	0.150	0.169	0.203	0.087	0.506	0.470	0.449	0.437	0.414	0.357
DAP+92	0.136	0.144	0.151	0.170	0.201	0.079	0.500	0.462	0.439	0.415	0.383	0.311
DAP+96	0.140	0.141	0.150	0.168	0.204	0.078	0.509	0.475	0.449	0.425	0.393	0.322
DAP+100	IT	0.039	0.049	0.079	0.080	0.016	IT	0.196	0.123	0.098	0.073	0.058
DAP+104	IT	0.000	0.000	0.000	0.000	0.000	IT	0.000	0.000	0.000	0.000	0.000
DAP+108	IT	0.000	0.000	0.000	0.000	0.000	IT	0.000	0.000	0.000	0.000	0.000
DAP+112	IT	0.034	0.050	0.040	0.031	0.018	IT	0.211	0.124	0.184	0.246	0.330
DAP+116	IT	0.000	0.000	0.000	0.000	0.000	IT	0.000	0.000	0.000	0.000	0.000
DAP+120	IT	0.000	0.000	0.000	0.000	0.000	IT	0.000	0.000	0.000	0.000	0.000
Total	3.618	3.964	4.099	4.292	4.496	2.668	11.610	18.246	18.265	18.618	19.147	18.934

IT = Irrigation Terminated, ‡ = land preparation, ∞ = fertilizer application, and † = weeding.

the amount of SS load was kept maintain. In terrace II, the highest SS load was found after weeding activity, while in the lower position (terrace II, IV, V and drainage water) the maximum SS consignment was recorded during preparation activities. These data indicated that SS transport mostly occurred within land preparation period.

The similar loading pattern was found for dissolve organic matter (DOM) transport during the study period. The seasonal amount of DOM consignment into terrace I ranged from 1.34 to 1.91 kg ha^{-1} at DAP+92 and DAP+4, correspondingly. The variation of suspended solid (SS) loads in this terrace smallest as compare with the lower position. The rate of SS movement (rain moment was not included) into terrace II, III, IV and V ranged from 1.39 to 2.05 kg ha^{-1}, 1.48 to 2.11 kg ha^{-1}, 1.66 to 2.29 kg ha^{-1} and 1.64 to 2.32 kg ha^{-1}, respectively, while in drainage water it was ranged from 0.77 to 2.36 kg ha^{-1} (Table 1). Although the minimum DOM load was occurred in different time for each terrace position, the maximum DOM transport was also found during land preparation time.

During the study period, total SS entering the paddy field system was 1126 kg ha^{-1}, while the amount of SS leaving the system is 706 kg ha^{-1}. This result was higher than recorded in terrace paddy field in Java, where the total sediment entering the paddy field system within a cropping season was 864 kg ha^{-1}, and the amount of sediment leave was 528 kg ha^{-1}. Although the total amount of SS transport in this study was much higher than in Java, the discharge of SS distributed evenly within the cropping period. In Java, on the other hand, SS transported more than 55% during land preparation (Agus *et al.* 2006; Huang *et al.* 2006; Cabangan *et al.* 2002)).

The seasonal amount of SS and DOM entering paddy field system (terrace I) was much lower than the total SS discharge from the system (drainage channel) (Figure 1). Although irrigation supply was terminated on some rainy days, small amount of SS and DOM found moved downward to the lower position. In this condition, the amount of SS and DOM discharge tend to increase to the lower position as the amount of water flow was also much higher into that direction. This results was in agreement with mass balance study in Japan (Udo *et al.* 2000) and Korea (Yoon *et al.* 2002)

Mineralized nitrogen (ammonium nitrogen and nitrate nitrogen) in SS transport varied similarly with DOM during the study period. It was vary from 0.136 to 0.193 kg ha^{-1}; 0.141 to 0.207 kg ha^{-1}; 0.150 to 0.214 kg ha^{-1}; 0.168 to 0.232 kg ha^{-1}; 0.166 to 0.235 kg ha^{-1} and 0.078 to 0.241 kg ha^{-1} for terrace I, II, II, IV, V and drainage channel, respectively. Eventhough the minimum amount of seasonal mineralized nitrogen transport occurred in drainage channel, the maximum transport was also found in the same place during land preparation (Table 2).

Eventhough the rate of seasonal mineralized and dissolved nitrogen movement were varied from one terrace to another, total load of these parameter into paddy field system were lower than their discharges. Within the study period, total amount of mineralized nitrogen load from irrigation water was 3,618 kg ha^{-1}, while the total mineralized nitrogen discharge in drainage water was 2,668 kg ha^{-1}. The amount of dissolved nitrogen load into paddy field system was 11,610 kg ha^{-1} and move

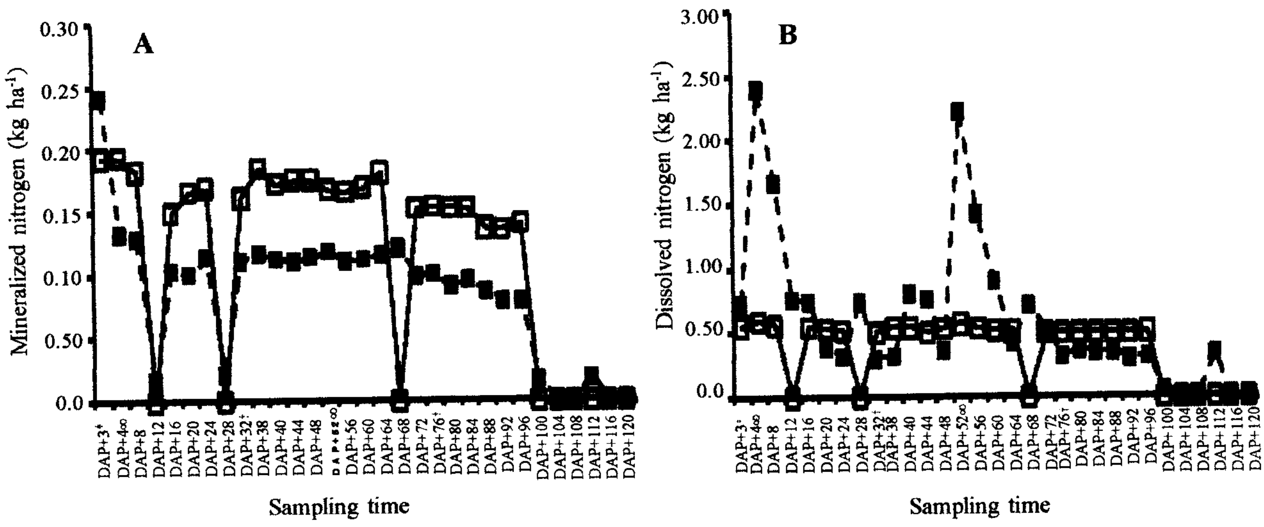

Figure 2. Seasonal transport of mineralized nitrogen (A) and dissolved nitrogen (B) into and out of terrace paddy field through irrigation (IR = —□—) and drainage (DR = - ■ -) water (kg ha^{-1}) within a rice cropping season.

Table 3. Effect of cascade irrigation system on seasonal load and discharge of total phosphorous (TP) and dissolved P (DP) in irrigation and drainage water within a rice cropping season.

Sampling time	Suspended solid in irrigation and drainage water (kg ha^{-1})						Organic matter suspended solid in irrigation and drainage water (kg ha^{-1})					
	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage
DAP-3ǂ	0.43	0.54	0.65	0.66	0.67	0.68	0.086	0.090	0.097	0.101	0.105	0.104
DAP+4∞	0.47	1.59	1.68	1.73	1.79	1.87	0.079	0.140	0.168	0.183	0.186	0.288
DAP+8	0.44	1.22	1.26	1.36	1.41	1.53	0.082	0.154	0.177	0.207	0.226	0.235
DAP+12	IT	0.65	0.74	0.78	0.80	0.85	IT	0.103	0.153	0.166	0.179	0.130
DAP+16	0.43	0.91	1.02	1.05	1.11	1.19	0.084	0.167	0.182	0.190	0.199	0.183
DAP+20	0.41	0.78	0.81	0.84	0.91	0.98	0.079	0.180	0.218	0.222	0.225	0.151
DAP+24	0.50	0.73	0.75	0.78	0.79	0.81	0.086	0.205	0.214	0.216	0.219	0.125
DAP+28	IT	0.46	0.49	0.49	0.52	0.53	IT	0.160	0.168	0.195	0.198	0.082
DAP+32†	0.50	0.67	0.80	0.80	0.84	0.89	0.081	0.153	0.164	0.184	0.191	0.137
DAP+38	0.51	0.60	0.68	0.70	0.71	0.82	0.081	0.146	0.160	0.175	0.180	0.126
DAP+40	0.52	0.55	0.55	0.58	0.60	0.66	0.080	0.146	0.155	0.169	0.173	0.102
DAP+44	0.52	0.53	0.54	0.54	0.57	0.63	0.081	0.144	0.152	0.167	0.169	0.097
DAP+48	0.51	0.53	0.52	0.53	0.56	0.59	0.082	0.137	0.149	0.165	0.167	0.091
DAP+52∞	0.52	0.47	0.51	0.52	0.55	0.57	0.081	0.128	0.145	0.161	0.165	0.088
DAP+56	0.51	0.45	0.43	0.42	0.40	0.40	0.079	0.122	0.138	0.161	0.161	0.062
DAP+60	0.50	0.45	0.41	0.39	0.37	0.39	0.079	0.118	0.136	0.155	0.158	0.060
DAP+64	0.50	0.44	0.40	0.39	0.34	0.39	0.080	0.117	0.134	0.135	0.156	0.060
DAP+68	IT	0.36	0.38	0.38	0.41	0.42	IT	0.174	0.179	0.182	0.185	0.064
DAP+72†	0.49	0.43	0.40	0.39	0.37	0.37	0.079	0.131	0.158	0.165	0.166	0.057
DAP+76	0.49	0.44	0.35	0.32	0.32	0.33	0.079	0.127	0.145	0.160	0.161	0.051
DAP+80	0.48	0.43	0.34	0.32	0.31	0.32	0.079	0.125	0.130	0.156	0.156	0.049
DAP+84	0.49	0.43	0.33	0.32	0.31	0.29	0.079	0.077	0.119	0.134	0.134	0.045
DAP+88	0.49	0.43	0.33	0.31	0.31	0.31	0.077	0.073	0.088	0.082	0.084	0.048
DAP+92	0.48	0.42	0.32	0.31	0.31	0.30	0.079	0.069	0.083	0.076	0.082	0.046
DAP+96	0.49	0.42	0.31	0.31	0.30	0.32	0.078	0.060	0.063	0.052	0.067	0.049
DAP+100	IT	0.19	0.12	0.09	0.07	0.06	IT	0.057	0.065	0.045	0.034	0.010
DAP+104	IT	0.00	0.00	0.00	0.00	0.00	IT	0.000	0.000	0.000	0.000	0.000
DAP+108	IT	0.00	0.00	0.00	0.00	0.00	IT	0.000	0.000	0.000	0.000	0.000
DAP+112	IT	0.20	0.12	0.08	0.04	0.03	IT	0.049	0.057	0.039	0.021	0.004
DAP+116	IT	0.00	0.00	0.00	0.00	0.00	IT	0.000	0.000	0.000	0.000	0.000
DAP+120	IT	0.00	0.00	0.00	0.00	0.00	IT	0.000	0.000	0.000	0.000	0.000
Total	10.66	15.31	15.26	15.36	15.72	16.52	1.770	3.350	3.800	4.040	4.150	2.540

IT = Irrigation Terminated, ǂ = land preparation, ∞ = fertilizer application, and † = weeding.

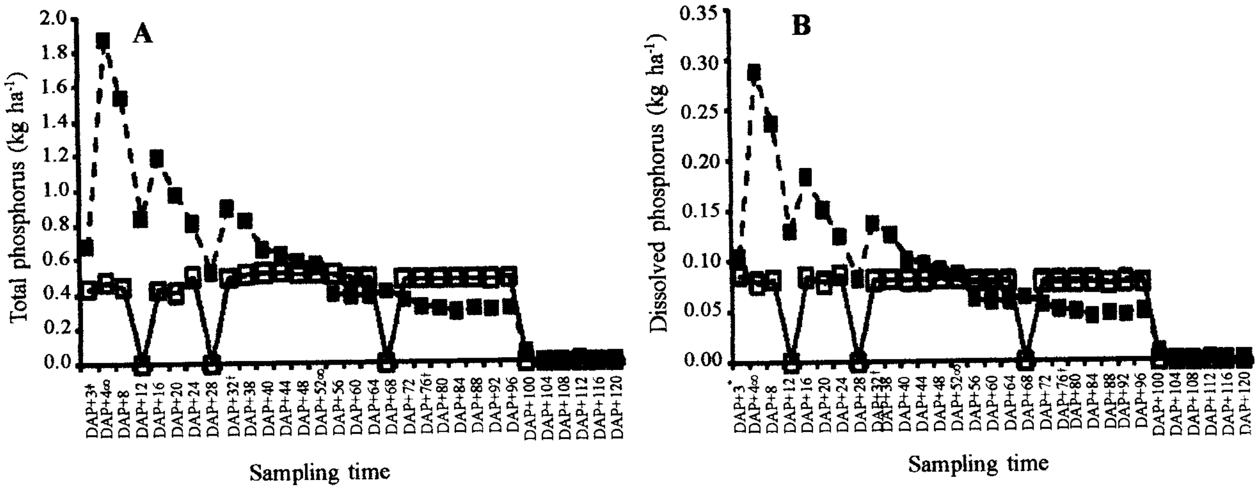

Figure 3. Seasonal transport of total phosphorous (A) and dissolved phosphorous (B) into and out of terrace paddy field through irrigation (IR = —□—) and drainage (DR = - ■ -) water (kg ha^{-1}) within a rice cropping season.

out from paddy field system with the rate of 18.934 kg ha^{-1} (Table 2 and Figure 2). These data point out that irrigation water contributed to some amount of available nitrogen which could be accounted in chemical fertilizer recommendation formula (Matsumoto *et al.* 2006; Bouman and Tuong 2001).

The peak of dissolved nitrogen discharge of study site found was just after chemical nitrogen application. This suggested that irrigation water application should be stop at this period to decrease the nutrient lost through surface run-off. The amount of dissolve nitrogen sent out from paddy field indicated the chemical fertilizer addition was higher than rice plant needs (Figure 2). Application of excessive amount of chemical fertilizer resulted in enhancement of nutrient content in the surface run-off (Chun *et al.* 2003).

Seasonal transport of total phosphorous (P) in SS was found similar to P dissolved in the irrigation and drainage water and varied from one terrace to another (Table 3). Terrace I which was located closest to irrigation channel transported the smaller amount of total P as compared to other terrace in a lower position. Total P from terrace I irrigation ranged from 0.41 to 0.52 kg ha^{-1}, while in a terrace II, III, IV, V and drainage channel transport total P were in the ranged of 0.36 to 1.59 kg ha^{-1}, 0.31 to 1.68 kg ha^{-1}, 0.31 to 1.73 kg ha^{-1}, 0.30 to 1.79 kg ha^{-1} and 0.29 to 1.87 kg ha^{-1}, respectively. The lowest amount of transported total P was found about at DAP+92 when rice plant entering maturity period while the highest loading and discharge was just after chemical fertilizer application.

Dissolved P transport had similar pattern with total P, where the smallest amount of dissolved P was found within the maturity period and the highest was after chemical fertilizer application. Although this result indicated that by the time some part of available P was taken up by plant and just small portion of them found in the soil solution, but totally, the amount of available load was smaller than discharged from paddy field. Within the study period, the total and available P entering paddy field was 10.66 and 1.77 kg ha^{-1}, respectively. At the same time, the amount of those discharges out was 16.52 and 2.54 kg ha^{-1}, respectively (Table 3). These phenomena indicated that the amount of nutrient applied might sufficient in upper terrace but it seemed to be excess in the lower. Chun *et al.* (2003) stated that excess amount of nutrient supply to paddy field could resulted in eutrophication which the most common problem surrounding the agriculture field.

Figure 3 show that the moving pattern of total and available P was similar. After chemical fertilizer application, the content of total P in SS increased amazingly and then decreased gradually. The rate of total and available P movement also influence by weeding activity. Since all of land management handled by man power, the weeding process will increase the sediment content in irrigation and drainage water which content some amount of total and available P. When rice plant entering the end of vegetative growth period, the content of available P in sediment and water decrease below the original content of these parameter from irrigation channel (Figure 3).

Table 4 shows the effect of cascade irrigation system on suspended solid, organic matter, mineralized nitrogen, and dissolved nitrogen, total phosphorous and dissolved phosphorous in intensive terrace paddy field within a rice cropping

Table 4. Effect of cascade irrigation system on suspended solid, organic matter, mineralized nitrogen, dissolved nitrogen, total phosphorous and dissolved phosphorous in intensive terrace paddy field within a rice cropping season. All parameters express in kg ha^{-1}.

Terrace position		Suspended Solid	Organic matter	Mineralize nitrogen	Dissolved nitrogen	Total phosphorous	Dissolved phosphorous
I	Input	1126	33.75	3.618	11.610	10.66	1.77
	Output	1135	39.15	3.964	18.246	15.31	3.35
	Balance	-9	-5.41	-0.346	-6.636	-4.65	-1.58
II	Input	1135	39.15	3.964	18.246	15.31	3.35
	Output	1093	40.50	4.099	18.265	15.25	3.80
	Balance	42	-1.35	-0.135	-0.019	0.06	-0.45
III	Input	1093	40.50	4.099	18.265	15.25	3.80
	Output	1058	42.40	4.292	18.618	15.36	4.04
	Balance	35	-1.90	-0.193	-0.353	-0.11	-0.24
IV	Input	1058	42.40	4.292	18.618	15.36	4.04
	Output	1021	44.42	4.496	19.147	15.72	4.15
	Balance	37	-2.02	-0.204	-0.529	-0.36	-0.11
V	Input	1021	44.42	4.496	19.147	15.72	4.15
	Output	706	26.15	2.668	18.934	16.52	2.54
	Balance	315	18.27	1.828	0.213	-0.80	1.61

season. In terrace I all of parameters had negatively balance. The SS balance had positive value from terrace II to drainage channel, while DOM, mineralized and dissolved nitrogen were negative, except for drainage channel. Total and available P balance had different balance pattern. Total P content in SS was negative in drainage channel, but it was opposed with available P. The positive balance of available P indicated that the amount of P entering the paddy field was excess as there was some addition from irrigation water. According to Takeda (2001) and Takeda and Fukushima (2004) some paddy field was considered as purifying if the nutrient balance was negative, and the other categorize as discharging when the nutrient balance was positive. Base on this statement, the upper part of study site was classified as purifying paddy field and the lower was discharging.

CONCLUSIONS

As the mountainous area most of paddy field in West Sumatra are located in the middle slope of mountain and form a beautiful terrace. The water flow is not just carrying some sediment to the lower position, but also carries some amount of nutrient as well. This study found that the quantity of sediment and nutrient load and discharge from paddy field was affected by terrace position, quality of irrigation water and the amount of chemical fertilizer applied to the field. The upper terrace which directly received water from irrigation had a tendency to be a purifying paddy field as the balance of nutrient in this position mostly negative. In the lower position, the nutrient balance much depended on the land management activities. To avoid the demerit of cascade irrigation system in intensive terrace paddy field, the chemical fertilizer applied should base on site specific characteristic and taking into account of natural source contribution. In order to invent an effective nutrient management in terrace paddy field, we need to conduct more monitoring research to minimize the bias of the data.

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