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# Cascade Irrigation Effects on Nutrient Migration in Terrace Sawah Ecosystems of West Sumatra, Indonesia

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West Sumatra is one of Indonesian rice bowl. The landscape of this province dominated by mountainous area with beautiful terrace sawah 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 sawah management sustains are 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 along 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.

**Key words:** Cascade irrigation, chemical fertilizer, nutrient balance, terrace sawah.

## INTRODUCTION

Indonesia is the third rice producing country 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 sawah distributed in the whole country, including West Sumatra. Although total sawah area in West Sumatra just about 250 thousand hectare, but due to the high productivity, this province has been supplied rice by 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 sawah in this region. Cascade irrigation system indicates continuous water flow from upper to lower terrace pass-through sawah field. Agus et al. (2006) recorded that sediment gain in terrace sawah in Indonesia ranged from 2 to 5.4 Mg ha<sup>-1</sup> per hectare 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 is 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). An important question is whether or not cascade irrigation system

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brings substantive amounts of nutrients from upper terrace to the lower and whether these nutrients contribute to lake eutrophication and algal bloom problems. Some studies have suggested that sawah can have beneficial effects, including water quality attenuation, air cooling and refreshing, groundwater recharge, and soil erosion control (Eom, 2001).

Phosphorus (P) and nitrogen (N) are two kinds of nutrient which are 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 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; Simard et al., 1995). 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 sawah occupied by cascade irrigation system (Tabuchi and Hasegawa, 1995; Tabuchi and Takamura, 1985; Nakamura et al., 1999; Kudo et al., 1995). The main purpose of this research is to study the characteristic of P and N movement in intensive terrace sawah occupied by cascade irrigation in West Sumatra, Indonesia.

## MATERIALS AND METHODS

### Study site characteristic

This study conducted in Solok District, one of rice production center in West Sumatra. The area located in (GPS reading) about 80 km Southeast Padang, the capital of West Sumatra province. This intensive old sawah lies at 650 m above sea level and receive about 3500 mm precipitation which is evenly distributed 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  $27 \text{ g kg}^{-1}$ , total nitrogen  $1.4 \text{ g kg}^{-1}$ , mineralized nitrogen ( $\text{NO}_3\text{-N} + \text{NH}_4\text{-N}$ ) of  $0.12 \text{ g kg}^{-1}$ , total phosphorous  $0.37 \text{ g kg}^{-1}$  and available phosphorous  $8.9 \text{ mg kg}^{-1}$ . To examine the nutrient movement from upper to lower terrace,  $10 \times 4 \text{ m}^2$  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 attain. 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  $200 \text{ kg Urea ha}^{-1}$  (half applied at 52 day after planting),  $125 \text{ kg Super-phosphate}$  and  $100 \text{ kg potassium chloride}$ . Month-old rice seedlings (*Anak daro*, local variety) were transplanted  $25 \text{ cm}$  by  $25 \text{ cm}$  wide. Three days after transplanting, irrigation water was sent into sawah field up to the ponded level (about  $5 \text{ cm}$ ). After that, each plot will follow 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 calculated as 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 HOB0 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  $500 \text{ ml}$  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 occurred during the study period (12, 28, 68 and 100 days after transplanting). To avoid surface run-off, irrigation water was terminated in each 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 found very slow (less than  $0.5 \text{ cm}$  a day). Due to this condition, the amount of nutrient loss through water infiltration was excluded from the nutrient movement calculation.

### Laboratory analyses and calculation

All sample 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 ( $40 \text{ m}^2$ ) 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  $80^\circ\text{C}$  for about 24 h 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 analyze by putting six grams of soil in a glass tube was submerged with distilled water and cover with rubber stopper. These tubes were incubated at  $30^\circ\text{C}$  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 H<sub>2</sub>SO<sub>4</sub>-NaOH method (Bowman, 1989).

## RESULTS AND DISCUSSION

The nutrient movement characteristic seemed influenced by irrigation water quality, land management activities and weather condition (Tables 1 and 2). The rate of 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 stop at most upper terrace, small amount of SS still found move downward by excess water into the lower terrace in every rain moment.

The seasonal amount of SS consignment into terrace I ranges from 46.1 to 54.5 kg ha<sup>-1</sup> 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, 40.1 to 57.0, 37.5 to 61.9 and 36.2 to 62.7 kg ha<sup>-1</sup>, respectively, while in drainage water it was ranged from 20.8 to 63.7 kg ha<sup>-1</sup>. Since terrace I received water directly from irrigation channel, the amount of SS load was keep maintain. In terrace II, the highest SS load found after weeding activity, while in the lower position (terrace II, IV, V and drainage water) the maximum SS consignment recorded during preparation activities. These data indicated that SS transport mostly occurred within land preparation period (Figure 1).

The similar loading pattern was found for DOM transport during the study period. The seasonal amount of DOM consignment into terrace I ranges from 1.34 to 1.91 kg ha<sup>-1</sup> at DAP+92 and DAP+4, correspondingly. The variation of SS loads in this terrace smallest as compare with the lower position. The rate of SS movement (rain moment was not include) into terrace II, III, IV and V ranged from 1.39 to 2.05, 1.48 to 2.11, 1.66 to 2.29 and 1.64 to 2.32 kg ha<sup>-1</sup>, respectively, while in drainage water it was ranged from 0.77 to 2.36 kg ha<sup>-1</sup> (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 sawah system was 1126 kg ha<sup>-1</sup>, while the amount of SS leaving the system is 706 kg ha<sup>-1</sup>. This result was higher than recorded in terrace sawah in Java, where the total sediment entering the sawah system within a cropping season is 864 kg ha<sup>-1</sup>, and the amount of sediment leave is 528 kg ha<sup>-1</sup>. Although the total amount of SS transport

in this study was much higher than in Java, the discharge of SS distribute evenly within the cropping period. Java on the other hand transported more than 55% during land preparation (Agus et al., 2006).

The seasonal amount of SS and DOM entering sawah 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 move 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.

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, 0.141 to 0.207, 0.150 to 0.214, 0.168 to 0.232, 0.166 to 0.235 and 0.078 to 0.241 kg ha<sup>-1</sup> for terrace I, II, III, IV, V and drainage channel, respectively. Even though 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).

Even though the rate of seasonal mineralized and dissolved nitrogen movement were varied from on terrace to another, total load of these parameter into sawah system was lower than their discharges. Within the study period, total amount of mineralized nitrogen load from irrigation water was 3.618 kg ha<sup>-1</sup>, while the total mineralized nitrogen discharge in drainage water is 2.668 kg ha<sup>-1</sup>. The amount of dissolved nitrogen load into sawah system was 11.610 kg ha<sup>-1</sup> and move out from sawah system with the rate of 18.934 kg ha<sup>-1</sup> (Table 2 and Figure 2). These data point out that irrigation water contribute to some amount of available nitrogen which can be account in chemical fertilizer recommendation formula.

The peak of dissolved nitrogen discharge of study site found 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 sawah filed indicates the chemical fertilizer addition was higher than rice plant needs (Figure 2). Application of excess 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 found similar with dissolved in the irrigation and drainage water and varied from one terrace to another (Table 3). Terrace I which located closest to irrigation channel transport the smaller amount of total P as compare with other terrace in lower position. This terrace total P from irrigation from 0.41 to 0.52 kg ha<sup>-1</sup>, while terrace II, III, IV, V and drainage channel transport total P with the ranged of 0.36 to 1.59, 0.31 to 1.68, 0.31 to 1.73, 0.30 to 1.79 and 0.29 to 1.87 kg ha<sup>-1</sup>, respectively. The lowest amount of total P transport found about DAP+92 when rice plant entering maturity period while the highest loading and discharge was just

**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 <sup>-1</sup> )						Organic matter suspended solid in irrigation and drainage water (kg ha <sup>-1</sup> )					
	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage
DAP-3 <sup>‡</sup>	51.4	55.3	57.0	61.9	62.7	63.7	1.90	2.05	2.11	2.29	2.32	2.36
DAP+4 <sup>‡</sup>	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	0.0	6.6	7.7	6.2	5.0	4.6	0.00	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	0.0	6.2	6.8	5.9	7.1	5.5	0.00	0.22	0.25	0.23	0.21	0.20
DAP+32 <sup>†</sup>	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	50.5	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 <sup>‡</sup>	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	49.9	48.0	30.7	1.78	1.85	1.88	1.93	1.96	1.14
DAP+68	0.0	22.6	25.0	27.8	29.7	32.0	0.00	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 <sup>†</sup>	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	0.0	21.0	13.1	10.5	7.8	4.3	0.00	0.39	0.49	0.78	0.79	0.16
DAP+104	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00
DAP+108	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00
DAP+112	0.0	10.6	13.3	9.0	5.0	4.7	0.00	0.33	0.49	0.39	0.31	0.17
DAP+116	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00
DAP+120	0.0	0.0	0.0	0.0	0.0	0.0	0.00	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

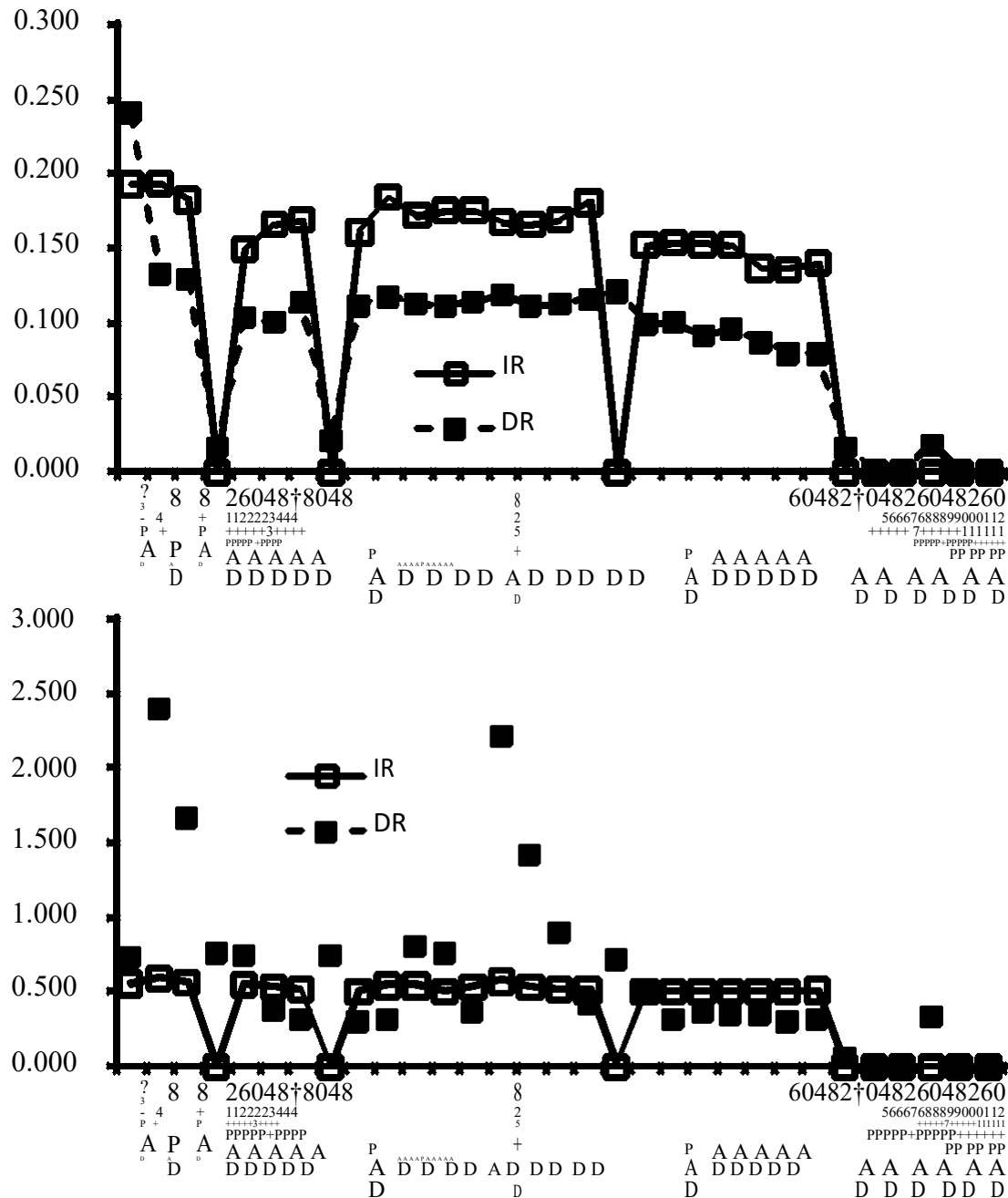
IT = Irrigation Terminated

**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	Mineralized nitrogen suspended solid in irrigation and drainage water (kg ha <sup>-1</sup> )						Dissolved nitrogen in irrigation and drainage water (kg ha <sup>-1</sup> )					
	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage
DAP-3 <sup>‡</sup>	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 <sup> </sup>	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	0.000	0.025	0.029	0.023	0.019	0.017	0.000	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	0.181	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	0.000	0.022	0.025	0.023	0.021	0.021	0.000	0.385	0.431	0.553	0.668	0.750
DAP+32 <sup>†</sup>	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 <sup> </sup>	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	0.000	0.104	0.094	0.117	0.119	0.121	0.000	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 <sup>†</sup>	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	0.000	0.039	0.049	0.079	0.080	0.016	0.000	0.196	0.123	0.098	0.073	0.058
DAP+104	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DAP+108	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DAP+112	0.000	0.034	0.050	0.040	0.031	0.018	0.000	0.211	0.124	0.184	0.246	0.330
DAP+116	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DAP+120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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





**Figure 2.** Seasonal transport of mineralized nitrogen (upper) and dissolved nitrogen (lower) into and out of terrace sawah through irrigation (IR) and drainage (DR) water (kg ha<sup>-1</sup>) within a rice cropping season.

P was similar. After chemical fertilizer application, the content of total P in SS increases amazingly and then decreases 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).

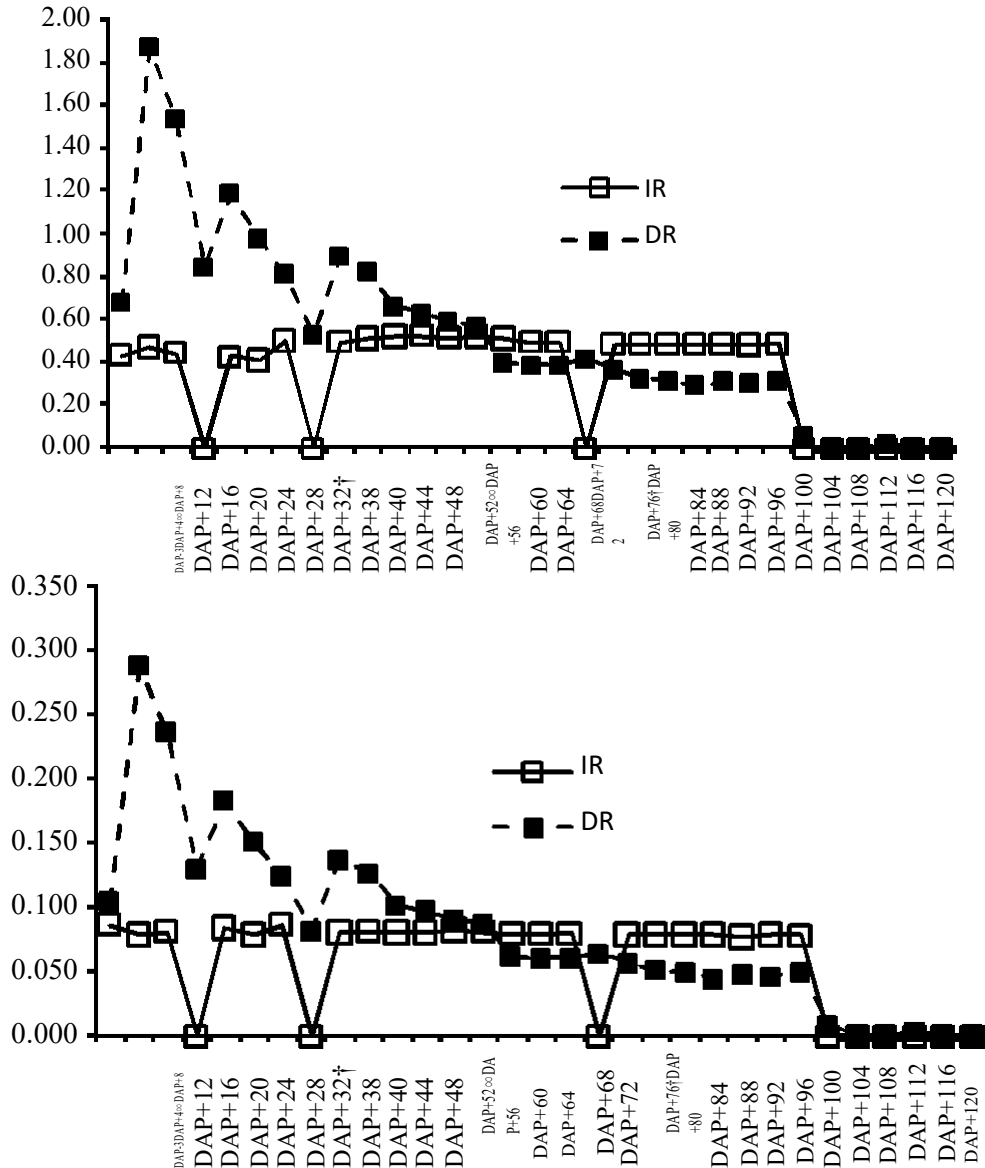
Table 4 shows the effect of cascade irrigation system on suspended solid, organic matter, mineralized nitrogen, and dissolved nitrogen, total phosphorous and dissolved phosphorous in intensive terrace sawah within a rice cropping season. In terrace I all of parameter observed found has negatively balance. The SS balance has positive value from terrace II to drainage channel, while

**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	Total P in suspended solid (kg ha <sup>-1</sup> )						Dissolve P in irrigation and drainage water (kg ha <sup>-1</sup> )					
	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage	Terrace-I	Terrace-II	Terrace-III	Terrace-IV	Terrace-V	Drainage
DAP-3 <sup>‡</sup>	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 <sup>l</sup>	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	0.00	0.65	0.74	0.78	0.80	0.85	0.000	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	0.00	0.46	0.49	0.49	0.52	0.53	0.000	0.160	0.168	0.195	0.198	0.082
DAP+32 <sup>†</sup>	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 <sup>l</sup>	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	0.00	0.36	0.38	0.38	0.41	0.42	0.000	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 <sup>†</sup>	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	0.00	0.19	0.12	0.09	0.07	0.06	0.000	0.057	0.065	0.045	0.034	0.010
DAP+104	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
DAP+108	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
DAP+112	0.00	0.20	0.12	0.08	0.04	0.03	0.000	0.049	0.057	0.039	0.021	0.004
DAP+116	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
DAP+120	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
Total	10.66	15.31	15.25	15.36	15.72	16.52	1.77	3.35	3.80	4.04	4.15	2.54

IT= Irrigation Terminated, <sup>l</sup>= land preparation, <sup>l</sup>=fertilizer application, <sup>†</sup>= weeding





**Figure 3.** Seasonal transport of total phosphorous (upper) and dissolved phosphorous (lower) into and out of terrace sawah through irrigation (IR) and drainage (DR) water ( $\text{kg ha}^{-1}$ ) within a rice cropping season

DOM, mineralized and dissolved nitrogen were negative, except for drainage channel. Total and available P balance found has different balance pattern. Total P content in SS was negative in drainage channel, but opposed with available P. The positive balance of available P indicates that the amount of P entering the sawah field was excess as there are some addition from irrigation water. According to Takeda (2001) and Takeda and Fukushima (2004) some sawah field is consider as purifying if the nutrient balance is negative, and the other categorize as discharging when the nutrient balance is positive. Base on this statement, the upper part of study site classify as purifying sawah and the lower was discharging.

## Conclusion

As the mountainous area most of sawah in West Sumatra located in the middle slope of mountain and form a beautiful terrace. To irrigate such kind of sawah, the most common irrigation system apply in this area is cascade system which allow water flow-down through sawah field. 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 sawah field 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 have a

**Table 4.** Effect of cascade irrigation system on suspended solid, organic matter, mineralized nitrogen, dissolved nitrogen, total phosphorous and dissolved phosphorous in intensive terrace sawah within a rice cropping season. All parameters express in kg ha<sup>-1</sup>.

Terrace Position		Suspended solid	Organic matter	Mineralized nitrogen	Dissolved nitrogen	Total phosphorous	Dissolved phosphorous
Terrace-I	Input	1126	33.75	3.62	11.61	10.66	1.77
	Output	1135	39.15	3.96	18.25	15.31	3.35
	Balance	-9	-5.40	-0.35	-6.64	-4.65	-1.58
Terrace-II	Input	1135	39.15	3.96	18.25	15.31	3.35
	Output	1093	40.50	4.10	18.27	15.25	3.80
	Balance	42	-1.35	-0.14	-0.02	0.06	-0.45
Terrace-III	Input	1093	40.50	4.10	18.27	15.25	3.80
	Output	1058	42.40	4.29	18.62	15.36	4.04
	Balance	35	-1.90	-0.19	-0.35	-0.11	-0.24
Terrace-IV	Input	1058	42.40	4.29	18.62	15.36	4.04
	Output	1021	44.42	4.50	19.15	15.72	4.15
	Balance	37	-2.02	-0.20	-0.53	-0.36	-0.11
Terrace-V	Input	1021	44.42	4.50	19.15	15.72	4.15
	Drainage	706	26.15	2.67	18.93	16.52	2.54
	Balance	315	18.27	1.83	0.21	-0.80	1.61

SS = suspended solid, OM = organic matter, N-SS = nitrogen in suspended solid, N-W = nitrogen in irrigation or drainage water, P-SS = phosphorous in suspended solid, Disolv. P = phosphorous in irrigation or drainage water, Min. = mineralized

tendency to be a purifying sawah as the balance of nutrient in this position mostly negative. In the lower position, the nutrient balance much depends on the land management activities. To avoid the demerit of cascade irrigation system in intensive terrace sawah, 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 sawah, we need to conduct more monitoring research to minimize the bias of the data.

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