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Plot Scale Phosphorous and Potassium Balances of Newly Opened Wetland Rice Farming Originated from Wetland

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ABSTRACT

Development of newly opened wetland rice fields both from dry land and wetland in Indonesia are important to meet rice growing demand, increase soil productivity, keep rural food security and provide jobs as well as generate income. Most soils of newly opened rice fields are low in P and K contents, but the farmers do not apply P and K recommended fertilisers. The study was conducted on newly opened wetland rice farming in Panca Agung village, Bulungan District, East Kalimantan Province, Indonesia in 2009. The aims were to evaluate phosphorous and potassium input – out of newly opened wetland rice and to validate the P and K recommendation. Six treatments were tested including farmers practices (as control), farmer practices + straw compost + dolomite, NPK with recommendation rate in which N and K was split in two applications, NPK with recommendation rate in which N and K was split three applications, NPK with recommendation rate + straw compost + Dolomite , in which N and K was split three applications, and NPK with recommendation rate + straw compost + dolomite, in which N and K were split two applications. The N, P and K rates were 250 kg urea, 100 kg SP-36 and 100 kg KCl ha^{-1} $season^{-1}$, while the farmer practices 100 kg urea and 100 kg SP-36 ha^{-1} $season^{-1}$. Parameters to be measured were concentration P and K in mineral fertilizer, compost, irrigation water and grains as well as straw. The results showed that surplus P ranged from 5.75 to 12.85 kg P ha^{-1} $season^{-1}$, meaning that SP-36 application rate was more than enough to replace P removed by harvest product. In contrast, potassium application rate should be increased from 100 to 200 kg KCl ha^{-1} $season^{-1}$ to fix K removed by harvest product. However, when the compost will also be increased to 3 Mg ha^{-1} $season^{-1}$ K fertilizer can be increased to 150 kg KCl ha^{-1} $season^{-1}$ to substitute K taken away by rice harvest product and to keep higher rice grain yield. These P and K recommendation rate imply that total SP-36 and KCl should be available at district level will be about 984.9 Mg SP-36 and 1.477 Mg KCl $district^{-1}$ $season^{-1}$, respectively.

Keywords: Newly opened wetland rice, nutrient balance, nutrient input, nutrient losses, plot scale wetland

INTRODUCTION

The Indonesian Agriculture challenge ahead especially in food is producing more rice to meet rice growing demand with limited land and water. Attentions should be addressed not only to irrigated lowland rice (fully regulated technical irrigation) systems, but also to other wetland rice system including newly opened wetland rice fields in outside Java and Bali Islands. Study on nutrient balance in newly opened wetland rice in Indonesia is rarely carried out and not well documented. Most the study is partial analysis based on removal by harvest products and unreturned crop residues, while the main input is mineral fertilisers.

Highly weathered soils, especialy ultisols and oxisols are mainly granted for extending newly opened wetland rice areas, besides potential acid sulphate soil. These soils are acidic with low natural level of major plant nutrients including P and K, but having Al, Mn, and Fe in toxic levels (Sukristiyonubowo *et al*. 2012; Sukristiyonubowo *et al*. 2011b). These soils require more mineral including P and K and organic fertilisers to improve nutrients level. However, for the poor farmers, living in transmigration areas, the cost of inorganic fertilisers is too expensive. Thus, for sustaining crop production proper fertiliser recomendation is needed. Using more organic, liming, and inorganic fertiliser are often recomended (Sukristiyonubowo *et al.* 2012; Sukristiyonubowo *et al*. 2011a; Sukristiyonubowo and Tuherkih 2009; Yan *et al.* 2007; Fageria and Baligar 2001; Sukristiyonubowo *et al.* 1993). Therefore, it is urgent to assess nutrient input given to the field and taken away from the field as a basis to improve fertilizer recommendation. In addition, quantification of nutrient inputs and outputs is also important for agronomical, economical and environmental analyses.

Nutrient balances can be defined as the differences between nutrient gains and losses. Nutrients coming from fertilizers, returning crop residues, irrigation, rainfall, and biological nitrogen fixation are grouped as nutrient input [Sukristiyonubowo *et al.* 2012; Sukristiyonobowo *et al.* 2011b; Sukristiyonubowo *et al.* 2010; Sukristiyonubowo. 2007; Wijnhoud *et al.* 2003; Lefroy and Konboon. 1999; Miller and Smith 1976). According to Sukristiyonubowo *et al.* (2012), Sukristiyonubowo *et al.* (2010), Sukristiyonubowo (2007) and Uexkull (1989), nutrient outputs include removal through harvested biomass (all nutrients), erosion (all nutrients), leaching (mainly nitrate, potassium, calcium and magnesium), fixation (mainly phosphate), and volatilization (mainly nitrogen and sulphur). When the nutrient removals are not replaced by sufficient application of fertilisers or returning of biomass, soil mining takes place and finally crop production do not reach its potential yields and finally reduces.

Nutrient balances can be developed at different scales and purposes, including (a) plot, (b) field, farm or catchment, (c) district, province, and (d) country scale (Sukristiyonubowo *et al.* 2012; ; Sukristiyonubowo *et al.* 2011a; Sukristiyonubowo *et al.* 2011b; Sukristiyonubowo *et al.* 2010; Sukristiyonubowo. 2007; Lefroy and Konboon. 1999; Bationo *et al* 1998; Hashim *et al.* 1998;Van den Bosch *et al.* 1998a and Van den Bosch *et al.* 1998b; Syer 1996; Smaling *et al.* 1993; Stoorvogel *et al.* 1993). Many studies indicate that at plot, farm, district, province, and national levels, agricultural production are characterised by a negative nutrient balance (Sukristiyonubowo *et al.* 2012; Sukristiyonubowo *et al.* 2011b; Sukristiyonubowo *et al.* 2010; Sukristiyonubowo 2007; Nkonya *et al.* 2005; Sheldrick *et al.* 2003; Harris 1998; Van den Bosch *et al.* 1998b).

A complete study of nutrient balances is very complicated. In a simple approach, nutrient loss is mainly calculated based on removal by harvested products and unreturned crop residues, while the main inputs are organic and mineral fertilizers. So far, it is reported that most assessment is partial analysis of these in- and output data (Wijnhoud *et al.* 2003; Drechsel *et al.* 2001; Lefroy and Kanboon. 1988).

Crop residue including rice residue is a fundamental natural resource for conserving and sustaining soil productivity. It supplies essential plant nutrients, improves physical and biological conditions of the soil, and prevents soil degradation (Aulakh *et al.* 2001; Puget and Drinkwater 2001; Jastrow *et al.* 1998; Tidale and Oades 1979; Walter *et al.* 1992). However, the nutrients present in roots are often discounted in nutrient balance assessment of cropping systems. Most attention is paid to cover crops since they are considered to be a potential source of nitrogen for the following crops (Kumar and Goh 2000; Thomsen 1993; Harris and Hesterman 1990). Now, it has been observed that the contribution of plant nutrients from roots is important, ranging between 13 and 40% of total plant nitrogen (Sukristiyonubowo 2007; Chaves *et al.* 2004).

The study of phosphorous and potassium balances on newly opened wetland rice field, Bulungan district, was aimed (a) to evaluate phosphorous and potassium input – output of newly opened wetland rice under different treatments and (b) to validate the P and K recommended application rates. It was hypothesized that proper P and K fertilizer application rate based on P and K studies would lead to optimal rice yield.

MATERIALS AND METHODS

Study Site

Field experiment was conducted in nutrient balance of newly opened wetland rice of Panca Agung Village, Bulungan District, East Kalimantan Province, Indonesia in 2009. The site was relatively flat and developed in 2007. The site originated from dryland area, which was left out for several years because low productivity.

Research Design and Treatment

Six treatments were tested namely T0: farmers practices (as control), T1: farmer practices + straw compost + dolomite, T2: NPK with recommendation rate, in which N and K were split in two times, T3: NPK with recommendation rate, in which N and K were split in three times, T4: NPK with recommendation rate, in which N and K were split in three times, and T5: NPK with recommendation rate + straw compost + dolomite, in which N and K were split in two times. These treatments were constructed according to the fact that soil fertility status was classified as low with low pH, low soil organic carbon, farmers did not apply P and K as recommendation rate or the farmers did not apply K fertiliser. They were arranged in a Randomized

Completely Block Design (RCBD) with three replications.

Plot and Fertilizers Used

The plot sizes were 5m × 5m with the distance among plot was 50 cm and between replication was 100 cm. NPK fertilisers used were originated from single fertiliser namely urea, SP-36 (Super Phosphate) and KCl (Potassium Chloride). Based on the direct measurement with Soil Test Kits, the recommendation rate was determined about 250 kg urea, 100 kg SP-36 and 100 kg KCl ha^{-1} $season^{-1}$, while the common farmer practices rate was 100 kg urea and 50 kg SP-36 ha^{-1} $season^{-1}$. The urea and KCl were splited three times namely 50% at planting time, 25% at 21 DAT (days after transplanting) and the last 25% was given at 35 DAT. Dolomite as much as 2 Mg ha^{-1} and rice straw compost of about 2 Mg ha^{-1} were broadcasted a week before planting. Only the treatments of T2 and T5, P was applied two times: 50% at planting time and 50% at 21 DAT. In the farmer practices, N was splited two times, 50% at planting time and 50% at 21 DAT, while for P was given one time at planting time. Before broadcasting the compost, one kg of composite compost was taken and analysed for its chemical contents. The detail treatments are presented in Table 1.

Planting and Observation

Cilliwung rice variety was cultivated as plant indicator. Transplanting was conducted in the end of June 2011 and harvest in the beginning of October 2011. Twenty-one-day old seedlings were transplanted at about 25 cm × 25 cm cropping distance with about three seedlings per hill. Rice biomass productions including grains, straw, and residues were measured at harvest. Sampling units, (1m × 1 m plot), were randomly selected at every plot. Rice plants were cut about 10 to 15 cm above the ground surface. The samples were manually separated into rice grains, rice straw, and rice residues. Rice residues included the roots and the part of the stem (stubble) left after cutting. Fresh weights of rice grain, rice straw, and rice residues were immediately weighed at harvest at each sampling unit. In this input-output analysis, rice residue was not considered as an input, as it was always remained in the field.

Balanced Calculation

The nutrient inputs were the sum of nutrients coming from mineral fertiliser (IN-1), rice straw compost (IN-2), irrigation (IN-3), and precipitation (IN-4). Outputs were sum of nutrients removed by rice grains (OUT-1) and rice straw (OUT-2). See formulas 1, 2 and 3 (Sukristiyonubowo *et al.* 2012; Sukristiyonubowo *et al.* 2011a; Sukristiyonubowo *et al*. 2011b; Sukristiyonubowo 2007).

Nutrient Inputs (IN) = IN-1 + IN-2 + IN-3 + IN-4 ...[1]
Nutrient Outputs (OUT) = OUT-1 + OUT-2 ... [2]
Nutrient Balance = IN - OUT ……......…....... [3]

To quantify phosphorous and potassium gains, data included concentrations of P and K in SP-36 and KCl, rate of SP-36 and KCl, amount of P and K in compost, irrigation water supply, P and K concentrations in irrigation waters and in rainfall were collected. The output parameters were rice grain yields, rice straw production, P and K concentrations in rice grain and rice straw.

IN-1 and IN-2 was calculated based on the amount of mineral and organic fertilizers added multiplied by the concentration of P and K in SP-36 and KCl and compost, respectively. IN-3 was estimated according to water input and nutrients content in irrigation water. Water input was the

Table 1. The detail treatment of NPK fertilisation, dolomite and compost made of rice straw of newly opened rice field.

Treatments	Urea	SP-36	KCl	Dolomite	Compost
	...................................kg ha^{-1}...............................				
Farmer practices (as control) (T0)	100	100	-	-	-
Farmer practices + Compost + Dolomit (T1)	100	100	-	2,000	2,000
NPK with recommendation rate (T2)	250	100	100	-	-
NPK with recommendation rate (N and K were split 3×) (T3)	250	100	100	-	-
NPK with recommendation rate + Compost + Dolomite (N and K were split 3×) (T4)	250	100	100	2,000	2,000
NPK with recommendation rate + Compost + Dolomite (T5)	250	100	100	2,000	2,000

different between incoming water and outgoing water. Incoming water was calculated by mean of water discharge multiplied by time the inlet was open and close the inlet and outlet during rice life cycle, mainly from land soaking to repining stage. As the P and K concentrations from the outlet were not measured, thus the contribution of these nutrients from irrigation water was predicted based on water input multiplied by the P and K contents in incoming water, respectively. In this experiment, the pounding water layer was maintained about three cm. The water discharge was measured using Floating method. IN-4 was estimated by multiplying rainfall volume with nutrient concentrations in the rain water. In a hectare basis, it was counted as follow:

$$IN\text{-}4 = \frac{A \times 10{,}000 \times 0.80 \times B \times 1{,}000}{1{,}000 \times 10^6}$$

Where:

IN-4 is P or K input of rainfall water in kg P and K ha^{-1} $season^{-1}$

A is rainfall in mm

10,000 is conversion of ha to m^2

0.80 is correction factor, as not all rain water goes into the soil

B is P and K concentrations in rainfall water in mg l^{-1}, respectively

1,000 is conversion from m^3 to l

1,000 is conversion from mm to m

10^6 is conversion from mg to kg

To monitor rainfall events, data from rain gauge and climatology station of Bulungan were considered. Rain waters were sampled once a month from a rain gauge in 600 ml plastic bottles and was also analysed according to the procedures of the Laboratory of the Soil Research Institute, Bogor (Soil Research Institute 2009)

P and K losses can be through harvested product (rice grain and rice straw). As all rice grains were transported out of plots, OUT-1 was estimated based on rice grain yield multiplied with P and K concentrations in the grains, respectively. OUT-2 was calculated according to the total rice straw production multiplied with P and K concentrations in the straw, respectively. Rice straw was considered as output because all rice straw was taken out from the field for making compost and the compost will be applied for coming planting season.

Leaching may contribute significant to the output. However, it was not consider as an output because it was not measured and we did not find the practical method. The outputs are thus expected to be a bit underestimated.

Plants were sampled at harvest and were collected from every plot, one hill per plot. After pulling out, the plant roots were washed with canal water. For the laboratory analyses, the samples were treated according to the procedures of the Analytical Laboratory of the Soil Research Institute, Bogor. Samples were washed with deionised water to avoid any contamination, and dried at 70^0 C. The dried samples were ground and stored in plastic bottles. P and K were measured after wet ashing using $HClO_4$ and HNO_3 (Soil Research Institute 2009).

Statistical Analysis

All data were statistically examined by analysis of variance (ANOVA) and computed using software SPSS program. Means were compared to Duncan Multiple Range Test (DMRT) with a 5% degree of confidence.

RESULTS AND DISCUSSION

A chemical soil property of newly opened rice in Panca Agung Village, where the experiment is located, is given in Table 2. The textures of the soils varied from silty clay loam to clay and were classified into medium to fine textures. The pH was very acid, varying between 4.62 and 4.70. The cation exchange capacities (CEC) value ranged from 5.81 to 9.53 $cmol^+$ kg^{-1} and it was categorised as low. The levels of soil organic carbon (SOC) and total N were low, ranging from 0.71 to 1.29% and from 0.03 to 0.05%, respectively. This may be due to the fact that in the past all rice straws or crop residues were always burnt or taken out from the field. Sommerfieldt *et al.* (1988) and Clark *et al.* (1998) observed higher soil OM levels in soils managed with animal manure and cover crops than in soils without such inputs.

Total P or potential P extracted with HCl 25% ranged from 31 to 58 mg P_2O_5 kg^{-1} and these values were classified as very low. Furthermore, available P was also very low, ranging between 1.09 and 2.69 mg P_2O_5 kg^{-1}, suggesting application of 100 kg SP-36 ha^{-1} $season^{-1}$ increased the availability of P leading to soil function improvement. Total K was low, varying from 59 to 138 mg K_2O kg^{-1}, indicating application of 100 kg KCl ha^{-1} $season^{-1}$ also increased the total K in the soil. Clark *et al.* (1998) ; Rasmussen and Parton (1994) and Wander *et al.* (1994) also reported similar findings.

Base saturation was relatively low, varying from 16 to 39%. This was mainly due to the very low concentration of exchangeable Ca (1.04 – 1.83 $cmol^+$ kg^{-1}) and K (0.05 – 0.11 $cmol^+$ kg^{-1}) and exchangeable Mg concentrations (0.21 - 0.27 $cmol^+$ kg^{-1}). Considering the ratio of exchangeable

Table 2. Chemical soil properties of newly opened wetland rice Panca Agung Village, Bulungan District established in 2007.

Parameter	Unit	Value	Criteria
pH		4.62 – 4.70	Very acid
Organic Matter			
Organic C	%	0.71 – 1.29	Very low
Total N	%	0.03 – 0.05	Very low
C/N ratio		20 – 26	low
Total P (HCl 25 %)	ppm	31 – 58	Very low
Total K (HCl 25 %)	ppm	55 –138	Low
P Bray I	ppm	1.09 – 2.69	Very low
CEC	cmol (+) kg^{-1}	5.81 – 9.53	Very low
K	cmol (+) kg^{-1}	0.05 – 0.11	Very low
Ca	cmol (+) kg^{-1}	1.04 – 1.83	Very low
Mg	cmol (+) kg^{-1}	0.21 – 0.27	Low
Na	cmol (+) kg^{-1}	0.05 – 0.19	
Fe	ppm	170 – 210	High
Mn	ppm	50.40	High
Texture 1			Silty clay loam
Sand	%	6.10	
Silt	%	64.80	
Clay	%	29.10	
Texture 2			Clay
Sand	%	1.30	
Silt	%	18.30	
Clay	%	80.40	

Source: Sukristiyonubowo *et al.* 2011b.

Table 3. The contribution of inorganic fertilizer and compost to P and K inputs, study on nutrient balance of newly opened wetland rice of Panca Agung village at Bulungan District.

Treatments	Rate of fertilizer and compost ($kg\ ha^{-1} season^{-1}$)			Contribution to P ($kg\ P\ ha^{-1} season^{-1}$)		Contribution to K ($kg\ K\ ha^{-1} season^{-1}$)	
	SP-36	KCl	Compost	IN-1	IN-2	IN-1	IN-2
T0	100	-	-	16.00	-	-	-
T1	100	-	2.000	16.00	3.60	-	51.20
T2	100	100	-	16.00	-	50.70	-
T3	100	100	-	16.00	-	50.70	-
T4	100	100	2000	16.00	3.60	50.70	51.20
T5	100	100	2.000	16.00	3.60	50.70	51.20

T0: Farmer Practices (as control), T1: Farmer practices + compost + dolomite, T2: NPK with recommendation rate, T3: NPK with recommendation rate (N and K were split 3×), T4: NPK with recommendation rate + compost + dolomite (N and K were split 3×), T5: NPK with recommendation rate + compost + dolomite, IN-1: P or K input of mineral fertiliser, and IN-2: P or K input of compost.

calcium, magnesium and potassium percentage, the data also indicated an imbalanced ratio. In normal conditions, the ratio ranges from 60 to 65% of calcium, 10 to 15% of magnesium, and 5 to 7% of potassium. Therefore, it may be concluded that in general the chemical soil fertility was very low due to very acid pH, very low organic matter content, and low available P and K concentrations. Hence, applications of proper mineral fertilizers improve inherent soil fertility leading to rice yield.

Phosphorous and Potassium Inputs

The P and K input originated from application of SP-36 and KCl (IN-1), compost (IN-2),

Table 4. The contribution of irrigation water to phosphorous and potassium input, study on nutrient balance of newly opened wetland rice Panca Agung village at Bulungan District.

Treatments	Water input, P and K concentrations			Contribution to input	
	Water input (L)	P Concen. (mg l^{-1})	K Concen. (mg l^{-1})	IN-3 (kg P $ha^{-1}season^{-1}$)	IN-3 (kg K $ha^{-1}season^{-1}$)
T0	15×10^6	0.03	0.15	0.45	22.50
T1	15×10^6	0.03	0.15	0.45	22.50
T2	15×10^6	0.03	0.15	0.45	22.50
T3	15×10^6	0.03	0.15	0.45	22.50
T4	15×10^6	0.03	0.15	0.45	22.50
T5	15×10^6	0.03	0.15	0.45	22.50

T0: Farmer Practices (as control), T1: Farmer practices + compost + dolomite, T2: NPK with recommendation rate, T3: NPK with recommendation rate (N and K were split 3×), T4: NPK with recommendation rate + compost + dolomite (N and K were split 3×), T5: NPK with recommendation rate + compost + dolomite, and IN-3: P or K input of irrigation water.

Table 5. The contribution of rainfall water to phosphorous and potassium input, study on nutrient balance of newly opened wetland rice of Panca Agung site, Bulungan District.

Treatments	Rainfall, P and K concentrations			Contribution to input	
	Rainfall (mm)	P Concen. (mg l^{-1})	K Concen. (mg l^{-1})	IN-4 (kg P $ha^{-1}season^{-1}$)	IN-4 (kg K $ha^{-1}season^{-1}$)
T0	2.715	0.04	0.08	0.29	1.74
T1	2.715	0.04	0.08	0.29	1.74
T2	2.715	0.04	0.08	0.29	1.74
T3	2.715	0.04	0.08	0.29	1.74
T4	2.715	0.04	0.08	0.29	1.74
T5	2.715	0.04	0.08	0.29	1.74

T0: Farmer Practices (as control), T1: Farmer practices + compost + dolomite, T2: NPK with recommendation rate, T3: NPK with recommendation rate (N and K were split 3×), T4: NPK with recommendation rate + compost + dolomite (N and K were split 3×), T5: NPK with recommendation rate + compost + dolomite, and IN-4: P or K input of rain water.

Table 6. Rice biomass production including rice grain and rice straw of Inpari 10 variety and total P loss from rice grain and rice straw at newly opened wetland rice of Panca Agung site, Bulungan District.

Treatments	Biomass production (Mg ha^{-1} $season^{-1}$)		P concentration (%)		P loss (kg P ha^{-1} $season^{-1}$)		Total P loss
	Rice grain	Rice straw	Rice grain	Rice straw	OUT-1	OUT-2	
T0	2.51 d*)	3.83 b	0.08	0.06	2.01	2.30	4.31
T1	2.97 cd	3.94 b	0.09	0.07	2.67	2.76	5.43
T2	3.09 bc	5.02 a	0.09	0.08	2.79	4.02	6.81
T3	3.68 abc	4.64 ab	0.12	0.07	4.42	3.25	7.67
T4	4.29 a	5.20 a	0.21	0.09	9.01	4.68	13.69
T5	3.80 ab	5.24 a	0.17	0.12	6.46	6.29	12.75

*)The mean values in the same column followed by the same letter are not statistically different by DMRT test. T0: Farmer Practices (as control), T1: Farmer practices + compost + dolomite, T2: NPK with recommendation rate, T3: NPK with recommendation rate (N and K were split 3×), T4: NPK with recommendation rate + compost + dolomite (N and K were split 3×), T5: NPK with recommendation rate + compost + dolomite, OUT-1: P losses by rice grain, and OUT-2: P losses by rice straw.

irrigation water (IN-3) and rainfall water (IN-4) and their nutrient contribution are presented in Tables 3, 4 and 5. The IN-1 (contribution of mineral fertiliser) was about + 16.00 kg P ha^{-1} $season^{-1}$, while for potassium was about + 50.70 kg K ha^{-1} $season^{-1}$. Thus, it can be said that the higher the rate of SP-36 and KCl fertilisers, the higher their contribution to the P and K inputs (Table 3).

Meanwhile, the IN-2 was about 3.60 kg P ha^{-1} $season^{-1}$, from the mean of phosphorous content in compost of 0.09%, 0.11% and 0.27% P, while for K was about 51.20 kg K ha^{-1} $season^{-1}$, from the K concentrations of 2.90%, 2.92% and 2.85% K (Table 3). Hence, besides the application rate of compost, the nutrient concentration in compost influenced the contribution. It can also be concluded that application of 2 Mg compost ha^{-1} $season^{-1}$ was a little bit higher than application of 100 kg KCl ha^{-1} $season^{-1}$, the KCl recommendation rate.

Phosphorous and potassium contribution inputs from irrigation water (IN-3) was about 0.45 kg P ha^{-1} $season^{-1}$ equivalent to about 3.0 kg SP-36 ha^{-1} $season^{-1}$, meanwhile for potassium was about 11.26 kg K ha^{-1} $season^{-1}$ equivalent to about 22.52 kg KCl ha^{-1} $season^{-1}$ (Table 4), which was considered high, almost one fourth of potassium fertiliser recommended rate.

The input coming from rain water was about 0.29 kg P, equal to 1.00 kg SP-36 and for potassium about 1.74 kg K equal to 3.50 kg KCl ha^{-1} $season^{-1}$ (Table 5), which were considered insignificant. Similar results were found in terraced paddy field system in Semarang District of about 2.60 kg P and 6.10 kg K ha^{-1} $season^{-1}$ (Sukristiyonubowo 2007).

Phosphorous and Potassium Losses

P and K losses were estimated from rice grain and by rice straw taken out from the plots (Table 6 and 7).

P taken away by rice grain ranged between 2.01 and 9.01 kg P ha^{-1} $season^{-1}$ depending on the rice grain production. P removed by rice straw varied from 2.30 to 6.29 kg P ha^{-1} $season^{-1}$. The highest P removed by rice grain and rice straw were shown by T4 and TS, respectively. However, the total P taken away by harvest product of about 13.69 kg P ha^{-1} $season^{-1}$ was shown by T4 because of the highest rice yield and rice straw of this treatment. Therefore, it can be said that increasing rice harvest product will remove more nutrients.

Output-Input Analysis

The P and K balances of newly opened wetland rice originated from wetland are presented in Tables 8 and 9. In general, the results indicated that inorganic fertiliser (IN-1) contributed considerably to total P and K input in all treatments. The amounts were about 16.00 kg P and about 50.60 kg K ha^{-1} $season^{-1}$. In the T2 to T5 treatments, IN-1 contributed to about 79% to 96% of total P input and from 46 to 68% of total K inputs. Similar result was observed in farmer practices rates (T0 and T1), which contributed from 76 to 96% of the total P input. It may be greater in the newly opened wetland rice areas than in the other wetland rice fields, as the inherent soil fertility of newly opened wetland rice fields are classified low and developed from highly weathered soils and potential sulphate soils (Sukristiyonubowo *et al*. 2011a)

Compost (IN-2) was also an important nutrient source, covering about 18% of total P and from 41 to 68 % of total K input depending on the treatment. The IN-2 is more important, when less or no inorganic fertilisers are applied and more organic fertiliser is added. Nutrient supplied by compost was equivalent to 22.50 kg of SP-36 and about 101 kg KCl. This will be more when the rate of compost

Table 7. Rice biomass production including rice grain and rice straw of Inpari 10 variety and total K loss from rice grain and rice straw at newly opened wetland rice Panca Agung village, Bulungan District.

Treatments	Biomass production (Mg ha^{-1} $season^{-1}$)		K concentration (%)		K loss (kg K ha^{-1} $season^{-1}$)		Total K loss
	Rice grain	Rice straw	Rice grain	Rice straw	OUT-1	OUT-2	
T0	2.51 d*)	3.83 b	0.23	2.35	5.77	90.00	95.77
T1	2.97 cd	3.94 b	0.26	2.99	7.72	117.81	125.53
T2	3.09 bc	5.02 a	0.21	2.98	6.49	149.60	156.09
T3	3.68 abc	4.64 ab	0.27	3.16	9.94	142.62	152.56
T4	4.29 a	5.20 a	0.22	3.11	9.44	161.72	171.16
T5	3.80 ab	5.24 a	0.22	2.85	8.36	148.29	156.65

*)The mean values in the same column followed by the same letter are not statistically different by DMRT test. T0: Farmer Practices (as control), T1: Farmer practices + compost + dolomite, T2: NPK with recommendation rate, T3: NPK with recommendation rate (N and K were split 3×), T4: NPK with recommendation rate + compost + dolomite (N and K were split 3×), T5: NPK with recommendation rate + compost + dolomite, OUT-1: K losses by rice grain, and OUT-2: K losses by rice straw.

Table 8. Input-output analysis for phosphorous of newly opened wetland rice of Panca Agung site, Bulungan District.

Parameter	Treatments					
	T0	T1	T2	T3	T4	T5
	P Input (kg P ha^{-1} $season^{-1}$)					
IN-1	+ 16.00	+ 16.00	16.00	+ 16.00	+ 16.00	+ 16.00
	96%	79%	96%	96%	79%	79%
IN-2	-	+ 3.60	-	-	3.60	+ 3.60
	0%	18%	0%	0%	18%	18%
IN-3	+ 0.45	+ 0.45	+ 0.45	+ 0.45%	+ 0.45	+ 0.15
	3%	2%	3%	3%	2%	2%
IN-4	+ 0.29	+ 0.29	0.29	+ 0.29	+ 0.29	+ 0.29
	1%	1%	1%	1%	1%	1%
Total P Input	+ 16.74	+ 20.34	+ 16.74	+ 16.74	+ 20.34	+ 20.34
	100%	100%	100%	100%	100%	100%
	P Output (kg P ha^{-1} $season^{-1}$)					
OUT-1	- 2.01	- 2.67	- 2.79	- 4.42	- 9.01	- 6.46
	47%	49%	41%	58%	66%	51%
OUT-2	- 2.30	- 2.76	- 4.02	- 3.25	- 4.68	- 6.29
	53%	51%	59%	42%	34%	45%
Total Output	- 4.31	- 5.43	- 6.81	- 7.67	- 13.69	- 12.75
	100%	100%	100%	100%	100%	100%
Balance	+ 12.43	+ 14.91	+ 9.93	+ 9.07	+ 6.65	+ 7.59

T0: Farmer Practices (as control), T1: Farmer practices + compost + dolomite, T2: NPK with recommendation rate, T3: NPK with recommendation rate (N and K were split 3×), T4: NPK with recommendation rate + compost + dolomite (N and K were split 3×), and T5: NPK with recommendation rate + compost + dolomite. IN-1: P or K input of mineral fertiliser, and IN-2: P or K input of compost, IN-3: P or K input of irrigation water, IN-4: P or K input of rain water, OUT-1: P losses by rice grain, and OUT-2: P losses by rice straw.

application increased. Although the amounts of potassium coming from irrigation water (IN-3) were smaller compared to the amounts of nutrients originating from inorganic fertilisers (IN-1) and organic fertiliser (IN-2), the contributions of IN-3 to K input was still important, covering between 17% and 93% of the total K input.

IN-4 (contribution rainfall water) was about 0.29 kg P ha-1 and 1.74 kg ha-1, although it was considered low, it was also an important nutrient source, particularly for N during the wet season.

With respect to the output, depending on the treatment and grain yield around 41% - 66% of total P was taken up by rice grains and the rest by rice straw. This means that P was highly removed by rice grains than by rice straw.

Assessment of P input and output shows a positive balance for all treatments (Table 8). The surplus of P ranged between 6.65 and 14.91 kg P ha^{-1} $season^{-1}$. The P balances in the T4 and T5 were less surplus than in other treatments. This may be explained by increasing rice grains and rice straw production. In T4 and T5 treatments P removed by harvest product was higher than the other. In contrast, K input and output analysis indicated negative balances for all treatments (Table 9). The deficit ranged from – 31.51 to 81.15 kg K ha^{-1} $season^{-1}$, depending on the treatment. For T4 and T5, the K balances were also more negative than the others. This was due to K taken away by rice grains and rice straws were higher than other treatments. To replace K taken out by rice harvest products, therefore, K fertiliser application rate should be increased from 100 to 200 kg KCl ha^{-1} $season^{-1}$ when the rate of compost was not increased. However, when the compost was increased from 2 Mg to 3 Mg ha^{-1} $season^{-1}$, K fertiliser application rate could be increased from 100 to 150 kg KCl ha^{-1} $season^{-1}$ as the compost from rice straw was rich in K. Regarding the farmers condition, the last option is more feasible since the rice straw is available in the fields.

The positive P balances in all treatments also demonstrated that the application rates of inorganic fertiliser were more than enough to replace P removed by rice grains and straw. Therefore, it can

Table 9. Input-output analysis for potassium of newly opened wetland rice of Panca Agung site, Bulungan District.

Parameter	Treatments					
	To	T1	T2	T3	T4	T5
	K Input (kg K ha^{-1} $season^{-1}$)					
IN-1	-	-	+ 50.70	+ 50.70	+ 50.70	+ 50.70
	0%	0%	68%	68%	40%	40%
IN-2	-	+ 51.20	-	-	+ 51.20	+ 51.20
		68%	0%	0%	41%	41%
IN-3	+ 22.50	+ 22.50	+ 22.50	+ 22.50	+ 22.50	+ 22.50
	93%	30%	30%	30%	17%	17%
IN-4	+ 1.74	+ 1.74	+ 1.74	+ 1.74	+ 1.74	+ 1.74
	7%	2%	2%	2%	2%	2%
Total K Input	+ 24.24	+ 75.44	+ 74.94	+ 74.94	+ 126.14	+ 126.14
	100%	100%	100%	100%	100%	100%
	K Output(kg K ha^{-1} $season^{-1}$)					
OUT-1	- 5.77	- 7.72	- 6.49	- 9.94	- 9.44	- 8.36
	6%	6%	4%	6%	5%	5%
OUT-2	- 90.00	- 117.81	- 149.60	-142.62	- 161.72	- 148.29
	94%	94%	92%	94%	95%	92%
Total Output	- 95.77	- 125.53	- 156.09	- 152.56	- 171.16	- 156.65
	100%	100%	100%	100%	100%	100%
Balance	- 71.53	- 50.09	- 81.15	- 2.50	- 45.02	- 30.51

T0: Farmer Practices (as control), T1: Farmer practices + compost + dolomite, T2: NPK with recommendation rate, T3: NPK with recommendation rate (N and K were split 3×), T4: NPK with recommendation rate + compost + dolomite (N and K were split 3×), and T5: NPK with recommendation rate + compost + dolomite. IN-1: P or K input of mineral fertiliser, and IN-2: P or K input of compost, IN-3: P or K input of irrigation water, IN-4: P or K input of rain water, OUT-1: K losses by rice grain, and OUT-2: K losses by rice straw

be said that to obtain better rice production, P fertiliser application rate should be maintained as P can be longer kept in the soil without damage the environment and will improve soil function. However, for potassium the application rate should be increased from 100 to 200 kg KCl ha^{-1} $season^{-1}$. As rice straw is abandon in the rice fields and can easily be composted, instead of increasing inorganic fertilisers to 200 kg KCl ha^{-1} $season^{-1}$, to replace K removed by rice harvest product and keep the higher rice grain yield, the inorganic fertiliser can be increased to 150 kg KCl ha^{-1} $season^{-1}$ with adding more compost, from 2 to 3 Mg ha^{-1} $season^{-1}$.

CONCLUSIONS

Assessment of P and K input and output of newly opened wetland rice, Bulungan District indicated the surplus P ranged from 6.65 to 14.91 kg P ha^{-1} $season^{-1}$, meaning that SP-36 application rate was more than enough to replace P removed by harvest product. However, to obtain better rice production and to improve soil function, P fertiliser application rate should be maintained as P can be longer kept in the soil without damage the soil. On the contrary, potassium application rate should be increased from 100 to 200 kg KCl ha^{-1} $season^{-1}$ to fix K removed by harvest product. However, when the compost will also be increased to 3 Mg ha^{-1} $season^{-1}$, K fertilizer can be increased to 150 kg KCl ha^{-1} $season^{-1}$ to substitute K removed by rice harvest product and to keep higher rice grain yield. These P and K recommendation rate simply that total SP-36 and KCl should be available at district level will be about 984.9 Mg SP-36 and 1.477 Mg KCl $district^{-1}$ $season^{-1}$, respectively (100 kg SP-36 × 9,849 ha and 150 kg KCl × 9,849 ha).

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