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Nitrogen and potassium balances of newly opened wetland rice field

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Soils allocated for development of newly opened wetland rice fields in Indonesia can be from dry land or/and wetland to meet rice growing demand. The soils are low in major nutrient contents, but high in Fe concentration. The farmers do not apply N and K fertilisers' bases on recommendation. The study was conducted on newly opened wetland rice farming originated from wetland in Tanjung Buka SP-2 village, Bulungan District, East Kalimantan Province, Indonesia in 2011. The aims were (1) to evaluate nitrogen and potassium input – out of newly opened wetland rice and (2) to validate the N and K recommendation. The results indicated that surplus N ranged from 39.03 to 71.62 kg N ha^{-1} season^{-1}, meaning the amount of urea is more than enough to replace N removed by harvest product. The recommended urea should be reduced to 150 kg urea with added compost of 3 tons ha^{-1} season^{-1}. If the compost increased to 3 tons 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 N and K recommendation rate imply the total urea and KCl available at district level with about 1,477 tons urea and 1,477 tons KCl district $^{-1}$ season $^{-1}$, respectively (150 kg urea x 9,849 ha and 150 kg KCl x 9,849 ha).

Keywords: Nutrient balance, plot scale, nutrient input, nutrient losses, newly opened wetland rice, wetland.

INTRODUCTION

The Indonesian Agriculture is challenge ahead in producing more rice with limited land and water to meet rice growing demand. Attentions should be addressed not only to technical irrigated lowland rice system, but also to other wetland rice system including newly opened wetland rice fields outside Java and Bali Islands. Study on nutrient balance in newly opened wetland rice Indonesia is not yet carried out.

In Indonesia, dryland (utisols and inceptisols) and wetland (potential acid sulphate soils) are mainly allocated for development newly opened wetland rice fields (Agus, 2007; Prasetyo, 2007; Hardjowigeno and Rayes, 2005). These soils are acidic with low natural level of major plant nutrients; however it has Fe in toxic levels (Sukristiyonubowo *et al*., 2011a; Sukristiyonubowo *et al*., 2012). More mineral and organic fertilizers are required to improve nutrients level and unfortunately the cost of inorganic fertilizers is too expensive. Consequently, to keep crop production better, proper fertilizers recommendation are needed with more organic matter, liming, and inorganic fertilizer (Sukristiyonubowo *et al.,* 2011a; Sukristiyonubowo *et al*., 2010; Sukristiyonubowo and Tuherkih, 2009; Yan *et al.,* 2007; Fageria and Baligar, 2001). Therefore, it is critical to assess nutrient input given and taken away from the field to develop 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, returned crop residues, irrigation, rainfall, and biological nitrogen fixation are grouped as nutrient input (Sukristiyonubowo *et al*., 2011b; Sukristiyonubowo *et al.,* 2010; Sukristiyonubowo. 2007; Wijnhoud *et al.* 2003; Lefroy and Konboon, 1999). According to Sukristiyonubowo *et al.,* (2011b and 2010), Sukristiyonubowo (2007) and Uexkull (1989), nutrient outputs included removal through harvested biomass (all nutrients), erosion (all nutrients), leaching (mainly nitrate, potassium, calcium and magnesium), fixation (mainly phosphate), and volatilization (mainly nitrogen and

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sulphur). When the nutrient removals are not substituted by sufficient application of fertilizers or returning of biomass, soil mining takes place and 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*., 2011b; Sukristiyonubowo *et al.,* 2010; Lefroy and Konboon. 1999; Bationo *et al.* 1998; Hashim *et al.* 1998; Van den Bosch *et al.* 1998a and 1998b; Syers .1996; Smaling *et al.* 1993; and Stoorvogel *et al.* 1993). Many studies indicate that at plot, farm, district, province, and national levels, agricultural production is characterised by a negative nutrient balance (Sukristiyonubowo *et al*., 2010; Sukristiyonubowo, 2007; Nkonya *et al.,* 2005; Sheldrick *et al.,* 2003; Harris. 1998; and Van den Bosch *et al.,* 1998b).

A complete study of nutrient balances is very complicated. In a simple approach, the main inputs are organic and mineral fertilizers while nutrient loss can be calculated based on removal by harvested products and unreturned crop residues.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 Konboon, 1998).

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 (Sukristiyonubowo. 2007; Aulakh *et al.,* 2001; Puget and Drinkwater, 2001; Jastrow *et al.,* 1998; Tisdale 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 was 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 N (Sukristiyonubowo *et al*., 2011b; Sukristiyonubowo. 2007; Chaves *et al.,* 2004; Kumar and Goh, 2000).

The study of nitrogen and potassium balances on newly opened wetland rice field originated from wetland at Tanjung Buka SP-2, Bulungan district, was aimed (a) to evaluate nitrogen and potassium input – output of newly opened wetland rice under different treatments and (b) to validate the N and K recommended application rates. It was hypothesized that proper N and K fertilizer application rate based on N and K studies will lead to optimal rice yield.

METHODOLOGY

Plot scale nitrogen and potassium balances of newly opened wetland rice originated from wetland were studied in Tanjung Buka SP-2 Village, Bulungan District, East Kalimantan Province, Indonesia in 2011. The site was relatively flat and developed in 2007. Seven treatments were tested namely T0: farmers practices (as control), T1: farmer practices + straw compost + dolomite, T2: NPK with recommendation rate, in which P was split two times, T3: NPK with recommendation rate + straw compost, T4: NPK with recommendation rate, T5: NPK with recommendation rate + straw compost + dolomite and T6: NPK with recommendation rate in which P was split 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 fertilizer. They were arranged in Randomized Complete Block Design (RCBD) and replicated three times. The plot sizes were 5m x 5m with the distance among plot was 50 cm and between replication was 100 cm. NPK fertilizer used originated from single fertilizer 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 split three times namely 50 % at planting time, 25 % at 21 DAT (days after planting) and the last 25 % was given at 35 DAT. Dolomite as much as two tons ha^{-1} and rice straw compost of about two tons ha^{-1} were broadcasted a week before planting. Only the treatments of T2 and T6, P were applied two times: 50 % at planting time and 50 % was given at 21 DAT. In the farmer practices, N was split two time, 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 composite compost were taken and analysed for its chemical contents. The detail treatments are presented in Table1.

Inpari 10 rice variety was cultivated as plant indicator. Transplanting was carried out in the end of June 2011 and harvest in the first week of October 2011. Twenty-one-day old seedlings were transplanted at about 25 cm x 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 x 1 m plot), were randomly selected at every plot. Rice plants were cut about 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 is always remained in the field.

The nutrient inputs were the sum of nutrients coming from mineral fertiliser (IN-1), rice straw compost (IN-2),

Table 1. The detail treatment of NPK fertilization, dolomite and compost made of rice straw of newly opened rice field originated from wetland.

Code	Treatment	Urea	SP-36	KCl	Dolomite	Compost
		....................................kg ha^{-1}................................				
T0	Farmer Practices (as control)	100	50	-	-	-
T1	Farmer Practices+Compost+Dolomit	100	50	-	2000	2000
T2	NPK with recommendation rate, in which P was split two time	250	100	100	-	-
T3	NPK with recommendation rate + Compost	250	100	100	-	2000
T4	NPK with recommendation rate	250	100	100	-	-
T5	NPK with recommendation rate + Compost + Dolomite	250	100	100	2000	2000
T6	NPK with reccomendation rate + compost + Dolomite, in which P was split two times	250	100	100	2000	2000

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*. 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 nitrogen and potassium gains, data included concentrations of N and K in urea and KCl, rate of urea and KCl, amount of N and K in compost, irrigation water supply, N and K concentrations in irrigation waters and in rainfall were collected. The output parameters were rice grain yields, rice straw production, N 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 N and K in urea and KCl and compost, respectively. IN-3 was estimated according to water input and nutrients content in irrigation water. Water input was the different between incoming water and outgoing water. Incoming water was calculated by mean of water discharge multiplied by time the inlet is open and close the inlet and outlet during rice life cycle, mainly from land soaking to repining stage. As the N 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 N 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:

$$\text{IN-4} = \frac{A \times 10.000 \times 0.80 \times B \times 1000}{1000 \times 10^6}$$

Where:

- IN-4 is N or K input of rainfall water in kg N and K ha^{-1} $season^{-1}$
- A is rainfall in mm
- 10000 is conversion of ha to m^2
- 0.80 is correction factor, as not all rain water goes into the soil
- B is N and K concentrations in rainfall water in mg l^{-1}, respectively
- 1000 is conversion from m^3 to l
- 1000 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).

N and K losses can be through harvested product (rice grain and rice straw). As all rice grains are transported out of plots, OUT-1 was estimated based on rice grain yield multiplied with N and K concentrations in the grains, respectively. OUT-2 was calculated according to the total rice straw production multiplied with N 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.

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. Nitrogen was determined by wet ashing using concentrated H_2SO_4 (97%) and selenium. Potas-

Table 2. Chemical soil properties of newly opened wetland rice originated from wetland in Tanjung Buka SP-2 Village, Bulungan District established in 2007 (Soil taken in June 2011)

Parameter	Unit	Site	criteria
		Tanjung Buka SP-2	Tanjung Buka SP-2
pH		3,78 – 4.50	Very acid
Organic Matter			
Organic C	%	1.96 – 2.10	Low
N	%	0,20 – 0.60	Low
C/N ratio		9.80	low
P ekstrak HCl 25 %	ppm	58 -79	Very Low
K ekstrak HCl 25 %	ppm	129 - 176	Low
P Bray I	ppm	11,61- 19.61	Very Low
CEC	cmol (+) kg^{-1}	23 - 25	High
K	cmol (+) kg^{-1}	0.11 – 0.19	Very Low
Ca	cmol (+) kg^{-1}	1.36 - 5,49	Low
Mg	cmol (+) kg^{-1}	1,73 – 2.61	Low to medium
Fe	ppm	251 - 270	High

sium was measured after wet ashing using $HClO_4$ and HNO_3 (Soil Research Institute, 2009).

RESULTS AND DISCUSSION

Soil Properties

A chemical soil property of newly opened rice originated from wetland in Tanjung Buka SP-2 village, where the experiment was located, is given in Table 2. The pH was very acid, varying between 3.78 and 4.50. The cation exchange capacities (CEC) value ranged from 23 to 25 $cmol^+ kg^{-1}$ and it was categorised as high. The levels of soil organic carbon (SOC) and total N were low, ranging from 1.96 % to 2.10 % and from 0.20 to 0.60 %, respectively. According to Sommerfeldt *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 58 to 79 mg P_2O_5 kg^{-1} and these values may be classified as very low. Furthermore, available P was also very low, ranging between 11.61 and 19.61 mg P_2O_5 kg^{-1}, suggesting application of 100 kg SP-36 ha^{-1} $season^{-1}$ increases the availability of P leading to soil function improvement. Total K was low, varying from 129 to 176 mg K_2O kg^{-1}, indicating application of 100 kg KCl ha^{-1} season $^{-1}$ also increase the total K in the soil. Clark *et al.* (1998); Rasmussen and Parton (1994) and Wander *et al.* (1994) also reported similar findings.

The concentrations of exchangeable Ca (1.36 – 5.49 $cmol^+$ kg^{-1}) and K (0.11 – 0.19 $cmol^+$ kg^{-1}) and exchangeable Mg concentrations (1.73 - 2.61 $cmol^+$ kg^{-1}) were low to medium. Considering the ratio of exchangeable 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 recommended N, P and K fertilizers improve inherent soil fertility leading to rice yield.

Nitrogen and potassium inputs

The N and K input originated from application of urea and KCl (IN-1), compost (IN-2), 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 fertilizer) was about + 45.00 for farmer practices and + 112.50 kg N ha^{-1} $season^{-1}$ for recommendation rates, while for potassium was about + 50.70 kg K ha^{-1} $season^{-1}$ for recommendation rate. It can be said that the higher rate of urea and KCl fertilizers, the higher their contribution to the N and K inputs (Table 3).

The IN-2 was about + 21.00 kg N ha^{-1} $season^{-1}$, from the mean of N content in compost of 1.56 %, 0.93 % and 0.67 % N, while for K was about 51.20 kg K ha^{-1} $season^{-1}$, from the K consentrations of 2.90 %, 2.92 % and 2.85 % K (Table 2). Hence, besides the application rate of compost, the N and K concentrations in compost influenced the contribution. Therefore, it can also be concluded that application of two tons compost ha^{-1} $season^{-1}$ was relatively similar to application of 100 kg KCl ha^{-1} $season^{-1}$, the KCl recommendation rate.

The quality of water for irrigation were considered good contained of 2.35 mg l^{-1} NH_4^+, 0.76 mg l^{-1} K^+, 0.03 mg l^{-1} $P0_4^{3-}$ and 2,94 mg l^{-1} $N0_3^-$.

Nitrogen and potassium contribution inputs from irrigation water (IN-3) was about 0.79 N kg ha^{-1} $season^{-1}$

Table 3. The contribution of inorganic fertilizer (IN-1) and compost (IN-2) to P and K inputs, study on nutrient balance of newly opened wetland rice originated from wetland of Tanjung Buka SP-2 at Bulungan District.

Treatment	Rate of Fertilizer and Compost (kg $ha^{-1}season^{-1}$)			contribution to N (kg N $ha^{-1}season^{-1}$)		Contribution to K (kg K $ha^{-1}season^{-1}$)	
	Urea	KCl	Compost	IN-1	IN-2	IN-1	IN-2
T0	100	-	2.000	45.00	-	-	-
T1	100	-	2.000	45.00	21.00	-	51.20
T2	250	100	-	112.50	-	50.70	-
T3	250	100	2.000	112.50	21.00	50.70	51.20
T4	250	100	-	112.50	-	50.70	-
T5	250	100	2.000	112.50	21.00	50.70	51.20
T6	250	100	2000	112.50	21.00	50.70	51.20

T0: Farmer Practices (as control)
T1: Farmer Practices + Compost + Dolomite;
T2: NPK with recommendation rate, in which P was split two times
T3: NPK with recommendation rate + Compost
T4: NPK with recommendation rate
T5: NPK with recommendation rate+ Compost + Dolomite
T6: NPK with recommendation rate + Compost + dolomite, in which P was spli two times
IN-1: N or K input of mineral fertilizer
IN-2: N or K input of compost

Table 4. The contribution of irrigation water (IN-3) to phosphorous and potassium input, study on nutrient balance of newly opened wetland rice originated from wetland of Tanjung Buka SP-2 at Bulungan District.

Treatment	Water input, P and K concentrations				Contribution to input			
	Water input (L)	NH_4^+ ... mg l^{-1}......	NO_3^-	K Concen. Mg l^{-1}	IN-3 (kg N $ha^{-1}season^{-1}$)			IN-3 (kg K $ha^{-1}season^{-1}$)
T0	15 x 10^6	2.35	2.94	0.76	0.35	0.44	0.79	11.26
T1	15 x 10^6	2.35	2.94	0.76	0.35	0.44	0.79	11.26
T2	15 x 10^6	2.35	2.94	0.76	0.35	0.44	0.79	11.26
T3	15 x 10^6	2.35	2.94	0.76	0.35	0.44	0.79	11.26
T4	15 x 10^6	2.35	2.94	0.76	0.35	0.44	0.79	11.26
T5	15 x 10^6	2.35	2.94	0.76	0.35	0.44	0.79	11.26
T6	15 x 10^6	2.35	2.94	0.76	0.35	0.44	0.79	11.26

T0: Farmer Practices (as control)
T1: Farmer Practices + Compost + Dolomite;
T2: NPK with recommendation rate, in which P was split two times
T3: NPK with recommendation rate + Compost
T4: NPK with recommendation rate
T5: NPK with recommendation rate + Compost + Dolomite
T6: NPK with recommendation rate + Compost + dolomite, in which P was spli two times
IN-3: N or K input of irrigation water

equivalent to about 1.75 kg urea 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 3), which was considered high, almost one fourth of potassium fertilizer recommended rate.

The input coming from rain water was about 20.42 kg N, equal to 45 kg urea and for potassium about 1.74 kg K equal to 3.50 kg KCl ha^{-1} $season^{-1}$ (Table 4), which were considered insignificant. Similar results are reported in terraced paddy field system in Semarang District of about 20.6 kg N and 6.1 kg K ha^{-1} $season^{-1}$ (Sukristiyonubowo. 2007).

Nitrogen and potassium losses

N and K losses were estimated from rice grain (OUT-1) and by rice straw (OUT-2) taken out from the plots. The N and K loss are presented in Table 6 and 7.

N taken away by rice grain ranged between 22.50 and 53.50 kg N ha^{-1} $season^{-1}$ depending on the rice grain production. Meanwhile, nitrogen removed by rice straw varied from 14.68 and 38.45 kg N ha^{-1} $season^{-1}$(Tabel 6). The highest N removed by rice grain and rice straw were indicated by T6 (NPK with recommendation rate + Compost + dolomite, in which P was spli two times). The

Table 5. The contribution of rainfall water (IN-4) to nitrogen and potassium input, study on nutrient balance of newly opened wetland rice originated from wetland of Tanjung Buka SP-2 at Bulungan District.

Treatment	Rainfall, N and K concentrations			Contribution to input	
	Rainfall (mm)	NH4$^+$	K Concen. (mg K l^{-1})	IN-4 (kg N $ha^{-1}$$season^{-1}$)	IN-4 (kg K $ha^{-1}$$season^{-1}$)
T0	2,715	0.94	0.08	20.42	1.74
T1	2,715	0.94	0.08	20.42	1.74
T2	2,715	0.94	0.08	20.42	1.74
T3	2,715	0.94	0.08	20.42	1.74
T4	2,715	0.94	0.08	20.42	1.74
T5	2,715	0.94	0.08	20.42	1.74
T6	2,715	0.94	0.08	20.42	1.74

T0: Farmer Practices (as control)
T1: Farmer Practices + Compost + Dolomite;
T2: NPK with recommendation rate, in which P was split two times
T3: NPK with recommendation rate + Compost
T4: NPK with recommendation rate
T5: NPK with recommendation rate + Compost + Dolomite
T6: NPK with recommendation rate + Compost + dolomite, in which P was spli two times
IN-4: N or KInput of rain water

total N taken away by harvest product of about 91.95 kg N ha^{-1} $season^{-1}$ was also indicated by T6 because of the highest rice yield and rice straw of this treatment. Therefore, it can be said that increasing rice harvest product remove more nitrogen.

The similar results was shown by potassium, The highest K removed by rice grain and rice straw were indicated by T6 (NPK with recommendation rate + Compost + dolomite, in which P was spli two times). The total K taken away by harvest product of about 148.93 kg K ha^{-1} $season^{-1}$ was also indicated by T6 because of the highest rice yield and rice straw of this treatment. Therefore, it can be said that increasing rice harvest product also remove more potassium (Table 7).

Output-Input Analysis

The N 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) contributes considerably to total N and K input in all treatments. In the T0 to T6 treatments, IN-1 contributed to about 46 % to 84 % of total input of N and from 40 to 68 % of total K inputs. Similar result was observed in farmer practices rates (T0 and T1), which contributed from 46 to 59 % of the total N inputs. 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*. 2011)

Compost (IN-2) was also an important nutrient source, covering about 14 % to 22 % of total N 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 47 kg of urea and about 101 kg KCl. This will be more when the rate of compost application increased.

The IN-3 was considered insignificant for contribution to nitrogen of about 1% from total input of N for all treatment. However, the contributions of IN-3 to K inputs were still important, covering between 16 % and 93 % of the total K inputs.

Assessment of N input and output shows a positive balance for all treatments (Table 8). The surplus of N ranged between 39.03 and 71.62 kg N ha^{-1} $season^{-1}$. The treatment T3 indicated the N balance in the highest surplus. This may be explained by total inputs was the highest the same as treatments T5 and T6 and the total output (rice grain and straw productions) was considered lower than T5 and T6. In contrast, K input and Output analysis indicated negative balance for all treatments (Table 9). The deficit ranged from – 2.50 to – 60.43 kg K ha^{-1} $season^{-1}$, depending on the treatment. For T2 and T4, the K balance were also more negative than the others. These are due to K taken away by rice grains and rice straws. It was higher than other treatments and total inputs because of no input from compost. Therefore, to replace K taken out by rice harvest products, K fertilizer application rate should be increased from 100 to 200 kg KCl ha^{-1} $season^{-1}$ when the rate of compost is not increased. However, when the compost is increased from 2 tons to 3 tons ha^{-1} $season^{-1}$, K fertilizer application rate could be increased from 100 to 150 kg KCl ha^{-1} $season^{-1}$ as the compost from rice straw is rich in K. Regarding the farmers condition, the last option is more feasible since the rice straw is abundant in the fields.

The positive N balances in all treatments also demon-

Table 6. Rice biomass production including rice grain and rice straw of Inpari 10 variety and total N loss from rice grain (OUT-1) and rice straw (OUT-2) at newly opened wetland rice originated from wetland of Tanjung Buka SP-2 site, Bulungan District (in kg N $ha^{-1}season^{-1}$)

Treatments	Biomass Production ($t\ ha^{-1}$ $season^{-1}$)		N concentration (%)		N loss ($kg\ N\ ha^{-1}$ $season^{-1}$)		Total N loss
	Rice Grain	Rice Straw	Rice Grain	Rice Straw	OUT-1	OUT-2	
T0	2.05 c*)	2.33 c	1.10	0.63	22.50	14.68	37.18
T1	3.15 b	2.97 b	1.14	0.83	35.91	24.65	60.56
T2	3.93 a	4.20 a	1.18	0.87	46.37	36.54	82.91
T3	4.02 a	4.17 a	1.15	0.86	46.23	35.86	82.09
T4	3.88 a	3.97 a	1.14	0.76	44.23	30.17	74.40
T5	4.11 a	4.22 a	1.22	0.88	50.14	37.14	87.28
T6	4.18 a	4.32 a	1.28	0.89	53.50	38.45	91.95

T0: Farmer Practices (as control)
T1: Farmer Practices + Compost + Dolomite;
T2: NPK with recommendation rate, in which P was split two times
T3: NPK with recommendation rate + Compost
T4: NPK with recommendation rate
T5: NPK with recommendation rate+ Compost + Dolomite
T6: NPK with recommendation rate + Compost + dolomite, in which P was spli two times
OUT-1: N losses by rice grain
OUT-2: N losses by rice straw
*) The mean values in the same column followed by the same letter are not statistically different

Table 7. Rice biomass production including rice grain and rice straw of Inpari 10 variety and total K loss from rice grain (OUT-1) and rice straw (OUT-2) at newly opened wetland rice originated from of Tanjung Buka SP-2 site, Bulungan District (in kg K $ha^{-1}season^{-1}$)

Treatments	Biomass Production ($t\ ha^{-1}$ $season^{-1}$)		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	2.05 c*)	2.33 c	0.20	2.10	4.10	48.93	53.03
T1	3.15 b	2.97 b	0.22	2.68	5.53	77.56	83.09
T2	3.93 a	4.20 a	0.26	2.98	10.21	125.16	135.37
T3	4.02 a	4.17 a	0.25	2.95	10.05	118.59	128.64
T4	3.88 a	3.97 a	0.25	2.97	9.70	117.91	127.61
T5	4.11 a	4.22 a	0.31	3.11	11.74	131.24	142.98
T6	4.18 a	4.32 a	0.32	3.14	13.38	135.65	148.93

T0: Farmer Practices (as control)
T1: Farmer Practices + Compost + Dolomite;
T2: NPK with recommendation rate, in which P was split two times
T3: NPK with recommendation rate + Compost
T4: NPK with recommendation rate
T5: NPK with recommendation rate + Compost + Dolomite
T6: NPK with recommendation rate + Compost + dolomite, in which P was spli two times
OUT-1: K losses by rice grain
OUT-2: K losses by rice straw
*) The mean values in the same column followed by the same letter are not statistically different

strated that the application rates of urea were more than enough to replace N removed by rice grains and straw. Recommendation rate should be reduced to avoid any negative impact and to reduce operational cost. Therefore, to get better rice production, to prevent the environment from pollution hazard and to keep soil quality, N fertilizer application rate should be 200 kg ha^{-1} $seson^{-1}$ or when compost increased from 2 to 3 ton ha^{-1} $season^{-1}$, the N recommended rate is 150 kg $ha^{-1}season^{-1}$. For potassium the application rate should be increased from 100 to 200 kg KCl ha^{-1} $season^{-1}$. However, as rice straw was abandon in the rice fields and can easily be composted, the K fertilizer can be increased to 150 kg KCl ha^{-1} $season^{-1}$ with adding more compost, from 2 to 3 ton ha^{-1} $season^{-1}$. It can be concluded that to sustain higher rice yield, the recommendation rates are 150 kg

Table 8. Input-ooutput analysis for nitrogen of newly opened wetland rice originated from wetland of Tanjung Buka SP-2 site, Bulungan District (kg N ha^{-1} $season^{-1}$)

	Treatments						
Parameter	**T0**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
N INPUT (kg N ha^{-1} $season^{-1}$)							
IN-1	+ 45.00	+ 45.00	+ 112.50	+ 112.50	+112.50	+ 112.50	+ 112.50
	59%	46%	84%	73%	84%	84%	84%
IN-2	-	+ 21.00	-	+ 21.00	-	+ 21.00	+ 21.00
	0%	22%	0%	14%	0%	14%	14%
IN-3	+ 0.79	+ 0.79	+ 0.79	+ 0.79	+ 0.79	+ 0.79	0.79
	1%	1%	1%	1%	1%	1%	1%
IN-4	+ 20.42	+ 20.42	+ 20.42	+ 20.42	+ 20.42	+ 20.42	+ 20.42
	40%	31%	15%	13%	15%	13%	13%
Total Input	+ 76.21	+ 97.21	+ 133.71	+ 153.71	+ 133.71	+ 153.71	+ 153.71
	100%	100%	100%	100%	100%	100%	100%
N OUTPUT(kg N ha^{-1} $Season^{-1}$)							
OUTPUT-1	- 22.50	- 35.91	- 46.37	- 46.23	- 44.23	- 50.14	- 53.50
	60%	59%	56%	56%	59%	57%	58%
OUTPUT-2	- 14.68	- 24.65	- 36.54	- 35.86	- 30.17	- 37.14	- 38.45
	40%	41%	44%	44%	41%	43%	42%
Total Output	- 37.18	- 60.56	- 82.91	- 82.09	- 74.40	- 87.28	- 91.95
	100%	100%	100%	100%	100%	100%	100%
N Balance	+ 39.03	+ 36.65	+ 50.80	+ 71.62	+ 63.31	+ 66.43	+ 61.76

Table 9. Input-ooutput analysis for potassium of newly opened wetland rice originated from wetland of Tanjung Buka SP-2 site, Bulungan District (kg K ha^{-1} $season^{-1}$)

	Treatment						
Paramenter	**To**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
K INPUT (kg K ha^{-1} $season^{-1}$)							
IN-1	-	-	+ 50.70	+ 50.70	+ 50.70	+ 50.70	+ 50.70
			68%	40%	68%	40%	40%
IN-2	-	+ 51.20	-	+ 51.20	-	+ 51.20	+ 51.20
		68%	0%	41%	0%	41%	41%
IN-3	+ 22.50	+ 22.50	+ 22.50	+ 22.50	+ 22.50	+ 22.50	+ 22.50
	93%	30%	30%	16%	30%	16%	16%
IN-4	+ 1.74	+ 1.74	+ 1.74	+ 1.74	+ 1.74	+ 1.74	+ 1.74
	7%	2%	2%	3%	2%	3%	3%
Total Input	+ 24.24	+ 75.44	+ 74.94	+ 126.14	+ 74.94	+ 126.14	+ 126.14
	100%	100%	100%	100%	100%	100%	100%
K OUTPUT(kg K ha^{-1} $Season^{-1}$)							
OUTPUT-1	- 4.10	- 5.53	- 10.21	- 10.05	- 9.70	- 11.74	- 13.38
	8%	7%	8%	8%	8%	8%	9%
OUTPUT-2	- 48.93	- 77.56	- 125.16	-118.59	- 117.91	- 131.24	- 135.65
	92%	93%	92%	92%	92%	92%	91%
Total Output	- 53.03	- 83.09	- 135.37	- 128.64	- 127.61	- 142.98	- 148.93
	100%	100%	100%	100%	100%	100%	100%
Balance	- 29.79	- 8.65	- 60.43	- 2.50	- 52.67	- 16.84	- 22.79

Note: percentage in the same couloum indibated the contribution to to input/output urea and 150 kg KCl ha^{-1} $season^{-1}$ with 3 tons ha^{-1} $season^{-1}$ compost and 2 tons ha^{-1}.

CONCLUSION

Assessment of N and K input and output of newly opened wetland rice originated from wetland in Tanjung Buka SP-2, Bulungan District indicated the surplus N ranged from 39.03 to 71.62 kg N ha^{-1} $season^{-1}$, meaning that urea application rate is more than enough to replace N removed by harvest product. To obtain better rice production and to improve soil function, N fertilizer application rate should be reduced to 150 kg urea with added more compost, up to of 3 tons ha^{-1} $season^{-1}$. 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 tons 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 N and K recommendation rate imply that total urea and KCl should be available at district level will be about 1,477 tons urea and 1,477 tons KCl $district^{-1}$ $season^{-1}$, respectively (150 kg urea x 9,849 ha and 150 kg KCl x 9,849 ha).

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