

# Study on Nutrient Balances of Newly Developed Lowland Rice Fields at Kleseleon Village, Malaka District, Nusa Tenggara Timur

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## ABSTRACT

The land allocated for newly opened lowland rice can be from ultisols, oxisols, inceptisols, and potential acid sulfate soils. The study was aimed to evaluate nitrogen (N), phosphorous (P), and potassium (K) inputs – outputs of newly developed lowland rice under different treatments and to validate the N, P, and K recommended applications rate according to N, P, and K balances. The study was conducted in Kleseleon village, Malaka District. Five treatments were tested namely T0: farmers practices, T1: NPK at recommendation rate + Rice straw compost, T2: NPK at recommendation rate + Smart + Rice straw compost, T3:  $\frac{3}{4}$  NPK at recommendation rate + Smart + Rice straw compost, and T4: NPK at recommendation rate + Smart + Rice straw compost. The treatments were arranged in a randomized complete block design with three replications. The nutrient balances were constructed according to the difference between nutrient inputs and losses. The results indicated that there were surplus N, P, and K across the treatments and more than adequate to replace N, P, and K removed by harvest products. The suggested N, P, and K application rates were 100 kg urea, 100 kg SP-36, and 100 kg KCl with the addition of compost 3 Mg ha<sup>-1</sup> season<sup>-1</sup>.

**Keywords:** Newly developed lowland rice, nutrient balances, nutrient input, nutrient losses, nutrient surplus

## ABSTRAK

Tanah dialokasikan untuk padi sawah yang baru dibuka dapat berasal dari ultisols, oxisols, inceptisols dan potensi tanah asam sulfat. Penelitian dilakukan di Desa Kleseleon, Kabupaten Malaka pada tahun 2014. Lima perlakuan yang diujikan yaitu T0: Praktik petani, T1: NPK tingkat rekomendasi + Kompos jerami, T2: NPK tingkat rekomendasi + smart + Kompos jerami, T3:  $\frac{3}{4}$  NPK pada tingkat rekomendasi + Smart + Kompos jerami padi dan T4: NPK pada tingkat rekomendasi + Smart + Kompos jerami padi, dimana aplikasi N, P dan K dibagi dua kali. Perlakuan disusun dalam Rancangan Acak Kelompok Lengkap dengan tiga ulangan. Keseimbangan hara dibangun menurut perbedaan antara hara yang masukan dan diambil tanaman padi. Tujuannya adalah (1) untuk mengevaluasi masukan - keluaran nitrogen, fosfor dan kalium dan (2) untuk memvalidasi tingkat rekomendasi nitrogen, fosfor dan kalium menurut keseimbangan nitrogen, fosfor dan kalium. Hasil menunjukkan bahwa ada kelebihan N, P dan K di seluruh perlakuan dan lebih dari cukup untuk menggantikan N, P dan K yang dihilangkan oleh produk panen. Dosis aplikasi N, P dan K adalah 100 kg urea, 100 kg SP-36 dan 100 kg KCl dengan penambahan kompos 3 Mg ha<sup>-1</sup> musim<sup>-1</sup>.

**Kata Kunci:** keseimbangan hara, unsur hara yang diterima, unsur hara yang diambil tanaman, sawah bukaan baru, kelebihan unsur hara

## INTRODUCTION

The land granted for newly opened low land rice fields in Nusa Tenggara Timur Province have

many shortcomings (Sukristiyonubowo *et al.* 2014), namely the soils are basic with a low level of macro- and micro-nutrients. Furthermore, a study on the nutrient balances of newly developed lowland rice in Indonesia neither simple nor complete nutrient balance is still rare and not well documented (Sukristiyonubowo *et al.* 2016). A complete nutrient

balance is very complicated, therefore, the researchers reported that most assessments are partial analysis of these in-and output data (Miller *et al.* 1976; Smaling *et al.* 1993; Drechsel *et al.* 2001; Wijnhoud *et al.* 2003). Also, the quantification of nutrient inputs and outputs is important for agronomical, economic, and environmental analyses.

According to the researchers, the differences between nutrient gains and losses are called nutrients balance. Nutrient coming from fertilizers (IN-1), returned crop residues (IN-2), irrigation (IN-3), rainfall (IN4), as well as biological nitrogen fixation is grouped as nutrient inputs (Sukristiyonubowo *et al.* 2010; Sukristiyonubowo 2007; Wijnhoud *et al.* 2003; Lefroy and Konboon 1999; Smaling *et al.* 1993). Nutrient losses 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 sulfur). Researchers concluded when the nutrient removals are not replaced by sufficient application of fertilizers or returning of biomass, soil mining takes place and crop production does not reach its potential yields and finally reduces (Sukristiyonubowo *et al.* 2012; Sukristiyonubowo *et al.* 2010; Sukristiyonubowo 2007; Uexkul 1989).

According to many researchers, nutrient balances in dry land and wetland crops 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.* 2010; Sukristiyonubowo 2007; Bationo *et al.* 1998; Hashim *et al.* 1998; Van den Bosch *et al.* 1998a; Van den Bosch *et al.* 1998b; Syers *et al.* 1996; Smaling *et al.* 1993; and Stoorvogel *et al.* 1993). Many studies indicated that at plot, farm, district, province, and national levels, agricultural production is characterized by a negative nutrient balance (Sukristiyonubowo 2017; Sukristiyonubowo *et al.* 2012; Sukristiyonubowo 2007; Nkonya 2005; Sheldrick 2003; Harris 1998; Van den Bosch *et al.* 1998a; Van den Bosch *et al.* 1998b). In upland crop, a long-term nitrogen experiment at plot scale in the dry land sloping area of Kuamang Kuning, Jambi Province, Indonesia confirmed that the balance in the plot without input is deficit 4 kg N ha<sup>-1</sup> yr<sup>-1</sup>. However, this did not happen in the plots treated with a combination of high fertilizer application rate and *Flemingia congesta* leaves planted in a hedgerow system (Santoso *et al.* 1995).

The objectives of the study were (a) to evaluate nitrogen, phosphorous, and potassium inputs –

outputs of newly developed lowland rice under different promising treatments and (b) to validate the N, P and K recommended applications rate. It was hypothesized that proper N, P, and K fertilizer applications rate based on N, P, and K studies lead to optimal rice yield.

## MATERIALS AND METHODS

### Study Sites

A study on nitrogen, phosphorous, and potassium balances of newly developed lowland rice was conducted in Kleseleon Village, Malaka District, Nusa Tenggara Timur Province, in 2014. Soil type was ustifluent with ustic to hemic soil moisture regimes. The site was relatively flat and developed in 2011.

### Research Design

Five promising treatments were tested namely T0: farmers practices (as control), T1: NPK with recommendation rate + Rice Straw Compost, T2: NPK with recommendation rate + Smart + Rice Straw Compost, T3: ¾ NPK with recommendation rate + Smart + Rice Straw Compost, and T4: NPK with recommendation rate + Smart + Rice Straw Compost. These treatments were constructed according to the fact that a soil fertility status was classified as low with soil pH about 8.02 to 8.20, low soil organic carbon, and the farmers did not apply N, P, and K fertilizers properly and some did not apply K fertilizer and organic fertilizer.

The treatments were arranged in a randomized complete block design (RCBD) and replicated three times. The plot sizes were 5 m × 5 m with the distance among the plot was 50 cm and between replication was about 100 cm.

### Fertilizer and Compost Application

NPK fertilizers used were originated from single fertilizers namely urea, SP-36 (Super Phosphate), and KCl (potassium chloride). Based on the direct measurement with Soil Test Kits, the recommendation rate was determined by about 250 kg urea, 100 kg SP-36, and 100 kg KCl ha<sup>-1</sup> season<sup>-1</sup>, while the common farmer practices rate was 100 kg urea and 50 kg SP-36 ha<sup>-1</sup> season<sup>-1</sup>. The urea and KCl were split three times namely 50% at planting time, 25% at 21 DAT (days after transplanting), and the last 25% was given at 35 DAT. Rice straw compost of about 3 Mg ha<sup>-1</sup> was broadcasted a week before planting. Only in treatment

Table 1. The detailed treatments of NPK fertilization, biofertilizer, and rice straw compost under this study.

Code	Treatment	Urea	SP-36	KCl	Smart/ Biofertilizer	Straw Compost
.....kg ha <sup>-1</sup> .....						
T0	Farmer Practices (as control)	100	50	-	-	-
T1	NPK with recommendation rate + Rice Straw Compost	250	100	100	-	3.000
T2	NPK with recommendation rate + Smart + Rice Straw Compost	250	100	100	10	2.000
T3	¾ NPK with recommendation rate + Smart + Rice Straw Compost	187.50	75	75	10	2.000
T4	NPK with recommendation rate + Smart + Compost, in which N, P, and K were split two times: 50% were given at planting time and 50% was added at 21 days after planting	250	100	100	10	2.000

T4, N, P, and K fertilizers were applied two times: 50 % at planting time, and 50 % was given at 21 DAT. In the farmer practices, N was split two times, 50 % at planting time and 50 % at 21 DAT, while P was given one time at planting time. A week before broadcasting the compost, one kg of composite straw compost were taken and analyzed for its chemical contents. Biofertilizer namely Smart was applied as seed treatment with a rate of 10 kg ha<sup>-1</sup> or 10 kg Smart for 25 kg seeds. The detailed treatments are presented in Table 1.

Ciherang rice variety was cultivated as a plant indicator. Transplanting was carried out at the beginning of March 2014 and harvest at the end of June 2014. Twenty-one-day-old seedlings were transplanted at about a 25 cm × 25 cm cropping distance with about three seedlings per hill.

**Biomass and Rice Yields Quantification**

Rice biomass production including grains, straw, and residues were measured at harvest. When water content in rice grains was 16 %, the rice plants were harvested, and for measurement, the constant weight of rice grains yield the water content of 14 % was used. Sampling units (1 m × 1 m plot), were randomly selected at every plot. Rice plants were manually cut about 15 to 20 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 input-output analysis, rice residue was not considered as an input, as it always remains in the field.

The inputs of nitrogen, phosphorous, and potassium were the sum of N, P, and K coming from mineral fertilizers (IN-1), rice straw compost (IN-2), irrigation (IN-3), and precipitation (IN-4). Outputs were the sum of nitrogen, phosphorous, and potassium removed by rice grains (OUT-1) and rice straw (OUT-2). To quantify nitrogen, phosphorous, and potassium gains, data included concentrations of N, P and K in urea, SP-36 and KCl, rate of urea, SP-36 and KCl, amount of N, P and K in compost, irrigation water supply, N, P and K concentrations in irrigation waters and rainfall were collected. The output parameters were rice grains yield, rice straw production, N, P, and K concentrations in rice grains and rice straw.

IN-1 and IN-2 were calculated based on the amount of mineral and organic fertilizers added multiplied by the concentration of N, P, and K in urea, 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 difference between incoming water and outgoing water. Incoming water was calculated through water discharge multiplied by the time the inlet is open and close inlet and outlet during the rice life cycle, mainly from land soaking to the repining stage. As the N, P, and K concentrations from the outlet were not measured, thus the contribution of nitrogen, phosphorous, and potassium from irrigation water was predicted based on water input multiplied by the N, P, and K contents in incoming water, respectively. In this experiment, the pounding water layer was maintained at about three cm. The water discharge was measured using the Floating method (WMO 1994). IN-4 was estimated by mul-

tiplying rainfall volume with nitrogen, phosphorous, and potassium concentrations in the rainwater. On a hectare basis, it was counted as follows (Sukristiyonubowo 2007; WMO 1994).

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

Where:

- IN-4 is N, P or K input of rainfall water in kg N, kg P and K ha<sup>-1</sup> season<sup>-1</sup>
- A is rainfall in mm
- 10000 is conversion of ha to m<sup>2</sup>
- 0.80 is the correction factor, as not all rainwater goes into the soil
- B is N, P and K concentrations in rainfall water in mg l<sup>-1</sup>, respectively
- 1000 is conversion from m<sup>3</sup> to l
- 1000 is conversion from mm to m
- 10<sup>6</sup> is conversion from mg to kg

### Samples Analysis

To monitor rainfall events, data from the rain gauge and climatology station of Malaka were considered. Rainwaters were sampled once during rice growth and development from a rain gauge in 600 ml plastic bottles and were also analyzed according to the procedures of the Laboratory of the Soil Research Institute, Bogor (Soil Research Institute 2009).

Theoretically, the nitrogen loss can be through harvested products (rice grains and rice straw), leaching, and ammonia volatilization. Due to leaching and ammonia volatilization was not yet measured, thus the nitrogen loss was calculated only from the harvested product. Consequently, the total nitrogen output was a bit underestimated. Hence, nitrogen, phosphorous, and potassium losses were calculated through harvested products (rice grains and rice straw). As all rice grains were transported out of plots, OUT-1 was estimated based on rice grains yield multiplied with N, P, and K concentrations in

the grains, respectively. OUT-2 was calculated according to the total rice straw production multiplied with N, 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 is applied for the coming planting season.

For the laboratory analyses, rice plants from every plot with the best tiller number from the five teen samples of plant height (vegetative growth) were chosen. 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 deionized water to avoid any contamination and oven-dried at 70 °C. The dried samples were ground and stored in plastic bottles. Nitrogen was determined by wet ashing using concentrated H<sub>2</sub>SO<sub>4</sub> (97%) and selenium (Soil Research Institute 2009), P and K were measured after wet ashing using HClO<sub>4</sub> and HNO<sub>3</sub> (Soil Research Institute 2009).

## RESULTS AND DISCUSSION

### Nitrogen, Phosphorous and Potassium Inputs

Application of Urea, SP-36, and KCl (IN-1), rice straw compost (IN-2), irrigation water (IN-3), and rainfall water (IN-4) are considered as the N, P, and K inputs and presented in Tables 2, 3, and 4. The IN-1 (contribution of mineral fertilizer) varied from +45.00 for farmer practices to +112.50 kg N ha<sup>-1</sup> season<sup>-1</sup> for recommendation rates and +8.00 for farmer practices and +16.00 kg P ha<sup>-1</sup> season<sup>-1</sup> for recommendation rates, while for potassium was about +50.70 kg K ha<sup>-1</sup> season<sup>-1</sup> for recommendation rate (Table 2). Therefore, it can be concluded that the higher the dosage of urea, SP-36, and KCl

Table 2. The contribution of inorganic fertilizer (IN-1) to N, P and K inputs.

Treatment	Rate of Fertilizer (kg ha <sup>-1</sup> season <sup>-1</sup> )			Contribution of Mineral Fertilizer (IN-1)		
	Urea	SP-36	KCl	IN-1 (kg N ha <sup>-1</sup> season <sup>-1</sup> )	IN-1 (kgP ha <sup>-1</sup> season <sup>-1</sup> )	IN-1 (kg K ha <sup>-1</sup> season <sup>-1</sup> )
T0	100	50	-	45	8.00	-
T1	250	100	100	112.50	16.00	50.70
T2	250	100	100	112.50	16.00	50.70
T3	187.50	100	100	82.50	16.00	50.70
T4	250	100	100	112.50	16.00	50.70

Table 3. The contribution of organic fertilizer (IN-2) to N, P and K inputs.

Treatment	Rate of Compost (kg ha <sup>-1</sup> season <sup>-1</sup> )	Contribution of Compost (IN-2)		
		IN-2 (kg N ha <sup>-1</sup> season <sup>-1</sup> )	IN-2 (kg P ha <sup>-1</sup> season <sup>-1</sup> )	IN-2 (kg K ha <sup>-1</sup> season <sup>-1</sup> )
T0	-	-	-	-
T1	3000	30.60	4.80	83.70
T2	2000	20.40	3.20	55.80
T3	2000	20.40	3.20	55.80
T4	2000	20.40	3.20	55.80

fertilizers, the higher their contribution to the nitrogen, phosphorous, and potassium inputs (Table 2).

The IN-2, the contribution of rice straw compost was about +20.40 to +30.60 kg N ha<sup>-1</sup>, from the average of nitrogen contents in rice straw compost of 1.52 %, 0.93 %, and 0.60% N and +3.20 to +4.80 kg P ha<sup>-1</sup> season<sup>-1</sup>, from the mean of phosphorous content in rice straw compost of 0.09%, 0.11%, and 0.27% P, while for K was about +55.80 to +83.70 kg K ha<sup>-1</sup>season<sup>-1</sup>, from the average of K concentrations of 2.90%, 2.62% and 2.85% K (Table 3). Thus, besides the application rate of compost, the nutrient concentration in compost influenced the contribution. It can also be concluded that the application of two and three tons of rice straw compost ha<sup>-1</sup> season<sup>-1</sup> was higher than the application of 100 kg KCl ha<sup>-1</sup> season<sup>-1</sup>, the KCl recommendation rate.

While the contribution of nitrogen, phosphorous, and potassium inputs from irrigation water (IN-3) was about +23.76 kg N equivalent to about

55 kg urea and input from rainwater was about +8.74 kg N, equal to about 20 kg urea (Table 4) and 0.15 kg P ha<sup>-1</sup> season<sup>-1</sup> equivalent to about 0.9 kg SP-36 ha<sup>-1</sup> season<sup>-1</sup>, meanwhile for potassium was about +11.26 kg K ha<sup>-1</sup> season<sup>-1</sup> equivalent to about 22.52 kg KCl ha<sup>-1</sup> season<sup>-1</sup> (Table 5), which was considered high, almost one-fourth of potassium fertilizer recommended rate.

The input from rainwater was about +0.38 kg P, equal to 2.40 kg SP-36, and for potassium was about +0.77 kg K equal to 3.00 kg KCl ha<sup>-1</sup> season<sup>-1</sup> (Table 6), which were considered insignificant. Similar results were found in the terraced paddy field system in the Semarang District of about +20.6 kg N, +2.6 kg P, and + 6.1 kg K ha<sup>-1</sup> season<sup>-1</sup> (Sukristiyonubowo 2007).

**Nitrogen, Phosphorous and Potassium Losses**

The losses of nitrogen, phosphorous, and potassium were estimated from rice grains (OUT-1) and rice straw (OUT-2) taken out from the plots.

Table 4. The contribution of irrigation (IN-3) and rain water (IN-4) to nitrogen input(kg N ha<sup>-1</sup> season<sup>-1</sup>).

Treatments	water input, NH <sub>4</sub> <sup>+</sup> and NO <sub>3</sub> <sup>-</sup> concentration				Rain Water		
	Water input (L)	NH <sub>4</sub> <sup>+</sup> (mg l <sup>-1</sup> )	NO <sub>3</sub> <sup>-</sup> (mg l <sup>-1</sup> )	IN <sup>-3</sup> (kg N ha <sup>-1</sup> )	Rainfall (mm yr <sup>-1</sup> )	NH <sub>4</sub> <sup>+</sup> (mg l <sup>-1</sup> )	IN <sup>-4</sup> (kg N ha <sup>-1</sup> )
T0-T4	15 × 10 <sup>6</sup>	0.77	0.92	23.76	1200	0.91	8.74

Note: T0: Farmer Practices (as control)

T1: NPK at recommendatin rate + Rice straw Compost

T2: NPK at recommendation rate + Smart + Rice straw Compost

T3:¾ NPK with recommendation rate + Smart + Rice straw Compost

T4: NPK at recommendation rate+ Smart + Rice straw Compost (N, P and K were split 2×)

Table 5. The contribution of irrigation water (IN-3) to phosphorous and potassium inputs.

Treatment	Water input, P and K concentrations			Contribution to input	
	Water input (L)	PO <sub>4</sub> <sup>3-</sup> Concen. (mg l <sup>-1</sup> )	K Concen. (mg l <sup>-1</sup> )	IN-3 (kg P ha <sup>-1</sup> season <sup>-1</sup> )	IN-3 (kg K ha <sup>-1</sup> season <sup>-1</sup> )
T0-T4	15 × 10 <sup>6</sup>	0.03	0.76	0.15	11.26

Table 6. The contribution of rain water (IN-4) to phosphorous and potassium inputs.

Treatment	Rainfall, P, and K concentrations			Contribution to input	
	Rainfall (mm)	P Concen. (mg PO <sub>4</sub> l <sup>-1</sup> )	K Concen. (mg K l <sup>-1</sup> )	IN-4 (kg P ha <sup>-1</sup> season <sup>-1</sup> )	IN-4 (kg K ha <sup>-1</sup> season <sup>-1</sup> )
T0-T4	1200	0.04	0.08	0.38	0.77

The N, P and K loss are presented in Tables 7, 8, and 9. Nitrogen removed by rice grains varied from -30.27 to -53.87 kg N ha<sup>-1</sup> season<sup>-1</sup> depending on rice grains yield. Nitrogen removed by rice straw was about -19.84 to -35.73 kg N ha<sup>-1</sup> season<sup>-1</sup>. The highest N removed by rice grains was shown by T1 and by rice straw was by T3. However, the total N taken away by harvest product of about kg -85.72 N ha<sup>-1</sup> season<sup>-1</sup> was shown by T1 because of the highest rice grains yield and rice straw of this treatment (Table 7). Therefore, it can be said that increasing rice harvest product remove more nitrogen.

P taken away by rice grains ranged between -8.69 and -16.90 kg P ha<sup>-1</sup> season<sup>-1</sup> depending on the rice grains production. While P removed by rice straw varied from -2.48 to -3.57 kg P ha<sup>-1</sup> season<sup>-1</sup>. The highest P removed by rice grains was shown

by T1 and by rice straw was by T3. However, the total P removed by harvest product of about -20.47 kg P ha<sup>-1</sup> season<sup>-1</sup> was shown by T3 because of the highest rice grains yield and rice straw of this treatment (Table 8). Therefore, it can be said that increasing rice harvest product also remove more phosphorous.

Potassium removed by rice grain ranged between -15.46 and -34.02 kg K ha<sup>-1</sup> season<sup>-1</sup> depending on the rice grains production. K removed by rice straw varied from -45.63 to -81.20 kg K ha<sup>-1</sup> season<sup>-1</sup> (Table 9). The highest K removed by rice grains was shown by T1 as well as rice straw. Thus, total K removed by harvest product of about -115.22 kg K ha<sup>-1</sup> season<sup>-1</sup> was shown by T1 because of the highest rice yield and rice straw of this treatment. Therefore, it can also be said that increasing rice harvest product remove more potassium.

Table 7. Rice biomass production including rice grains and rice straw of Ciherang variety and total nitrogen loss from rice grains (OUT-1) and rice straw (OUT-2).

Treatments	Biomass Production (Mg ha <sup>-1</sup> season <sup>-1</sup> )		N concentration (%)		N loss (kg N ha <sup>-1</sup> season <sup>-1</sup> )		Total N loss
	Rice Grains	Rice Straw	Rice Grains	Rice Straw	OUT-1	OUT-2	
T0	3.22 a	2.48 a	0.94	0.80	30.27	19.84	50.11
T1	5.67 b	3.50 ab	0.95	0.91	53.87	31.85	85.72
T2	5.27 b	3.37 ab	1.01	0.88	53.23	29.66	82.89
T3	4.97 b	3.97 b	1.00	0.90	49.70	35.73	85.43
T4	4.88 b	2.97 a	0.97	0.87	47.34	25.84	73.18

Table 8. Rice biomass production including rice grain and rice straw of Ciherang variety and total P loss from rice grains (OUT-1) and rice straw (OUT-2).

Treatments	Biomass Production (Mg ha <sup>-1</sup> season <sup>-1</sup> )		P concentration (%)		P loss (kg P ha <sup>-1</sup> season <sup>-1</sup> )		Total P loss
	Rice Grains	Rice Straw	Rice Grains	Rice Straw	OUT-1	OUT-2	
T0	3.22 a	2.48 a	0.27	0.10	8.69	2.48	11.17
T1	5.67 b	3.50 ab	0.29	0.09	16.44	3.15	19.59
T2	5.27 b	3.37 ab	0.29	0.08	15.28	2.70	17.98
T3	4.97 b	3.97 b	0.34	0.09	16.90	3.57	20.47
T4	4.88 b	2.97 a	0.31	0.09	15.13	2.67	17.80

Table 9. Rice biomass production including rice grain and rice straw of Ciherang variety and total K loss from rice grain (OUT-1) and rice straw (OUT-2).

Treatments	Biomass Production		K concentration		K loss		Total K loss
	(Mg ha <sup>-1</sup> season <sup>-1</sup> )		(%)		(kg K ha <sup>-1</sup> season <sup>-1</sup> )		
	Rice Grains	Rice Straw	Rice Grains	Rice Straw	OUT-1	OUT-2	
T0	3.22 a	2.48 a	0.48	1.84	15.46	45.63	61.09
T1	5.67 b	3.50 ab	0.60	2.32	34.02	81.20	115.22
T2	5.27 b	3.37 ab	0.55	2.05	28.98	69.09	98.07
T3	4.97 b	3.97 b	0.54	1.73	26.84	68.68	95.52
T4	4.88 b	2.97 a	0.60	1.97	29.28	58.50	87.78

Table 10. Output-input analysis of nitrogen at study on nutrient balances at plot scale of newly developed lowland rice field at Kleseleon site, Malaka District, Nusa Tenggara Timur Province (kg N ha<sup>-1</sup> season<sup>-1</sup>).

Treatments	N INPUT (kg N ha <sup>-1</sup> season <sup>-1</sup> )					N OUTPUT (kg N ha <sup>-1</sup> season <sup>-1</sup> )			N Balance
	IN-1	IN-2	IN-3	IN-4	Total N INPUT	OUT-1	OUT-2	Total N OUTPUT	
	To	45.00	-	23.76	8.74	77.50	-30.27	-19.84	
	58%	-	30%	12%	100 %	60 %	40 %	100 %	
T1	112.50	30.60	23.76	8.74	175.60	-53.87	-31.87	-85.72	+89.88
	64%	17%	13 %	6 %	100 %	63 %	37 %	100 %	
T2	112.50	20.40	23.76	8.74	165.40	-53.23	-29.66	-82.89	+82.66
	68%	12%	14 %	6 %	100 %	64 %	36 %	100 %	
T3	82.50	20.40	23.76	8.74	135.40	-49.70	-35.79	-85.49	+49.91
	61%	15%	17 %	7 %	100 %	59 %	41 %	100 %	
T4	112.50	20.40	23.76	8.74	165.40	-47.34	-25.84	-83.18	+82.22
	68%	12%	14 %	6 %	100 %	57 %	43 %	100 %	

### Output-Input Analysis

The N, P and K balances of newly developed lowland rice are presented in Tables 10, 11, and 12. In general, the results indicated that inorganic fertilizer (IN-1) contributes considerably to total N, P, and K input in all treatments. The amounts varied from +45.00 to +112.50 kg N ha<sup>-1</sup> season<sup>-1</sup> depending on the treatment. The contribution to P was about + 8.00 to +16.00 kg P depending on treatment and about + 50.70 kg K ha<sup>-1</sup> season<sup>-1</sup>, respectively. In the T1 to T4 treatments, IN-1 contributed about 75% to 84% of the total input of P (Table 11) and from 35 to 43% of total K inputs (Table 12).

Rice straw compost (IN-2) was also an essential nutrient source, contributing about 12% to 17% of total N (Table 10); 16% to 22% of total P (Table 11), and from 47 to 56% of total K input (Table 12) depending on the treatment. The IN-2 is more important when less or no inorganic fertilizers are applied and more organic fertilizer is added.

Nutrient supplied by compost was equivalent to about 45- 68 kg of urea; 20-25 kg of SP-36 and about 110 - 130 kg kcal. There will be more nutrients when the rate of compost application increased.

In general, the assessment of nitrogen input and output showed a surplus or positive balance for all treatments (Table 10). The surplus ranged between +27.39 and +89.88 kg N ha<sup>-1</sup> season<sup>-1</sup>, depending on the treatment. The nitrogen balances in the T1, T2, and T4 were more surplus than in the other treatments. This may be explained by the increase in nitrogen fertilizer application rate. It should also be noted that the N output will even be higher when NH<sub>3</sub> volatilization and leaching are taken into account.

Like nitrogen evaluation, assessment of P input and output shows a positive balance for all treatments (Table 11). The surplus of P ranged between +1.74 and +1.93 kg P ha<sup>-1</sup> season<sup>-1</sup>. The P balances in the T4 was the best surplus compared to the other treatments. Although the amounts of potassium com-

Table 11. Output-input analysis of phosphorus, study on nutrient balances at plot scale of newly developed lowland rice field at Kleseleon site, Malaka District, Nusa Tenggara Timur Province (kg P ha<sup>-1</sup> season<sup>-1</sup>).

Treatments	P INPUT (kg P ha <sup>-1</sup> season <sup>-1</sup> )					P OUTPUT (Kg P ha <sup>-1</sup> season <sup>-1</sup> )			P Balance
	IN-1	IN-2	IN-3	IN-4	Total P INPUT	OUT-1	OUT-2	Total P OUTPUT	
To	+8.00 94%	- 0%	+0.15 2%	+0.38 4%	+8.53 100%	-8.69 78%	-2.48 22%	-11.17 100%	- 2.64
T1	+16.00 75%	+4.80 22%	+0.15 1%	+0.38 2%	+21.33 100%	-16.44 84%	-3.15 16%	-19.59 100%	+1.74
T2	+16.00 81%	+3.20 16%	+0.15 1%	+0.38 2%	+19.73 100%	-15.28 85%	- 2.70 15%	-17.98 100%	+1.75
T3	+16.00 81%	+3.20 16%	+0.15 1%	+0.38 2%	+19.73 100%	-16.90 82%	-3.57 18%	-20.47 100%	-0.97
T4	+16.00 81%	+3.20 16%	+0.15 1%	+0.38 2%	+19.73 100%	-15.13 85%	- 2.67 15%	-17.80 100%	+1.93

ing from irrigation water (IN-3) were smaller compared to the amounts of nutrients originating from inorganic fertilizers (IN-1) and organic fertilizer (IN-2), the contributions of IN-3 to K inputs were still important, covering between 8 % and 93 % of the total K inputs (Table 12).

Similar to the P balance, K input and Output analysis also indicated positive balances for all treatments (Table 12). The surplus ranged from +20.46 to +31.72 kg K ha<sup>-1</sup> season<sup>-1</sup>, depending on the treatment. For T1 and T4, the K balances were also more positive than the others. These were due to K input from compost were higher than other treatments. To replace K taken out by rice harvest products, therefore, K fertilizer application rate should be sustained to 100 kg KCl ha<sup>-1</sup> season<sup>-1</sup> when

the rate of compost was not increased. However, when the compost is increased to more than 3 tons ha<sup>-1</sup> season<sup>-1</sup> as the compost from rice straw is rich in K, then application mineral fertilizer rate can be reduced. Regarding the farmers' condition, the last option was more feasible since the rice straw is available in the fields.

The positive N, P, and K balances in all treatments also demonstrated that the application rates of organic and inorganic fertilizers were more than enough to substitute N, P, and K removed by rice grains and straw. But when P and K fertilizers application rates were less than 100 kg ha<sup>-1</sup> season<sup>-1</sup> or no application P dan K fertilizers were added, the deficit or negative P and K balances occurred. Therefore, it can be said that the P and K fertilizer

Table 12. Input-output analysis for potassium, study on nutrient balances at plot scale of newly developed lowland ricefield at Kleseleon site, Malaka District, Nusa Tenggara Timur Province (kg K ha<sup>-1</sup> season<sup>-1</sup>).

Treatments	K INPUT (kg K ha <sup>-1</sup> season <sup>-1</sup> )					K OUTPUT (Kg K ha <sup>-1</sup> season <sup>-1</sup> )			K Balance
	IN-1	IN-2	IN-3	IN-4	Total K Input	OUT-1	OUT-2	Total K Output	
T0	-	-	+11.26 93%	+0.77 7%	+12.03 100%	-15.46 25%	-45.63 75%	-61.09 100%	-49.06
T1	+50.70 35%	+83.70 56%	+11.26 8%	+ 0.77 1%	+146.43 100%	-34.02 30%	-81.20 70%	-115.22 100%	+31.21
T2	+50.70 43%	+55.80 47%	+11.26 9%	+0.77 1%	+118.53 100%	-28.98 29%	-69.09 71%	-98.07 100%	+20.46
T3	+50.70 43%	+55.80 47%	+11.26 9%	+0.77 1%	+118.53 100%	-26.84 27%	-68.68 73%	-95.92 100%	+22.61
T4	+50.70 43%	+55.80 47%	+11.26 9%	+0.77 1%	+119.50 100%	-29.28 33%	-58.50 67%	-87.78 100%	+31.72



application rate should be maintained as well as the application of compost as P can be longer kept in the soil without damage the environment and will improve soil function. As rice straw was a lot in the rice fields and can easily be composted, to replace N and K removed by rice harvest product and keep the higher rice grains yield, the organic fertilizer can be increased to more than 3000 kg compost ha<sup>-1</sup> season<sup>-1</sup>.

### CONCLUSIONS

Assessment of N, P, and K inputs and outputs of newly developed lowland rice in Malaka District indicated that there were surplus N, P, and K balances. The surplus of nitrogen varied from +27.39 to +89.88 kg N and P and K were from +1.74 to +1.93 kg P and +20.48 to +31.72 kg K ha<sup>-1</sup> season<sup>-1</sup>, respectively. To keep high rice production, the N, P, and K fertilizer rates were 100 kg urea, 100 kg SP-36, and 100 kg KCl ha<sup>-1</sup> season<sup>-1</sup> plus 3000 kg straw compost ha<sup>-1</sup> season<sup>-1</sup>.

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