Extent and determining factors of fertilizer applications and rice straw management in major irrigated rice areas of the Philippines

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Trends in fertilizer applications and rice straw management should be documented to help craft appropriate recommendations that increase productivity and minimize air pollution in major rice areas. This study was done to assess the extent of fertilizer applications (FA), and the nature of rice straw management (RSM) in major irrigated lowland rice areas of the Philippines. It compared FA and RSM in Pangasinan, Nueva Ecija and Laguna. It also determined factors that affect such applications relative to expected rice yields and irrigation water sources. A questionnaire was used to survey farmers' FA and RSM in 79 rice farms during wet and dry cropping seasons. Results showed that all farmers interviewed applied chemical and nitrogen (N) fertilizers, and most of them applied phosphorus (P) and potassium (K) every season. Chemical fertilizers were applied two or three times every season, mostly urea (46-0-0) and complete (14-14-14) fertilizers, averaging 7 bags in a season. Mean seasonal nitrogen-phosphate-potash (N-P_2O_5-K_2O) rate was 114-24-21 kg/ha. Most Nueva Ecija farmers applied ammonium phosphate (16-20-0). Wet season N rates in Pangasinan were higher at 132 kg/ha, with most of them applying foliar fertilizers. Laguna farmers did not burn rice straw in the wet season. More chemical fertilizers were applied in high-yield farms irrigated by national and communal irrigation systems than in low-yield farms irrigated by rivers and deep wells. Most farmers did not apply zinc and organic fertilizers, but they openly burned rice straw. The study suggests that application of chemical and N fertilizers is a general practice among farmers in the country's irrigated lowland rice areas. The study also confirms that N is applied in highest quantities, and that open burning of rice straw is a common malpractice among Filipino rice farmers. Diagnostic tools should be used to monitor soil N and K levels, and optimize efficiency of N fertilizers. The losses and crop assimilation of applied N should be studied in Pangasinan farms to improve N use, and cut fertilizer expenses. Incorporation of rice straw is also recommended to increase soil nutrient levels and prevent health problems from open burning.

KEYWORDS

agriculture, chemical fertilizers, fertilizer application, irrigated rice, nutrient management, rice straw

DEFINITION OF TERMS

chemical fertilizer — inorganic or urea fertilizer in granular form that contain N, NPK, NP, K or NK
N, P or K fertilizer — chemical fertilizer that contains N, P or K

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INTRODUCTION

The use of fertilizers and management of rice straw affect productivity of rice areas. Chemical and organic fertilizers increase levels of nutrients in rice soils, which are absorbed by rice plants and removed from rice fields upon harvesting. But some nutrients are returned into the soil if rice straw is incorporated. The amounts and balance of remaining nutrients in the soil greatly affect rice yields in the next cropping season. Hence, information about farmers' fertilizer (Adesina 1996; Caňete et al. 2016a,b,c) or rice straw management (Magahud et al. 2016) have been gathered to craft recommendations (Witt et al. 2004, Magahud et al. 2016) that maintain or restore the balance of soil nutrients in major rice-producing countries (Dobermann et al. 2004), or areas (Magahud et al. 2016; Caňete et al. 2016a,b,c).

Filipino farmers usually apply fertilizers in a scheduled manner two or three times in a season based on the growth stages of the rice crop (Palis et al. 2007), mostly 46-0-0 and 14-14-14 (PSA 2017, PhilRice-SED 2017, Rola et al. 2016). Mean nitrogen-phosphate-potash ($N-P_2O_5-K_2O$) rate in the country based on Gregory et al. (2010) is 50-8-3 kg/ha. PhilRice-SED (2017) reported higher rates (kg/ha) at 78-85 N, 16-18 P_2O_5, and 13-16 K_2O. The average $N-P_2O_5-K_2O$ rates in Central Luzon, the major rice-producing region of the Philippines, were 130-34-26 kg/ha in high-yielding areas, and 88-30-22 kg/ha in low-yielding areas (Moya et al. 2004).

Most rice straw produced in the Philippines are openly burned (Gadde et al. 2009a). Burning causes the loss of major nutrients for the succeeding rice crop (Dobermann and Fairhurst 2002). Emissions from open burning also pollute the air in surrounding areas (Tiparayom and Oanh 2007, Yang et al. 2006, Oanh et al. 2011, Viana et al. 2008), and can incur huge monetary losses in terms of health damages (P Kumar and S Kumar, unpublished observations). Only a small fraction of the straw produced are used as animal feed, mulching material in onion production, and as medium to grow mushrooms (Gadde et al. 2009b).

Information about applications of organic, foliar, and zinc fertilizers in the country's rice areas is limited.

Applications of fertilizers and management of rice straw had been surveyed but should be regularly updated as farmers' nutrient management practices can change through time. Rice-farming decisions are affected by several dynamic factors such as agroclimatic characteristics of farms (Mariano et al. 2012, Magahud and Dimaano 2015, Onyenweaku et al., 2007), and socio-economic status of farmers (Mariano et al. 2012, Adesina 1996, Yagos and Demayo 2015, Pantoja et al. 2016, Onyenweaku et al. 2007). Information about chemical fertilizer inputs and factors that affect them can be used in formulating fertilizer recommendations for specific locations (Adesina 1996). Assessment of farmers' rice straw management is also essential in developing fertilizer recommendations (Dobermann and Fairhurst 2002), and estimates the extent of negative health effects of rice straw-burning on people exposed to emissions.

The study assessed the extent of fertilizer applications, and the nature of rice straw management in major irrigated lowland rice areas of the Philippines. It compared practices in Pangasinan, Nueva Ecija and Laguna. It also determined factors that affect such applications relative to expected rice yields and irrigation water sources.

MATERIALS AND METHODS

Study Sites and their Characteristics

Seventy-nine (79) irrigated lowland rice farms in Cagayan Valley, Pangasinan, Central Luzon, Laguna, Bicol, Western Visayas, and Southern Mindanao were studied (Figure 1, Table 1). These farms represent the major soil series devoted to irrigated rice production across different agroclimatic conditions of the country's rice-growing areas (Miura et al. 1995).

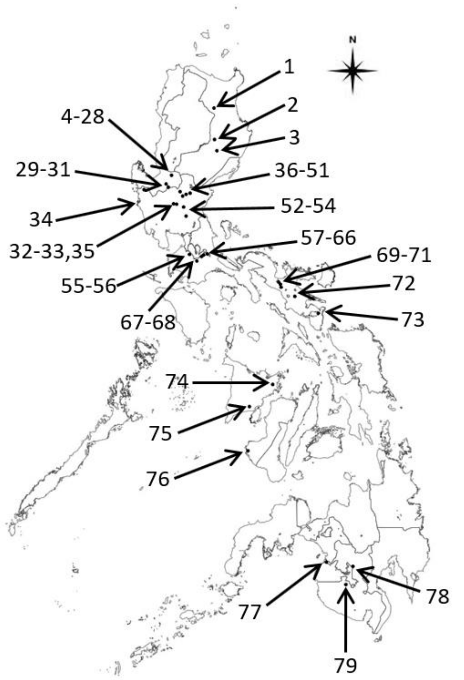

Figure 1: Map of the Philippines showing the study sites

Table 1: Location of study sites

Region/Province	Municipality and Province
Cagayan Valley	1) Solana, Cagayan; 2) Cabatuan, Isabela; 3) Echague, Isabela;
Pangasinan	4-11) San Manuel; 12-14) Asingan; 15-17) Urdaneta City; 18-23) Manaoag; 24) Laoac; 25) Sta. Maria; 26) Rosales; 27) Villasis; 28) Sto. Tomas;
Central Luzon	29-31) San Manuel, Tarlac; 32-33) La Paz, Tarlac; 34) Sta. Cruz, Zambales; 35) Zaragoza, Nueva Ecija (N.E.); 36-45) Muñoz City, N.E.; 46) Talavera, N.E; 47-49) Llanera, N.E.; 50-51) Rizal, N.E.; 52-53) San Leonardo, N.E.; 54) San Miguel, Bulacan;
Laguna	55-56) Sta. Rosa City; 57-60) Sta. Cruz; 61-62) Pila; 63-66) Lumban; 67-68) Bay;
Bicol	69) Canaman, Camarines Sur (C.S.); 70) Minalabac, C.S.; 71) Milaor, C.S.; 72) Polangui, Albay; 73) Casiguran, Sorsogon;
Western Visayas	74) Sara, Iloilo; 75) San Miguel, Iloilo; 76) Sipalay City, Negros Occidental;
Southern Mindanao	77) Cotabato City, Maguindanao; 78) Kabacan, North Cotabato; 79) Tacurong City, Sultan Kudarat

Bicol region has <2 dry months; Laguna, Western Visayas, and Southern Mindanao have 2 to 4; and Cagayan Valley, Pangasinan and Central Luzon have >4 (Huke 1982). Soil and agroclimatic features of the study sites were characterized by Miura et al. (1995) and Magahud et al. (2015a, 2015b, 2015c, 2016); while their pest management practices were described by Magahud and Dimaano (2015).

Annual cropping patterns are as follows: 66 sites pursue rice-rice; others pursue rice-rice-rice, corn-rice, rice, rice-mungbean, onion-rice, rice-mungbean-rice, corn-mungbean-rice, corn-rice-corn, and onion-corn-rice. Farm sizes ranged at 0.3 – 8.5 ha, while fresh grain yields ranged at 3.3 – 9.3 t/ha (Table 2).

Table 2: Characteristics of study sites. number of sites = 79

Farm characteristic	Mean	Median	Mini-mum	Maxi-mum
Size, ha	1.6	1.2	0.3	8.5
Fresh grain yields, t/ha	5.5	5.4	3.3	9.3
No. of years farmer-interviewees have been managing the farm at the time of survey	20	20	2	50

Survey of Farmers' Nutrient Management Practices and Rice Straw Management

Questionnaires were used to survey farmers' practices in terms of fertilizer applications and rice straw management in wet and dry cropping seasons. The surveys were done from July 2012 to April 2016. Farmers have been managing their rice farms for at least two years at the time of survey (Table 2).

Farmers were asked about their practices in applying chemical fertilizers: application or non-application, number of applications done, kinds of fertilizer materials used, and amounts of fertilizers applied (bags). N-P_2O_5-K_2O rates (kg/ha) were computed from the kinds and amounts of fertilizer materials applied. Most farm sizes were validated by gathering the farms' GPS coordinates and confirming their sizes in Google Earth™ satellite images. Validated farm sizes were used to adjust the amounts of fertilizers applied and their N-P_2O_5-K_2O rates.

Factors that have potential relationships to N-P_2O_5-K_2O rates used were surveyed. Correlation analyses for chemical fertilizers applied vs. rice yields and irrigation water sources were performed and significant correlations were then explained.

Farmers' applications of foliar, zinc and organic fertilizers, and management of rice straw produced in their farms were also surveyed.

Twenty-one (21) sites in Pangasinan, 17 in Nueva Ecija, and 8 in Laguna were selected to assess geographical preferences in nutrient management. Such sites pursue the rice-rice annual cropping pattern, and are irrigated by national or communal irrigation systems. Soils in Pangasinan are San Manuel series – either well drained or moderately well drained (Bacatio et al. 2007, Miura et al. 1995, PhilRice 2013); those in Nueva Ecija are Maligaya, Prensa, Quingua, and Bantog series – either moderately well drained or imperfectly drained (Miura et al. 1995); those in Laguna are Lipa and Bay series – either imperfectly or poorly drained (Miura et al. 1995).

Results of surveys are presented as percentages, means, or ranges in graphs or tables.

RESULTS AND DISCUSSION

Applications of Chemical Fertilizers

All sites applied chemical and N fertilizers every season, mostly with P and K materials (Figure 2). Filipino farmers probably

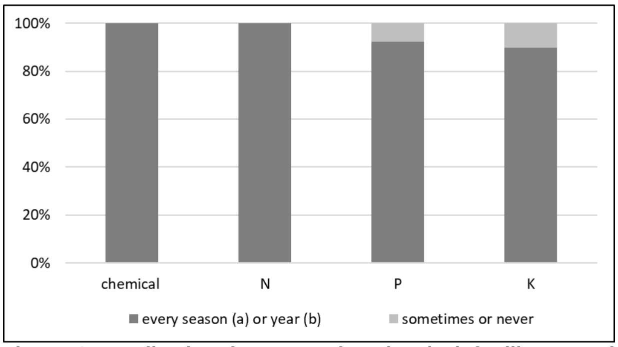

Figure 2: Application frequency for chemical fertilizers, and nitrogen(N), phosphorus (P) and potassium (K) fertilizers. number of sites = 79
(a) every season for sites with two or more rice croppings per year
(b) every year for sites with one rice cropping per year

perceive the need for applying chemical fertilizers. Such need was also observed in a survey involving 175 rice farmers of Zamboanga, Philippines (Yagos and Demayo 2015).

Most farmers surveyed applied fertilizers two or three times every season (Table 3). This agrees with the report of Palis et al. (2007) that farmers usually apply fertilizers in a scheduled manner two or three times per season based on growth stages of the rice crop. Furthermore, based on their interviews of 1387-1847 farmers in the country's irrigated rice areas, PhilRice-SED (2017) reported that applications averaged 1.9-2.7 times in July 2006-June 2007 and July 2011-June 2012.

Table 3: Distribution of sites based on seasonal frequency (number) of chemical fertilizer applications. n = number of sites

Cropping Season	1	2	3	4	Average
	% of study sites†				
Dry, n=70	5.7	38.6	50.0	5.7	2.6
Wet, n= 73	8.2	50.7	38.4	2.7	2.3

Fertilizer application frequencies varied. Nueva Ecija's and Laguna's 2.9 times in dry season were higher than in Pangasinan sites (Table 4). Applications were more frequent in dry than in wet seasons in Nueva Ecija and Laguna; the same for both seasons in Pangasinan.

Table 4: Seasonal frequency (number) of fertilizer applications in three provinces. n = number of sites.

Province	Dry season	Wet season
Pangasinan, n=21	2.5	2.5
Nueva Ecija, n=16	2.9	2.4
Laguna, n=8	2.9	2.6

Most commonly used fertilizer materials in the study sites were 46-0-0 and 14-14-14 (Figure 3). This agrees with the report of PSA (2017) that the same materials were applied in highest quantities from 2003 until 2014. Moreover, PhilRice-SED (2017) reported that 57-70% of farmers applied 46-0-0, and 41-62% applied 14-14-14 in July 2006-June 2007 and in July 2011-June 2012.

Applications of certain fertilizer materials varied (Table 5). Nueva Ecija farmers interviewed applied 16-20-0, while most Pangasinan and all Laguna farmers did not apply. Some Pangasinan and Nueva Ecija farmers used ammonium sulfate (21-0-0) as source of N, while Laguna farmers did not. Gines et al. (2004) also reported that 16-20-0 was one of the dominant nutrient sources of rice farms in Nueva Ecija.

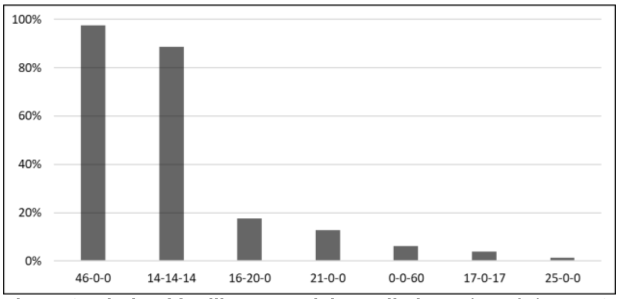

Figure 3: Kinds of fertilizer materials applied. number of sites = 79.

Table 5: Percentage (%) of study sites applied with various fertilizer materials in three provinces. n = number of sites.

Province	46-0-0	14-14-14	16-20-0	21-0-0	25-0-0
Pangasinan, n=21	100.0	90.5	9.5	14.3	0.0
Nueva Ecija, n=17	100.0	94.1	52.9	5.9	5.9
Laguna, n=8	100.0	100.0	0.0	0.0	0.0

Seasonal average of chemical fertilizers applied in study sites was 7.4 bags/ha (Table 6), which is higher than that reported by PSA (2017) – 4.7-5.1 bags/ha in 2012-2014.

Amounts of chemical fertilizers applied grow with increasing yield levels of >4, 5-6, and >7 t/ha (Table 6). Furthermore, sites that yield >7 and 5-6 t/ha were applied with more chemical fertilizers in dry than in wet season.

Mean seasonal N-P_2O_5-K_2O rate of the study sites (114-24-21 kg/ha) is higher than the 50-8-3 kg/ha reported by Gregory et al. (2010) (Table 7); also higher than the PhilRice-SED (2017) report at 78-85 N, 16-18 P_2O_5, and 13-16 K_2O. PhilRice-SED interviewed 1,386-1,847 Filipino farmers in irrigated rice areas in 2006, 2007, 2011 and 2012.

Mean seasonal N-P_2O_5-K_2O rate (kg/ha) in sites that yield >7.0 (125-36-31) is comparable, while rate in sites that yield 5-6 t/ha (119-22-18) is lower than that reported in high-yielding sites in Central Luzon (130-34-26) (Table 7). Furthermore, seasonal rate in sites that yield <4 t/ha (88-16-16) has the same N but lower P_2O_5 and K_2O than those reported in low-yielding sites in Central Luzon (88-30-22).

The study recorded similar N, lower P_2O_5, and higher K_2O rates (Table 7) than the rates in other major rice-producing countries. In 20 farms of Mekong Delta in Vietnam, Pham et al. (2004) reported N-P_2O_5-K_2O rates (median, kg/ha) of 104-41-8 in 1996 dry season (DS), and 102-46-16 in 1997 wet season (WS). In 24 farms of Suphan Buri in Thailand, Satawathananont et al. (2004) noted rates (median, kg/ha) of 113-55-0 in 1998 DS and 91-46-0 in 1998 WS.

Rates of fertilizer nutrients varied (Table 8); wet season N rates in Pangasinan, at 132 kg/ha, was higher than in Nueva Ecija and Laguna. Farmer-interviewees based their fertilizer applications on their past farm experiences; higher N rates can be due to observations that rice crops are healthier if supplied with higher amounts of fertilizers. Such observations can be caused by better drainage of Pangasinan soils than those of the two provinces, which could translate to less efficiency and the need for more N fertilizers in Pangasinan. Paddy soils with better drainage exhibit more N losses such as leaching (Kim et al. 2004, Zhou et al. 2011, Zheng et al. 2017), nitrification-denitrification (Zhou et al. 2011), and ammonia volatilization (Li et al, 2008, He et al. 2014); less plant uptake and soil adsorption (Zhou et al. 2011) than soils with poor drainage. The losses and crop assimilation of applied N should be studied in Pangasinan farms to improve N use efficiency, and cut farmers' fertilizer expenses.

Fertilizer application rates in the study sites were at least three times higher compared with P_2O_5 and K_2O rates, which reinforce the findings of Gregory et al. (2010) and Moya et al. (2004). These rates may indicate the need for decision support systems and tools that can determine the amounts of N fertilizers to be applied based on the needs of the rice crop. The use of leaf color chart, for instance, can minimize over-fertilization of N in rice, increase profitability, and decrease fertilizer pollution in the environment (Balasubramanian et al. 1998).

Non-recycling of rice straw combined with low K_2O application rates (mean of 21 kg/ha) (Table 7) can deplete the soil K levels in the study sites that continuously produce high rice yields (mean of 5.5 t/ha) (Table 2). Dobermann and Fairhurst (2000) reported that 102 kg K are taken up by rice plants in a one-hectare field that yields 6 tons. In an 18 kg K_2O/ha input from fertilizers, the authors also estimated a -72 kg/ha K balance if all straw is removed, while -2 kg/ha K balance if 80% of straw is incorporated. As such, recycling all straw, and monitoring soil and plant K levels in the sites as basis for applying K are recommended to maintain the nutrient's optimum levels.

P and K rates in Nueva Ecija sites – 48 kg seasonal P_2O_5/ha and 36 kg seasonal K_2O/ha – were higher than in Pangasinan and Laguna. Gines et al. (2004) mentioned Nueva Ecija N-P_2O_5-K_2O rates (kg/ha) at 123-33-27 for DS and 84-30-18 for WS, which are lower than the Nueva Ecija rates in this study.

Relationships of Chemical Fertilizer Applications to Yields and Irrigation Water Sources

Amounts of chemical fertilizers and their N, P_2O_5 and K_2O contents were significantly correlated to average seasonal yields (Table 9). Mean amounts of fertilizer applied grow with increasing yields of <4, 5-6, and >7 t/ha (Table 6). Moya et al. (2004) also reported that mean NPK rates used in Central Luzon in the Philippines, Red River Delta in Vietnam, and Tamil Nadu in India were higher during high-yielding seasons than during low-yielding seasons. Farmers probably perceive the need to apply more fertilizers in high-yielding rice farms or seasons. For instance, Yagos and Demayo (2015) found that 56% of 175 rice farmers in Zamboanga perceive that application of more fertilizer results in higher yield.

Amounts of chemical fertilizers and their N, P_2O_5 and K_2O contents were significantly correlated to irrigation water source in the sites (Table 9). More inputs applied in rice farms irrigated by national and communal irrigation systems can be due to higher expected yields in these farms. Water supplies in these areas are more dependable compared to those irrigated through pumping of water from deep wells and adjacent rivers.

Applications of Foliar, Zinc, and Organic Fertilizers

Most farmers surveyed applied foliar fertilizers (Figure 4). In their experiments in intensively-cultivated rice farms of Asia, Moya et al. (2004) also reported that foliar fertilizers were common in a site in Southern Vietnam; but in other locations, extremely rare. Their experiments also included rice farms in the Philippines, Thailand, Indonesia, India and China.

Most farmers interviewed did not regularly apply zinc fertilizers (Figure 4). They applied only upon seeing zinc deficiency symptoms such as stunted growth and reddish leaves.

All farmers in the sites applied chemical fertilizers, while only few used organic fertilizers from outside sources (Figure 4). This

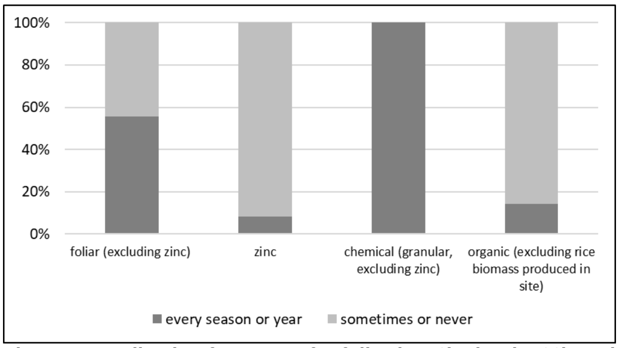

Figure 4: Application frequency for foliar (n=70), zinc (n=60), and organic (n=70) fertilizers. n = number of sites.

supports the report of Moya et al. (2004) that chemical fertilizers account for most nutrients applied in irrigated rice areas of Asia. Furthermore, Vu et al. (2007) found that only 5% of the total manure volume produced in swine farms in Thai Binh province of Vietnam are applied to crops. This was higher in Bac Giang province, where 35% of total manure was used for crops.

Farmers in the local study sites applied fertilizers based on their farm experiences and seminars attended in the past. They probably prefer chemical over organic fertilizers. A farmer respondent applied organic fertilizers only when it was given free; another considered it as supplement to chemical fertilizers to improve rice growth. Yagos and Demayo (2015) also noted that 52% of 175 rice farmers in Zamboanga consider chemical fertilizers to be better and cheaper than organic fertilizers. Furthermore, factors that hindered adoption of organic rice production in four Philippine provinces were due to farmers' perceptions of its less yield and more labor and time requirements compared to conventional production (Pantoja et al. 2016).

Applications of foliar, zinc and organic fertilizers varied (Table 10). Most Pangasinan farmers interviewed applied foliar fertilizers, but only few Nueva Ecija and Laguna farmers did the same. They seemed to consider foliar fertilizers important for grain formation and development as they apply during panicle initiation and exertion, and grain filling stages.

Few Pangasinan and Nueva Ecija farmers, and no Laguna farmers surveyed applied zinc fertilizers. Most Laguna farmers applied organic fertilizers, while most of the other farmers did not. Gines et al. (2004) also found that most farmers in Nueva Ecija do not apply manure or other organic materials.

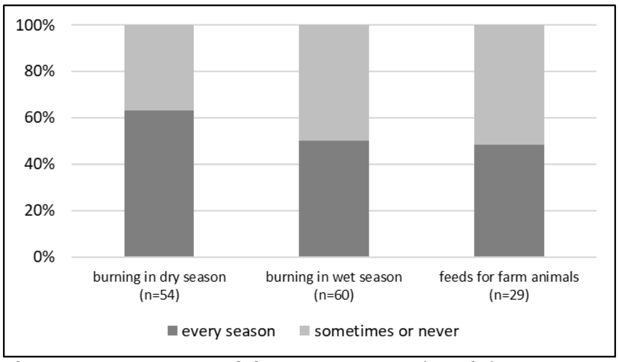

Figure 5: Management of rice straw. n = number of sites.

Management of Rice Straw

Most farmers in the study sites practiced open burning of rice straw (Figure 5). Gadde et al. (2009a) also estimated that out of the 10.68 million tons (Mt) rice straw produced annually in the Philippines, 95% or 10.15 Mt are burned on the field. Dobermann and Fairhurst (2002) also mentioned that, in the Philippines, straw is heaped into piles at threshing sites and burned after harvest. The practice of open burning was also reported in other major rice-producing countries. Annually, 48% or 10.45 Mt are burned out of the 21.86 Mt rice straw produced in Thailand (Gadde et al. 2009a). Open burning is practiced in over 90% of all Thai rice paddies in the peak of harvesting from November to December (Tipayarom and Oanh 2007). In their biomass energy flow estimation in the Mekong Delta of Vietnam, Tu et al. (2009) noted that out of 34.57 Mt of rice straw produced, 21.40 Mt are subject to open burning. Out of the 22.29 Mt of rice straw surplus produced yearly in India, 62% or 13.92 Mt are burned (Gadde et al. 2009a). The intensive rice-wheat crop rotation in Punjab, Haryana, and Uttar Pradesh of India does not allow crop residues to remain in the field for a long time. Moreover, farmers consider burning of rice straw to be more convenient than spreading and incorporation (Dobermann and Fairhurst 2002).

Rice straw-burning causes the loss of macronutrients such as N, P, K and sulfur (S) (Dobermann and Fairhurst 2002), and emissions from open burning may pollute the air in surrounding areas (Tipayarom and Oanh 2007). As such, farmers should incorporate rice straw and other farm biomass into the soil to save fertilizer costs and prevent air pollution. Launio et al. (2015) also found that the most cost-effective option for farmers is to incorporate stubble and straw into the soil >30 days before rice establishment.

Rice straw management in three provinces varied (Table 11). Most farmer-interviewees in Pangasinan openly burned rice straw in the wet season, while all Laguna farmers did not. All Laguna farmers returned or incorporated straw into their fields, while most Pangasinan and Nueva Ecija farmers did otherwise.

Most farmers in the study sites did not feed rice straw to farm animals (Figure 5). Gadde et al. (2009b) also reported that out of 10.68 Mt rice straw produced annually in the Philippines, only 0.53 Mt or 5% are used as animal feed, mulching material in onion production, and as medium to grow mushrooms. In Thailand, 3.28 Mt or 15% are used as animal feeds out of their 21.86 Mt rice straw (Gadde et al. 2009a). Tu et al. (2009) also found that out of 34.57 Mt rice straw from the Mekong Delta of Vietnam, only 1.82 Mt are fed to animals.

Table 6: Seasonal amounts (bags) of chemical fertilizers applied in the study sites with varying yield levels. n = number of sites.

Average Seasonal Yield in Study Sites	Dry Season		Wet Season		Seasonal	
	Mean	Range	Mean	Range	Mean	Range
7 t/ha and above, n=17-18	10.2	5.9 - 15.0	7.6	5.0 - 12.0	8.9	5.0 - 15.0
5-6 t/ha, n=27-31	7.8	2.1 - 14.0	7.1	2.1 - 12.0	7.4	2.1 - 14.0
4 t/ha and below, n=12-13	5.3	0.8 - 9.0	5.2	0.8 - 9.0	5.3	0.8 - 9.0
All sites, N=56-62	8.0	0.8 - 15.0	6.8	0.8 - 12.0	7.4	0.8 - 15.0

Table 7: Use of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) (kg/ha) in the study sites with varying yield levels. n = number of sites

Average Seasonal Yield in Study Sites†	N		P_2O_5		K_2O	
	Mean	Range	Mean	Range	Mean	Range
7 t/ha and above, n=17	125	82 - 188	36	9 - 68	31	9 - 56
5-6 t/ha, n=33	119	26 - 184	22	0 - 57	18	0 - 42
4 t/ha and below, n=14	88	15 - 152	16	0 - 49	16	0 - 49
All sites, N=64	114	15 - 188	24	0 - 68	21	0 - 56
Fertilizer Use in Literature						
Philippines, 2007††	50	_	8	_	3	_
high-yielding sites in Central Luzon, Philippines†††	130	_	34	_	26	_
low-yielding sites in Central Luzon, Philippines†††	88	_	30	_	22	_

†average seasonal yield represented by dry season yield for 1 site, and wet season yield for 6 sites/ ††Gregory et al. (2010), †††Moya et al. (2004).

Table 8: Average amounts (kg/ha) of fertilizer nutrients applied in three provinces. n = number of sites.

Province	Dry Season Nitrogen	Wet Season Nitrogen	Seasonal Nitrogen	Seasonal Phosphate	Seasonal Potash
Pangasinan, n=21	141	132	137	24	20
Nueva Ecija, n=16	136	94	115	48	36
Laguna, n=8	137	95	116	17	19

Table 9: Pearson correlation coefficients for amounts of chemical fertilizers applied vs. rice yields and irrigation water sources. n = number of sites.

Fertilizer Rate	Average Seasonal Yield† n = 58-64	Irrigation Water Source†† n = 70-76
Dry season chemical fertilizer	0.53**	0.37**
Wet season chemical fertilizer	0.26*	0.33**
Average seasonal chemical fertilizer	0.43**	0.33*
Average seasonal nitrogen (N)	0.34**	0.24*
Average seasonal phosphate (P_2O_5)	0.36**	0.36**
Average seasonal potash (K_2O)	0.29*	0.28*

†average seasonal yields and seasonal chemical fertilizer, N, P_2O_5 and K_2O represented by dry season data for 1 site, and wet season data for 6 sites; ††average seasonal yields and seasonal chemical fertilizer, N, P_2O_5 and K_2O represented by dry season data for 2 sites, and wet season data for 6 sites; ††river or deep well vs. national or communal irrigation system; correlated at 5% (*) and 1% (**) levels of significance

Table 10: Percentage (%) of study sites regularly applied with foliar, zinc and organic fertilizers in three provinces. n = number of sites.

Province	Foliar	Zinc	Organic
Pangasinan, n=19-20	76.2	10.5	21.1
Nueva Ecija, n=11-16	33.3	12.5	6.7
Laguna, n=6-7	14.3	0.0	57.1

Table 11: Percentage (%) of study sites employed with various rice straw management practices in three provinces. n = number of sites.

Province	Burning of Straw in Dry Season	Burning of Straw in Wet Season	Straw Returned or Incorporated into the Field
Pangasinan, n=11-14	55.6	38.9	40.0
Nueva Ecija, n=7-13	76.9	76.9	42.9
Laguna, n=7-8	62.5	0.0	100.0

CONCLUSIONS AND RECOMMENDATIONS

All farmers in the major irrigated lowland rice areas of the Philippines apply chemical and N fertilizers, and most of them apply P and K fertilizers every season. Chemical fertilizers are usually applied two or three times every season, mostly 46-0-0 and 14-14-14, averaging 7 bags/ha in a season. Mean seasonal N-P_2O_5-K_2O rate is 114-24-21 kg/ha.

Nutrient management practices vary across provinces. Most Nueva Ecija farmers apply 16-20-0. Wet season N rates in Pangasinan are higher at 132 kg/ha, with most farmers applying foliar fertilizers. Laguna farmers do not openly burn rice straw in the wet season; they return it into their fields.

Higher amounts of chemical fertilizers are applied in high-yield farms irrigated by national and communal irrigation systems than in low-yield farms irrigated by rivers and deep wells. Most farmers do not apply zinc and organic fertilizers, and practice open burning of rice straw.

The study suggests that applications of chemical and N fertilizers are general among farmers in irrigated lowland rice areas of the Philippines. The study also confirms that N is applied in highest quantities among fertilizer nutrients, and that open burning of rice straw is a common malpractice among Filipino rice farmers.

Diagnostic tools should be used to monitor soil N and K levels, and optimize efficiency of N fertilizers. The losses and crop assimilation of applied N should be studied in Pangasinan farms to improve N use, and cut fertilizer expenses. Incorporation of rice straw is also recommended to increase soil nutrient levels and prevent health problems from open burning.

Farmers' applications of fertilizers and management of rice straw, and the factors that affect such application and management need more analyses. Other data, such as farmers' levels of education, training and income, can be included to produce more holistic results and conclusions. Moreover, various uses of rice straw – organic fertilizer, mulching material for vegetable production, and medium for growing mushrooms – can also be included under farmers' management of rice straw. Information on the method of harvesting and the manner of piling or scattering rice straw on the field can also be gathered to come up with a simple partial analysis on the contribution of rice straw management in the N-P-K-S status of soils.

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CONFLICT OF INTEREST

There is no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

Conceived and designed the experiments: JCM, SLPD, PBS, WBC. Acquired funds: JCM, WBC. Acquired the data: JCM, SLPD. Analyzed and interpreted the data: JCM, PBS, WBC. Wrote and/or revised the paper for important intellectual content, accountable for the paper's accuracy or integrity, and approved the final version to be published: JCM, SLPD, PBS, WBC.

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