Partial Nutrient Balances from Agronomic and Economic Viewpoints: The Case of Corn Cultivation in the Acid Upland Soils of Isabela, the Philippines

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ABSTRACT

It is estimated that the acid upland soils in the Philippines cover approximately 12.5 million ha and account for 42 percent of the country's land area. *Inter alia*, these soils are characterized by rapid degradation, toxicities of aluminum and manganese, and deficiencies in a number of elements, with deficiency of phosphorus being a widespread problem. Current efforts to address the nutrient limitations in acid upland soils include the ACIAR Project 9414 which, is a four-year collaborative project entitled 'The Management of Phosphorus for Sustainable Food Crop Production on Acid Upland Soils in Australia, Philippines, and Vietnam'.

The two project sites in the Philippines representative of the acid upland soils are located in Isabela Province in Northern Luzon and Bukidnon Province in Central Mindanao. These soils are extensively cropped to corn (*Zea mays* sp.) with Isabela Province being the leading corn producer in the Philippines. Data sets from the ongoing study in Isabela were utilized to produce partial nutrient budgets as a complementary decision making tool for the selection of 'best option' treatments that will be recommended to farmers, extension workers, and related stakeholders. The partial nutrient balances covered N, P, and K for two crops in six selected treatments. Only the mineral fertilizer, manure, and other organic inputs, and the harvested product and removed crop residues were considered.

The partial N, P, and K balances for corn varied in the two seasons for the different treatments. The results indicate that among the treatments investigated the optimal fertilizer treatment is TSP applied at a rate of 80 kg P_2O_5 ha^{-1}. These results complement the preliminary economic evaluation of yield response. The complementary decision support tool provides strong support for encouraging farmers, extension workers, and related stakeholders to apply the recommended fertilizer rate. It helps in regulating fertilizer usage over time and thus is a tool for precise and sustainable agriculture. From an economic standpoint, the partial nutrient budget is a complementary tool to facilitate partial crop budgeting and a means to evaluate proposed treatments/technologies. The partial nutrient budget provides the technical basis for the farmers to pursue an economic strategy of minimizing capital outlay for fertilizer use and it provides the basis for assessing the economic sustainability of current fertilizer practice.

INTRODUCTION

It is estimated that the acid upland soils of the Philippines cover approximately 12.5 million ha and account for 42 percent of the country's land area. (Evangelista, 1993). These soils are generally infertile and difficult to manage. They are characterized by rapid degradation due to leaching of bases (nutrients); low organic matter content; aluminum (Al) and manganese (Mn) toxicities; and deficiencies of nitrogen (N), phosphorus (P) potassium (K), calcium (Ca), magnesium (Mg), and molybdenum (Mo) (Pushparajah and Bachic, 1985 *In* Evangelista et. al., 1999).

Phosphorus deficiency is the most widespread problem for sustainable food production on acid upland soils. Initial efforts to correct P deficiency in the country were reported by Duque and Samonte (1990), Atienza (1990), and Palis et al., (1997). ACIAR Project 9414 aims to address the nutrient limitations of these areas. This collaborative project on the management of phosphorus for sustainable food crop production on acid upland soils has project sites in Australia, the Philippines, and Vietnam. A multidisciplinary study, this four-year project will end in June 2002 and provide results on the biophysical and socioeconomic evaluation for the various sites. In the Philippines, Isabela (Northern Luzon) and Bukidnon (Central Mindanao) were the representative project sites.

Data sets from the ongoing study in Isabela were utilized to produce partial nutrient budgets as a complementary decision making tool for the selection of 'best option' treatments that will be recommended to farmers, extension workers, and related stakeholders.

BACKGROUND OF THE STUDY

In 1996 Isabela Province was ranked fifth in terms of corn production. By 2000, it had become the leading producer of corn in the country. From 1996-2000 the harvest area for corn expanded from 0.14 to about 0.196 million ha. Prime corn land on the river terraces comprised at least 65,000 ha. Collectively, in 2000 the corn areas contributed almost 71 percent of regional production or 15 percent of the national production. Average yield in the province improved from 2.22 mt ha^{-1} in 1996 to 3.44 mt ha^{-1} in 2000, posting an annual growth rate of 11 percent.

To provide baseline data on P management research, a socioeconomic survey was conducted in October 1997 in 12 barangays (villages) of Ilagan, Isabela covering the 1996 to 1997 cropping period. The study revealed that few changes in the cropping system had occurred over 10 years. The majority of farmers surveyed (86 percent) planted two crops of corn with the remaining 14 percent undertaking a single crop strategy. Only a few farms grew corn in rotation with rice and turnip and in association with rice, mungbean, and vegetables. Table 1 provides some of the economic data generated during the survey. Nutrient application varied widely among farms both in the river and residual terraces. However, there was little difference in the nutrient application by season. On average, on a seasonal basis, farmers applied with 123 kg N, 14 kg P, and 22 kg K ha^{-1}. Farmers did not apply organic fertilizer or lime. Most farmers incorporated corn stover into the soil during land preparation although burning of the stover and use of the stover as feed for livestock was also practiced. Cobs, on the other hand, were mainly sold and used as fuel. However, a number burned the cobs while a minority incorporated them into the soil.

Table 1. Characteristics of corn farms, Ilagan, Isabela, Philippines, 1996–97.

Item	Unit	River terrace			Residual terrace		
		Min	Mean	Max	Min	Mean	Max
		First crop					
n		51			50		
Crop area	ha	0.25	0.95	4.00	0.45	1.200	3.000
Yield	mt ha^{-1}	0.8	3.55	7.04	0.1	3.05	5.63
N	kg ha^{-1}	35	115	200	23	151	318
P	kg ha^{-1}	6	14	20	2	16	24
K	kg ha^{-1}	12	26	39	0	29	46
Fert cost	PhP ha^{-1}	1,460	2,806	4,733	740	3,701	6,600
Other income	PhP yr^{-1}	-	11,394	81,260	-	19,152	185,000
		Second crop					
n		52			51		
Crop area	ha	0.25	0.94	4.00	0.45	1.23	3.00
Yield	mt ha^{-1}	0.38	3.75	9.9	0.11	3.16	7.2
N	kg ha^{-1}	35	116	200	23	154	318
P	kg ha^{-1}	6	14	24	2	17	24
K	kg ha^{-1}	12	26	46	3	30	46
Fert cost	PhP ha^{-1}	1,300	2,894	4,733	740	3,793	6,900
Other income	PhP yr^{-1}	-	11,178	81,260	-	18,777	101,620

Utilization of stover and cobs (percent of total farms)

Item	River terrace		Residual terrace	
	First Crop	Second Crop	First Crop	Second Crop
Stover				
Burned	12	12	19	20
Incorporated into the soil	84	85	81	78
Feed for livestock	4	4	0	2
Total n	51	52	47	50
Cobs				
Burned	16	15	48	47
Incorporated into the soil	8	10	11	10
Used as fuel	34	35	30	33
Sold	36	35	11	10
Mushroom use	6	6	0	0
Total n	50	52	46	51

* Figures may not tally because of rounding.

PhP = Philippine Peso

An inventory of livestock and poultry in Ilagan showed the dominance of backyard husbandry over commercial operations. Animal husbandry, however, was not integrated into the cropping system.

Corn yield averaged 3.83 mt ha^{-1} in the fertile areas associated with river terraces and 2.51 mt ha^{-1} in the less fertile residual terrace areas. On a seasonal basis net crop income from farms in river terraces varied from approximately PhP 8,000 ha^{-1} for share-tenants to almost PhP 10,500 ha^{-1} for owner occupiers. Conversely, on a seasonal basis net crop income from farms on residual terraces varied from PhP 300 ha-1 for share-tenants to almost PhP 2,200 ha^{-1} for owner occupiers.

The results of the study revealed that there is more than twice the yield increase per unit of N application on river terraces as compared to the residual terraces.

The experimental site is located on residual terraces at longitude 121°55'05' and latitude 17°10'12" N at Ilagan, Isabela, Philippines, about 9 km northeast of the town proper and 100 m from the national road.

The surface texture up to about 30 cm is sandy clay loam to clay with a bulk density of 1.58 kg m^{3-1} and total porosity ranging from 40.4 to 50.6 percent. The chemical analysis in Table 2 indicates that the soil is acidic, has low organic matter content, but sufficient Zn and Cu. The soil has a high amount of Fe and excessive amounts of Mn.

Table 2. Chemical analysis of the composite soil sample, Isabela, Philippines, 1996.

Property	**Unit**	**Value**
pH		4.7
Organic matter	%	1.62
Nitrogen	%	0.08
Phosphorus	mg kg^{-1}	0.72
Potassium	cmol kg^{-1}	0.04
Calcium	cmol kg^{-1}	1.43
Magnesium	cmol kg^{-1}	1.1
Zinc	mg kg^{-1}	1.06
Copper	mg kg^{-1}	4.72
Iron	mg kg^{-1}	98.7
Manganese	mg kg^{-1}	145

The ACIAR study completed the omission trial and established five croppings from 1997 to 2000 for 16 treatments each covering 7.5 m^2 in field trials. Within the 16 treatments were three superimposed trials: 1) rate of lime application; 2) calibration of inorganic P application; and 3) inorganic P sources and organic material application and their combination in a 3 x 3 factorial.

Study Coverage and Limitations

Although the agronomic and laboratory results for yellow corn in Isabela cover five croppings, only the two most recent croppings namely, January to May 1999 and August to November 1999 were covered in the partial nutrient budget. Further work may include all the five croppings to show the temporal variations in the partial nutrient balance.

As indicated in Table 2, the laboratory analysis covered major and minor elements, namely, N, P, K, Na, Ca, Mg, Zn, Cu, Fe, and Mn, however, the partial nutrient budget was limited to N, P, and K. The other equally important elements may be considered in understanding the nutrient dynamics in acid upland soils. As stated the ACIAR study covered 16 treatments. However, only selected treatments (Table 3), were included to demonstrate the effectiveness of the partial nutrient budget as a decision support tool.

Table 3. Selected treatments and their details, Isabela, Philippines.

Treatment	**Details**
T1 Absolute control	Limed to pH 5.5, without NPK
T2 TSP 80	Limed to pH 5.5, 80 kg P_20_5, 100 kg N ha^{-1}, 50 kg K ha^{-1}
T4 Chicken manure (M)	Limed to pH 5.5, 1.6 mt ha^{-1} M, 100 kg N ha^{-1}, 50 kg K ha^{-1}
T5 M + TSP 80	Limed to pH 5.5, 1.6 mt ha^{-1} M, 80 kg P_20_5, 100 kg N ha^{-1}, 50 kg K ha^{-1}
T7 EM	Limed to pH 5.5, 1.6 mt ha^{-1} EM, 100 kg N ha^{-1}, 50 kg K ha^{-1}
T8 EM +TSP 80	Limed to pH 5.5, 1.6 mt ha^{-1} EM, 80 kg P_20_5, 100 kg N ha^{-1}, 50 kg K ha^{-1}
T10 Control	Limed to pH 5.5, 100 kg N ha^{-1}, 50 kg K ha^{-1}
T11 TSP 10	Limed to pH 5.5, 10 kg P_20_5, 100 kg N ha^{-1}, 50 kg K ha^{-1}
T12 TSP 20	Limed to pH 5.5, 20 kg P_20_5, 100 kg N ha^{-1}, 50 kg K ha^{-1}
T13 TSP 40	Limed to pH 5.5, 40 kg P_20_5, 100 kg N ha^{-1}, 50 kg K ha^{-1}
T14 TSP 160	Limed to pH 5.5, 160 kg P_20_5, 100 kg N ha^{-1}, 50 kg K ha^{-1}

EM = Effective Microorganisms, TSP = Triple Super Phosphate

The study recognized the need for accurate measurements of the nutrient contents of the fertilizer inputs, particularly the organic fertilizers, and was limited by one time analysis as follows;

	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})
Chicken manure	6.3	0.67	2.59
Effective microorganisms	1.86	0.66	1.58

Nutrient Budget

Several studies as cited by Konboon et al., (2000) recognize that the nutrient budget can be used as a powerful tool for assessing a critical component of the sustainability of land-use systems. As a decision support tool to multidisciplinary R&D activities, it provides a technical basis for improved management recommendations on fertilizer usage. Winjhoud et al., (2000) provides a conceptual nutrient balance model that includes five nutrient input parameters and five output parameters, as follows:

Inputs:	Outputs:
1. Mineral fertilizers	1. Harvested product
2. Manure and other organic inputs	2. Removed crop residues
3. Deposition by rain and dust	3. Leaching
4. N-fixation	4. Gaseous losses
5. Sedimentation	5. Erosion

Source: Winjhoud et al., (2000)

This study, however, adopted a partial nutrient budget that assessed N,P,K considering the inputs in mineral and organic fertilizers and removal in produce, excluding outputs by leaching, erosion, gaseous losses, and removed crop residues.

RESULTS

Soil Nutrient Stocks

The first soil analysis revealed that initial stocks of NPK were 0.08 % N, 0.17 mg P kg^{-1} and 0.04 cmol K kg^{-1}. The final soil NPK stocks reflect the variability in the soil nutrient stocks over a period of 2.5 years (Figures 1a to 1c and 2a to 2c).

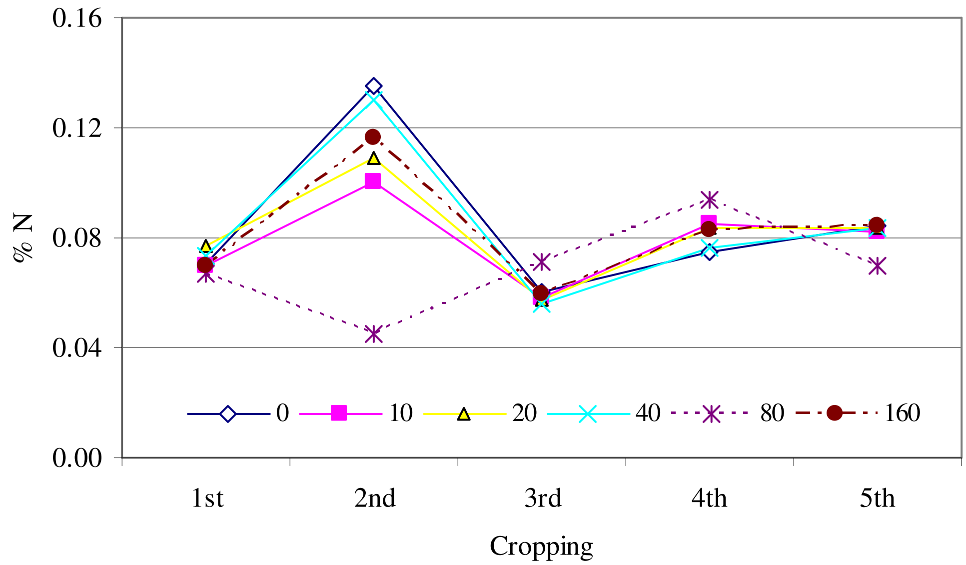

Figure 1a.
Soil N after harvest in corn fields following the application of various rates (kg ha^{-1}) of TSP.

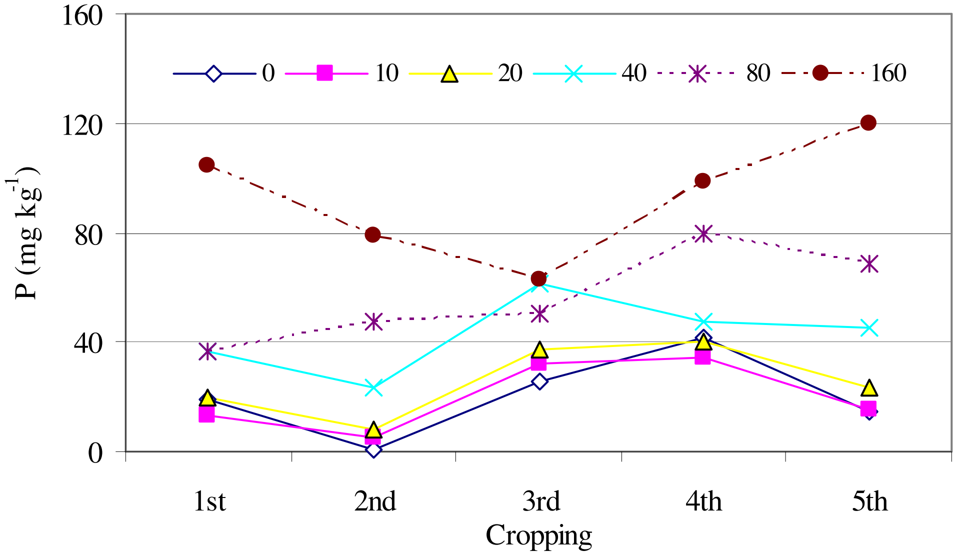

Figure 1b.
Soil P after harvest in corn fields following the application of various rates (kg ha^{-1}) of TSP.

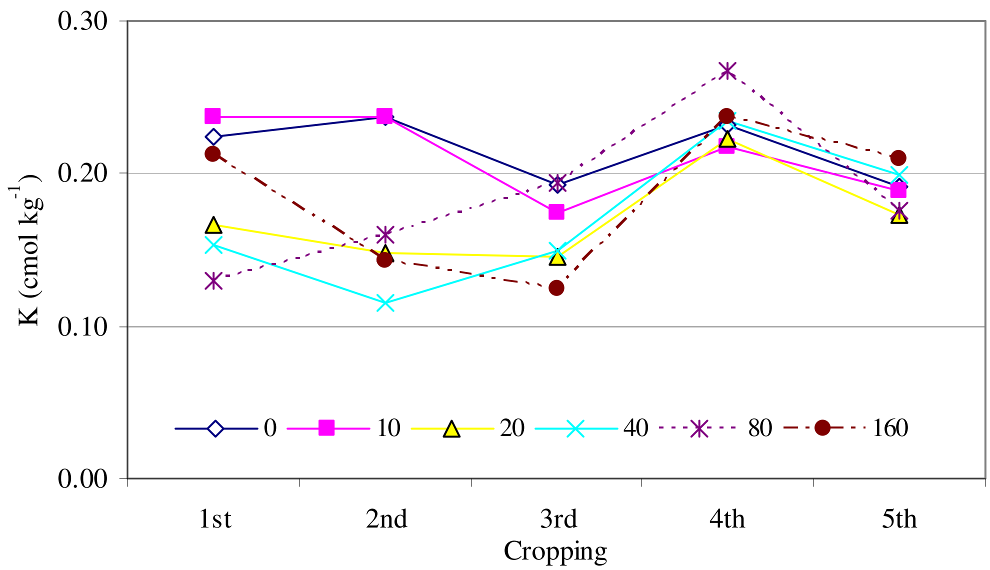

Figure 1c.
Soil K after harvest in corn fields following the application of various rates (kg ha^{-1}) of TSP.

With the application of 100 kg ha^{-1} N from inorganic sources, soil N after the second harvest varied from 0.05 to 0.14 %. In contrast for all other harvests, soil N was similar to the initial soil N (Figure 1a). Combining organic fertilizer with inorganic sources did not show a substantial improvement in the N content of the soil over time (Figure 2a). Without fertilizer, soil N declined by 0.01 to as much as 0.04 % as compared to the initial soil N content indicating the depletion of soil N.

Periodic addition of TSP at increasing rates of application (10, 20, 40, 60, 80 and 160 kg P_2O_5 ha^{-1}) resulted in corresponding increases in soil P content (Figure 1b). Combining organic fertilizer application with the application of TSP at a rate of 80 kg P_2O_5 ha^{-1} showed no marked difference in soil P as compared with to TSP alone (Figure 2b). Without TSP application, soil P content also improved, to values similar to the initial pre-treatment value which corresponds to an application rate of 20 kg P_2O_5 ha^{-1}. Further research is required in order to fully understand P dynamics over time.

With the blanket application of 50 kg K ha^{-1}, the soil available K content in all treatments improved as compared to the initial pre-treatment value (Figures 1c and 2c).

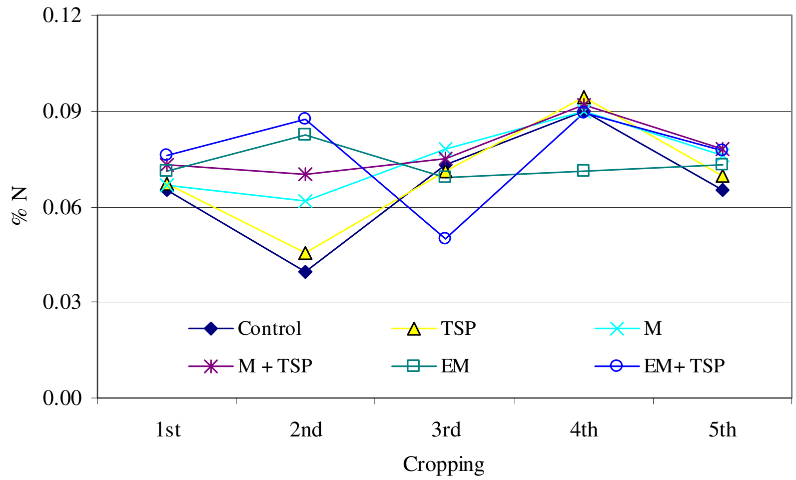

Figure 2a. Soil N after harvest in corn fields following the combined application of organic and inorganic fertilizers. Where M = Chicken Manure, EM = Effective Micro-organisms, TSP = Triple Super Phosphate

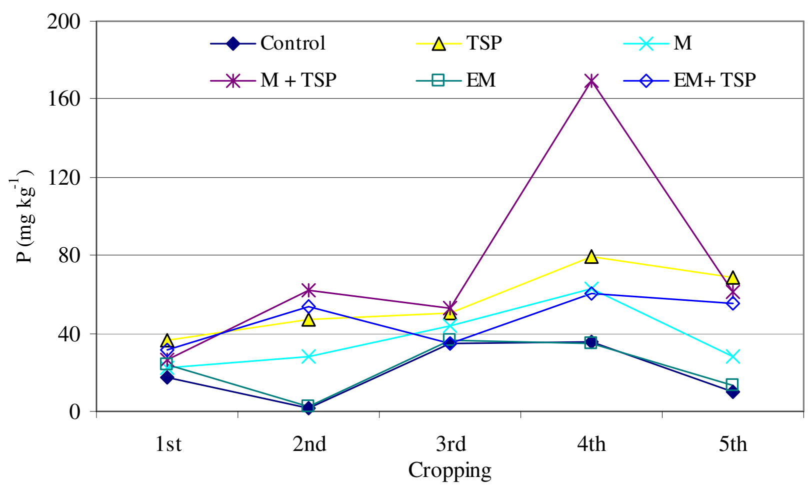

Figure 2b. Soil P after harvest in corn fields following the combined application of organic and inorganic fertilizers. Where M = Chicken Manure, EM = Effective Micro-organisms, TSP = Triple Super Phosphate

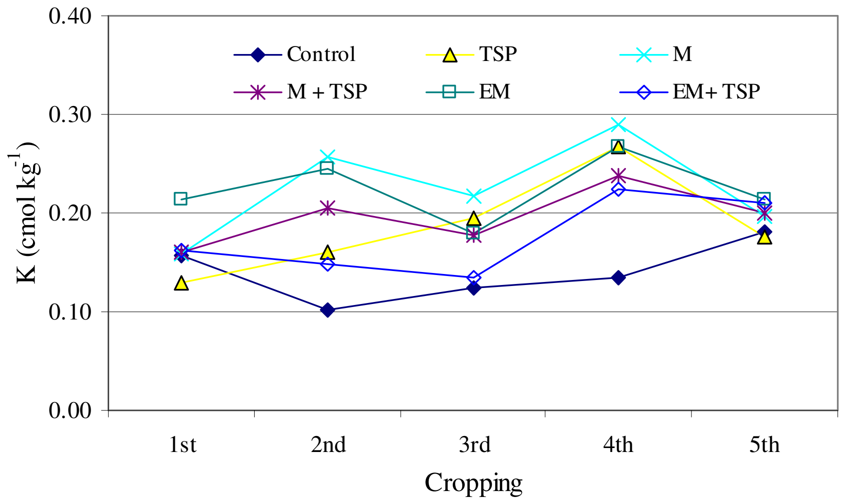

Figure 2c. Soil P after harvest in corn fields following the combined application of organic and inorganic fertilizers. Where M = Chicken Manure, EM = Effective Micro-organisms, TSP = Triple Super Phosphate

Partial Nutrient Balance

Table 4 presents the partial nutrient budget for corn to which both organic and inorganic fertilizers have been applied. The results illustrate the nutrient uptake of the crop relative to the amount of fertilizer applied. Clearly, there was considerable variability in nutrient uptake during the two croppings. In both croppings, P was deposited mainly in the grains while K was mainly absorbed in the stems and leaves. Conversely, N uptake showed no distinct pattern in the two seasons although N content occurred mainly in grains rather than stems and leaves during the dry season (January–May 1999) as compared with the wet season (August–November 1999).

The nutrient budget compares the nutrient balance for different treatments including the combined application of inorganic or organic fertilizers. A positive partial balance denotes that the plant was not able to consume all that was applied during the period. On the other hand, a negative partial balance suggests that the crop uptake exceeded the fertilizer application. The deficit is thus derived from the soil nutrient stock. The partial balance for NPK, depicted in Figures 3a to 3c, showed the temporal variability of these nutrient balances.

Table 4. Partial nutrient budget for corn following the application of the organic and inorganic fertilizer treatments evaluated.

	Jan - May 1999						**Aug - Nov 1999**					
	N (kg ha^{-1})						***N (kg ha^{-1})***					
Item	Control	TSP	Chicken Manure (M)	M + TSP	EM	EM+ TSP	Control	TSP	Chicken Manure (M)	M + TSP	EM	EM+ TSP
Addition												
Organic	0	0	101	101	30	30	0	0	101	101	30	30
Inorganic	0	100	100	100	100	100	0	100	100	100	100	100
Total	0	100	201	201	130	130	0	100	201	201	130	130
Removal												
Grain	28	36	23	72	37	38	19	66	60	49	46	60
Stem & leaves	8	27	23	28	27	36	28	55	69	53	58	57
Cobs & husks	6		6	13	3	4	2	10	10	8	12	18
Total	42	63	52	113	67	78	49	131	139	110	116	135
Partial balance	-42	37	149	88	63	52	-49	-31	62	91	14	-5
	P (kg ha^{-1})						***P (kg ha^{-1})***					
Item	Control	TSP	Chicken Manure (M)	M + TSP	EM	EM+ TSP	Control	TSP	Chicken Manure (M)	M + TSP	EM	EM+ TSP
Addition												
Organic	0	0	11	11	11	11	0	0	11	11	11	11
Inorganic	0	35	0	35	0	35	0	35	0	35	0	35
Total	0	35	11	46	11	46	0	35	11	46	11	46
Removal												
Grain	7	20	15	23	10	17	5	18	15	11	12	15
Stem & leaves	1	4	3	4	3	3	3	4	3	3	3	4
Cobs & husks	2	4	2	5	2	4	0	1	1	1	1	1
Total	10	28	20	32	15	24	8	23	19	15	16	20
Partial balance	-10	7	-9	14	-4	22	-8	12	-8	31	-5	26
	K (kg ha^{-1})						***K (kg ha^{-1})***					
Item	Control	TSP	Chicken Manure (M)	M + TSP	EM	EM+ TSP	Control	TSP	Chicken Manure (M)	M + TSP	EM	EM+ TSP
Addition												
Organic	0	0	41	41	25	25	0	0	41	41	25	25
Inorganic	0	50	50	50	50	50	0	50	50	50	50	50
Total	0	50	91	91	75	75	0	50	91	91	75	75
Removal												
Grain	18	30	26	36	23	29	3	13	12	10	7	12
Stem & leaves	21	64	76	79	32	12	8	18	37	11	29	18
Cobs & husks	8	10	8	11	7	10	3	12	13	8	9	13
Total	47	104	110	126	62	51	14	43	62	29	45	43
Partial balance	-47	-54	-19	-35	13	24	-14	7	29	62	30	32

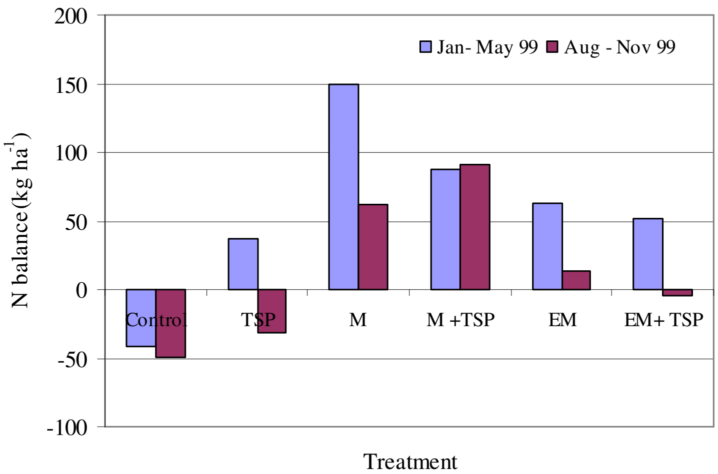

Figure 3a. Partial N balance for the organic and inorganic fertilizer treatments evaluated.

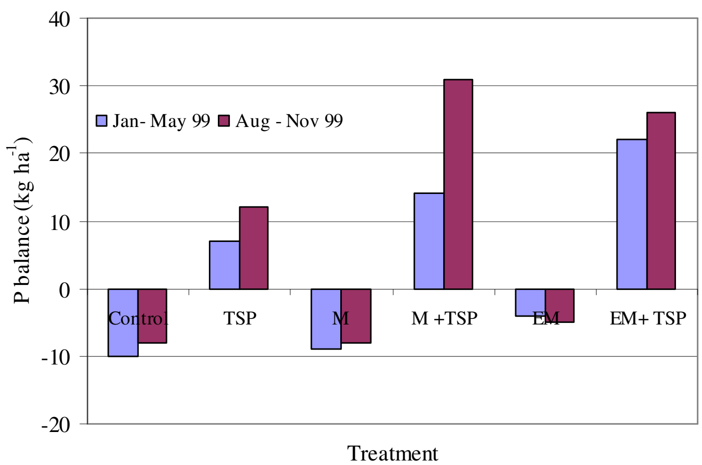

Figure 3b. Partial P balance for the organic and inorganic fertilizer treatments evaluated.

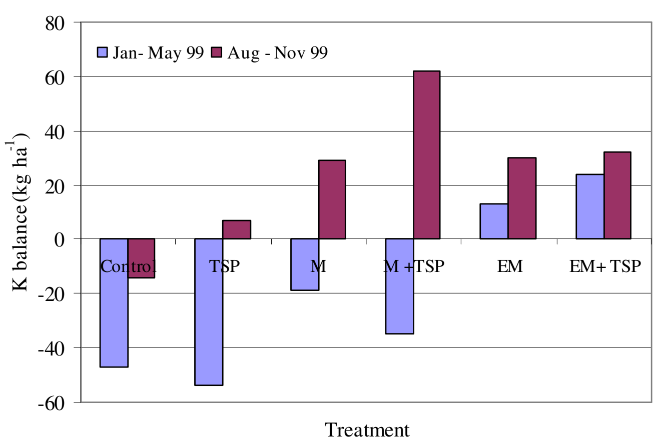

Figure 3c. Partial K balance for the organic and inorganic fertilizer treatments evaluated.

Without fertilizer application, the amount of nutrients removed from the soil was at least 42 kg N ha^{-1}, 8 kg P ha^{-1}, and 14 kg K ha^{-1}. The data for the two cropping seasons showed that applying 100 kg N ha^{-1} and 50 kg K ha^{-1} from inorganic sources may or may not be enough to supply the N and K requirements of corn and therefore may result in a negative partial nutrient balance. Combining organic fertilizer with inorganic fertilizer resulted in substantial increases in the partial N balance. Consequently, one needs to reconsider whether further application is necessary to supply the N demands of the next crop. In the case of K, the combined use of these two sources resulted in either a positive or negative partial K balance.

With 80 kg P_2O_5 ha^{-1} from an inorganic source (TSP), a positive partial P balance resulted, thus indicating that the available P content of the soil had improved. Applying organic fertilizer (Chicken Manure) or Effective Microorganisms at a rate of 1.6 mt ha^{-1} resulted in a negative P balance. However, the combined use of these organic and inorganic fertilizers increased the partial P balance.

Agronomic Perspective

As a decision support tool, the partial nutrient budget provides a basis for selecting and advocating the appropriate treatment/technology. It provides the initial basis for deciding the amount of fertilizer usage for location-specific fertilizer application. The partial nutrient balance shown in Table 4 provides the basis for assessing the sustainability of the farmers' practice presented in Table 1. It encourages farmers, extension workers, and related stakeholders to apply fertilizers whilst considering that a negative nutrient balance may result in excess nutrient removal and 'soil mining'.

The most suitable partial nutrient balance is a neutral or marginally positive balance.. This indicates that the nutrients applied meet the crop requirements. Thus, in deciding which of the six treatments would be appropriate for P-deficient soils, particularly the acid upland soils investigated, TSP at an application rate of 80 kg P_2O_5 ha^{-1} is the optimal option when considering the sustainability of meeting crop P requirement. An alternative option would be the combined use of organic and inorganic sources rather than organic fertilizer alone. Considering the high partial N balance resulting from the combined use of organic and inorganic fertilizer, the rate of organic fertilizer to be applied in the next cropping has to be adjusted. In selecting 80 kg P_2O_5 ha^{-1} from TSP, the N and K application might have to be adjusted accordingly. In essence, the partial nutrient balance is a tool for precision and sustainable agriculture.

Economic Perspective

The partial nutrient budget and the partial crop budgeting are complementary tools to evaluate and decide on proposed treatments/technologies. It provides the basis for assessing the economic sustainability of proposed treatments. The economic evaluation for this study is based on the partial crop budget and the marginal analysis. The results indicate that a TSP application of 80 kg P_2O_5 ha^{-1} is the 'economically' optimal rate. The economic analysis revealed that it is unprofitable to apply organic fertilizer *per se* or combined with inorganic fertilizers. Utilizing the partial nutrient budget, allows the addition of subsequent nutrients to be regulated at a level at which the soil nutrients can be sustainably managed. Corresponding economic evaluation can immediately be undertaken to evaluate the affordability of the proposed technology. The partial nutrient budget clearly provides a technical basis for the farmers to pursue an economic strategy of minimizing capital outlay for fertilizer use.

For the TSP treatment at a rate of 80 kg P_2O_5 ha^{-1} given the partial nutrient budget, the equivalent savings from returning all the stems, leaves, cobs, and husks to the field would be as follows;

Equivalent nutrient supply (kg ha^{-1})	**Equivalent savings: (PhP ha^{-1})**
♦ 65 N - 50% of N uptake	962
♦ 5 P - 22% of P uptake	303
♦ 30 K - 70% of K uptake	456
Total	1,721*

PhP = Philippine Peso *Equivalent to 44% of total nutrient cost

Future Work

The partial nutrient budget, however, has its limitations and thus should be pursued further to come up with a comprehensive nutrient account. Using the partial nutrient budget as a basis, a simplified nutrient account for available P and K is presented to further illustrate the nutrient flows from the soil to the plants, considering fertility intervention and natural processes.

Table 5 confirms that the negative partial balance is not necessarily detrimental to the crop. Additional work has to be done to fully account for nutrient flows particularly the other processes not captured in the partial nutrient budget. The current effort focused on NPK. Further studies should include other essential nutrients. A follow-up activity would be to determine the partial nutrient balance of the farms covered by the economic survey.

Table 5. Nutrient account for corn applied with organic and inorganic fertilizers, Isabela, Philippines.

Item	Jan - May 99						Aug - Nov 99					
	N (kg ha^{-1})						***N (kg ha^{-1})***					
	Control	TSP	Chicken Manure (M)	M +TSP	Compost (C)	C+ TSP	Control	TSP	Chicken Manure (M)	M +TSP	Compost (C)	C+ TSP
Pre-treatment	1,659	1,659	1,896	1,659	1,659	(474)	2,133	2,133	2,133	2,133	1,659	2,133
Addition	0	100	201	201	130	130	0	100	201	201	130	130
Organic	0	0	101	101	30	30	0	0	101	101	30	30
Inorganic	0	100	100	100	100	100	0	100	100	100	100	100
Removal	42	63	46	100	64	74	49	131	139	110	116	135
Grain	28	36	23	72	37	38	19	66	60	49	46	60
Stem & leaves	8	27	23	28	27	36	28	55	69	53	58	57
Cobs & husk	6	0	6	13	3	4	2	10	10	8	12	18
Adjustment	516	437	82	373	(66)	2,551	-662	-443	-299	-328	-14	5
Ending	2,133	2,133	2,133	2,133	1,659	2,133	1,422	1,659	1,896	1,896	1,659	2,133
	P (kg ha^{-1})						***P (kg ha^{-1})***					
Pre-treatment	82	119	104	126	86	82	84	231	149	401	82	143
Addition	0	35	11	46	11	46	0	35	11	46	11	46
Organic	0	0	11	11	11	11	0	0	11	11	11	11
Inorganic	0	35	0	35	0	35	0	35	0	35	0	35
Removal	10	28	20	32	15	24	8	23	19	15	16	20
Grain	7	20	15	23	10	17	5	18	15	11	12	15
Stem & leaves	1	4	3	4	3	3	3	4	3	3	3	4
Cobs & husks	2	4	2	5	2	4	0	1	1	1	1	1
Adjustment	13	105	53	261	0	39	-53	-80	-74	-286	-45	-38
Ending	84	231	149	401	82	143	24	164	67	145	32	131
	K (kg ha^{-1})						***K (kg ha^{-1})***					
Pre-treatment	111	176	204	167	167	120	130	250	269	222	250	213
Addition	0	50	91	91	75	75	0	50	91	91	75	75
Organic	0	0	41	41	25	25	0	0	41	41	25	25
Inorganic	0	50	50	50	50	50	0	50	50	50	50	50
Removal	47	104	110	126	62	51	14	43	62	29	45	43
Grain	18	30	26	36	23	29	3	13	12	10	7	12
Stem & leaves	21	64	76	79	32	12	8	18	37	11	29	18
Cobs & husks	8	10	8	11	7	10	3	12	13	8	9	13
Adjustment	66	128	84	91	70	69	51	-90	-112	-99	-86	-51
Ending	130	250	269	222	250	213	167	167	185	185	195	195

CONCLUSION

The partial nutrient balance is a decision tool for researchers as well as for farmers, extension workers, and other stakeholders. In the case of the acid uplands of Isabela, the partial nutrient budget provided further complementary support to the earlier economic evaluation that the optimal rate of P application (TSP) is 80 kg P_2O_5 ha^{-1}.

While the partial nutrient budget showed that the combined use of organic and inorganic fertilizer is an alternative option, the economic analysis does not confirm its viability. A full nutrient budget would entail much work but nonetheless be useful to explain further nutrient flows and ultimately nutrient accounting not only of NPK but also for essential and possibly limiting trace elements.

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