PLANT NUTRIENT BALANCES IN THE ASIAN AND PACIFIC REGION - THE CONSEQUENCES FOR AGRICULTURAL PRODUCTION

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ABSTRACT

Asia and the Pacific will have to feed an additional 1.8 billion people over the next 30 years. It is vital for the region's future to meet the rising food demand from a limited production area by intensification.

The recent stagnation of rice yields observed in the lowlands of the region has become a major agronomic concern. The main reasons are a decrease in nutrient productivity and an increasing imbalance in the nutrient supply.

Nutrient input/output balances for main crops and for rice in ten selected Asian countries are presented. Negative balances for N, P, K, Mg, Ca, to a total of 7 million mt, were observed in lower income economies with large and growing populations (e.g. Bangladesh, Indonesia, Myanmar, Philippines, Thailand, Vietnam). An oversupply of nutrients (a total of 1.1 million tons) was found in higher income economies with stable populations (Japan, Korea, Malaysia).

The principle of balanced fertilization requires that this damaging trend be halted through judicious use of fertilizers, in order to sustain an economically viable and environmentally friendly agriculture which meets the requirements of the future.

INTRODUCTION

The United Nations Food and Agriculture Organization (FAO), in its latest report on the food outlook, has expressed deep concern with regard to the future supplies and prices of staple foods.

"The politics of surplus will be replaced by the politics of scarcity" commented the Worldwatch Institute.

This year's rice shortage in the Philippines significantly disturbed the recovery of the whole economy in that country by driving the inflation rate to an unforeseen two digit level. In Indonesia, after 10 years of self-sufficiency in rice, decision-makers in 1994 had to realize that stagnating yields, declining production areas and a growing population had forced the nation into a new era of rice imports. This paper, based on statistical data from selected Asian countries, discusses plant nutrient balances as indicators for current and future trends in the food supply.

At present, Asia has to feed nearly 60% of the world's population on approximately 30% of the global land area available for food production.

Of the potentially arable land area in Asia, 92% is already in use. The present population of 3.1 billion is expected to swell by 1.8 billion (to a total of 4.9 billion) by the year 2025 (Table 1). Therefore, Asia's agronomic problem will remain for the next generation: How to meet the increasing demand for agricultural produce of a huge and steadily growing population from a limited area of arable land?

Keywords: Asia, fertil-

Year	Asia	Latin America	Africa	World
1990	3,100	441	651	5,285
2000	3,664	525	870	6,204
2025	4,901	703	1,587	8,415

Table 1. Projected population growth 1990 - 2025 in Asia, Latin America and Africa (millions)

Year	Asia	Latin America	Africa	World
1990	3,100	441	651	5,285
2000	3,664	525	870	6,204
2025	4,901	703	1,587	8,415

Source: Bulatao, R. *et al. World Population Projection*. 1989-90 edition, World Bank. 1990

During the early 1960s, the average area of arable land per capita in Asia was 0.24 ha, comparable to that of present-day Europe. By 1990, Asia's level had dropped to only 0.137 ha per capita, and this is expected to fall to 0.084 ha by 2010 and to 0.056 ha by 2030 (Ange 1993). This means that the number of people to be supplied from one hectare of arable land in Asia will increase from 7 in 1990 to 18 by 2030.

In the past, increases in human food needs could be met by:

- Opening up new land;
- Increased cropping intensity on the same land;
- Use of better soil tillage and irrigation;
- Re-cycling of organic matter;
- Transfer of fertility from non-agricultural land to agricultural land.

With the first and last option rapidly diminishing, people are increasingly being forced to provide extra food by increasing yields on existing arable lands. In this process, mankind is moving away from the traditional and rather static "soil dependent" agriculture to a dynamic "fertilizer dependent" agriculture.

In a fertilizer dependent agriculture, "balanced fertilization" has to be the cornerstone of all activities, as the imbalanced use of manufactured fertilizer can lead to soil degradation and to a decline in soil productivity.

The balanced use of fertilizers, on the other hand, can lead to lasting improvements in soil fertility and soil productivity, as has been demonstrated in many long-term experiments in Europe, North America and Asia.

Long-term experiments lasting for more than 100 years (e.g. those at the Rothamsted Experiment Station, England, see Fig. 1) clearly show that continuous nutrient withdrawal from the natural pools will result in reduced yields. At the same time, these experiments also reveal that nutrient supplementation, regardless of whether it is from organic or inorganic nutrient sources (fertilizers), can sustain yields over long periods of time. Obviously both sources used in Rothamsted — farmyard manure as well as nitrogen fertilizer in combination with P, K, Na, and Mg — have more or less balanced nutrients exported from the soil in harvested materials.

Asia's success in increasing grain output has been largely based on three components — modern varieties, irrigation and synthetic nitrogen fertilizer. Nitrogen is the nutrient element most widely deficient, and its application therefore results initially in very large yield increases. However, applying nitrogen does not contribute to a buildup of soil fertility. On the contrary, unbalanced use of nitrogen is currently the biggest factor causing soil nutrient depletion. De Datta (1985) showed that the application of 174 kg of N to a farmer's field increased the rice yield by a factor of 2.9, but increased the removal of P, K and S by factors of 2.6, 3.7 and 4.6, respectively (Table 2).

Historic patterns of fertilizer use in mixed farming (cattle) systems have resulted in a gradual build-up of soil fertility, whereas fertilizer use patterns in Asia have resulted in a depletion of native soil fertility. The two contrasting scenarios are illustrated in Fig. 2.

RICE CULTURE

Intensified cropping has been Asia's answer to rising population densities for centuries, and has been successfully centered around wetland rice as the cereal grown as the staple food of the region.

Rice has been grown as a food crop for more than 6000 years in Asia. More than 90% of global rice supplies are still produced and consumed in Asia, where rice contributes 30-75% of dietary calories.

The 40 million ha of irrigated rice systems in Asia are perhaps the most intensive cereal crop production system in the world, and account for 76% of global rice production (IRRI 1993).

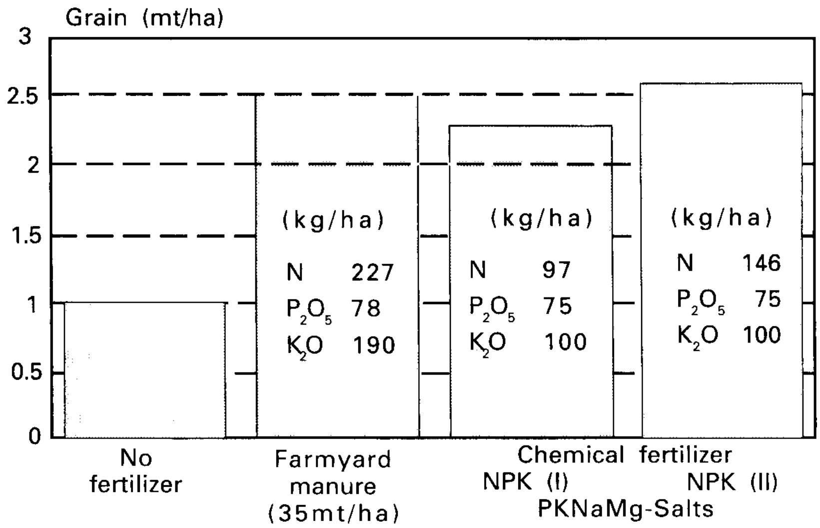


Fig. 1. Rothamsted 1852-1967: comparison of wheat yields under various nutrient supplements

Table 2. Nutrient removal of rice (variety IR 36), with and without fertilizer N, in a farmer's field experiment in Calauan, Laguna, Philippines, 1983 dry season

Nutrient element	Amount of nutrients removed by the crop harvest (kg/ha)					
	Without fertilizer			With 174 kg N/ha		
	Straw	Grain	Total	Straw	Grain	Total
N	18	34	52	75	143	218
P_2O_5	2	10	12	5	26	31
K_2O	59	10	69	232	26	258
S	0.8	1.0	1.8	3.3	4.9	8.2
		Yield (mt/ha)			Yield (mt/ha)	
Grain		3.4			9.8	
Straw		2.8			8.2	

Source: De Datta 1985

Further intensification of the lowland rice system that produced 479 million mt in 1990, will be needed to meet Asia's future requirements of 686 million mt (as projected by IRRI 1993) for the year 2025. Much of this increase must come from existing irrigated land that is already now harvested twice a year, since a net increase in the irrigated area of lowland rice is not to be expected.

In view of the required increase of 50 - 70% in rice production over the next generation, it appears that one of the most stringent agronomic problems in Asia is to find the reasons behind the recent plateau in rice yields, and develop measures which will ensure adequate growth rates in the future (Table 3).

Cassman *et al.* (1995), who have analyzed a number of long-term experiments on continuous, irrigated rice systems in Asia, suggest that when soil is continuously submerged, its N supplying capacity is reduced. This leads to a decreased partial factor productivity from nutrient inputs, thus causing the yield decline phenomenon. The authors had observed a consistent yield decline trend during the dry season at the IRRI Research Farm between 1968 and 1991, at nitrogen rates of 150 kg N/ha. However, when N rates were increased to 190 kg N/ha in 1992 and 216 kg N/ha in 1993, the highest yields from these treatments were 40% higher than in 1989-91 and became comparable to mean yield levels achieved in the early years (1970-72) of the experiment.

There are now clear indications from long-term fertility experiments (some of them begun as early as 1964) in irrigated rice systems of developing Asia, including soils of high inherent fertility, that negative P and K balances may impede nitrogen efficiency.

Dobermann *et al.* (1995) provided data from 11 sites in China, India, Indonesia and Vietnam. Most of these showed a negative net K-balance for all treatments, and a net negative P-balance for treatments without P inputs when monitored in 1993 (Table 4).

BALANCED FERTILIZATION

The aim of balanced fertilization is to correct any nutrient deficiency that may occur during the time a crop is being grown in a specific location.

The balance of nutrients in soil ecosystems, whether natural or agricultural, can be described by the following equation (Follett *et al.* 1987, Miller and Larson 1992).

$$RN_{tn} = \acute{Y}^{tn}(AP_{tn} + AR_{Đt} - RM_{Đt} + L_{Đt})$$

Where RN is the soil inorganic and organic nutrients remaining at time (tn), AP is the soil inorganic and organic nutrients present at time t, AR is the inorganic and organic nutrients added or returned to the soil during the time interval Đt, RM is the plant nutrients removed with the harvested product during the time interval Đt, L is the inorganic and organic nutrients lost during the time interval Đt, t is the beginning time, tn is the ending time, and Đt is the time interval between t and tn. The equation simply states that if nutrients removed are greater than

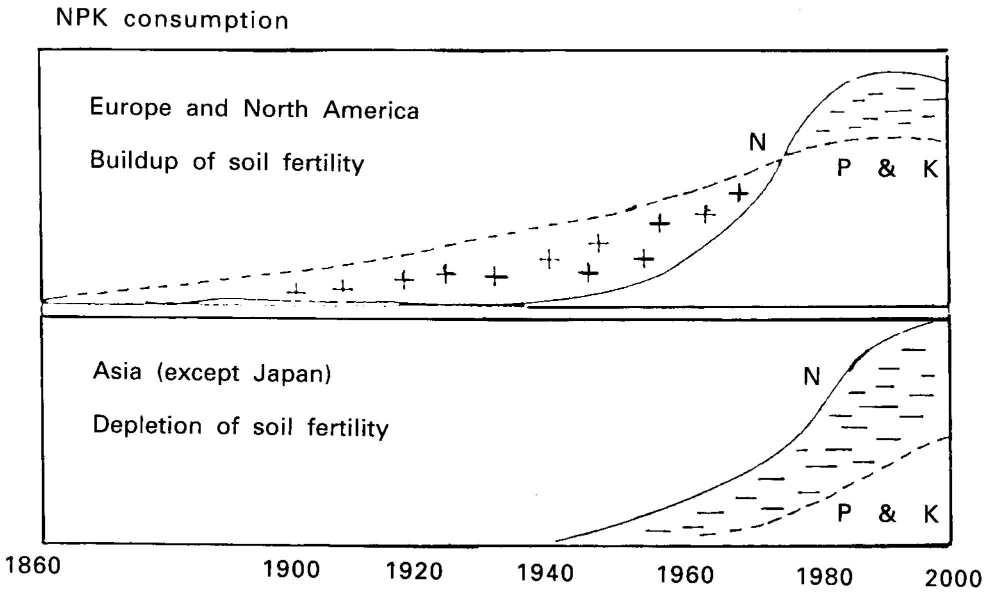


Fig. 2. Trends in the use of N versus P and K in Europe and North America, relative to Asia

Source: von Uexkull and Mutert 1993

Table 3. Increases in rice (paddy) yields and population in the Asian and Pacific region, 1980 - 1993

Year	1980	1985	1990	1991	1992	1993
Yield (mt/ha)	2.8	3.4	3.6	3.6	3.7	3.7
Population (billions)	2.6	2.8	3.1	3.2	3.2	3.3

Source: FAO

Table 4. Mean partial net P and K balances under different fertilizer treatments in long-term fertility experiments for irrigated rice in five Asian countries

1. Phosphorus (10 sites, 1993)

Treatment	Olsen -P mg/kg[1]	Grain yield kg/ha^{-1}	Fertilizer P input	Recycled P in stubble	Total P uptake	Net P balance
				—— $kg\ P\ ha^{-1}$ ——		
Control	3.9	3341	0	0.6	7.6	-7.0
+ N	3.3	4654	0	0.6	8.5	-7.9
+ NP	9.5	5530	20	2.1	17.2	4.9
+ NK	3.3	5112	0	0.5	8.5	-8.0
+ NPK	9.4	6189	20	2.0	18.3	3.7

2. Potassium (9 sites, 1993)

Treatment	Extract K $cmol/kg^{-1}$	Grain yield kg/ha^{-1}	Fertilizer K/input	Recycled K in stubble	Total K uptake	Net K balance
				—— $kg\ K\ ha^{-1}$ ——		
Control	0.279	3277	0	11	54	-43
+ N	0.260	4565	0	14	71	-57
+ NP	0.251	5426	0	12	75	-63
+ NK	0.326	4795	38	18	90	-34
+ NPK	0.312	5855	44	25	111	-42

Source: Doberman *et al.* 1995

additions, the reservoir of nutrients remaining within the soil pool will decline.

Balanced fertilizer use is "the deliberate application of all those nutrients which the soil cannot supply to meet crop demand" (Tandon 1992). Crop performance is best when all essential nutrient elements (17) are provided in sufficient amounts and held readily available during crop growth (= maximum exploitation of yield potential).

As agro-ecosystems (Fig. 3) are open and dynamic systems, balanced fertilization can only aim at nutrient supplementation in order to assist crop performance and at the same time to minimize losses.

NUTRIENT INPUT/OUTPUT BALANCES IN SELECTED ASIAN COUNTRIES

Ten Asian countries were selected for the calculation of nutrient balances for the main crops (usually representing more than 90% of the total cropped area in each respective country) and for rice as the staple food. Cropping patterns vary from one country to another, but generally the main crops comprise food crops (e.g. rice, wheat, maize, pulses, soybean, groundnut, white and sweet potato, cassava), fruits and vegetables, cash crops (e.g. sugarcane, tobacco, cocoa, tea, coffee) and tree crops (e.g. coconut, rubber, oilpalm). Among the selected countries are low-income economies (Bangladesh, Myanmar, Sri Lanka, Vietnam), plus some low-middle income (Indonesia, Philippines, Thailand), upper middle income (Korea Rep., Malaysia) and high income countries (Japan).

To calculate nutrient inputs and outputs, the following assumptions have been made:

- The inputs are the amounts of N, P_2O_5, K_2O, MgO, CaO (for rice only N, P_2O_5, K_2O) added to cropped soil in the form of farmyard manure at a rate of 5 mt/ha and in manufactured fertilizers at the rate of consumption per country (or per rice crop in that country).
- One ton of farmyard manure contains 3 kg N, 1.5 kg P_2O_5, 4 kg K_2O, 1.6 kg MgO and 0.7 kg CaO if applied to main crops, and 4 kg N, 1.5 kg P_2O_5 and 5 kg K_2O if applied to rice.
- The rates of recovery from manu-

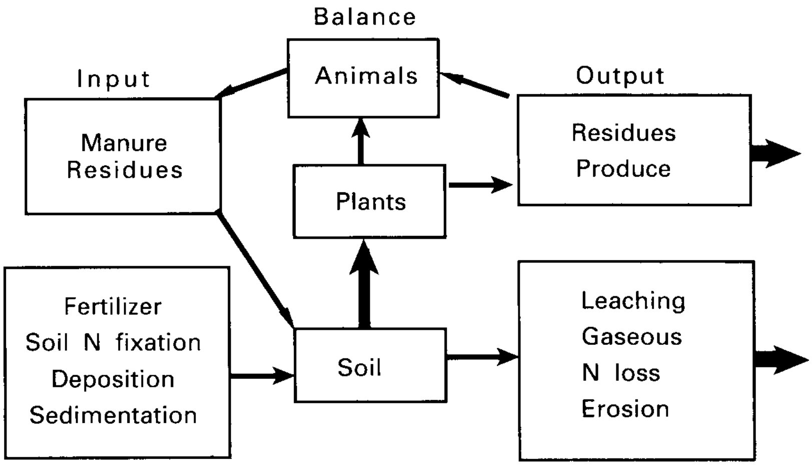


Fig. 3. Nutrient balance of an agro-ecosystem

Adapted from Stoorvogel and Smaling 1990

factured fertilizer inputs are 60% for N and P, 100% for K and 50% for Mg and Ca.

- Outputs are the amounts of N, P_2O_5, K_2O, MgO and CaO removed from the cropped soil at rates documented in the World Fertilizer Use Manual (IFA 1992) and compiled in Table 5.
- Outputs in nutrient balances for rice are based on an estimated average removal per ton of rice of 18 kg N, 6 kg P_2O_5 and 15 kg K_2O.
- Nutrient inputs from the soil, irrigation water and the atmosphere, as well as outputs due to leaching and erosion, are not fully accounted for.
- Similarly, contributions and effects by essential nutrients other than those included here are not taken into account.
- The latest available FAO statistics were used for harvested areas of crops, crop yields and crop production data (FAO 1994, RAPA 1994).
- Fertilizer inputs to rice were compiled from data published by FAO/IFA/IFDC (1992, 1993).

Results

Main Crops 1993

A negative balance for all five nutrients was found in Bangladesh, Indonesia, Myanmar, Philippines, Thailand (which was however positive for P) and Vietnam. In 1993, a total of 7.6 million mt of major nutrients was not accounted for by inputs in these five countries. Three countries, Malaysia, Japan and Korea, showed a general positive balance, while Sri Lanka appears to have achieved a balance, with the exception of potassium (Table 6). Of the five nutrients, potassium is the most in demand, since there is a negative balance totaling 4.5 million mt of K_2O for nine of the ten selected countries. Only Malaysia shows a clear positive (+ 191,000 mt K_2O) balance for potassium, although Japan's and Korea's K accounts could also be considered balanced.

Bangladesh, Indonesia, Myanmar, Philippines, Thailand and Vietnam show a negative balance for nitrogen (total of 2.1 million mt N). With the exception of Thailand, the same countries also have a severe deficit of phosphorus (total 380,000 mt P_2O_5).

Rice

Although the result from rice and main crops are not fully comparable, because they use different input and output assumptions and – in some cases – different years of accounting, the results from NPK nutrient balances for rice generally underline those from the NPK-Mg-Ca nutrient balances for main crops in 1993 (Table 6). NPK nutrient balances for rice are negative for Bangladesh (1990), Indonesia (1990), Myanmar (1992) and Vietnam (1991). A total of 1.3 million mt of N + P_2O_5 + K_2O nutrients has not been counterbalanced by nutrient

Table 5. Removal of N, P_2O_5, K_2O, MgO, CaO by crops in selected Asian countries, as used to calculate input/output balances

Crops		Removal				
		N	P_2O_5	K_2O	MgO	CaO
Rice	kg/mt	222	7	33	4	4*
Wheat	kg/ha	130	39	51	16	8*
Millet	kg/ha	60	35	75	15	8*
Maize	kg/ha	150	50	100	30	15*
Pulses	kg/mt	80	14	33	18	24*
Soybean	kg/mt	80	14	33	18	24*
Peanut	kg/ha	64	14	41	17	36*
Sweet potato	kg/ha	52	17	71	6	6*
White potato	kg/ha	150	30	200	15	5*
Cassava	kg/ha	50	10	15	14	29*
Vegetables	kg/ha	120	40	120	20	30*
Sugarcane	kg/mt	1.7	4	1.1	.5	.4*
Tobacco	kg/ha	202	22	161	11	146*
Cocoa	kg/ha	20	10	13	5	1.5*
Tea	kg/mt	70	30	31	12	20*
Coffee (green)	kg/mt	39	5	24	4	4*
Rubber	kg/mt	16	3	14	4	4*
Oilpalm	kg/ha	60	22	95	29	29*

* of $N/P_2O_5/K_2O/MgO/CaO$

Source: IFA World Fertilizer Use Manual (1992).

inputs to rice cropping systems in these countries. This is equivalent to an average of 39 kg/ha of rice cropping area. Positive balances for NPK in rice were found in Japan (negative for N) and Korea. Although NPK nutrient inputs for rice appear to be balanced with output in Malaysia and Sri Lanka, rice in the Philippines and Thailand seems to be sufficiently supplied with N and P_2O_5 but undersupplied with K_2O. Potassium has a negative balance in six of the ten selected countries. A total of 842,000 mt K_2O was not accounted for by K_2O inputs from organic or manufactured fertilizer sources.

Discussion

In an attempt to analyze the relationship between nutrient inputs and output in the agricultural production systems of ten selected Asian countries, two approaches have been chosen:

- To calculate the balances for N, P_2O_5, K_2O, MgO and CaO for the majority (>90%) of cropping systems in each country, based on assumed nutrient inputs in farmyard manure and nutrient inputs from consumed manufactured fertilizers against estimated nutrient outputs by crop removal.
- To calculate balances for N, P_2O_5 and K_2O for rice in each country, based on assumed nutrient inputs in farmyard manure, and estimated nutrient inputs from manufactured fertilizers applied to rice versus estimated nutrient outputs by rice crop removal.

Given the wide range of soils, climates and socio-economic conditions in the selected countries, these approaches are not expected to result in an accurate picture of the real situations. It is, however, expected that these approaches are realistic enough to show trends, and create awareness of obvious shortcomings and oversupplies with regard to essential plant nutrients in representative agro-ecosystems of Asia.

Other indicators have been found to support these results. A comparison of applied and recommended rates of NPK fertilizer for rice (Table 7) has been found useful in this respect. Countries with applied rates below those recommended for rice (e.g. Bangladesh, Myanmar, Vietnam) have been found to have a negative balance, and vice versa (e.g. Korea). Another useful indicator, especially with respect to the potassium balance, is the N: P_2O_5: K_2O ratio derived from the level of NPK fertilizers applied to rice. Countries where rice had a negative K_2O balance were found to have a wide ratio of N:K_2O in fertilizers applied to rice (Table 8). Some examples are by Indonesia (100:5), Myanmar (100:0), and Thailand (100:6). In these countries, and also in

	Main crops 1993 (000 mt)					Area	Area	Rice (000 mt)			
	N	P_2O_5	K_2O	MgO	CaO	(million ha)	(million ha)	N	P_2O_5	K_2O	Year
Bangladesh	-174	-20	-704	-12	-30	13.1	10.4	-126	+15	-146	1990
Indonesia	-41	-75	-1,481	-184	-229	24.4	10.9	-42	-25	-390	1990
Japan	+23	+330	-19	+7	+7	4.1	2.1	-89	+27	+15	1993
Korea Rep.	+92	+74	-10	+5	+4	2.1	1.1	+43	+45	+29	1993
Malaysia	+49	+71	+191	+8	+117	5.4	0.7	+3	+4	0	1993
Myanmar	-341	-86	-523	-25	-64	7.1	5.0	-146	-47	-97	1992
Philippines	-431	-144	-549	-73	-47	11.8	3.5	+21	-2	-29	1993
Sri Lanka	+37	+15	-29	0	-8	1.9	0.8	+7	-1	+4	1993
Thailand	-269	+72	-442	-43	-56	15.9	9.3	+56	+32	-44	1991
Vietnam	-154	-53	-694	-35	-22	9.3	6.3	-64	-49	-136	1991

Table 6 Nutrient input and output in selected Asian countries

Bangladesh, the Philippines and Vietnam, soils planted in rice are in effect being mined for potassium, and may not be able to supply future demands for this nutrient. The situation is aggravated in countries where organic nutrient sources (farmyard manure, compost) are in short supply (Vietnam, Indonesia, Myanmar) or in heavy demand (Thailand, Philippines), especially where rice stubble and cowdung are used for fuel (Bangladesh). On the other hand, countries like Malaysia (100:33) and Sri Lanka (100:36) were found to have a sufficient balance for potassium in rice at current yield levels.

The NPK ratios and application rates used in Japan (100:114:100) and Korea (100:36:44) reveal a partial oversupply. At the same time, the high and sustained rice yields over more than ten years in these countries reflect the benefits from a sufficient nutrient supply. Comparatively low rice yields which have been stagnating for yields in many of the countries with a negative NPK balance for rice are signaling an increasing dependency on fertilizer for the future staple food supply.

In particular, countries such as Bangladesh, Indonesia, and the Philippines, which are challenged for self-sufficiency by rapidly growing populations and a decline in prime rice-growing areas, due to urbanization and industrialization, should respond to such signals soon. Similarly, those countries which are now rice exporters (Thailand, Vietnam) or which expect to be so in future (Myanmar) will have to watch closely the nutrient balance of their rice systems, and the nutrient content of the soils which are the foundations of their trade.

A comparison of the levels of available potassium in the soils of Northern Vietnam in the early sixties and those in 1993 provides an alarming example in this respect (Fig. 4). A very significant decline in available potassium was observed in these soils, to the extent that there was a state of deficiency, even in the naturally potassium-rich Red River alluvial soils.

Assuming a low efficiency of fertilizers and associated inputs, according to Ange (1993), developing Asia will have to apply 230 kg NPK nutrients per ha in order to meet the minimum average cereal yield requirements of 3.5 mt/ha in the year 2010.

With population growth continues until 2030, for a cereal yield requirement of 5.5 mt/ha, applications of 475 kg NPK nutrients per ha would be needed. According to the same author, only if technical standards comparable to those applied presently in Japan and Korea are going to be widely accepted in developing Asia, will it be possible to meet cereal food requirements with application levels of 300 kg N, P_2O_5, K_2O per ha (Ange 1993).

Average applications of NPK fertilizer nutrients to rice in the ten countries presented here was around 85 kg/ha in the early 1990s. This figure falls to 68 kg/ha if Japan and Korea are excluded. The respective N: P_2O_5: K_2O ratio is 100:35:16, and 100:29:8 if Japan and Korea are excluded, but the average for Japan and Korea is 100:70:68. The consumption of NPK fertilizer nutrients per hectare of cropped area in Asia and the Pacific averaged around 126 kg N + P_2O_5 + K_2O per ha in 1992.

Ahmed (1994) provides figures on "theoretical maximum NPK nutrient fertilizer consumption"*, and has projected NPK nutrient fertilizer demand into the year 2000 for eight of the ten countries presented here. Estimates comprising all ten countries (Table 9) result in a theoretical maximum consumption in the year 2000 of 16.3 million mt N + P_2O_5 + K_2O, against a projected demand of 14.8 million mt, and an estimated consumption of 10 million mt in the early 1990s. The calculated total demand deriving from the negative nutrient balances in these ten countries amounts to 6.2 million mt of N + P_2O_5 + K_2O, a figure which, if added to the 10 million mt of actual NPK nutrient consumption, agrees well with the theoretical maximum consumption. In other words, applying recommended rates of NPK nutrients could avoid nutrient imbalances and assist in meeting future food requirements.

CONCLUSIONS

Asia's agricultural production has become increasingly dependent on fertilizers, a situation which is expected to continue. In order to meet the cereal requirements of around five billion Asians in 2030, NPK nutrient inputs must at least triple. Efficient and adequate fertilizer use will be essential to achieve sustainable, economically viable and environmentally friendly agricultural produc-tion.

A calculation of input/output balances on the basis of countries, cropping systems or crop can create awareness of whether there is soil mining or any oversupply of nutrients in agroecosystems. Realistic data on nutrient input/output balances are an invaluable guide to farmers, researchers and in particular, policymakers.

A sample of nutrient input/output balances for the main crops and rice in ten selected Asian countries revealed a significant undersupply of NPK nutrients from organic and manufactured sources in low and lower middle income economies, as well as an oversupply in higher income economies. Approximately seven million mt of N + P_2O_5 + K_2O +

Country	Year	Yield	Area	Applied rate (kg/ha)			Recommended rate (kg/ha)			Actual balance (kg/ha)		
		mt/ha	mill. ha	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Bangladesh	1990	2.6	10.4	61	36	19	80	28	17[1]	-12	+1	-14
Indonesia	1993**	4.4	10.9	92	28	5	110	25	30[2]	-4	-2	-36
Japan	1993	6.3*	2.1	82	93	82	170	122	170[3]	+42	+27	+15
Korea Rep.	1993	6.3*	1.2	200	73	87	130	50	60[6]	+38	+35	+26
Malaysia	1992	3.1	0.6	90	40	30	80	30	30[4]	+4	+6	0
Myanmar	1992	2.9	5.0	12	2	0	50	30	10**	-29	-9	-19
Philippines	1993**	2.8	3.5	60	14	8	90	28	28[5]	+6	-1	-8
Sri Lanka	1993	3.1	0.8	75	17	27	73	58	58[7]	+9	-1	+5
Thailand	1991	2.0	9.3	45	16	3	50	20	10**	+6	+3	-5
Vietnam	1991	3.3	6.3	45	6	0	80	30	20[8]	-10	-8	-22

*1992 ** PPI Singapore Estimates

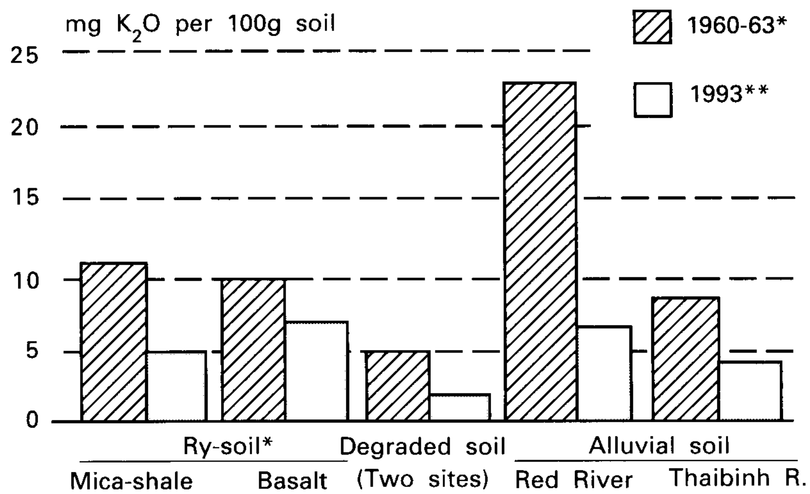
Table 7. Rice NPK nutrition in selected Asian countries (applied and recommeended rates of fertilizers)

Table 8. Selected Asian countries NPK fertilization for rice (paddy)

Country	Year	Area (million ha)	Consumption (000 mt) N	P_2O_5	K_2O	N = 100 $N:P_2O_5:K_2O$
Bangladesh	1990	10.4	500	165	48	100:33:10
Indonesia	1993**	10.9	1,003	300	55	100:30:5
Japan	1993	2.1	176	200	176	100:114:100
Korea	1993	1.2	231	84	101	100:36:44
Malaysia	1991/92	0.6	46	20	15	100:43:33
Myanmar	1991/92	5.0	33	6	0	100:18:0
Philippines	1993**	3.5	207	48	28	100:23:14
Sri Lanka	1992/93	0.8	59	14	21	100:24:36
Thailand	1990/91	9.3	380	135	21	100:36:6
Vietnam	1990/91	6.3	271	36	0	100:13:0

** PPI Singapore Estimates

Source: FAO/IFA/IFDC, *Fertilizer Use by Crop*, Rome 1994.



* Analysed in 1960-63 (n = 43 -1472); **Analysed in 1993 by D.V. Cung, N.V. Chien and L. K. Dung

Fig. 4. Available potassium in selected soils of Northern Vietnam

Source: Nguyen Vy 1995

MgO + CaO were unaccounted for in terms of nutrient inputs, while 1.1 million mt were found to be in oversupply. Some wealthy, industrialized countries like Japan, Korea, and Taiwan (ROC) will have to react to an oversupply of nutrients from manufactured fertilizers, and will have to make more efficient use of nutrients in organic wastes and industrial by-products in order to protect their environments.

However, in most developing countries of Asia and the Pacific, the rising food needs of a growing population, stagnation (or even decline) in the area available for food production, and a reduced nutrient supply from organic sources, must be counterbalanced by a more efficient nutrient supply from manufactured fertilizers in the years to come.

Table 9. Theoretical maximum NPK nutrient fertilizer consumption, and projected demand for the year 2000, in selected Asian countries

Source: Ahmed 1994
* PPI Singapore Estimates 1995

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* The "maximum" level to which fertilizer use can rise in any country is a theoretical estimate which assumes that each cropped hectare receives fertilizer applications of the recommended rate of NPK suitable for local conditions (Ahmed 1994).

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DISCUSSION

A Malaysian participant asked whether an oversupply of nutrients implied that fertilizer efficiency is poor in these countries. Dr. Mutert suggested that an oversupply should be a warning signal, and data should be gathered concerning its extent, and its effect on fertilizer efficiency and the environment. He felt that Malaysia is not in an oversupply situation, since rubber and oil palm are very important crops in this country. He pointed out that when nutrients are invested in trees, they are present not only in products such as rubber taken from the living tree, but also timber. Thousands of tons of nutrients have accumulated in the trunks of several million hectares of tree plantation, and these will return to the soil after a cycle of twenty or twenty-five years.

The comment was made that in promoting the efficient use of fertilizer, population is the single most important issue. Cutting down on population growth is even more important than achieving a production increase. Dr. Mutert suggested that wealth is the best birth control, and that developing agricultural investment will affect the level of population growth.

One participant was interested in the negative balance, particularly of potash, and commented that Dr. Mutert's model seemed to assume a high level of removal. He asked whether the model assumed that all the crop residues such as rice straw were being utilized and removed. Dr. Mutert replied that the model assumes a standard application rate of five mt/ha of manure. The same assumption had been made for all countries, although this does not represent the actual situation in all cases. In most countries of Southeast Asia, rice straw is used for fuel or burned in the field for reasons of convenience. The resulting ashes are returned to the soil, although they are distributed insufficiently.

Dr. Saleem Ahmad commented that a great deal of potassium is being brought into low-income countries in the form of food aid. He asked whether projected fertilizer needs are based on the nutrient requirements of current rice varieties, or projected new varieties of the future. Dr. Mutert replied that they are based on current varieties, according to information from the International Rice Research Institute.