AGRICULTURE-FERTILMZER INTERFACE IN THE ASIAN AND PACIFIC REGION: ISSUES OF GROWTH, SUSTAINABILITY, AND VULNERABILITY

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ABSTRACT

Since the scope for bringing additional land under cultivation is limited, Asian and Pacific countries must rely increasingly on fertilizers and complementary inputs to increase food and agricultural production. The region is the world leader, with 42% of the 1992 global fertilizer use (56.7 million nutrient mt valued at $17 billion, out of the total world consumption of 134 million nutrient tons valued at $40 billion., at an average price of $300/nutrient ton), and its importance in fertilizer production, trade, and use is likely to increase. The region's fertilizer consumption is expected to reach 73.3 million tons by the year 2000. This increasing dependence on fertilizer highlights, on the one hand, the vulnerability of fertilizer importing countries to disruption in supplies, due to human or natural causes, and on the other, forewarns of the possible adverse environmental consequences of high fertilizer use. Japan, South Korea, and Taiwan may already be over-fertilizing by 23-63% – thus wasting a valuable resource and possibly contributing to environmental pollution – and Malaysia and China may have reached their "agronomic maximum" level of fertilizer use. By the year 2000, Bangladesh, India, Pakistan, Indonesia, and the Philippines might also approach their "agronomic maximum" fertilizer use levels. A comparison of a country's fertilizer use rate against its theoretical "maximum" fertilizer use level is a better measure of the country's stage of fertilizer use development than a straight comparison of use rates across countries.

To help meet future food needs, governments should consider promoting non-cereal food crops such as potato and vegetables which utilize land, water, and sunlight more efficiently and yield 5-10 times more per hectare than cereals. Finally, the possibility of active "informal" fertilizer trade (smuggling?) across some international boundaries is also postulated.

FOOD AND AGRICULTURE SITUATION

A Global Overview

An outstanding human achievement during the past three or four decades has been the ability of the world to feed itself, despite a 50% increase in population. This was due, in large part, to the energies devoted to agricultural research and extension during the 1950s and 1960s, at a time when prospects of widespread famine in several developing countries loomed large in the minds of policymakers. As a consequence, on a worldwide basis, during the 1960-90 period, food available for direct human consumption increased by 18% (from 2,290 calories per capita per day to 2,700 calories per capita per day); and protein availability, by 13% (from 62.6 g per capita per day to 70.9 g per capita per day) (FAO 1992a). Growth was even more impressive in developing countries – a 27% increase in per capita calorie availability (from 1940 to 2475 calories per capita per day) and a 22% increase in per capita protein availability (from 49.7 g to 60.6 g per capita per day) – as many Asian and Latin American

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countries managed to keep their agricultural production growth ahead of their population growth. For example, during the 1980-90 period, average wheat productivity in Asia increased by 40% (from 1700 kg/ha to 2372 kg/ha), and rice productivity, by 28% (from 2806 kg/ha to 3582 kg/ha), while population increased by 19% (from 2.6 billion to 3.1 billion).

Some Negative Features

However, there were also some negative features and failures associated with this growth (Aziz 1990):

1. In certain regions, such as sub-Sahelian Africa, per capita food consumption has remained stagnant at about 2,050 calories/day.
2. In many developing countries, rapid economic growth has been accompanied by a worsening pattern of income distribution and a growth in poverty and malnutrition.
3. The world's smallholder farmers and landless tenants have generally benefitted little from the agricultural transformation. Over the years, prices of many basic agricultural commodities such as wheat, rice, maize, and sugar have declined in real terms. Unlike the manufacturing sector, in which gains from higher productivity have gone at least in part to industrial workers through higher real wages, productivity gains in agriculture resulting from higher yields and lower costs have gone partly to consumers and partly to land values. Thus, smallholders and landless tenants have generally faced adverse and declining terms of trade. While in developed countries, governments have often helped farmers by providing subsidies, the agricultural sector has generally faced disincentives in many developing countries as governments tended to promote industrialization – especially during the late 1980s.
4. The environmental cost of the progress achieved has also increased. Apart from the dangers inherent in the overall increases in carbon dioxide and acid rain, the intensification of agricultural production during the past few decades has lead to other harmful ecological effects. These include the leaching of nitrates into the groundwater, and soil contamination from the overuse of fertilizers and pesticides. Deforestation and soil degradation have been additional problems.

Unless these are tackled effectively and in a timely manner, it may be difficult to sustain the agriculture sector's productivity in the future. Since viable alternatives to the use of chemical fertilizers do not currently appear on the horizon for large-scale application, policies should focus on how fertilizer use can be sustained with a minimum impact on the environment (Desai 1991).

AGRICULTURE IN ASIA

Importance in National Economy

Agriculture occupies an important place in the economy and politics of many countries of the Asian and Pacific region. In 1992, for example, its contribution to the GDP among the developing countries of the Asian and Pacific region was generally upwards of 25%, rising to 62% in Nepal (Asian Development Bank 1992); and it provides employment to a significant proportion of the total labor force in many countries. In Japan, South Korea, and Taiwan, while agriculture's contribution to the GDP is under 10% (only about 4% in Taiwan), many city dwellers maintain their roots in the countryside, where parents or other close relatives still live on ancestral land. And while the economy of the latter countries is tied to industrial development, governments are struggling to find strategies to maintain a balance between industrial development and agricultural stability. Their buoyant economies notwithstanding, they are concerned about issues of food and agricultural security as they import increasingly larger quantities of food and other agricultural products. They are also concerned about the possible environmental and psychological effect of the gradual disappearance of vegetation (OECD 1988).

The Current Situation

A. Performance of Agriculture

During the period between 1982 and 1992, total agricultural production grew by 18% to 88% in 17 of the 24 countries covered in this report, with the Philippines and Malaysia being at the two extremes (Table 1). On the other hand, growth was sluggish in Fiji (8%) and New Zealand (6%), and decreased by 4-26% in five other countries (Afghanistan, Sri Lanka, Japan, Mongolia, and Taiwan). The biggest reductions were in Afghanistan (26%) and Taiwan (24%). Disturbed political conditions in Afghanistan, and a significant reduction in the net cropped area in Taiwan, contributed to this reduction. With cereals (mostly rice) being the major crop category in practically all surveyed countries (the major exception being Malaysia), the pattern of growth in total food production closely paralleled the pattern for total agricultural production. In Malaysia, where cereals occupy only about 14% of the net cropped area, food production grew by 132% (compared to the 88% growth in total agricultural production), due to a major government effort to increase paddy production. The Malaysian government's aim is to be about 65% self-sufficient in food production.

Contributors to the Increased Production

Part of the increased total agricultural production in most countries surveyed was due to an increase in the net cropped area. This grew annually by 0.8-3.4% in south Asia and by 1.8-4.0% in southeast Asia. Among the east Asian countries, the area under cultivation increased only in China – and that by a mere 0.1% annually. In Japan, South Korea, and Taiwan it decreased annually by 1.6%,

Table 1. Index of food and agricultural production, Asian and Pacific Region, 1982-92 (1979-81 = 100)

	Food production		Agricultural production	
	1982	1992	1982	1992
South Asia				
Afghanistan	97	74	97	74
Bangladesh	104	128	104	126
India	105	158	104	156
Myanmar	118	128	117	126
Nepal	100	146	99	144
Pakistan	109	165	109	168
Sri Lanka	101	96	99	92
Southeast Asia				
Cambodia	130	183	129	190
Indonesia	106	174	105	170
Laos	111	148	111	148
Malaysia	122	232	115	188
Philippines	105	119	106	118
Thailand	107	131	107	139
Vietnam	91	110	111	163
East Asia				
China	111	164	113	166
Japan	102	99	102	96
Mongolia	105	92	104	93
North Korea	105	124	105	126
South Korea	102	122	103	120
Taiwan	101	93	104	76
Oceania				
Australia	88	119	91	121
Fiji	107	109	107	108
New Zealand	104	114	104	106
Papua New Guinea	106	146	104	131

Source: FAO 1992a and Taiwan Statistical Data Book 1992

1.4%, and 2.0%, respectively. This was due to a dramatic shift in favor of industrialization and urbanization. Even in China and Malaysia, the net cropped area fluctuated due to competing demands for land. During the 1982-92 period, the area under arable and permanent crops grew annually by around 0.5% in Fiji, 1.1% in Australia, and 1.5% in Papua New Guinea. However, it decreased by about 0.5% annually in New Zealand.

The region also recorded gains in the average per hectare crop yield. This grew annually by an average of 0.9-3.2% in south Asia, 0.1-3.4% in southeast Asia, and 1.6-5.8% in east Asia. Because of this significant gain in productivity, agricultural production in east Asian countries did not fall by as much as it could have in south or southeast Asia had there been a similar decrease in the cultivated area there. In Oceania, cereal productivity increased annually by about 3% in Australia, 2.8% in New Zealand, and 1.7% in Fiji. And in Papua New Guinea, while cereal productivity decreased slightly, that of root crops (the country's major produce) increased modestly by about 0.2%.

C. Pattern of Agricultural Production

In examining cropping patterns and crop productivity, the following points are noteworthy (Ahmed 1994):

- *Stable cropping patterns*: While the area under cultivation increased in all countries during the past 25 years, the cropping pattern (in terms of the percentage area under cereals compared to other crops) remained quite stable over the years, with the change being under 5 percentage points in a majority of the surveyed countries;
- *Dominance of cereals in the cropping patterns*: Rice and wheat, with a smaller percentage of maize and sorghum, have continued to occupy 50-80% of the net cropped area in most of the countries surveyed. The exceptions are Malaysia, Fiji, and Papua New Guinea, where cereals make up under 15% of the net cropped area (Table 2); and
- *Lower productivity of cereals compared to other food crops*: Cereals are less efficient utilizers of land, water, sunlight, and fertilizer compared to many noncereal food crops. They yield, on average, less than 5 mt/ha while crops such as potato, vegetables, and fruits yield, on an average, 10-40 mt/ha (Table 2).

Future Agricultural Production Needs

Future Agricultural Production Targets

To maintain the same total agricultural production per capita that we have at present, or slightly improve it, total agricultural production in south and southeast Asian countries and China should increase by 16%-35% (Thailand and Sri Lanka at the lower end and Pakistan at the higher) during the period 1990-2000 (Ahmed 1994). This reflects the rate of population growth, and also assumes that the cropping pattern will remain more or less the same as it has been over the past 25 years. On the other hand, the situation is very different in Japan, South Korea, and Taiwan – the three countries in which agriculture has taken a "back seat" in the overall economic development, with the area under agriculture gradually decreasing. Here, during the 1990-2000 period, a modest growth (8%) is projected for South Korea and an even lower 2% in Taiwan; in Japan a decline of about 1% might take place.

Options for Increasing Food Production: Cereals or Other Food Crops?

Increasing food production to meet domestic demand will continue to receive priority in many countries. However, a heavy reliance on cereal crops, while justified in the past, may need rethinking because, as stated earlier, cereals generally yield much less than other food crops such as potato and vegetables. Under the currently known technology and even under the best of circumstances, it may not be possible to increase average cereal yields in tropical countries beyond 5 mt/ha (compared to the average of around 1.8-3.8mt/ha now obtained in south and southeast Asian countries, Table 2). Potato and vegetables currently yield more than 10-40 mt/ha in the same countries—with a potential for much higher yields. They utilize sunlight, land, water and fertilizer more efficiently than cereals. Thus, chances of helping meet food needs on a long-term basis appear much higher with them than with cereals. So far, cereals have been preferred (except in countries such as Papua New Guinea) because they are generally easier to grow than root crops and vegetables. They also require much less post-harvest care, as they are not perishable. However, now that farming standards have risen in practically all countries, and the infrastructural support available is

Table 2. Agricultural situation in the Asian and Pacific Region, 1992 and Year 2000

Country/year	Population	Harvested crop area			Agric. production			Av. crop yield		
		FCR	NFC	TTL	FCR	NFC	TTL	FCR	NFC	AV
	(million)		(million ha)			(million mt)			(mt/ha)	
	(1)		(2)			(3)			(4)	
Afghanistan	19.1	2.3	0.1	2.4	3.8	0.1	3.9	1.6	1.9	1.6
Bangladesh	119.3	12.3	0.8	13.1	34.0	8.6	42.6	2.8	11.2	3.2
India	879.5	150.9	13.	164.8	343.8	265.8	609.6	2.3	19.0	3.7
Myanmar	43.7	7.9	0.3	8.2	19.8	2.5	22.3	2.5	8.8	2.7
Nepal	20.6	3.1	0.1	3.2	7.3	1.3	8.6	2.3	24.0	2.7
Pakistan	124.8	13.7	3.6	17.3	32.0	43.7	75.7	2.3	12.0	4.4
Sri Lanka	17.7	1.0	0.3	1.3	4.2	3.0	7.2	4.2	10.8	5.7
South Asia	1224.7	191.2	19.1	210.3	444.9	325.0	769.9	2.3	17.0	3.7
Cambodia	8.8	2.0	neg	2.0	3.2	0.3	3.5	1.6	13.0	1.8
Indonesia	191.2	19.2	7.1	26.3	90.3	41.5	131.8	4.8	25.9	6.5
Laos	4.5	0.7	neg	0.7	2.2	neg	2.2	3.2	2.7	3.0
Malaysia	18.8	0.7	4.2	4.9	3.9	10.0	13.9	2.4	2.9	2.8
Philippines	65.2	6.9	3.8	10.7	27.6	36.3	63.9	2.0	11.4	5.5
Thailand	56.1	13.7	3.5	17.2	53.1	50.3	103.4	3.9	14.4	6.0
Vietnam	69.5	8.5	0.3	8.8	36.1	7.2	43.3	4.2	24.0	4.9
S.E. Asia	414.1	51.7	18.9	70.6	216.4	145.6	362.0	4.2	7.7	5.1
China	1188.3	125.3	11.1	136.4	723.2	108.2	831.4	5.8	9.7	6.1
Japan	124.1	3.2	0.8	4.0	38.7	6.8	45.7	11.9	8.7	11.3
Mongolia	2.3	0.5	neg	0.5	0.6	neg	0.6	1.0	var1.0	
North Korea	22.6	2.5	neg	2.6	18.9	0.1	19.0	7.5	1.5	7.3
South Korea	44.2	1.8	0.4	2.2	21.8	0.3	22.1	11.8	0.7	9.9
Taiwan	20.4	0.5	0.3	0.8	1.8	6.9	8.7	3.6	23.0	10.9
East Asia	1401.9	133.8	12.7	146.5	805.0	122.3	927.3	6.0	9.7	6.3
Australia	17.6	16.0	1.7	17.7	33.1	33.1	56.2	2.1	19.5	3.2
Fiji	0.7	.02	.07	0.1	0.1	3.8	3.9	5.0	54.0	39.0
New Zealand	3.4	0.2	0.2	0.4	2.6	0.6	3.2	13.0	3.0	8.0
P. New Cuinea	4.1	0.2	0.2	0.4	1.7	1.9	3.6	8.5	9.5	9.0
Oceania	25.8	16.4	2.2	18.6	37.5	39.4	76.9	2.3	17.9	4.1
A-P Region	3066.5	393.1	52.9	446.0	1503.8	632.3	2136.1	3.8	12.9	4.8

also better, this might be an appropriate time to consider the gradual promotion of alternative food crops, preferably through nonfinancial intervention. Potato and vegetables appear good candidates for consideration. Some crop combinations might also be better from a standpoint of human nutrition.

A change in dietary habits usually takes place with rising affluence, as has been the trend in Japan, South Korea, and Taiwan over the past few decades, and as is happening currently in Malaysia and Thailand. However, a shift to noncereal food crops may become a necessity in many countries in the near future. While many factors – such as agroclimatic suitability of the crop, crop nutrient requirements, pest problems, perishability of the harvest, and dietary preferences of the people – need to be considered in promoting new crops, a start can be made by encouraging farmers to grow potato and vegetables for home consumption, where appropriate. This would also make a dent in monocropping, which has become all-pervasive in many countries.

It could be argued that countries such as Japan, South Korea, and Taiwan, with a comfortable balance-of-payments surplus, need not worry about producing enough food domestically as they can easily afford to import it. It might also be argued that countries with a comparative advantage in producing nonfood crops (e.g., cotton, jute, sugarcane, rubber, oil palm, etc.) would also be better off not worrying about producing enough food. However, to the extent that political realities make these countries feel concerned about *food insecurity*, the proposed strategy of gradually increasing the area under noncereal food crops might deserve consideration. A drastic shift is not suggested, but a gradually increased promotion of these "other crops" should be considered. The area under vegetables, although starting from a low base, has grown faster than the area under cereals in many areas. For example, in south Asia, while the area under cereals grew by 17%, 11%, and 34% respectively in Bangladesh, India, and Pakistan during the 1965-90 period, that under vegetables grew by 37%, 96%, and 326%, respectively. Data for Nepal and Sri Lanka are incomplete. In southeast Asia, while the area under cereals grew by 39%, 4%, and 37% in Indonesia, Malaysia, and the Philippines during the same period, that under vegetables grew by more han 1500% (from a very low base), 25%, and 1 %, respectively. In Thailand, while the c real area grew by 66%, that under ve etables remained unchanged; however, the area nder root crops increased by 1060%. In hina, while the area under cereals grew by 2%, that under vegetables grew by 128%. And finally, in Japan, South Korea, and Taiwan, where the area under cereals decreased by 43%, 39%, and 42% respectively, the area under vegetables either decreased by a lower percentage, or grew. In many cases, this change has taken place primarily at the dictate of market forces.

Possible drawbacks in the production and marketing of potato and vegetables include: (i) They require more inputs (fertilizer, labor, water, etc); (ii) They are more prone to pest damage (by insects, diseases, and weeds); (iii) They require much better crop management; (iv) They are more sensitive to weather changes; (v) They are perishable and thus require much greater post-harvest care; (vi) They are costlier to grow and more expensive to purchase in the market; and (viii) They are highly subject to price fluctuations. All the more reason that an objective feasibility study be initiated early in various countries to consider the appropriate agroclimatic and socio-economic niche for the initial promotion of these crops.

THE FERTILIZER SITUATION

Fertilizer Consumption

Quantities

During the 1981/82 – 1991/92 period, fertilizer consumption in the Asian and Pacific region grew by 81%, from 30.9 million mt to 56.7 mt (Table 3). The region used 42% of the total global 1991/92 consumption of 134 million mt, (FAO 1992b), and is now the world's largest fertilizer consumer – and the fastest growing market. A region-wide analysis follows:

South Asia: A doubling (102%) of fertilizer consumption recorded in south Asia was due primarily to rapid growth in Bangladesh (150%), India (110%),and Nepal (200%); Pakistan (74%) came a little behind. More modest rates of growth were recorded in Sri Lanka (20%) and Afghanistan (11%). In Myanmar, on the other hand, a 45% reduction in fertilizer consumption took place. The reduction here and the limited growth in Afghanistan could be attributed to the prevailing disturbed political situation. Sri Lanka's smaller growth may also reflect the fact that the level of fertilizer use there (136 kg/ha) is already high for the crops grown (Table 3).

Southeast Asia: A robust 122% growth took place in southeast Asia, due to high growth rates in Vietnam (239%), Thailand (170%), and

Malaysia (141%). Indonesia (67%) was slightly behind, while the Philippines recorded a more modest growth of 37%. However, fertilizer consumption decreased in Cambodia and Laos by 53% and 25% – again due to the disturbed political situation.

East Asia: East Asia's growth of 77% was due primarily to a near-doubling in China's fertilizer consumption (96% growth), while Mongolia and South Korea had growth rates of only 23% each, and very modest growth rates were recorded in North Korea (3%) and Taiwan (10%). Japan experienced a decrease of 3% in fertilizer consumption, a result of the significant reduction in the net cropped area.

Oceania: Here, fertilizer consumption remained nearly stagnant, with a growth of only 3% – due to a modest 12% growth in Australia. The other three major fertilizer consumers – Fiji, New Zealand, and Papua New Guinea – registered decreases of 26%, 17%, and 8%, respectively. While the reduction in Fiji was due to the prevailing disturbed political situation, that in New Zealand – as in Japan – was due to a significant drop in the net cropped area. Fertilizer consumption in French Polynesia, New Caledonia, and other Pacific islands remained unchanged.

Rate of Fertilizer Use

Among the countries surveyed, fertilizer use rates (kg/ha nutrients) ranged in 1992 from 4 (Cambodia and Laos) and 8 (Myanmar), to 548 (Taiwan), 441 (Japan), and 430 (South Korea). In more recent years, the increase in fertilizer use has been tapering off in Japan, South Korea and Taiwan; consumption may have already peaked. These three are among the world's heaviest fertilizer users. Estimating New Zealand's level of fertilizer use is somewhat problematic because it is difficult to assess the percentage of pasture land that is fertilized. If we do not include this land, the average fertilizer use approximates 958 kg NPK/ha – which is highly inflated. And if we include all pasture land, then the figure drops to 27 kg/ha – which is a gross underestimate.

Because of differences in agroclimatic conditions and crops grown, however, a straight comparison of the level of fertilizer use/ha across countries provides only partial information regarding the stage of fertilizer use development. A comparison of each country's consumption against its own agronomic "maximum" fertilizer consumption may be a better indicator (Ahmed and Mapa 1986). This is discussed below.

Projected Fertilizer Demand in the Year 2000

To be able to meet projected agricultural production targets in the year 2000, NPK use in the region should increase by about 29% compared to the 1991-92 situation (Ahmed 1994). A country-wise discussion follows (Table 3):

South Asia: NPK use should grow by about 50%, with individual country growths ranging between 10% (Afghanistan) and 96% (Pakistan). Relatively high growths are also needed in Bangladesh (84%) and Nepal (71%), while India, Myanmar, and Sri Lanka will need to have somewhat lower growths (40-43% each). This compares with a doubling in fertilizer use in Bangladesh and India over the past decade, and 71% and 17% growths in Pakistan and Sri Lanka.

Southeast Asia: A 61% growth is needed for the region as a whole, with more than a doubling taking place in the Philippines (188% growth), and high growths also being needed in Cambodia (67%), Indonesia (68%), Laos (67%), and Thailand (60%). Only in Vietnam (34%) and Malaysia (10%) are the projected growth rates lower.

East Asia: Because of the near-saturation ("over-saturation?") with fertilizer use in this region, fertilizer consumption may grow by only 15% during the period 1992-2000. China leads with a projected 16% growth, and Japan and Mongolia may have about 12% growth each. North and South Korea may have lower growth rates of 3% and 8%, respectively. Fertilizer use in Taiwan may have already peaked. In Japan also, projected growth of 13% is based on the assumption that the government will formulate policies to help bring about a modest increase in the net cropped area. All east Asian countries (especially Japan, South Korea, and Taiwan) which are concerned about the decrease in net cropped area may offer incentives to turn this situation around.

Oceania: A growth of only 8% might take place in this region, and that due primarily to a 9% growth in Australia. Fiji and Papua New Guinea may have growths of 9-14%, and New Zealand may arrest the declining trend in its fertilizer use and register a 4% increase.

N:P:K ratios: No major shift in this ratio is expected over the 10-year period in the surveyed countries. In south and southeast Asian countries (except Sri Lanka and Malaysia), governments will try to narrow the ratio, and some narrowing might take place – at about the same speed as in the past. In Sri Lanka and Malaysia, the ratios are already quite narrow because of the types of crops grown.

Table 3. Fertilizer use in the Asian and Pacific region, 1981/82 to 1991/92, and projections for the year 2000

	Quantity (1000 nutrient tons) 1981-82	1991-92	Growth (%)	Quantity Year 2000	Application levels (kg/ha, 1991-92)
Afghanistan	46	51	11	*56	21
Bangladesh	400	1003	150	1849	77
India	6085	12763	110	17890	77
Myanmar	126	70	(45)	*100	8
Nepal	24	72	200	123	22
Pakistan	1080	1879	74	3684	109
Sri Lanka	147	177	20	252	136
South Asia	7908	16015	102	23954	76
Cambodia	19	9	(53)	*15	4
Indonesia	1454	2426	67	4065	92
Laos	4	3	(25)	*5	4
Malaysia	400	965	141	1061	197
Philippines	320	437	37	1258	41
Thailand	313	846	170	1357	49
Vietnam	219	743	239	*1000	84
S.E. Asia	2447	5429	122	8761	77
China	15153	29646	96	34530	217
Japan	1879	1763	(3)	1989	441
Mongolia	13	16	23	*18	38
North Korea	786	811	3	*835	312
South Korea	769	945	23	1020	430
Taiwan	398	438	10	440	548
East Asia	18998	33619	77	38832	229
Australia	1144	1280	12	*1400	72
Fiji	19	14	(26)	*16	140
New Zealand	463	383	(17)	*400	958/27?
Pap. New Guinea	12	11	(8)	*12	28
Oceania	1640	1688	3	1830	91
Total	30993	56751	83	73377	127

Source: (i) Historical: [FAO, 1992b and Taiwan Fertilizer Co. Ltd]; Projections: [Ahmed 1994], (except for countries marked with {*}, which are preliminary estimates, based on historical trends).

The Increasing Importance of Fertilizers in the Region

The limit on additional land that can be brought under cultivation in most countries increases the critical role of fertilizers and other complementary inputs in helping meet future agricultural production needs in all countries. An analysis follows (Ahmed 1994):

South Asia: Compared to 1965, when fertilizer use accounted for 0-6% of the total agricultural production in Bangladesh, India, Nepal, and Pakistan, and 43% in Sri Lanka, fertilizer dependence had grown to 24-52% in 1990. This might reach 39-54% by the year 2000. Thus, by that time, about one-third to half of the total agricultural production needed in south Asia will have to be obtained by using fertilizers.

Southeast Asia: Because of the high fertilizer use already prevailing in Japan, South Korea, and Taiwan in 1965, the dependence on fertilizers to meet agricultural production was already high there at that time (66-72%). Because of the "near saturation" in fertilizer use, dependence rose at a slower pace over the next 25 years than in south and southeast Asia. This dependence might rise to about 82-87% by the year 2000. The vulnerability of these countries to disruption in fertilizer supplies is, thus, very high. In China, a different picture is seen. Because fertilizer use there averaged only 16 kg/ha in 1965, dependence on fertilizers for agricultural production was almost non-existent at that time. However, because of the rapid growth in fertilizer use over the past 25 years, fertilizer use is estimated to have been responsible for about half of the total agricultural production there in 1990. By the year 2000, this dependence might have risen to about 56%.

Theoretical Maximum Level of Fertilizer Use

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). An "optimum" (economic) level of fertilizer recommendation depends on the output:input price ratio. However, since it is difficult to estimate what this ratio might be in various countries 10-15 years hence, it is assumed that the currently recommended rates of fertilizer use will continue to represent the "optimum" situation in the future also. As NPK recommendations become updated and fine-tuned for newer crop varieties in specific areas, the theoretical maximum levels of fertilizer use will also change accordingly.

The 1990 and 2000 theoretical maximum levels are indicated in Table 4. For the year 2000, any expansion in the net cropped area has been assumed to be proportional to the 1990 cropping pattern, thereby influencing the ultimate use level in the same proportion. This is based on the general observation that fertilizer recommendations for various crops have remained unchanged in practically all the countries studied over the past 10-15 years (except that secondary and trace elements are also being recommended in certain cases). Thus, if a country's net cropped area were to increase by 10%, it is assumed that the theoretical "maximum" fertilizer demand level will also increase by 10%. The following points emerge from Table 4:

1. All four east Asian countries are either at their maximum level of fertilizer use (China) or are already "overusing" fertilizers (Japan, South Korea, and Taiwan). Unless fertilizer use for nonagricultural purposes (such as golf courses, parks, and forested areas) is also included in the fertilizer consumption statistics of these countries – without the inclusion of their respective areas – there appears to be a considerable wastage in the amount of fertilizer used; a wastage which may increase at the current fertilizer use projections. This fertilizer over-use can lead to environmental problems in future. Since fertilizer cost is a small percentage of the total cost of production in these countries (Ahmed 1994), farmers want to ensure good yields by using more than the recommended fertilizer rates. They do not generally know that they are wasting money – or even reducing yields. Thus, it appears that fertilizer is "overused" because it may be oversubsidized. By the year 2000, fertilizer use might range between 123% (China) and 189% (Taiwan) of the projected maximum use levels at that time. Thus, the amount of over-use and wastage is likely to increase.

2. The south and southeast Asian countries appear to be currently using fertilizer at a level of between 16% (Nepal) to 107% (Malaysia) of their respective theoretical maximum fertilizer-use levels. By the year 2000, fertilizer use levels may rise to between 25% (Nepal) and 148% (Malaysia) of the theoretical maximum level at that time. In most countries of these two regions, use levels in the year 2000 will range between 70-90% of the theoretical maximum. The Philippines might also be at about "saturation point" then.

Comparing Fertilizer Use Across Countries

Because of variation in soil types, agroclimatic conditions, and crops grown, a direct comparison of fertilizer use across countries is not a meaningful measure of the stage of fertilizer use in different countries. A comparison of current fertilizer use in each country against its theoretical "maximum" use (calculated on the basis of agronomic recommendations, discussed above) may be more meaningful (Ahmed and Mapa 1986). For example, India, with an average current fertilizer use of about 77 kg NPK/ha (against a theoretical optimum level of 110 kg/ha), may be a "higher" fertilizer user than Pakistan, where the current average use is about 109 kg NPK/ha (against a theoretical optimum of about 228 kg/ha) (Table 3 Table 4). Thus, India's current fertilizer use is around 70% of its agronomic optimum level, while Pakistan's is about 48% of its agronomic optimum level. The national average optimum fertilizer use level/ha in India appears to be about half of Pakistan's because a large proportion of India's agriculture is in semiarid rainfed regions where the recommended fertilizer application rates for most crops are about half of those in the irrigated Punjab and Harayana provinces, where sophisticated irrigated farming takes place.

FERTILIZER AVAILABILITY

Region's Increasing Dependence on Imports

About one-third of the fertilizer used in the region is imported. During 1991-92, for example, the 24 countries surveyed collectively imported 16.4 mt NPK nutrients (35% of their total nutrient needs), valued as $5.8 billion (at an approximate average CIF price of $300 per nutrient ton) (Table 5). Seven countries (Nepal, Cambodia, Laos, Thailand, Mongolia, Fiji, and Papua New Guinea) are 100% dependent on fertilizer imports. With 25-50% of their total agricultural production being dependent on fertilizer use, the vulnerability of these countries to disruption in fertilizer supplies is very high indeed. Hence, *fertilizer security* is as important a consideration as *food security*. Other countries with a high vulnerability to disruption in fertilizer supplies are Myanmar (50% import dependent), Sri Lanka (84%), Vietnam (88%), Japan (41%), Australia (64%), and New Zealand (43%). And although Bangladesh, India, Pakistan, and China are 23-34% import-dependent, their potential vulnerability to disruption in fertilizer supplies is also large because of the larger volume of their total food and agricultural consumption and also because of the high dependence of their respective economies on agriculture.

In terms of volume, the two biggest fertilizer importers are China and India. During 1991-92, China imported 9.8 mt NPK (33% of its needs) valued at approximately $2.9 billion; and India, 2.8 mt (29% of its needs), valued at $840 million. These two countries are also the world's biggest fertilizer importers. During 1991-92, they collectively imported 65% of the region's total fertilizer imports. Their share of the Region's total NPK consumption during that year was 76%.

Outlook for Future Fertilizer Production

While the region's own fertilizer production is expected to increase by about 36% during the next few years (from 38.3 mt in 1991 to nearly 52 mt, Table 6). Unless additional facilities are constructed, the shortfall in availability may rise from 15.9 million mt by the year 2000 (Table 7). And, while the percent shortfall will be only slightly higher than in 1991/92 (29.4% of estimated consumption versus 29.2% in 1991), the value of the estimated fertilizer imports will increase from US$4.8 billion in 1991 to US$6.5 billion by the year 2000, at the 1991/92 estimated average fertilizer price of 300/mt NPK.

The production of nitrogenous fertilizers (primarily urea) has grown significantly over the past 25 years in Asia. Indonesia, South Korea, Japan, Malaysia, Bangladesh, and the Philippines have been the major fertilizer exporters. However, exports from Japan, South Korea, Taiwan, and the Philippines may decline. China, Japan, South Korea, and the Philippines are the region's major exporters of phosphatic fertilizers. So far, China and Taiwan are the region's only countries producing small quantities of potassic fertilizers. With the recent discovery of a major potash deposit in Thailand, a fairly lage K-producing unit is now under construction there. This will put Thailand among the world's few K exporters.

"Informal" Fertilizer Trade between Neighboring Countries

Significant quantities of fertilizer may currently be smuggled from Nepal to India and from Malaysia to Thailand. This is based on the following considerations:

Nepal-India case: (1) The border between these two countries is very porous; (2) Fertilizer prices in Nepal have generally been about $30-132/mt lower in various years than in India; (3) Frequent fertilizer shortages have been occurring in the neighboring state of Uttar Pradesh in India; and (4) No statistical relationship between agricultural productivity/ha and fertilizer use/ha was observed in Nepal – in contrast to the highly significant relationship obtained in several other countries (Ahmed 1994). Although a movement of, say, 10,000 mt fertilizer from Nepal to India would hardly make a dent either in India's total fertilizer consumption or in its total agricultural production, it would have a significant impact in Nepal on both accounts. To minimize smuggling, the Nepalese government has recently decided to maintain fertilizer retail prices in the country at levels 5-10% higher than in India.

Malaysia-Thailand case: (1) The border between these two countries is also very open; (2) There is a significant price differential, with prices for urea and TSP being US$10-192/mt lower in Malaysia than in Thailand; and (3) Using the "need-

Table 4. Theoretical maximum level of fertilizer demand in Asia, with projected level of fertilizer demand

Country	Year	(1) Theoretical maximum fertilizer use (kg/ha)	(2) Projected maximum harvested area (mt/ha)	(3) Theoretical maximum fertilizer consumption (mt)	(4) Projected fertilizer demand (mt)	(5) Projected demand as % of theoretical max. consumption
				(Col. 1 x 2)		(Column 4/Column 3)
Bangladesh	1990	150	13.7	2.055	0.933	45
	2000	155	13.8	2.139	1.849	86
India	1990	110	165.9	18.029	12.561	70
	2000	115	170.0	19.550	17.890	91
Nepal	1990	130	3.5	0.455	0.073	16
	2000	135	3.6	0.486	0.123[(NS)]	25
Pakistan	1990	228	17.7	4.036	1.893	47
	2000	230	18.0	4.140	3.684	89
Sri Lanka	1990	221	1.4	0.309	0.171	55
	2000	225	1.5	0.338	0.252	75
Indonesia	1990	205	23.2	4.756	2.510	53
	2000	210	23.5	4.935	4.065	82
Malaysia	1990	182	4.9	0.892	0.952	107
	2000	185	5.0	0.925	1.371[1]	148
Philippines	1990	103	11.4	1.174	0.588	50
	2000	105	11.5	1.207	1.258[(NS)]	104
Thailand	1990	144	16.9	2.434	1.044	43
	2000	150	17.0	2.550	1.357[1]	53
China	1990	194	137.7	26.714	27.077	101
	2000	200	140.0	28.000	34.530	123
Japan	1990	347	3.4	1.180	1.839	156
	2000	350	3.4	1.190	1.989	167
S. Korea	1990	395	2.0	0.770	0.970	123
	2000	400	1.9	0.760	1.020	134
Taiwan	1990	365	0.7	0.256	0.417	163
	2000	365	0.6	0.219	0.415	189

based" methodology for fertilizer need projection (Ahmed 1994), the variation between the calculated 1990 fertilizer consumption and actual consumption was much higher in these two countries than elsewhere: 27% for Malaysia and 50% for Thailand – as opposed to 10% or less variation in other countries having significant R^2 values. If this hypothesis is correct, the Malaysian government has a choice: either let the *status quo* continue, in which case it will continue to subsidize the Thai farmers and – probably to a larger extent – the smugglers, or raise the fertilizer prices to bring them to a level comparable to these over the border (as Nepal has done). The latter option would undoubtedly draw protests from Malaysian farmers, however – as was also experienced by Nepal.

AGRICULTURE-FERTILIZER INTERFACE: AN OVERVIEW

Agriculture's Increasing Dependence on Fertilizers

Fertilizers are currently used to produce about 50% of the total agricultural harvest among the countries surveyed (up from around 10% in 1965), the range being from about 20% in the Philippines (where fertilizer use is about 52 kg NPK/ha) to 81-86% of the total agricultural harvest in Japan, South Korea and Taiwan (where fertilizer use is between 484-595 kg/ha) (Table 2). By the year 2000, fertilizers – along with complementary inputs – may be needed to help produce 40-87% of the projected total agricultural production needs among the surveyed countries, merely to maintain the same output per capita as in 1990. This highlights the growing strategic importance of fertilizers, as well as the vulnerability of fertilizer importing countries (in which category many Asian countries fall) to disruption in fertilizer supplies due to natural or human causes. This increasing dependence on fertilizers suggests a reexamination of the fertilizer-sustainability issue. The issue is not whether growth in fertilizer use is desirable, but how it can be sustained with a minimum adverse impact on the environment (Desai 1991).

Issues of Sustainability

Agriculture is not sustainable if its resource base declines, or if it has an adverse impact on the environment, or if it leads to economic hardship for farmers – especially for limited resource farmers and landless tenant cultivators. The decline in resource base may occur through soil degradation (depletion of nutrients or the development of soil problems such as salinity, alkalinity, waterlogging, or acidity), the cutting of forests, reduction in water quality, or changes in the prevailing climate (Swindale 1992). Attempts to intensify agriculture in marginal areas may also trigger such changes.

Excessive or improper use of fertilizers may lead to serious environmental problems. Inadequate and unbalanced use may also cause similar problems. While adverse environmental impacts from fertilizers are not as dramatic as those from pesticides, they are nevertheless insidious, with as yet undetermined long-term effects on human beings and the environment. Problems of nitrite toxicity in drinking water, eutrophication of lakes, and build-up of heavy metals such as cadmium (an impurity in some phosphatic fertilizers, which has been found to be carcinogenic) have already been observed in certain localities; and a build-up of nitrous oxides in the atmosphere (which may attack the ozone layer) has been speculated (OECD 1988). Thus, suitable legislation to regulate the production and use of fertilizers should be enacted in all countries and their compliance monitored. The levels of fertilizer nutrients in soil, groundwater, and lakes should also be monitored. Greater environmental awareness is already stimulating research into alternative agriculture. We are rediscovering the virtues of crop rotation, mixed farming, the use of cover crops, and the recycling of agricultural wastes.

Agriculture's Adverse Environmental Impact

While agriculture still makes a significant contribution to the landscape in many areas, a number of significant environmental problems have emerged because of the failure to integrate agricultural and environmental policies (Bockman *et al.* 1990) (Tabale 8). These include:

1. A reduction in the area of biotypes valued for nature conservation. For example, it is estimated that a 33-fold increase has taken place in the rate of species extinction in the intensive crop production area of Niedersachen, Germany, where 14 species became extinct between 1950 and 1970, with 85% of the losses being attributed to agricultural practices.

Table 5. NPK trade in countries of the Asian and Pacific region, 1992

	Nitrogen			Phosphate			Potash	Total NPK				% IMP dependence	
	Prd	Imp	Exp	Prd	Imp	Exp	Imp	Con	Prd	Imp	Exp	Total	export (Less)
Afghanistan	49	2	0	0	6	0	0	51	49	8	0	16	16
Bangladesh	757	6	64	50	214	0	72	1003	807	293	64	29	23
India	7302	566	12	2596	968	0	1236	12763	9898	2770	12	22	22
Myanmar	61	18	2	0	15	0	5	70	61	37	2	53	50
Nepal	0	61	0	0	16	0	6	72	0	83	0	100	100
Pakistan	1045	359	0	106	257	0	15	1879	1151	631	0	34	34
Sri Lanka	0	104	0	6	21	0	23	177	6	149	0	84	84
S. Asia	9214	1116	78	2758	1497	0	1357	16015	11972	3971	78	25	24
Cambodia	0	4	0	0	5	0	0	9	0	9	0	100	100
Indonesia	2255	11	696	501	13	34	184	2426	2756	208	730	9	**(27)
Laos	0	2	0	0	1	0	.1	3	0	3	0	100	100
Malaysia	325	172	184	0	170	0	53	965	325	871	184	90	71
Philippines	143	301	95	192	30	122	143	437	335	473	217	100	57
Thailand	0	486	0	0	236	0	149	846	0	870	0	100	100
Vietnam	21	578	0	68	60	0	16	743	89	654	0	88	88
S.E. Asia	2744	1554	975	761	515	156	545	5429	3505	3088	1131	57	36
China	15309	4663	16	4636	2706	58	*2413	29646	20042	9782	75	33	33
Japan	931	172	213	425	299	29	500	1763	1356	971	242	55	41
Mongolia	0	10	0	0	4	0	2	16	0	16	0	100	100
N. Korea	660	9	10	137	0	0	4	811	797	24	10	3	2
S. Korea	580	72	187	398	0	147	359	945	978	437	334	46	11
Taiwan	257	74	5	78	0	0	**18	438	392	92	5	21	20
E. Asia	17137	5000	431	5674	3009	234	3296	33619	23565	11322	666	34	32
Australia	233	293	22	229	400	.7	144	1280	462	838	22	65	64
Fiji	0	10	0	0	2	0	2	14	0	14	0	100	100
New Zealand	57	23	34	170	70	.5	105	383	227	198	35	52	43
PNG	0	6	0	0	2	0	2	11	0	11	0	100	100
Oceania	290	332	56	399	474	1	253	1688	689	1061	57	63	59
AP region	29385	8002	1540	9592	5495	391	5451	56751	39731	19442	1932	34	31

Table 6. Fertilizer production outlook, 1990/91-2000

	Nitrogen fertilizer			Phosphatic fertilizer			Total NPK fertilizers		
Country	Rated 1991 Capacity	Total Projected Addition	Rated Capacity Outlook	Total 1991 Capacity	Rated Projected Addition	Total Capacity Outlook	1991 Capacity	Projected Addition	Capacity Outlook
Afghanistan	58	0	58	0	0	0	58	0	58
Bangladesh	855	680	1,535	57	0	57	912	680	1,592
India	8,414	2,810	11,224	686	33	719	9,100	2,965	11,943
Myanmar	211	0	211	0	0	0	211	0	211
Nepal	0	0	0	0	0	0	0	0	0
Pakistan	1,225	1,598	2,823	neg	0	neg	1,225	1,598	2,823
Sri Lanka	0	0	0	9	0	9*	9	0	*9
South Asia	10,763	5,210	15,973	752	33	785	11,515	5,243	16,758
Cambodia	0	0	0	0	0	0	0	0	0
Indonesia	2,775	2,094	4,869	172	0	172	2,947	2,094	5,041
Laos	0	0	0	0	0	0	0	0	0
Malaysia	328	0	328	0	0	0	328	0	328
Philippines	140	0	140	392	0	392	532	0	532
Thailand	0	0	0	0	0	0	0	[1]600	[1]600
Vietnam	60	0	60	0	0	0	60	0	60
SE Asia	3,303	2,094	5,397	564	0	564	3,867	[1]2,694	[1]6,561
China	18,013	4,229	22,242	139	848	987	[2]18,272	[3]5,557	[2,3]23,829
Japan	1,100	0	1100	700	0	700	1,800	0	1,800
Mongolia	0	0	0	0	0	0	0	0	0
North Korea	867	0	867	0	0	0	867	0	867
South Korea	688	0	688	344	160	504	1,032	160	1,192
Taiwan	300	0	300	75	0	75	[4]437	0	[4]437
East Asia	20,968	4,229	25,197	1,258	1,008	2,266	[2,4]22,408	[3]5,717	[2,3,4]28,125
Australia	233	?	233	229	?	229	462	?	462
New Zealand	57	?	57	170	?	170	227	?	227
Oceania	290	?	290	246	?	246	536	?	536
Total	35,324	11,533	46,857	2,820	1,041	3,861	[2,4]38,326	13,654	[1,2,3,4]51,980

Table 7. Fertilizer "security" of selected Asian countries, 1990/91 and 2000 (1000 NPK nutrient mt)

Country	NPK consumption		NPK production		NPK supply/demand balance	
	1991/92	2000	1991/92	2000	1991/92	2000
Afghanistan	51	56	58	58	5	2
Balgladesh	933	1,849	912	1,592	(21)	(257)
India	12,561	17,890	9,100	11,943	(3,461)	(5,947)
Myanmar	72	100	211	211	139	111
Nepal	73	123	0	0	(73)	(123)
Pakistan	1,893	3,684	1,225	2,823	(668)	(861)
Sri Lanka	171	252	9	9*	(162)	(243)
South Asia	15,754	23,954	11,515	16,636	(4,241)	(7,318)
Cambodia						
Indonesia	2,564	4,065	2,947	5,041	383	976
Laos	3	5	0	0	(3)	(5)
Malaysia	952	1,371	328	328	(624)	(1,043)
Philippines	588	1,258	532	532	(56)	(726)
Thailand	1,044	1,357	0	600	(1,044)	(757)
Vietnam	743	1,000	60	60	(683)	(940)
Southeast Asia	5,894	9,056	3,867	6,561	(2,027)	(2,495)
China	27,077	34,530	18,272	23,829	(8,805)	(10,701)
Japan	1,839	1,989	1,800	1,800	(39)	(189)
Mongolia	16	18	0	0	(16)	(18)
North Korea	811	835	867	867	56	32
South Korea	970	1,020	1,032	1,192	62	172
Taiwan	417	415	437	437	20	22
East Asia	31,130	38,807	22,408	28,125	(8,722)	(10,682)
Australia	1,280	1,400	462	462	(818)	(938)
Fiji	25	28	0	0	(25)	(28)
New Zealand	383	400	227	227	(156)	(173)
Oceania	1,713	1,828	536	536	(999)	(1,139)
ASIA	54,491	73,645	38,326	#51,858	(15,898)	(21,634)

* May reduce somewhat. # It is assumed that no new capacity will be added in Oceania.
Source: (FAO, 1992b; FADINAP, 1992; Ahmed 1994)

2. Agricultural pollution problems associated with the growth of intensive animal husbandry.
3. Air pollution problems from intensive animal production, manure spreading, and crop spraying.
4. Soil salinization problems, which are contaminating water supplies and causing losses in soil productivity and landscape amenity values.
5. Losses in landscape amenity values and wildlife habitat caused by the amalgamation of farms; spread of monoculture; removal of hedges, walls, and terraces; draining of wetlands; and deterioration and destruction of traditional farm buildings. For example, in one part of Germany, 36% of the hedgerows were cut down between 1954 and 1971. In another, 50% of hedgerows were cut between 1971 and 1979.
6. Soil compaction, erosion, and pollution, which have led to productivity losses, a decline in the quality of water resources, and a reduction in water storage capacity.
7. Adverse effects on human health of chemical fertilizers, synthetic pesticides,

heavy metals, feed supplements, and other contaminants in soil, water, food products, and the food chain. During the last few years, for example, 56 pesticides have been detected in groundwater in the U.S.A.

8. Contamination of ground and surface waters and the eutrophication of surface waters by nitrates and phosphates, leading to local health risks, decline in the quality of aquatic resources, loss in recreational values of the affected areas, and increased water treatment and supply costs.

The last two points are discussed below.

Overuse of Fertilizers

There is mounting evidence of fertilizer overuse. For example, a survey in the U.S.A. showed that over half of the nitrogen applied in the corn belt was not needed to achieve maximum profits. In a survey in Sweden, it was found that net farm income could increase by US$10-15/ha if farmers used only the amount of fertilizer needed for maximum profits, supplemented by animal manure (OECD 1988). Ahmad compared actual fertilizer use with the recommended use with the recommended use levels in Japan (Ahmed 1993), and concluded that Japanese farmers may be overusing fertilizer by 20-50%.

Reasons for fertilizer overuse

While reasons vary, they can be summarized as follows:

1. In developed countries, the cost to farmers of a marginal increase in the amount of fertilizer used is small, while fixed costs, particularly application costs, are high.
2. Fertilizer use rates for individual fields are not accurately known; thus, over-application appears to be an optimal risk-averse strategy.
3. Farmers find it too expensive to utilize animal manure or are unaware of its fertilizer value.
4. The livestock density of individual farms is too high (leading to overuse of animal manure).
5. There is peer pressure on farmers to produce high yields of insect- and disease-free crops.
6. In many cases production incentives and guaranteed market prices reduce the risk of high input use.
7. Sometimes marketing regulations, government assistance programs, product guarantees, etc. require the use of certain practices and chemicals which have adverse effects on the environment.
8. Sometimes food processors require farmers to use certain pesticides on fruits, vegetables, and other cash crops.

Problems with Excessive Fertilizer Use

The major environmental problems with fertilizer use, summarized in Table 8, are as follows (Bockman *et al.* 1990; Constant and Sheldrick 1992):

Denitrification/volatilization:

N loss to the atmosphere through denitrification (change of N compounds into nitrous oxide) may contribute to "greenhouse gases" in the atmosphere, thereby exacerbating the problem of the breaking down of the ozone layer. N losses can be particularly high from intensively cultivated and fertilized land, whether the fertilizer is from organic or inorganic sources.

Nitrate leaching:

The nitrate ion (NO_3) *per se* is not toxic. The concern is with nitrite (NO_2) which is formed by bacterial reduction of nitrate in the body. It is also produced in soil by the process of denitrification of the nitrate ion. Concern about nitrate intake is based on, firstly, a concern for infant health, as infant feed made with water containing more than 50 mg nitrate per litre is believed to involve a risk of attacks of acute infant Methemoglobinemia ("blue babies"). Secondly, there is concern that nitrate may react with food components in the stomach to form carcinogenic compounds, such as nitrosamines, thus causing cancer, especially of the stomach, but also of the liver and esophagus. The third concern is that nitrate may cause a variety of other diseases such as goiter, malformations, and heart problems.

Nitrate concentration in drinking water is approaching the World Health Organization (WHO) and European Community (EC) limit of 50 mg nitrate per litre in parts of Denmark, England, France, Germany, Sweden, and the USA. In France approximately 1 million people, and in the United Kingdom 1.6 million people, are reportedly already being supplied with drinking water in which nitrate concentration may at times exceed this statutory limit. There is also concern about nitrate discharge into coastal waters from rivers as a possible contributor to eutrophication. Nitrates in the groundwater come mainly from agricultural operations. Nitrates in

Table 8. Some adverse environmental effects of fertilizer use

Fertilizer Practice	Effect on					
	Soil	Groundwater	Surface water	Flora	Fauna	Other
Nitrogen application		Nitrate leaching affecting water				
Phosphate application	Accumulation of heavy metals heavy metals (cadmium, etc)	Accumulation of (cadmium, etc)	Run-off leaching, or direct discharge	Effects on microflora Eutrophication leading to: i) excess algae and water plants	ii) oxygen depletion affecting fish	
Manure, slurry application	Accumulation of phosphates and copper (pig slurry)	Accumulation of nitrates and phosphates	Eutrophication	Eutrophication leading to: i) excess algae and water plants	ii) oxygen depletion affecting fish	Stench, ammonia
Sewage sludge application	Accumulation of heavy metals and contaminants	Accumulation of heavy metals and contaminants				Residues

rivers and surface waters originate from agriculture and urban sewage.

Eutrophication of waters: An excessive accumulation of dissolved nutrients such as phosphorus, nitrogen, silicon, and other elements in water leads to an excess production of algal biomass. This requires a corresponding increased supply of oxygen for decomposition of the organic material. When the algae and their remnants sink to the bottom, reduced oxygen content and eventually anaerobic conditions may prevail. This is symptomatic of severe eutrophication and may lead to a serious loss of marine life, blockage of aquatic passages, and a major reduction in real estate value of the affected areas. The normal nitrogen:phosphorus ratio in waters is around 20:1. Algal growth increases when this ratio drops to around 7:1.

Serious pollution and eutrophication now occur in the Baltic Sea, the Kattegat-Skagerrak area, the southeastern parts of the North Sea, and in many adjoining coastal and fjord areas (Bockman *et al.* 1990). Additionally, in the Dutch, German, and Danish coastal regions, currents transport river water with nutrients along the coast, exacerbating the problem. This is also happening in the Mediterranean Sea and coastal regions of the USA. The nutrient input into the Baltic Sea has increased above its natural level by a factor of about 4 for nitrogen and 8 for phosphorus; for the Kattegat-Skagerrak area, the corresponding factors are 6 and 10-20 respectively (Bockman *et al.* 1990).

In the North Sea area as a whole, nutrients are transported with river water and land drainage, and the effect is particularly felt in the coastal regions. Here, nitrate concentration has now increased four-fold, and phosphate concentration is seven times above the natural level. The relative contribution from agricultural, industrial, and urban sources is uncertain, but it is estimated that, of the nutrients coming from human activity, about 60% of the nitrogen and 25% of the phosphorus might originate from agriculture, with most of the balance coming from sewage.

Cadmium (Cd)

Cadmium is highly toxic to humans but less so to plants. Rock phosphates, and therefore phosphorus fertilizers, may contain traces of Cd. There is a concern that the use of P fertilizer will slowly increase Cd level in soils. The problem was first observed in Japan in the 1960s, when the *itai-itai* disease (poisoning) was associated with the use of rice grown in fields irrigated with water containing cadmium from a geological mine.

Policy options

Suitable legislation to regulate the production and use of fertilizers and pesticides should be enacted in all countries, and their compliance monitored. The levels of chemicals in soil, groundwater, and lakes should also be monitored. Suitable policy measures (OECD 1988) include:

1. Strictly enforcing and strengthening the existing environmental regulations.
2. Controlling agricultural production through decoupling income support from price support, eliminating target prices, and, in some countries, reducing the total area cultivated.
3. Reviewing current research programs and developing new ones which seek to reduce the pollution associated with the use of agricultural chemicals.
4. Reducing the intensity of cultivation practices via input taxes.

Leaching of nitrates is a principal environmental and health issue related to fertilizer use. Current disagreements center, not on whether measures should be taken to prevent deterioration of water reservoirs, but on what measures are appropriate when effects and benefits are taken into consideration.

Major problem in legislation

A problem in introducing suitable legislation is the difficulty in assessing the levels of chemical fertilizers that may pose an environmental problem, and also the relative contribution of organic fertilizers. In 1991, after two years of debate, the EC environmental ministers agreed on a draft directive to reduce the nitrate levels to a maximum of 50 mg per liter by amending current agricultural practices (Constant and Sheldrick 1991). Under the new directive, member states will have to establish "nitrate vulnerable areas" where NO_3 levels exceed 50 mg/L or where there is a risk of eutrophication. No mandatory levels of N use are to be set up by the EEC, and each state is to set its own national level by 1999. However, a mandatory level of inorganic manure application will be established by the EC. About 10 million hectares of agricultural land may be affected by this legislation.

In North America, the problem of nitrates in drinking water is not as great as in Europe. For example, a recent geological survey showed that in 91 of the principal aquifers in 46 states, NO_3 levels were below 3 mg/L, while the levels in the other four states were 3-10 mg/L (with the "maximum contaminant level" (MCL) being 10 mg/L). A 1990 EPA study showed that about 2.4% of private drinking wells were contaminated above the MCL. Most studies seem to suggest that the contamination may be from organic sources rather than from chemical fertilizers. Since fertilizer use levels in USA have been stable over the last decade, the problem of NO_3 contamination may not be as high as in Europe. However, there is no room for complacency.

Research needs

There is also a need to recast our research priorities in agriculture to minimize future adverse environmental effects. Sustainable agriculture aims at maintaining, if not enhancing, soil organic matter content, especially in the topsoil. Greater environmental awareness has stimulated research into alternative agriculture. We are rediscovering the virtues of crop rotation, mixed farming, the use of cover crops, and the recycling of agricultural wastes. Japan's organic farming system, in which farmers and consumers jointly participate in production, pricing, and marketing decisions, and consumers also help in weeding, needs to be examined to assess the extent to which it could be emulated in other countries (Ahmed 1993).

Because of the inadequacy of economic analyses of the cost of soil degradation, and our lack of knowledge regarding farmer perceptions of its importance (Anderson and Thampapillai 1988), the research agenda in soil science for sustainable agriculture must emphasize determining physical thresholds for the main degradation processes (Swindale 1992). Such data already exists for soil erosion in some countries. The rate of formation of topsoil, for example, varies widely according to the action of various soil forming factors (E1-Swaify *et al.* 1982). Research on sustainable agriculture should therefore include a determination of thresholds or standards of rates of soil loss, salinization, and fertility decline. Physical and biological research is needed to obtain data from more sites; and socioeconomic research is needed to encourage wider adoption of the application of thresholds and standards.

Steps to Overcome the Environmental Problem

There is thus a need for integration of policies so that, whenever possible, mutual benefits can be realized and whenever necessary, conscious trade-offs can be made between agricultural and environmental objectives. Thus, consideration needs to be given to a trilogy of independent factors:

Need to enhance the positive contribution that agriculture makes to the environment: This can be facilitated through the introduction of management agreements and other similar arrangements which can produce the expected environmental benefits through agriculture with minimum adverse environmental impact. In some cases, farmers may need to be compensated for the lost net value of production and additional maintenance costs. The main use of agreements should be to improve landscape amenity and conservation values.

Need to reduce agricultural pollution: Different measures, either individually or in combination, need to be considered. In some cases, the setting and enforcement of standards would be the most effective; in other cases, the implementation of advisory procedures, or the application of economic measures such as incentives or charges, may be superior to regulatory enforcement. In all cases, the "Polluter Pays" principle should be considered. Efforts should be made to overcome the perceived difficulties associated with applying this principle to the control of agraicultural pollution from diverse sources.

Need to adapt agricultural policies to take the environment into account: Policies designed to achieve agricultural and other sectoral objectives, such as the reduction of agricultural support, should also be to produce maximum environmental benefits.

CROPPING PATTERNS, FOOD PRODUCTION, AND THE ENVIRONMENT

Root crops and vegetables yield three to five times more per unit area than cereals under most agroclimatic conditions. Governments in food-deficit countries such as Bangladesh should consider encouraging an increase in the area under these crops at the expense of the area under cereals. Although the intake of vegetables usually rises with rising affluence, we feel it should rise out of necessity. Notwithstanding the fact that perishable crops, such as vegetables usually require more pre- and post-harvest care, there is room for a greater attention to their promotion. Here, some lessons may be learnt from Japan's organic farming system, the foundations of which are composting, crop rotation, crop diversity, following the natural crop calendar, and weeding (Ahmed 1993). Where possible, cold-storage facilities for meeting the needs of larger urban centers for these perishable commodities should also be constructed – preferably by the private sector.

In vast parts of south and southeast Asia where monocropping with cereals is the order of the day, encouraging farmers to set aside a small piece of land for growing vegetables for home consumption would be a beginning. It would also help reduce pest problems, marketing problems, and soil nutrient deficiency problems that may arise with intensive monocropping.

ISSUES OF EQUITY

Issues of agricultural sustainability are also linked to issues of equity, access to opportunities, and social justice. For example, while Asia's much-heralded "green revolution" of the 1960s and 1970s helped boost agricultural production significantly through the introduction and spread of high-yielding varieties (HYVs) of rice and wheat, it also widened the gap between rich farmers who could afford to purchase the inputs needed for successful adoption of HYVs and their poorer neighbors. Rising prices have also forced many limited-resource farmers to sell their meager landholdings and migrate to urban areas – exacerbating the problems of city slums in the process. Thus, government policies which promote rural development, small-scale farming, village-based industries, and assured markets – backed up by suitable research, extension, and skill-building opportunities which empower peasants to help improve their economic well-being – are also needed.

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DISCUSSION

In the Discussion, Dr. Hong of Korea discussed the theoretical maximum fertilizer use as applied to Korea, and the 63% overuse estimated by Dr. Saleem Ahmed, who explained that this estimate was based on the recommended levels for each crop multiplied by the cropping area, compared to actual consumption. However, possibly the fertilizer used on parks and golf courses in Korea may have been included with that used in agriculture, and may have distorted the results. He pointed out that the figures given of the theoretical optimum etc. in his paper were only a first approximation, and hoped scientific colleagues such as Dr. Hong would help in refining these.