The State of Food and Agriculture in Asia and the Pacific: Challenges and Opportunities

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International Fertilizer Industry Association 1927-2002

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
INTERNATIONAL FERTILIZER INDUSTRY ASSOCIATION

Paris, 2002

The State of Food and Agriculture in Asia and the Pacific
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First version, published by IFA and FAO
Paris, France, April 2002

ISBN 2 9506299-8-9

The text of the document is available on IFA's internet site

Further copies can be obtained from:

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Printed in France
Layout: Claudine Aholou-Pütz, IFA
Graphics: Hélène Ginet, IFA

Preface

This report was written by R.B. Singh, Assistant Director General and Regional Representative for Asia and the Pacific, Food and Agriculture Organization of the United Nations (FAO) Regional Office, Bangkok, Thailand. It is an adaptation of a keynote speech presented at the International Fertilizer Industry Association (IFA) Annual Conference in Sydney, Australia in May 2001. This special reprint has been prepared to highlight a key issue facing the region in the lead-up to the World Summit on Sustainable Development in Johannesburg, 26 August - 4 September 2002.

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INTRODUCTION

Over the past 50 years, the Asia-Pacific Region[1] has undergone an unprecedented transformation in food and agricultural production, food security and rural development. The Green Revolution process, a science-led synergism among enhanced genetic potential (improved seeds), irrigation and fertilizers triggered in the mid-1960s, was the engine of this transformation. During the past 30 years, between 1969 and 1999, Asian cereal production more than doubled to reach nearly one billion tonnes. Despite the addition of 1.3 billion people to the region's population, average per capita food availability for the Region had increased from about 2,000 kcal/person/day in 1965/66 to over 2600 kcal/person/day in 1999/2000. No longer does one hear the phrase "basket case" countries. Increased agricultural productivity, rapid industrial growth in many countries and expansion of the non-formal rural economy had almost tripled the per capita GDP. During the last 30 years, the poverty level had reduced from about 60 per cent to less than 30 per cent.

Yet, over 500 million Asians are chronically undernourished, accounting for about two-thirds of the world's hungry people. Child malnutrition exacts its highest debilitating toll in the Asia-Pacific region, especially South Asia. Likewise, nearly 800 million, two-thirds of the world's poor, have their homes in the Asia-Pacific Region. It is disquieting that in the recent years the numbers of hungry and poor people have not been decreasing and remain stubbornly high. Moreover, agricultural intensification in the Region has often been associated with environmental degradation such as erosion of topsoil, salinization, depletion of soil fertility, lowering of water table and fast decline in water availability, waterlogging, pollution of water bodies, eutrophication, buildup of greenhouse gases, ecosystem acidification and loss of biodiversity.

[1] Asia-Pacific Region refers to the 38 FAO member countries which fall within the geographical jurisdiction of the FAO's Regional Office for Asia and the Pacific (RAP). These include 26 South Asian, South-east Asian, East Asian and 12 Oceania and Pacific Island countries. The present analysis relates to the developing Asian countries of the Region.

Given that the per capita availability of land in Asia-Pacific Region is one-sixth of that in the rest of the world and nearly three-fifths of the future increase in world population will occur in this Region, the future increases in food and agricultural production will have to be realized from the ever-shrinking and generally deteriorating land, water and other production resources. This is indeed an uphill task.

Recognizing that agriculture is the engine of the broad-based economic growth and overall development of most developing countries and must play the pivotal role in achieving sustainable food security and poverty alleviation, appropriate policies, strategies, technologies, inputs and human resources must be in place to meet the environmental and socio-economic challenges, including those arising from globalization, by rendering Asian agriculture more and more productive, resilient, environment-friendly and equitable. This paper analyses the current Asian food and agricultural situation, identify the problems and challenges of major crop production systems and finally discuss the various policy, strategy and technology options, including the uncommon opportunities presented by biotechnological, information and management revolutions, for ensuring a vibrant, responsive, sustainable and productive agriculture.

The focus of this document is crop agriculture, which directly and indirectly accounts for 75 to 80 per cent of the total agricultural production and employment in most developing countries of the Region. It draws heavily on FAO's Technical Interim Report *Agriculture: Towards 2015/2030,* which has adopted a 'positive' approach to give an idea of the future as it is likely to be rather than as it ought to be from a normative perspective. Past experience shows that FAO projections are not merely trend extrapolations but incorporate well researched probable deviations from past trends, as proven by the close match between the projections and actual outcomes (Alexandratos, 1995).

State of Food and Agriculture

Current Production and Consumption Scenario

The first forecast of world cereal output in 2001 is 1889 million tonnes, almost 2 per cent above 2000. Output of wheat is forecast at 585 million tonnes, unchanged from last years' crop, while that of coarse grains is seen to rise by almost 4 per cent to 905 million tonnes. Production of rice (milled basis) is tentatively forecast to remain unchanged at 399 million tonnes (FAO Food Outlook, April 2001). The projected cereal production in 2001 would be insufficient to meet global utilization in the 2001/02 season, requiring a withdrawal of 48 million tonnes from stocks, or 4 per cent, to 645 million tonnes.

World cereal trade in 2000/01 is forecast at 233 million tonnes, about 2 million tonnes below the previous season's record level. International cereal prices have generally remained depressed, a positive factor for cereal-importing developing countries.

During the 31-year period from 1964/66 to 1995/97, coinciding with the Green Revolution, per capita food consumption in the developing countries had increased by 28 per cent, from 2053 kcal/person/day to 2626 kcal/person/day (Table 1). The corresponding increases for South and East Asia respectively were 20 and 43 per cent, the latter being the highest among various regions and sub-regions of the world. It is gratifying that between 1979/81 and 1996/98 there has been an 11 percentage point decline in the prevalence of undernourishment in the developing world (FAO, 2000). It is still more

Table 1
Per Capita Food Consumption (kcal/person/day)

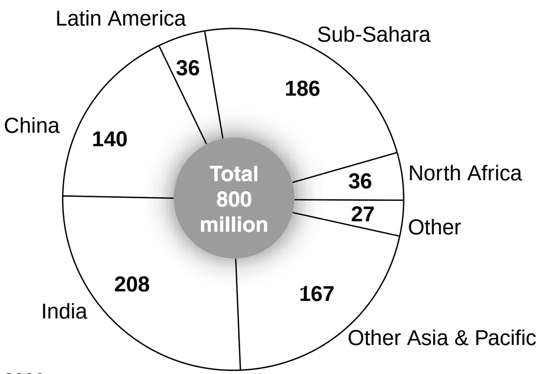
Region	1964/66	1995/97	2015	2030
World	2357	2761	2960	3100
Developing countries	2053	2626	2860	3020
South Asia	2013	2424	2790	3040
East Asia	1953	2783	3020	3170
Industrial countries	2945	3374	3490	3550

Source: *Agriculture: Towards 2015/2030*, FAO

gratifying in the Asian context as the bulk of the decline had taken place in Asia. In East and South-east Asia, the percentage of undernourished population decreased from 29 to 13 and in south Asia from 38 to 23 (Table 2).

Despite the significant declines, with 524 million malnourished people inhabiting Asia, the Region continued to be home to two-thirds of world's malnourished people in 1996-98. Globally little change was noticed from the preceding three-year average, and the prevalence of undernourishment in the developing world stagnated at 18 per cent. As seen from Table 3, only two sub-regions - East Asia and Southern Africa - achieved a reduction in both the percentage as well as the absolute number of undernourished. It was disturbing to note that South Asia, which houses 37 per cent of the world's malnourished people, had witnessed an increase of over 10 million in its number of malnourished people between 1995/97 and 1996/98. India alone accounts for one-fourth of the world's malnourished people (Figure 1).

Figure 1
Number of undernourished (by region, in millions of people)



Source: FAO, *SOFI*, 2000

Anthropometrically also, over two-thirds of an estimated 174 million undernourished under five children in the developing world were Asian children (especially South Asian). According to World Health Organization (WHO, 1998), it is estimated that more than half of the young children in South Asia suffer from protein-energy malnutrition, which is about five times the prevalence in the Western hemisphere, at least three times the prevalence in the Middle East and more than twice that of East Asia. Mortality rates for children under five provide a good indicator of the nutritional status of their

Table 2
Percentage of Population Undernourished in the Developing Regions

Region	% undernourished 1979-81	1990-92	1996-98
Sub-Saharan Africa	37	35	34
Near East and North Africa	9	8	10
East and South-east Asia	29	17	13
South Asia	38	26	23
Latin America and the Caribbean	13	13	11

Source: FAO, CFS: 2001/2

Table 3
A Comparison of Undernourishment Estimates for 1995-97 and 1996-98

Sub-Region	1995-97		1996-98	
	Number of under-nourished people (million)	Prevalence of under-nourishment (%)	Number of under-nourished people (million)	Prevalence of under-nourishment (%)
Reduction in Number and Prevalence				
East Asia	176.8	14	155.0	12.6
Southern Africa	35.0	44	34.5	42
Increase in Number				
South East Asia	63.7	13	64.7	13
South Asia	283.9	23	294.2	23
Caribbean	9.3	31	9.6	31
South America	33.3	10	33.6	10
North Africa	5.4	4	5.6	4
East Africa	77.9	42	79.9	42
West Africa	31.1	16	33.0	16
Increase in Number and Prevalence				
Central America	5.6	17	6.6	20
North America	5.0	5	5.1	6
Near East	27.5	12	30.3	13
Central Africa	35.6	48	38.5	50

Source: FAO, CFS: 2001/2

Table 4
Trends in Mortality of Children Under Five (per 1,000)

Region	1970	1980	1990	1997	1998	Reduction 1990-1998
East Asia & Pacific	126	82	55	46	43	22%
Europe & Central Asia	n.a.	n.a.	34	29	26	24%
Latin America & Caribbean	123	78	49	41	38	24%
Middle East & North Africa	200	136	71	58	55	22%
South Asia	209	180	121	100	89	26%
Sub-Saharan Africa	222	188	155	153	151	3%
Developing countries	167	135	91	84	79	14%
OECD	26	14	9	6	6	30%

Source: World Bank Statistical Information Management and Analysis (SIMA) database.
Note: n.a. = Not Available

mothers as well as their own. As seen from Table 4, on an average, in 1998, the child mortality-rate in developing countries was 13 times of that in OECD countries. It is now widely accepted that malnutrition is the major cause of child mortality in developing countries. Child mortality rate in developing countries declined by 14 per cent between 1990 and 1998, against the targeted decline of 30 per cent. The decline rates in East Asia and Pacific and South Asia were 22 and 26 per cent, respectively.

The present FAO Food Outlook (2001) suggests that there were 35 hunger hotspots where food emergencies of varying intensity persist for over 60 million people worldwide as a result of natural and man-made disasters. In the Asia-Pacific Region, two countries, namely, Mongolia and Democratic People's Republic of Korea, have been severely affected. In Mongolia, another extremely cold winter has killed large numbers of livestock, aggravating the food insecurity of nomadic herders, who lost millions of their livestock last year. In DPR Korea the food security situation remained tight due to drought, economic difficulties and the coldest winter in decades. Severe floods and other natural disasters, such as earthquake in India, had created pockets of severe food insecurity in Cambodia, Bangladesh, Southern Thailand and Gujarat State in India.

There is a strong link between poverty and food insecurity. As seen from Table 5, during the period from 1987 to 1998, as the incidence of poverty fell in Asia and the Middle East - North Africa, the prevalence of undernourishment concurrently declined. South Asia, which in 1998 had 522

Table 5
A Comparison of Poverty and Undernourishment Data

Region	1998 People living in households that consume less than $1/day (%)	1996-98 Share under-nourished (%)	1996-98 Number under-nourished (million)	1998 Number of poor (million)
East Asia	15.32	12	155.0	278.32
Eastern Europe and Central Asia	5.14	6	26.4	23.98
Latin America and the Caribbean	15.57	11	54.9	78.16
Middle East and North Africa	1.95	10	35.9	5.55
South Asia	39.99	23	294.2	522.00
Sub-Saharan Africa	46.30	34	185.9	290.87

Source: FAO, CFS, 2001/02

million people with income less than US $ 1/- a day, 44 per cent of the world's people in this category, also had the largest number of undernourished people, 294 million, over 39 per cent of the world's hungry people. Therefore, the twin objectives of the World Food Summit (WFS) and the UN Millennium Summit of halving undernourishment and poverty by 2015 are highly interconnected and interdependent. In order to heighten this linkage, the theme of the 2001 World Food Day is "Fighting Hunger to Eliminate Poverty"

FAO Global Information and Early Warning Systems, working closely with extensive networks of governmental and non-governmental organizations continues to play an important role in assessing the food and agriculture situation, determining food aid needs and informing the international community. The Organization's expertise has been invaluable within the framework of consolidated appeals for humanitarian assistance and, especially by providing direct assistance to farmers and other directly affected people. During the past two years, FAO has implemented nearly 40 emergency projects for a total value of over US$15 million in more than a dozen countries of Asia and the Pacific. The efforts were directed to rehabilitate agriculture damaged by snowstorms in Mongolia, drought in Pakistan and DPR Korea, floods in Bangladesh, Thailand, Laos, Cambodia, cyclones and earthquake in India and Tonga and/or civil strife such as in Timor, Sri Lanka and the Philippines.

The differential performance of East Asia, South-east Asia and South Asia in the recent years could be attributed to the policy priorities, the intensity of the financial crisis, and the capacity to manage the financial crisis in individual countries. Among the East Asian countries, the sub-regional trend was set primarily by China which was not as severely hit by the Asian financial crisis and had continued with its high priority of food security. The Republic of Korea, although severely hit by the crisis, bounced back quickly and restored its high economic growth. Mongolia and DPR Korea were severely hit by natural disasters and the usual sluggish economic policies and environment. The South-east Asian countries - particularly Indonesia, Malaysia, Philippines, and Thailand - were worst hit by the 1997 financial crisis. Of these, Malaysia recovered rather well, but the remaining countries, although on the path of recovery, are far from the desired level. In Indonesia and the Philippines, the economic emergency coincided with political upheavals and pockets of civil unrest. Thus many people who had earlier escaped poverty or were on the borderline have now slipped back, hence the slight increase in the number of hungry people in 1996/98. However, social safety net programmes in several of these countries and other socio-economic provisions had lessened the exacerbation of chronic food insecurity in East and South-east Asia. As regards South Asia, although it was not as badly hit as South-east Asia by the financial crisis, the high concentration of poverty, high population pressure and growth, and unsatisfactory level of policy priority on food security, coinciding with natural disasters, were responsible for the increase in the number of malnourished people in this sub-region.

The latest FAO Assessment of Food Insecurity in the World revealed that the proportion of the developing country population being undernourished was halved from 37 per cent in 1969/71 to 18 per cent in 1995/97, although the population had increased from 2.6 billion to 4.4 billion. As mentioned earlier, the per capita food consumption in developing countries as a whole increased by 28 per cent between the 1964/66 and 1995/97, from 2053 kcal/person/day, being lower than the minimum required level of 2200 kcal/person/day, to 2626 kcal/person/day. The performance of East Asia was most remarkable. As regards individual Asian countries, five countries, namely, Mongolia, DPR Korea, Cambodia, Laos and Bangladesh, in that order, fell short of the minimum required consumption. Concerted national and international efforts are needed to pull these countries out of the state of chronic hunger. In More recent years, Bangladesh, Laos and Cambodia, despite natural disasters, have significantly increased their domestic food and agricultural production. But, Mongolia and DPR Korea continue to be under serious food insecurity and poverty situations.

Demand and Supply Outlook to 2015/2030

Food demand in developing countries is essentially a function of population growth and income increase. As regards population, with 4.44 billion people in 1995/97, developing countries accounted for 77 per cent of the world population (Table 6). In 2030, the proportion will increase to 83 per cent with an estimated population of 6.7 billion. South and South-east Asia together will continue to account for more than 50 per cent of the world's population, 53 and 52 per cent towards 2015 and 2030, respectively, although the rates of growth will decelerate considerably, especially in East Asia. Given the high base level population and not-so-low growth rate, the share of South Asia in the world's population will increase from the current level of 22 per cent to 24 per cent in 2030, annually adding 19 million towards 2015 and 16 million people towards 2030. The corresponding increments for East Asia were 16 and 9 million. During the next 30 years, nearly one billion additional people will be added to the population of South, South-east and East Asia, and half of this addition will take place in India and China.

Table 6
Population Data and Projections

	1995/97		2015		2030		Growth rate %	
	million	% of world	million	% of world	million	% of world	1995/97-2015	2015-2030
World	5745	100	7154	100	8112	100	1.2	0.8
Developing countries	4436	77	5778	81	6718	83	1.4	1.0
South Asia	1251	22	1651	23	1915	24	1.5	1.0
South East Asia	1800	31	2133	30	2307	28	0.9	0.5

Source: *Agriculture: Towards 2015/2030*, FAO

Growths in per capita income (GDP) in Asia sub-regions between 1995/97 and 2015 and between 2015 and 2030 ranged from 3.6 to 5.7 per cent and were generally higher than the corresponding growths for the developing countries as a whole (Table 7). This growth will greatly help in reducing poverty level in the region and maintain a fairly high demand for food and agricultural products, leading to the reduction of undernourishment.

An analysis of the changes in the commodity composition of food by country groups, brings out the relative emphasis to be given between crops and animal production systems in the sub-regions. The data given in Table 8 indicate that in developing countries the use of cereals as food will stabilize at

Table 7
GDP Growth Rate (per cent per annum)

Region	Total GDP 1995/97-2015	Total GDP 2015-2030	Per Capita GDP 1995/97-2015	Per Capita GDP 2015-2030
World	3.1	3.6	2.0	2.7
Developing Countries	4.8	5.4	3.4	4.3
South Asia	5.1	5.1	3.6	4.0
East Asia	5.8	6.3	4.9	5.7

Source: *Agriculture: Towards 2015/2030*, FAO

Table 8
Changes in the Commodity Composition of Food by Major Country Groups (kg/person/year)

Commodities	Developing countries as a whole			South Asia			East Asia		
	1995/97	2015	2030	1995/97	2015	2030	1995/97	2015	2030
Cereals, food	172	178	178	169	186	192	194	193	187
Roots and tubers	65	69	74	21	26	30	63	62	63
Sugar	20	23	25	24	29	33	11	14	16
Dry pulses	6.9	6.8	6.8	10.6	9.1	8.0			
Vegetable Oils, oilseeds and oil products	9.4	12.4	14.8	8.5	11.9	14.6	8.6	12.2	15.3
Meat (carcass weight)	23	30	34	5.5	8.2	11.8	33	47	55
Milk and dairy, excl. butter	42	53	67	59	81	116	10	14	19
Total food (Kcal/person/day)	2626	2860	3020	2424	2790	3040	2783	3020	3170

Source: *Agriculture: Towards 2015/2030*, FAO

around 178 kg/person/year. Whereas, in South Asia it will increase from 169kg/person/year in 1995/97 to 192 kg/person/year in 2030, the reverse is the trend in East Asia. The share of pulses in South Asia - a main source of protein and an important group of crops in crop rotation - is expected to decrease, which is a setback from the points of view of nutrition and soil fertility. But, the quantity of vegetable oils and oilseeds is expected to increase to more or less the same degree in the two sub-regions. The contribution of meat will attain a far greater level in East Asia with 47 kg/person/year in 2015 and 55

Kg/person/year in 2030 against 8.2 and 11.8 kg in South Asia during the corresponding periods. The converse is projected in the use of milk and milk products, excluding butter. The per capita use of these products is expected to be 81 kg/person/year and 116 Kg/person/year respectively in 2015 and 2030 in South Asia against 14 and 19 kg/year in East Asia. Thus increased livestock production for meat in East Asia and dairying in South Asia will assume greater proportion as enterprises.

A "livestock revolution" is underway in the developing countries, particularly in Asian countries, with profound implications for crop-livestock balance, nutrition, income and the environment. Asia had registered the highest growth rate in the world in livestock production in the past decades and is projected to maintain this trend for the next three decades (Table 9). South Asia, in particular, will register much higher growth rates, 3.2 per cent against 1.7 per cent for the world as a whole. East Asia will also maintain high growth rate particularly during 1997-2015.

Table 9
Annual Growth Rate of Total Livestock Production (per cent per annum)

Region	1987-97	1995/97-2015	2015-2030
World	1.8	1.7	1.4
South Asia	4.3	3.2	3.2
East Asia	8.9	2.6	1.6

Source: *Agriculture: Towards 2015/2030*, FAO

Cereals and oilseeds are the main group of crops which are consumed both by human beings and animals, and the allocation of these commodities to livestock is likely to grow faster than in the past. Based on the cereal balances (rice, wheat, and coarse grains) in the production scenario and demand given in Table 10, it is seen that in South Asia the demand growth will outstrip the production growth by 0.1 percentage point up to the year 2030, whereas in East Asia, the demand will outpace production by 0.2 percentage point up to the year 2015 and will break even afterwards. As regards oilseeds, oilcake and oil, in South Asia the consumption will exceed production by 0.7 percentage points up to the year 2015, after which it will even out (Table 11). But in East Asia a gap of 0.3 percentage point will persist up to 2030.

Other international studies have also arrived at similar projections. The International Model for Policy Analysis of Commodities and Trade (IMPACT) developed by the International Food Policy Research Institute (IFPRI)

Table 10
Cereal Balances: Growth Rates of Demand, Production and Population (per cent per annum)

Region	Demand		Production		Population	
	1997-2015	2015-2030	1997-2015	2015-2030	1997-2015	2015-2030
World	1.4	1.1	1.4	1.1	1.2	0.8
South Asia	2.0	1.3	1.9	1.2	1.5	1.0
East Asia	1.4	0.9	1.2	0.9	0.9	0.5

Source: *Agriculture: Towards 2015/2030*, FAO

Table 11
Oil Crops, Vegetable Oils and Products Production and Consumption Growth Rate (per cent per annum)

Region	Total food use (in million tonnes)	Production growth rate		Consumption growth rate	
	1995/97	1995/97-2015	2015-2030	1995/97-2015	2015-2030
World	62.9	2.1	1.9	2.2	1.9
South Asia	10.6	2.5	2.4	3.2	2.4
East Asia	15.6	2.3	1.9	2.6	2.2

Source: *Agriculture: Towards 2015/2030*, FAO

forecasts an increase in global demand for cereals by 654 million tonnes between 1997 and 2020. About 85 per cent of this increase will be in developing countries, with Asia's share being 53 per cent. China alone will account for 27 per cent of the increased cereal demand, followed by India's share of about 12 per cent. As regards meat, the global demand is projected to increase by 119 million tonnes, and some 86 per cent of this increase is expected to materialize in developing countries, China alone accounting for 40 per cent, while Asia's share will be about 58 per cent. The analysis had further revealed that by 2020 East Asia's per capita demand for meat could exceed that of South Asia by as much as seven times. Fuelled by the demand for meat, developing countries' demand for feedgrains, especially maize, will more than double.

Table 12 gives balances of cereals production and demand for 1995/97, 2015 and 2030 as analyzed by FAO (2000). By the year 2030, the world cereal production would need to be increased to 2.8 billion tonnes, an addition of nearly 1 billion tonnes. Of this increment, nearly half will be for food, and

Table 12
Cereal Balances, Demand and Production (million tonnes)

Years	Demand		Production	SSR*
	Food	All Uses		%
World				
1995/97	979	1844	1836	100
2015	1257	2393	2397	100
2030	1428	2801	2805	100
Developing Countries				
1995/97	765	1107	996	90
2015	1029	1550	1352	87
2030	1197	1886	1615	86
South Asia				
1995/97	211	235	227	97
2015	306	343	327	95
2030	368	418	392	94
East Asia				
1995/97	348	526	493	94
2015	413	683	624	91
2030	432	787	708	90

*SSR = Self Sufficiency Rate = Production / Demand (all uses)
Source: *Agriculture: Towards 2015/2030*, FAO

about 44 per cent for feed, with the balance 6 per cent for seed, industrial non-food use and other uses. In South, South-east and East Asia, cereal production is expected to increase by 380 million tonnes, from 720 million tonnes in 1995/97 to 1100 million tonnes in 2030. Comparing the subregions, South Asia is expected to register an increase of 73 per cent, whereas East Asia (including South-east Asia) is expected to register an increase of 44 per cent. Non-food use of cereals in South Asia is currently about 10 per cent and is expected to slightly increase to 12 per cent towards 2030. But, in East Asia, the nonfood use proportion was much higher, 33 per cent in 1995/97 and 45 per cent in 2030.

Cereals demand is expected to outstrip production both in South and East Asia, the self-sufficiency rate in South Asia falling from 97 to 94 per cent and in East Asia from 94 to 90 per cent over 1995/97 - 2030 (Table 12). In order to meet the gaps between local production and consumption, South Asia which is currently a net importer of about 8 million tonnes of cereals, will become a net importer of 16 and 26 million tonnes in 2015 and 2030, respectively (Table 13).

Table 13
Net Trade of Cereals (million tonnes)

Region	19965/97	2015	2030
Developing countries	-107	-198	-270
South Asia	-1	-16	-26
East Asia	-37	-60	-79

Source: *Agriculture: Towards 2015/30*, FAO

East Asia which is already a high net importer of 37 million tonnes of cereals, will raise its net import to 60 and 79 million tonnes in 2015 and 2030, respectively. Most of this increase will occur in China primarily to meet the increasing demands for animal feed. The bulk of this increase will comprise coarse grains, particularly maize. In 1995/97 nearly 79 per cent of the use of maize grain in China was for non-food purposes, mostly as feed.

The various demand and supply projections of cereals, livestock and oilseed crops will lead to a significant increase in per capita food consumption particularly in developing countries, 2860 and 3020 Kcal in 2015 and 2030, respectively. In South Asia the corresponding figures are 2790 and 3040 Kcal and in East Asia are still higher, 3020 and 3170 Kcal (see Table 1). These increases would lead to further significant drop in the share of persons undernourished: to 10 per cent in 2015 and 6 per cent in 2030 for the developing countries, to 10 per cent and 4 per cent for South Asia and to 7 per cent and 4 per cent for East Asia (Table 14). However, due to demographic growth, in absolute numbers, globally the decrease of persons undernourished will be to: 576 million in 2015 and 401 million in 2030 from 790 in 1995/97, for Asia to 309 million in 2015 and 168 million in 2030 from 524 million in 1995/97. Likewise, Asia's share of the persons undernourished in the world will decrease from 66.3 per cent in 1995/97 to about 41.9 per cent in 2030. Thus,

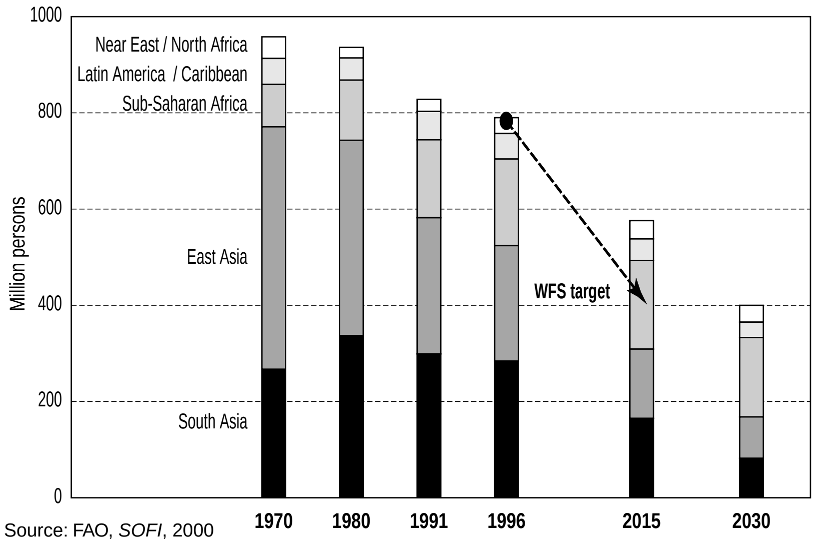
Table 14
Incidence of Undernourishments in Developing Countries

Region	Million Persons			% of Population		
	1995/97	2015	2030	1995/97	2015	2030
Developing Countries	790	576	401	18	10	6
South Asia	284	165	82	23	10	4
East Asia	240	144	86	13	7	4

Source: *Agriculture: Towards 2015/2030*, FAO

the Asian countries are not too far from meeting the target set at the World Food Summit in 1996. However, as things stand today, largely due to the unsatisfactory situation in Sub-Saharan Africa, the World Food Summit (WFS) goal of halving the number of undernourished persons no later that 2015, would only be reached toward 2030 (Figure 2).

Figure 2
Incidence of undernourishement



Source: FAO, *SOFI*, 2000

SALIENT FEATURES OF FARMING SYSTEMS IN ASIA

South Asia

For the sub-region as a whole, the growth rate of rice production at the rate of 2.7 per cent per annum is expected to reach 269 million tonnes in 2030 and wheat production, at 4.2 per cent annual rate of growth, is expected to reach 169 million tonnes. The large ruminant population is expected to stabilize or even decline. Globalization provides comparative advantages to adopt integrated farming systems, producing niche export markets for horticultural, livestock and fish products. Even within the sub-region, per capita consumption of both meat and dairy products is forecast to double in the next 30 years. Urbanization, which is now at 28 per cent of the population, will reach 53 per cent in 2030, necessitating increased off-farm employment for adult males, low labour systems of agricultural production to fit in with off-farm employment and more mechanization leading to an increase in the area of land per operator.

Irrigated land area is expected to grow slowly, from 40 per cent as of now to 44 per cent in 2030. Soil erosion and overgrazing, if not arrested, could lead to further degradation of natural resource base and water resources must be managed more efficiently from basin level to farm level to avoid a water crisis over major part of the region.

If significant climate change were to occur, low lying coastal areas could come under intensive pressure from rising sea levels, storms and flooding. Semi-arid rain-fed areas are likely to be seriously affected by increased rainfall variability.

Key features of the sub-region in terms of production and the farming systems are summarized in Table 15.

South-east and East Asia

In this most populous sub-region of the world, the population is projected to grow to 2.31 billion by 2030. The proportion of urbanization is expected to rise from the current 37 per cent to 53 per cent by 2030. There are eight low-income food-deficit countries in the region. The current average food intake is 2783 kcal/person/day and is expected to increase to 3170 kcal by 2030. This is expected to be accompanied by a better quality diet with significant growth in

Table 15
Key Characteristics and Potential of Farming Systems of South Asia

Principal farming systems are shaded.

Farming Systems	Land area (% of region)	Agric Popn* (% of region)	Principal livelihood	Incidence of poverty	Potential for poverty reduction	Potential for agric. growth
Rice	7	17	Rice (both seasons), vegetables, legumes, off-farm activities	Extensive severe poverty	Moderate	Moderate
Coastal artisanal fishing	1	2	Fishing, coconut, Rice, legumes, livestock	Moderate to severe poverty	Moderate	Low
Rice-wheat	19	33	Rice, wheat, vegetables, livestock including diary, off-farm activites	Extensive moderate and severe poverty	High	Moderate-high
Highland mixed	13	7	Cereals, livestock, horticulture, seasonal migration	Moderate to severe poverty	Moderate	Moderate
Rainfed mixed	29	30	Cereals, legumes, fodder crops, livestock, off-farm activities	Extensive poverty, severity varies vaseasonally	Moderate	Moderate
Dry rainfed	4	4	Coarse cereals, irrigated cereals, legumes, off-farm activities	Moderate poverty	Moderate	Moderate-high
Pastoral	11	3	Livestock, irrigated cropping, migration	Severe poverty, especial. drought included	Low	Low
Sparse (arid)	11	1	Livestock where seasonal moisture permits	Severe poverty especially drought induced	Low	Low
Sparse (mountain)	7	0.4	Summer grazing of livestock	Severe poverty, especially in remote areas	Low	Low
Tree crop	little, dispersed	little	Export or agro-industrial crops, cereals, wage labour	Moderate poverty mainly of agric. workers	Moderate	High
Urban based	neg	little	Horticulture, dairying, poultry, other activities	Moderate	Low	Low

Source: Weatherhogg, Dixon and de Alwis, FAO, Rome, 2001
*Defined as those working in crop or livestock production or forestry and their dependents.

the consumption of meat (65 per cent increase by 2030) and milk and dairy products (90 per cent increase for the same period), thus underpinning strongly the need for promotion of synergistic linkages between crop-agroforestry-livestock sectors for growth in agricultural GDP and poverty reduction.

Crop yield in the sub-region is projected to grow only by 1.2 per cent per annum, up to 2030. Rice production is projected to increase by only 0.7 per cent per annum up to 2030. Wheat production is expected to rise by 1.4 per cent per annum during the period 2000-2015. Substantial increases in production of maize and barley are expected, while little increase in production is anticipated for millets, sorghum, cassava and pulses. The production of oil crops, fruits and vegetables are expected to increase substantially by 2030.

The past and future trends for bovines and small ruminant production in the region are similar and projected to increase annually by 1.3 per cent up to 2030. The potential for increasing the supply of feeds for ruminants is anticipated to be a significant constraint and calls for a system-wide integration between crop and livestock sectors in land use and allocation of different crops. Animal feed supplies are expected to come largely from an increase in maize production at the expense of rice and wheat production.

Key features of the sub-region in terms of production and the farming systems are summarized in Table 16.

Table 16
Key Characteristics and Potential of Farming Systems of South-east and East Asia

Principal farming systems are shaded.

Farming Systems	Land area (% of region)	Agric Popn* (% of region)	Principal livelihood	Incidence of poverty	Potential for poverty reduction	Potential for agric. growth
Lowland rice	12	44	Rice, maize, pulses, sugarcane, oilseeds, vegetables, livestock, aquaculture	Extensive severe poverty	Moderate	Moderate
Tree crops mixed	5	3	Rubber, oil palm, coconut, coffee, tea, cocoa, spices, rice, livestock	Moderate poverty mainly of smallholders	High	High
Upland intensive mixed	20	28	Rice, pulses, maize, sugarcane, oil seeds, fruits, vegetables, livestock	Extensive moderate and severe poverty	Moderate	Moderate
Highland extensive mixed	6	4	Upland rice, pulses, maize, oil seeds, fruits, forest products, livestock	Moderate to severe poverty	Moderate	Moderate
Temperate mixed	6	14	wheat, maize, pulses, oil crops, livestock	Extensive moderate and severe poverty	Moderate	Low
Pastoral	20	1	livestock with irrigated crops in local suitable areas	Severe poverty especially drought induced	Low	Low
Root-tuber	1	<1	Root crops (yam, taro, sweet potato), vegetables, fruits, livestock (pigs and cattle)	Limited poverty	Good	Moderate
Sparse (forest)	11	1	Hunting, gathering	Moderate poverty	Low	Low
Spare (arid)	20	2	Local grazing, where water available	Severe poverty	Moderate	Low
Urban based	n.a.	little	Horticulture, dairy, poultry	Low to moderate	Low	Moderate
Costal artisanal fishing	n.a.	little	Fishing, coconut, mixed cropping	Moderate	Moderate	Low

Source: Ivory, D., FAO, Rome/Bangkok, 2001
* Agricultural populations are defined as those working in farming forestry or gishing and their dependents.

PROSPECTS FOR AGRICULTURAL PRODUCTION

Agricultural production at the global level has kept pace with demand, and had there been greater demand, world agriculture could have responded to meet it. Three main factors were responsible for this demand side limit: (a) the slowdown in population growth, (b) a growing share of world population that has attained fairly high levels of per capita food consumption, and (c) the poverty of the undernourished that prevented them from demanding more food or from having the resources to produce more food. The existing situation and projected trends of these factors suggest slowing down of the demand. On the other hand, the production side will be greatly influenced by the per capita availability of material and other production resources, the levels of various yield gaps, overall environmental condition, new technologies, appropriate policies and nature and quality of socio-economic settings.

As seen from Table 17, demand growth rates for the world, the developing countries, South Asia and East Asia are expected to decline during the period 1997-2015 when compared with those during 1977-1997. This deceleration is in line with the population growth rates during the two periods. Production growth at the global level matched demand growth rates. For the developing countries as well as for South and East Asia demand growth marginally outstripped production growth. The decrease over the two periods was most pronounced in East Asia, primarily due to the trend in China; the demand growth rate dropping from 4.8 per cent in 1977-97 to 1.9 per cent in 1997-2015 against the corresponding production growth rates of 4.7 and 1.8 per cent.

Table 17
Growth Rates of Aggregate Demand, Production and Population (per cent per annum)

Region	Demand		Production		Population	
	1977-97	1995/97-2015	1977-97	1995/97-2015	1977-97	1995/97-2015
World	2.1	1.6	2.1	1.6	1.6	1.2
Developing countries	3.7	2.2	3.6	2.1	2.0	1.4
South Asia	3.3	2.6	3.3	2.5	2.2	1.5
East Asia	4.8	1.9	4.7	1.8	1.5	0.9
idem, excl. China	3.5	1.9	3.2	1.9	1.8	1.2

Source: *Agriculture: Towards 2015/2030*, FAO

The deceleration in the growth of demand will have varied impacts on the different commodities in the different sub-regions. Cereals will largely be used as human food in South Asia and consumption may stabilize at around 200 kg/person/year. In East Asia, nearly 50 per cent will be used for feed and other uses, and use for human food may stabilize at around 180 kg/person/year. Net imports of cereals to developing countries will increase to 270 million tonnes in 2030 from 107 million tonnes in 1995/97. Asia's net imports of cereals will increase from 38 to 105 millions tonnes (see Table 13).

By 2030, total agricultural production in developing countries is projected to be 87 per cent higher than in 1995/97, while the projected increase for meat is 120 per cent and for crops 75 per cent. By 2030, developing countries will account for 72 per cent of world crop production, up from 66 per cent in 1995/97 and 53 per cent in 1961/63.

SOURCES OF GROWTH IN CROP PRODUCTION

During the period 1967-97, the developing countries registered a satisfactory crop production growth rate of 3.1 per cent (Table 18). East Asia, with a growth rate of 3.6 per cent, outstripped the global average. South Asia, with a growth rate of 2.8 per cent, also performed well. During the succeeding 34-year period, growth is expected to slow to 1.2 per cent in East Asia but to maintain a moderate rate of 1.9 per cent in South Asia.

The yield gains during the Green Revolution era were generally attributed to almost equal contributions of genetically improved seeds, irrigation and fertilizer with highly significant interactions.

Table 18
Annual Crop Production Growth Rate (per cent per annum)

Region	1967-1997	1995/97 - 2030
South Asia	2.8	1.9
East Asia	3.6	1.2
All Developing Countries	3.1	1.6
Industrial Countries	1.4	0.8
World	2.2	1.3

Source: *Agriculture: Towards 2015/2030*, FAO

Table 19
Sources of Growth in Crop Production (per cent)

Region	Arable land expansion		Increase in cropping intensity		Yield increases	
	1961-1997	1995/97-2030	1961-1997	1995/97-2030	1961-1997	1995/97-2030
South Asia	7	5	14	12	79	83
East Asia	26	5	-6	12	80	83
All developing countries	24	20	5	11	71	69

Source: *Agriculture: Towards 2015/2030*, FAO

There are three sources of future growth in crop production: (i) arable land expansion (ii) increase in cropping intensity and (iii) yield growth. Yield growth is likely to account for 83 per cent of production growth in Asia, whereas the net area expansion will contribute only 5 per cent and the remaining 12 per cent will be through increased cropping intensity (Table 19). In other words, 95 per cent of the crop production growth in Asia will accrue through more production per unit of land, while in other regions net area expansion will be contributing between 20 - 30 per cent.

As regards individual major crops, about four-fifths of the growth in wheat and rice production in developing countries will have to come from gains in yield, whereas for maize, expansion of land under cultivation will be an equally important source, even more so than in the past. In Asia, for wheat and rice, there will be negligible or zero net area growth (even negative growth in some major producing countries), thus yield growth will be the exclusive source of increased production.

Agricultural Land

Developing countries will expand their total arable land area by 120 million hectares between 1995/97 and 2030 (Table 20). This includes an increase of only 15 million hectares in Asia (9 million ha in South Asia and 6 million hectares in East Asia with annual growth rates of 0.13 and 0.07 per cent, respectively). India and China together account for about 28 per cent of the developing countries' arable land. For South Asia, India's share in the arable land is overwhelming, 82 per cent. In South Asia, nearly 90 per cent of arable land is already under use, whereas in East Asia, more than 40 per cent of the available potential is unused. In South Asia excluding India, about 15 million ha of land which is not suitable for agriculture has been brought under plough,

Table 20
Total Arable Land (data and projections)

Region	Arable land in use (million ha)			Annual growth (%)		Land in use as % of potential		Balance (million ha)	
	1995/97	2015	2030	1961-97	1995/97-2030	1995/97	2030	1995/97	2030
South Asia	207	212	216	0.18	0.13	84	88	13	4
excl. India	37	38	39	0.37	0.15	90	95	-14	-16
East Asia	232	236	238	0.91	0.07	57	58	134	128
excl. China	98	108	113	0.89	0.41	47	53	89	74
Developing Countries	960	1033	1079	0.68	0.34	32	36	1822	1703
excl. China/ India	656	731	777	0.81	0.50	25	30	1751	1630

Source: *Agriculture: Towards 2015/2030*, FAO

raising sustainability concerns. In all developing countries about 1.7 billion ha additional potential arable land will be available in 2030, but only 132 million ha of this will be in Asia (4 million ha in South Asia and 128 million ha in East Asia), again emphasizing the importance of yield growth in this region.

The cropping intensity for developing countries overall will rise by 7 per cent over 1995/97 - 2030, from 91 to 98 per cent (Table 21). In 1995/97, cropping intensity was the highest under irrigated conditions in South and East Asia (particularly China): 126 per cent in South Asia and 158 per cent in East Asia. In rainfed areas also it was over 100 per cent. Towards 2030, there will be further intensification both in South and East Asia. In certain agro-ecological settings, covering vast irrigated areas in South and South-east Asia,

Table 21
Cropping Intensity (per cent)

Region	Rainfed use		Irrigated use		Total land in use	
	1995/97	2030	1995/97	2030	1995/97	2030
South Asia	102	109	126	137	111	122
East Asia	118	120	158	169	130	137
Developing countries	82	85	129	140	91	98
excl. China/India	68	75	105	118	73	81

Source: *Agriculture: Towards 2015/2030*, FAO

cropping intensity is 200 per cent or more. Increased cropping intensities are associated with increased risk of land and environmental degradation, unless accompanied by appropriate technologies and policies.

Irrigation and Water Use

As seen from Table 22, the irrigated area in the developing countries will increase by 45 million ha (or 23 per cent) between 1995/97 and 2030. This means that 22 per cent of potentially irrigable land will be brought under irrigation, and 60 per cent of all land with irrigation potential (402 million ha) will be in use by 2030. About 75% of the developing countries' irrigated area in 1995/97 was in Asia and this share is projected to remain the same in 2030. In other words, nearly 75 per cent of projected increase in irrigated area in the developing countries will happen in Asia. Furthermore, China and India together will continue to possess about 54 per cent of the developing countries' irrigated area, India alone accounting for 28 to 29 per cent of the area. The South Asian irrigation figures are heavily impacted by India's situation as it accounts for 71 and 74 per cent of the sub-region's total irrigated area in 1995/97 and 2030, respectively. Of the projected increase of 17 million ha under irrigation in South Asia, 15 million ha is expected be in India.

The expansion of irrigation during the Green Revolution era in the developing countries registered a growth of 94 million hectare or 1.9 per cent per annum, but as the demand rate decelerates, during the next 34 years the

Table 22
Irrigated Arable Land (data and projections)

Region	Irrigated land in use (million ha)			Annual growth (%)		Irrigated land as % of potential		Balance (million ha)	
	1995/97	2015	2030	1961-97	1995/97 -2030	1995/97	2030	1995/97	2030
South Asia	78	85	95	2.2	0.6	55	67	64	47
excl. India	23	24	25	1.9	0.2	82	89	5	3
East Asia	69	78	85	1.5	0.6	62	76	43	27
excl. China	18	22	25	2.0	0.8	40	52	29	23
Developing countries	197	220	242	1.9	0.6	49	60	206	160
excl. China/ India	91	103	112	2.0	0.6	40	50	134	113

Source: *Agriculture: Towards 2015/2030*, FAO

growth rate will drop to 0.6 per cent. This will also be affected by the increasing cost of bringing additional areas under irrigation as well as the growing scarcity of water resources. However, due to the increase in cropping intensity under irrigation, the harvested irrigated area in the next 34 years will increase by 86 million ha. And, most of this gain, will take place in Asia, where irrigated land will reach about 40 per cent of total arable land, against 14 per cent in the developing countries excluding China and India (Table 23). It is important to note that in South Asia, excluding India, where there is very high pressure for crop intensification, the irrigation intensity is already extremely high, 62 to 64 per cent. In Pakistan irrigation intensity rises to 80 per cent. Therefore, the performance of irrigated agriculture in India, China and Pakistan will greatly impact the developing world's irrigated agriculture production.

Table 23
Irrigated Land As Per cent of Total Arable Land

Region	1995/97	2015	2030
South Asia	38	40	44
idem. excl. India	62	63	64
East Asia	30	33	36
idem. excl. China	18	20	20
Developing Countries	21	21	23
idem. excl. China/India	14	14	14

Source: Adapted from *Agriculture: Towards 2015/2030*, FAO

Agriculture accounts for about 70 per cent of the freshwater use in the world. Increasing withdrawals of freshwater for agriculture is one of the main causes of water scarcity which several countries are facing today, and the situation will continue to worsen. Therefore, irrigation water must be used more efficiently. As seen from Table 24, irrigation efficiency in developing countries was estimated around 43 per cent on average in 1995/97, varying from 26 per cent in Latin America (having abundant water resources) to 50 per cent in the Near East/North Africa region and 49 per cent in South Asia (water-scarce regions). With the improvement in irrigation technologies, modernization and rehabilitation of irrigation and appropriate water resources policies, each region is projected to improve its irrigation efficiency, with the greatest gains taking place in the Near East/North African region (15 per cent), followed by South Asia (9 per cent). In East Asia, barring China, the efficiency is rather low and must be improved considerably. This may be attributed partly to the predominance of rice cultivation in South-east Asia where paddy fields are flooded to facilitate land preparation and for weed management.

Table 24
Irrigation Efficiency in Developing Countries (per cent)

Year	Sub-Saharan Africa	Latin America	Near East/ North Africa	South Asia	East Asia	All developing countries
1995/97	42	26	50	49	38	43
2030	44	29	65	58	42	50

Source: *Agriculture: Towards 2015/2030*, FAO

Land/Yield Combinations for Major Crops

Crops must be matched to the soil and agro-ecological conditions to achieve their genetic potential. Table 25 gives production and yield of ten major crops in the developing countries. Between 1961/63 and 1995/97 yields have increased between 50 to more than 100 per cent, led by wheat, rice, maize, sorghum, soybeans, cotton seed, groundnuts and sugarcane. All crops together registered a growth rate of 2.1 per cent per annum. From now until 2030, an annual growth rate of 1.0 per cent is estimated. For cereals, which occupy 55 per cent of the developing countries' harvested area, the projected yield growth rate is only 1.0 per cent against the historical growth rate of 2.5 per cent.

Table 25
Production and Yield of the Ten Major Crops in Developing Countries

Crops	Production (million tonnes)			Yield (tonnes/ha)		
	1961-63	1995/97	2030	1961-63	1995/97	2030
Rice (paddy)	208	541	765	1.83	3.50	4.63
Wheat	65	272	418	0.87	2.46	3.44
Maize	69	257	506	1.16	2.60	3.68
Pulses	32	39	60	0.61	0.65	1.06
Sorghum	28	44	75	0.69	1.08	1.67
Millet	21	26	40	0.53	0.71	1.13
Soybeans	8	63	157	0.68	1.69	2.54
Cotton seed	15	38	73	0.67	1.44	2.28
Groundnuts	14	28	59	0.83	1.24	1.69
Sugarcane	385	1127	2014	46.55	60.60	88.45

Source: *Agriculture: Towards 2015/2030*, FAO

Irrigation enhances yield and total production (including through increased cropping intensity). On an average, in 1995/97, for the developing countries yield of cereals in rainfed areas was 1.71 tonnes per hectare, which is projected to grow to 2.23 tonnes per hectare in 2030. This is compared to 3.82 and 5.16 tonnes per hectare under irrigated conditions (Table 26).

Table 26
Cereal Yields in Developing Countries, Rainfed and Irrigated

Water regime	Share in area (%)		Share in production (%)		Average (weighted) yield (tonnes/ha)			Annual yield growth (% p.a.)		
	1995/ 97	2030	1995/ 97	2030	1961/ 63	1995/ 97	2030	1961- 97	1987- 97	1995/ 97- 2030
Rainfed	62	57	42	37	-	1.71	2.23	-	-	0.8
Irrigated	38	43	58	63	-	3.82	5.16	-	-	0.9
Total	100	100	100	100	1.17	2.52	3.49	2.5	1.9	1.0

Source: *Agriculture: Towards 2015/2030*, FAO

Irrigation of different crops varied considerably, wheat being the most intensively irrigated. In South Asia, in 1995/97, wheat occupied 35.1 million ha and accounted for nearly 80 per cent of total regional wheat production (84.9 million tonnes) (Table 27). The area dedicated to wheat is projected to increase by about 9 million ha by 2030 (mostly through double cropping), further increasing irrigated wheat area to 82.5 per cent of regional wheat production (93.1 tonnes). Between 1995/97 and 2030, wheat yield is projected to increase from 2.73 tonnes per hectare to 4.23 tonnes per hectare under irrigation and from 1.19 tonnes per hectare to 1.49 tonnes per hectare where rainfed.

Table 27
South Asia, Land/Yield Combinations of Wheat Production

Years	Irrigated Land			Rainfed Land		
	Area ('000 ha)	Yield (tonnes/ha)	Production ('000 tonnes)	Area ('000 ha)	Yield (tonnes/ha)	Production ('000 tonnes)
1995/97	28,004	2.73	76,463	7,131	1.19	8,468
2015	32,882	3.52	115,731	7,514	1.35	10,175
2030	37,240	4.23	157,492	7,874	1.49	11,741

Source: *Agriculture: Towards 2015/2030*, FAO
Note: The expansion of cultivated land area will essentially occur through increased double cropping.

Bridging Yield Gaps

In order to realize the projected yield levels, a two-pronged approach is called for: firstly, maintenance and protection of the high yields already being obtained in some countries and certain pockets in several countries, and secondly bridging of the yield gaps at various levels, including elevating the yield ceilings. As seen from Table 28, it is encouraging to note that wheat and rice yields in Asia have continued to increase during the past 40 years and are projected to increase towards 2030, albeit at a decelerating rate, suggesting the continued scope for bridging the yield gaps.

Recently FAO analyzed yield gaps in selected Asian countries and found that 50-100 per cent transferable yield gaps are not uncommon. For instance, for rice in India the gap between the national average and the average result of experimental trials was more than 3 tonnes per hectare, or more than 100 per cent. Gap of state averages over experimental average at the national level was of the magnitude of 52.3 per cent. The yield gaps differed widely from state to state, being lowest (800 to 600 kg per hectare) in Tamil Nadu and highest (4903 kg per hectare) in Rajasthan. Likewise, the state average yields also varied widely. Led by Punjab with an average yield of 5 tonnes per hectare, Tamil Nadu and Haryana, in that order, also recorded yields higher than 4 tonnes per hectare, Yields were generally low in Bihar, eastern Uttar Pradesh, Madhya Pradesh, Rajasthan, Assam, Himachal Pradesh and Orissa.

Generally, yield gaps across sub-regions are high for rainfed crops, such as coarse grains and groundnut. These gaps can be bridged by (i) extending the area under high yielding varieties; (ii) increasing the use of pulses and fertilizers based on soil test results, (iii) timely planting under quality and treated seed, (iv) ensuring desired plant population, (v) strengthening agricultural services, including appropriate processing and timely disposal of surplus production, and (vi) ensuring efficient use of irrigation water.

Table 28
Annual Increase in Wheat (South Asia) and Rice (South-east Asia) Yields (kg/ha)

Period	Wheat, South Asia	Rice, South-east Asia
1960s	45	40
1970s	35	45
1980s	55	65
1990-1997	53	35
1995/97 - 2030	39	29

Source: *Agriculture: Towards 2015/2030*, FAO

An analysis of sources of yield growth of rice and wheat in India during 1973-95 had revealed that for rice, price was the most important determinant (accounting for 40 per cent of the yield growth). Total factor productivity (TFP), which encompasses technological components, contributed only 24 per cent, and was closely followed by electricity (20 per cent). Irrigation had a rather modest contribution of only 8.4 per cent. However, the situation was somewhat different in case of wheat, where irrigation was the main source of yield growth (39 per cent), followed by price (29 per cent) and TFP (24 per cent) (Kumar, 2001).

There are serious yield gaps although there are already proven paths for increasing productivity per hectare, therefore it is very important to maintain a steady growth rate in total factor productivity. In the latest decade, the TFP growth rates both in paddy and wheat have decelerated in several countries and under certain production regimes. This trend must be reversed as the projected increases in food production must come essentially through increasing yield per hectare. A higher TFP growth rate means greater efficiency in the use of various inputs, especially fertilizer and water, for a greater return on investment.

As the TFP increases, the cost of production would decrease and the prices would also decrease and stabilize. The IFPRI IMPACT Assessment has projected a declining real world food price between 1995 and 2020. While low grain prices have been extremely helpful in improving the access on the part of the poor masses to the food in the market, farmers, especially with marketable surpluses, have suffered and will further suffer. Should economic growth in Asia return to about 8 to 10 per cent per annum, there are chances of increased demand for livestock feed, livestock products and other high value commodities, exerting an upward pressure on prices. This would induce intensification as well as diversification and enhanced TFP growth.

Aggarwal, Talukdar and Mall (2000) have analyzed potential yields of rice, wheat and rice-wheat systems in various Indian districts/states of the Indo-Gangetic plain using validated crop growth simulation models, spatial weather databases, land-use patterns, agronomic management details and Global Imaging Satellites (GIS). The simulated potential grain yield varied between 12.0 and 19.5 tonnes hectare (Table 29). Potential was higher in the northern region compared to the eastern region. Temperature and solar radiation during crop season had high impact.

Table 29
Potential Yields of Rice/Wheat Systems in the Indo-Gangetic Plains

State	Average potential yield (tonnes/ha)					
	Optimal rice-wheat planting system			Rice-late wheat planting system		
	Rice-wheat	Rice	Wheat	Rice-wheat	Rice	Wheat
Punjab	18.29	10.60	7.69	17.18	10.60	6.58
Haryana	17.87	10.53	7.34	16.87	10.53	6.33
Utar Pradesh	17.48	10.34	7.14	16.46	10.34	6.12
Bihar	16.43	9.73	6.70	15.47	9.73	5.75
West Bengal	13.37	8.07	5.30	13.35	8.07	5.28
Indo-Gangetic plains	16.70	9.88	6.82	15.85	9.88	5.97

Source: Aggarwal, Talukdar and Mall, 2000

These models can be used to calculate the extent of yield gaps in different regions and to find ways to overcome them. In fact, several farmers in north India already harvest nearly 16 tonnes hectare from a rice-wheat system, indicating negligible yield gaps with the current genetic potential of the cultivars used. These yields can be rated as one of the highest in the world and if realized, there would be no food problem in India. The analysis revealed huge potential for growth in Uttar Pradesh and Bihar. These efforts will call for development of precision agriculture with due concern for economic and environmental costs. Therefore, systems approaches with effective decision support systems are needed.

Inter-country differences in yields are rather high. Rice and wheat yields in 10 per cent of the highest yields developing countries were more than five times higher than those in the lowest 10 per cent yield countries (Table 30). For wheat this gap is expected to remain until 2030. For rice the gap between the top and bottom deciles may be somewhat narrowed by 2030; the yields in the bottom decile are projected at 28 per cent of yields in the top decile. This suggests that in rice the yield ceilings are being approached faster than in wheat. The average yield obtained by the largest producers, accounting for bulk of the global production, are about half of those achieved by top performers. In spite of continuing yield growth in these largest producing countries, their average levels will still be at 54 per cent of yields in the top decile in 2030.

There are several agro-ecological and socio-economic causes for the gap in bridging the exploitable yield gaps. With increasing emphasis on precision agriculture, there are greater chances for narrowing the yield gaps. For example, Australia, from an already a high average rice yield of 6.8 tonnes per hectare in 1985/89, harvested 8.4 tonnes per hectare ten years later, with many individual farmers obtaining 10-12 tonnes per hectare. The existing exploitable yield gaps should be seen as an opportunity for future growth consistent with agro-ecological, socio-economic, political and technological settings in the major producing countries and regimes. An important question is whether such opportunities exist with the large number of resource-poor small farmers in Asia, most of whom live in rain-fed and other problematic areas.

Table 30
Average Wheat and Rice Yields for Selected Country Groups

Country groups	1961/63		1995/97		2030	
	tonnes/ ha	as % of top decile	tonnes/ ha	% of top decile	tonnes/ ha	as % of top decile
Wheat						
No. of developing countries included	32		30		35	
Top decile	2.14	100	4.83	100	7.11	100
Bottom decile	0.40	19	0.85	18	1.22	17
Decile of largest producers (by area)	0.87	41	2.53	52	3.82	54
All countries included	0.97	45	2.13	44	3.02	42
Major developed country exporters	1.75		3.06		4.10	
World	1.18		2.42		3.23	
Rice (paddy)						
No. of developing countries included	44		52		56	
Top decile	4.51	100	6.43	100	8.05	100
Bottom decile	0.71	16	1.12	17	2.27	28
Decile of largest producers (by area)	1.82	40	3.45	54	4.38	54
All countries included	1.88	42	3.06	48	4.31	54
World	2.09		3.30		4.54	

Source: *Agriculture: Towards 2015/2030*, FAO
Notes:
1. In all country groups only countries with over 50 000 harvested ha are included;
2. Countries included in the deciles are not necessarily the same for all years;
3. Average yields are simple averages, not weighted by area.

In order to bridge the potential yield gaps, two main routes are being adopted. The hybrid or heterosis exploitation route, primarily led by Chinese scientists, has pushed up yield ceilings by about 20 per cent. Combining the hybrid route with new plant types, new 'Super Hybrid' rice varieties have been developed in China giving another 20 per cent yield gain. Large-scale pilot demonstrations have yielded 10-12 tonnes per hectare on an average. In some trials yields as high as 17 tonnes per hectare were obtained. At the International Rice Research Institute (IRRI), the new plant type promises a yield gain of 2-3 tonnes per hectare, yielding up to 13 to 14 tonnes per hectare. When combined in best hybrid combinations, these new plant hybrids will give an additional 15 to 20 per cent yield advantage. In wheat, a similar approach is being pursued by the International Maize and Wheat Improvement Center(CIMMYT) and some national programmes.

Notwithstanding the good success in overcoming yield ceilings in intensively managed production regimes, the challenge for global food security through large-scale production gains is to narrow the exploitable yield gaps. The following recommendations were made at the "Expert Consultation on Bridging the Rice Yield Gap in the Asia-Pacific Region", in1999 (FAO/RAP 1999):

- Development of more location-specific technologies for crop management is required. The sharing, testing and utilization of technology and knowledge across the national boundaries have to be facilitated by regional and international bodies through various networks.
- Integrated Crop Management can expedite the bridging of yield gaps and thus increase production. Location specific packages of technologies should be made available and popularized.
- The yield deceleration, stagnation and decline observed in high-yielding environments must be arrested, first by systematic studies to understand the causes and then by the development of new varieties and crop management practices.
- Technical knowledge is an important factor in determining the adoption of improved crop management practices. New paradigms for technology transfer are required for seed and knowledge-based technologies.
- Yield variability must be confronted. The diversion of resources towards risk reduction is a trade-off in yield performance. The trade-off between high yield and yield stability may be considered.
- The efforts to break the rice yield ceiling (NPT rice, hybrid rice, and agronomic manipulation) need to be geared up to attain higher yields.
- Technologies to decrease the cost of production and increase profitability must be considered. Issues in poverty alleviation, social justice and diversification in agriculture are inter-linked.

- The trade globalization provided by GATT, WTO, regional trade groups and geographic comparative advantages can provide major incentives for farmers to bridge yield gaps.

More alarming than stubbornly high yield gaps and decelerating yield growth rates are signs of decline of actual yields under certain production regimes. The long-term decline in yield potential of rice from continuous cropping experiment at IRRI is attributable to a degradation of the soil base and/or a decline in the genetic potential of the breeding materials used for generating cultivars. In-depth analysis, corrected for the annual rate of decline in IR-8 yield, indicated that the highest yields were increasing significantly. This implies that the paddy environment, namely the soil, is degrading faster than potential yield is growing.

These results illustrate that a long-term strategy and site-specific, knowledge intensive approaches are needed for the fertilizer use technology to be transferred by the extension advisory system and adopted by farmers. Soil-test based fertilizer application, real-time management of the crop nitrogen levels through leaf chlorophyll meter/leaf colour chart (IRRI) and soil nutrient budgeting are elements of precision agriculture to sustain high yields and reduce the deceleration of partial factor productivity due to fertilizers. This approach calls for a paradigm shift in the technology transfer approach, based on intensive knowledge and higher capacity of both the public and private sectors' extension agents.

Conventionally bred varieties, 'super rice' (New Plant Type), hybrid rice, super hybrid rice and biotechnologically engineered rice, all point to increased yield potentials. Exploited appropriately, these can increase the biological potential to stabilize yield at high levels. However, the countries of the region are at various levels of development, especially with respect to transfer and use of technology and policy support. No single formula with respect to transfer and use of technology and policy support, can be applied across the board.

While the yield ceiling must be raised and stabilized, the declining yield trends should be reversed and the yield gap narrowed. At the same time the production system must remain sustainable and environment-friendly. Increasing attention must be paid to the management of soil, water and other production resources. Problems in bridging the yield gap under the limitations of social, biological, cultural, environmental and abiotic constraints need close scrutiny. On a positive note, some groups of farmers have been able to achieve yields close to the yield potential for their respective locations, reducing the existing yield gap. A clear understanding of factors contributing to this phenomenon could lead to the recovery of a significant part of the current yield potential and boost production and farm income.

The Role of Fertilizer in Asian Agriculture

Fertilizer Consumption

In Asia, yield growth is the only avenue for future production growth. The yield growth witnessed during the Green Revolution era was closely linked with the increased use of mineral fertilizers which contributed about one-third to one-half of the increase in cereal production. In the future, the application of mineral fertilizers will also be crucial to achieving greater production, but increasingly alongside nutrients available from other sources and tailored to the needs of the individual crops and crop varieties.

Fertilizer consumption in the world is expected to increase from 134 million tonnes in 1995/97 to 182 million tonnes in 2030, at an annual growth rate of 0.9% (Table 31). Wheat, maize and rice will continue to be the main fertilized crops, with maize emerging to be the leader in 2030, closely followed by wheat and rice. This is reflected in the projected growth rate of fertilizer consumption, maize registering a growth rate of 0.9%, rice a growth rate of 0.6% and wheat a growth rate of 0.5%. Since these three crops are the predominant crops in Asia, this pattern will determine the trend of fertilizer use in the developing countries as a whole.

South, South-east and East Asia are projected to consume 86 million tonnes of mineral nutrients by the year 2030, accounting for 47 per cent of the world's and 77 per cent of the developing countries' fertilizer consumption (Table 32). China is projected to consume 46.4 million tonnes whereas India

Table 31
Fertilizer Consumption (million nutrient tonnes)

Crops	1995/97	2030	Growth 1995/97-2030 (% p.a.)
Wheat	24.6	29.5	0.5
Maize	22.3	30.4	0.9
Rice	22.2	27.2	0.6
All cereals	78.2	98.8	0.7
All crops	134.0	182.0	0.9

Source: *Agriculture: Towards 2015/2030*, FAO

Table 32
Fertilizer Consumption, Total Nutrient (historical and projected)

Region	Million nutrient tonnes			Growth rate (% p.a.)	
	1961/63	1995/97	2030	1961-1997	1995/97-2030
South Asia	0.6	18.1	27.2	10.0	1.2
excl. India	0.2	4.0	6.1	9.7	1.3
East Asia	1.7	44.4	58.8	9.7	0.8
excl. China	0.9	8.9	12.4	7.2	1.0
Developing countries	4.1	78.7	112.4	8.8	1.1
Industrial countries	24.6	46.3	58.3	1.5	0.7
World	34.3	133.9	181.6	3.9	0.9

Source: *Agriculture: Towards 2015/2030*, FAO

would be consuming 21.1 million tonnes. These two countries together will account for 60 per cent of the fertilizer consumption in the developing world and about 37 per cent of the world total. Commensurate with the deceleration in yield and production growths, the growth rate of fertilizer consumption in Asia will decrease to about one per cent during 1995/97 - 2030 against 9-10 per cent per annum during 1961-97.

As regards global nutrient consumption per hectare, the amount almost trebled during the Green Revolution period (1961/63 - 1995/97). In the developing countries the amount increased 13 times, from 7 kg per hectare in 1961/63 to 90 kg per hectare in 1995/97 (Table 33). In South Asia the increase was still more dramatic, from 3 kg to 79 kg per hectare and in the East Asia from 9 kg to 147 kg per hectare. Having achieved a moderately high rate of

Table 33
Per Hectare Nutrient Consumption (historical and projected)

Region	Nutrient use (kg/ha)			Growth rate (% p.a.)	
	1961/63	1995/97	2030	1961-1997	1995/97-2030
South Asia	3	79	104	9.4	0.8
excl. India	6	99	127	8.6	0.7
East Asia	9	147	180	8.9	0.6
excl. China	15	93	106	5.8	0.4
Developing countries	7	90	107	7.9	0.5
Industrial countries	125	206	253	1.1	0.6
World	35	107	124	3.3	0.5

Source: *Agriculture: Towards 2015/2030*, FAO

fertilizer use, the consumption growth rate is bound to decline towards the year 2030.

China is the world's second largest producer and the largest consumer of fertilizers, with 1510 fertilizer factories across the country and production of 26 million nutrient tonnes of fertilizers in 1995. On average, 50 per cent of farmers' production costs in China go to fertilizer. Fertilizer also accounted for 45-50 per cent increase in grain production, especially in the 1980s. In the high yield provinces of China the level of fertilizer use is over 300 kg per hectare. Fertilizer consumption in China during 1978-1999 increased from 8.88 million tonnes of nutrients to 40.8 million. In recent years, fertilizer imports accounted for 15-30 per cent of total consumption.

As in China, the role of fertilizer in the agricultural production in India has been significant. From a level of 17 kg per hectare in 1975/76 the nutrient consumption has increased to 97 kg per hectare of gross cropped area in 1999/2000. The total consumption of N and P fertilizers increased from 2.1 million nutrient tonnes and 0.47 million nutrient tonnes respectively in 1975/76 to 11.9 million nutrient tonnes and 4.7 million nutrient tonnes in 1999/2000.

East and South Asia will continue to experience deficits in all three nutrients, accounting for more than 90% of the projected global deficit towards the year 2020. Led by India in South Asia and by China in South-east Asia, the two sub-regions together will import 49 million tonnes of fertilizers by 2020 to meet their demands (Table 34). Therefore these sub-regions must continue to invest in fertilizer capacity while maximizing benefits from fertilizer trade. It would not be prudent to pursue a policy of fertilizer self-sufficiency in every region or country. Some of the large countries such as China and India may rely on trade and joint ventures to meet their fertilizer requirements.

Table 34
Fertilizer Supply Demand Balance (2000 and 2020)

	2000				2020			
	N	P_2O_5	K_2O	Total	N	P_2O_5	K_2O	Total
West Asia	2.5	0.6	2.3	5.4	1.2	-0.6	2.1	2.7
South Asia	-1.7	-3.8	-1.8	-7.3	-10.3	-7.1	-3.1	-20.5
East Asia	-5.1	-3.6	-4.6	-13.3	-13.2	-8.3	-6.9	-28.4
Asia	-4.3	-6.8	-4.1	-15.2	-22.3	-16.0	-7.9	-46.2

Source: Bumb, B.L. and Baanante, C.A., 1996

Fertilizer Use Efficiency

Fertilizer use and demand depend on (1) relative prices of fertilizer and crop output, (2) the availability and use of irrigation, assured water and fertilizer-responsive varieties, the suitability of soil type and the climate, and (3) government policy, infrastructures and physical and economic access to fertilizers. These factors, in varying measures, have impacted and will continue to impact the intensity and pattern of fertilizer use in different Asian countries. Recognizing that cereal production in the region must be increased by 60 per cent in the next 20 years essentially through the increase in yield per hectare, the demand for fertilizer in most developing countries will increase (Hossain and Singh, 1995). It is estimated that in order to achieve the targeted yield level average per hectare fertilizer use must be about 250 kg/ha, which is higher than the current technical optimum. The latter is in turn higher than the economic optimum (Table 35). The crop production environment, including the generation and transfer of appropriate technology packages, must be improved to increase fertilizer-use efficiency to meet the challenge of "feeding a fertile population from infertile soil in fragile world" (Borlaug and Dowswell, 1993). The judicious integration of organic and inorganic fertilizers in a farming system served through multidisciplinary research and technology development is called for.

It is estimated that average nutrient uptake efficiency is 50 per cent in developed countries and 40 per cent in developing countries. In rice in Asia the

Table 35
Projected increase in Yield and Fertilizer Intake in Cereal Production to Achieve Food Security by 2020 (technical and economic rates of application)

Country	Cereal grain requirements for 2020		Projection of fertilizer requirement NPK/ha	Optimum fertilizer application rate	
	Production (million tonnes)	Yield rate (tonnes/ha)		Technical	Economic
Bangladesh	50.1	4.52	244	213	140
China	528.0	5.73	336	-	-
India	385.2	3.78	276	-	-
Indonesia	77.0	5.73	297	221	198
Myanmar	19.8	3.69	105	-	-
Philippines	28.7	1.04	245	165	136
Thailand	24.1	2.17	51	195	160
Vietnam	32.7	5.60	239	-	-

Source: Modified from Hossain and Singh, 1995 nitrogen uptake efficiency is only 30-35 per cent. The response yardstick used to calculate fertilizer requirements has been fixed at 1:10, for decades. Extension and adoption of best fertilizer management practices on a large scale should result in the realization of higher fertilizer-use efficiency and an average response higher than 10. Improved nutrient efficiency would not only compensate for the negative price effect but also create positive environmental impacts. Gains in fertilizer-use efficiency in the United States in the 1990s set an example for other countries. As seen from Table 36, national maize yield increased from 7 to 8 tonnes per hectare while the per hectare N fertilizer use on maize had decreased from 150 kg to 145 kg. (Bumb and Baanante, 1996).

The rice-wheat cropping system, being practiced on 12.5 million hectares in the Indo-Gangetic Plains region of South Asia and on 10 million hectares in China is the most important production system for food security. A critical analysis of the prospects for enhancing and sustaining the productivity of rice-wheat system in South and East Asia highlighted the importance of organic recycling and integrated plant nutrient management leading to improved organic carbon, soil bulk density, infiltration rate, macro-micro-nutrient balance and other soil chemical and physical properties. (Singh and Paroda, 1994).

Recent reports from analyses of long-term experimental field data indicate that the rice-wheat system manifests production fatigue as yields have started declining over time in plots receiving unbalanced fertilizer application. However, an analysis by Yadav, et al. (2000) of the yield trends of the two crops under a continuous rice-wheat cropping system and of sustainability of the production system across seven locations in India over 12-15 years with fertilizers alone and in combination with organic sources, namely farmyard manure, green manure and crop residue (wheat straw incorporation), indicated that the decline in yields may either be reversed or minimized by application of complete doses of NPK fertilizer to both crops. Application of

Table 36
Maize Production and N Fertilizer Use in the United States

	Three year average			
	Maize Production		N fertilizer used on maize	
	Total (million tonnes)	Yield (kg/ha)	Total (1000 tonnes)	Per hectare (kg/ha)
1980-82	208.5	7022	4897	150.2
1990-92	225.4	8037	4339	144.6

Source: Bumb, B.L. and Baanante, C.A., 1996

fertilizers, either alone or in combination with organic manures, significantly increased the yields of rice and wheat over control plots (Table 37). 100F-treated plots produced significantly greater rice yields than those receiving 50F+FYM or 50F+CR. The yields receiving 50F+GM treatment were, however, statistically similar to those under 100F treatment. The wheat yield differences between 100F and between 50F+manures were not statistically significant.

It is important to note that the rice yield trends were positive and significant (P<0.01) under integrated nutrient supplies through fertilizers and manures, whereas in plots receiving 100F the annual increase in rice yield was not significant (P=0.08). The trends of wheat yields were also positive,

Table 37
Grain yield (t/ha) and yield trends of rice and wheat averaged over 12-15 years and seven locations for long-term rice-wheat system under fertilizer NPK applied alone or in combination with organic manures

Crop	Treatment[a]	Initial yield averaged over locations[b]	Yield averaged over years and locations	Annual yield change[c] b-value	t-statistic	p-value
Rice	Control	2.22	1.97	-0.032	-2.072	0.065
	50F	3.28	3.18	-0.001	-0.031	0.976
	100F	4.25	4.55	0.052	1.950	0.080
	50F+FYM	3.59	4.24	0.102	4.596	0.001
	50F+CR	3.51	4.01	0.082	3.673	0.004
	50+GM	3.94	4.47	0.085	3.398	0.007
Wheat	Control	1.17	1.07	-0.013	-2.297	0.045
	50F	2.30	2.32	0.009	0.709	0.495
	100F	3.65	3.51	-0.012	-0.560	0.588
	50F+FYM	3.62	3.63	0.008	0.460	0.655
	50F+CR	3.45	3.47	0.010	0.464	0.653
	50+GM	3.48	3.53	0.015	0.694	0.503

LSD 5% for rice treatment = 0.217 and for wheat treatment = 0.161
F = fertilizer alone
FYM = farm yard manure
GM = green manure
CR = crop residue: wheat straw incorporation
[a]In50F+Manure treatments, FYM, CR or GM were applied to rice only, and subsequent wheat received complete recommended dose of NPK through fertilizers
[b]The intercept (a-value) of liner regression
[c]Computed from liner regression
Source: Yadav, R.L. et. al. 2000

although not significant, in 50F+ manure treatment. The trends indicate that the average yield levels are likely to shift in favour of 50F+manure treatments, if the trends are extrapolated. This brings out the importance of organic recycling and integrated inorganic and organic plant nutrient systems in the intensive production regimes to enhance overall soil health, nutrient factor productivity and sustainability of the system, apart from nutrient substitution effect and economy in fertilizer investment.

Best fertilizer management practices revolve around five R's:

1. Right type of fertilizer material in relation to soil-crop combinations
2. Right quantity and proportion of fertilizer nutrients in relation to crop requirement, yield target and contribution of nutrients from soil as determined by soil testing and the need to avoid nutrient deficiencies
3. Right time of application in relation to climatic, soil and crop growth stage conditions and crop rotation
4. Right method of application in relation to form of fertilizer material, soil conditions and rooting pattern of crops
5. Right synergy with water management practices, use of soil amendments, organic sources of nutrients and good agronomic practices

A soil testing service, backed up by soil test/crop response correlation research and soil test-based Integrated Plant Nutrient Management (IPNM) demonstration trials in farmers' fields, should form one of the strategic elements of fertilizer sector policy in developing countries. If not managed properly, nutrients from natural resources are no more environmentally friendly than those from manufactured fertilizer and hence IPNM offers the best way of recycling and managing nutrients at the farm level. FAO's advocacy of good farming practices in the Special Programme on Food Security (SPFS) emphasizes horizontal convergence of three integrated management sectors: Integrated Plant Nutrient Management (IPNM), Integrated Pest Management (IPM) and Integrated Water Management (IWM).

Fertilizers and the Environment

Historical patterns of manure and fertilizer use in mixed farming (cattle) systems have resulted in the gradual build-up of soil fertility as in Europe and North America, whereas inadequate fertilization practices in Asia have led to nutrient depletion and a progressive reduction in the production potential of the soil. It is estimated that between 1945 and 1990, nutrient depletion in Asia caused light, moderate and severe degradation of 4.6, 9.0 and 1.0 million hectares of land, respectively. On the other hand adequate fertilization of crops not only maintains soil production potential but also increases carbon sequestration in soils, via enhanced photosynthesis, bio-mass production and organic matter in soils, thus helping reduce global warming.

The discharge of wastewater from ammonia plants can add to nitrate levels. The emission of N_2O, SO_2 and CO_2 can contribute to greenhouse gases and acid rain. The excessive use of nitrogenous fertilizer can lead to groundwater contamination with NO_3, and that of N and P can lead to eutrophication of water bodies, leading to fish mortality. The possibility of heavy metal accumulation in plants and soils, such as cadmium, through their presence in fertilizer materials has received growing attention in recent times. Phosphogypsum is a by-product of production of phosphoric acid. For every tonnes of phosphoric acid produced, 4 to 5 tonnes of phosphogypsum is produced. It contains radium and can emit radon, a radioactive gas which is hazardous to humans and animals.

Further analysis and research are needed to increase the understanding of the environmental interactions of fertilizer production and use. Internalizing the externality argument suggests that costs of treating pollutants should be borne by fertilizer producers where pollution is related to production and by farmers where pollution results from fertilizer use. Because fertilizer plays a key role in food production and security, provision of some "social support" or cost-sharing arrangements for implementing environmental measures related to fertilizer industry is desirable.

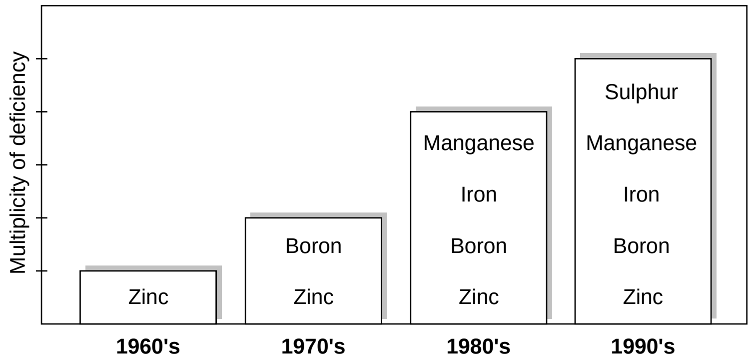
Fertilizer Policy

In a land-hungry region like Asia, the synergy of genetic engineering, irrigation, plant nutrients and crop protection must be maintained to boost crop yields. In doing so sustainability and environmental concerns must be kept in mind. Poor management of mineral fertilizer use in many parts of the world have led to environmental pollution and degradation of soil fertility and nutrients base, particularly in the developing countries. In Asia, nutrient imbalances and deficiencies are already adversely affecting crop yield.

Crop intensification in the absence of balanced fertilization during the green revolution era resulted in deficiencies of growing numbers of micronutrients. In the 1960s, the deficiencies were confined to zinc only. In the 1990s deficiencies for zinc, boron, iron, manganese and sulfur were not uncommon (Figure 3). Therefore, along with the use of inorganic fertilizers, the application of organic fertilizer, soil conservation measures, and the integrated management of plant nutrients will all need to be combined in one programme so that the primary nutrients-N, P and K, the secondary nutrients-S, Ca, and Mg, and the micronutrients are available in the correct absolute and

Figure 3

Emergence of multiple micro-nutrient deficiencies in soils



relative quantity and at the right time, place and price for high crop yields to be realized.

The technological package of Integrated Plant Nutrient Management (IPNM) should be coupled with effective and efficient pest, soil and water management technologies. Government policy should promote this synergy between the different technological components by improving research, monitoring, participation, and the extension of effective plant nutrient management approaches. New biotechnological inventions for increasing the efficiency of plant nutrient uptake should also be encouraged. As discussed later, government policy on the pricing of inputs and outputs coupled with institutional and infrastructural supports will be essential to maximize the positive effects of technological and non-technological factors enhancing and sustaining crop production.

Appropriate policy measures and guidelines, specific to each country, need to be based on analysis and research of the factors that affect the fertilizer supply side, such as investment in fertilizer production, imports, marketing and distribution infrastructure, exchange rate stability, allocation of sufficient foreign exchange to ensure an adequate and timely supply of fertilizers, and those that affect the demand side, namely fertilizer and credit subsidies, fertilizer price and minimum crop price support programmes. Policy changes and reforms must be placed and sequenced properly in time, lest they cause steep reductions in fertilizer use as has happened in many countries. Since

investment in fertilizer production is capital intensive, foreign exchange rate stability is one of the most important macro-economic factors which has critical influence. Fertilizer subsidies over the long term, if not used judiciously, may create unsustainable fiscal burdens.

The availability of adequate funds at reasonable rates of interest continues to be critical in enlarging fertilizer use in developing and reforming countries. To ease the financial burden on dealers, a programme of warehouse collateral could be developed and fertilizer and grain trade could be integrated to a suitable degree. A programme to train dealers and bankers in fertilizer trade will be increasingly needed. The private sector should play a dominant role in fertilizer storage, distribution and marketing since it can make its own decisions concerning the four P's - product, price, promotion, place. A 'gradualist approach' to market reform is preferable to the 'big-bang approach'. In landlocked countries, it may be desirable to subsidize transport.

Management and marketing skills, regulatory mechanisms, financial institutions and information networks need to be promoted for the efficient functioning of market-based fertilizer and food sectors. There is an urgent need to provide training and technical assistance to develop these skills and institutions. Without such development support, deregulated market systems could degenerate into inefficient private monopolies. Although these policy issues are challenging and daunting, their successful resolution will help food security, reduce poverty and protect the environment.

In preparation for its WTO membership, China has been undertaking a series of policy reforms in the fertilizer sector, aimed at the use of economic and legal instruments and free markets instead of mandatory central management of the fertilizer sector. Policy changes after 1998 included the phasing out of mandatory production quotas, freedom of product sales, competitive retail price, invoking 'Green Box' policies, etc.

Significant policy reforms in the fertilizer sector were also initiated by India, like decontrolling of P and K fertilizers in 1992. Recent initiatives tend towards the removal of quantitative restrictions from April 2001 and a long-term fertilizer policy of a uniform normative referral price, feedstock differential cost reimbursement for naphtha and fuel-oil based fertilizer plants, possible complete deregulation of gas sector and a uniform pricing regime.

The policy reforms of both China and India in the fertilizer sector are pointers to other developing countries and shall have far-reaching implications both in developing world fertilizer production, consumption and agricultural production and in the global fertilizer trade and industry.

The Way Forward

Significant progress was made in the past 30 years and must continue to be made in the coming years in raising food consumption levels, improving nutrition and reducing poverty through agricultural transformation in most developing countries. The foremost challenge for South, South-east and East Asia, which are home to nearly two-thirds of the world's malnourished and poor people, is to fight hunger and poverty. The agriculture-led broad-based economic growth - the main policy response - must occur in a difficult context. The base of natural productive resources, such as land, water and biodiversity, has shrunk. There is widespread environmental and agro-ecological deterioration. New socio-economic regimes have emerged, especially globalization and liberalization, with both positive and negative implications for developing countries.

For all practical purposes, in Asian countries agricultural growth amounts to the growth of crops and livestock sectors. At the global level, the limits to agricultural production were posed by the limits on demand. But, this may not long hold true for the Asian region. It has to feed 57 per cent of the world's population from only about 33 per cent of the world's arable land, with the ratio of land per person steadily declining. In the next 30 years, on average, one tonnes of additional grain is projected to be added to the produce of each hectare to meet projected food demand. The additional production is bound to exert extra pressure on the environment. Moreover, equity and other socio-economic concerns must be addressed in order to realize potentials of new technologies. Can new technologies, management approaches and policies assist in minimizing and even reversing the negative trends and promoting the positive effects?

Enhanced and Sustained Food and Agricultural Production

There is ample scope for improving our average yields. The effective assessment and diffusion of packages of appropriate technologies involving system- and programme-based approaches, participatory mechanisms, greater congruency between productivity and sustainability through integrated pest management and integrated soil/water/nutrient management, should be aggressively promoted to bridge the yield gaps in most field crops. Besides this, efforts must be in place to protect gains and to achieve new gains particularly through the congruence of gene technology, information technology, better management practices and eco-technology.

The food and agricultural products thus produced where most needed, improve the livelihood of local populations. In predominantly agrarian economies, there is no mechanism for distributing entitlements to peasants other than that of enabling them to develop their food and agricultural production. Rainfed and other hard to cultivate areas, where the entitlements are low, must receive high priority.

Building Technological and Human Resource Capital

Research, by helping to generate appropriate technologies is the engine of growth. Directed research policies and support are fundamental to the growth and development process, which must increasingly become science-based. Blending new, conventional and indigenous technologies, called "ecotechnologies", is the right path. (Swaminathan, 1999)

The prospects of biotechnology must be carefully analyzed. It is fortuitous that as we have entered the new millennium, and seeking the technological break-through, which may spearhead agricultural production in the next 30 years at a pace that is faster than that during the past 30 years (the Green Revolution era), modern biotechnology with multiple and far reaching potential has appeared on the horizon. It is already being used for and has the potential to enhance yield levels, increase input-use efficiency, reduce risk and depress effects of biotic and abiotic stresses, and enhance nutritional quality leading to increased food security, adequate nutrition, poverty alleviation, environmental protection and sustainable agriculture. Often referred to as the "Gene Revolution" or "Bio-revolution" if judiciously harnessed, blended with traditional and conventional technologies and supported by appropriate policies, biotechnology can lead to evergreen revolution that brings together growth and development sustainably (Singh, 2000).

The way potential must map out the ways to optimize the benefits and minimize the potential negative effects of biotechnology on a case-by-case basis. Biotechnology should be kept in perspective by integrating it within the national technology research and development framework and using it as an adjunct to - and not as a substitute for - conventional technologies in solving problems identified through national priority setting mechanisms. Priority setting should also take into account national development policies, private sector interests, market possibilities, public perceptions and consumers' views, and, above all, the needs and aspirations of small-scale holders and the poor (Persley, 2000). Accordingly, various stakeholders, the public sector, business and industry, NGOs and civil society should be involved in the formulation and implementation of national biotechnology policies, strategies, plans and programmes.

The technology-inherent as well as technology-transcending risk must be critically and scientifically assessed in a transparent manner. Capacities and measures should be in place to manage the risks, minimize the negative effects and promote the policy impacts. Each country must have the necessary infrastructure, human resource, financial support and policies for meeting the challenges and capturing new opportunities. Competence in formulating country-specific rules and regulations on biosafety and intellectual property rights management regimes will be particularly crucial, along with commensurate financial and institutional support information. Strong human resources development will be needed for their effective implementation.

Keeping Pace with Globalization

The globalization of agricultural trade will facilitate market access, new opportunities for employment and income generation, productivity gains and increased flow of investments into sustainable agriculture and rural development. If managed well, the liberalization of agricultural markets will be beneficial to developing countries in the long run. It will force the adoption of new technologies, shift production functions upwards and attract new capital into this deprived sector. However, this will only come to pass if we are mindful of the interests of hundreds of millions of small and subsistence oriented farmers, fisher-folk and forest dwellers in the short and medium terms. As we globalize, it is imperative that we do not forget social aspirations for a more just, inclusive, equitable and sustainable way of life. Trade agreements must be accompanied by operationally effective measures to ease the adjustment process for a small farmer in developing countries.

Exploiting Cyberspace

Information is power and will underpin future progress and prosperity. Efforts must be made to strengthen information technology in agriculture by developing new databases, linking databases with international databases and adding value to information to facilitate decision-making at various levels. Development of models for various agro-ecological regimes to forecast the production potential should assume greater importance. Using remote-sensing and GIS technologies, natural and other agricultural resources should be mapped at micro and macro levels and effectively used for land and water use planning as well as for agricultural forecasting, market intelligence and e-business, contingency planning and predicting disease and pest outbreaks.

Accent on Less-Favoured Areas

Rainfed and other less favoured areas have the highest concentration of poor and malnourished people as these areas are characterized by low agricultural productivity, high natural resource degradation, limited access to infrastructure and markets and other socio-economic constraints. During the Green Revolution era, greater investment was made in irrigation and irrigated areas and in the development and promotion of high-yielding varieties, seed, fertilizer and irrigation technology. This approach paid off well and rapid advances were made in food production. However, in recent years additional investments in favoured areas have faced diminishing returns and social and environmental problems, whereas there is evidence to suggest that investment in less-favoured areas can yield relatively high rates of economic returns and significantly reduce poverty and environmental and resource degradation (Table 38). (Fan, et. al., 1999)

Table 38
Effects of Additional Government Spending on Poverty in India

Sources	Number of poor reduced per million Rupees spent	Ranks
Research and development	91.4	2
Irrigation	7.4	5
Roads	165	1
Education	31.7	3
Power	2.9	7
Soil & water	6.7	6
Rural development	27.8	4
Health	4	8

Source: Fan, Hazell and Thorat, 1999

Increased Investment in Agriculture, Agricultural Research and Infrastructures with Focus on Small Farmers

Public investment in agriculture has been declining and is one of the main reasons behind the declining productivity and low capital formation in the agriculture sector. With the burden on productivity-driven growth in the future, this worrisome trend must be reversed. Private investment in agriculture has also been slow and must be stimulated through appropriate policies. World Bank and other international and regional financial and banking systems have drastically reduced their support to rural and agricultural sectors. Financial support to FAO and other concerned UN agencies has also stagnated and declined. For instance, FAO's total annual budget permits an annual allocation of hardly 40 cents per malnourished person. On the other hand, OECD countries spend US$ 1 billion everyday on subsidies to their farmers.

Realizing that nearly 70 per cent of Asia still lives in villages, agricultural growth will continue to be the engine of broad-based economic growth and development as well as of natural resource conservation, let alone food security and poverty alleviation. Accelerated investment is needed to facilitate agricultural and rural development through: (1) Strengthened research and technology development capacities leading to enhanced productivity and sustainability; (2) Reliable and timely availability of quality inputs at reasonable prices, institutional and credit supports, especially for small and resource-poor farmers, and support to land and water resources development; (3) Improved rural employment opportunities, including those coming from agriculture-based rural agro-processing and agro-industries, gender equity, improved rural infrastructures, including access to information, and effective markets, farm to market roads and related infrastructure; and (4) Primary education, health care, clean drinking water, safe sanitation, as well as adequate nutrition, particularly for children (including through mid-day meal programmes at school) and women. (Pinstrup-Andersen, 2000)

The above investments will need to be supported through appropriate policies that do not discriminate against agriculture and the rural poor. Given the increasing role of small farmers in food security and poverty alleviation, development efforts must be geared to meet the needs and potential of such farmers through their active participation in the growth process (Singh, 2001).

Natural Resource Management (Water, Land, Biodiversity)

Asia will be required to produce more and more from less and less land and water resources. Alarming rates of groundwater depletion and serious environmental and social problems of some of the major irrigation projects on the one hand and the multiple benefits of irrigation water in enhancing production and productivity, food security, poverty alleviation, on the other, although well known will be further elaborated here. Further, the quality of available water is deteriorating. Gross inequalities exist between basins and geographic regions.

Agriculture is the biggest user of water, accounting for over 70 per cent of the water withdrawals. There are pressures for diverting water from agriculture to other sectors. An IFPRI study has warned that re-allocation of water out of agriculture can have a dramatic impact on global food markets. It is projected that availability of water for agricultural use in India may be reduced by 21 per cent by 2020, resulting in lower yields from irrigated crops, especially rice, resulting in higher prices and less food availability for the poor. Policy reforms are needed immediately to avoid such negative developments in the years to come. These reforms may include the establishment of secure water rights for users, the decentralization and privatization of water management functions to appropriate levels, pricing reforms, markets in tradable property rights and the introduction of appropriate water-saving technologies.

The needs of other sectors for water cannot be ignored. Therefore it is necessary that an integrated water use policy is formulated and judiciously implemented. Several international initiatives on this aspect have been taken in recent years. Developing countries should critically examine these initiatives and develop their country-specific system for judicious and integrated use and management of water. National institutions should be established to assess the various issues, regulatory concerns, water laws and legislation, research and technology development and dissemination, social mobilization and participatory and community involvement - including gender and equity concerns - and economic aspects.

Sustained soil fertility and overall soil health are prerequisites to a sustained agricultural production. An all out effort is thus needed to maintain and restore soil fertility and health. At the same time, production systems must be promoted and developed according to soil capacities to optimize production and sustainability. Location-specific generation of technology and its transfer demand a more detailed understanding of each soil resource its variability, potential and limitations through detailed soil survey, classification and mapping. Suitable soil management technologies in the areas of soil conservation, soil tillage and soil/water/nutrient management in an integrated approach need to be adapted to the soil units (types) and the type of farming systems practiced. Reclamation technologies must be fine-tuned and made more cost-effective. Bio-remediation for abiotic stresses approaches must be appropriately dovetailed with overall soil management strategy. These practices must in the long run ensure restoration of soil quality, rather than its deterioration. Monitoring soil health, in all its aspects, will be crucial for ensuring sustainable agriculture, which should be centred around good husbandry of both seed and soil.

As regards the third type of natural resources, namely, biodiversity, it may be reiterated that genetic resources are the building blocks of functions and forms of living organisms, and will always be needed to produce new genotypes to meet the ever changing needs of humankind. Biotechnology and bioinformatics, coupled with conventional sciences, should be judiciously used to develop efficient and effective methods to conserve, utilize and exchange genetic resources. Due to economic and population pressures these resources are eroding fast. Moreover, their availability is increasingly restricted due to intellectual property rules. International Undertaking on Plant Genetic Resources for Food and Agriculture provides largely accepted and harmonized practices and standards and should be accepted by all countries. Along with Plant Breeders Rights, Farmers' Rights should be honoured and implemented for equitable and fair sharing of benefits arising from the use of genetic resources.

The FAO-led International Undertaking and Global Plan of Action on plant genetic resources for food and agriculture provide the mechanism for rationally conserving and utilizing such resources. Dynamic national research systems should be in place to address the research, development and sharing of germplasms. On the pattern of UNESCO's Human Genome and Human Rights, FAO should adopt a universal declaration on the plant genome and farmers' rights to provide a balance between the rights of conservers of biodiversity and the researchers, developers and users of modern biotechnological products. In this gene-rich region there is an urgent need to develop guidelines and procedures for realization of the farmer's rights to sustain on-farm *in-situ* community-based conservation of biodiversity and associated traditional knowledge. A fair, transparent and implementable reward and recognition system should be created for this purpose.

Focus on Poverty Alleviation

There is an unholy alliance between poverty and food insecurity, which must be broken. Appropriate policy and institutional frameworks are needed to provide clearly defined and enforceable property rights, reduce transaction costs and encourage broad-based, decentralized development of rural activities to enhance growth efforts. Policy reforms that encourage private and public sector participation in economic activities in accord with their comparative advantage should also be encouraged. In this regard, the public sector should focus on addressing cases of market failure to enhance the efficiency of private operations, ensure competitiveness and quality of service and to fulfill the long-term social welfare objectives of protecting the environment, public goods and basic human resources development.

Prudent macroeconomic management to restore growth and to prevent erosion of the gains in poverty reduction must urgently be put in place. The growth-led poverty-alleviation strategy that has proven effective in the past, and measures to bridge the various equity divides must continue. As past experience has shown, it is essential to develop appropriate institutions and national capabilities including robust and well-regulated financial markets. This must be supplemented with appropriate input and output pricing policies, water rights and irrigation systems design and management to encourage efficient, equitable and sustainable use of resources and attract investment.

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