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**THE STATE OF FOOD AND AGRICULTURE IN ASIA  
AND THE PACIFIC : CHALLENGES AND  
OPPORTUNITIES**

**by**

**R.B. SINGH**

# **THE STATE OF FOOD AND AGRICULTURE IN ASIA AND THE PACIFIC : CHALLENGES AND OPPORTUNITIES**

*R.B. Singh*

Assistant Director-General  
and Regional Representative for Asia and the Pacific  
FAO Regional Office, Bangkok

## **INTRODUCTION**

It is an honour and pleasure for me to give a keynote address at this 69<sup>th</sup> Annual Conference of the International Fertilizer Industry Association (IFA). I should like to express my sincere thanks to the organizers of this Conference for inviting me to participate in this global meeting on fertilizers. IFA's mission to actively promote efficient and responsible use of plant nutrients to maintain and increase agricultural production worldwide in a sustainable manner is of great interest to FAO. Therefore I should like to thank in particular Dr. Luc M. Maene, IFA Director-General, my long-time friend, for giving me this opportunity.

Over the past 50 years, the Asia-Pacific Region<sup>1</sup> 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 tons. Despite the addition of 1.3 billion people to the region's population, average per caput 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 percent to less than 30 percent.

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

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<sup>1</sup> 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, Southeast Asian, East Asian and 12 Oceania and Pacific Island countries. The present analysis relates to the developing Asian countries of the Region.

availability, waterlogging, pollution of water bodies, eutrophication, buildup of greenhouse gases, ecosystem acidification and loss of biodiversity. Given that the per caput 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. In my presentation, I will analyse 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.

Of necessity, my presentation will essentially cover crop agriculture, which directly and indirectly accounts for 75 to 80 percent 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).

Further, consistent with the thrust of this Conference, a section of the paper deals exclusively with fertilizer use trend, demand and supply balance in Asia, integrated plant nutrient system and fertilizer policy

## **STATE OF FOOD AND AGRICULTURE**

### **Current Production and Consumption Scenario**

The first forecast of world cereal output in 2001 is 1889 million tons, almost 2 percent above 2000. Output of wheat is forecast at 585 million tons, unchanged from last years' crop, while that of coarse grains is seen to rise by almost 4 percent to 905 million tons. Production of rice (milled basis) is tentatively forecast to remain unchanged at 399 million tons (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 drawdown of 48 million tons from stocks, or 4 percent, to 645 million tons.

World cereal trade in 2000/01 is forecast at 233 million tons, about 2 million tons 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 caput Food consumption in the developing countries had increased by 28 percent, 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 percent, 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 gratifying in the Asian context as the bulk of the decline had taken place in Asia. In East and Southeast Asia, the percentage of undernourished population decreased from 29 to 13 and in south Asia from 38 to 23 (Table 2).

**Table 1: Per caput 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

**Table 2: Percentage of population undernourished in the developing regions**

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

Source: FAO, CFS: 2001/2

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-

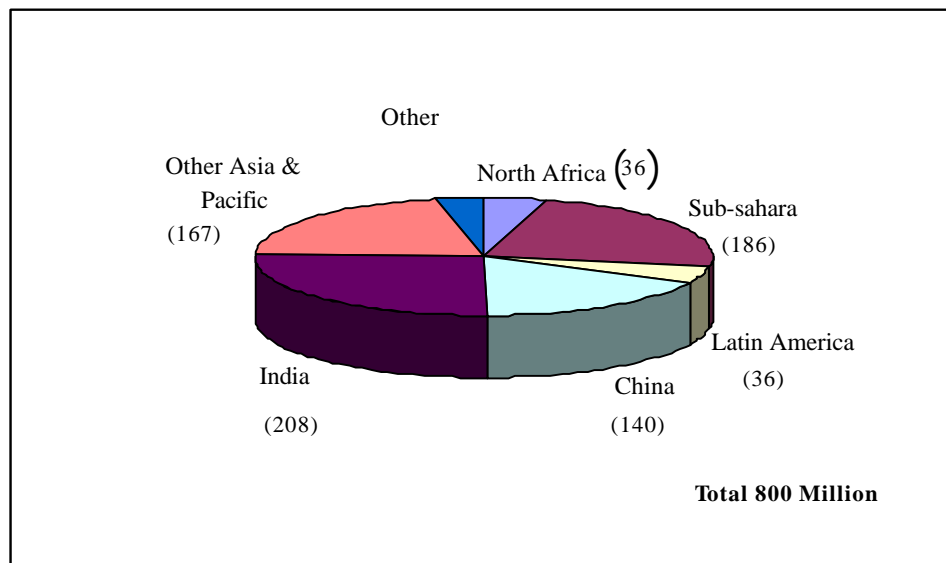
98. Globally little change was noticed from the preceding three-year average, and the prevalence of undernourishment in the developing world stagnated at 18 percent. As seen from Table 3, only two sub-regions – East Asia and Southern Africa – achieved a reduction in both the percentage as well as the absolute number of undernourished. It was disturbing to note that South Asia, which houses 37 percent 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).

**Table 3: A comparison of undernourishment estimates for 1995-97 and 1996-98**

Sub-Region	1995-97		1996-98	
	Number of undernourished people (million)	Prevalence of under-nourishment (percent)	Number of undernourished people (million)	Prevalence of under-nourishment (percent)
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	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

**Figure 1 : Number of undernourished, by region**



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 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 for child mortality in developing countries. Child mortality rate in developing countries declined by 14 percent between 1990 and 1998, against the targeted decline of 30 percent. The decline rates in East Asia and Pacific and South Asia were 22 and 26 percent, respectively.

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.

**Table 4: Trends in mortality of children under 5, selected years, 1970-1998 (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

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 million people with income less than US \$ 1/- a day, 44 percent of the world's people in this category, also had the largest number of undernourished people, 294 million, over 39 percent 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"

**Table 5: A comparison of poverty and undernourishment data**

Region	1998	1996-98	1996-98	1998
	People living in households that consume less than \$1/day (percent)	Share undernourished (percent)	Number of undernourished (million)	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	46.3	34	185.9	290.87

Source: FAO, CFS, 2001/2

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, Southeast 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. 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 Southeast 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 of recovery. 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 border line 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 Southeast Asia. As regards South Asia, although it was not as badly hit as Southeast 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 percent in 1969/71 to 18 percent in 1995/97, although the population had increased from 2.6 billion to 4.4 billion. As mentioned earlier, the per caput food consumption in developing countries as a whole increased by 28 percent 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 kca/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 percent of the world population (Table 6). In 2030, the proportion will increase to 83 percent with an estimated population of 6.7 billion. South and Southeast Asia together will continue to account for more than 50 percent of the world's population, 53 and 52 percent 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 percent to 24 percent 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, Southeast 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 caput income (GDP) in Asia sub-regions between 1995/97 and 2015 and between 2015 and 2030 ranged from 3.6 to 5.7 percent 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 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 and 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 set back 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 11.2 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.

**Table 7: GDP growth rate, percent per annum**

Region	Total GDP		Per Caput GDP	
	1995/97 – 2015	2015 – 2030	1995/97 – 2015	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			
Veg. 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 wt.)	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

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 towards the year 2030 (Table 9). South Asia, in particular, will register much higher growth rates, 3.2 percent against 1.7 percent 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**

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 oilcrops are the main group of crops which are consumed both by human beings and animals and 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.

**Table 10: Cereal balances: growth rates of demand, production and population (percent 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

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) forecasts an increase in global demand for cereals by 690 million tons between 1995 and 2020. About 84 percent of this increase will be in developing countries, with Asia's share being 52 percent. China alone will account for 25 percent of the increased cereal demand, followed by India's share of about 13 percent. As regards meat, the global demand is projected to increase by

115 million tons, and 84.6 percent of this increase is expected to materialize in developing countries, China alone accounting for 41 percent, while Asia's share will be 58 percent. 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 meat demand, developing countries' demand for feedgrains, especially maize, will more than double.

**Table 11: Oil crops, vegetable oils and products production and consumption growth rate (percent per annum)**

Region	Total food use (in million tons)	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

Table 12 gives balances of cereals production and demand over 1995/97 – 2015-2030 as analysed by FAO (2000). By the year 2030, the world cereal production would need to be increased to 2.8 billion tons, an addition of nearly 1 billion tons. Of this increment, nearly half will be for food, and about 44 percent for feed, with the balance 6 percent for seed, industrial non-food use and other uses. In South, Southeast and East Asia, cereal production is expected to increase by 380 million tons, from 720 million tons in 1995/97 to 1100 million tons in 2030. Comparing the subregions, South Asia is expected to register an increase of 73 percent, whereas East Asia (including Southeast Asia) is expected to register an increase of 44 percent. Non-food use of cereals in South Asia is currently about 10 percent and is expected to slightly increase to 12 percent towards 2030. But, in East Asia, the nonfood use proportion was much higher, 33 percent in 1995/97 and 45 percent 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 percent and in East Asia from 94 to 90 percent 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 1 million tons of cereals, will become a net importer of 16 and 26 million tons in 2015 and 2030, respectively (Table 13). East Asia which is already a high net importer of 37 million tons of cereals, will be enhancing its net import to 60 and 79 million tons in 2015 and 2030, respectively. Most of this increase will occur in China primarily for meeting the increasing demands for animal feed and bulk of this increase will comprise primarily coarse grains, particularly maize, as in 1995/97 nearly 79 percent of the use of maize grain in China was for non-food purposes, mostly as feed.

**Table 12: Cereal balances, demand and production (million tons)**

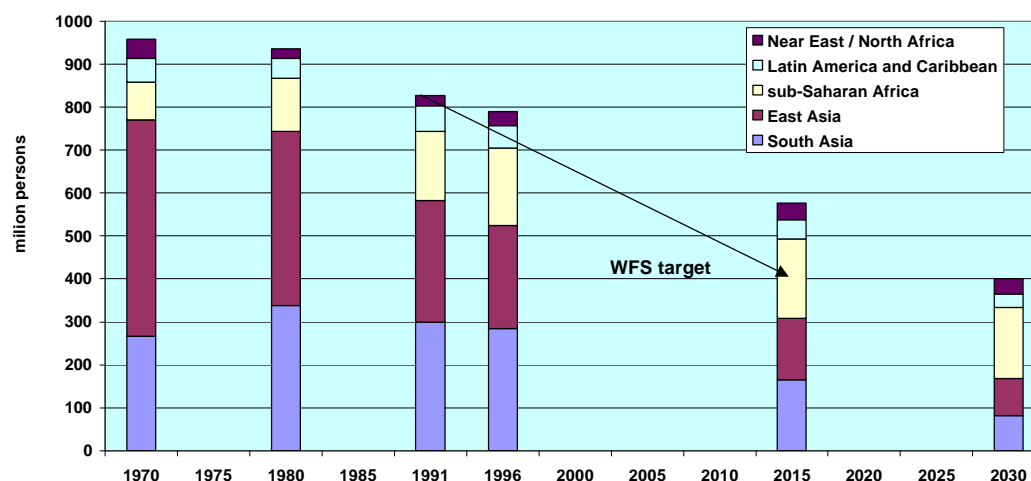
Years	Demand		Production	SSR* %
	Food	All Uses		
World				
1995/97	979	1844	1836	100
2015	1257	2393	2397	100
2030	1428	2801	2805	100
Developing Countries				
1995/97	765	1107	996	90
2015	1029	1550	1352	87
2030	1197	1886	1615	86
South Asia				
1995/97	211	235	227	97
2015	306	343	327	95
2030	368	418	392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

The various demand and supply projections of cereals, livestock and oilseed crops will lead to a significant increase in per caput 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 percent in 2015 and 6 persons in 2030 for the developing countries, to 10 percent and 4 percent for South Asia and to 7 percent and 4 percent for East Asia (Table 14). However, due to demographic growth, in absolute numbers, globally the decrease of persons undernourished will be to : 576 in 2015 and 401 million in 2030 from 790 in 1995/97, for Asia to 309 in 2015 and 168 million in 2030 from 524 in 1995/97. Likewise, Asia's share of the persons undernourished in the world will decrease from 66.3 percent in 1995/97 to about 41.9 percent in 2030. Thus, the Asian countries are not too far from meeting the target set at the World Food Summit in 1996. However, as the 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 undernourishment (million persons)**



Source: FAO, SOFI, 2000

**Table 13: Net trade of cereals (million tons)**

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

**Table 14: Incidence of undernourishments, developing countries**

Region	Million Persons			Percent 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

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

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

If significant climate changes were to occur, low lying coastal areas would come under intensive pressure from sea level rise, storms and flooding and rainfed semi-arid 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 box 1.

### **Southeast 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 percent to 53 percent 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, accompanied by improvement in the quality of the diet with significant growth in consumption of meat (65 percent increase by 2030) and milk and dairy products (90 percent), 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 percent per annum, up to 2030. Rice production is projected to increase by only 0.7 percent per annum upto 2030. Wheat production is expected to rise by 1.4 percent 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.

**Box 1: Key characteristics and potential of farming systems of South Asia**

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, coconuts, rice, legumes, livestock	Moderate to severe poverty	Moderate	Low
Rice-wheat	19	33	Rice, wheat, vegetables, livestock including diary, off-farm activities	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 seasonally	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, especially 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 agricultural workers	Moderate	High
Urban based	neg	little	Horticulture, dairying, poultry, other activities	Moderate	Low	Low

Source: Weatherhogg, Dixon and de Alwis, FAO, Rome, 2001  
Principal farming systems are shaded.

\* Defined as those working in crop or livestock production or forestry and their dependents.

The past and future trends for bovines and small ruminant production in the region are similar and projected to increase annually by 1.3 percent upto 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 is expected from large 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 box 2.

## PROSPECTS FOR AGRICULTURAL PRODUCTION

Agricultural production at the global level had kept pace with the demand. Had there been greater demand, world agriculture would have positively responded to meet the demand. Three main factors were responsible for this demand side limit: (a) the slow down in population growth, (b) a growing share of world population has attained fairly high levels of per caput food consumption, and (c) the undernourished were too poor to demand more food or were too resource-poor 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 caput 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 15, demand growth rates for the world, the developing countries, South Asia and East Asia have declined during the period 1997-2015 when compared with those during 1977/1997. This deceleration was in line with the population growth rates during the two periods. Production growths at the global level matched the demand growth rates. For the developing countries as well as for South and East Asia the demand growth marginally outstripped the 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 percent in 1977-97 to 1.9 percent in 1997-2015 against the corresponding production growth rates of 4.7 and 1.8 percent.

**Table 15: Growth rates of aggregate demand, production and population (percent 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

**Box 2: Key characteristics and potential of farming systems in Southeast and East Asia**

Farming Systems	Land area (percent of region)	Agric Popn <sup>@</sup> (percent 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, coconuts, 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	Low	Low
Spare (arid)	20	2	Local grazing where water available	Severe	Moderate	Low
Urban based	n.a.	little	Horticulture, dairy, poultry	Low to moderate	Low	Moderate
Coastal artisanal fishing	n.a.	little	Fishing, coconut, mixed cropping	Moderate	Moderate	Low

Source: Ivory, D., FAO, Rome/Bangkok, 2001

Principal farming systems are shaded.

<sup>@</sup> Agricultural populations are defined as those working in farming forestry or fishing and their dependents.

The deceleration in the demand growth will varyingly impact the different commodities in the different sub-regions. Cereals will largely be used as human food in South Asia and the consumption may stabilize at around 200kg/person/year, whereas in East Asia, nearly 50 percent will be used for feed and other uses and its use as human food may stabilize at around 180 kg/person/year. Cereals net import of developing countries will increase to 270 million tons in 2030 from 107 million tons in 1995/97. Asia's net import of cereals will increase from 38 to 105 millions tons (see Table 13).

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

## SOURCES OF GROWTH IN CROP PRODUCTION

During the 30-year period of 1967-97, the developing countries registered a satisfactory crop production growth rate of 3.1 percent (Table 16). East Asia, with a growth rate of 3.6 percent, played the eminent role in pushing the global average. South Asia, with a growth rate of 2.8 percent, also performed well. During the succeeding 34-year period, the growth will slow down to 1.2 percent in East Asia but will maintain a moderate rate of 1.9 percent 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 16: Annual crop production growth rate (percent 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

There are three sources of growth in crop production: (i) arable land expansion (ii) increase in cropping intensity and (iii) yield growth. Yield growth will account for 83 percent of production growth in Asia, whereas the net area expansion will contribute only 5 percent and the remaining 12 percent will be through the increase in cropping intensity (Table 17). In other words, 95 percent of the crop production growth in Asia will accrue through crop intensification, while in other regions net area expansion will be contributing between 20 – 30 percent.

**Table 17: Sources of growth in crop production (percent)**

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

As regards individual major crops, growth in wheat and rice production in the developing countries will have to come from gains in yield (about four-fifths), whereas for maize, the area expansion 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 in some major producing countries), thus yield growth will be the exclusive source of the production growth.

### **Agricultural Land**

The developing countries will expand their total arable land area by 120 million hectares between 1995/97 and 2030 (Table 18). 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 percent, respectively). India and China together accounted for about 28 percent of the developing countries' arable land. For South Asia, India's share in the arable land was overwhelming, 82 percent. In South Asia, nearly 90 percent of the arable land is already under use, whereas in East Asia, more than 40 percent 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, raising sustainability concerns. By 2030, while in the developing countries about 1.7 billion ha additional potential arable land will be available, in Asia only 132 million ha will be potentially available for area expansion (4 million ha in South Asia and 128 million ha in East Asia), again emphasizing the importance of yield growth in Asia.

By increasing cropping intensity, gross cropped area can be expanded. The overall cropping intensity for developing countries will rise by 8 percent over 1995/97 – 2030, from 91 to 98 percent (Table 19). Of necessity, and also as one-third of the cultivable land is irrigated, in South and East Asia (particularly China) cropping intensity was the highest, 126 percent in South Asia and 158 percent in East Asia under irrigated conditions. In rainfed also it was over 100 percent. Towards 2030, there will be further intensification of 11 percentage points both in South and East Asia. In certain agro-ecological settings, covering vast irrigated areas in South and Southeast Asia, cropping intensity is 200 percent or more. It may be emphasized that increase in cropping intensities is associated with increased risk of land and environmental degradation, when it is not accompanied by appropriate technologies and policies.

**Table 18: Total arable land: data and projections**

Region	Arable land in use (million ha)			Annual growth (%)		Land in use as percent 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

**Table 19: Cropping intensity (percent)**

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

## Irrigation and Water Use

As seen from Table 20, the irrigated area in the developing countries will increase by 54 million ha (or 23 percent) between 1995/97 – 2030. This means that 22 percent of the potentially irrigable land will be brought under irrigation, and 60 percent of all land with irrigation potential (402 million ha) would 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 be retained in 2030. In other words, nearly 75 percent of projected increase in irrigated area in the developing countries would materialize in Asia. Further, China and India together will continue to possess about 54 percent of the developing countries' irrigated area, India alone accounting for 28 to 29 percent of the area. The South Asian irrigation figures are heavily impacted by India's situation as it accounted for 71 to 74 percent of the sub-region's total irrigated areas in 1995/97 and 2030, respectively. Of the projected increase of 17 million ha under irrigation in South Asia, 15 million ha will be in India.

The expansion of irrigation during the Green Revolution era in the developing countries registered a growth of 94 million ha, 1.9 percent per annum, but as the demand rate decelerates, during the next 34 years the growth rate will drop to 0.6 percent, also due to the increasing cost of bringing additional area under irrigation as well as the retreating 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 the total irrigated percentage will reach about 40 percent, against 14 percent in the developing countries excluding China and India (Table 21). It is important to note that in South Asia, where there is very high pressure for crop intensification, excluding India, the irrigation intensity is already extremely high, 62 to 64 percent, particularly due to Pakistan where irrigation intensity is as high as 80 percent. Therefore, the performance of irrigated agriculture in India, China and Pakistan will greatly impact the developing world's irrigated agriculture production.

**Table 20: Irrigated (arable) land: data and projections**

Region	Irrigated land in use (million ha)			Annual growth (%)		Irrigated land as percent 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

**Table 21: Irrigated land as percent 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 percent of the freshwater use in the world. Increasing withdrawal of freshwater for agriculture is one of the main causes of water scarcity which several countries are facing today and many more will face in the future, and more acutely. Therefore, irrigation water must be used most efficiently. As seen from Table 22, on an average, for the developing countries, irrigation efficiency was estimated around 43 percent in 1995/97, varying from 26 percent in Latin America (having abundant water resources) to 50 percent in the Near East/North Africa region and 49 percent 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, maximum improvement taking place in the Near East/North African region (15 percent), followed by South Asia (9 percent). In East Asia, barring China, the efficiency is rather low and must be improved considerably. Partly this may be attributed to the predominance of rice cultivation in Southeast Asia where paddy fields are flooded to facilitate land preparation and for weed management.

**Table 22: Irrigation efficiency (percent) in developing countries**

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 unfold their genetic potentials. Table 23 gives production and yield of ten major crops in the developing countries. Between 1961/63 and 1995/97 led by wheat, yields of rice, maize, sorghum, soybeans, seed cotton, groundnuts and sugarcane have increased by 50 to more than 100 percent, all crops together registering a growth rate of 2.1 percent per annum. During the projection period, a growth rate of 1.0 percent is estimated. For cereals, which occupy 55 percent of the developing countries' harvested area, the projected yield growth rate was only 1.0 percent against the historical growth rate of 2.5 percent.

The role of irrigation in enhancing yield and total production (including through increased cropping intensity) is also evident. On an average, in 1995/97, for the developing countries, cereals rainfed yield was 1.71 tons/ha, which is projected to grow to 2.23 tons/ha in 2030, as compared to 3.82 and 5.16 tons/ha for irrigated conditions (Table 24).

Irrigation under different crops varied considerably, wheat being most intensively irrigated. In South Asia, in 1995/97, wheat occupied 35.14 million ha, nearly 80 percent of the total wheat production (84.9 million tons) (Table 25). Wheat acreage was

projected of increase by about 9 million ha by 2030 (mostly through double cropping), further increasing irrigated wheat area and production proportions to 82.5 and 93.1 percent, respectively. Between 1995/97 and 2030, wheat yield was projected to increase from 2.73 ton/ha to 4.23 ton/ha under irrigation and from 1.19 ton/ha to 1.49/ha under rainfed.

**Table 23: Production and yield of the ten major crops in developing countries**

Crops	Production (million tons)			Yield (tons/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
Soy beans	8	63	157	0.68	1.69	2.54
Seed cotton	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

**Table 24: Cereal yields in developing countries, rainfed and irrigated**

Water regime	Share in area (percent)		Share in production (percent)		Average (weighted) yield (tons/ha)			Annual yield growth (percent per annum)		
	1995/97	2030	1995/97	2030	1961/63	1995/97	2030	1961-1997	1987-1997	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	-	-	-	-	1.17	2.52	3.49	2.5	1.9	1.0

Source: Agriculture: Towards 2015/2030, FAO

**Table 25: South Asia, land-yield combinations of wheat production**

Years	Irrigated Land			Rainfed Land		
	Area ('000 ha)	Yield (Tons/ha)	Production ('000 tons)	Area ('000 ha)	Yield (tons/ha)	Production ('000 tons)
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 area expansion 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 26, 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.

**Table 26: Annual increase in wheat (South Asia) and rice (Southeast Asia) yields in kg/ha**

Period	Wheat, South Asia	Rice, Southeast 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

Recently FAO had analyzed yield gaps in selected Asian countries and found that 50-100 percent transferable yield gaps were not uncommon. For instance, in India, for rice, the most important food crop of the Region, the gap between the national average and the experimental trials average was of more than 3 tons per ha, which was more than 100 percent. Gap of state averages over experimental average at the national level was of the magnitude of 52.3 percent. The yield gaps differed widely from state to state, being lowest (800 to 600 kg/ha) in Tamil Nadu and highest (4903 kg/ha) in Rajasthan. Likewise, the state average yields also varied widely. Led by Punjab with an average yield of 5 tons per ha, Tamil Nadu and Haryana, in that order, also recorded yields higher

than 4 tons/ha, Yields were generally low in Bihar, eastern U.P., 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.

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 percent of the yield growth). Total factor productivity (TFP), which encompasses technological components, contributed only by 24 percent, and was closely followed by electricity (20 percent). Irrigation had rather a modest contribution of only 8.4 percent. However, the situation was somewhat different in case of wheat, where irrigation was the main source of yield growth (39 percent), followed by price (29 percent) and TFP (24 percent) (Kumar, 2001).

Recognizing that there are serious yield gaps and there are already proven paths for increasing productivity per ha, 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 accrue essentially through increasing yield per ha. Higher TFP growth rate means greater efficiency in the use of various inputs, especially fertilizer and water to render greater comparative advantage in production.

As the TFP increases, the cost of production would decrease and the prices would also decrease and stabilize. IFPRI IMPACT has projected a declining real world food price between 1995 and 2020. While the low grain prices have been extremely helpful in improving the access on the part of the poor masses to the food in the market, the farmers, especially with marketable surpluses, have suffered and will further suffer. Should the rapid economic growth in Asia return to about 8 to 10 percent per annum, there are chances of increased demand of livestock feed, livestock products and other high value commodities, exerting an upward pressure on prices. This will 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 Indogangetic plain using validated crop growth simulation models, spatial weather data bases, land use patterns weather generates, agronomic management details and GIS. The simulated potential grain yield varied between 12.0 and 19.5 ton ha (Table 27). Potential was higher in the northern region compared to the eastern region. Temperature and solar radiation during crop season had high impact.

These models can be used to calculate the extent of yield gaps in different regions and pathways for bridging the yield gaps can be created. In fact, several farmers in north India already harvest nearly 16 ton ha<sup>-1</sup> from rice-wheat system, indicating negligible yield gaps with current genetic potential of the cultivars used. These yields can be rated as one of the highest in the world and if realized, there will 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 approach with effective decision support systems are needed.

**Table 27: Potential yields of rice-wheat systems in the Indo-Gangetic plains**

State	Average potential yield, t ha <sup>-1</sup>					
	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

Inter-country differences in yields are rather high. Rice and wheat yields in 10 percent of the highest yields developing countries were more than five times higher than those in the lowest 10 percent yield countries (Table 28). For wheat this gap is expected to remain until 2030, while for rice the gap between the top and bottom deciles may be somewhat narrowed by 2030, the yields in the bottom decile were projected at 28 percent of yields in the top decile. This suggests that in rice the yield ceilings are being approached faster than in wheat. The average yield levels 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 yield levels will still be at 54 percent 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 already a high average rice yield level of 6.8 tons/ha in 1985/89 has pushed it to 8.4 tons/ha in 1995/99, with many individual farmers obtaining 10-12 tons/ha. 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. Important question is whether such opportunities exist with

resource-poor majority small farmers in Asia, most of whom live in rainfed and other non-congenial areas.

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

**Table 28: Average wheat and rice yields for selected country groups**

Country groups	1961/63		1995/97		2030	
	tons/ha	as % of top decile	tons/ha	as % of top decile	tons/ha	as % of top decile
<b>Wheat</b>						
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	
<b>Rice (paddy)</b>						
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.

Notwithstanding the good success in piercing the yield ceilings for intensively managed production regimes, the crux of the problem in a global sense of food security through large scale production gains is to narrow the exploitable yield gaps. An Expert Consultation on Bridging the Rice Yield Gap in the Asia-Pacific Region, 1999 (FAO/RAP 1999) had made the following recommendations:

- 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.
- The Integrated Crop Management approach 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 and COMESA, and geographic comparative advantages can provide major incentive for farmers to bridge the yield gap.

Not only that the yield gaps remain stubbornly high and the yield growth rates have decelerated, but much more alarming is that there 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 soil resource base and/or decline in the genetic potential of the breeding materials used for generating cultivars. Further analysis of the results, after compensating the highest yields with an amount equal to the annual rate of decline in IR-8 yield, indicated that the highest yields were increasing significantly. This implies that the yield decline is due to faster rate of

degradation of the paddy environment namely soil, which is greater than the rate of growth in the yield potential.

These results point out as to how a long term strategy and site-specific and knowledge intensive soil fertility orientation are needed for the fertilizer-use technology, transfer, adoption and monitoring by the extension advisory system and the farmers themselves. Soil-test based fertilizer use, real-time nitrogen nutrition management of the crop by the use of leaf chlorophyll meter/leaf colour chart (IRRI) and soil nutrient budgeting, will be the elements of precision agriculture, for sustaining high yields and reducing the deceleration of partial factor productivity due to fertilizers. This approach calls for paradigm shift in the technology transfer approach which is based on intensive knowledge and higher capacity of extension agents of both public and private sectors.

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, and 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. But, on a positive note, 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**

As mentioned earlier, 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 half of the increase in cereal production. In the future also, the application of mineral fertilizers will be crucial to achieve the projected production, but increasingly in concert with 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 tons in 1995/97 to 182 million tons in 2030, at an annual growth rate of 0.9% (Table 29). Wheat, maize and rice will continue to be the main users of fertilizers with maize emerging to be the foremost user 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 pre-dominant crops in Asia, the Asian trend of fertilizer use will determine the trend of use in the developing countries as a whole.

**Table 29: Fertilizer consumption (nutrient, million tons)**

Crops	1995/97	2030	Growth 1995/97 – 2030 (% per annum)
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

South, Southeast and East Asia are projected to consume 86 million tons of mineral nutrients by the year 2030, accounting for 47% of the world's and 77% of the developing countries' fertilizer consumption (Table 30). China is projected to consume 46.4 million tons whereas India would be consuming 21.1 million tons. These two countries together will account for 60% of the fertilizer consumption in the developing world and about 37% of the whole world. For reasons already described earlier, commensurate with the deceleration in yield and production growths, the growth rate of fertilizer consumption in Asia will decrease to about 1% during 1995/97 - 2030 against 9-10% per annum during 1961-97.

**Table 30: Fertilizer consumption, total nutrient: historical and projected**

Region	Nutrient (million tons)			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

As regards per hectare nutrients consumption for the world, the amount had almost trebled during the Green Revolution period (1961/63 – 1995/97). In the developing countries the amount had increased 13 times, from 7 kg per hectare in 1961/63 to 90 kg

per hectare in 1995/97 (Table 31). In South Asia the increase was still more dramatic, from 3 kg to 79 kg per hectare and in the East Asia from 9 to 147 kg per hectare. Having achieved a moderately high rate of fertilizer use, the consumption rate is bound to decline towards the year 2030.

**Table 31: Per hectare nutrient consumption: historical and projected**

Region	Per hectare 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

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

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

East and South Asia will experience deficits in all three nutrients, accounting for more than 90% of global deficit. Led by India in South Asia and by China in Southeast Asia, the two sub-regions together will be required to annually import 49 million tons of fertilizers by 2020 to meet their demands (Table 32). Therefore these sub-regions must continue to invest in fertilizer capacity while maximizing benefits from fertilizers 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 32: Fertilizer supply-demand balance: projection, 2000 and 2020**

	2000				2020			
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Total	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	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 and suitability of soil type and climate regime, 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 percent 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 the average per hectare fertilizer use will be about 250 kg, which is higher than the technical optimum which in turn is higher than the economic optimum (Table 33). The crop production environment, including generation and transfer of appropriate package of technologies, must be improved to increase fertilizer use efficiency to justify increased fertilizer doses to meet the challenge of “feeding a fertile population from infertile soil in fragile world” (Borlaug and Dowsell, 1993). A 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% in developed countries and 40% in developing countries. In rice in Asia the nitrogen uptake efficiency is only 30-35%. It is an irony that the response yardstick to fertilizers has been fixed and used at 1:10, for decades, for calculating the fertilizer requirement. Extension and adoption of best fertilizer management practices at large scale should result in realization of higher fertilizer use efficiency average response yardstick higher than 10, and in realistic estimation of fertilizer demand over time. Improvement in nutrient use efficiency would not only compensate for the negative price effect but also create positive environmental effects. Accent on improved fertilizer use efficiency in USA in the 1990s is a success story to be followed in other countries. As seen from Table 34, national maize yield had increased from 7 to 8 tons/ha while the per hectare N fertilizer use on maize had decreased from 150 kg to 145 kg. (Bumb and Baanante, 1996).

**Table 33: Project increase in yield and fertilizer intake in cereal production to achieve food security by 2020 and technical and economic rates of application**

Country	Cereal grain requirements for 2020		Projection of fertilizer requirement (NPK/ha)	Optimum fertilizer application rate	
	Production (million tons)	Yield rate (ton/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

**Table 34: Maize production and N fertilizer use in USA**

	Three year average			
	Maize Production		N fertilizer used on maize	
	Total (million m. tons)	Yield (kg/ha)	Total (1000 tons)	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

Rice-wheat cropping system, being practiced in 12.5 million ha in the Indo-Gangetic Plains region of South Asia and in 10 million ha in China is the most important production system for food security. Singh and Paroda (1994) had critically analysed the prospects of enhancing and sustaining the productivity of rice-wheat system in South and East Asia and 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. Recent reports from analysis 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 chemical fertilizers alone. However, an analysis by Yadav, *et. al.* (2000) of the yield trends of the two crops and sustainability of the production system across six locations in India, over 12-15 years long term experimentation with fertilizers (F) alone

and in combination with organic sources, namely FYM (farm yard manure), GM (green manure) and CR (crop residue: wheat straw incorporation) indicated that the yield trend of rice and wheat was sustained at higher level with an integrated nutrient management strategy of applying 50% of nutrients as chemical fertilizers and 50% as organic sources to rice and 100% of nutrients as chemical fertilizers to wheat than application of 100% of nutrients as fertilizers to both rice and wheat, as given in Table 35. 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.

**Table 35: Grain yield (kg ha<sup>-1</sup>) averaged over years for rice and wheat in the long-term rice-wheat system under fertilizer NPK applied alone or in combination with organic manures at different locations**

Treatment <sup>a</sup>	Ludhiana	Pantnagar	Kanpur	Faizabad	Sabour	Kalyani	Jabalpur	Mean of locations
Rice								
Control	2051	2806	1776	1663	1587	1372	2512	1967
50F	3957	3397	3042	2917	2781	2538	3627	3180
100F	6083	4564	4470	4205	4111	3328	5094	4551
50F+FYM	5573	4037	3804	4034	4083	3376	4784	4242
50F+CR	5059	3841	3658	3780	3873	3467	4371	4007
50F+GM	6049	4292	4220	3883	3903	3685	5220	4465
Mean	4790	3823	3495	3413	3390	2961	4268	
LSD 5% Treatment (T) = 217, Location(L) = 201, T x L = 532								
Wheat								
Control	1251	1533	1142	855	884	877	910	1065
50F	3205	2673	2881	2414	1786	1631	1654	2321
100F	4459	3753	4532	3449	3128	2671	2553	3506
50F+FYM	4860	3630	4503	3638	3391	2891	2488	3629
50F+CR	4400	3449	4384	3310	3154	3093	2483	3468
50F+GM	4332	3731	4635	3377	3161	3024	2467	3532
Mean	3751	3128	3680	2841	2584	2365	2093	
LSD 5% Treatment (T) = 161, Location(L) = 174, T x L = 427								

<sup>a</sup> In 50F+Manure treatments, FYM, CR or GM were applied to rice only, and subsequent wheat received complete recommended dose of NPK through fertilizers.  
Source: Yadav, R.L. et. al, 2000

Best fertilizer management practices revolve round 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 revealed by soil testing and avoiding emergence of 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

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

### **Fertilizer and the Environment**

Historical patterns of manure and fertilizer use in mixed farming (cattle) systems have resulted in gradual build up of soil fertility as in Europe and North America whereas inadequate fertilization practices in Asia have led to nutrient depletion and 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. On the other hand adequate fertilization of crops can not only maintain soil production potential but also increase carbon sequestration in soils, via enhanced photosynthesis, bio-mass production and organic matter in soils and reduce global warming.

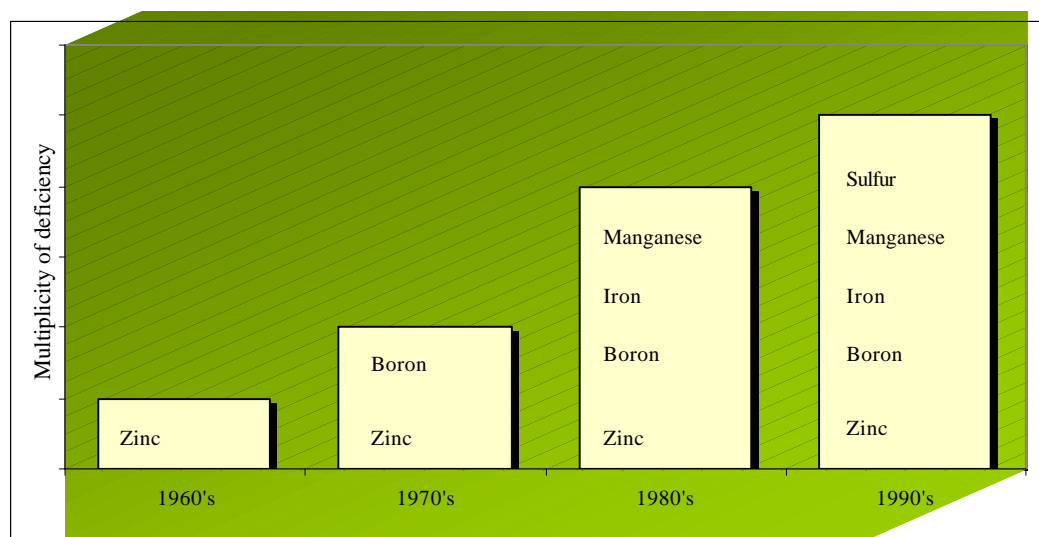
Discharge of wastewater from ammonia plants can add to nitrate levels. The emission of  $N_2O$ ,  $SO_2$  and  $CO_2$  can contribute to greenhouse gases and acid rain. Excessive use of nitrogenous fertilizer can lead to groundwater contamination with  $NO_3$ , and that of N and P can lead to eutrophication in water bodies leading to fish mortality. Heavy metals accumulation in plants and soils, such as cadmium, through their presence in fertilizer materials is of concern in recent times. Phospho-gypsum is a by-product of production of phosphoric acid. For every ton of phosphoric acid produced, 4 to 5 tons of phosphogypsum is produced. It contains radium, can emit radon, a radioactive gas which is hazardous to humans and animals.

Further analysis and research need to be continued to increase the understanding of the environmental interactions of fertilizer production and use. Internalizing the externality argument suggests that cost 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 as related to fertilizer industry is desirable.

### Fertilizer Policy

In a land-hungry region like Asia, the synergy of genetic engineering, irrigation and plant nutrients must be maintained to boost crop yields. In doing so the sustainability and environmental concerns must be kept in mind. Poor management of mineral fertilizer use in many parts of the world had 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, not coupled with balanced fertilization during the green revolution era, has resulted in deficiencies of growing numbers of micronutrients. In the 1960s, while 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 in-organic fertilizer, the application of organic fertilizer, soil conservation measures, and the integrated management of plant nutrients sources will all need to be integrated 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 relative quantity and at the right time, place and price for high crop yields to be realized.

**Figure 3: Emergence of multiple micro-nutrient deficiencies in soils**



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 be geared to promote this synergy between the different technological components by improving research, monitoring, participation, and the extension of effective plant nutrients management approaches. New biotechnological inventions for increasing the efficiency of plant nutrients system should also be encouraged. As discussed in the later section, government policy on pricing of inputs and outputs, institutional and infrastructural supports will be essential to maximize the positive effects of technological and non-technological factors towards enhancing and sustaining crop production.

Appropriate policy measures and guidelines, specific to each country, need to be framed based on analysis and research of the factors that affect fertilizer supply side viz investment in fertilizer production, imports, marketing and distribution infrastructure, exchange rate stability, allocation of sufficient foreign exchange to adequate and timely supply of fertilizers and those that affect the demand side viz 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 may cause steep reduction in fertilizer use as it 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 long period and if not used judiciously may tend to 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 felt and needed. 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 marketing reforms is preferable to the 'big-bang approach'. In landlocked countries, a subsidy on transportation cost may be desirable.

Management and marketing skills, regulatory mechanisms, financial institutions, information networks need to be promoted for 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.

China joined WTO negotiations from 1995 and is undertaking a series of policy reforms in fertilizer sector, aimed at use of economic and legal instruments and free market system instead of mandatory method of central planning to manage fertilizer sector. The policy contrast taken after 1998 include phasing out of mandatory production quota, freedom of product sales, competitive retail price, invoking 'Green Box' policies etc.

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

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 the internal fertilizer production, consumption and agricultural production of developing world and in the global fertilizer trade and industry.

### **THE WAY AHEAD**

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 homes to nearly two-third of world's malnourished and poor people, is to fight hunger and poverty. The agriculture-led broad-based economic growth – the main recourse to fight the maladies – must take place under the settings where the natural base of production resources, such as land, water and biodiversity, have shrunk, there is widespread environmental and agro-ecological deterioration, and 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 hold true for the Asian region for too long as the region has to feed 57 percent of the world's population from only about 33 percent of the world's arable land and that too has been shrinking at a much faster rate than in the rest of the world and the man land ratio has steadily been declining. In the next 30 years, on an average, one tonne of additional grain is projected to be added to the produce of each hectare to meet the 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. Generation and effective assessment and diffusion of packages of appropriate technologies involving system and programme based approach, participatory mechanisms, greater congruency between productivity and sustainability through integrated pest management and integrated

soil-water-irrigation-nutrient management, should be aggressively promoted to bridge the yield gaps in most field crops. Besides this, efforts must be in place to defend the gains and to make new gains particularly through the congruence of gene revolution, informatics revolution, management revolution and eco-technology.

The food and agricultural products thus produced in pockets where needed most, improve the entitlements of the inhabitants. 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 non-congenial 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 desired support are fundamental to the growth and development process, which must increasingly become science based. Blending of new, conventional and indigenous technologies, called as "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 millenium, 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, nutritional adequacy, poverty alleviation, environmental protection and sustainable agriculture. Often referred to as "Gene Revolution or Bio-revolution" if judiciously harnessed, blended with traditional and conventional technologies and supported by policies, biotechnology can lead to ever-green revolution synergising the sustainable pace of growth and development (Singh, 2000).

The way ahead must map out the ways to optimise the benefits and minimize the negative effects of biotechnology on a case by case basis. Biotechnology should be kept in a balanced perspective by integrating it within the national. research technology 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 and public perceptions and consumers' views, and above all, the needs and aspirations of small-scale holders and the poor (Persley, 2000). Accordingly, various stake holders, public sector, private sector, industries, NGOs and civil societies 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 policy for meeting the challenges and capturing the novel opportunities. Competence will particularly be needed in formulation of country-specific rules and regulations on biosafety and intellectual property rights management regimes along with commensurate financial and institutional support information. Strong network and human resources will be needed for their effective implementation.

### **Keeping Pace with Globalization**

The globalization of agricultural trade will bring to the fore : access to markets; 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 the 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 term. 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 the informatics 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 production models for various agro-ecological regimes to forecast the production potential should assume greater importance. Using the 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 prediction of disease and pest incidences.

### **Accent on Less-Favoured Areas**

Rainfed and other less favoured areas have the highest concentration of poor and malnourished people as these areas are characterised 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 HYV seed - fertilizer - 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 are evidences 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 36) (Fan, et.al., 1999).

**Table 36: Effects of additional government spending on poverty, 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**

The 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 have 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 as subsidy to their farmers.

Realising that nearly 70 percent 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 are needed to facilitate agricultural and rural development through: (1) Strengthening 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 through creating 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, adequate nutrition particularly for children (including through mid-day meal 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 ground water depletions and serious environmental and social problems of some of the major irrigation projects on one hand and the multiple benefits of irrigation water in enhancing production and productivity, food security, poverty alleviation, as mentioned earlier, are well known to be further elaborated here. Further, the quality of available water is deteriorating. Also, there are gross inequalities between basins and geographic regions.

Agriculture is the biggest user of water, accounting for over 70 percent 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 percent by 2020, resulting in drop of yields of irrigated crops, especially rice, thus price rise and withdrawal of food from poor masses. Policy reforms are needed from now to avoid the negative developments in the years to come. These reforms may include the establishment of secure water rights to users, the decentralisation 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 legislations, research and technology development and dissemination, social mobilisation 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. 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 the 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, soil-water-nutrient management in an integrated approach need to be refined appropriate to the soil units (types) and the type of farming systems that are 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 group 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 the humankind. New sciences of biotechnology and bioinformatics, coupled with conventional sciences, should be judiciously used for developing efficient and effective methods of conservation, utilization and exchange of genetic resources. Due to economic and population pressures the resources are eroding fast. Moreover, their availability is getting increasingly restricted due to their propriety protection under several systems. Cartagena protocol for conservation, biosafety and sharing of genetic resources provide 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 genetic resources.

The FAO-led International Undertaking and Global Plans of Actions on genetic resources provide the mechanism for rationally conserving and utilizing the genetic resources. Dynamic national research systems should be in place to address the research, development and sharing issues of germplasm. 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 Farmers' 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. There must be policy and institutional environments to provide clearly defined and enforceable property rights, reduce transaction costs and encourage broad-based, decentralized development of activities in rural areas to enhance growth efforts. Along with implementation of policy reforms that encourage private and public sector participation in economic activities in accord with their comparative advantage should be encouraged. In this regard, the public sector should focus on addressing cases of market

failure to enhance efficiency of private operations, ensure competitiveness and quality of service, and to fulfill the long-term social welfare objectives of protecting the environment, common property resources, 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, with an eye on equity and measures to bridge the various divides must continue. Based on the hindsight, 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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