Trans. Natl. Acad. Sci. Tech. Philippines 21: 130-147 (1999).
ISSN 0115-8848

GLOBAL PERSPECTIVE ON CEREALS – FOCUS ON RICE"

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ABSTRACT

Rice is considered by many governments as a strategic commodity due to its importance in ensuring national food security and in generating employment and income for the poor in society. Since the mid-1960s, rice production has increased by 2.5% yearly with nearly 80% of the growth in production to be due to increases in yields brought about by the gradual use of modern cultivars. However, poverty and food insecurity still affects 1.3 billion people, 70% of whom live in Asia. The paper discusses the main factors affecting demand for rice in the region: income, urbanization and population growth. In one nation, demand may fall as incomes rise, but this may be outweighed by population growth elsewhere. The paper further noted that in the mid-1980s, the growth in rice yield has failed to outpace population growth in a large number of countries. It discusses the factors that contribute to the slowing growth in rice yield: labor and wages, water availability, competing demand for land, incentive to sustain interest of farmer in rice farming, trade liberalization, limitation of technological process.

Keywords: rice, sustainability, trade liberalization, green revolution, food security

OVERVIEW OF FOOD SECURITY SITUATION

In talking to you today about a global perspective on cereals and rice, I especially wanted to focus on food security and look at some of the issues and challenges we face it we are to ensure there is enough food for everyone well into the next millennium.

As you all know, rice is the staple food and principal crop in most of Asia, with other cereals playing a smaller, but still significant role. From the Philippines in the east to Eastern India in the West, and Central and Southern China in the north

to Indonesia in the South, rice accounts for 30 to 50 per cent of agricultural production and 50 to 80 per cent of the calories consumed by people.

Because of its importance in ensuring national food security, as well as generating employment and income for the poor in society, rice, unlike other cereals, is regarded by many governments as a strategic commodity. Maintaining self-sufficiency in rice production and ensuring stability in rice prices, therefore, remain important political objectives of the governments of most Asian nations.

Partly because of such policies, Asia has done remarkably well in meeting the food needs of the region's growing population over the past three decades. Since the mid-1960s, rice production has increased by an impressive 2.5 per cent year; keeping pace with population and income growth induced changes in per capita food consumption. Nearly four-fifths of the growth in this production was due to increases in yields, made possible by the gradual replacement of traditional varieties by modern cultivars. These were mostly developed in rice research stations, supported by public investment.

In addition, the downward trend in real rice prices, experienced in many Asian countries since the late 1970s because of increased production, has contributed greatly to poverty alleviation by allowing the rural landless, and the urban laboring class, to acquire more food from the market (See Graph 1). However, poverty and food insecurity is still widespread in many low-income Asian countries. Recent World Bank estimates indicate that nearly 1.3 billion people still live in poverty, while 840 million suffer from hunger, 70 per cent of them living in Asia. It should also be noted that this situation is expected to get worse before it gets better, because of the continuing impact of the Asian economic crisis in Southeast Asia, especially in countries such as Indonesia.

Therefore, a key question for the future is whether Asia, as the most heavily populated region of the world, will be able to sustain favorable food supplies, and further improve food security for low-income households over the next few years. Many factors adversely affect Asia's food security position. These include: food production performance; population growth; income growth and distribution; and available foreign exchange to import food.

Emerging trends involving these factors indicate that many countries remain vulnerable to food security problems. Failure to do the right thing now will further exacerbate the precarious food security situation of these nations, especially in the low-income countries that still contain a large section of the Asian population.

While other cereals will play a role in answering the food security question, obviously rice is the most important crop. It is important, not only as the predominant source of energy in Asian diets, but also as a vital source of income and employment for rural people. For the rest of my presentation I would like to focus on the supply and demand issue of rice, as well as look at how science and research may cause an impact on the global perspective for this crop.

EMERGING TRENDS IN RICE-CEREAL DEMAND

I would like to begin by looking at some of the emerging trends in rice-cereal demand starting with incomes.

The Income Effect

An important factor that influences the per capita consumption of any staple food is the income level of the consumer. At low-income levels, meeting energy needs is the most basic concern of any individual. Staple foods, such as starchy roots, rice, wheat and coarse grains provide the cheapest source of energy. Thus, poor people spend most of their income on such food.

In rice producing regions, the extreme poor often make do with coarse grains and sweet potatoes because they lack purchasing power. As incomes grow, per capita rice consumption increases, with consumers substituting rice for coarse grains and root crops. But as incomes increase beyond a threshold, people can afford to have a high-cost, balanced diet containing foods that provide more proteins and vitamins, such as vegetables, fruits, fish and livestock products. From that income threshold, per capita rice consumption starts declining.

The above pattern of changes in food consumption with economic growth is amply demonstrated by the experience of Japan, South Korean, and Taiwan which made transitions from low to a high-income levels within a relatively short period of time. In South Korea, the per capita consumption of rice increased from 318 grams per day in mid-1960s, when it was a low-income country, to 386 grams by 1979 when it reached the middle income level. Since then, the per capita consumption of staple grains which consist mostly of rice has been declining (Table 1).

You can see there has been a substantial reduction in the consumption of cereals and root crops, but a surge in the demand for livestock products, fish, fruits

Table 1. Changes in food consumption pattern in South Korea, 1974-75 to 1992-94.

Food item	1974-76	1992-94	Change
Cereals	686	513	-173
Roots	101	43	-58
Vegetables	373	511	138
Fruits	63	229	166
Sugar	23	88	65
Oils and fats	11	35	24
Fish	132	181	49
Meat and eggs	32	124	92
Milk	12	58	46
Total	1433	1782	349

Source: FAO 1996: Food Balance Sheets, 1992-94 average.

and vegetables over the past two decades. We can expect similar changes to occur in other Asian countries as they move along the same path of economic development.

However, in South Asia, particularly in the Philippines and Vietnam, 30 to 50 per cent of the people who live in poverty do not have adequate incomes to buy food they need. With economic growth and a reduction in poverty, per capita rice consumption is expected to further increase in these countries, since the poor can then afford to satisfy their unmet demand for a staple food. The expected rice demand in such nations, which constitute about 40 per cent of the regional total, will easily overcome the downward pressure on demand from the middle- and high-income industrialized countries whose share is a mere 10 per cent.

Urbanization

The other force that will affect the demand for rice is urbanization. As people move from rural to urban areas, their energy needs correspondingly decreases as they move from more physical jobs to more intellectional ones. Also, the cost of meeting basic non-food needs, such as education, health care, transportation and recreation services, is higher in urban areas; therefore a smaller share of the family budget is available for staple food.

The consumption composition between staple and non-staple food also changes because of greater nutritional awareness of the importance of a balance diet, and the widespread practice of eating outside the home. So, for the same level of income, the per capita consumption of rice is generally lower in urban areas compared to rural districts. The evidence from Thailand and Bangladesh as shown in Table 2 demonstrates this.

In Asia, the urbanization level is still low but will continue to grow over the next two decades (Table 3). Thus, the demand for rice will decline because of a larger proportion of people living in urban areas.

Urbanization also increases the demand for high quality food and processed products. Urban consumers may not increase their consumption of rice with an increase in income, but they will pay premium prices for preferred varieties, particularly if they meet certain health standards (such as produced under organic farming or are non-transgenic) and have improved nutritional quality.

Table 2. Per capita consumption of rice (kg/yr) by income groups and regions, Thailand and Bangladesh.

Ranks in the	Thailand			Bangladesh	
Income scale	Rural	Semi-urban	Urban	Rural	Urban
Bottom 25%	151	133	97	148	141
Middle 50%	146	125	89	179	147
Top 25%	134	125	83	175	142

Source: National Household Expenditure surveys.

Table 3. Projection of populations residing in urban areas in selected countries. (In percent of total population)

Country	1960	1990	2010	2020
Japan	56	77	81	84
South Korea	28	74	91	93
Thailand	13	19	31	35
Indonesia	15	31	54	57
China	19	26	43	51
India	18	26	34	41
Bangladesh	5	16	28	36

Source: United Nations.

In Japan and Korea we have seen a surge in demand for high-quality non-glutinous rice over the past two decades and a drastic fall in the consumption of standard quality rice. The same pattern of change in the composition of demand is in progress in China after the liberalization of the food market, with a growing demand for Japonica rice at the expense of low-quality hybrid Indica rices. The demand for rice-based products, such as noodles, and rice cakes is growing with urbanization and women's involvement in activities outside home.

Population growth

Given the per capita consumption level, the increase in total demand depends on the number of mouths to be fed. In the developed world, the total demand for cereals has decreased as many of them have achieved stationary population. But most Asian countries still have populations growing at 1.5 to 2.8 per cent per year. (except Japan, South Korea, China and Thailand). However with increasing economic prosperity, population growth will slow down as experienced be developed nations during the early stages of development.

According to UN projections, population growth in most Asian countries over the period 1995-2025 will be reduced to almost half of the level experienced by these countries since the mid-1960s (Table 4).

However, due to the expanded base of population (from 3.5 billion in 1995 to 4.8 billion in 2025), the absolute increase in the number of people over the next three decades will remain as large as ever from 1.21 billion to 1.45 billion. Ironically, it is in the poverty-stricken regions, where the per capita rice consumption is expected to increase and population growth will also be the fastest. In South Asia, for example, the population is projected to increase by 732 million over 1995-2025, compared to 670 million over 1965-95. It is only in East Asia that the additional number of mouths to be fed is going to be substantially lower in the future compared to what they have been in the past.

Table 4. Population projections (millions) for Asia, 1995-2020.

Country	1995	2020	% change	Annual growth
China	1220	1449	19	0.69
India	929	1272	37	1.26
Indonesia	197	264	34	1.17
Bangladesh	118	171	45	1.50
Vietnam	118	171	45	1.50
Thailand	58	68	16	0.61
Myanmar	45	64	42	1.41
Japan	125	124	-1.0	-0.04
Philippines	68	100	47	1.56
South Korea	45	52	16	0.58
Asia	3147	4121	31	1.08

Source: Asia includes countries in South, Southeast and East Asia.

Source: United Nations.

Projected growth of demand

The International Food Policy Research Institute (IFPRI) has developed a Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) for developing long term projections of the demand and supply balances for major food items. It specifies a set of country or regional sub-models, each with a particular structure within which supply, demand and prices for the commodities are determined. The demand projections for rice for Asian regions obtained from a revision of the model that incorporates the most recent population projections by the UN (1997), and slower growth in East and Southeast Asia due to the recent economic turmoil, show demand for rice growing at only 1.02 per cent per year. This implies an increase of 31 per cent over the 1998-2025 period (Table 5).

The projected growth in demand is substantially lower than the historical growth in rice production of 2.5 per cent per year over the past three decades. This is mainly because of East Asia, where it is projected to grow at only 0.6 per cent per year. However, the low-income poverty stricken countries of South and Southeast Asia are expected to experience strong growth in the demand for rice. The countries in Asia where the demand is expected to grow rapidly over the next 25 years are: Philippines (65%); Malaysia (56%); Bangladesh (51%); India (46%); Vietnam (45%); Myanmar (42%); Indonesia (38%).

An important point to note in this context is that although the demand is quantity terms may relax, the market for quality rice will expand rapidly following growth in the size of the middle class and with urbanization, as demonstrated by Japan and South Korea.

Table 5. Projected growth of demand for rice in Asian regions.

Region	1993	2020	Percent increase 1993-2020	Annual rate growth of demand	Annual rate of growth of population
East Asia	143.2	163.3	14.0	0.58	0.60
Southeast Asia	73.6	103.8	41.0	1.29	1.17
South Asia	101.7	150.2	47.7	1.46	1.40
Asia	318.5	417.3	31.0	1.02	1.02

Source: IFPRI updated IMPACT model.

Therefore, the main factors affecting demand for rice in the region will continue to be income, urbanization and population growth. In one nation, demand may fall as incomes rise, but this may be outweighed by population growth elsewhere.

Let us now look at the supply situation.

Emerging trends in supply

The impressive growth in rice production during the first two decades of the green revolution (1966-86) generated a sense of complacency in Asia's ability to feed itself. Recent trends in rice production growth, however, raise serious concerns regarding the sustainability of these past achievements (Fig. 1).

The growth in rice yield has slowed considerably since the mid-1980s, and has failed to outpace population growth in a large number of countries (Table 6). Several factors that I will now discuss suggest that this is perhaps the beginning of a long-term trend more than a cyclical downswing.

The growing scarcity of agricultural inputs

The availability of labor, water and land for rice cultivation depends on economic growth. Competing demand for these inputs from other economic activities affects their relative scarcity and prices, and thereby changes relative profitability, depending on the use intensity these inputs in a particular activity.

Labor and wages. Economic growth brings dramatic changes in the structure of employment, the adoption of labor saving technology and increases in labor productivity. With opportunities for more remunerative employment elsewhere, workers move out of low productive, poorly paying food production activities. Although the agricultural sector tries to address the problem of labor shortages by adopting labor saving technologies, it cannot compete with the manufacturing and services sectors which enjoy strong markets and can easily diversify and adjust according to the change in demand.

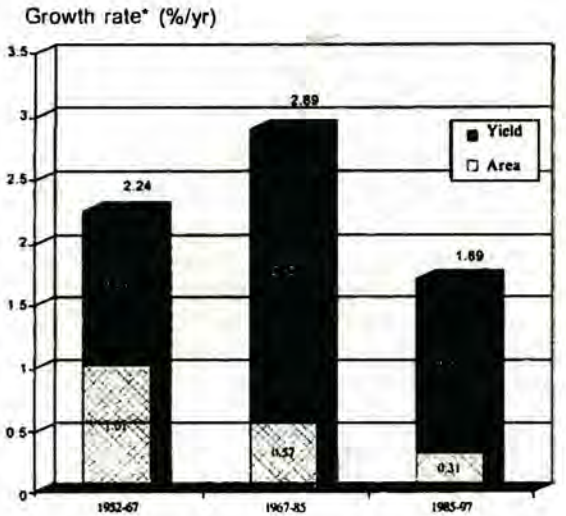

Figure 1. Growth in rice production and productivity: pre- and post-green revolution period.

Table 6. Population projections (millions) for Asia, 1995-2020.

Country	Growth rate in production (% yr-1) 1966-86	1986-96	1966-86	Growth in yield (% yr-1) 1986-96
South Korea	2.48	-2.62	2.35	-0.53
China	3.20	0.66	2.97	1.38
Indonesia	5.18	2.44	3.95	1.06
Philippines	3.77	2.07	3.95	1.06
Vietnam	2.98	5.41	1.85	2.94
Thailand	2.53	1.07	0.52	1.61
India	2.49	2.99	1.86	2.46
Bangladesh	2.03	1.62	1.59	2.22

Note: Growth rate estimated by fitting semi-logarithmic trend lines to the time series data taken from FAO electronic database.
Source: Dr. Mahabub Hossain

The other disadvantage of agriculture in competing with other sectors is caused by constraints in increasing farm size. This is particularly the case in Asia, where there is extreme population pressure on land and exorbitant land prices. Therefore, productivity differences continue to grow with manufacturing increased by 4.3 times during the 1966-90 period, compared to only a 1.2 times increase in the agricultural sector. The total agricultural labor force increased from 4.5 to 6.1 million persons between 1966 and 1975. However, it started to decline in absolute terms and reached 3.2 million by 1990.

Labor scarcity is reflected in the price of labor – the wage rate. According to the 1996 World Development Report, East and Southeast Asia, which experienced more than five per cent per year growth in per capita incomes, saw their real wage rates increase by 170 per cent over a 20-year period. In contrast, in South Asia, where economic growth was moderate, the real wage rate increased by only 50 per cent.

Water availability. Water resource development has been the key to increasing rice production in virtually all Asian countries where land is a scarce factor of production. Water has generally been regarded as an abundant resource for humid Asia. But with rapidly increasing populations, per capita availability has been declining and the substitution of water for scarce land has taken place to meet growing food needs. As a result, the perception of abundant water has been changing.

Many Asian nations now face emerging water resource problems which include:

(a) The stress of meeting human and industrial needs in exploding urban centers;
(b) The plateauing of full economic exploitation of irrigation potential in many regions;
(c) And, the expansion of coastal salinity because of reduced river flows during the dry season.

As populations increase and economic development intensifies, satisfying public needs for drinking water, sanitation and industrial activities have to be accorded higher priority in the allocation of water resources. Almost all Asian governments now face hard decision-making choices involving long-term plans for the regulation, allocation and utilization of water resources.

In absolute terms, annual water withdrawals are by far the greatest in Asia, where agriculture accounts for 86 per cent of total annual withdrawals compared to 38 per cent in Europe and 49 per cent in North and Central America. The per capita availability of water resources declined by 40 to 60 per cent in most Asian countries over the 1955-1990 period and are expected to decline further.

The scope for further conversion of rainfed land to irrigated plots, which was a major source of past growth in rice production, is also becoming limited. Irrigation has increased substantially, as other options for irrigation development are already being used. In addition, environmental concerns such as adverse effects of irrigation and flood control projects on waterlogging, salinity, fish production and

the quality of ground water, have been growing. Already, there has been a drastic decline in investment for the development and maintenance of large-scale irrigation projects in many Asian countries.

Competing demand for land. Economic prosperity and industrial progress is leading to rapid urbanization. As more and more people move to live in large cities. Most of the additional increase in population beyond 2000 will be found in urban areas. By 2025, 53 per cent of the people in Asia will live in urban areas compared to 30 per cent in 1990. An important implication of growing urbanization is that fertile agricultural land must be diverted to meet the demand for housing, factories and roads.

As the frontier of cultivable land was closed long ago, the per capita availability of arable land has been declining rapidly with growing population. China now supports 17 persons per hectare of arable land; the figure is 13 for Bangladesh, 11 for Vietnam and 8 to 10 for India, Indonesia, and the Philippines. Only Thailand, Myanmar and Cambodia have favorable endowments of land, with 2 to 4 persons per hectare. The population pressure is reflected in the high cropping intensity for food grain production. The cropped area under food grains per unit of arable land is 148 per cent for China, 132 per cent for Bangladesh, 112 per cent for India, and 108 per cent for Vietnam, compared to about 60 per cent for Thailand and Myanmar.

The area under rice cultivation is also expected to decline with economic prosperity and urbanization, as the demand for land for non-agricultural uses will grow. There will also be economic pressure to release rice land in favor of vegetables, fruits and fodder, whose markets become stronger with economic progress. In China, the rice harvested area declined from 37 million hectares in 1976 to 32 million in 1992; in the Philippines, it declined from 3.7 to 3.2 million hectares within the same period.

Future growth in rice production must occur on smaller land, use less labor, and water. The downward pressure of input availability on the growth of supply is thus obvious. Rice yields labor and water productivity must grow at a rate faster than increase in the demand for rice, to maintain a favorable demand-supply balance and to release resources for other economic activities.

Sustaining farmer's incentives in rice cultivation

Despite the impressive increases in land productivity, countries and regions that have achieved high yields are finding it difficult to sustain producers' interest in rice farming. Because rice farming is a highly labor intensive activity, the growing labor scarcity and higher wages have pushed up the cost of rice production and reduced profits and farmers' incomes. But it is not only the wage laborers who are tempted to move to non-farm urban and rural occupation. Even small scale rice farmers find it more attractive to leave rice farming and join the farm-farm labor force because of increasing wage rates as shown in Table 7.

Table 7. Long-term trend in wages rates, (US$/day) selected Asian countries.

	1961	1971	1981	1991
Bangladesh	0.46	0.44	0.86	1.39
Philippines	1.39	0.59	1.51	2.16
Korea	0.82	1.86	10.84	32.59
Japan	1.22	8.19	24.16	51.93

Source: IRRI World Rice Statistics, 1993-94.

Efforts are underway to improve the competitiveness of rice farming by:

(a) Improved farm management practices that increase efficiency in the use of non-land inputs and increase total factor productivity.
(b) Increased use of capital to replace labor through the mechanization of farming operations so that labor productivity can be continually raised when no further increases in land productivity are possible.
(c) Use of price mechanisms to transfer income from relatively well off rice consumers to low income rice producers, so the balance between rural and urban incomes can be maintained.

In spite of these policies, in sustaining farmer interest in rice cultivation has remained a major challenge in fast growing Asian nations. In countries and regions where yield levels are high, such as Japan, South Korea, Java in Indonesia, as well as Punjab and Tamil Nadu in India, the scope for increasing profitability through the efficient use of inputs has almost been exhausted.

As labor accounts for only one fourth of the cost of rice production, the substitution of capital for labor increased farmers' incomes only up to a point, particularly when the average farm size was small. Land prices remained high and increased over time due to the extreme pressure of population and growing land demand for housing and industrial purposes. In South Korea, rural wage rates and land prices increased by 18 per cent per year from 1970 to 1990, when machinery and fertilizer prices rose by just seven per cent.

As the cost of rice cultivation continued to increase due to rising opportunity cost of labor and land, governments had to continually raise rice prices and increase farm subsidies to maintain a balance between rural and urban household incomes. The protection of domestic rice industries encouraged high-cost domestic production. A study on costs and returns conducted by the FAO shows that in the late 1980s, the cost of producing rice in Japan was about 17 times higher than in Thailand and Vietnam and about 10 times higher than the USA (see Table 8). Thus, with economic growth, the comparative advantage in rice production shifts to low-income countries.

Table 8. A comparison of domestic rice prices and the cost of production in selected countries, 1987-89.

Country	Paddy yield (t/ha)	Cost of production (US$/T)	Domestic farm gate price of paddy (US$/T)
Japan	6.5	1,987	1,730
Korea	6.6	939	957
USA	6.3	220	167
Vietnam	4.6	100	130
Thailand	1.8	120	141
Philippines	2.6	124	160
Indonesia	5.8	118	132
Bangladesh	4.6	138	180

Source: IRRI for Bangladesh and Vietnam. For other countries, FAO.

The impact of trade liberalization

The implementation of the GATT Uruguay Round of Agreements may further dampen incentives for rice production, particularly in middle-and high-income countries. They will not be able to compete with the low-income economies of Asia, where the wage rates and opportunity cost of family labor is low, or with large land-surplus countries in the developed world (e.g., Australia, USA, Italy). These nations will reap economies of scale because of the large size of their rice farms. If the domestic market is opened for competition, the price of rice will decline substantially, providing incentives to consumers to buy imported food staples, and forcing farmers to abandon rice cultivation in favor of more lucrative economic activities.

An important way of gaining competitive strength in the face of rice trade liberalization is the consolidation of tiny holdings into large-scale farms, as rural households migrate to urban areas leaving their land behind. The so-called "smart farming" of large-scale holdings as currently practiced in the developed world, and the vertical integration of the rice industry (production, processing and marketing managed by the same farm), may contribute to more efficient use of large-scale machinery. It may also lead to a reduction in the number of part-time farmers that are now tied-up in the supervision of numerous tiny rice farms.

The main constraint to the consolidation of holdings in Asia is, however, exorbitant land prices that prohibit the development of an active land market. At existing land prices, the rate of return in rice farming from an investment in land will be substantially lower than the return on an investment in other enterprises. Thus, for Asia, we cannot expect any consolidation of holdings of the same scale as happened in North America and Europe during the early sages of their development.

Because of the forces mentioned above, middle-and and high-income countries will not be able to generate any exportable surplus, even when domestic rice consumption declines with growing economic prosperity. Rather, rice area and production will decline as domestic production is adjusted in line with the downward trend in demand. In Japan, the peak rice harvest was 18.8 million tons in 1967; it has recorded a secular downward movement since then, reaching 12 million tons in 1997. In Taiwan, the peak reached 3.6 million tons in 1976, with the present level of production at less than 2 million tons. South Korea is going to follow the same trend soon. These countries could have maintained their peaks by exporting any surplus over their domestic needs. However, this did not happen because they could not compete in the world market due to their high cost of production in the domestic market.

The exploitation of excess capacity

Any expected drop in global rice production on account of the high-income countries of Asia could be compensated for by an increase in rice production from outside Asia. There is some potential for an expansion in the rice area in the humid tropics of Africa and Latin America. The FAO estimates there are 20 million hectares of potentially suitable rice land in the river valleys of West and Southern Africa, of which only 15 per cent is currently cultivated.

In tropical South America, rice cultivation can be extended to an additional 20 million hectares. The exploitation of this potential will, however, require a substantial increase in price, as well as the capacity of the countries to invest in the reclamation of new land and the development of marketing infrastructure. The unit cost of production and the marketing margin is many times higher in Africa and Latin America than in Asia. Also, the demand for rice has been growing faster in other continents compared to Asia (at more than 4.0 per cent per year in Africa) so the exportable surplus available for Asia from these continents could be quite small.

Eastern India also has considerable excess capacity in rice. However, with the alleviation of poverty and the high growth of population, Eastern India may need to exploit any excess capacity to meet its own growing internal demand. Only Myanmar and Cambodia could generate additional exportable surplus' to meet potential shortages in other Asian nations. The exploitation of such potential would, however, require substantial investment for land reclamation, the expansion of irrigation systems, technologies for the improvement of rice quality, and the development of marketing infrastructure.

Also, additional exports from Myanmar and Cambodia may not add much to the world rice market, as exports from Thailand and Vietnam are likely to decline over the long run. Thailand's comparative advantage in generating an exportable surplus is its favorable land endowment. However, this advantage is being gradually eroded due to rapid increases in farm wages and opportunity cost of family labor, a process that Japan, Taiwan and South Korea have already gone through in

the past three decades. Vietnam has almost fully exploited its potential for increasing rice cropping intensity and production, and may have to reduce exports in the future to accommodate growing internal demand.

Technological progress: Running out of steam

One of the most important factors behind the recent slowdown in the growth of rice production (See Table 9) is that the technological progress needed to improve rice cultivation is running out of steam.

The increases in rice yields in the past originated mainly from:

a) The gradual adoption of modern varieties on existing irrigated land.
b) Public and private investment in the expansion of irrigation areas to support the diffusion of modern varieties and improved farming practices.

The green revolution was successful mostly in irrigated ecosystems where yields increased from 3.0 to 5.8 ton/ha over the past three decades while the yield growth remained moderate in rainfed systems. Today, however, almost the entire irrigated land are of the region has been covered with modern varieties. In addition, the yields of the best farmers are already approaching the potential that scientists were able to attain with today's knowledge in that particular environment. In addition, with the intensive monoculture of rice in the irrigated systems and high doses of chemicals, natural resources are becoming stressed.

Table 9. The race between population and rice production.

Country	Rice harvested area (000 ha)	Population growth (%/year)		Growth in (%/year)	
	1994	1965-85	1985-95	1965-85	1985-95
India	42,034	2.2	1.9	2.4	2.4
China	30,373	1.9	1.1	3.3	0.6
Indonesia	10,646	2.3	1.6	5.7	2.0
Bangladesh	9,912	2.8	1.9	1.8	1.9
Thailand	8,482	2.6	1.4	2.5	0.0
Vietnam	6,500	2.3	2.3	2.5	3.9
Myanmar	6,477	2.2	2.3	2.8	2.6
Brazil	4,446	2.4	1.6	1.8	1.2
Philippines	3,350	2.8	2.4	3.9	1.5
Japan	2,212	1.0	0.3	-0.5	-0.6
Madagascar	1,180	2.7	2.9	1.5	1.5
South Korea	1,160	1.8	0.9	2.0	-1.7
Malaysia	665	2.5	2.3	2.1	1.8
World	146,452	1.9	1.6	3.1	1.4

Agronomists have also noted yield declines in the experimental farms that tested the effect of intensive rice farming on yields and the soil's nitrogen supplying capacity. In the humid tropics, maximum achievable yields at the farmer level are lower than 6.0 tons per hectare because of increased pest pressure, frequent cloudy days with below optimal sunshine, and susceptibility of the crop to floods, droughts and strong winds.

In regions with good irrigation infrastructure, this potential yield level is about to be reached. Further research is needed to shift the yield frontier for irrigated systems and develop appropriate crop and resource management technologies to sustain high yields.

There are some technologies in the pipeline which may help raise land productivity and input-use efficiency in the irrigated ecosystem, and thereby contribute to further increases in rice supplies (Khush, 1995). These will help, but will not provide all the answers. Please allow me to briefly detail two. In 1989, IRRI began to design a new rice plant type, one that would make it possible to grow an irrigated rice crop with up to 30 per cent higher yield. It is also designed to increase nutrient efficiency with fewer numbers of larger panicles per plant, to reduce unproductive tillers and to increase photosynthesis efficiency through erect and thick leaves. The field evaluation of the breeding lines has just begun. The new plant architecture also needs to be matched with agronomic practices such as planting method, nitrogen application and weed control. Work is also needed to develop resistance to insects and diseases and to improve grain quality. Therefore, it may take another five to 10 years for this technology to reach the rice farmers.

Another technology which is within reach of the farmer is hybrid rice for the tropics (Virmani, 1994). Hybrids have a yield advantage of 15 to 20 per cent over the currently inbred high-yielding varieties. Rice hybrids were developed earlier in China. Increases in rice yields in China in the 1975-1990 period were largely due to the diffusion of hybrid varieties to 50 per cent of the country's rice area. Chinese hybrids, however, are not suitable for the tropical climates of Southeast and South Asia. IRRI scientists have already developed other suitable hybrid lines for the tropics, which are now being used by scientists in India and Vietnam to develop varieties for release to farmers. The main constraint in any rapid expansion of hybrid rice among the small farmers is the development of infrastructure for the production and distribution of seeds. Farmers will need to change seeds every season, which is an unconventional practice.

It should also be noted that the potential for raising yields in the rainfed ecosystems is still vast, as the current yields is only about 2.0 tons per hectare. Across nearly 45 per cent of arable Asia, rice is grown under rainfed conditions. Indeed, this ecosystem is the dominant one in the low-income countries of Asia, where the demand for rice is projected to remain strong. If rice science succeeds in developing appropriate technologies, this ecosystem could make a major contribution to any future growth in rice production.

However, rainfed ecosystems are subjected to the vagaries of nature such as droughts, floods, typhoons and erratic monsoons. Traditional low-yielding varieties have developed traits that enable them to withstand temporary submergence in water and prolonged droughts that cause large year to year fluctuations in yields for this ecosystem. Rice scientists have had limited success in identifying these traits, and incorporating them into high-yielding modern cultivars. Where the rainfall is unreliable and the drainage is poor, farmers still grow traditional varieties, and use fertilizers in sub-optimal amounts on modern varieties, due to the uncertainty of returns from investments. This is the main factor behind the low-yields and the large yield gap in the rainfed ecosystems.

If rice research succeeds in incorporating traits that help withstand such abiotic stresses, improved systems management help avoid these stresses, modern varieties will be adopted more extensively in the rainfed system. This will help increase the stability of yields and reduce risks in rice cultivation; thereby providing incentives to farmers to apply inputs in optimal amounts that will contribute to further increases in yields and rice production.

CONCLUSION

Let me say clearly that IF we cannot meet most of the challenges that I have just outlined to you, then the food crisis in Asia that are now just a distant memory could return to haunt us all. The global outlook for rice and cereals is quite clear: there will not be enough for every one unless more resources are committed to research so problems faced by most of the developing world can be overcomed.

This is no time for complacency, we should not be resting on our laurels as scientists. There is still a large unmet demand for food not just in Asia but in many other parts of the world. There are other issues involved in achieving food security, many of them political, but increasing production or output is one sure way to avoid potential problems in the future.

If the region succeeds in alleviating poverty, the demand for rice will increase much above the level induced by population growth. The amount of arable land per capita is already low, and farm size has been declining due to rapid increases in population and the slow absorption of labor in the nonfarm sector.

In addition to these problems, the rainfed areas which account for half the area planted to rice have benefited little from the Green Revolution. This is because scientists have had limited success in developing varieties that could adapt to the difficult natural and environmental conditions such as drought, floods, temporary submergence and soil salinity common in much of the region. The conversion of rainfed land to irrigated ecosystems has also been slow due to the high and rising cost of irrigation, the difficult physical conditions for irrigation development, and growing environmental concerns over irrigation projects.

Thailand, Myanmar, and Cambodia to have considerable excess capacity to meet potential shortages in other countries in South and Southeast Asia. If rice

prices go up due to tightness in the world market, farmers will be encouraged to increase rice production by investing in irrigation and adopting high-yielding varieties. But achieving food security through trade may not be possible due to foreign exchange constraints in low-income, food-deficit countries.

Also, since rice production is a major rural economic activity and land and labor cannot be easily diverted to other economic activities during the monsoon season, the poor would not have the economic capacity to acquire the imported food if rice productivity remains stagnant. Any increase in rice prices would only aggravate the poverty situation in these countries, unless the economic condition of small farmers and the landless improve.

Therefore, Asian countries must continue to focus on technological progress that reduces the cost of production per unit of output, and thereby maintains the profitability of farmers while keeping prices affordable to the urban and the rural poor. The conflicting interests of the rice producers and consumers can only be reconciled by strengthening the infrastructure of science and technology and thereby creating a firm base for cost-reducing technological progress.

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