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THE ASIAN RICE ECONOMY IN TRANSITION

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In the years following World War II there was growing concern about the food problem in Asia. The population was growing at close to 3 % per annum and potential for further expansion of cultivated area was limited. Attention focused on the need to increase the yield of rice, the primary dietary staple. The International Rice Research Institute was established in 1960 with a clear mission (IRRI 1982a).

– *to conduct research on the rice plant, on all phases of rice production, management, distribution and utilization with a view to attaining nutritive and economic advantage or benefit for the people of Asia and other rice-growing areas of the world through improvement in quality and quantity of rice.*

– *to develop and educate promising young scientists from Asia and the other major rice-growing areas of the world along lines connected with or relating to rice production, distribution, and utilization, through resident and joint training programs under the guidance of well-trained and distinguished scientists.*

The work of IRRI and other Asian scientists in developing new rice varieties (and CIMMYT in wheat) coupled with the widespread use of ever-cheaper forms of chemical fertilizer and a rapid expansion in irrigated area, achieved what came to be known as the *green revolution.* And indeed it was a revolution that could be seen with the naked eye as across Asia the traditional tall rice varieties were rapidly replaced by higher yielding

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semi-dwarfs. The impact for consumers was also visible as retail food grain prices fell sharply from their highs in the early 1970s.

The food security achieved by the *green revolution* was but a critical first step in Asia's transition from an agricultural to an industrial society. In the 1960s two thirds of the labor force and one third of the gross domestic product (GDP) for most Asian countries was in agriculture. As those economies grew, agriculture became an ever-smaller portion of the total economy. This is the normal pattern of development. Rice remains the dominant staple in the Asian diet, however, and the most widely grown crop. It contributes one third to one half of agricultural value added and 50 - 80 % of calories consumed by people in much of the region (Hossain and Pingali 1998). Large numbers of poor Asians still cannot afford an adequate diet. But the well-to-do consumers are diversifying their diets and rice-farming households are looking for new sources of income to compensate for low returns to rice production due to the decline in price.

The introduction of new technologies and growth in production continues but at a much slower pace. More than a decade of low and stable world rice prices has led to complacency among policy makers and a slackening of investments in research, irrigation, and other factors that would promote productivity growth in the rice sector. There is concern, particularly in the scientific community, that rice production may not keep pace with the growth in demand due to population, let alone meet the needs of the growing numbers of poor who lack adequate purchasing power.

The comparative advantage in rice production is shifting away from the regions that were the early beneficiaries of the green revolution back to those major river deltas where labor is cheap and water plentiful -- the Mekong, the Ganges-Bramaputra, and potentially the Irradwaddy. Many governments are faced on the one hand with internal pressures to subsidize rice production to maintain food security and on the other hand with external pressures to remove tariff restrictions and liberalize trade.

We describe the transition in the Asian rice economy from several dimensions. We examine in turn:

- the trends and sources of growth in rice production;
- the beneficiaries of technological change and impact on poverty alleviation and negative impacts on environment and health;
- diversification in consumption and production away from rice; and
- the shift in comparative advantage and expanding world rice trade.

We conclude with a discussion of the needs and potential gains from continued investments in rice research and a retrospective look at the reasons for the success of IRRI, "the house that Chandler built."[1]

TRENDS AND SOURCES OF GROWTH IN PRODUCTION AND PRODUCTIVITY

The growth in rice production over more than three decades since the release of the first high yielding rice variety, IR8, in 1966 and the factors explaining that growth are well documented (Barker and Herdt 1985, Pingali and Hossain 1998, Pingali et al., 1997). Today there is general concern in many quarters about the slowdown in rice production growth and the potential implications for food security and poverty alleviation.

How was it possible to achieve a 3 % per annum growth in Asian rice production for more than two decades, a growth rate far exceeding what had ever been previously achieved?

Political imperatives and climatic shocks

In the post-World War II era, the concern of the West regarding the deteriorating food situation in Asia and its implications for political stability was driven to a large

[1]Bob Chandler was a diehard Red Sox fan. But we are sure that he would appreciate this analogy to Yankee Stadium, "the house that (Babe) Ruth built" after he was traded from the Boston Red Sox to the New York Yankees in 1919.

degree by cold-war politics. The Great Game (see Hopkirk, 1991) that had dominated the struggle between Great Britain and Russia for control of Asia in the 19th century was very much alive, albeit in a new format and with a different cast of players. Among the governments of Asia and the West and the international development agencies the priority was clear – *increase cereal grain production in Asia.* A consensus gradually emerged as to how to get the job done as the pieces of the green revolution technology began to fall into place.

Two weather events, which have now come to be known as *Los Niños* (which lead to shortfalls in annual rains throughout much of the world) served to catalyze the commitment to the food security goal. The first of these occurred in the Indian sub-continent in the mid-1960s, where a shortfall in grain production threatened famine. The second occurred as a result of a short-fall in crop production in 1972 leading to a sharp rise in world rice prices (Fig. 1) and forcing Thailand, the world's largest rice exporter to ban exports for several month in 1973.

Technological change

The so-called *green revolution* is most commonly associated with the development of the *modern semi-dwarf varieties* of rice and wheat (MVs). However, two other critical components of the green revolution technology are *fertilizer* and *irrigation.* As with new varieties, so also with these other two factors, there has been a steady stream of technological improvements contributing to rice productivity growth. Because the inputs were highly complementary, efforts to apportion the share of the output growth to each have proved difficult. An analysis by Herdt and Capule (1983) suggested that the MV effect, fertilizer effect, irrigation effect, and other factors (a residual) contributed almost equally to growth in production. Included in "other factors" would be the extraordinary investment of the West in human capital development in Asia. This often overlooked investment helped to provide the policy and institutional changes needed to facilitate the development and spread of the new technology. This would help to account for the speed with which these technologies spread. For example, as discussed in more

detail in the final section of this paper, the importance given to training in agricultural research and extension explains in large part IRRI's success.

Varietal improvement. At the time that IRRI began operations in 1962, no one would have predicted that a breakthrough in rice yield potential could be achieved in just four years. The serendipitous early discovery of the dwarfing gene in the Taiwan collection led to the release in 1966 of the first semi-dwarf variety, IR8. Traditional tall varieties (about waist high) yielded a biomass consisting of 80 % straw and 20 % grain while the grain to straw ratio in the semi-dwarfs (about knee high) was 50/50. These shorter, stiffer strawed varieties gave a higher yield response to fertilizer without lodging at harvest time. Equally important, the new varieties matured in just 120 days or less compared to 150 days for the traditional varieties. The release of IR8 established a yield ceiling in open pollinated rice in the tropics that has lasted to this day.

The susceptibility of IR8 to pests and diseases quickly shifted the emphasis to breeding for resistance. The release of IR36 a decade after IR8 (1976) marked another milestone characterized by the development of the second generation of insect and disease resistant modern varieties. It was estimated in the early 1980s that over 10 million hectares were planted to IR36 (IRRI 1982b). However, this led to concerns that the genetic base of the new varieties was too narrow increasing the downside risk of widespread crop loss in a single year (Evans 1986). The release of IR64 in 1985 with more than 40 land races in its ancestry provided insurance against risk of this nature.

To date drought and the impact of *El Niño* and *La Niña* weather conditions remain the major source of year to year variation in crop production. Breeding for marginal environments with frequent droughts or adverse soil conditions is more complex. There are those who argue that aided by biotechnology the greatest potential for productivity gains (and poverty alleviation) in the future lies in the rain fed environments. Others anticipate that a future breakthrough in the yield ceiling will continue to favor the irrigated areas and that these areas will produce an ever-larger share of the world's rice.

Advances in fertilizer technology. Since the advent of the *green revolution* in the 1960s, chemical fertilizers have had a central place in transforming farm production in Asia. Asian fertilizer consumption has risen from 7 million nutrient (N,P,K) tons in the 1965 to 17 million in 1975, the year of the "fertilizer crisis", to 39 million in 1985 and 69 million in 1995, essentially doubling every ten years. The extraordinary growth in fertilizer consumption, over 7 % per year for three decades, was due to a steady decline in the price of fertilizer (Fig. 2) and learning by farmers about the benefits of fertilizer when used with MVs.

The major factor explaining this reduction in cost has been a stream of discoveries in applied chemistry and mechanical engineering relating to the production of superphosphates, phosphoric acid, and above all ammonia which is converted into nitrogen fertilizer (Tomich et al. 1995). One of the most dramatic developments occurred in 1963 just before the *green revolution.* The shift from piston to centrifugal compressor tripled the optimum plant size for manufacturing urea further dropping the cost of production. Given the speed of technological change, and the sophistication and capital intensive nature of the technology, the developed countries have a comparative advantage in fertilizer production. Some Asian countries, ignoring this fact and seeking to become self sufficient in fertilizer have constructed plants, often with assistance from the developed countries, that were obsolete almost the day they were completed.

Technological advances in irrigation and water management. Technological advances in irrigation can be divided between: (i) those relating to development of surface water or canal irrigation systems largely through public investment and (ii) those relating to the exploitation of groundwater largely through private investment. Prior to World War II Asian irrigation was dominated by so-called run-of-the-river systems by which water was diverted by barrages to provide supplemental irrigation to insure the main wet season crop. Advances in the technology of large dam and reservoir construction in the western United States prior to World War II became the foundation for surface irrigation system development in Asia in the post World War II period. High rice prices justified the substantial investment in large public sector irrigation systems in

the 1970s. But the subsequent decline in rice prices, rising construction costs, and growing opposition of the environmentalists have led to a sharp decline in investments since the mid-1980s (Rosegrant and Pingali, 1994).

By contrast, advances in technology and declining costs have resulted in a continuing rapid expansion of tube wells (and more recently in other micro-irrigation technologies such as sprinkler and trickle irrigation). In India and China, for example, well over half of the total area irrigated is served by tube wells. Farmers, often reluctant to pay irrigation fees for unreliable deliveries of canal irrigation water, are willing to pay full cost for pump irrigation that can facilitate the shifts from rice to higher valued crops. But unregulated expansion of tube wells is leading to a serious overexploitation of groundwater particularly in the semi-arid regions that include two of the major breadbaskets of Asia, the Punjab and the North China Plain.

Growth in production and yield

The growth in rice production and yield is shown in Figure 3 for the *green revolution* years (1967-85) and for the pre- and post-green revolution +-years. Following a rapid growth in production of close to 3 % in the green revolution period, the growth rate declined by almost one half. The considerable variation over time and space in the rate of adoption of the new technology and growth in production is illustrated in Table 1. Insular Southeast Asia, China, and other select regions such as the Indian Punjab were the early beneficiaries of the green revolution technology. By 1980, 50 % or more of the rice area in these regions had been planted to the MVs (Herdt and Capule, 1982). In other parts of Asia including Bangladesh and Eastern India, the adoption has been much more recent and the growth in yields has been more rapid after 1985. Vietnam has shown a strong growth in land area and yields since 1985. Surprisingly, Thailand, the world's largest exporter of rice, has had the lowest rate of MV adoption among all major Asian countries, approximately 15 % in 1995. Yield growth and fertilizer consumption have also been low as Thailand has chosen to expand rice area and continue to grow low yielding but high quality export varieties.

Much of the variation in timing of MV adoption seems to be associated with developments in irrigation and water management. Investments in large irrigation schemes occurred in the 1970s and early 1980s in many parts of Asia and the expansion of the dry season rice area gave a major boost to production. But the shifts in cropping pattern and adoption of irrigation technologies that allowed the delta areas to avoid the low yields associated with deep-water rice and take advantage of more favorable growing seasons came much later.

The area in rice in Asia has remained almost constant since the mid-1980s. The continued expansion of tube well irrigation has resulted in a major portion of new irrigated area being used for crops other than rice. However, the portion of the rice area that is irrigated increased between the late 1970s and the early 1990s from 51 to 56 %. This was the result of a decline in both upland and deep-water acreage, a trend that seems likely to continue (Fig. 4).

What explains the slowdown in growth?

What explains the slower growth in production, area, and yield since 1985? The most obvious cause is the dramatic drop in world rice prices between 1981 and 1985 (Fig. 1). Marking the successful introduction of *green revolution* technologies, supply grew more rapidly than demand. Over the past fifteen years world prices have remained remarkably stable, allaying earlier fears that adoption of the *green revolution* technology would result in greater yield and price variability. A new equilibrium in supply and demand seems to have been reached at a lower price and slower growth rate.

The slower growth is influenced by both supply and demand factors. On the supply side, in many areas of Asia the yield gains from adoption of the new technologies had been almost fully exploited and typically in these areas intensification of rice production has been leading to the overexploitation and degradation of soil and water resources. It is no longer possible to sustain a growth in production at 2.5 to 3 % per

year. In addition, with sharply lower domestic rice prices and rising wage rates farmers have found it far less profitable to produce rice. Simultaneously, the growth in demand for rice was declining due both to a rise in incomes and fall in the rate of population growth. The factors that have contributed to slower growth and the implications for rice research are discussed in more detail in the sections that follow.

PRODUCTIVITY, POVERTY, AND SUSTAINABILITY

The words "poverty alleviation" or "poverty eradication" do not appear in the earlier mission statements of either IRRI or the CGIAR. Yet, there was certainly an implicit belief that success in raising rice production in Asia and increasing farm incomes would have a positive impact on poverty alleviation by averting famine and providing food security for millions of people. Michael Lipton (1989, p. 400) an early critic of the *green revolution* wrote more recently that "if social scientist had in 1950 designed a blueprint for pro-poor agricultural innovation, they would have wanted something like the modern varieties: labor-intensive, risk-reducing, and productive of cheaper, coarser varieties of food staples." Even better would have been a range of modern varieties benefiting less-favored, rain-parched areas. But if initial emphasis had been given to the marginal areas, such emphasis could not have produced enough extra food in the 1960s to avert disaster.

A recent article in the *Economist* states that "the green revolutions tool kit probably saved more than a billion people from starvation" (Economist, March 25-31st, 2000). However, even today, despite convincing evidence to the contrary, a large share of public opinion views the *green revolution* as having made the rich richer and the poor poorer. This fact not withstanding, there are legitimate concerns about the benfits and costs associated with the *green revolution* in the past, and more particularly with future technological change in agriculture. In the next two sections we look at the plus side of the ledger – how the increase in rice productivity has helped the poor. In the third section we discuss the negative impacts of the *green revolution* technology and issues related to sustainability in growth of rice production.

How has the increase in rice productivity helped the poor?

Research that leads to an increase in the productivity of rice contributes to poverty alleviation through pathways that lead to benefits for rice producers, agricultural laborers, and consumers. Initially higher productivity results in higher profits for farmers and more employment particularly for agricultural laborers and for those in farm-related businesses. The early adopters benefited the most because initially the growth in production was too small to affect the rice price. Subsequently as the adoption of new technologies spread and rice prices fell, the farmers with the largest marketed surplus suffered the largest decline in income.

Due to the sheer size of the rice economy and the importance of rice in the Asian diet, productivity gains in rice compared to any other agricultural commodity grown in Asia have the widest potential impact on poverty reduction. The lower prices for consumers are the inevitable result of growth in production that outstrips growth in demand. Lower rice prices for consumers benefit the poor – including urban poor, rural landless, and non-rice farmers – disproportionately because rice makes up as much as 70 % of their total calorie intake. A lower rice price stimulates employment in the industrial and service sectors of the economy drawing labor out of agriculture. For many economies the structural transformation has not been smooth particularly where slow growth in the non-farm sector fails to create sufficient jobs to employ the surplus agricultural labor. However, this transformation in the economy, described in more detail in Section IV, is essential for long-term poverty alleviation.

As the modern varieties spread, initial concerns focused on equity rather than productivity impacts on poverty reduction. Large farmers and landowners were seen to be benefiting at the expense of the small farmers, tenants, and the landless. Over two thirds of the published research on what MVs do to the poor was focused on this issue (Lipton, 1989). There is convincing evidence particularly in the case of rice (where nearly all farms are small) that in those environments where MVs have been widely

adopted, the benefits have accrued to the well-to-do and poor alike (Barker and Herdt, 1985, David and Otsuka, 1994). The poor consumers, for whom rice represents a much larger share of total calorie consumption, often have benefited disproportionately.

The new technology did favor irrigated areas over marginal environments. A study of the effect of modern rice technology on income distribution based on case studies in seven Asian countries concluded that factor and product market adjustments largely counteract the potentially adverse effects of differential modern variety adoption across production environments (David and Otsuka, 1994). For example, either seasonal or permanent labor migration to irrigated areas has been a common phenomenon in Asia.

It is scientifically more difficult to develop varieties for unfavorable production environments. However, a pro-poor strategy must target those unfavorable environments where there is potential for success. This is illustrated by recent gains in production in the river delta areas of Eastern India, Bangladesh, and Vietnam made possible by the introduction of irrigation technology and a change in cropping pattern which allowed a shift from low-yielding deep water rice to MVs. By contrast, there is a general consensus that crops other than rice normally would be better suited to the upland (non-paddy) areas.

Measuring the impact on poverty alleviation

The period from 1965 to 1985 saw a large fall in poverty (as measured by numbers of people below the dollar a day poverty line) based on rising food yields, employment, and public agricultural research effort but all four have stalled since then (Lipton, 1999). The decline in numbers below the dollar-a-day poverty line from 1970 to 1990 is shown for six East and Southeast Asian countries in Table 2. The majority of the poor are in the rural area and it is in these areas that the decline in poverty has been most dramatic.

The decline in percentage of people below the poverty line in South Asia has been equally dramatic. This is best illustrated in a study conducted by Datt and Ravallion (1998a). The research is based on surveys of poverty and consumption conducted periodically by the National Sample Survey for the 15 major states in India spanning the period 1957-58 to 1990-91. The study links the reduction in rural poverty to growth in farm productivity in India. Figure 5 compares the downward trend in the squared poverty gap index (SGP)[2] with the upward trend in yield. There is an 88 % correlation, but there was a considerable lag with the decline in poverty not occurring until after 1975.

In a separate study based on the same data Datt and Ravallion (1998b) identify factors that explain why some Indian states have performed better than others. They conclude that while the trend rate of growth of average farm yields is important, starting endowments of physical infrastructure and human resources – higher irrigation intensity, higher literacy, and lower initial infant mortality - all contribute to higher long-term rates of poverty reduction in rural areas. With the exception of Bihar and Assam, the rice growing states have performed at or above the average in rural poverty reduction.

In contrast to Southeast Asia, the absolute numbers of poor in South Asia are stagnant or continue to grow. For example, the number of rural poor in India in 1994 was still nearly 250 million, essentially unchanged from 1970 despite data showing that the incidence of poverty in rural India has fallen from 55 % to 37 % over the same period (Fan et al., 2000). India exports rice, while large segments of the population still lack the purchasing power to provide an adequate diet. This hidden food gap in cereal grains due to lack of effective demand is projected in one study to reach 160 thousand tons in South Asia in 2020 (Conway, 1997).

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[2] The poverty gap (PG) is the average distance of the population below the poverty line – defined in this study as the level of average per capita expenditure to achieve a nutritional norm of 2400 calories per person per day. For the squared poverty gap (SPG) the distances below the poverty line are squared so that the measure will penalize inequality among the poor

Negative impacts and sustainability

The intensification and rapid growth in rice production has led to a growing number of environmental and health problems and raised questions about our capacity to sustain growth in production for the foreseeable future. Pingali et al., (1997) provide a comprehensive analysis of these problems and their environmental and health impacts.

The various problems affecting sustainability of production were a result of the intensification process imbedded in the *green revolution* technology. The new technology led not only to an increase in yields, but with the development of irrigation made it possible to grow two or three crops of rice where only one had grown before. As the ecology of the rice paddy changed a range of environmental problems emerged gradually over time. Solutions have been found with varying degrees of success but have often proved to be only temporary. A continuing research effort has been needed simply to maintain the yield potentials (so-called maintenance research).

Following the initial release of the MVs there were serious pest and disease problems – most notably the brown plant hopper and tungro virus. This resulted in the development of more insect and disease resistant varieties (e.g. IR36) and in the very successful efforts of the FAO to mount a campaign in integrated pest management - IPM (FAO, 1990). Soil nutrient problems such as zinc and phosphorous deficiencies led to increased research on nutrient balances. Soil degradation and water pollution problems were traced to the increased use of chemicals. Chemicals have also had negative impacts on human health, livestock, and fish culture. Clearly some of the emerging problems or side effects have extended well beyond those related simply to rice cultivation.

One of the most recent and less tractable problems to arise relates to the management of water resources. Until recently most people believed that we would always have enough water to grow food, to drink, and to support industry. However, we need only to be reminded by the current drought in India that many countries are entering

a period of severe water shortage (Seckler et al., 1998, Barker et al., 1999). Many of the water problems such as salinity, waterlogging, and overexploitation of groundwater, are largely confined to the semi-arid regions. However, these regions include two of the major breadbaskets of Asia – the Punjab and the North China Plain – where rice and wheat are commonly grown in rotation. Furthermore, the growing scarcity and competition for water will be pervasive extending well beyond the semi-arid regions and profoundly affecting the way we value and utilize water resources.

A common perception is that in paddy rice production enormous quantities of water are being "wasted." However, the rice plant consumes about the same amount of water as other cereal grains. Much of the water that is "lost" from one farmer's paddy field is used elsewhere, perhaps in the next farmers field, perhaps as return flow, or through groundwater extraction further down the basin.

This fact not withstanding, most irrigation systems in monsoon Asia have been poorly designed, managed, and maintained (Pingali et al., 1998). Through better management practices at farm and system level, there appears to be ample scope for increasing the productivity of water (Guerra et al., 1998). There is growing research interest in *integrated water resource management* (IWRM) which focuses on allocation of scarce water resources at the basin level among competing uses – irrigation, municipal, industrial, hydropower generation, and environment. IWMI research is also concerned with the competing and complementary relationship between canal and groundwater development in the basin. IRRI and the International Water Management Institute (IWMI) are currently working with colleagues at a site in China to determine how the Chinese have been able to reduce the allocation of water to irrigation from the main reservoir from 70 to 30 % without reducing rice output.

Another piece of the water puzzle relates to the development of technologies and water management practices for the rain fed and drought prone areas largely untouched by the *green revolution.* This includes a combination of breeding for drought tolerance and managing limited water supplies to be sure that adequate water is available at critical

stages of growth such as flowering. Scientists disagree as to the potential gains that can be achieved from research on the unfavorable environments. Pingali et al., (1997) suggest that a pro-poor research prioritization should partition IRRI research resources 50/50 between the irrigated lowland environments and less-favorable rice growing environments.

In summary, the gradual emergence and recognition of problems related to the intensification of rice production has broadened the research agenda of IRRI and other research institutes. Maintenance research to insure the *sustainability* in rice production to meet future demands is a continuing process that extends beyond initial focus on higher yields and productivity to assess the potential impact of productivity gains on environment and health and on poverty alleviation.

AGRICULTURE AND STRUCTURAL TRANSFORMATION

All countries are striving for a successful transformation - the gradual evolution of an economy from one based primarily on agriculture to one in which the large majority of labor and output is in the industrial and service sectors (Timmer, 1997). Diversification and commercialization of agricultural systems are part and parcel of the process of transformation. But for such a transformation to take place there must initially be a rise in agricultural productivity to generate food surpluses and free up labor and other resources needed to support growth in the non-agricultural sector. Whether through the improvement in rice production following the Mejii restoration (1888) in Japan, the introduction of high yielding Ponlai varieties in Taiwan in the 1920s, or the spread of the *green revolution* technology in South and Southeast Asia in the 1960s and 70s, the starting point has been much the same. That is to say, for most Asian economies the initial step in this transformation has been an increase in land and labor productivity in the production of rice.

This structural transformation in the Asian economies is depicted in Table 3. Over the past 30 years the share of GDP and the percentage of the labor force in agriculture have been declining, more rapidly in some countries such as South Korea, Taiwan, Indonesia, Malaysia, and Thailand, more slowly in others such as the Philippines and Sri Lanka. Due to the slow absorption of labor into the non-farm sectors in these later two countries, a substantial portion of the labor force has looked overseas for work and remittances have become a significant foreign exchange earner and source of household income.

For most Asian countries in the 1990s, GDP in agriculture was 25 % of total GDP, but 50 % or more of the labor force remains in agriculture. The two or three to one ratio of labor force to GDP in agriculture shows that labor productivity is higher in the non-agricultural sector, and that labor will continue to be pulled toward the more productive non-agricultural sector.

It is somewhat of a paradox that the success in increasing rice productivity leads not only to further changes in production practices but to a gradual decline in the importance of rice in both consumption and as a source of farm household income. This is accompanied by both diversification of consumption and production, and the move from a largely subsistence to a commercial or market oriented agriculture.

The demographic transition

Historically, structural transformation has been accompanied by *demographic transition* (Tomich et al., 1995). In the first phase of the transition mortality rates decline but fertility remains high and the rate of population growth rises significantly. In the second phase rapid population growth ends as population growth declines to levels nearer the greatly reduced mortality rate.

Table 4 shows the trend in annual growth in population for East Asia, South East Asia, South Asia, China and India for three time periods. Although the decline has been

most dramatic in China, clearly South and Southeast Asia are rapidly entering the second stage of the demographic transition. Due to the downward trend in population growth and rising incomes, we can expect the growth in demand for rice to decline. However, the growth in the labor force will remain high in the immediate future and finding gainful employment for this expanding workforce will be the major concern of most governments. The greatest pressure will occur in South Asia, where as noted in the previous section the number of people below the poverty line will continue to grow.

Changes in food-consumption patterns

There is an inherent desire for diversity in dietary patterns among most populations of the world. For many of the poor in Asia, rice remains the priority in the diet composing 70 % or more or the calories supplied. But as incomes rise the proportion of rice in the diet declines giving way initially to wheat and more gradually to consumption of livestock and other products. For most of Asia this means a growing level of imports and the challenge is to find agricultural exports to offset this import bill.

In Table 5 countries have been ranked according to the percentage decline in rice as a portion of the calories supplied in the diet from between 1965 and 1995. The rate of decline is clearly associated with the rate of economic growth with Myanmar experiencing no decline at all and at the other extreme Japan experiencing a decline of 50 %.

Changes in farming practices

Earlier we indicated how the spread of the semi-dwarf high yielding varieties had brought a visible change in the paddy fields. More visible changes have followed. As the rate of growth in yield has declined, the demand for labor in the non-agricultural sector has grown. The growth in labor productivity, due initially to the increase in rice crop yields is now being achieved largely through adoption of labor saving technology. Table 6 shows the change in man days of labor for rice production in a survey of Central Luzon farms. Between 1966 and 1979 labor input increased as more labor was needed for crop

care activities and for the harvesting of the increase in rice production. After 1979 labor input declined and this decline can be expected to continue.

This rising and then falling trend in labor input reflects the fact that in the early stages of the agricultural transition in Asia labor was in surplus. The *green revolution* technologies created jobs by increasing the labor requirements for a single crop, by making it possible in many areas to grow two crops of rice, and by generating employment off the farm in a host of farm and non-farm related activities. As the transition proceeds and the demand for labor in the non-farm sector grows, wage rates rise and there is a growing demand at the farm level for labor-saving technologies. With more than 50 % of the total labor force still in agriculture, there is the danger that the adoption of labor saving technologies may move faster than the ability of the non-farm sector to absorb labor. The temporary set back in demand for non-farm labor as a consequence of the Asian financial crisis in 1998 illustrates this point. Lipton (1999) cautions that the top priority for anti-poverty research should be to raise yields in ways that substantially raise the demand for labor. Attempts to save labor with research into direct seeding, mechanical rice transplanters, weedicide screening, and mechanical threshing are conducive to despair as a use of aid funds in Asian research centers. The issue is largely a matter of timing. As economies grow, the point is reached where there is no longer a surplus but a shortage of labor in the agricultural sector.

The speed of adoption of these labor-saving technologies has varied by region, but the unmistakable trend is marked by the gradual disappearance in many regions of practices and techniques that have been used for centuries in the production of paddy rice. The tractor is replacing the water buffalo for land preparation; direct seeding of rice is replacing transplanting; herbicides are replacing hand weeding; the mechanical thresher is replacing traditional hand threshing of paddy.

Indeed, the traditional Philippine song: "planting rice is never fun, work from morn to setting sun; cannot stand, cannot sit, cannot rest for a little bit", seems to have been a harbinger of things to come. While the youth no longer look to rice farming as a

way of life, those left behind to tend the paddy fields are adopting new practices to lighten the burden and increase the productivity of their labors.

Change in source of rural household incomes

While rice is becoming a smaller part of the total economy, for rice farmers it also is becoming a smaller share of household income. The study by Hayami and Kikuchi (2000) of a Laguna, Philippines village over three decades documents the direction of this change (Fig. 6). The share of income from rice fell from 50 % in the 1970s to 15 % in the 1990s. The share of income from other farm activities fell, but more gradually, and by the 1980s it exceeded income from rice. The income from non-farm activities rose from 10 % to over 60 %.

Surveys identifying sources of household income were conducted in six villages in two locations in Thailand in 1987 and 1994 (Isvilanonda and Hossain, 1998) and in four villages in the Philippines in 1985 and 1997 (Marciano, Gascon, Cabrera, and Hossain, 2000). The villages represented three rice growing ecosystems – irrigated, rain fed, and upland. The results are summarized in Table 7. Despite the shorter period of time, the pattern is much the same as in the Laguna village. The importance of rice as a source of household income declines and non-farm income increases in all three rice-growing environments.

One needs to be cautious about generalizing from these village case studies particularly as regards the speed and magnitude of change. For example, the location of the village will have much to do with opportunities for non-farm employment. A sample survey was conducted in Bangladesh consisting of 1245 rural households in 1988 and 1316 rural households in 1995 (Hossain, 1998). The pattern of change was similar but more gradual with the share of income from rice falling from 28 to 24 % and the share of income from non-agricultural activities rising from 37 to 46 %.

Diversification in the agricultural sector

Successful agricultural development requires the diversification of agriculture away from the staple crops such as rice for which demand gradually declines. For smaller countries diversification must be associated with the development of export markets. Diversification of agriculture can occur at the farm level, or in the agricultural sector as a whole, with different regions of a country specializing in different crops.

By and large in Asia the diversification of rice farms to crops other than rice has been difficult. This is because the surface irrigation systems have been designed and managed to provide adequate supply water for rice but not to provide water when needed for non-rice crops. The systems are said to be "supply" rather than "demand" driven. A notable exception has been Taiwan (Levine et al., forthcoming). Here, the irrigated area remained fairly constant from the mid-1960s to the mid-1980s. But during this period the area in rice and sugar cane fell by almost 50 % and was replaced by fruits, vegetables, and feed grains allowing the value of agricultural production to continue to rise and the value of exports – including livestock – to contribute significantly to foreign exchange earnings. The ability of farmers to make these crop adjustments was due in large measure to the major government investments in land consolidation and in irrigation and drainage infrastructure during the 1950s and 60s that allowed water to be rotated at the 10- hectare level. Many Chinese irrigation systems have been designed with the same high degree of infrastructure articulation and of water control and management needed to facilitate diversification from paddy to other crops.

But for much of the rest of Asia, diversification of irrigated agriculture is largely occurring through private farmer investment in tube wells and more recently in micro irrigation systems such as sprinklers, surge, and trickle irrigation. As noted earlier, groundwater irrigation has been growing more rapidly than surface irrigation in a number of countries and the cost of these micro-irrigation technologies has been falling rapidly. Large sections of the new irrigated area are not being cropped with rice. The initial

exploitation (and now overexploitation) of groundwater occurred largely in the semi-arid regions but is now gradually spreading to the monsoon areas.

Several Asian countries have been successful in developing non-irrigated crops for export. Following an initial success in development of rubber exports, Malaysia in the 1970s and 80s captured 80 % of the world's palm oil market. While Thailand remains the world's largest rice exporter they successfully developed export markets in cassava, maize, and sugar. Vietnam has become the world's second largest exporter of rice, but also the fourth largest exporter of coffee.

THE WORLD RICE MARKET, CHANGING COMPARATIVE ADVANTAGE, AND DOMESTIC RICE POLICIES

High and unstable world rice prices in the 1960s and 70s provided a major incentive in Asian importing countries to adopt *green revolution* technology and strive for rice-self sufficiency. Major investments in irrigation gave those countries and regions outside of the major river deltas of Asia at least a temporary comparative advantage in producing rice. For political reasons the collapse of exports from Burma, Cambodia, and Vietnam added further uncertainty to the world market. But the successful adoption of the new technologies and the growth and maturation of the Asian rice economies has dramatically changed the picture.

The world rice market

The opening of the Suez canal in 1856 promoted the development of rice exports from the major river deltas of Southeast Asia – the Irrawaddy, Chao Phia, and Mekong. The dominance of Burma, Thailand, and Indochina in the world rice trade continued until after World War II providing a major source of foreign exchange earnings for these countries. Rice exports remained small as a portion of total production – 3 to 5 %. After World War II rice exports to South and Southeast Asia rose to exceed more than half of the total. Through the 1950s to the mid-1960s rice export prices remained stable. The

withdrawal of Burma, Cambodia, and Vietnam from the export market and shift in policies in Thailand and the rice importers led to wide fluctuations in world prices. The rice importers adopted policies to stabilize their domestic prices thus shifting instability to the world market. Between 1961 and 1980, the coefficient of variation in world rice prices was 30 % while the coefficient of variation for domestic rice prices in most Asian countries was less than half of that (Siamwalla and Haykin, 1983).

A combination of factors led to a surge in per capita rice production (Fig. 7) between 1981 and 1985. This resulted in the sudden plunge in world rice prices to less than 50 % of their previous levels (Fig. 1). One might ask why the steady upward trend in per capita production prior to the early 1980s had not led to a much earlier decline in world prices. The most likely reason is that Asian countries were much poorer in this earlier period, which meant that income elasticity of demand was still positive. Thus, growth in rice production had to keep pace not only with population growth, but also with income growth. Increases in per capita production were necessary to keep world prices constant in real terms. As the economies have grown, population growth has been declining (Table 4) and the proportion of rice in diets also is declining (Table 5). Future growth in demand is projected to be roughly equal to the now lower rate of population growth (Rosegrant et al. 1995).

For the last 15 years world rice prices have remained low and relatively stable. The greater importance of irrigation in rice production and improved pest and disease resistance in modern varieties has tended to reduce variability in production per capita. The re-emergence and strengthening of the commercial orientation of major rice exporting nations and the move toward freer trade and increasing integration will improve the performance of the world rice market. In addition to Thailand and Vietnam, with luck Cambodia and Myanmar (Burma) may emerge to become important players once again in the near future.

Finally, between 1995 and 1999 there has been a sharp increase in world market rice exports (Fig. 8). The average world export in 1990-94 was 14.3 million metric tons,

and in 1995-99 22.5 million metric tons. Although there has been a steady growth in demand for exports in Africa and Latin America, this sudden spurt is due to a doubling of demand in OPEC countries and tripling of demand among Asian importers – largely due to shortfalls in production in Indonesia and the Philippines in 1998. Whether or not this volume of trade will be maintained or continue to grow will depend on the continuing growth in demand outside of Asia, and upon the decision of Asian importers regarding the level of protection to provide to domestic rice production.

Comparative advantage

The introduction of new technology increased the comparative advantage in rice production for many of the Asian importing countries. Asia's total imports of rice declined from an average 4.5 million metric tons in 1965-75 to approximately 3 million metric tons in 1985-95. In the former period Asian exports represented approximately half of world exports while in the latter period they represented only 25 %. More recently Asian imports have once again been on the rise, but it remains to be seen whether this trend will continue.

Since the early 1980s many Asian importers have begun to lose their comparative advantage. Recent studies of economic comparative advantage have been conducted in the Philippines (Estudillo et al., 1999) and in Sri Lanka (Kikuchi et al., forthcoming). In both studies there has been an upward trend since the 1980s in domestic costs of rice production, due largely to an increase in wage rates. The domestic cost of production per metric ton of rice has risen above the level of the cost of importing a ton of rice. For these countries the benefit-cost ratios no longer justify the investment in new irrigation facilities on economic grounds.

By contrast, comparative advantage in the deltas, which include the traditional exporting countries, has been strengthened. Recent improvements in water management and the development of groundwater have facilitated the introduction of *green revolution* technology and accelerated growth in rice yields in Vietnam, Bangladesh, and West

Bengal. Due to low wage rates, reflecting the lack of demand for non-farm labor, and plentiful water, the deltas will maintain a strong comparative advantage in rice production for the foreseeable future.

Domestic rice policies

Domestic rice policymakers face two decisions – at what level to set the domestic rice price and how to insure price stability. Setting the level of the domestic rice price became a more difficult political issue when world rice prices fell substantially in the middle of the 1980s. The more developed Asian rice producing countries have all made essentially the same choice in recent years: keep domestic prices above world rice prices. Japan and Korea currently have very high nominal rates of protection, and provide the most dramatic examples of this choice (Table 8). This choice may have been due in large part to substantial appreciation of the national currency (the yen and won), since higher real domestic rice prices have been only a minor contributor to higher nominal rates of protection (Timmer, 1993). Thus, whether other countries follow the path of high protection taken by Japan and Korea may depend on what happens in the future to world rice prices and exchange rates.

It is not clear how this conflict between high protection for rice and increased trade liberalization will be resolved. While the Uruguay Round of the GATT was a major milestone for international agricultural trade, no Asian rice producers have yet made major binding international commitments in the direction of allowing equilibration between world and domestic prices. Perhaps the most significant commitments have been made under the ASEAN Free Trade Agreement (AFTA). Indonesia and Malaysia have agreed to end non-tariff barriers (NTBs) on rice by 2010 with a maximum tariff of 20% for intra-ASEAN trade. The Philippines has also agreed to the removal of NTBs by that date, but with an as yet unspecified maximum tariff. These agreements could have major effects on rice producers and consumers in those countries, especially since the world's two leading rice exporters (Thailand and Vietnam) are members of ASEAN. Yet there remain safeguard provisions whose effects could in principle be quite important. Large

domestic protection for the traditional Asian rice importers would retard the development of a vibrant international market for rice.

Ensuring domestic rice price stability has become an easier task in the past decade for at least two reasons. First, world rice prices were more stable during the past 15 years than they were from 1965-1980. In fact, world rice prices were more stable than world wheat and maize prices from 1985-1999, which was not true in the earlier era when the world rice market gained a reputation for severe instability. Second, even after accounting for the setback due to the recent economic crisis, most countries in the region have experienced significant economic growth and structural transformation during the past 30 years. As a result, the importance of rice to consumers, producers, and the macroeconomy is correspondingly less.

Nevertheless, rice price instability will not go away as a problem in the eyes of policymakers. For one, with the increased liberalization of financial markets, free trade in rice would expose consumers and producers not only to instability on world rice markets, but also exchange rate instability. More important, there are still many poor consumers and farmers for whom rice still constitutes a substantial share of their expenditures (for net buyers) or income (for net sellers). Large sudden price movements will profoundly affect the effective purchasing power of these poor individuals, and there is a legitimate role for government to smooth such fluctuations.

PROJECTIONS AND REFLECTIONS

Asia's transition from an agricultural to an industrial society is well advanced. Despite the setback caused by the Asian financial crisis in 1998, economic development and the structural transformation appear to be back on course. Growth in agriculture has supported industrial growth. Incomes have risen and population growth rates have declined accompanied by a gradual decline in per capita demand for rice. There have been significant gains in poverty reduction. Rice prices have been low and stable for more than a decade. The declining budgets for research suggest that many donors are

asking why they should continue to invest in rice research. This is a reasonable question and one deserving serious consideration.

Why continue investing in rice research and related technological developments?

The short answer to this question is *sustainability* and *poverty reduction.* As noted in section III, the intensification of rice production and rapid growth in output has been achieved at a significant cost in terms of environmental degradation and pollution. The engine of agricultural growth has slowed or stalled. How much of this is due to declining prices, to the near full exploitation of existing technological potential, or to the environmental degradation? For example, what will be the impact of overexploitation of groundwater and falling water tables in the Punjab and North China Plain on Asian food supplies? We don't know the answer to questions such as this. But we face a Catch 22 (see Heller, 1962). At today's low world food grain prices, it doesn't seem to pay to invest in research and development that will lead to sustainable gains in productivity in the future. But given the long gestation period for most research and development efforts, failure to invest could lead to higher food prices and even erase some of the gains in poverty reduction achieved in the past.

A second, more compelling and challenging reason for investing in research and development relates to the need to extend productivity gains and poverty reduction to those segments of Asian society and the rest of the developing world who have not benefited from the *green revolution.* The projected number of people in South Asia who cannot afford an adequate diet will still be large for the foreseeable future. Under the baseline assumptions of IFPRI's IMPACT model, which projects a slight decline in world rice prices by 2020, there will still be more than 50 million malnourished children below the age of six in India and Bangladesh at that time, accounting for nearly half the population in that age cohort (Rosegrant et al., 1995). If world prices were to rise, the situation would be much worse. If we ignore this issue than a large segment of Asian society will fail to participate in economic growth.

We emphasize that reduction in poverty will be achieved in the future as it has in the past by sustained growth in agricultural productivity. In CGIAR circles where "poverty eradication" is now the main theme, this point seems to be poorly understood. Lipton (1999), referring to what he calls "mission creep" in the CGIAR, reports that investments to increase productivity fell from 74 % in 1972-76 to 39 % in 1997-98.

What are the prospects for further gains in rice productivity?

Major advances in varietal improvement designed to break the yield ceiling established by IR8 include a new plant architecture and the development of hybrid rice that is adaptable to the tropics (Dawe, 1998). Compared to current modern varieties, the new plant type (sometimes referred to as 'super rice') will have fewer tillers but these tillers will have longer panicles bearing more grains, plus sturdier stems and deeper roots to support the increased grain weight. The grain bearing panicles will also sit lower relative to the tops of the leaves to reduce shading and enhance photosynthetic activity.

Hybrid rice will give a yield advantage of about 15 to 20 % over inbred lines. Hybrids have been grown for twenty years in China and until recently covered half of China's rice growing area. It appeared that hybrids were poised to spread rapidly in India, but consumers have regarded the quality as inferior to popular inbred lines and the price has been discounted by over 10 % (Janaiah and Hossain, 2000).

Whether the above technologies will have a major impact on production and productivity is uncertain. However, biotechnology – tissue culture, gene mapping, gene transfer etc. - has now become an important avenue for advances in plant breeding. Owing to the advent of molecular mapping and the ability to scan the genomes of wild species for new and useful genes, we may now be in a position to unlock the genetic potential of these germplasm resources (Tanksley and McCouch. 1997). In the case of rice, for example, exotic germplasm is a likely source of new and valuable genes capable of increasing yield and other complex traits important to agriculture.

However, the ability to capture intellectual property rights has led to rapid private sector investments in biotechnology and in some instances a virtual buy-out of public-sector research capacity at the universities. The concern is that the priorities of the private firms are likely to draw funding away from important crop improvement work that would benefit the developing countries and in particular the poorer segments of these economies.

The Rockefeller Foundation over the past fifteen years has been supporting biotechnology research on rice by over 50 researchers from advanced and developing countries. They and other interested researchers have met every 18-24 months to review progress, exchange experiences, and make arrangements for training opportunities in one another's facilities. Over 400 scientists from developing countries have been trained at the PhD or Post Doctoral level in this effort. The recent development of varieties fortified by vitamin A and iron demonstrate the potential of such work not only in the traditional lines of improving yields, insect and disease resistance etc. but also in nutrition and health. Hopefully the Foundation's program will insure that support for research in rice biotechnology will remain a public sector priority.

As a result of the growing scarcity and competition for water and the persistent poverty in drought prone areas, more research is needed that ties together management of scarce water resources, agronomic practices, and development and selection of suitable rice varieties. New technology and management practices are needed to increase rice productivity in many of the water-stressed areas by-passed by the *green revolution.*

Reflections on the legacy of Bob Chandler

In this final section of the paper we would like to reflect briefly on the role of IRRI and the course set by its first director in helping to build the foundation for rice research in Asia. Most of us associate IRRI with the development of the semi-dwarf or modern varieties (MV) of rice. But by the time IRRI was established much progress had

already been made in this direction. We knew about the progress being made in developing modern wheat varieties. We were less aware of the fact that the Chinese were developing their own semi-dwarf varieties. The new technology was just around the corner, which explains why in just four short years IRRI was able to release IR8 or as the saying goes "get to first base". While not minimizing IRRI's role in technology development, we would like to suggest that much of IRRI's success and unique contribution was in the development of trained man power that built a research and extension foundation in the national programs and enabled the rapid dissemination of the new technologies.

IRRI was established initially for twenty five years. A major objective was not only to solve the then current food problem but *to develop capacity in rice research to allow developing countries to solve their own problems.* This would require a major effort in manpower training at all levels from hands-on extension to PhDs. The founding fathers from the Ford and Rockefeller Foundation decided to locate IRRI in Los Banos knowing that both the Foundations were supporting major programs to strengthen agricultural research at the University of the Philippines College of Agriculture (UPCA) in Los Banos. The Ford Foundation's contribution was through a ten-year grant to the University of the Philippines and Cornell University (1962-1972) to develop an exchange program to strengthen graduate training (Turk, 1974).

What emerged was a *de facto* joint-venture between IRRI and the University of the Philippines at Los Banos (UPLB –formerly UPCA). UPLB graduates formed the foundation of IRRI's excellent research support staff. Early emphasis was given to training at all levels. IRRI staff served as members of graduate student committees at UPLB and helped to supervise their research and some IRRI staff taught courses at the University. Other graduate students did thesis research at IRRI receiving their degrees from universities in other countries. The number of trainees at IRRI is summarized in Table 9. The impact on the development and dissemination of new rice technology has been enormous.

Those who remember with a sense of nostalgia IRRI, Los Banos and the paddy fields of Asia during the Chandler days will be shocked and perhaps a little dismayed at the changes that have taken place. One is reminded of the words of the famous American author, Thomas Wolfe (1940), "you can't go home again.... back home to the old forms and systems of things which once seemed everlasting but which are changing all the time." IRRI has, of course, played an important role in bringing about these changes. The process of transformation described in this paper extends well beyond the paddy fields. Gains in agricultural productivity have supported wider economic development.

But rice remains the single most important crop in Asia, and continued advances in rice research will bring benefits to millions, particularly the poorer segments of Asian society.

Fortunately, the research foundation is strong. Today it is impossible to go anywhere in the rice-growing world and not find people that have been to Los Banos. In short, the house that Chandler built has rooms all over the rice-growing world. This is the legacy of Bob Chandler.

Table 1 **Average Annual Compound Growth in Rice Area, Yield and Production for Asia and Selected Countries or Regions 1966-85 and 1985-1998**

		1966-85	1985-98
Asia	Area	0.6	0.4
	Yield	2.3	1.2
	Production	2.8	1.6
Early Adopters			
China	Area	0.3	-0.3
	Yield	2.9	1.3
	Production	3.1	1.0
Indonesia	Area	1.3	1.1
	Yield	3.9	0.7
	Production	5.3	1.8
Philippines	Area	0.2	0.7
	Yield	3.5	1.2
	Production	3.6	1.8
Punjab (India)	Area	9.5	2.3
	Yield	4.9	0.4
	Production	14.8	2.6
Late Adopters			
Bangladesh	Area	0.4	-0.1
	Yield	1.4	2.0
	Production	1.8	1.9
Vietnam	Area	0.9	1.9
	Yield	2.3	2.6
	Production	3.2	4.6
West Bengal (India)	Area	0.5	1.1
	Yield	1.7	2.8
	Production	2.1	3.9
Low Adopter			
Thailand	Area	1.7	0.4
	Yield	0.7	0.8
	Production	2.5	1.2

For India States, Growth Rates are for 1985-96 period

Source: IRRI, World Rice Statistics

Table 2 Absolute poverty 1970-90 for selected countries

		Number of absolute poor (millions)			Incidence of poverty		
		1970	1980	1990	1970	1980	1990
China	Total	275	220	100	33	29	9
	Rural	267	211	95	39		11
	Urban	8	9	5	5		2
% poor in rural areas					97	96	95
Indonesia	Total	70	42	27	60	29	15
	Rural	56	33	18	58	28	14
	Urban	14	9	9	73	29	17
% poor in rural areas					82	80	66
Korea	Total	7	4	2	23	10	5
	Rural	6	1.5	0.4	28	9	4
	Urban	1	2.5	1.6	16	10	5
% poor in rural areas					84	37	20
Malaysia	Total	2	1	0.4	18	9	2
	Rural	1.7	0.9	0.3	21		4
	Urban	0.3	0.1	0.1	10		1
% poor in rural areas					85	85	85
Philippines	Total	13	14	13	35	30	21
	Rural	11	11	10	42	35	27
	Urban	2	3	3	20	18	11
% poor in rural areas					85	75	77
Thailand	Total	9.5	7.9	9	27	17	16
	Rural	9	7.4	8.5	30	19	20
	Urban	0.5	0.5	0.5	9	5	4
% poor in rural areas					94	94	94
Six countries	Total	377	289	152	35	23	10
	Rural	351	265	132	40	27	12
	Urban	26	24	20	13	9	5
% poor in rural areas					93	92	87

Source: Lipton, 1999

Table 3 Percent GDP and Labor Force in Agriculture – 1960s and 1990s

	Percent GDP in Agriculture		Percent Labor Force in Agriculture	
	1960s	**1990s**	**1960s**	**1990s**
East Asia				
China	40	21	82	70
South Korea	37	7	66	18
Taiwan	28	3	56	10
Southeast Asia				
Indonesia	54	17	75	57
Malaysia	30	13	60	25
Philippines	26	22	62	43
Thailand	40	11	84	64
Vietnam	-	40	-	70
South Asia				
Bangladesh	53	31	86	61
India	47	26	75	62
Sri Lanka	28	23	56	47

Source: World Bank, World Development Report, Various Issues and Council of Agriculture, Taiwan

Table 4 Annual Population Growth (%) in Asia 1965-70 and 1990-95

Country	1965-70	1990-95
East Asia	2.5	1.2
South East Asia	2.5	1.7
South Asia	2.4	1.9
China	2.6	1.1
India	2.3	1.8

Source: FAOSTAT Database

Table 5 **Change in Percentage of Calories from Rice in Total Percapita Calorie Supply for Asian Countries ranked by Percent change from 1965 to 1995**

Country	1965	1995	Change	% Change
Asia	38	33	-4	-12
Japan	42	23	-19	-45
Malaysia	49	31	-19	-38
South Korea	51	34	-17	-33
Thailand	69	47	-23	-33
Philippines	44	38	-6	-13
China	37	34	-4	-10
Sri Lanka	43	39	-4	-9
Vietnam	72	68	-5	-6
Bangladesh	76	73	-3	-4
Nepal	37	37	-1	-2
Cambodia	76	76	0	0
India	33	33	0	1
Myanmar	73	76	3	4
Indonesia	47	51	4	8

Source: IRRI, World Rice Statistics

Table 6 **Labor input in Rice Production (man days/ha) Central Luzon, Wet season 1966-98**

	1966	1970	1979	1986	1990	1994	1998
Pre-harvest labor	40	53	49	52	40	40	34
Family	21	32	22	14	14	13	9
Hired	19	21	27	28	26	27	25
Harvesting-threshing labor	20	21	28	19	29	28	25
Family	2	3	2	1	5	6	4
Hired	18	18	26	18	24	22	21
Total	60	74	77	61	69	68	59
Family	23	35	24	15	19	19	13
Hired	37	39	53	46	50	49	46

Source: 1966-94 Estudillo, et al.; 1998 update from latest IRRI survey.

Table 7 **Change in Percent Income from Rice, Other Farming, and Non-farm Selected Villages in Thailand and Philippines**

	Irrigated		Rainfed		Upland	
Philippines	1985	1997	1985	1997	1985	1997
Rice	42	29	55	41	25	17
Other farming	18	6	26	10	42	22
Non-farm	40	65	19	49	33	61
Thailand -	1987	1995	1987	1995	1987	1995
Suphan Buri						
Rice	56	21	53	17	53	27
Other farming	36	31	27	18	8	36
Non-farm	8	48	20	65	39	37
Khon Kaen						
Rice	46	8	28	8	30	19
Other farming	10	5	14	7	19	32
Non-farm	44	87	58	85	51	49

Source: Philippines – Marciano et al., 2000
Thailand – Isvilanonda and Hossain, 1998

Table 8 Nominal Protection Rate for Rice in Nine Asian Countries

Country	1960-70	1970-80	1980-88	1988-95
Japan	70	148	443	496
South Korea	17	65	243	431
Taiwan	-12	6	101	246
Philippines	31	-3	6	39
Bangladesh	68	51	32	18
Indonesia		3	27	18
Sri Lanka	36	42	-4	8
Thailand	-28	-28	11	5
India	19	-5	-3	-17

Source: David and Huang (1996), and IRRI, World Rice Statistics

Table 9 Short term Group Training Degree and Non-degree Training at IRRI, 1962 to 1999

- **Short-term Group Training**

Total No. of trainees from 1962 – 1999	5,823

- **Degree and Non-degree Training (1962-1999)**

Completed:	PhD	345
	MS	569
	OJT/Interns	1114
Affiliate Scholars:		
	PhD	135
	MS	81
	Total	2244

Figure 1 Real World Rice Prices (100Bs, FOB Bangkok)

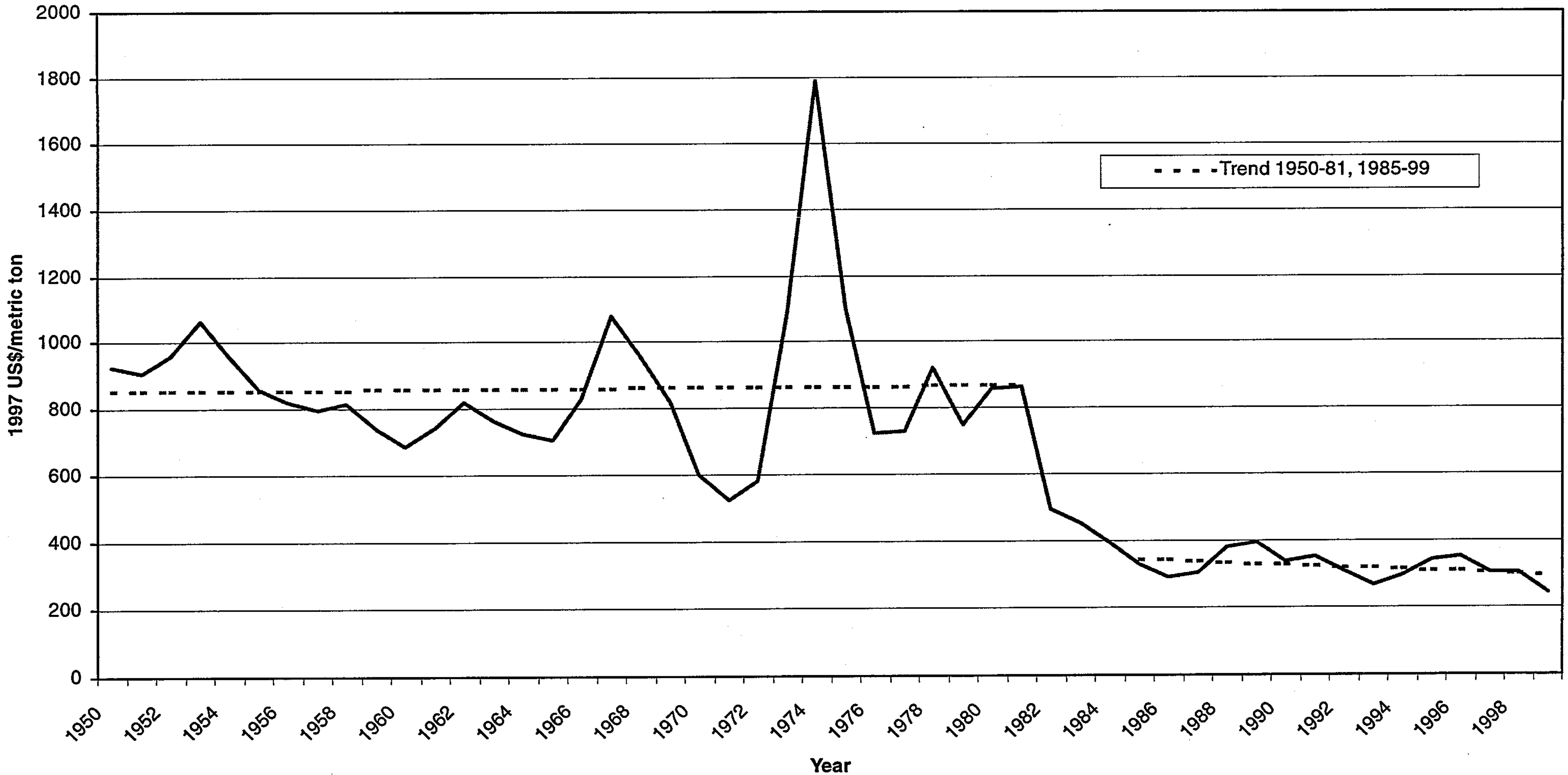


Figure 2 Relationship betwen World Price of Urea and Total Fertilizer Consumption in Asia

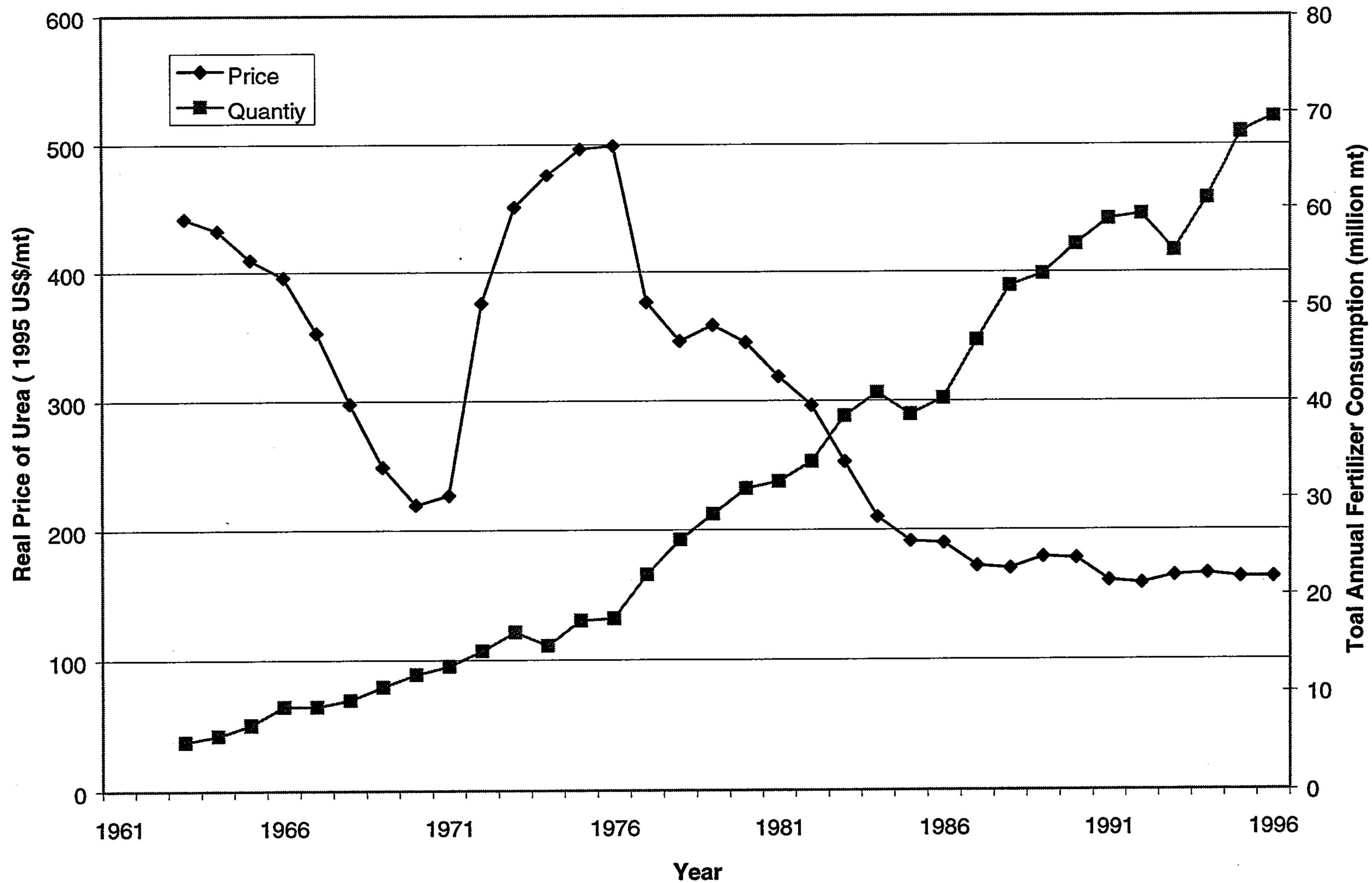


Figure 3 Changes by Area and Yield Towards Production Growth in Asia

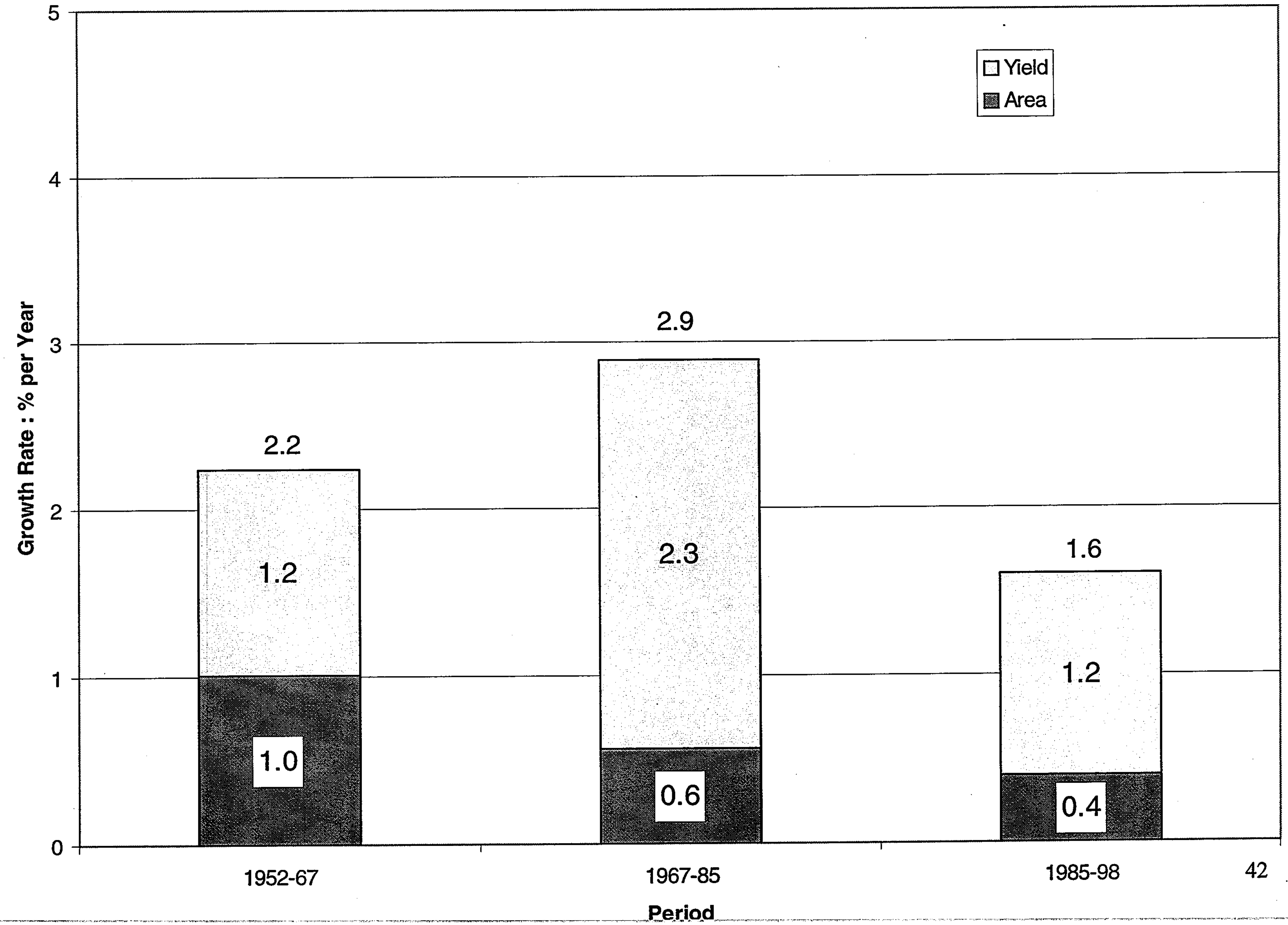
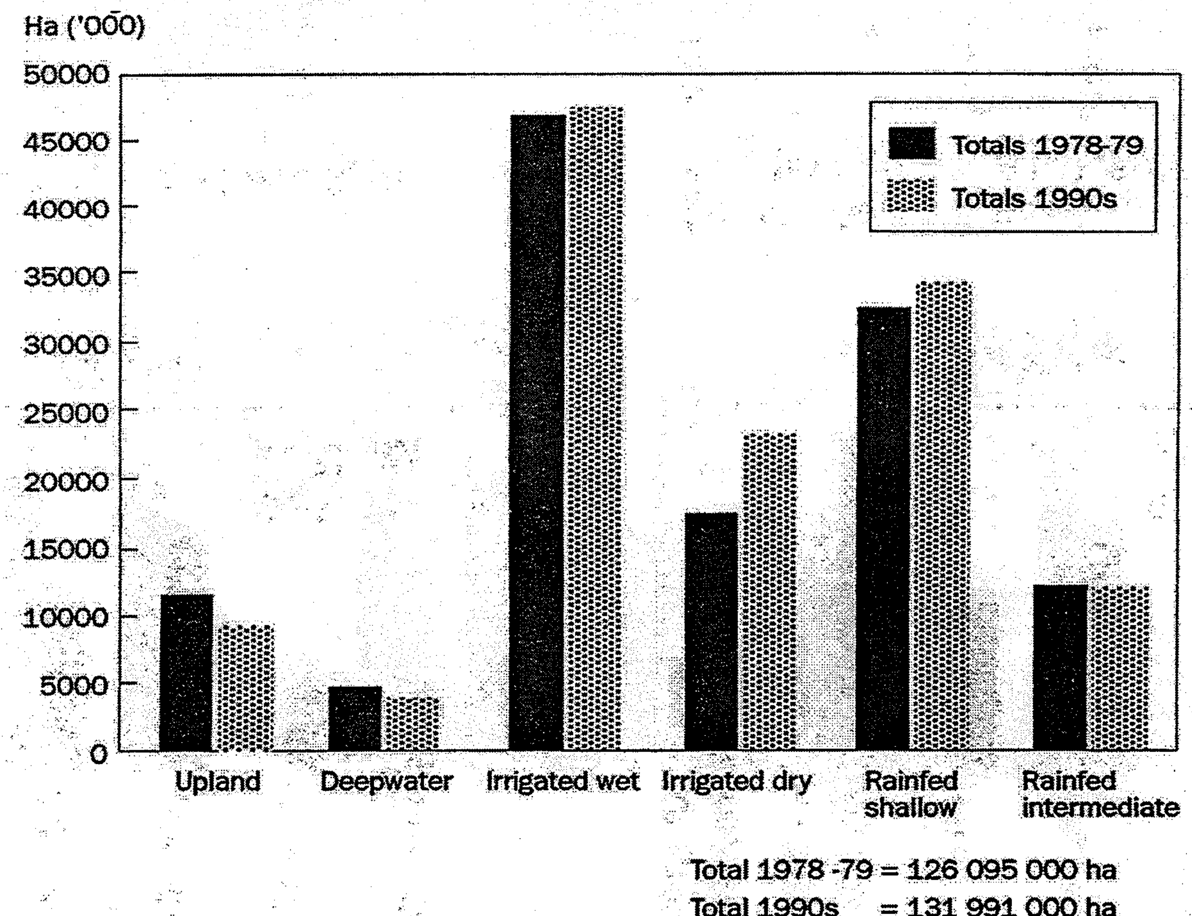


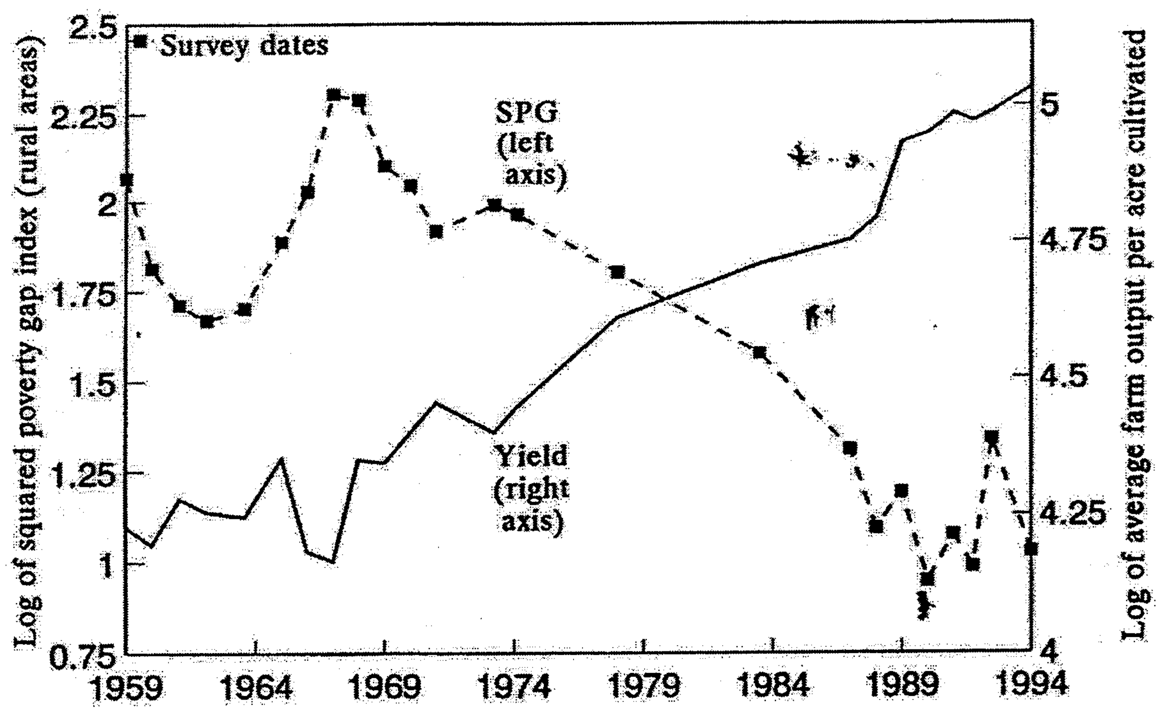
Figure 4 Summary of rice areas by type of culture for Asia



Source: Huke & Huke, 1997.

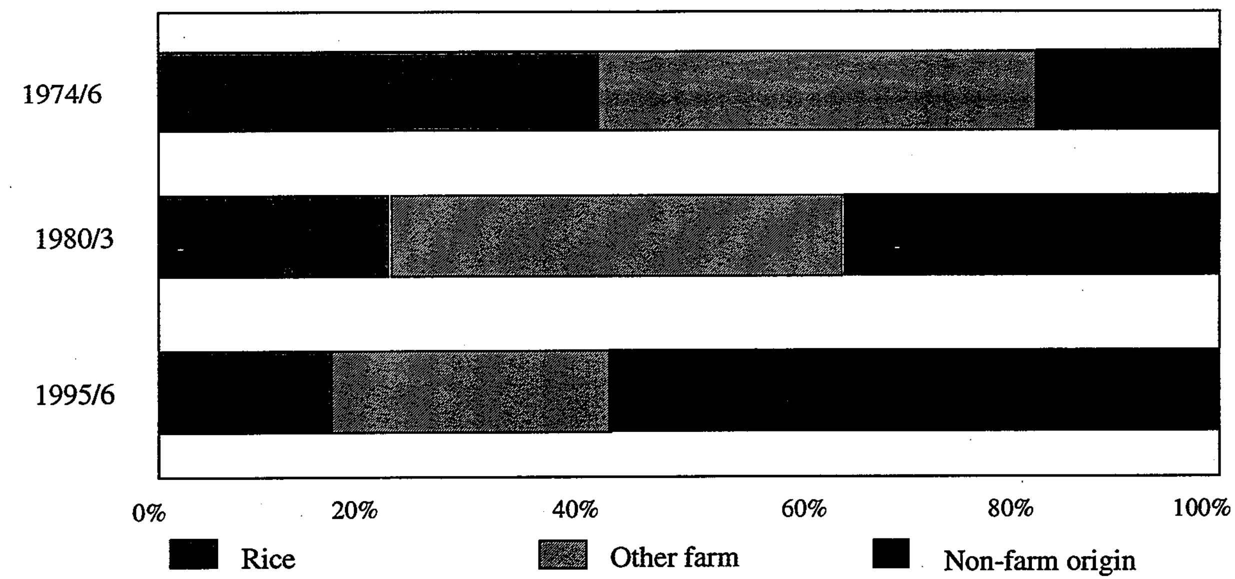
Figure 5

SQUARED POVERTY GAP AND AVERAGE FARM YIELD RURAL INDIA 1959–94



Source: Datt and Ravillion, 1998

Figure 6 **Change in Percent Income from Rice, Other Farming, and Non-Farm Activities in a Laguna Village**



Source: Adapted from Hayami & Kikuchi, 2000

Figure 7 Per Capita Asian Rice Production

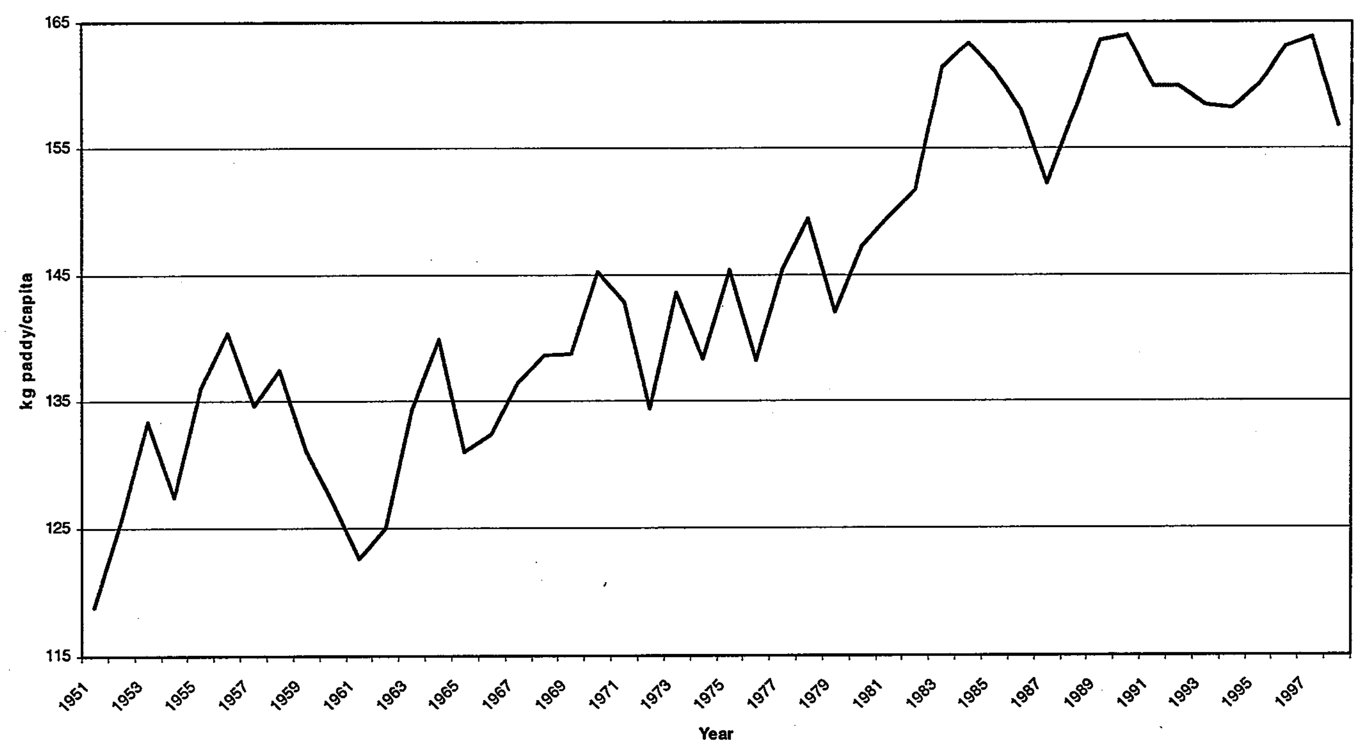
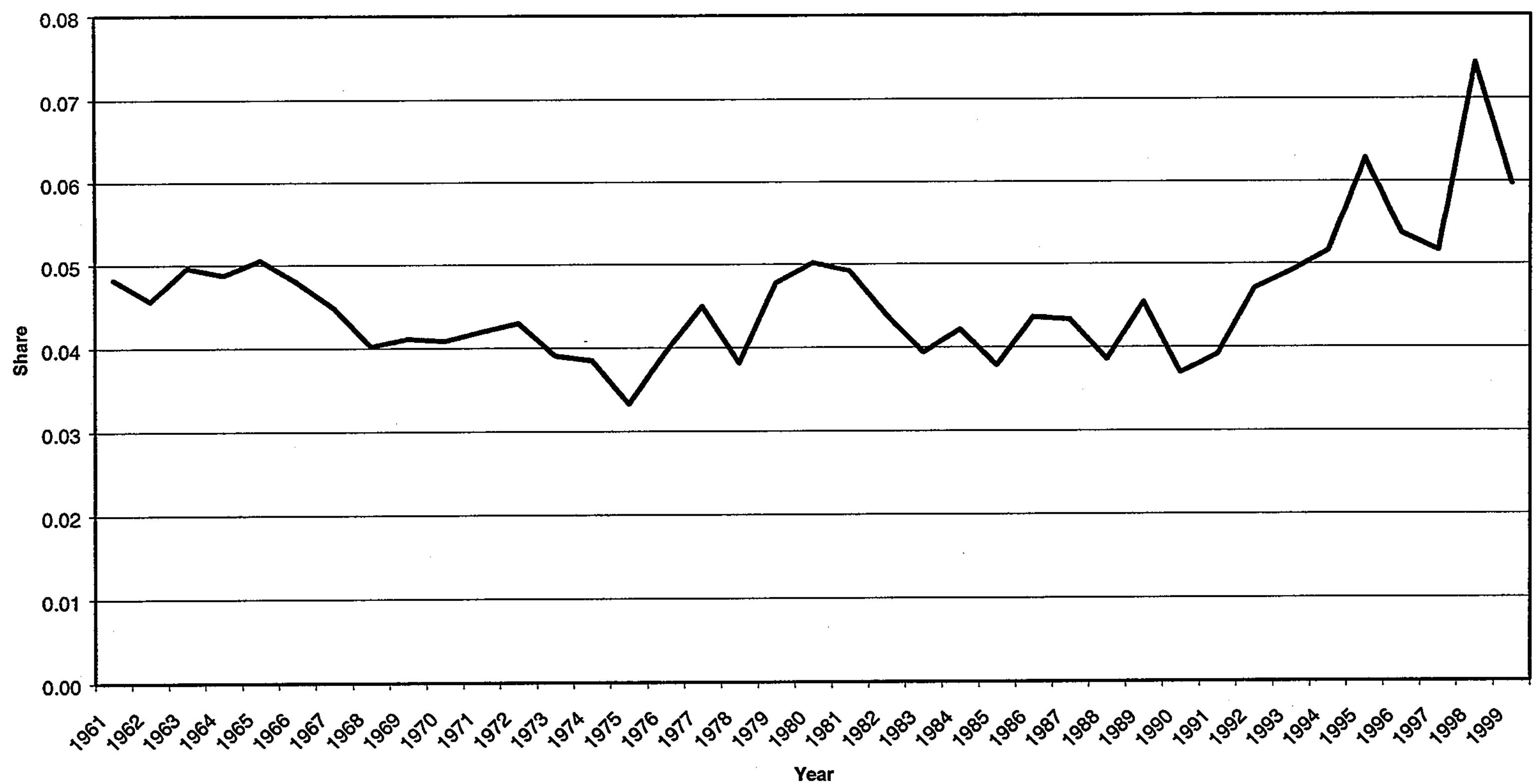


Figure 8 World Rice Exports as a share of World Rice Production



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