I The Performance of Agriculture in Asia

INTRODUCTION

Sustainability is a concept that has been gaining popularity since the 1980s. The most commonly cited definition of sustainability is that adopted by the Brundtland Commission: "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 43).

For agriculture, the issue of sustainability is linked to that of food security, i.e. the sustained ability of agriculture to provide adequate food supplies. Concern about food security stems from the fear that as population increases, our ability to meet increasing food needs will be limited by the natural resource base. In addition, the technology of the green revolution, which was the introduction from the late 1960s of high-yielding varieties of rice, wheat and maize, application of chemical fertilizers and modern pest control methods, coupled with increased capital investment in irrigation and on farms, may have exhausted its potential. Furthermore, second-generation problems, which are related to the high-technology package and agricultural intensification, are claimed to be undermining future productivity through soil, water, and genetic degradation. Investment in irrigation infrastructure has also slowed down. Agriculture has encroached into wilderness lands, affecting biodiversity, which is fundamental to the sustainability of agriculture. The Food and Agriculture Organization of the United Nations (FAO) has estimated that between 1995 and 2010 the increase in agricultural cropland will place 85 million hectares (ha) of forests at risk. This trend of increasing threats to natural forests further exacerbates the possibility of climatic change through the release of additional carbon dioxide into the atmosphere. Indeed, the agricultural sector is being accused of undermining its own sustainability.

The concerns cited above are not at all recent. The issues concerning the possibility of sustained agricultural growth began in the 1940s and 1950s (Rattan, 1994), when the physical availability of natural resources was thought to be a possible limit to future growth. The second wave of concern, prevalent in the 1960s and 1970s, arose from the increasing intensification of agriculture and conflicts related to the multiple uses of natural resources and the environment, e.g. as inputs for production, recreational services, tourism sites, pollution sinks, and sources of potential future wealth (i.e. biodiversity). The third, and current, wave of concern was initiated by scientists in developed countries and deals more with global issues, such as climate change, ozone depletion, and acid rain.

In order to combat natural resource and environmental pressures, national and international research communities have joined forces in producing technologies that increase productivity, augment the existing natural resource endowment, and prevent food scarcity and starvation. The green-revolution technology was believed to be a win-win solution that overcame natural resource constraints and institutional changes.

The Brundtland Commission's definition of sustainable development, as cited above, applies to the concept in general. As far as agriculture is concerned, the Asian Development Bank (ADB) has another definition, namely "that which can evolve indefinitely toward greater productivity and human utility, enhance protection and conservation of the natural resource base, and ensure a favorable balance with the environment" (Tarumizu, 1992). This definition of sustainability is not just about maintaining environmental quality for a given level of resources. Nor is it about maintaining yields at current levels in perpetuity. The concept also includes (i) the need for enhancing productivity, and (ii) the need to meet increasing demands from growing populations. It is, therefore, not a static definition of constant production but refers to a *sustained increase* in production and consumption over time.

The ADB definition is particularly ambitious, considering that the standard economic interpretation of the Brundtland Commission's concept of sustainability requires that the per capita consumption of future generations remain at least as high as the current level. In order to maintain constant consumption levels over time, an amount equivalent to the economic depreciation of the exploited resources must be ploughed back into the investment as capital formation (Hartwick, 1977). This capital formation needed to replenish depleted stocks does not necessarily have to be physical capital. For agriculture, the ploughed-back amount could be in the form of investments in new technology and human resources. If consumption is allowed to increase over time, greater levels of plough-back investment are necessary. This volume adopts the ADB definition; the increase in yield levels or yield growth, a performance indicator for investment in technology, is used here as a proxy indicator for the need for more investment in technology to maintain agricultural sustainability.

This volume traces the past successes and the challenges yet to be overcome in achieving sustainable agriculture. The role of the State in management of technology transfer and of the natural resources sector is assessed vis à vis that of alternative institutions, such as the open market and local communities. We argue that technology, which has been a very powerful instrument in helping to meet food security needs in Asian countries, will not be able to continue in this role if policy and institutional reforms are not undertaken. This is especially true of those reforms related to natural resources and the environment. Current environmental degradation is a result of the mismanagement of technology, and failed policies and inappropriate government interventions. There are some early indications that the growth in productivity of rice production is leveling off, implying that the nature of research and technology development as well as the extension system will have to be modified.

We also argue that the yield gaps that continue to persist despite the green revolution are a reflection of the lack of attention that has been paid to less favorable environments. Past development efforts have concentrated on solutions designed in the laboratory rather than field-based crop management and, except for the People's Republic of China (PRC) and the transition economies, on technology and infrastructure rather than on policy and institutional reform. Although there is no large leap forward in productivity gains on the horizon for the next decade, substantial cumulative incremental gains could be made. The size of these gains depends on the ability of governments to fine-tune their research, development, and extension systems. This volume also emphasizes that agricultural sustainability can only come about if policies, including agricultural as well as economy-wide and natural resource policies, and institutions reflect environmental costs and demonstrate a proper understanding and appreciation of the complex relationships between nature, technology, and society.

THE SUCCESS AND SHORTCOMINGS OF THE GREEN REVOLUTION

The green revolution has been central to Asia's agricultural success. A key element is the use of new "improved" crop varieties developed with the aid of modern plant breeding techniques. Before the Second World War, Japan and its then colonies were the only Asian economies to employ crossbreeding extensively to increase crop productivity. Similar efforts did not begin in the rest of Asia until 1950, at which time breeding programs were instituted almost simultaneously in most Asian countries. International breeding programs began shortly afterwards, for rice in 1960 at the International Rice Research Institute (IRRI), for maize and wheat in 1966 at the International Center for Maize and Wheat Improvement (CIMMYT), and for soybean, mungbean, and some major vegetables at the Asian

Vegetable Research and Development Center (AVRDC). Modern varieties (MVs), the new varieties developed through both national and international breeding programs, began to be released and diffused in Asia beyond Japan, the Republic of Korea, and Taipei,China, from 1965.

The new varieties were generally superior in terms of yield potential, tolerance to pathogens and pests, and responsiveness to fertilizer and irrigation. They were also insensitive to photoperiod and / or required shorter growth time, making them more suitable for intensive cropping systems. The success of one group of MVs, the high-yielding varieties (HYVs), was internationally highlighted by the realization of a spectacular increase in output regionwide and the conferring of the Nobel Peace Prize on Norman Borlaug, who was the chief breeder of the technology development program at CIMMYT (Fairbain, 1995). The green revolution was the true Asian miracle of the 1970s and 1980s.

Without international assistance, the PRC was able to raise yield potential even further by developing, at the end of the 1970s, hybrid technology for rice and maize. The advent of the green revolution has saved Asia from famine and starvation (Box I.1). Nowhere has the impact of seed-fertilizer technology been greater than in South Asia where almost all countries have managed to feed their populations despite predictions of famine.

Bangladesh changed from being a net importer of 3.5 million metric tons (t) of grain annually in 1965 to self-sufficiency in grain by the early 1990s, by which time its population had grown from 53 million to 115 million (Gill, 1995). In India, where large-scale food shortages were avoided, the green revolution enabled food production to outpace population growth. Between 1970 and 1991, the annual rate of increase in food grain production was about 2.5 percent, while the annual rate of population growth over the same period was 2.2 percent. Technology had enhanced the food-growing capacity of India to the extent that it could have fed an additional 350 million people during that same period (Repetto, 1994). In the PRC, the food production index rose from 50 in 1975 to 145 in 1995, which implies that enough food was produced for an additional

Box I.1 Food and Famines

Globally, the world now produces enough food for its entire population. It is not the shortage of food but rather poverty, poor distribution, and mismanagement that have caused starvation and malnutrition. In 1943, inflation in Bengal drove food prices beyond the reach of the poor and caused 2-3 million deaths from starvation (FAO, 1995a). Major famines are mostly manmade, through war, ethnic or religious conflict, lack of foreign exchange, or abrupt economic crises, or are simply the result of inaccurate statistics and falsehoods.

The Great Famine that resulted in 30 million deaths in the PRC in 1959-1961 has been blamed on a number of factors. Explanations range from bad weather, inappropriate policies and incentives, poor reporting of crop yields, and even fraud. In order to satisfy the central leadership, local governments exaggerated grain output, leading to an excessive flow of grain out of the rural agricultural areas (Johnson, 1996). When the famine struck, the transportation system at that time and the sheer vastness of the country did not allow for the timely delivery of supplies to the deprived regions, resulting in one of the most devastating tragedies of our time. Some have claimed that it was forced collectivization that led to a decline in grain output in 1959 and 1960 (Chisholm and Jayasuriya, 1994). Lin (1988, cited in Lin, 1998a) suggested that it was due to "the deprivation of the peasant's right to withdraw from the collectives."

Brown (1995) warned that famine in the PRC may occur again. He estimated that by 2030 the PRC population will have increased by half a billion, putting tremendous pressure on the global food supply, and cited the increase in grain prices and large imports of grain by the PRC during 1994 as early signs of a growing imbalance between supply and demand.

In reality, the performance of agriculture in the PRC throughout the 1990s has been remarkable, except for areas affected by natural disasters. Cereal output rose steadily after 1950 through the middle 1990s. Wheat imports dropped from

(continued next page)

Box I.1 (continued)

7.2 million t in 1994 to 1.9 million t in 1997. In 1997, the PRC boasted a net export of about 1.1 million t of rice.

Highlighting famines and paying too much attention to statistics showing food production per capita may lead to "Malthusian optimism", i.e. the belief that raising the growth of food production per capita above the growth rate of the population will solve the starvation problem, which neglects the more pervasive and permanent problem of hunger and nutrition (Sen, 1986). Neither prices nor food production per capita are good warning signs or early indications of famines (Sen, 1986). More importantly, long-run food policies should not be limited to expanding food production per capita but should also enhance the ability of the individual to secure and be guaranteed food entitlements.

292 million people over that period. Similar success stories were repeated in Indonesia, Pakistan, Sri Lanka, and Viet Nam. Some countries, especially India, Thailand, and the Philippines, are now rapidly catching up with hybrid maize technology.

The green revolution not only helped to increase food production and supply, but also altered agricultural practices and cropping and trading patterns, and transformed rural livelihoods throughout Asia. The increased incomes and volume of trade encouraged associated activities such as food processing and transport. Expansion of electrically and mechanically powered irrigation and increased adoption of tractors and other farm machinery reduced the need for draft animals. A village-level study in Punjab, India, covering 1965 to 1978, revealed that camels were no longer used as draft animals and that the use of bullocks had decreased substantially (Leaf, 1984 and 1987, cited by Goldman and Smith, 1995). In their place, the numbers of food animals such as buffaloes and goats increased. Milk and meat became more readily available for household consumption. Rural poverty in India declined substantially as a result of government spending related to the green revolution (Fan, Hazell, and Thorat, 1998).

The impact of the green revolution on equity was questioned in early critiques. The technology involved can be seen to be selective and biased in favor of resource-rich regions and wealthy farmers. Fertilizer-responsive technology needs to be supported by a favorable environment, such as one with good irrigation, and tends to further aggravate the unequal distribution of income between resource-rich and resource-poor regions. Farmers also need credit worthiness, which tends to favor the large rather than the small farmer. Landless labor derives little benefit from these improvements, and employment levels have actually dropped due to the mechanization made possible by the higher productivity resulting from the green revolution. Rich and influential farmers were seen to maximize gains by ending tenancy agreements and lobbying for input and price subsidies (Fairbairn, 1995).

The increase in the supply of labor-intensive crops kept real wages low, which helped to support the expansion of labor-intensive enterprises. Fairbairn (1995) reviewed over 300 studies on the impact of the green revolution and found that 80 percent of the studies conducted between 1970 and 1989 concluded that the impact on equity of the green revolution was negative and that inequality increased during that period. It has been feared that the green revolution is a potential cause of increasing social antagonism and unrest (Frankel, 1971, cited in Sharma and Poleman, 1993).

The counter argument is that the negative effects on equity were the result of the early stages of the green revolution only. Citing field evidence from the northern Arcot region, Tamil Nadu, India, proponents of the green revolution indicated that the difference in yields between large and small farmers, evident in the 1970s, disappeared in the 1980s because smaller farmers were late adopters (Hazell and Ramaswamy, 1991). In fact, small rice farmers and the landless made larger gains in family income than did large rice farmers, farmers of other crops, and nonagricultural households. There was no increase in the concentration of land ownership. One study that found widened regional disparities in India between the mid-1960s and 1970s also found that a second-generation effect of the green revolution was increased output and profitability of small farmers. Other benefits have included widespread employment opportunities in postharvest operations such as storage, milling, marketing, and transportation (Sharma and Poleman, 1993). Increased rural incomes further brought about a diversification of rural economies and new opportunities for nonfarm activities. There was some loss in employment because of mechanization and the use of pumping for irrigation, but improvements in real wages led to increased earnings for the landless and nonagricultural households.

Another study (David and Otsuka, 1994) on the impact of adoption of HYVs in seven Asian countries (Bangladesh, PRC, India, Indonesia, Nepal, the Philippines, and Thailand) concluded that although HYVs improved productivity in favorable (irrigated) areas relative to that in less favorable areas, other indirect effects have tended to prevent significant worsening of disparities in income distribution. These indirect effects have included increased real wages in unfavorable areas through migration out to favorable areas where employment opportunities are higher, decline in the real price of rice, which has benefited consumers, and changes in land tenure that have mitigated the worsening of disparities in income distribution. An exception is the development of hybrid rice in the PRC where there has been a direct positive impact on equity, because the new rice was adopted in the mountains in unfavorable regions.

A more recent study (Hazell and Fan, 1998), on marginal returns to technology inputs in India in 1994, found that the marginal return in rainfed areas from government HYV expenditure was almost twice that in irrigated areas. On the basis of State-level data for 1970 to 1994, the authors confirmed that increased agricultural productivity reduced poverty directly by increasing farmer income and indirectly through employee wages and reduced agricultural prices. Poverty of the landless increased, although to a small extent.

Most studies on the impact of income distribution concentrate on income from rice farming. When the total income of all households, both those adopting and those not adopting the new technology, is considered, the impact of income distribution on rural households is negligible (Lin, 1998b). In his study of 500 households in Hunan Province, Lin found that technology adopters tended to increase the amount of resources allocated to rice production relative to other activities, while the reverse was true for those not adopting the new technology. Therefore, if rice is the only source of income considered, an inequality is to be expected because the nonadopters tend to reduce the amount of resources committed to rice production. By examining total income for all outputs, the impact on equity of the new technology is seen to be minimal.

Later critiques of the green revolution have focused on its ecological and biological impact. The high-technology package used has disturbed the ecological equilibrium, creating undue dependence on external inputs and stretching the Earth's support system beyond its capacity. The spread of HYVs, which have a narrow genetic base, increases the risk of greater exposure to pest and insect attacks. The associated intensive use of agrochemicals could have a negative impact on the quality of water, harming the health of farmers, consumers, farm animals, wildlife, and the environment. Also, since the green-revolution technology concentrates on a few staple crops grown in favorable regions, farmers in unfavorable areas have no option but to engage in extensive agriculture, resulting in encroachment into natural forests and fragile ecosystems. The green-revolution package has inherent weaknesses and second-generation effects associated with its high input practices. Finally, the technology involved depends on fossil-fuel energy sources, which are nonrenewable. This could undermine the long-term sustainability of green-revolution technology.

The above arguments are examined in later sections. Here, it is sufficient to note that the least recognized, but probably greatest, benefit of the green revolution is that the increase in food output has reduced the need for opening up more land for agriculture, especially in the more fragile ecosystems. This has prevented large-scale deforestation. It is estimated that without the green revolution, at least 60 percent more land would be required to maintain the current population at the prevailing nutritional standards (ODI, 1994, cited in Gill, 1995). In 1985, The Consultative Group on International Agricultural Research (CGIAR) estimated that without the modern varieties about 20–40 million ha more would be needed to produce rice and maize in the humid tropics (CGIAR, 1985, cited in Harrington, 1993). The various criticisms should not be taken as a rejection of the green revolution or of the value of an increase in food supply and food security. Rather they should be taken as providing directions for future research and improvement.

AGRICULTURAL GROWTH TRENDS (1967-1997)

The ability to meet increasing demands from growing populations requires that production growth exceeds population growth (Table I.1). The green revolution has made this possible over the last few decades. Demand and supply projections up to 2010 indicate that production growth of cereals will be high enough to allow a slight fall in the real price of food. Rice is the only major staple crop for which prices may increase (Rosegrant and Hazell, 1999). Some other developments occurring in tandem with the green revolution have been innovations in the areas of livestock, aquaculture, and coastal and oceanic resources. This section examines the growth trends and environmental impact of the food sectors as well as those of tree plantations, the latter being brought into the analysis for their relatively more benign impact on the environment and their implications for land use.

Annual Crops

Asia contributes over 90 percent of the world's production of rice, about one third of all wheat and about one fifth of all coarse grain (Khan, 1996). Three major trends can be observed in the yields of field crops in Asia. First, growth in the production levels of food crops, mainly cereals and pulses, has been decelerating during the third decade of the green revolution (Table I.1). The yield increases of cereals and pulses peaked at 3.8 percent per annum during 1977–1986, but slowed to 2.3 percent during the next decade. However, the latter growth rate was still above that of population growth for the decade. The average annual yield growth of crops other than cereals and pulses rose from almost zero from 1977 to 1986 to almost 2 percent in the following decade. Asia's population grew at an annual rate of 1.82 percent during 1987–1997, down from 1.87 percent a decade earlier (Annex Table A1).

Table1.1: Crop Production in Asia, 1977–1997

	Average Growth (percent per year)			
	Production		Yield	
	1977–1986	1987–1997	1977–1986	1987–1997
Cereals and pulses	3.82	2.60	3.80	2.29
Others[a]	3.22	5.16	0.20	1.81
Total	3.47	4.08	2.51	2.71

[a] includes fibers, oils, roots, sugar, tea, coffee, tobacco, rubber, vegetables, fruits, and nuts.

Source: FAOSTAT Database. *Available: http://apps.fao.org*

The second trend is a shift away from, or a fairly strong diversification out of, food grains in favor of higher value crops (Table I.2, Annex Tables A2, A3, and A4). The decline has been most drastic for rice, millet, and sorghum (Annex Table A5). The trend has also reduced the dominance of food grains in the total cropping system. In the PRC, the loss of land sown with food grains was substantial, amounting to 8 million ha or about 10 percent of total harvested food grain area. The reasons for the shift to nonfood grains were the decline in real prices of food grains (Beckerman, 1995), a declining profitability due to a price / cost squeeze, and an increased demand for high-value horticultural crops.

Table 1.2: Diversification of Asia's Cropping System 1977–1997

	Area				Average Growth (percent per year)	
	ha, million		percent of total			
	1976–1978[a]	1995–1997	1977	1996	1977–1986	1987–1997
Cereals and pulses	304.570	307.554	73.84	63.60	0.03	0.25
Others[b]	107.919	176.034	26.16	36.40	3.06	2.78
Total	412.489	483.588	100.00	100.00	0.82	1.05

[a] three-year mean.
[b] includes fibers, oils, roots, sugar, tea, coffee, tobacco, rubber, vegetables, fruits, and nuts.
Source: FAOSTAT Database. *Available: http://apps.fao.org*

Third, despite criticism voiced since the 1970s that the seed-fertilizer package is beneficial only in favorable environments, little progress on technology applicable to less favorable areas has been made. For example, rainfed rice yields are only half of those of irrigated agriculture, with even lower yields for upland and deepwater areas (Rosegrant and Pingali, 1990). Maize yields in Rajasthan, Uttar Pradesh, and Madya Pradesh in India and in many other countries are low. The exceptions are countries where rapid diffusion of hybrid maize has occurred, such as the PRC, Thailand, and the Philippines.

Amongst the major cereals, wheat and maize continued to show robust yield growth during the last decade (Annex Table A2). Rice is the only staple for which the yield growth, or the average annual increase in output per hectare, has fallen below 2 percent, almost half that of the preceding decade.

The highest average annual rice yields in Asia were 6.564 and 6.545 t/ha in 1977 and 1997, respectively, both in the Republic of Korea (Annex Table A6). In the PRC, yields jumped to 6.187 t/ha from 3.704 t/ha. For Asia as a whole, yields went up from 2.596 to 3.840 t/ha during the same period. The Asia-wide average, annual yield growth rate, however, did decline substantially, from 3.35 percent during 1977–1986 to 1.50 percent during 1977–1996. This deceleration reflects the fact that the growth potential of the early innovations of the green revolution has been exhausted in the best-suited areas. IR8, developed by IRRI, was the first HYV to break the yield barrier for rice and started the green revolution outside the PRC. In fact, other HYVs have never been able to better the yields of IR8, although the progress made in pathogen and pest resistance in later HYVs has been remarkable. Considering that 74 percent of wet riceland is sown with MVs, there is now a renewed need for new rice varieties that will raise the yield potential.

Examining the rice industry more carefully also reveals that the slow down in yield growth could be related to the diversification of MVs into traditional varieties that have higher eating quality but lower yields. For example, yield declines in Karnal, Haryana, in the heart of India’s green revolution riceland, were a result of the move to grow *basmati* rice (Chaudhary and Harrington, 1993). A similar but stronger trend has been observed along Asia’s Pacific rim where a boom in manufacturing has increased the opportunity cost of agricultural labor. While the high-quality rice production area has expanded in response to greater demand and better prices, the production of low-quality rice and also of marginal food crops has declined. However, migration from rice to more lucrative crops and to higher paying jobs in the city has also increased the cost of rice.

Rapid economic growth in the cities has fuelled the demand for high-quality rice and horticultural products. In the southern PRC, the heartland of rice production in that country, a drastic decrease in the area being sown has been observed (Hong, 1996). In Thailand, where the industrial boom continued unabated for a decade before coming to an abrupt end in 1997, productive resources, especially labor, moved away from the agricultural sector in general and the rice sector in particular as a result of competition for these resources (Ammar, 1996; Coxhead and Jiraporn, 1998). Rapid growth in other newly industrialized economies has also placed pressure on rice production in terms of labor and land costs. Economic recessions will dampen demand somewhat, but this does not reduce the need for an effort to increase rice productivity.

In contrast with rice, the yield growth in wheat and maize remains strong (Annex Tables A7 and A8). This is particularly true of wheat in the PRC, India, and Pakistan. For maize, growth potential can be further tapped in favorable areas in Cambodia, India, Indonesia, the Philippines, and Viet Nam.

The relatively strong growth trends in wheat are partly related to the success of breeding programs, which have raised the yield potential of new varieties at a rate of about 1 percent per year, while maintaining their resistance to the main pathogens. For example, the average number of newly released wheat varieties per year in India increased from 2.6 in the 1960s to 3.4 in 1970s and 7.2 during 1980 to 1985 (Byerlee, 1990). The yield potential of wheat MVs in South Asia has increased at a rate of 0.5 to 1 percent per year due to genetic improvement. The historical trend of productivity gains in the PRC has continued, with annual productivity gains averaging 3.33 percent from 1987 to 1997 (Annex Table A7), a further suggestion that the sustainability of the yield potential for wheat should not be a great cause for concern. However, as with rice the profitability of wheat is decreasing, for example in areas like Karnal (Chaudhary and Harrington, 1993). This should be a greater cause for concern.

The rapid growth in maize production is a response to the boom in the poultry industry, which is a major consumer of maize. The PRC has produced three generations of hybrid maize in the last three decades with a 10 percent productivity gain from each new generation (Chen, 1995). Elsewhere, hybrid maize was adopted much later, spearheaded mainly by the seed or feed businesses in the private sector. Recent successes in Southeast Asia, starting with open-pollinated varieties followed by hybrids, imply that the potential exists for an expansion of maize output and increase in yield potential in the tropical environment.

Asia dominates the world in both rice production and rice consumption, accounting for over 90 percent of each (Hossain, 1996). Rice is consumed universally in Asia, whereas wheat is consumed as a major part of the diet only in Pakistan and some parts of Bangladesh, PRC, India, Nepal, and Central Asia. Wheat output in Asia is about 40 percent that of rice, and land sown with wheat covers about 60–70 million ha, about half the rice-growing area, 130 million ha (Annex Table A2). The amount of land sown with maize (35 million ha) is only about one third of that sown with rice. This relative order of magnitude is important when planning the allocation of R&D expenditure on food crops in Asia.

Despite the fact that rice production in Asia is enormous, the internationally traded volume is small, accounting for only a small proportion of the total production–3 percent during 1994 to 1996–while 18 percent of wheat was traded internationally in the same period. The small international rice market implies that a reduction in production by any major rice-consuming country will have a significant impact on international trade and that rice prices may potentially vary considerably. This in turn implies that the poor in Asia are relatively more vulnerable with respect to food prices. The low levels of foreign exchange held by some Asian governments following the financial and economic crisis in Asia may further aggravate food security.

Sorghum, millet, and barley have shown a declining trend in production and area sown over the past 20 years, although yield growths have been positive and increasing at between 1.4 and 1.8 percent per year (Annex Table A2). Among other major crops, there has been an increase in oilseed production, particularly for soybean, rapeseed, sunflower, and castor during this period, while tubers have shown different growth trends. Cassava production declined from an average annual increase of 2.9 percent for 1977–1986 to negative 0.68 percent for 1987–1997, although potato production has shown signs of remarkable growth over these two decades.

Crop production is thought to affect the environment not only directly, through nutrient depletion and the emission of greenhouse gases, but also indirectly where expansion of crop areas is a threat to forest areas. These issues are discussed further in later chapters.

Perennial Crops

The major perennial crops in Asia, as measured in terms of harvested area (above 1 million ha) in 1997, are coconuts (9.1 million ha), sugar cane (8.6 million ha), rubber (6.7 million ha), oil palm (4.7 million ha), tea (2 million ha), and coffee (1.6 million ha). Together, the harvested area of coconuts and sugar cane (17.7 million ha) is less than half of the area devoted to maize and close in size to the area devoted to fruits (16.8 million ha) and vegetables (20.8 million ha). In Asia, perennial crops may be grown on large plantations, in smallholdings, or under a subcontracting system as is the case with the Thai sugar cane industry.

Tree-based systems, when properly managed either as plantations or agroforestry systems, have a relatively benign impact on the environment, especially when grown in the uplands and on steeper slopes. Also, once an investment is made in trees, the land is committed to a fixed pattern and therefore cannot be easily converted into land for food crops, at least in the short term.

The largest producers of coconuts in 1997 were Indonesia (14.7 million t), the Philippines (12.1 million t), India (9.8 million t), and Sri Lanka (2 million t) (Annex Tables A9, A10, and A11). In the last decade, a small decline in harvest areas has occurred only in the Philippines. The World Bank has forecast a substantial decline in prices for both copra and coconut oil until 2010.

Southeast Asia produces almost all of the world's rubber output of 5.2 million t (Annex Tables A12, A13, and A14). Thailand is the largest producer, contributing on average about 2 million t of output, which is about one third of the world's total natural rubber production, from harvested areas that covered 1.5 million ha in 1997. The second largest producer, Indonesia, produces on average 1.5 million t per year from 2.3 million ha of plantations, followed by Malaysia, with about 1 million t from 1.5 million ha. These three countries together produce about three quarters of the world's total output. Harvested areas in Malaysia are experiencing a declining output, while Indonesia has seen a slight increase over the last seven years. Countries showing strong increasing trends but from relatively small bases are Viet Nam, Myanmar, and Cambodia. The World Bank's forecast for rubber prices indicates a short-term price drop followed by a recovery towards 2010.

Tea is a traditional crop in many Asian countries, but it is grown on a relatively large scale only in the PRC (0.9 million ha), India (0.4 million ha), Sri Lanka (0.19 million ha), and Indonesia (0.11 million ha) (Annex Tables A15, A16, and A17). The total area used for tea production has been relatively stagnant since 1975. India and Indonesia are the only countries showing slight increases in harvest areas. Sri Lanka, a world-renowned producer of black tea, has experienced a clearly decreasing trend in area under tea.

Harvested areas for coffee in Asia total 1.6 million ha and almost all of this is in Southeast Asia, i.e. Indonesia (0.8 million ha), India (0.24 million ha), Viet Nam (0.19 million ha), and the Philippines (0.15 million ha). The area under coffee is increasing strongly in Indonesia and Viet Nam and slightly in India (Annex Tables A18, A19, and A20).

Oil palm is not yet a very widespread crop in Asia, but the area under harvest is growing rapidly in Indonesia, Thailand, and Malaysia (Annex Tables A21, A22, and A23). The crop has high yield potential and requires a relatively small amount of labor for planting, maintenance, and harvesting. It demands a warm climate and evenly distributed rainfall, making Indonesia, Malaysia, and southern Thailand suitable growing areas. In 1997, the industry suffered from the widespread fires in Sumatra and Kalimantan, Indonesia (Box I.2). It can be expected that further expansion of oil palm will be somewhat hindered by the financial and economic crises occurring in the three major producing countries. Moreover, the World Bank has forecast a rapid decrease in the price of palm oil until the year 2010 due to excess competition and production.

Land clearing for agricultural tree plantations in Sumatra was proven to be partly responsible for the fires in 1997 that erupted into a regional environmental problem. The fires, exacerbated by the long drought associated with El-Niño, lasted from mid-1997 to early 1998, producing enormous quantities

Box I.2 The Great Haze: Who was Responsible?

Fire has always been a part of agricultural management in Asia because it is the cheapest and least capital-intensive method of clearing land (ICRAF, 1996). It reduces pests, diseases, and weeds. Farmers also believe that burning increases soil fertility. Fire is used as a land-clearing tool by both smallholders and large plantation companies. Traditionally, institutions in communities engaged in slash-and-burn agriculture monitored and enforced measures, such as fines and other penalties, to ensure that fires did not go out of control. However, local communities have no control over the large companies that also use fire for clearing land to establish plantations.

Before the great haze of 1997, smallholders had often been blamed as the cause of forest fires in Indonesia. An advanced, high-resolution oceanic and atmospheric satellite identified 12,000 fire spots in Sumatra in September and October 1997. The fires were not really ‘forest fires’, as only 44 percent of the hotspots were in forest areas. Satellite images verified that the large companies were in fact responsible for the fires.

Researchers have indicated that under the existing development policies, fire is not unexpected and will return with or without El Niño (Tomich et al., 1998b). The Government provides incentives and grants land to large companies for the development of large-scale plantations, but does not recognize the rights of the local farmers occupying the lands provided to companies for plantations. Fire has thus become a ‘weapon’ of the companies to get rid of smallholders, and vice versa. Moreover, Indonesia’s policies tend to favor export of sawn timber rather than roundwood or logs in order to nurture forward linkages, which encourages the treatment of wood felled during clearing as waste, and discourages the protection of standing timber. In addition, peat swamps are converted for rice production. Fires from peat forests tend to linger underground and are difficult to extinguish.

Alternatives to slash-and-burn agriculture are now being sought for small farmers by the International Center for Research in Agroforestry (ICRAF), but for the time being, banning the use of fire by smallholders is impractical. Attempts must be made

(continued next page)

Box I.2 (continued)

to solve the problem in a holistic manner. A number of policies have been suggested, such as a ban on rice production in peat swamps, finding land for plantation agriculture in grasslands rather than forests, recognition of land rights of local communities, the revision of promotion incentives and conditions for large-scale plantations, and a review of forest-product export policies. At the regional level, a system with shared responsibilities needs to be devised to effect better management and monitoring and to improve fire-fighting capacity.

of smoke and haze that covered Indonesia, Singapore, Malaysia, and southern Thailand. In Indonesia, 5 million ha of forest and agricultural lands were damaged and 70 million people in the region were affected (EEPSEA and WWF, 1998). The haze also seriously affected the previously booming tourism industry in the four countries. Total damages (calculated up to December 1997) to Indonesia were estimated at $3.8 billion[1] while about $670 million worth of damage was done to neighboring countries. Development policies favoring the conversion of forest into plantation have been seen as a major contributor to the haze problem (Murdiyarso, 1998).

Well-managed tree plantations tend to be less harmful to the environment than some field and garden crops. Well-managed plantations with good ground cover can reduce the rate of run-off and erosion to below 5 t/ha per year, which is a better rate than that of degraded forests and shrubs. For example, a well-managed tea plantation results in an annual loss of only 0.24 t/ha of soil, compared with 25–100 t/ha for vegetables, potatoes, and tobacco, and 0.3 t/ha for dense forest (Chisholm, Ekanyake, and Jayasuriya, 1997). In the early stages

---

[1] $ indicates US dollars throughout the text.

of establishment, erosion rates tend to be high but the mulching done during the first two years of planting can considerably reduce run-off and soil erosion.

Asia is a big producer and consumer of sugar. It has five of the world's top ten consumers, namely India, PRC, Indonesia, Pakistan, and Japan. The top five producers of sugar in 1997 were India (277 million t), PRC (82.57 million t), Thailand (45.85 million t), Pakistan (42 million t), and Indonesia (27.76 million t) (Annex Tables A24, A25 and A26). The Philippines was a much bigger producer than both Pakistan and Thailand in the 1970s and early 1980s but the latter two countries increased their capacity substantially during the 1990s. Asia produces about one third and consumes about 45 percent of the world's sugar output. Hence, the region has a sugar deficit. The annual rate of growth of sugar cane production has also declined, from 4.9 percent in the 1950s to 1.6 percent in the 1990s.

The sugar cane industry in Asia is dominated by smallholders, implying a need for an efficient institutional arrangement between them and factories. Yields are highest for Indonesia and the PRC (about 71 and 75 t/ha, respectively), both of which benefit from irrigation (Annex Table A26). Yields in the Philippines and Thailand, which use relatively low-input rainfed systems, are about 69 and 49 t/ha, respectively. However, Thailand has the highest average sucrose content at 13 percent, followed by India (12 percent), Philippines (11 percent), and Indonesia (9.6 percent). Thailand has the lowest production cost, followed by India and Indonesia (Fry, 1998).

As a C4 plant[2], sugar cane has relatively efficient photosynthesis and hence absorbs more CO_2. However, the

[2] C4 plants have a special CO_2 -concentrating mechanism within their leaves by which they can increase the CO_2 concentration to several times that of ambient levels.This is done by CO_2 first being incorporated into a 4-carbon compound. This allows these plants to maintain lower intercellular CO_2 concentrations than C3 plants. C4 plants tend to grow in warmer, more water-limited regions, and include many tropical grasses and the agriculturally important species maize, sugar cane, and sorghum (IPCC, 1996).

current harvesting method in Asia involves burning, which releases the absorbed CO_2. Green harvesting methods have emerged and need to be introduced in Asia. This will be more important to Asian exporters when the EU market, which is now highly protected, opens up.

Forest Plantations and Agroforestry

Forest plantations in the region, such as teak plantations in India, Myanmar, and Thailand, were established early in the 20th century. These plantations were established mainly by government organizations for several reasons, including production and conservation. The harvesting rotations vary from medium, i.e., 20–30 years, to long, 40–80 years, aiming primarily to produce high-quality timber for the international market. Currently, most of the plantations are State owned. Since 1980, the private sector has become increasingly involved in setting up large-scale plantations of species that are especially fast growing, such as *Acacia, Albizzia, Eucalyptus, Gmelina, Paraserianthes,* and bamboo in the PRC, India, Indonesia, Malaysia (Sabah and Sarawak), the Philippines, and Thailand. The primary objective of these commercial or private plantations is to produce industrial raw material, including roundwood and pulpwood, with short and medium harvesting rotations of 10–20 years. This objective is being promoted by the governments concerned. With very few exceptions, modern breeding techniques and improved clones are increasingly used in Asian plantations. There are also a few examples of manmade forests, established by indigenous people using traditional knowledge (Box I.3), and which have gained national and international recognition.

Forest plantations in Asia in 1995 totaled 59 million ha or about 15 percent of the area of natural forests. Between 1980 and 1995, Asia lost 63.26 million ha of natural forest cover (FAO, 1995b, 1997a). The total area devoted to forest plantations is about nine times that occupied by rubber plantations. Despite the fact that about four fifths of the existing plantation areas

Box I.3 The Manmade Forest of Krui, Lampung Barat, Indonesia

Privately operated plantations are generally large and are established using capital-intensive technology. They are usually planted with introduced species. In the village of Pahmungun, Lampung Barat, a damar *(Shorea javanica)* forest was established by the indigenous communities in the 1890s. The damar tree was domesticated along with coffee and fruit trees. It is a dipterocarp resin-yielding tree and is valued both for resin and timber. Damar agroforest owners are estimated to earn slightly greater incomes than owners of monoclonal rubber plantations. Apart from supplying 70 percent of the annual cash income of villagers, the damar forest also provides ecological functions and acts as a storehouse of biodiversity. The forest, approximately 55,000 ha, supports 17 species of rare plants, 17 species of protected mammals, and 92 species of birds.

Until the discovery and identification of the human contribution to its sustainability, the damar forest of Krui was simply assumed to be a natural forest. In 1998, the Indonesian Government issued a decree that acknowledged and legitimized the indigenous land-use system in State forestland as a distinct forest-use classification. Under this decree, local people are allowed to harvest the timber they have planted in State forests. A limited amount of logging is also allowed in the watershed forests. Local communities are given the right to manage a part of the State forests under their traditional customs. The Krui forests were among the first to be provided with such rights.

Sources: de Foresta and Michon (1997); Fay et al. (1998).

are used for nonindustrial purposes, e.g. for conservation and for household consumption or community uses, forest plantation establishment rates have lagged far behind deforestation rates.

The PRC has the largest plantation area, with an annual planting rate of 1.1 million ha (Table I.3). Most of the PRC's plantations are aimed at conservation and nonindustrial purposes. Recent devastating flooding has prompted the Government of the PRC to stop commercial logging in the western watersheds.

India has the largest area of industrial plantations, totaling 5.7 million ha, consisting of fast-growing species (5-10 year rotation) covering 0.9 million ha, and other industrial species covering 4.8 million ha. In Southeast Asia, Indonesia has the largest area of forest plantations, 6.1 million ha, one third of which is planted for industrial purposes. Lao PDR lies at the

Table I.3: Forest Plantations by Type in Selected Countries in Asia in 1990
(annual change of planting area during 1981–1990)

	Plantation Area (ha'000)				Annual Change (ha)
	Fast Growing	Other Industrial	Non-industrial	Total	
China, People's Rep. of	2,120	1,000	28,711	31,831	1,140
Taipei,China	0	0	10	10	
East Asia, total	**2,120**	**1,000**	**28,721**	**31,841**	**1,140**
Cambodia	0	0	7	7	
Lao PDR	0	3	1	4	0.1
Myanmar	0	155	80	235	19.6
Thailand	180	85	264	529	29.4
Viet Nam	560	0	910	1,470	49.0
Indonesia	1,150	280	4,695	6,125	331.8
Malaysia	80	0	1	81	6.3
Philippines	1	5	143	149	
Southeast Asia, total	**1,971**	**528**	**6,101**	**8,600**	**436.2**
Afghanistan	0	0	8	8	
Bangladesh	50	85	100	235	12.3
Bhutan	0	4	0	4	0.2
India	900	4,770	7,560	13,230	1,009.0
Nepal	10	10	36	56	4.3
Pakistan	0	50	118	168	4.2
Sri Lanka	30	95	14	139	6.0
South Asia, total	**990**	**5,014**	**7,836**	**13,840**	**1,036**
Total	**5,081**	**6,542**	**42,658**	**54,281**	**2,612.2**

Sources : ADB (1995a); FAO (1997a, 1997b).

other extreme, having the smallest plantation area, 4,000 ha, most of which is recent and geared towards the pulp industry. Among developing countries, the proportion of industrial to nonindustrial plantation area is highest in Lao PDR, Myanmar, Malaysia, and Sri Lanka.

Although there are many different tree species planted, especially in tropical Asia and the Pacific countries, eucalyptus appears to be the preferred species group of regional planting programs. This species group accounts for about 16 percent (5.2 million ha) of the total plantation area in the region. Acacia, teak, and pine are also major groups, accounting for 11 percent (3.4 million ha), 6 percent (2.19 million ha), and 4 percent (1.25 million ha) of total plantation area, respectively (FAO, 1995b). The remaining 64 percent (20.6 million ha) of plantation area contains other or unclassified tree species such as *Albizzia, Dalbergia, Casuarina, Leucaena, Swietenia, Xylia, Gmelina,* and *Pterocarpus.*

Eucalyptus and acacia plantations are established primarily for the pulpwood and medium-fiber wood industries. They are also favorites of nonindustrial plantations established for community use, e.g. for fuelwood, small wooden poles, for land rehabilitation, and for environmental conservation. The eucalyptus species planted in the region include *Eucalyptus camaldulensis, E. deglupta, E. europhylla, E. globulus,* and *E. grandis,* the hybrid species. The most common acacias are *Acacia auriculiformis, A. mangium, and A. nilotica,* and the pines most often found are *Pinus kesiya, P. merkusii, P. caribaea,* and *P. oocarpa.*

The growth and yields of these species vary according to onsite characteristics and genetic material (improved seed sources and clones). In Indian and Indonesian teak plantations, the yield of an average plantation is about 2–3 m^3/ha/year after about 50–70 years. The average yield of eucalyptus plantations is about 6 m^3/ha/year after 8–10 years. The average yield of *Acacia mangium* plantations in Malaysia and Indonesia is more than 20 m^3/ha/year after 5 years.

Scientific progress relating to the establishment of forest plantations and logging operations has been stagnant because government agencies or State enterprises run these activities. Unlike forest plantations in developed countries or those operated by multinational corporations, forest plantations in Asia are run under low-input, low-output systems. Exceptions are found in the large-scale plantations in Sabah.

The impact of forest plantations on soil erosion is indicated in Table I.4. Surface erosion from well-managed forest plantations is small, averaging around 0.6 t/ha/year. However, if forest litter is removed for use as fuel, as is the case in the PRC, erosion can be much greater than for shifting cultivation.

Table I.4: Surface Erosion in Tropical Forests and Tree Plantations

Forest and Tree Plantations	Annual Soil Loss (t/ha)	
	Range	Mean
1. Natural forests	0.03–6.20	0.3
2. Shifting cultivation during fallow-period years	0.05–7.40	0.2
3. Forest plantations	0.02–6.20	0.6
4. Multistoried tree gardens	0.01–0.15	0.1
5. Tree plantations with cover crop / mulch	0.10–5.60	0.8
6. Shifting cultivation cropping	0.40–70.00	2.8
7. Agricultural intercropping in young forest plantations	0.60–17.40	5.2
8. Tree plantations, clean weeded	1.20–183.00	48.0
9. Forest plantations, litter removed or burned	5.90–105.00	53.0

Source: Wiersum (1984).

The impact of forest plantations also depends on the species planted. Villagers often find that *Eucalyptus camaldulensis* plantations tend to lower the water table and dry up shallow wells, as these forests can absorb up to ten times more water than pioneer forests and four times more water than secondary forests.

National and international attention has increasingly been paid to the possibility of combining tree species with field crops, i.e. agroforestry, for small landholders. The International Center for Research in Agroforestry (ICRAF), which is based in Kenya, has expanded its research activities to cover Asia. In Indonesia, about 70 percent of the total rubber is produced under agroforestry systems. These systems have been acknowledged as providing sustainable support in areas where the soils are too poor to grow food crops on a continuous basis. Agroforestry is estimated to have been adopted by about 7 million people and occupies approximately 2.5 million ha of land in Sumatra and Kalimantan, and includes the damar agroforest (Box I.3) (de Foresta and Michon, 1997).

Today, there are diverse and complex agroforestry systems that mix perennials with food crops. Some of the agroforests provide ecological functions similar to those of natural secondary forests, such as carbon sinks, sources of biodiversity, and means of alleviating soil erosion and flooding peaks (Garrity, 1998).

The development and adoption of agroforestry is largely dependent on various physical, environmental, political, social, and economic conditions. High population pressure combined with low per capita income and forest resources that are inadequate for local needs (including both timber and nontimber products) has necessitated the use of fuelwood and provides increased incentives for agroforestry. An abundance of State land under a strong land-use policy, together with government incentives and support, reduces the cost of and increases returns from agroforestry. However, the small amount of arable agricultural land per capita may limit the profitability of tree-based systems.

Agroforestry has been adopted and practiced widely in the PRC, India, Indonesia, Lao PDR, and Viet Nam. With the exception of Lao PDR, the population density in these countries is high, the income per capita low, and forest resources scarce. In India, for example, the annual requirement for fuelwood and timber is 220 million t and 280 million m^3, respectively, while the sustainable production levels of these products from the forests is only 30 million t and 12 million m^3, respectively (APAN, 1995). To meet the demand for such forestry products as well as to maintain sustained production from the forestry and agricultural sectors, agroforestry has been promoted in various parts of India.

The role of agroforestry in fuelwood supply is very important in both rural and urban areas of Bangladesh, where 90 percent of the fuelwood used is from home gardens. Agroforestry development in Lao PDR has been a response to government policy on land taxes and the desire of individuals to claim more land, especially land that is easily accessible.

In the PRC, agroforestry has the support of both central and local governments, with the aim of improving environmental and economic conditions. The systems used in the PRC are much more diverse than those in any other country in the region and include home gardens, strip shelter forests in combination with cropping systems, woodlot plantations, and tree shading with cropping systems. To address the shortage of fuelwood, more than 3 million ha of woodlot plantations have been established with an annual production of 10–30 t/ha, depending on the species planted. The shelter-forest system also increases wheat yields and latex production in rubber plantations. Further, it generates over 6 million m^3 of timber and 3 million m^3 of fuelwood per year through thinning and final harvesting.

The system in Lao PDR has been initiated mostly under the *taungya* system which involves planting teak or paper mulberry in combination with rice, pineapple, maize, or other cash crops to improve shifting cultivation. This is especially so in the northern part of the country where large shifting-cultivation areas are being replaced by teak.

Although agroforestry has been adopted and practiced successfully in many countries, the scale of its practice is limited to subsistence production. There are many factors that limit its growth and development, including insufficient mechanisms for the exchange of agroforestry experiences, inadequate policies, rules, and regulations, and an insufficiency or a lack of incentives from governments (APAN, 1996). Other factors include a lack of access to state-of-the-art technical information and farmer-generated knowledge among small households, a lack of up-to-date market information on agroforestry products, and inadequate support services for expanding agroforestry activities.

Livestock Subsector

Historically, livestock were raised using resources that were of little value for other uses, such as household food wastes or land that was not fertile enough for crops. Today, livestock production has emerged as one of the more advanced segments of agriculture, and also as one of the most important components of global agriculture. Of the three major production systems (land-based grazing, mixed farming, and industrial farming), industrial farming has seen the most rapid changes in the last decade, with most of the growth occurring in developing countries.

In Asia, where industrial and urban growth has been particularly rapid in the last decade, there has been a remarkable expansion of the peri-urban poultry and pig industries. This growth has been a response to increased demand as well as to technical advances. More concentrated feed and improved animal health have resulted in a more favorable feed-conversion ratio, giving these commodities a higher return on investment. The structural shift also reflects the pressure on land from population increase, rendering the expansion of land-intensive animal husbandry more difficult.

Livestock production is vital to the overall development goals of Asian countries: livestock production improves food security and nutrition and increases employment. Modern industrial farming operates side by side with small-scale farming, although there is still a predominance of mixed farming systems. Some 90 percent of livestock production in the developing countries of Asia comes from smallholders or landless persons.

Traditional farming is based on systems with minimal or no imported inputs and where livestock and crop activities are integrated. Farm products are mainly for domestic consumption and the excess is sold locally. The demand for livestock products has increased rapidly in urban centers, and traditional land-based livestock production with limited use of resources is unable to meet this increasing demand. The commercial nature of livestock production encourages specialized intensive farms to move nearer to the market place in the city, i.e. in peri-urban areas. Smallholder farms, because of their noncommercial nature, have little access to credit facilities or modern technologies to enhance their activities, further losing their competitiveness, resulting in their being supplanted and marginalized (FAO, 1998a). In some countries, rural producers, because of a lack of infrastructure, economies of scale, and insufficient marketing facilities, face heavy competition from urban producers, which often limits rural livestock production to subsistence levels.

In rural areas, there are many animals with a low level of productivity because they are only being fed at about maintenance level. With more feed, much of the additional nutrition would go directly to production. This has been demonstrated in Bangladesh where the provision of a small amount of supplemental nutrition has led to an increase in milk production from 1 to 6 liters per day in indigenous cows (Ramsay and Andrews, 1998). Increasing livestock production for poor farmers would provide a useful short- to medium-term benefit, especially where farm labor is underutilized. If animals already owned by the farmer become more productive, the benefit is received at little additional cost. Other constraints to livestock development in Asia for smallholders include the scarcity of feeds, high incidence of animal and poultry diseases, the prevalence of traditional livestock management systems, and inadequate access to credit.

Low livestock productivity can also be the result of poor animal husbandry. Appropriate livestock practices can make a contribution to raising productivity, but farmers often have limited access to education and training. Low productivity can also sometimes be attributed to the fact that these small-scale farmers do not have access to the better breeds of livestock. However, replacing local cattle with improved breeds will not solve the productivity problem unless feed resources on the farms are increased.

In the past, it has been government policy in many countries in Asia to focus on importing foreign breeds in order to achieve higher productivity levels. However, establishing a modern industry with imported breeds has proven difficult. This has been largely due to the fact that the greatest improvements that can be derived in animal productivity require better management and improvement of feed resources, not simply a different breed. Foreign breeds will most likely have different feed requirements that cannot be met by small-scale farmers and may not adapt to local conditions as well as do the indigenous breeds. Additionally, if feed requirements are not met for the foreign breeds, their reproduction rate may be affected.

Asia has relatively few major infectious disease problems in cattle and buffalo. However, foot-and-mouth disease has been difficult to prevent amongst countries with easily accessible land borders, unless joint programs have been implemented. In some Asian countries, notably Bangladesh, Indonesia, Philippines, and Thailand, the poultry sector is very important and the control of disease, especially Newcastle disease, is crucial, particularly at the village level. In Bangladesh, the estimated annual loss from poultry diseases is $240 million, of which about half is attributable to Newcastle disease alone. The increase in industrial livestock production has also increased the rate of livestock disease; diseases also spread more quickly and are harder to contain in intensive animal production.

In most developing countries, priority in the past has been given to the production of food crops. Several considerations highlight the current need to give greater priority to livestock development. While in the industrial world the demand for milk and meat will likely plateau, or even decline, in the developing world population growth and urbanization will fuel a strong increase in demand. For example, between 1986 and 1996, growth rates for meat in Asia were 7.7 percent, compared with only 0.7 percent for the rest of the world. Milk growth rates over the same period in Asia were 4 percent, whereas annual growth rates were negative at -0.8 percent for the rest of the world (FAO, 1998a). Current levels of milk and meat consumption in developing countries are only about one fifth of those in developed countries.

For the region as a whole, a strong trend has been observed towards the incorporation of more and more animal protein into the population's traditional vegetable-based diet. Connected with this trend is an increasing selectivity as to which parts of an animal are used for food. Traditionally, most parts of an animal were utilized, even if there was much wastage due to insufficient recovery and re-utilization technologies. Now the global trend is clearly to meat, and more often to lean meat. Other products, such as offal, blood, and bones, are increasingly used industrially and often recycled as feed.

The demand for livestock products is also highly income-elastic, and thus demand will increase with rising incomes. In Asia, the demand for meat is expected to triple by 2020 (de Haan, Steinfeld, and Blackburn, 1997). An accelerated livestock production program to satisfy this growing demand for primary livestock products such as milk, meat, and eggs will be required. Growth of all livestock sectors has been high over the past two decades (Table I.5), and this has been especially true of poultry and eggs. It will be a challenge for the livestock sector to satisfy future demands while at the same time preserving the natural resource base. The long-term objective is to produce and supply sufficient and safe animal protein for rapidly growing and urbanizing populations, under socially and environmentally acceptable terms.

Table I.5: Livestock Production in Asia

Livestock product	Production (t)				Annual Growth Rate (percent)		
	1965	1975	1985	1995	1966-1975	1976-1985	1986-1995
Total Meat	14,299,373	20,930,885	38,181,690	74,810,570	3.81	6.01	6.73
Pork	7,284,905	10,601,171	22,109,992	39,748,000	3.75	7.35	5.87
Poultry	1,512,179	3,078,570	6,027,808	13,951,590	7.11	6.72	8.39
Milk	44,975,411	58,064,570	89,094,320	142,617,600	2.55	4.28	4.7
Eggs	4,322,566	6,446,128	11,906,807	26,525,940	4.00	6.14	8.01

Source: FAOSTAT Database. *Available: http://apps.fao.org*

Growth in meat production until 2010 is expected to come from increases in productivity and from greater numbers of animals, with these factors accounting for about one third and two thirds of growth, respectively. Poultry production is projected to rise most rapidly, followed by pork production. More than 90 percent of the increase in pork production, however, will come from one region, East Asia, including the PRC. There are some differences between the major regions in structural changes, although the main trends are common to all. The proportion of poultry meat to total meat output is expected to continue to increase in every region while the contribution of cattle and buffalo meat will likely decline. Yields per animal are also expected to grow faster than in the past twenty years as a consequence of improvements in health, feed, and pasture carrying capacity.

Although the contribution of the livestock sector to GDP is relatively small, it is nevertheless significant in terms of the total output of the agricultural sector. The sector in Asia contributes from about 10 percent to about one third of agriculture's gross added value. However, livestock statistics generally quantify the products that are eaten and traded such as meat, milk, and eggs, and do not consider products such as draft power and manure (as fertilizer, fuel, or feed). As a result, the statistics greatly underestimate the role and importance of livestock (Ramsay and Andrews, 1999).

Growth rates have increased for all major livestock products over the past two decades. Productivity increases have been the main source of production increases, as opposed to the expansion of the industry or an increase in livestock numbers. Growth trends also differ within Asia, as there are subregional variations in production and consumption across the region. For example, South Asia consumes large quantities of milk but little meat. Farming is also still largely small scale with manure and draft power remaining highly important. East and Southeast Asia have seen the greatest increase in intensive production of monogastric animals such as pigs and poultry. In Thailand, poultry has become a major export earner.

The recent financial and economic crisis in Asia has also affected the industry, particularly in countries that rely on imported feed. These countries have seen a sharp increase in the prices of imported feed and other inputs as well as a contraction of demand. This has caused a drop in industrial production and in some cases it has been wiped out altogether. Industrial livestock production had grown rapidly in Indonesia until the crisis: large-scale poultry production, which was growing very fast there, was heavily damaged by the crisis, mainly because it is heavily dependent on imported feed. In Malaysia, although livestock production growth rates remain high, the industry also depends largely on imported feed.

Due to a lack of livestock feed resources and shortage of land for livestock feed production, most countries in the region are not in a position to develop large-scale intensive livestock industries without relying on imported feed (Ramsay and Andrews, 1998). However, some countries have turned to domestic feed resources. Thailand, for example, has now increased its use of cassava for livestock feed. Such developments offer a window of opportunity for the development of commercial smallholder livestock because the competitive pressure from large-scale industrial producers has, to a large extent, subsided.

In terms of total meat, less than 3 percent is produced under the grazing system. The bulk of meat production originates from mixed systems that account for two thirds of total production. Among the mixed farming systems, rainfed systems only account for one seventh, while the emerging industrial system now accounts for one quarter of total meat production (FAO, 1998a). About 21 percent of the world's arable land is producing feed for the livestock industry, and livestock production uses 32 percent of total cereal production. Maize accounts for half of all feed grain, with barley and wheat as the other main components. Soybean is the most important component among oilmeals.

The most remarkable growth trends have been in the PRC, Indonesia, Malaysia, and Thailand (Table I.6). The growth rate in total per capita meat production in Asia almost doubled from an average of 3.81 percent annually during 1966–1975 to 6.73 percent during 1986–1995. The PRC experienced the strongest growth rates for meat production, followed by Malaysia. Annual growth in pork production slowed slightly from 1976–1985 to 1986–1995 from an average of 7.4 percent to 5.9 percent (Annex Table A27). The PRC has the highest pork production per capita in Asia, followed by the Republic of Korea, the Philippines, and Viet Nam, and strong growth was seen only in these countries. Cambodia has maintained relatively fair growth rates, and is now experiencing moderate levels of pork production per capita.

Milk production shows a similar trend to that of meat production, although at lower rates (Annex Table A28). The highest per capita production is in South Asia, where India and Pakistan are leading, although growth in the industry is now slowing there. The PRC and Thailand have also shown strong growth rates, but per capita production is still low. Strong growth has continued for poultry and egg production, averaging 7 percent or more per annum during the last 30 years (Annex Tables A29 and A30). Malaysia and Thailand have had strong growth in both areas, and although the PRC has also shown strong growth rates in both areas, production per capita of poultry is still low. Japan has high egg production per capita and moderately high poultry production per capita, but growth rates are low because local demand is satisfied by imports, and the industry is now stabilizing.

Areas of South Asia have experienced strong growth in livestock production over the past 30 years. Strong growth in poultry has been manifested in India, Bangladesh, and Pakistan (Annex Table A29). In India, livestock production is a high priority at every administrative level for two primary reasons: production self-sufficiency and rural development. Small farm size remains the biggest obstacle to development of the livestock industry there.

Meat production has also shown a strong growth trend in Pakistan (Table I.6). Pakistan is particularly self-sufficient in livestock products. Although this country is the largest milk producer in the region, some milk powder is still imported due

Table I.6: Total Meat Production Per Capita in Asia

	Production (t)			Production Per Capita (t per 1,000)			Annual Growth Rate (percent)		
	1975	1985	1995	1975	1985	1995	1966–1975	1976–1985	1986–1995
ASIA	**20,930,885**	**38,181,690**	**74,810,570**				**3.81**	**6.01**	**6.73**
East Asia									
China, People's Rep. of	9,762,314	20,624,240	47,752,610	10.5	19.3	39.1	3.81	7.48	8.40
Japan	2,213,762	3,460,969	3,200,840	19.9	28.6	25.6	7.29	4.47	-0.78
Korea, Rep. of	249,120	735,408	1,416,683	7.1	18.0	31.5	5.71	10.82	6.56
Mongolia	229,060	226,000	214,427	158.3	118.4	87.1	4.16	-0.13	-0.53
Southeast Asia									
Cambodia	52,320	87,728	153,508	7.4	11.8	15.3	1.68	5.17	5.60
Indonesia	530,621	1,002,546	1,936,497	3.9	6.0	9.8	3.35	6.36	6.58
Lao PDR	18,370	35,554	49,141	6.1	9.9	10.1	-3.42	6.60	3.24
Malaysia	243,003	420,607	956,259	19.8	26.8	47.5	6.74	5.49	8.21
Myanmar	199,279	311,993	335,467	6.5	8.3	7.4	3.92	4.48	0.73
Philippines	603,416	704,408	1,622,850	14.0	12.9	23.9	2.68	1.55	8.35
Singapore	113,965	131,135	147,872	50.4	48.4	44.4	8.76	1.40	1.20
Thailand	657,438	1,074,149	1,473,500	15.9	21.0	25.3	4.66	4.91	3.16
Viet Nam	424,140	864,563	1,385,620	8.8	14.4	18.8	-0.20	7.12	4.72
South Asia									
Afghanistan	203,428	217,760	230,520	13.2	15.0	11.7	2.86	0.68	0.57
Bangladesh	239,957	259,907	370,837	3.1	2.6	3.1	1.72	0.80	3.55
Bhutan	4,613	6,544	7,764	4.0	4.5	4.4	2.48	3.50	1.71
India	2,238,951	3,077,774	4,391,485	3.6	4.0	4.7	2.15	3.18	3.55
Maldives	565	750	850	4.1	4.1	3.3	2.50	2.83	1.25
Nepal	101,015	166,456	204,648	7.9	10.1	9.5	3.60	4.99	2.07
Pakistan	564,780	946,774	1,856,250	7.6	9.4	13.6	3.32	5.17	6.73
Sri Lanka	58,176	55,373	88,108	4.3	3.4	4.9	1.12	-0.49	4.64
Central Asia									
Kazakhstan			1,065,236			63.3			
Kyrgyz Republic			179,900			40.3			
Uzbekistan			519,000			22.8			
Tajikistan			56,400			9.7			
Turkmenistan			110,500			27.1			

0 = zero or less than half of the unit measured.

Note: Annual Growth Rate = ((Ln(value year begin) - Ln(value year end)) / number of years) x 100.

Source: FAOSTAT Database. *Available: http://apps.fao.org*

to the lack of a proper fresh-milk collection network in the country. Live animals, hides, and skins are exported. The country has buffalo and cattle breeds for the production of milk whose quality is world famous. There is still much room for improvement, and it is estimated that the output of livestock products could double if extension services were improved. Among the constraints are an inadequate feed base and a low number of productive animals.

In Bangladesh there is a large and important livestock population, but the animals have low productivity, mainly due to the insufficient quality of feed resources and a high incidence of disease. Bangladesh is deficient in livestock production but cannot afford many imports. However, growth of the industry has been improving over the past 30 years.

Production has remained low in other countries in South Asia such as Nepal, where 90 percent of the population depends on integrated farming, including livestock raising. Feed resources need to be developed, which would lead to more productive animals. Difficult transportation conditions and weak marketing facilities are among other constraints facing Nepal today. However, egg and poultry production have shown moderate increases in growth rates since 1975.

Central Asia has the highest per capita production of milk and a high production of meat per capita. However, the production of other livestock products is low. Data have not been available to determine growth rate trends over the past three decades for Central Asia.

Livestock production has a great potential for contributing to either the degradation or the enhancement of the environment, depending on the technologies and practices adopted. The environmental challenges range from overgrazing (degradation and erosion of land), to deforestation, to degradation and pollution of water resources, emission of greenhouse gases, and loss of biodiversity. Growth rates in the more developed countries such as Hong Kong, China; Japan; and Singapore have begun to level off. Land scarcity in Hong Kong, China; and Singapore dictates that they will remain largely importers of livestock products. Recently, the governments in these countries have paid more attention to environmental pollution and health risks resulting from livestock farming than to increasing production capabilities.

The threat to human health from livestock production is exemplified by the spreading of a rare virus from pigs to humans in Malaysia in early 1999. More than 100 people died and almost one million pigs were destroyed to keep the virus from spreading.

Recent rapid growth of the livestock sector near urban areas has created additional pollution problems for already congested and relatively highly polluted areas. Wastes generated by intensive production units, especially pig production, are a major source of water, land, and air (odor) pollution. Heavy metals arising from feed can affect the health of nearby residents if wastes are not treated properly. The use of additional water to clean solid waste from production units further increases the amount of waste to be treated and in turn the cost of wastewater treatment.

Animal waste from intensive systems can be used to produce biogas for heating, drying, and power generation. The digester effluent can also be used to fertilize crops and fertilize / feed fishponds. Appropriate government intervention in this area would allow environmental problems to be solved and maintain long-run production, while deriving benefits from biogas energy and nutrient recycling (FAO, 1998a). Other initiatives, such as limitations on stocking density, would help to reduce pollution discharges.

Pressure for greater emphasis on environmental conservation is evident throughout the region. The greatest threat is from overgrazing and in many countries, especially in semi-arid areas, livestock numbers already exceed the carrying capacity of unimproved natural grasslands. Overgrazing is a major concern, especially in India and Central and inner Asia. It will be important to identify situations where the raising of livestock is out of balance with the adsorptive capacity of the soil, water, and air. Competition between crops and grazing generally results in resource degradation and finally in the collapse of livestock production, especially for the larger ruminants. In some areas, there is a need to restrict the density of animals raised, the objective being to optimize the long-term productivity of the land as a whole while maintaining ecological diversity and environmental balance.

In tropical Asia, the problem of deforestation is complicated as it is intertwined not only with livestock production, but also with logging operations and human population pressure, especially in areas where suitable land is scarce. Overgrazing, which leads to land degradation, also leads to deforestation as new land is cleared for use.

Of the livestock production systems, mixed farming tends be the most environmentally friendly: it allows reuse of animal waste as organic fertilizers that replenish the soil and reduce erosion. Mixed farming also provides protection against product/price fluctuation risks. Each year, livestock produce about 13 billion t of waste, and supply 22 percent of total nitrogen fertilizer and 38 percent of phosphates of animal origin (FAO, 1997a). Crop waste can also be reused as animal feed.

In livestock systems other than mixed farming, transport costs from nutrient-surplus to nutrient-deficient areas can be high. For example, with intensive systems, there is a need for transport of feed to and manure from production areas. It may eventually be less costly to relocate intensive production areas away from peri-urban centers, if a proper transportation infrastructure can be developed. Some rapidly expanding urban centers such as Ho Chi Minh City, Viet Nam, have already initiated programs to move intensive pig and poultry production outside city boundaries. The difficulties in transition from extensive to more intensive livestock production have also led to increased environmental degradation.

There have been massive investments in past decades in physical infrastructure, including the construction of roads, ports, and communication facilities, but also of slaughterhouses, and cold storage and retail facilities. All of these have greatly reduced transaction costs and have, in numerous places, made possible trade in livestock products. Because of the perishable nature of livestock products, infrastructure development has an extremely stimulating effect on livestock production.

As per capita incomes increase, more animal products pass through market and processing channels before consumption. This leads to even greater waste production. The most important environmental impact of animal product processing results from the discharge of wastewater. Additionally, heavy metals such as copper, zinc, and cadmium are used as growth stimulants in some feeds. Without proper management of these discharges, intensive farming systems discharge waste containing heavy metals at levels that are harmful to animals and human health. At present, only the Organisation for Economic Co-operation and Development has regulations that aim to reduce the level of heavy metals in feeds.

Fisheries

Asia accounted for more than half of total world fishery production in 1996 (ICLARM, 1999). During the two decades ending in 1996, total production of fish and shellfish in Asia increased at a much faster pace (approximately 4 to 5 percent per year) than did the production of food crops, rising from nearly 28 million t to 67 million t from 1975 to 1996, raising Asia's share of the world total from 42 percent to 55 percent (Table I.7). The overall performance of Asian fisheries is especially remarkable when their growth is compared with that of the rest of the world. Asian fishery production grew at an average 4.8 percent per year over the past decade, up from 3.6 percent a decade earlier, whereas that of the rest of the world declined from 2.6 to 0.3 percent over the same period (Table I.7). Asia was the main force propelling the overall increasing trend in world fishery production.

Two striking features of Asia's fisheries growth during the past decade are the emergence of the PRC as the predominant producer, and an increasing contribution from aquaculture. The PRC contributed nearly half of Asia's total fish and shellfish production in 1996, compared with only 16 and 21 percent in 1976 and 1986, respectively. Most of the remaining production was contributed by Japan, India,

Table I.7: Asia and the World: Fish and Shellfish Production, Selected Years

	Output (t, million)						Growth (%)	
	1950	1975	1985	1990	1995	1996	1977–1986	1987–1996
Asia	6.46	28.15	38.47	47.45	63.28	67.11	3.6	4.8
Rest of the World	12.74	37.59	48.67	51.56	54.00	53.90	2.6	0.3
World Total	19.20	65.74	87.14	99.01	117.28	121.01	3.0	2.6
Asia's Share in world (%)	33.7	42.8	44.1	47.9	54.0	55.5		

Source: From data presented in FAO (1998b).

Indonesia, Thailand, Republic of Korea, and the Philippines (in that order), each of which produced over 2 million t on average during the past decade (Annex Table A31). However, only a few have registered annual growth rates above 3 percent, while production in Japan and the Republic of Korea has declined. Japan, Asia's largest fish producer until 1988, now takes second place after the PRC. Japan's share in Asia's total fish and shellfish production dropped from 34 percent in 1976 to merely 10 percent in 1996.

Much of the growth of Asian fisheries during the past decade was fuelled by aquaculture production, which grew by over 11 percent per year between 1987 and 1996 in both freshwater and marine waters (Table I.8). Once again, most of this growth has taken place in the PRC, where fish production increased by a factor of 6.6 during 1977 to 1996, with particularly high growth, an annual average of 13 percent, during the past decade (Annex Table A31). Over half of the PRC's fish and shellfish production in 1996 came from aquaculture, and accounted for 75 percent of Asia's aquaculture production of fish and shellfish, up from 55 percent in 1986. The PRC is probably the only country in the world where culture production exceeds capture production (Lan and Peng, 1997). Aquaculture has also spread rapidly in other Asian economies, notably India, Indonesia, Japan, Republic of Korea, Philippines, and Thailand. However, in many of these countries, the commercialization and consequent intensification of aquaculture, the use of carnivorous species that depend on fishmeal extracted from capture fisheries, and the negative environmental and socioeconomic impact, have raised many doubts about its overall benefits and sustainability.

Asia has a long history of capture and culture fishery production, evident in the wide variety of traditional gear and culturing techniques that have evolved over time to exploit the diversity of resources. Fish form an important part of the diet of many Asians, although per capita consumption varies widely from country to country. It is generally low in land-locked countries, such as Bhutan, Kyrgyz Republic, Mongolia, Nepal,

Table 1.8: Fishery Production in Asia, 1976–1996

	Production (t)			Average Annual Growth Rate (%)	
	1976	1986	1996	1977–1986	1987–1996
Total (fish, shellfish, aquatic plants)	30,787,197	45,218,268	75,158,690	3.8	5.1
Fish, Shellfish	28,963,046	41,691,808	67,112,800	3.6	4.8
Aquatic Plants	1,824,151	3,526,460	8,045,890	6.6	8.3
Inland Fisheries (fish, shellfish)	4,122,941	7,869,782	19,403,434	6.5	9.0
Marine Fisheries (fish, shellfish)	24,840,105	33,822,026	47,709,366	3.1	3.4
Capture Fisheries (fish, shellfish)		34,447,940	43,647,733		2.4
Aquaculture (fish, shellfish)		7,243,868	23,465,067		11.8
Marine Capture (fish, shellfish)		31,424,480	38,899,011		2.1
Inland Capture (fish, shellfish)		3,023,460	4,748,722		4.5
Freshwater Culture (fish, shellfish)		4,526,454	14,177,520		11.4
Brackishwater Culture (fish, shellfish)*		590,105	1,218,798		7.3
Marine Culture (fish, shellfish)		2,398,956	8,810,994		13.0

Sources: From data presented in FAO (1998b, 1998c)

Note: * Brackishwater culture includes both inland and coastal waters. In 1996, the two represented, respectively, 39% and 61% of total brackishwater production, with average annual growth rates (1987–1996) of 4.0% and 10.1%, respectively.

and Tajikistan, and in South Asia, but relatively high in Southeast and East Asia, particularly among wealthier economies.

The contribution of this sector to food security is highlighted by the fact that increased supplies of fishery products in the PRC raised the annual consumption of aquatic products there from 2.67 kg to 7.29 kg per capita during 1952 to 1992. This is especially significant given that the PRC population more than doubled in that period from 575 million to 1,172 million (Wang, 1996, cited in Williams and Bimbao, 1998).

The fishery sector in Asia employs a large workforce. Even though the proportion of people dependent on fisheries in Asia might appear small against the region's vast population, their number is considerable in absolute terms. According to FAO (1998d) some 25 million fishers and fish farmers–four fifths of the world total–are employed in Asia. In South and Southeast Asia, fisheries employ 10.36 million people as full- or part-time fishers, with 8.64 million employed in marine fisheries and the remaining 1.72 million in inland fisheries (Hotta, 1996). Moreover, there may be a large number of occasional fishers, particularly in the inland fisheries. In addition to the direct employment provided by fisheries, considerable job opportunities exist in the related service and transport industries. Opportunities for women exist especially in aquaculture, fish retailing, and processing. In the PRC alone, the population engaged in these fishery-related activities (not including capture fisheries and aquaculture directly) numbers over 11 million (Bureau of Fisheries, Ministry of Agriculture, PRC, 1997).

Marine capture fisheries, which contribute the largest, albeit declining, share of Asia's total fisheries production, are characterized by the presence of a large number of small- and medium-scale fishers (Hotta, 1996) (Box I.4). They operate in shallow inshore waters of up to 50 m in depth, using traditional but increasingly modernized craft and gear as well as nontraditional craft and gear. Fishing pressure is intense along the continental shelves of the western coast of India, the Bay of Bengal, the Gulf of Thailand, the South and East China seas,

Box I.4 Multiple-Use Conflicts and Asian Fishers

Despite the technical advances made in other sectors in many Asian countries, the majority of Asia's fishers are small-scale coastal fishers who are generally among the poorest of the poor, and for whom the open-access nature of fisheries offers a last resort to eke out a living. For many of these people, the largest proportion of their income is spent on food and a large proportion of their food comes from coastal fisheries.

A diverse group of other stakeholders coexists with coastal fishers. These include the trawler operators, whose fishing gear is highly destructive, disturbs habitats, and harvests indiscriminately for the fishmeal industry. Commercial fishers with better equipment often compete for resources in the same fishing grounds as coastal fishers. The destruction of mangroves and water pollution from aquaculture both serve to reduce the regenerative capacity of coastal areas. Depleted fish stocks are the result of competition, coastal trawling, and environmental degradation, and pose direct threats to the livelihood of all fishers. It is not surprising that conflicts between small- and large-scale fishers are widespread (Silvestre and Pauly, 1997) and likely to increase.

A number of policy options are available to improve the livelihood and/or productivity of small-scale fishers. On the technical side, stock enhancement technologies could be introduced. Institutional solutions, such as rights for marine aquaculture and participatory management by local communities, may be needed to replace the lax enforcement of laws on trawling, for example. Protection afforded to the fishmeal industry could be scrapped. Alternative employment opportunities also need to be created. The large number of coastal fishers suggests that, for some, a transition away from small-scale fishing may be necessary.

In boom periods, a transition away from low-productivity small-scale fisheries is easier because there is increased demand for labor from other sectors. In Thailand, for example, the economic boom of the late 1980s to mid-1990s created new

(continued next page)

Box 1.4 (continued)

employment opportunities either outside the fishing sector or in other fishery subsectors such as aquaculture. Although the total number of people employed in marine fisheries seems to have declined relative to total population, there has been a large internal change, with traditional fishers moving out of the industry. In place of these traditional fishers are newcomers from the peripheral regions of the country (the northeast and upper north), or even from neighboring countries (Myanmar, Lao PDR, and Cambodia) where few income opportunities exist (Boonlert, 1994, cited in Mingsarn and Pednekar, 1998).

Such a high turnover is possible when economic growth creates alternative employment opportunities. When no such alternatives exist, however, fishers are left with no choice but to compete for a dwindling resource, leading to further overfishing, resource degradation, and finally untenable social conflicts. Unless drastic action is taken to strengthen and enforce responsible coastal fishing, coastal fisheries, which have been valuable assets for many Asian countries, will diminish and turn into social liabilities in the near future.

the Bohai and Yellow seas, and the parts of the Sea of Japan bordering Japan.

Only a handful of nations, notably Japan, Republic of Korea, Democratic People's Republic of Korea, and more recently the PRC, have sizeable fleets of large vessels (over 100 gross registered tons) (FAO, 1997c), allowing them to fish further offshore and in high seas. Following the 1982 Convention on the Law of the Sea, and the declaration of 200-mile exclusive economic zones (EEZs), many countries have enhanced their ability to fish further offshore. A number of South and Southeast Asian countries, such as India, Indonesia, Philippines, and Thailand, have begun developing their distant-water fishing fleets. These mostly operate in the EEZs of other countries under bilateral agreements.

The gross statistics of Asian fisheries might appear to contradict the general picture of ill health in most major fisheries of the world. Many of the world's major fisheries are facing serious falls in production; stocks of a number of commercially important fish species have been fully or overexploited or are rapidly dwindling, and many commercial species are endangered. The trend to fish "down the food chain" may have long-term and perhaps irreversible impact on the ecological balance in marine ecosystems (Pauly et al., 1998). The open-access nature of fisheries and "subsidy-driven over-capitalization" have been largely responsible for the trends of overfishing and excess capacity that have led to a global crisis in fisheries (Garcia and Newton, 1997, cited in Pauly et al., 1998). These trends already exist in many Asian waters, casting shadows on the sustainability of fisheries growth in Asia.

The predominance of a single country such as the PRC makes sustainability of Asian fisheries growth even more vulnerable because it hinges largely on the ability of the PRC to sustain its high production rates, particularly in aquaculture. However, even though further potential for aquaculture expansion in the PRC has been identified (e.g. ADB, 1995b), the two major constraints for aquaculture generally, viz. environmental degradation (from aquaculture itself as well as from external sources), and competition for land and water resources from other economic activities (FAO, 1997b), are also likely to threaten the goal of realizing that potential. Intensification of aquaculture has been contributing to further environmental degradation, which is already apparent in the PRC and elsewhere in Asia (FAO, ibid.).

There are several indicators that suggest that overfishing in many parts of Asia may have worsened during the last two decades. Demersal stocks have been heavily fished in much of the Gulf of Thailand since the 1970s. In Thailand, catch rates in terms of catch per unit effort are currently only 6 to 10 percent of their peak levels, which were reached soon after the introduction of otterboard trawling in the early 1960s (FAO, 1997b; Mingsarn and Pednekar, 1998). Catches of a number of large and small pelagic stocks also appear to have declined, although the recent decline in landings of small pelagic fish is largely attributed to the environment-linked fluctuations in catches of the Japanese pilchard in the northwestern Pacific (FAO, 1997c). More importantly, however, catches of miscellaneous species, which traditionally form a large part (nearly a quarter) of Asia's marine capture fisheries, have been on the rise (Annex Table A32). A considerable and increasing portion of these catches consists of juveniles of commercially important fish species. An environmental and natural resource accounting exercise carried out in the Philippines estimated the natural resource depreciation of fisheries in 1992 at 6.5 billion pesos (at 1988 prices), higher than that of forests and soils by a factor of 13 and 11, respectively (IRG / Edgevale / REECS, 1996).

A recent study analyzing the world's top 200 marine fish resources, indicated that in 1994 about 35 percent registered declining landings and thus were in the senescent phase. Another 25 percent were in the mature phase at a high level of exploitation, while the remaining 40 percent were still developing (Grainger and Garcia, 1996). Thus, 60 percent of the world's fisheries (including some in Asia) are in urgent need of management to control and reduce fishing capacity and effort (Grainger and Garcia, ibid.). For instance, large increases in the capture of marine cephalopods and other molluscs are attributed to a decline in demersal fish, which are their predators. Catches of these molluscs may increase in the short term, since the prey population is much larger than that of the predators, but the value per unit catch decreases and the increasing catches give "a misleading vision of the state of world fishery resources and a false sense of security" (Grainger and Garcia, 1996, cited in FAO, 1997b).

Capture Fisheries

The declining share of marine capture fisheries to total fishery production in Asia is mostly attributable to slower growth in the northwestern Pacific, traditionally dominated by the commercial fisheries of PRC, Japan, Republic of Korea, Democratic People's Republic of Korea, and nonAsian countries such as Russia, the USA, and several European nations. Yet, the average production growth rate of 1.9 percent per year in this fishing area during 1987 to 1996 was still higher than the world average of 1 percent (Annex Table A33). The drastic decline in recent years in the catches of the two dominant species, viz., the Japanese pilchard (sardine) and Alaskan pollock, has been the main reason for the slower growth of the northwestern Pacific capture fisheries. Large increases in the catches of other species, especially Japanese anchovy, largehead hairtail, Japanese flying squid, and salmon could not fully compensate for the losses from these two species.[3] Coastal fisheries in this region, particularly in the seas bordering the PRC (Yellow Sea, Bohai Sea, East China Sea, and South China Sea) are constrained by poor water circulation caused by the semi-enclosed nature of these seas (Deb, 1997).

Marine capture fisheries still account for the largest share of Asian as well as global fish production. The share of inland capture fisheries has been marginal. These fisheries have grown at twice the rate of marine capture production during the past decade, in part due to the large number of reservoirs constructed and increasing efforts to seed inland waterbodies. However, further expansion may be constrained by environmental degradation and the fact that most inland waterbodies have been already exploited.

The increased mechanization of traditional craft and the development of new gears have spurred more intensive fishing further offshore, leading to reduced catches despite increased fishing effort. For example, catches of pelagic fishes in much of the Gulf of Thailand declined within several years of the introduction of purse seines in Thailand in the early 1970s (Mingsarn and Pednekar, 1998). Some fishing technologies, e.g. mechanized trawlers and purse seiners, were introduced in India

---

[3] While the decline in Alaska pollock catches may have been due to overfishing, that of Japanese sardine seems to be caused by decade-long changes in the marine environment, and to correlate with the El Niño-Southern Oscillation (ENSO) index (FAO, 1997b).

somewhat later than they were in Southeast Asia (Devaraj and Vivekanandan, 1997). Unlike their Southeast Asian counterparts, local Indian craft did not really begin to be motorized until the 1980s. Nevertheless, there has been a rapid increase in their number in India in recent years: 47,000 such vessels in total according to recent estimates (Gopakumar, 1997). Mechanization has increased the ability of small-scale Indian fishers to fish further, up to 100 nautical miles, from shore. One consequence of this has been increased opposition from these small-scale fishers to the operation of foreign fishing fleets in India's EEZ (Gopakumar, ibid.), which begins 12 nautical miles from the eastern coast and 24 nautical miles from the western coast.

Similarly, since the introduction of otterboard trawling in Asia, demersal fishes have been overfished or heavily fished in most shallow coastal waters. Perhaps the only major exception is in the western Indian Ocean, where demersal production has steadily increased since the 1950s, especially of croakers and drums since the early 1980s (Devaraj and Vivekanandan, 1997).

Tunas have assumed greater importance, particularly in the western Central Pacific, following the rapid development in the early 1980s of purse seine fisheries in Southeast Asia for canning, and since the mid-1980s, of longline fisheries targeting tuna for the fresh *sashimi* (raw fish) market (FAO, 1997b). Significant catches also come from the eastern Indian Ocean and the northwestern Pacific. Although catches appear to have peaked recently, large potential resources may exist in the western Indian Ocean, given the strong upwellings in northwestern areas (FAO, 1997b).

The greatest growth in the past decade, however, has been registered not by catches of marine finfish, but by catches of diadromous fish such as salmon, shads, and trout, and by a variety of marine invertebrates (crustaceans, molluscs, echinoderms, and miscellaneous marine invertebrates) (Annex Table A34). The significant increases in catches of cephalopods and other molluscs are mainly due to more intensive fishing of these lightly exploited resources; however, their abundance may also result from the depletion of demersal fish, their predators, due to overfishing. Demersal fish stocks have been overfished since the 1970s in most areas, particularly the East and South China seas, the Yellow Sea, and the Gulf of Thailand.

Overfishing not only poses further threats to dwindling fish stocks and conservation efforts, but probably has also caused changes in the marine ecosystem. However, the exact nature of the predator-prey relationship between different species and its impact on stock abundance is not very well understood. It is, therefore, difficult to estimate, for instance, how much of the current upward trends in the landings of pelagic fish (as well as cephalopods) are due to the depletion of predatory demersal fish. It is also impossible "to determine to what extent the rehabilitation of the overfished demersals will affect the survival and potential of the pelagics" (FAO, 1997c).

The fishery industry, dominated by capture production, is among the few remaining frontiers of hunting and gathering in human society. The pressure exerted on the world's fishery resources, owing to modern fishing technology and lax resource management, has been so intense that in most cases making fisheries sustainable would require control of access and reduction of fishing effort on overexploited resources, including demersals and straddling stocks (i.e. of species whose range includes the waters of two or more countries). These measures would have to continue until some recovery, indicated by increased catch rates, became evident. Management efforts should therefore focus on sustaining rather than increasing catches from marine fisheries (Devaraj and Vivekanandan, 1997).

Largely due to population pressure on inland water resources, inland capture fisheries in Asia have not developed on a large scale, contributing only about 7 percent of total fish and shellfish production. Although inland capture production in Asia grew at the moderate rate of 4 percent during the last decade, its share in total production declined slightly. Worldwide, inland capture production has stabilized at around 6.5 million t after peaking in 1990, and this level is expected to be maintained until at least 2010, although wide local variations may occur (Coates, 1995). The major constraints to inland capture fisheries are the growing threat from pollution due to increasing urbanization and industrialization, and inadequate access and user rights (Coates, 1995).

It should be noted, however, that a significant part of inland capture landings does not enter into official statistics, because some of the harvest is consumed directly by fishers and their families. In Thailand, for example, such direct consumption is estimated at 25 percent of the reported catch (FAO, 1997c).

Realizing the importance of inland fisheries (both capture and culture) to rural food security, intensive aquaculture and culture-enhancement techniques are being used in many Asian countries to increase productivity through seeding or stocking of waterbodies. With the further development of hatchery technology, these practices should offer greater potential for realizing higher yields. Overall, culture-enhanced capture fisheries seem to offer better potential for low-income, resource-poor communities, because they use existing water resources and low resource-input systems, and create little, if any, pollution. They may thus be better suited than intensive aquaculture for rural communities.

Aquaculture

Records of aquaculture practices in Asia date back to the manual of fish culture written by Fan Li in China some 2,400 years ago (Deb, 1997). Long histories of aquaculture practices are also evident in a number of other Asian countries, such as polyculture of freshwater fishes in natural and human-made ponds and tanks in India and the tambak culture system in Indonesia. These traditional systems are mainly extensive forms of culture with little, if any, external inputs such as feed.

The rapid spread of aquaculture and its diversification in many Asian countries is due largely to successes in hatchery technology and balanced-diet feed manufacturing. These and various other technologies have allowed intensification of aquaculture, increasing productivity. Today, Asia is the largest producer of cultured fish, contributing almost 90 percent of the world culture production of 25 million t in 1994 (ICLARM, 1998). Particularly high growth rates have been attained for freshwater finfish culture (carps, tilapia, and a number of other species) and the culture in marine waters of cephalopods (squids, octopuses, cuttlefish) and oysters, for which technological breakthroughs have been achieved and adopted all over Asia.

Marine aquaculture has also grown at a fast pace. Its share of aquaculture rose from 33 to 37.5 percent during 1987–1996, while that of freshwater culture fell from 62 to 60 percent. In terms of value, however, brackishwater culture had a larger share (21 percent on average during 1987-1996), than its small volume (7 percent) would otherwise indicate. Although brackishwater culture overall grew relatively slowly, coastal aquaculture, particularly of penaeid shrimp, but also of cephalopods, grew at a high rate, especially for several major exporters such as Bangladesh, PRC, India, Indonesia, Thailand, and Viet Nam. In contrast, inland brackishwater culture declined in some countries, such as the Philippines and Thailand, and grew rapidly in others, particularly Bangladesh and Taipei,China.

Inland production grew at the rapid rate of 11 percent per year during the last decade, and its share in total fish and shellfish production increased from 19 to 29 percent. Much of this growth was contributed by fresh- and brackishwater finfish aquaculture, particularly in Bangladesh, PRC, India, and Indonesia. The PRC has recently become the major player in inland fishery production. Inland fisheries production there grew by a factor of 11.6 during 1977–1996, and its share of world inland production increased from less than 16 percent to 40 percent in the same period[4].

Much of the aquaculture growth in Asia is due to the PRC's great increases in freshwater carp culture, marine aquaculture of mussels and other molluscs, and the culture of algae such as kelp and laver, as well as brackishwater shrimp culture (ADB,

---

[4] From data presented in FAO (1998b).

1995b). The PRC's successes in inland culture, particularly of carp, are being repeated elsewhere. The PRC and India, in particular, have shown remarkable growth in aquaculture over the past decade, averaging 15 and 9 percent annually, respectively. These two countries accounted for 83 percent of Asia's total aquaculture production. The proportion of PRC freshwater production in total production is significantly higher than that of other countries. In India, freshwater culture has been growing by 6 percent annually and produces 1.6 million t per year from the current 800,000 ha of culture area. According to the head of one of India's leading aquaculture research institutes, the current area can be extended by an additional 2.2 million ha to meet the estimated potential demand of 4.5 million t (FAO, 1998e).

Growth in aquaculture is likely to continue, since much potential for inland aquaculture remains untapped in many countries, including the PRC, and new technology, particularly in genetic improvement and hatchery operations and rearing, continues to be developed. However, the ability to realize this potential also rests on a number of factors, such as the rehabilitation of degraded or polluted water resources, the development of and access to markets, price incentives, and processing facilities, as well as minimizing the environmental impact arising from aquaculture operations. In the PRC, the further utilization of waterlogged areas and rice fields, and the rehabilitation of ponds offer high growth potential (FAO, 1997c).

The fast growth of aquaculture is a response to both high- and low-end markets. Coastal shrimp culture has developed in response to increasing demand from international high-income markets and the resultant price increases, whereas freshwater finfish aquaculture is usually focused on low-value food fish. For the former, the income earned has been illusory and deceptive because neither the farmers nor the governments have fully considered the overall cost of shrimp farming (Box I.5). The boom in freshwater low-value food-fish aquaculture, by contrast, has benefited the poor, because fish is a major source of protein for a large number of Asian countries, including Bangladesh, PRC, Indonesia, Myanmar, and Thailand.

Box I.5 Shrimp Aquaculture

Since the mid-1980s, the culture of penaeid shrimp has increased dramatically in many economies of Asia, particularly in South and Southeast Asia. The main species cultivated in Asia is *Penaeus monodon* or black tiger prawn, due to its rapid growth, relatively large size, and increasing demand from world markets. Cultured shrimp production now accounts for over 30 percent of global shrimp production. Asia produced nearly 80 percent of the world's cultured shrimp; Latin America most of the rest.

Shrimp aquaculture is characterized by cycles of "boom and bust". In Taipei,China, where the intensive technology was first developed in the early 1980s, a series of production crashes occurred after a period of spectacular yields during the late 1980s (Csavas, 1992). Similar patterns of boom and bust followed elsewhere, most notably in Bangladesh, PRC, India, Indonesia, Thailand, and Viet Nam. Disease and poor crop and environmental management, especially of water quality, were the main causes of these failures. Farmers have overcome these problems by "shifting cultivation", i.e. moving to relatively pristine areas.

Intensive shrimp culture, driven by lucrative demand from overseas markets, has created adverse socioeconomic and environmental impact, not only to third parties but also to the shrimp industry itself, and which has raised questions about its sustainability. Among the major environmental consequences of shrimp farming are the destruction of mangroves, water pollution from pond discharges, land dereliction, saltwater intrusion to adjacent nonshrimp farms, and the introduction of exotic species and diseases in coastal waters (Briggs, 1994, and Dierberg and Woraphan, 1996, cited in Direk et al., 1998). Shifting cultivation further aggravates and spreads these pathogens and their impact to new locations. The introduction of shrimp farming has apparently affected rice and orchard farmers, whose production is suffering from increased soil salinity. Many shrimp farmers have themselves fallen into debt due to an outbreak of disease following a short-lived spell of prosperity.

Because the above social and environmental costs have not been internalized, the exporting countries have actually

(continued next page)

Box I.5 (continued)

underpriced their products. Many countries have started to adopt policy measures to limit shrimp farming and to reduce its environmental impact. The efforts to date have been either too little or too late. The prospect of making quick profits continues to attract more people to this activity, and cost considerations and concerns for profitability make them disregard most environmental regulations. Valuable lessons on curbing environmental impact could be learned from the experience of salmon farming in industrialized nations, where regulatory frameworks and strict enforcement have helped to limit the social costs of aquaculture and made the subsector truly high yielding.

The growth of freshwater aquaculture in these countries has substantially raised the nutritional level of the poor.

Tilapia, a group of fish of African origin, is emerging as a rising star of freshwater aquaculture in Asia. Between 1988 and 1996, the production of tilapia increased fourfold to 519,192 t (ICLARM, 1998). Opportunities for further increases, especially in Bangladesh, the Philippines, and Viet Nam, have been enhanced by the genetically improved Nile tilapia strain from the International Center for Living Aquatic Resources Management (ICLARM), which reduces costs by 20–30 percent and which will make tilapia more affordable. Tilapia are herbivorous and, therefore, can be fed at low cost, and they are easy to breed. Moreover, preliminary research findings in Viet Nam also suggest that tilapia help to clean stagnant water in ponds and sewage areas (ICLARM, 1998).

The growth potential of Asia's inland fisheries and aquaculture is constrained by the limited availability of water of suitable quality, and inadequate property rights for land and water resources (Ruckes, 1996). It is also threatened by land-based pollution, and the environmental impact generated by the mismanagement of aquaculture (Box I.5). The introduction of new species and the transfer of species to new locations could also help spread diseases and pathogens, or endanger native species and thereby affect biodiversity. The explosive growth of aquaculture necessitates more public investment in R&D in fisheries. This is especially true because, despite fish being a major source of food security, R&D in fisheries has lagged behind that in food crops and livestock (Williams, 1996). As future growth and food security will have to come from culture rather than capture fisheries, more attention should also be given to research, development, and monitoring of genetically improved species and strains, both from indigenous and foreign sources.

FACTORS UNDERLYING GROWTH

Institutions

The State, the market, and the community all affect and can help coordinate resource allocation. The efficiency of the market is the result of free competition and the profit motive, which tend to force economic agents to maximize private benefits while minimizing costs. The State is more efficient in providing large-scale public goods, or in supplying goods and services in situations of decreasing cost under which monopolies tend to emerge, or when free riders and externalities (when costs are not borne by the actor, but by the public at large or by those not involved in the act, e.g. pollution) tend to be prevalent. In many instances when the boundaries of products are not defined, the State may create a market by establishing property rights.

The community is more efficient in providing and regulating local public goods and services, where social norms and values remain effective in regulating the behavior of local economic agents. The role and the timing of their interactions are important underlying factors in the success of Asian agriculture. The changing roles of these three actors in rural transformation are examined in more detail in a companion volume (Ammar, 1999). In this volume, only their current role is discussed, focusing mainly on the role of the State in agriculture.

The success of Asian agriculture is the result of interactions between these major entities and their relative influence at certain critical moments. The green revolution was launched at a time when the power of the State in most Asian countries was for the most part preeminent. Commercial opportunities were limited because most Asian farmers were subsistent or semi-subsistent producers. Local markets were small and only surplus output was traded. The lack of adequate transportation infrastructure isolated local communities from the central authority. Local communities were left to manage and mobilize local resources and set up the necessary arrangements for local public goods and services, such as small irrigation systems, fire and theft prevention, temples, and public ponds.

However, over the last two decades, the State has provided substantial infrastructure support, such as irrigation and road networks. During 1976 to 1995, road construction expanded by about 2 percent per year in the PRC. In India, the annual rate of road construction rose from 2 percent between 1976 and 1985 to 5.8 percent from 1986 to 1995. Empirical investigations into the impact of government expenditure on roads in India have indicated a highly positive impact both on agricultural growth and poverty reduction (Fan, Hazell, and Thorat, 1998).

The most significant contribution of the State lies in the delivery of and support for modern technologies. The green revolution's technology package was a publicly created product. Therefore, the role of technological extension was considered crucial to its delivery. A growth-accounting exercise conducted as part of this overall study (Rosegrant and Hazell, 1999), indicates a substantial contribution of public investment for research into productivity growth between 1972 and 1993. This investment occurred in most Asian countries except the Philippines and Myanmar. In addition to the delivery of technology, most countries actively engaged in creating infrastructure support, such as irrigation and transport systems.

The exogenous nature of the green-revolution package also demanded that the State reach out to farmers. The extension support provided by the World Bank known as the Training and Visit system further reinforced the government's capacity to deliver the package. The top-down or command-and-control nature of the public extension system complemented the delivery of the package during the initial stage. Many countries launched large public irrigation schemes to the make green-revolution technology viable. The State further encouraged its adoption by providing subsidized inputs and credits, and also implemented various schemes involving price supports and guarantees. In the 1960s and 1970s, concern over food security gave the government an excuse for widening its role in controlling the agricultural sector, often resulting in a plethora of government interventions. The tradition of top-down or centralized decision making has lingered on to this day, even though needs have changed.

Another very important function of the State is the provision of education. In Thailand, for example, education accounted for almost 40 percent of the increase in agricultural output between 1961 and 1985, exceeding the contributions of land expansion, irrigation, and increases in capital (Ammar et al., 1989). For the periods 1976–1978 and 1983–1985, the contribution from education to output was even higher, reaching 80 percent. One reason why education is such an important variable in Thailand is that as an Asian country with relatively abundant land, Thailand has only partially adopted green-revolution technology; the country has paid greater attention to the eating quality of its crops than to increasing yields.

In countries where free markets have been allowed to operate, the increased production encouraged trade and associated activities such as transportation, warehousing, and processing. Local markets started to proliferate, not only related to growth in output; input and credit markets also became widespread. In parallel with government machinery, such markets have become another important institution for resource allocation. Private businesses have emerged not only as suppliers of goods and services but also of technology production, adaptation, and transfer. In India, even markets for water have started because private pumping of irrigation water has become a profitable proposition.

The incentives provided by market and institutional reforms manifested themselves most vividly in countries where individual production decisions had been suppressed. The social and political forces that brought about these institutional reforms are treated in greater detail in a companion volume (Ammar, 1999). Decollectivization and market reforms in the PRC and Viet Nam greatly enhanced output. Towards the end of the 1970s, the PRC started implementing economic reforms and allowed market mechanisms to play a role in promoting agricultural production. The success of reforms in the PRC persuaded Viet Nam to follow suit.

In the PRC, rapid average annual growth in the agricultural sector between 1978 and 1984 of 7.7 percent, compared with an average of 2.9 percent during 1952 to 1978, was the result of a package of policy and institutional reforms consisting of price reform, the decollectivization of markets, and planning reform (Lin, 1992). Quota and nonquota prices were substantially raised. Collective land was reassigned to individual households under 15-year contracts. Decollectivization greatly improved the incentives for farmers. A policy of self-sufficiency was abandoned and imports of grain were allowed. The State no longer controlled crop choice. During 1978 to 1984, growth in total output in the PRC was 42 percent. Decollectivization alone accounted for about half of that growth. A subsequent study indicated that such institutional changes could provide added incentives to adopt innovations that would have long-term impact.

In Viet Nam, rice yields increased from 2 to 3.5 t/ha in just a decade, despite deteriorating irrigation systems and the lack of functioning extension and credit systems. Annual exports of rice increased from almost zero to over 2 million t in the early 1990s, despite the country's dilapidated agricultural infrastructure. By 1990, there was a tendency to recognize the market as an effective mechanism for resource allocation, even in Central Asia. As the food security situation improved over time owing to an increasing food production capacity and an improved capacity to earn foreign exchange, market distortions in favor of food crops no longer became necessary, although they were normally retained for social and political reasons.

Ownership of natural resources has tended to be claimed by the State on behalf of the public. Command-and-control regimes, supported by numerous pieces of legislation, are imposed on all natural resource sectors. Actually, most natural resources are de facto open access and free to all. The objectives of State intervention in the natural resource sector have been mainly related to production or revenue raising. Among the various natural resources, land was the first to be privatized; property rights were assigned and markets for land established. However, private property still accounts for only a small proportion of total land. For example, about 75 percent of Indonesia's land is under the control of the Ministry of Forestry (ADB, 1998). As population pressures increase, most governments have found it increasingly difficult to protect natural resources from encroachment, unscrupulous and illegal theft, and fires.

The State apparatus that was so essential and successful in the first decade of the green revolution became less effective with expanding local and international markets, with natural resources that were no longer abundant but degraded, and with a greater diversification and commercialization of agriculture. The State is also less useful when dealing with problems of food scarcity and security that are no longer widespread but limited to certain areas or regions only. The centralized commodity approach to which the State has become accustomed is not suited to the diverse conditions in rural areas that need to be brought under production.

While most States in Asia have accepted the potential of the free market, the same cannot be said about the State's perception of the potential of communities. Conflicts between the State and its people continue to deepen, especially in the competition for the use of public resources such as forests, land, and water. A few governments have now devolved limited responsibilities for managing public resources to local governments and communities. For example, community-owned irrigation systems, some of which have almost a thousand years of tradition behind them, have been legitimized by the State, and some of them have been linked to public irrigation schemes. Recently, new models of self-reliance developed by popular organizations, nongovernmental organizations (NGOs–e.g. Box 1.6), and local governments for the protection of natural resources have emerged at the community and watershed level.

Box I.6 NGOs and Technology for Sustainable Agriculture

In 1971, the Mindanao Baptist Rural Life Center, a nonprofit civil organization in the Philippines, initiated a project aimed at improving the livelihood of upland farming households. A technology package for sloping agricultural land (SALT) was developed and adapted by means of a participatory approach to suit the needs of farming communities. Inherent in the package were the following properties: (1) food priority, (2) production efficiency, (3) small farm focus, (4) reliance on internal resources (i.e. credit free), (5) economy of time and labor, and (6) environmental conservation and improved soil structure and fertility. The package had also to be culturally acceptable, economically feasible, and ecologically sound.

Elements in the package included contour preparation, the establishment of hedgerows, alternate strips, and hedgerow trimming for green manure. The technology was proven to be more economical than the terraced or the bench terrace technologies. It has been disseminated through the Baptist network and was discovered to be appropriate in areas with the dual problem of land degradation and food deficits. It was finally accepted as an official program by the Philippine Department of Agriculture in 1991, and has been revised, demonstrated, and adopted in many areas of the Philippines, Thailand, and Nepal.

Sources: Watson (1987); Serrano (1988); Tacio (1990).

It should be noted that the perceived need for a change in roles of the three entities cited above and the relationships between them have not always evolved smoothly and harmoniously. In many instances, lessons were taught and learned the hard way. At least one lesson is clear: the role of the State needs to change. The Asian experience (described in the next section) shows that an institution that is very appropriate for one task may be inappropriate when dealing with the same issue when surrounding conditions change. This is clearly shown to be the case in research, development, and extension. Visionary thinking and participatory planning and management are increasingly considered necessary in order to continue to adapt existing institutions to fit the changing environment.

Technology

As noted above, technology has played a crucial role in the phenomenal growth of Asian crop production. In most reports on the subject, technological changes in crop production have generally been related to green-revolution innovations: HYVs of rice, wheat, and maize, and increased use of inputs, particularly fertilizers and irrigation. However, as can be seen from the growth trends in the previous section, another momentous change that occurred during 1977 to 1997 and that contributed significantly to Asia's growth in crop production was the diversification of cropping systems. Thus, contributions to Asia's crop production growth came from two very different sets of innovations, "new" crop varieties and new management practices.

Crop Varieties

The plant genetic resources that have contributed to yield growth include modern varieties (MVs) and traditional varieties. Included in the MVs are high-yielding varieties (HYVs) that generally refer to the green-revolution rice and wheat that originated in the internationally-funded breeding programs spearheaded by IRRI and CIMMYT, and also hybrid rice (mainly in the PRC) and hybrid maize. These HYVs, combined with major increases in the use of fertilizers and irrigation, were the primary drivers behind the greater than 3 percent annual yield growth in these crops. By the early 1990s, 74 percent of Asia's wet-season rice area was planted with MVs (Hossain and Pingali, 1998), and dry-season rice crops are invariably planted using HYVs.

Countries vary a great deal in their adoption rates of MVs. In addition to the industrialized economies of Japan and the Republic of Korea, which grow MVs on all their riceland, those countries in which more than three quarters of their rice crop are planted with MVs are the PRC (100 percent, with 40 percent of the crop consisting of hybrid rice), Indonesia, Malaysia, the Philippines, Sri Lanka, and Viet Nam. Countries using MVs on one half to two thirds of their riceland are India, Myanmar, and Thailand. Countries planting only one third to one half of their riceland with MVs are Bangladesh, Nepal, and Pakistan. Bhutan (12 percent) and Lao PDR (2 percent) have the lowest adoption rates. The diffusion of wheat HYVs seems to have been faster than that of rice HYVs. For example, in 1991/92, HYVs accounted for 84 percent of India's wheat area, compared with 67 percent for rice. In 1994, MVs accounted for 91 percent of Asia's wheat area outside the PRC (up from 69 percent in 1977), and 70 percent within the PRC (Pingali and Rajaram, 1998).

The IR8 rice strain, developed by IRRI, was the first HYV to break the yield barrier in rice and started the green revolution outside the PRC. Less publicized was the fact that by 1965, the year before IR8 was released, 3.3 million ha of Guang-chai-ai, the PRC's own semidwarf rice, were being grown in the southern provinces of Guangdong, Jiangsu, Hunan, and Fujian. Guang-chai-ai is similar to IR8, and actually contains the same dwarfing gene as Dee-geo-woo-gen, one of IR8's parents (Barker, Herdt, and Rose, 1985). India also brought out its own semidwarf HYV, Jaya, in 1968. Since these first successes, improvement in the yield potential of rice has been limited.

Some 20–30 percent gain has been made by hybrid rice in the PRC; IRRI's new plant type holds promise of about 25 percent increase, but the new plants are still to reach farmers' fields. Hybrid rice has so far been restricted to the PRC because of the high cost of seed as well as the poor grain quality. Also, the average yield of PRC's hybrid rice has remained steady at 6.6 t/ha, the level it reached in 1986 (Yuan, 1994; Mao, 1994).

While the ceiling yield potential of rice derived from IR8 has not been overtaken by the succeeding HYVs, yield improvements in wheat and maize have continuously raised their ceiling potential. This partially explains their more robust yield growth trends.

The genetic yield potential of new wheat varieties continued to increase, by 0.5–1 percent per year, since the first semidwarf varieties came out of Mexico in 1964 until 1990 (Waddington et al., 1986; Byerlee, 1990). Breeders are optimistic about prospects for substantial increases in wheat yield potential over the next 10 years. Further incremental gains are being made from the important plant breeding innovation of wide crosses, which helps to create a "genetic bridge" between cultivated wheat and its wild relatives and allows researchers to draw upon the genetic wealth of those hardy species.

Crosses between elite varieties of durum wheat (containing the AB sets of wheat chromosomes) and goat grass *(Aegilops squerosa)*, one of the original parents of bread wheat (containing the C set of wheat chromosomes), have given rise to a new "synthetic" wheat (with the complete three sets of ABC chromosomes of regular bread wheat). Through this synthetic but true bread wheat, desirable traits are being transferred more readily into elite bread wheats. This germplasm has been incorporated into CIMMYT's regular breeding programs, and the genetic material is already included in many advanced lines that have been tested in wheat-growing countries in Asia for several seasons now.

The growth of maize yields in the PRC during 1987 to 1997 of 2.76 percent per year was only half that of the preceding 10 years. However, Chinese hybrid maize breeders expect gains of about 10 percent in the yield potential from each generation of hybrids, i.e. 1 percent per year with about 10 years for each cycle (Chen, 1995). The capacity for yield growth is even greater for other Asian countries, where the diffusion of hybrid maize has only just begun. In less favorable areas there are also considerable yield gains that can be realized by the use of improved open-pollinated varieties, which have contributed significantly, even if not as spectacularly as the hybrids have done, to productivity gains in South and Southeast Asia over the last 20 years.

The diffusion of HYVs of rice, wheat, and maize is an ongoing process in which the HYVs continue to be replaced by successive generations of newer varieties. The need to sustain growth so far won, especially against emerging pests and pathogens, has been as important as the push for further productivity gains and has been made possible by a very important change in Asia's agricultural research and development (R&D) institutions, i.e. the increasing capacity for plant breeding in the national agricultural research systems. The national breeding programs have not only helped to fine-tune varieties for specific agro-ecological niches, such as adapting to local tastes, market preferences, and soil and climatic conditions, but also have contributed some important productivity gains.

The other MVs include all the new varieties of rice and maize as well as of other crops (fibers, oils, roots, sugar, tea, coffee, tobacco, and rubber) that have also benefited from the innovations of modern plant breeding. In addition there are some traditional varieties of crops that have found new agro-ecological niches (e.g. basmati and other special quality rice varieties).

Although the yield growth of these other MVs and traditional varieties has been more moderate, they have contributed to Asia's crop production over the last 20 years in two ways. First, unlike the HYVs, which are restricted to irrigated areas, many of the less high-yielding varieties have been tailored to or found their place in less favorable areas. Examples of these include the open-pollinated maize for lower-input production systems and rice varieties, such as rainfed rice, deepwater rice, and upland rice, for difficult environments. Secondly, the nonHYVs were an essential part of the technology that between 1977 and 1997 drove production growth in crops such as oilseeds, vegetables, and fruits to rates comparable to or even higher than those of the green-revolution HYVs.

In order to meet the varying needs of specific locations, the All India Coordinated Research Project on Soybean released a total of 50 new varieties between 1982 and 1995 (Bhatnagar, 1995). While there was little evidence of any yield growth, the varieties were nevertheless an important instrument for the expansion of the soybean area in India, which grew from almost zero in 1977 to more than 5 million ha in 1997. Significantly, the biggest expansion of soybean farming has been into those states with the least irrigation, e.g. Madhya Pradesh, Rajasthan, and Maharashtra.

In spite of the current rapid diffusion of hybrid maize in India, driven by a strong private seed industry that was itself the product of a liberalization policy in the 1980s, a collaborative study between the Indian Agricultural Research Institute and CIMMYT has highlighted the fact that the hybrid maize revolution has hardly touched states such as Rajasthan, Uttar Pradesh, and Madhya Pradesh where maize is grown as a food crop and with a very low level of inputs (Morris, Singh, and Pal, 1998).

Thailand provides another example of the less high-yielding traditional varieties that have found new agro-ecological niches. These traditional varieties are characterized by favorable prices for the special quality of their grains and their ability to grow in physical environments that are unsuitable for HYVs. The better prices fetched by special quality varieties have helped rice farmers on saline / sodic soils (northeast region) with no irrigation and farmers in deepwater areas (central plain) to maintain the value of their crops in the absence of yield growth.

The spread of less high-yielding varieties has given rise to two issues that relate to the future of Asian productivity and its capacity for further growth. The first is the importance of local plant genetic resources, in terms of meeting specific agro-ecological conditions as well as being a source of germplasm for crop improvement. Access to this important source of future growth is threatened by current developments concerning the expansion of the scope of intellectual property rights to cover plant genetic resources.

The second issue is related to declines in the relative value of the HYVs. This will certainly mean slower growth or even a decline in the productivity growth of food grains, especially rice and wheat, in the future. Attempts to address this second issue have come from the national breeding programs that are now beginning to produce newer generations of MVs with special grain qualities. For example, the HYVs Pusa 4-1-11 for fine grain white rice, Annapurna and TKM 9 for red rice for the Kerala market, and Pusa Basmati for the aromatic basmati-type grain, have been developed in India. Thailand has also just released two new MVs, Fragrant Khong Luang 1 and Fragrant Suphanburi, neither of which is high yielding, but both are sufficiently insensitive to photoperiod to be grown in the dry season.

Crop Management

The crop management innovations that helped to increase crop productivity in Asia between 1977 and 1997 were of two main types: (a) an increase in use of inputs, especially fertilizers, irrigation, and pesticides; and (b) the increase in efficiency (increasing the efficiency of input use, and increasing cropping intensity, i.e. the number of crops grown in succession on the same land in one year). It should be recalled that although many of the inputs accompanied the green-revolution HYVs as part of the “new technology package”, much of the increase in input use was also due to new high-value crops, especially fruits, vegetables, oil crops, and cotton.

Most of Asia’s expansion in irrigated land took place in the 1960s and 1970s. Subsequently, the use of inputs increased at a much faster rate (Table I.9a). The rate of growth of fertilizer use and mechanization increased faster in the PRC than in Asia as a whole, but the use of pesticides in the PRC declined sharply

Table I.9a: Intensification of Input Use in Asian Crop Production, 1977–1996

	1977–1979	1994–1996	Increase (% per year)
Fertilizer use (kg / ha arable land)	60.18	133.55	8.3
Pesticide imports ($ / ha arable land)[a]	1.669	3.628	7.5
Irrigation (% arable land)	30.50	35.75	1.0
Agricultural machines (units / 1,000 ha arable land)			
Tractors	6.361	13.471	7.1
Harvesters / threshers	1.788	3.699	6.3
All machines	8.481	17.576	6.7

[a] from 1979

Source: FAOSTAT Database. *Available: http://apps.fao.org*

Table I.9b: Input-Use Trends in the PRC, 1977–1996

	1977–1979	1994–1996	Increase (% per year)
Fertilizer[a] use (kg / ha arable land)	57.33	176.70	12.3
Pesticides (kg / ha)	9.94	5.87	-3.3
Irrigation (% arable land)	30.2	33.0	0.5
Machines (billion watt / ha)	0.79	2.28	11.7

[a] equivalent to ammonium sulfate with 20% N

Source: Adapted from Fan (1997).

(Table I.9b). The use of farm mechanization accelerated in the 1980s when rapid economic growth sharply raised the opportunity cost of labor, especially in Asia's Pacific-rim countries, and especially in the PRC and Thailand. However, owing to an existing large pool of labor in Bangladesh and Indonesia, the number of workers per tractor in those countries still remains high (Rosegrant and Hazell, 1999). The numbers in these two Tables should be used with caution as they do not reflect the size or the power of the tractors and machines.

The growth trends discussed in previous sections are clear evidence of the impact of input intensification. However, in addition to the obvious gains there have also been problems.

Pest Control

Crop losses from pests have always been a problem for Asian farmers. The availability of relatively cheap chemical pesticides since the Second World War has led to rapid increases in their use for "crop protection". The first pesticides used were mainly insecticides, and these have been applied to high-value crops such as vegetables, fruits, cotton, and plantation crops since the 1950s. Later, in the 1970s and 1980s, they were complemented by herbicides. The herbicides were used to lower production costs, either by reducing the cost of hand weeding or by enabling the use of certain labor-saving practices, such as broadcasting rice instead of transplanting it. Increases in horticultural production have led to the increased use of chemical pesticides, furthering the need for the greening of horticulture (Box I.7).

Box I.7 Greening the Production of Asian Vegetables

As incomes have risen in Asia so has the demand, and therefore supply, of vegetables. The major challenge to many developing countries is to produce quality products at affordable prices (Nangju, 1996). Vegetables typically require heavy investment in chemicals and are grown most profitably in highlands. This generates environmental impact in the form of soil erosion and chemical residues.

Research conducted at AVRDC and financed by the Asian Development Bank has resulted in high-yielding varieties of yard-long beans, tomatoes, hot peppers, and cucumbers, which have been distributed to farmers. Varieties that are resistant to disease have been identified. IPM and the use of a bio-insecticide *(Bacillus thuringiensis)* have been implemented. Varieties suitable for hot and humid regions have also been developed for the lowlands, thus spreading the benefits of high-value crops to the lowlands and easing the pressure for encroachment into fragile highland ecosystems.

The problem of pesticide use in foodgrain production is mostly associated with rice and is a consequence of the green revolution. In order to reduce crop losses from insect pests, the technology packages that delivered the first HYV (IR8) seed to farmers almost always included insecticides, usually one of the extremely potent organochlorines.

However, the organochlorines killed not only the insect pests but also their natural predators. Insect ecologists tried to draw attention to this from the early 1960s, but were ignored for the most part. Then the insect pests began to develop resistance to the pesticides, especially to some of the organophosphates that were replacing organochlorines. Attempts to combat these developments proceeded by either increasing the dose or combining several chemicals into even more lethal pesticide “cocktails”. These only worsened the situation because they served to kill even more of the pests’ natural predators and further increased the evolutionary pressure on pests to develop even greater resistance to the pesticides.

The most severe consequences of these problems were brown planthopper epidemics. Previously, this insect had been an inconsequential inhabitant of Asian rice fields. However, with its natural predators being greatly diminished it became a menace to Asian rice crops, and the severity of this menace increased in direct proportion to the intensity of insecticide used. In northern Sumatra, Indonesia, farmers were treating their fields with pesticides 6 to 20 times over periods of 4 to 8 weeks, with no success (Kenmore, 1991, cited by Conway, 1997). The density of the insect pest population increased with the increasing frequency of spraying.

In addition to insecticides, herbicide use has also been increasing rapidly in Asia. By 1996, the value of herbicide imports was two thirds that of insecticides. No data are available on the efficiency or impact of herbicide use. Weed resistance to herbicides, which is now one of the very serious problems in crop production in developed countries, could also become a threat in Asia in the near future. Resistance to some of the most extensively used herbicides in Asia, such as isoproturon and propanil, has begun to appear.

The green-revolution technology itself has intensified the pest problem and in many ways has stimulated the increased use of pesticides. Large monocultures and the year-round planting of single crops create ideal conditions for massive pest outbreaks. The high levels of nitrogen in the applied fertilizers make plants more susceptible to certain pathogens (e.g. blight in rice) and insects.

Large government subsidies for pesticides have also provided a critical boost in pesticide adoption. In Indonesia before 1986, for example, farmers were only paying about 15 percent of the actual cost for pesticides. As a result, 20 percent of all of the pesticide applied to rice worldwide was being applied to Indonesian rice crops, although Indonesia accounted for less than 9 percent of total world rice production. In Thailand, there was no government subsidy, but government pest control units distributed pesticides free of charge when "outbreaks" were reported. Unfortunately, the term outbreak was loosely defined, and very rarely were the pesticide handouts economically or ecologically justified.

Fertilizer Use

After three decades of annual growth in fertilizer use of around 10 percent, Asia's croplands in 1996 received on average around 135 kg/ha of fertilizer, from 38 kg/ha in 1965. In irrigated areas, fertilizer consumption per hectare is much higher than the national average. Malaysia, PRC, Republic of Korea, and Viet Nam use over 700 kg/ha of fertilizer on irrigated land (Table I.10). In Indonesia, the rate is over 500 kg/ha. Countries with low consumption levels, such as Cambodia and Myanmar, tend to be those with foreign exchange problems, lack of proper distribution and credit systems, and lack of incentives resulting from price ratios of grains to fertilizers. Much higher rates are applied in intensive cropping systems. Up to 1,000–2,000 kg/ha of fertilizer are used in intensive vegetable growing in countries throughout the region (Morris, 1997).

Indications of inefficiencies in fertilizer use are much less obvious than in insecticide use. No major ecological or economic

Table I.10: Total Fertilizer Consumption in Irrigated Areas in Asia

	Total Fertilizer Consumption (kg/ha)			Annual Growth Rate (%)	
	1975	1985	1995	1975–1985	1985–1995
East Asia					
China, People's Rep. of	160.17	378.00	713.67	9	6
Japan	568.05	689.02	609.26	2	-1
Korea, Rep. of	677.76	609.06	714.73	-1	2
Mongolia	152.17	310.00	31.25	7	-23
Southeast Asia					
Cambodia	1.12	0.00	58.38	-1	41
Indonesia	125.41	458.56	558.17	13	2
Lao PDR	2.50	16.81	34.97	19	7
Malaysia	805.26	1,830.54	3,323.53	8	6
Myanmar	56.07	178.88	109.59	12	-5
Philippines	218.17	196.65	381.72	-1	7
Thailand	74.47	113.44	311.64	4	10
Viet Nam	330.00	217.85	724.00	-4	12
South Asia					
Afghanistan	14.97	28.21	17.86	6	-5
Bangladesh	149.49	260.82	372.59	6	4
Bhutan	4.55	3.33	2.56	-3	-3
India	103.58	203.55	276.97	7	3
Nepal	53.30	57.12	105.90	1	6
Pakistan	40.63	95.88	145.80	9	4
Sri Lanka	150.83	335.31	363.38	8	1

0 = zero or less than half of the unit measured.

Note: Annual Growth Rate = ((Ln(value year 1) - Ln(value year 2)) / number of years) x 100.

Source: FAOSTAT Database. *Available: http://apps.fao.org*

disasters on the scale of the brown planthopper epidemics have yet been reported. Many authors have, nevertheless, pointed to two possible types of impact of fertilizer use in terms of (a) fertilizer-use efficiency and (b) nutrient imbalances.

Declines in the ratio of grain to fertilizer, e.g. in India from about 60:1 in 1966 to less than 10:1 in 1992 for rice and from 15:1 to 5:1 for wheat, have caused concern about a possible decline in the efficiency of fertilizer use. This has, however, been indicated as being somewhat misleading because the grain:fertilizer ratio is not a very accurate indicator of fertilizer-use efficiency; it erroneously assumes a zero yield in the absence of fertilizer use (Hobbs and Morris, 1996). In Karnal (in Haryana, the heart of India's green-revolution territory), the marginal response to fertilizer (the ratio of increase in yield to increase in fertilizer) for rice has declined somewhat. This can probably be explained by the diminishing returns from the very high rates of fertilizer now being applied. For wheat in India, the marginal response was still increasing slightly in the early 1990s (Chaudhary and Harrington, 1993).

It is now technically quite simple to achieve the twin goals of improving fertilizer-use efficiency and soil nutrient levels. Losses from nitrogen fertilizers can be effectively minimized through the use of such innovations as urea supergranules or deep placement of urea, and urease inhibitors. Fertilizers that are well balanced in relation to crop requirements and the soil's own nutrient capacity can be easily formulated with help from soil and plant analysis and fertilizer trials. Most of these, however, are still not yet applicable for use on the average Asian farm. Most farmers consider the deep placement of urea as too labor intensive. Supergranules are very costly. The urease inhibitors, which were only in the experimental stage in the early 1990s, have not yet been incorporated into the fertilizer manufacturing process. Access to services that would help to improve the match between the nutritional content of fertilizer, the capacity of the soil to supply nutrients, and the needs of crops is still unavailable to most Asian farmers.

In developed countries, individual farmers sometimes use tools such as plant and soil analysis and fertilizer trials for fertilizer management. More often, however, these facilities are provided as part of the service rendered by fertilizer companies and farm consultants. Such services are rare in Asia. Among the exceptions are the consultancy services that provide advice to the larger oil palm and rubber plantations in Malaysia and Indonesia. Their fertilizer recommendations are generally based on tissue analysis. Some fertilizer companies that provide soil analysis services as part of their marketing operations are now found in the region.

Lack of analytical facilities is not the main reason for the lack of services to support improved fertilizer management in Asia. Most analytical laboratories, many exceptionally well equipped by development assistance programs, are actually greatly underutilized. Logistical arrangements are lacking on how to take samples, determining where to send them, making sure of the timely return of results, and interpreting the results. The services provided by the analytical laboratories are, therefore, of little use to district farm advisors, farmers, or fertilizer marketing personnel. Most analytical chemists would also point out that the results from plant and soil analysis are useless without stringent quality control on laboratory procedures.

Most farmers in Asia have few resources for fertilizer management other than the "official recommendations". These recommendations are not generally very responsive to local variations or the impact of cropping intensification that has taken place in the last 20 to 30 years. For example, despite the thousands of fertilizer experiments that have been conducted in the past two decades throughout India and Pakistan, practically the same fertilizer recommendation is given in all irrigated areas (Byerlee, 1990).

Some experts are now advocating alternative agriculture, defined as alternatives to high-input technology such as that of the green revolution (Box I.8). However, more studies on costs and trade-offs are needed; there is no single formula that fits all circumstances.

Breeding of efficient varieties offers one widely adaptable solution, at least for deficiencies in some of the micronutrients. Such a strategy has been shown to be highly feasible in dealing with boron deficiency, which causes widespread yield losses in wheat in the southwestern PRC, Bangladesh, northeastern India, and Nepal. Boron deficiency causes the local standard varieties to set grain poorly. Many boron-efficient genotypes have been identified among CIMMYT's advanced materials (lines that have been widely tested and are almost ready for release as varieties), which will set grain normally. Simple screening has prevented inefficient varieties from being released into problem areas in Nepal. For much of the wheat-growing area of Bangladesh and the northeastern states of India, such as Bihar, Orissa, and West Bengal, it would surely be better to screen inefficient germplasm out before it is released, only to be rejected by farmers after it fails to set grain properly, as is currently the case.

Box I.8 Organic Farms

Organic farms have attracted the attention of many NGOs, and are sometimes held up as a general solution for agriculture. Organically grown or chemical-free agricultural products have now found a niche in high-income markets. Although these markets are small, they are expanding. This market niche, which attracts premium prices, is important for organic farm products because the cost per unit of organically grown produce is often higher than chemically grown alternatives (NRC, 1989). In Asia, there is little definitive evidence of this cost difference (i.e. when the alternatives are compared in terms of unit cost and net natural resources consumed). Most anecdotal evidence of success consists of production method and yearly income only. However, it has been observed that the more successful cases are those involving expert farmers; a high level of expertise is required.

The basic principle of organic farming is an emphasis on green manure and nutrient recycling. This principle has some trade-offs and limitations of its own. For example, rice fields fertilized with green manure legumes are likely to release much more methane than those fertilized with urea or ammonium sulfate; also, as greenhouse gases, nitrogen oxides from fertilizers are dwarfed by methane in quantity. In other words, nitrogen fertilizer is greener than green manure in this respect. Grain legumes may save the cost of nitrogen fertilizer, but they quickly run the soil into nutritional imbalances as they can deplete the soil of many other nutrients, e.g. potassium and calcium, much more quickly.

Organic farming can be an attractive alternative for farming in relatively favorable areas. Most prototypes of organic farms are in areas where soil fertility is favorable. However, in areas where a deficiency of nutrients other than nitrogen is a major problem, organic farming methods cannot provide nutrients to recycle. For example, in some parts of the Lao PDR, the soil is so deficient in phosphorus that cattle

(continued next page)

Box I.8 (continued)

manure does not offer a solution for improving soil fertility. Furthermore, cattle that are deficient in phosphorus do not reproduce; there is a cycle of not enough cattle, not enough manure, and, of course, little phosphorus in the manure. On some of the acidic soils of the mountainous areas of Viet Nam, legumes do not fix much nitrogen in the soil because of either acidity or molybdenum deficiency. Plants need 15–16 macro- and micronutrients; organic farming is not viable if there are no nutrients to be recycled.

Research, Development, and Extension

In the early period of the green revolution, 1971–1980, productivity growth accounted for about one third of the total growth in Indian rice production. This productivity growth was related to R&D, canal irrigation, the balanced use of fertilizers, and agricultural terms of trade (Kumar and Rosegrant, 1994). Public research alone accounted for about half of the productivity growth. Investment in technology is indisputably an indispensable input for sustainable development.

Four important factors in agricultural R&D institutions in Asia are (i) growth of national plant-breeding capacity, (ii) lagging capacity for generating crop management innovations, (iii) inadequate public extension systems, and (iv) evolving roles of the private and NGO sector in agricultural R&D. These have been instrumental in the technological changes discussed above and will be crucial in determining the future capacity for growth and sustainability of Asian agriculture (see also Rosegrant and Hazell, 1999).

National Plant-Breeding Capacity

The capacity for plant breeding in Asia has grown enormously in the last 20 years. While the first rice and wheat HYVs came to Asia directly from IRRI and CIMMYT, contributions to later generations of HYVs have come largely from national plant breeding programs. The increasingly active national agricultural research systems (NARS) have not only helped to fine-tune varieties for specific agro-ecological niches, but have also contributed some important productivity gains. Many countries in Asia now appear confident of their own rice-breeding capacity. A recent consultation, organized by IRRI, of national agricultural research leaders from Bangladesh, PRC, India, Republic of Korea, Philippines, Thailand, and Viet Nam reached a consensus that conventional plant breeding should be the responsibility of NARS and not IRRI.

For Asia's main crops–rice, wheat, maize, soybean, groundnuts, and mungbean–all the national breeding programs have drawn heavily from the germplasm support services of the CGIAR centers and AVRDC, which provides germplasm for soybean and mungbean. The important germplasm services provided include conservation, enrichment (in which new genes are introduced through new plant-breeding innovations such as intraspecific and other wide crosses as well as genetic engineering), and the transfer of genetic materials. This multilateral arrangement for germplasm management is unmatched by any other facility in its cost effectiveness and equitable sharing of plant genetic resources.

National funding of germplasm conservation tends to be very limited (NRC, 1991). Without multilateral arrangements for germplasm exchange, individual country access to plant genetic resources would be extremely limited. The international public germplasm services provided by the CGIAR centers and AVRDC will continue to be essential for the maintenance of the genetic diversity of Asia's (and the world's) important crops as well as for the capacity of national breeding programs to meet the need for long-term sustainable crop production. These services have, however, now been put under threat by a major controversy relating to the expansion in scope of intellectual property rights to cover plant genetic resources (More details on this are provided in a companion volume (Ammar, 1999)).

Capability for Generating Crop Management Innovations, a Critical Weakness

The green-revolution technology of MVs was widely adopted, and the diffusion process was relatively simple. Many of the problems that have since developed are much more location specific. The crop management innovations required to solve these problems as well as to provide further productivity gains need to be sensitive to the set of socioeconomic and biophysical conditions particular to each location.

Asia's capacity for crop management R&D, however, lags far behind its plant breeding capacity. The situation in South Asia as described by Byerlee (1990) has relevance for the whole region: "The strength of plant breeding research in South Asia contrasts with the relative weakness of crop and resource management (that is research on tillage, fertilization, pest control, irrigation scheduling, planting date and establishment, and so forth)". He argued that the current system of largely centralized agricultural R&D, although managing well enough for the development of new MVs, is poorly equipped to generate and transfer effectively the much needed innovations in crop management.

The need for crop management R&D to focus on the agro-ecological and socioeconomic differences between farmers was recognized by the early 1970s, when the green revolution was just beginning in Asia. That the need still remains today speaks clearly of the failure of attempts to deal with the problem in the intervening years. Notable among these was the farming systems movement that became fashionable and absorbed enormous amounts of resources in the 1970s and 1980s.

The lack of progress after such a long time prompts the conclusion that perhaps the benefits that can be expected from crop management research are limited. However, in South Asia, major productivity gains have been realized from research in crop management on problems such as the date of sowing, crop establishment, and weed control in the rice-wheat cropping system (Hobbs, Sayre, and Ortiz-Monsterio, 1998).

The PRC appears to be best meeting the need for crop management innovations. An important reason for this is the system of agricultural R&D, which is to a large extent locally controlled. The research extension network, involving the county, commune, brigade, and production team, provides a mechanism for rapid evaluation and selection of hybrids for local adoption and diffusion of technical information related to their management.

These results also illustrate an important weakness preventing effective transfer of crop management innovations, and which is why they are much less widely adapted than are the HYVs: crop management R&D in most of Asia is largely supply driven and not a response to farmer demand, making farmers less willing to adopt it. The following remark referring to Indonesia makes the point: “Researchers are oriented toward the publication of findings in ministry journals and magazines, not toward solving problems. The reward system (promotion, incentives) is structured that way” (Manwan et al., 1998). Manwan’s remark is also applicable in many other countries throughout the region. There is a critical lack of feedback mechanisms between the users (i.e. farmers) and the producers (agronomists, research scientists) of crop management innovations. Many countries in Asia have made great efforts to decentralize their agricultural R&D process. Unfortunately, the results have mostly been simply the creation of yet another layer of bureaucracy. The two elements that are important to the generation of effective crop management innovations for specific agro-ecological niches are (a) the flow of information from farmers on problems that need solving, and (b) the capacity to respond effectively. Unfortunately, these are still largely missing in most Asian countries.

In the PRC, an essential measure of quality control on crop management innovations has been provided by a contract system in which local agricultural officers share with farmers the rewards of production increases as well as punishment for failures incurred by any innovations they have suggested. The capacity for crop management R&D in the PRC can be expected to be much enhanced by the improved capacity in agricultural science that has taken place in the last 20 years. For example, obtaining an 18 percent yield increase (almost the gain made by the PRC's famous hybrid-rice technology) though improvements in plant nutrient management (Lin and Shen, 1994) seems highly feasible, given the more than 20,000-strong cadre of plant nutrition specialists in the PRC. Other nutritional limits to yields have also been identified in the new intensive cropping systems, e.g. widespread boron deficiency in rapeseed in Hubei and Zhejiang provinces (Lu et al., 1997; Wei et al., 1998).

In other parts of Asia, inadequate capacity in crop management, unless corrected, will continue to exact costs in three ways: (a) through yield and profitability losses, (b) by placing the system's sustainability under threat, and (c) through impact on human health and the environment.

A major obstacle to the decentralization of agricultural R&D and to farmers' participation in identifying R&D needs is the perception, still common among researchers and policymakers in the region, that the capacity to use complex technologies efficiently is limited by the low level of formal education among farmers in Asia. This has been proven wrong, not only for the PRC (some would argue that Chinese farmers are very different from South or Southeast Asian farmers), but also on a very large scale. One example is the IPM experience in Indonesia, where the transfer of crucial knowledge on insect ecology has been successfully done with farmers who have had no or very little schooling.

Public Extension Systems

In spite of the heavy international and national investment in farming systems research and extension in the 1970s and 1980s, agricultural technology transfer in Asia has remained very much "top-down". The approach has not worked well for crop management because there was insufficient consideration of onfarm conditions during the research phase, and inability to respond to second- and third-generation problems that emerged.

For example, agronomists and farmers in South Asia have known for a long time that delaying the sowing of wheat beyond the optimum planting date would lead to a yield loss of 1 percent per day. The simple solution of sowing earlier, however, was not an option for a large number of farmers in India and Pakistan, whose wheat crop is only one component in such systems as rice-wheat, cotton-wheat, and soybean-wheat. There were various legitimate reasons why the first crop could not be harvested early enough for the wheat to be sown by the optimal date. Reduced tillage was suggested as a solution because it reduces the turn-around time between crops. This appears to be a widely effective solution, but it has brought on another serious problem, herbicide resistance in some major weeds in the rice-wheat cropping system, because reduced tillage requires increased use of herbicides. Overcoming the problem will require feedback from the fields and further research effort.

As indicated earlier, except for the PRC, yields from farms lag far behind those from experimental stations. Productivity gains and environmental benefits can be achieved by plant nutritional balance and better water and soil management. This type of innovation requires two-way communication between scientists and extension officers on the one hand, and with farmers on the other. Such communication is not common in most research and extension activities in Asian countries. Most public extension systems have been criticized as being too centralized. In those countries where devolution has begun to taken place, local organizations lack adequate funding and lack linkages with R&D systems. Extension personnel tend to lack technical skills in crops other than rice, lack the flexibility and skills to adapt generic solutions to specific locations, have inadequate and irrelevant information vis à vis local needs, and are not responsive to farmers' interests.

As cropping systems have become mixed and complex, farmers have increasingly turned to other sources of technical information, e.g. private traders, factories, NGOs, and local universities (Mingsarn, Kanok, and Chaiwat, 1989; World Bank, 1996). However, farmers in unfavorable areas tend to have little access to public extension systems (World Bank, 1996). Further, public extension systems are generally geared towards male farmers. Female farmers tend to take care of subsistence crops or livestock, but have relatively less access to information on agriculture, including that concerning nutritional maintenance of, for example, livestock. Other means of extension, such as television, that reach women in their homes and overcome cultural obstacles limiting contact with the outside world, have rarely been used.

Evolving Roles of Private-sector and NGO Agricultural Research, Development, and Extension (RD&E)

The green revolution has basically been the product of massive public investment in agriculture. For the new generation of HYVs, there have been subsidies for inputs and the development of huge irrigation schemes. This level of public investment in agriculture is unlikely to be sustainable. Declines had already started in Asia by 1980 (Rosegrant and Pingali, 1991). Countries have been phasing out subsidies for various inputs, which, to a certain extent, may be desirable, as inefficiencies are often eliminated in the process.

The evolution of private-sector involvement in RD&E is more discernable in the seed industry. The liberalization of the seed industry in India since the 1980s has had a tremendous impact on the production of hybrid maize seed, which rose from almost none in 1984 to more than 12,000 t in 1992 (Morris, Singh, and Pal, 1998). Some 45 percent of India’s maize area was planted with improved open-pollinated varieties and hybrids in the 1994/95 season. A production increase of more than one million t for that crop season resulted from the adoption of maize hybrids. Similarly, the process now taking place in the PRC, with support from the World Bank, is expected to transform the seed industry there. Private vegetable seed producers have also been active in other Asian countries.

Many have argued, backed by a strong lobby from the seed industry, that the protection provided by intellectual property rights (IPR) legislation and exclusive marketing rights to seed varieties should (a) provide incentives for private R&D in plant breeding, (b) save the public the cost of seed production and dissemination, and (c) earn revenue for public breeding programs through the licensing of varieties. There are probably some significant savings to be gained from privatizing seed production and dissemination. There may also be greater public benefits from more efficient seed production and dissemination through variety licensing than the return on revenues from royalties from breeding programs.

For hybrid maize, however, private investment has preceded IPR laws. In Thailand, where a proposed Plant Variety Protection Act had not been enacted as of 1998, hybrid maize operations have been carried out by national and multinational seed companies since 1979 (Pongsroypech, 1994). These operations have involved every step of the business, including the introduction of germplasm and breeding. By 1981, hybrid seeds, largely imported, were put on the market by several companies. It was not until 1990, presumably when the yield potential from hybrids was finally realized by more locally adapted materials, that diffusion began to accelerate.

Experiences from Argentina and Chile have shown that IPR for plant breeders has had very little impact on private R&D investment in plant breeding. This is due, in part, to limited enforcement mechanisms, to court procedures that have yet to be established, and to seed companies' unwillingness to take violators to court (Frisvold and Condon, 1998). In the US, it has been concluded that a "farmer exemption" (a clause in the IPR law that allows farmers to keep progenies, i.e. succeeding generations of seeds of "proprietary" seed, for their own use) was the main reason why most of the seed companies ceased wheat R&D, and perhaps also soybean breeding (Pray, 1991).

NGOs and the private sector have recently taken a very active role in technology transfer in crop management. NGOs in particular have been able to adapt appropriate site-specific technology to the needs of local communities (see Box I.6). In many instances, they help to combine and enhance traditional knowledge with modern technology. However, sometimes technology proven successful by NGOs has failed to be effective when handed over to government agencies. At that stage, the participatory approach may become substituted by a top-down, seedling- and fertilizer-subsidy mentality.

In conclusion, a constant challenge for international crop breeders is to continue to increase yield potential in order to keep production ahead of population growth. Past successes have emphasized land-saving technology. Additional requirements for the next decade are to include in the technology package elements that provide environmental savings and are environment enhancing. The technologies should not be limited to water and soil conservation but should also include development of varieties for more extreme environments, such as saline or acidic soils, and varieties that are mineral efficient. This type of R&D requires substantial collaboration not only with national breeding programs but also with local universities, researchers, and the farmers who possess first-hand knowledge of local conditions.

For the national R&D programs, the challenge will be in crop management innovation. These innovations may deal with 1) fine tuning new varieties to suit specific agro-ecological niches, 2) improving efficiency in input use, and 3) increasing cropping intensity coupled with more effective environmental management. Again, the challenge is to reverse the "father-knows-best" approach currently employed by RD&E workers to a "farmer-first" system. A greater challenge is for the centralized agricultural agencies in many countries in Asia to recognize traditional knowledge and blend it with science-based technology and management systems. Room for this exists in water resources management, local nonchemical herbicides and pesticides, and cropping for local conditions.

Moreover, breeding new crop varieties depends on a fair and transparent system of international gene-pool management and exchange of genetic material. It is evident that there is an urgent need for proper multilateral germplasm management that recognizes the rights of prior users and providers of genetic materials, as well as the need to create sufficient but not undeserved incentives for private R&D.

Irrigation

Irrigation was key to the success of the green revolution. Irrigation not only augments the water supply but also improves and ensures the stability of water delivery, widens crop choices, and allows increased cropping intensity. Asia has 179 million ha or 69 percent (in 1995) of the world's irrigated areas. The PRC alone has 49 million ha under irrigation, India 50 million ha, and Pakistan 17.2 million ha (Table l.11).

Over the past two decades, irrigated areas have increased in most Asian countries, especially Bangladesh, Bhutan, PRC, India, Pakistan, Thailand, and Viet Nam (Table I.11), but the rate of increase has slowed down in the last decade except in PRC, Myanmar, and Bangladesh. Since 1980, the irrigated area in Asia has expanded at the rate of about 2 percent per year; about 35 percent of the arable land in the region is now under irrigation. Future growth in irrigated area may come from India where it is planned to add 17.3 million ha of irrigated land by 2020 (Rosegrant and Ringler, 1998). The general reduction in growth of irrigation is a result of the decline in funding by major lending agencies as well as of the difficulties in finding projects with high returns. In many countries, such as PRC, Japan, Republic of Korea, and Sri Lanka, the supply of land that would yield a high return under irrigation has been mostly exhausted. In other countries, such as India and Thailand, where expansion is being planned, the marginal cost of irrigation is high when social and environmental costs are taken into account.

Since 1980, the efficiency of irrigation systems has become an issue of increasing concern. Poor maintenance and rapid deterioration are common features of irrigation systems in many Asian countries. Irrigation agencies are interested in increasing physical capacity without commensurate increases in management capacity. Planned capacities have fallen short of

Table I.11: Proportion of Arable Croplands Under Irrigation in Selected Asian Economies

	Irrigated Area (ha'000)			Proportion of Arable Lands Under Irrigation (percent)			Annual Growth Rate of Irrigated Areas (percent)	
	1975	1985	1995	1975	1985	1995	1976–1985	1986–1995
Asia	**121,165**	**140,792**	**179,013**	**27**	**29**	**35**	**1.50**	**2.40**
East Asia								
China, People's Rep. of	42,776	44,581	49,857	43	46	52	0.41	1.12
Japan	3,171	2,952	2,700	62	62	62	-0.72	-0.89
Korea, Rep. of	1,277	1,325	1,335	57	62	67	0.37	0.08
Mongolia	23	60	80	3	4	6	9.59	2.88
Southeast Asia								
Cambodia	89	130	173	5	6	5	3.79	2.86
Indonesia	3,900	4.300	4,580	15	16	15	0.98	0.63
Lao PDR	40	119	177	6	14	20	10.90	3.97
Malaysia	308	334	340	7	6	4	0.81	0.18
Myanmar	976	1,085	1,555	10	11	15	1.06	3.60
Philippines	1,040	1,440	1,580	14	16	17	3.25	0.93
Singapore				0	0	0	0	0
Thailand	2,419	3,822	5,004	15	19	24	4.57	2.69
Viet Nam	1,000	1,770	2,000	16	28	30	5.71	1.22
South Asia								
Afghanistan	2,430	2,586	2,800	30	32	35	0.62	0.80
Bangladesh	1,441	2,073	3,200	16	23	37	3.64	4.34
Bhutan	22	30	39	20	23	26	3.10	2.62
India	33,730	41,779	50,100	20	25	30	2.14	1.82
Nepal	230	760	885	10	33	30	11.95	1.52
Pakistan	13,630	15,760	17,200	69	76	80	1.45	0.87
Sri Lanka	480	583	550	25	31	29	1.94	-0.58

0 = zero or less than half of the unit measured.

Note: 1. Annual Growth Rate = ((Ln(value year begin) - Ln(value year end)) / number of years) x 100.

Source: FAOSTAT Database. *Available: http://apps.fao.org*

actual needs, and some systems are unused owing to lack of water, inappropriate design, or poor maintenance (IRRI, 1983; Kikuchi, 1996). The overall system efficiency is low, for example 30 and 38 percent in northern India and Karnataka, respectively (Guerra et al., 1998).

In Central Asia, the breakdown of the drainage system in salt-affected irrigated areas has led to further elevation of the groundwater table, thereby increasing salinity, which has led to large yield losses and finally to the total loss of cropland in some areas.

Communal irrigation systems that have been taken over by centralized irrigation agencies often become inefficient because of a lack of appreciation of onfarm water needs. A study of 15 irrigation systems in South and Southeast Asia indicated the lack of two-way communication between irrigation agencies and water users (Murray-Rust and Snellen, 1993). "Flood" irrigation, which is the prevalent system in Asia, is in itself an important potential source of inefficiency and degradation. Prolonged or excessive flooding results in waterlogging and salinization. At the farm level, farmers tend to use more water than is needed. For rice, the amount of water used may be 6 to 10 times more than is necessary (Ghani et al., 1998). Water pricing has been suggested as a means of overcoming water waste, but farmers will then have to weigh the cost of water with the cost of weed control. Another method for saving water is the conversion from transplanting to direct seeding which reduces water use by half, although the yield may be lower even with good weed control. Other irrigation techniques, e.g. drip irrigation and methods that are site-specific water applications, are emerging where water is scarce and the crops are of high value.

In the past, the construction of multipurpose or agricultural large-scale dams was often planned top-down, with insufficient consideration given to the people who would be affected by the project. The impact on forests resources and biodiversity was usually not taken into account. Recently, some well-organized NGO networks have effectively publicized the plight of dam refugees and the ecological costs of large-scale infrastructure projects. This has rendered projects in the region more transparent and has enhanced the accountability and worthiness of the projects. In Thailand for example, a careful review of the feasibility of the Kaeng Sua Ten Dam in northern Thailand following protests by environmentalist groups revealed that the project proposed by the Government was not economically viable (TDRI, 1997). The rate of return was low even before the mitigation and environmental costs were taken into account.

The process for determining economic feasibility and environmental impact needs to be strengthened to improve irrigation efficiency and to avoid having dams that have insufficient inflows or that lead to an increase in soil salinity. To date, the feasibility study and the environmental impact assessment have been important only in terms of the loan application process. Irrigation projects are often not transparent or accountable to the public. Cost-benefit analyses have not been rigorously conducted. It is important that in the future, projects should involve the participation of a wider spectrum of stakeholders.

Recently, there has been global recognition of the value of consulting and involving water users in water management plans and activities related to irrigation systems. For the past two decades, more and more countries around the world have been turning over management authority for irrigation systems to farmers' groups or local entities, in a process commonly referred to as irrigation management transfer (IMT). There have been several studies on this process and the literature shows a mixture of positive and negative results (Vermillion, 1997).

Although most of the studies are deficient in assessing the real cost of farmers' participation, government expenditures for irrigation tend to decline and costs to farmers often rise. There is little evidence to suggest that yield, water productivity, or farm income has increased. Poor operation and management have a negligible impact on the irrigated crop. Studies that would make it possible to separate the impact of IMT from other factors such as weather are lacking. In many instances, the responsibility for rehabilitation is not clearly spelled out in the IMT agreement between the government and local entities.

The key to sustained success of farmers' participation is the incentive structure and quality of leadership, which can vary widely from place to place and from time to time. There is no available model to follow for molding the farmer-agency relationship that will work in all societies in all situations. Many innovations may be needed to develop the right relationship for a given set of conditions. It is hoped that as the real value of water becomes better understood by all users and as more realistic water pricing becomes feasible, workable models will emerge for sharing responsibility between agencies and users in managing irrigation water .

Urbanization

Urbanization, as measured by the percentage of the total population living in urban areas, has been increasing steadily in Asia for decades. The average annual urbanization rate for the whole of Asia between 1980 and 1985 was 3.6 percent (WRI, 1998) and the predicted averages for 2000–2005 and 2020–2025 are 2.8 and 2.0 percent, respectively. Urbanization occurred especially rapidly in parts of East and Southeast Asia. Nevertheless, the region is not yet highly urbanized, with about 30 percent of its inhabitants living in urban areas as of 1990. When compared to urbanization in other developing regions, Asia is close to Africa where only about a third of the population lives in urban areas.

Internal migration has fuelled much of Asia's urbanization, with approximately 60 percent of urban growth coming from rural migration. Economic growth has usually been accompanied by declining fertility rates. Therefore, the contribution of natural growth to urban population increases is likely to decline relative to that of rural migration as Asia's economies continue to develop. This can be seen in the markedly slower growth of rural populations. Moreover, as younger and more educated persons leave rural areas, farms are being managed by older generations and by women. This has happened in Japan and the Republic of Korea, and more recently in the PRC, Malaysia, and Thailand.

Rapid urbanization and industrialization in Asia have both positive and potentially negative effects on agriculture. Increased wages in urban and industrial areas lure labor away from agriculture. For high density areas, this rural-to-urban migration raises productivity in agriculture, but for a country such as Thailand where land is abundant, rapid growth has increased the cost of labor dramatically (Coxhead and Jiraporn, 1998), necessitating substitution of capital for labor.

In the past decade, Asia has gone through a period of rapid economic transformation. Urbanization and industrialization have taken land from agricultural production. Fertile and irrigated areas have been converted into housing estates and factories. Expanding urban markets often demand greater amounts of horticultural and livestock products, which lowers incentives for the production of grain. The annual loss of wet riceland to urbanization in Indonesia has been estimated by the Agency for Agricultural Research and Development at between about 20,000 and 100,000 ha per year. There have been fears that the PRC is on the verge of not being able to feed itself, based on a large expected loss of cropland in the next few decades as a result of industrialization and urbanization (Brown, 1995). However, Lindert (1996a) estimated that agricultural land lost to urbanization in the PRC has been quite small, i.e. 0.04 percent per year between 1983 and 1993. In addition, other studies (Wen Qi Xiao, 1984, cited in Lindert, 1996a) show that since the 1930s, urban industrial expansion has resulted in an increase in the supply of manure as well as the supply of chemical fertilizers (through more favorable market prices), which has offset the decline in land availability. Lindert, Lee, and Wu (1996, cited in Lindert, 1996a) estimated that the net effect of nutrition losses from land loss and positive gains from urban and industrial expansion during 1930 to 1980 was positive.