

Environmental consequences of agricultural commercialization in Asia

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ABSTRACT Agroindustrialization and agricultural commercialization are both consequences of economic growth and urbanization. Commercialization of agricultural systems leads to greater market orientation; progressive substitution out of non-traded inputs for purchased inputs; and the decline of integrated farming systems. Agricultural commercialization can have both negative and positive impacts on the natural resource base. Higher opportunity cost of labor increases farmer reliance on herbicides for weed control, primarily for the staple crops. The use of insecticides and fungicides could also rise, especially for high value fruit and vegetable crops. Increased use of agricultural chemicals could lead to higher environmental and human health risks. On the other hand, global integration and the consequent rationalization of agricultural policies could have significant environmental benefits, especially in terms of a reduced rate of salinity build up and ground water depletion in irrigated environments. The extent to which positive environmental effects manifest themselves depends on both macroeconomic and microeconomic policy reforms.

Introduction

Economic growth and urbanization are leading to the rapid rate of agroindustrialization in Asia, primarily targeted towards meeting the increasingly diversified food needs of the urban population. Agroindustrialization, along with the movement of labor out of rural areas, lead to the commercialization of agriculture. Agricultural commercialization is an essential requirement for successful and rapid agroindustrialization. Understanding the determinants of commercialization of agriculture is therefore important in assessing the process of agroindustrialization. Agricultural commercialization means more than the marketing of agricultural output. It means that product choice and input use decisions are based on the principles of profit maximization. Commercial reorientation of agricultural production occurs for the primary staple cereals as well as for the so-called high-value cash crops. Commercialization of agricultural systems leads to greater market orientation of farm production; progressive substitution out of non-traded inputs in favor of purchased inputs; and the gradual decline of integrated farming systems and their

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replacement by specialized enterprises for crop, livestock, poultry, and aquaculture products.

While the speed of the above structural transformation differs substantially across countries, they are all moving in the same direction. Timmer (1989) provides a comprehensive discussion on the process of structural change and commercialization of agriculture. For a recent review on agricultural commercialization, see Pingali, Hassain, and Gerpacio (1997), Pingali and Rosegrant (1995). Empirical evidence on commercialization trends is provided by Dyck, Huang, and Wailes (1993) for East Asia; Huang and Rozelle (1994) for China; Koppel and Zurich (1988) for Southeast Asia; and Naylor (1992) for Indonesia. This paper presents an overview of the process of commercialization of Asian agriculture and discusses the implications for the organization and management of food production systems and its impacts on the natural resource base.

What are the anticipated impacts of agricultural commercialization on the natural resource base? There definitely are environmental costs that we should be concerned about, especially in terms of chemical input use. Higher opportunity costs of labor increase farmer reliance on herbicides for weed control for rice and other staple food crops that are currently managed through hand weeding. Insecticide and fungicide use for high value crops, such as vegetables and fruit, is substantially higher than for staples, and improper use can have adverse environmental consequences as well as increase the incidence of pesticide-related illnesses. Also, where property rights are not clearly established, high-value crop production in the upland environments could lead to higher risks of soil erosion and land degradation. At the same time, we ought to be aware that global integration, and the consequent rationalization of agricultural, and broader economic policies could also have significant environmental benefits, especially in terms of a reduced rate of salinity build-up and ground water depletion in the irrigated environments. One could also see a reduction in cultivation of the marginal lands with consequent reductions in erosion risk on these lands. The net effects of globalization and commercialization on the environment are by no means clear and could vary on a case-by-case basis.

1. Commercial transformation of food production systems

Asian food production systems can be characterized as subsistence, semi-commercial, and commercial systems. Increased commercialization shifts farm households away from traditional self-sufficiency goals and towards profit- and income-oriented decision making; farm output is accordingly more responsive to market needs (see table 1). The returns to intensive subsistence production systems that require high levels of family labor generally decline relative to production for the market with predominant use of hired labor. Integrated farming systems give way to specialized units for the production of high-value crop and livestock products. The proportion of farm income in total household income declines as family members find more lucrative non-agricultural employment opportunities. At the same time, the share of agriculture in total household income declines.

Table 1. *Characteristics of food production systems with increasing commercialization*

<i>Level of market orientation</i>	<i>Farmers' objective</i>	<i>Sources of inputs</i>	<i>Product mix</i>	<i>Household income sources</i>
Subsistence systems	Food self-sufficiency	Household generated (non-traded)	Wide range	Pre-dominantly agricultural
Semi-commercial systems	Surplus generation	Mix of traded and non-traded inputs	Moderately specialized	Agricultural and non agricultural
Commercial systems	Profit maximization	Pre-dominantly traded inputs	Highly specialized	Pre-dominantly non-agricultural

Source: Pingali, Hossain, and Gerpacio (1997).

Table 2. *Substitution of traded for non-traded inputs*

<i>Level of market orientation</i>	<i>Power</i>	<i>Soil fertility</i>	<i>Fodder</i>	<i>Human nutrition</i>
Subsistence systems	Animal/human	Farm yard manure	Crop residues	Predominantly home produced
Semi-commercial systems	Motor/animal/human	FYM & chemical fertilizers	Crop residues	Home produced and purchased
Commercial systems	Motor	Chemical fertilizers	Purchased feed	Predominantly purchased

Source: Pingali, Hossain, and Gerpacio (1997).

On the demand side, the process of agricultural commercialization is triggered by rapid income growth and the consequent diversification in food demand patterns. A slowdown in income-induced demand for rice and for coarse grains is accompanied by a shift of diets to bread and higher-valued foods such as meat, fruit, and vegetables. These dietary transitions are induced by the growth in per capita income and by the rapid migration of population to urban areas. The need to provision the rapidly growing cities of Asia also acts as a trigger for the transformation of food production systems.

On the supply side, growing factor scarcities contribute to the demise of subsistence agricultural systems (refer to table 2). While growing land and water scarcity can be compensated for with increasing scientific knowledge and farmer management, farmer time required for sustaining productivity and profitability of intensive food production systems will become increasingly scarce. The collapse of subsistence systems will come about because of the competing demands for farmers' time.

The speed of transformation of Asian agriculture definitely depends on policy reforms, both macro as well as sector policies. Agricultural price and trade policies in many Asian countries have often been both internally inconsistent and costly for long-term diversified growth. On the one hand, general trade and exchange rate policies have penalized agriculture across the board, while, on the other hand, crop-specific interventions, such as output price protection and input subsidies, have attempted to favor individual crops, particularly rice and wheat (Pingali and Rosegrant, 1998). Progression towards global integration would reduce domestic cereal prices, improve consumer welfare, release productive resources to other crops and other enterprises with a comparative advantage in production, and reduce the pressure for cereal-crop-related degradation.

The process of structural transformation is well underway across much of Asia, although the speed at which it is occurring varies by country. East Asia¹, except China, is nearing completion of the transformation process. Southeast Asia² is rapidly transforming its agricultural systems, with Malaysia, Indonesia and Thailand taking the lead. South Asia³ continues to lag behind, although the macroeconomic liberalization policies initiated by these countries – especially India – in the early 1990s could lead to a faster rate of transformation. Relatively larger populations and continuing rapid population growth rates will continue to dampen the speed of transformation in South Asia.

Product choice: movement away from cereal monoculture systems

Product choice responses to increased commercialization vary by high potential versus marginal production environments. The irrigated lowlands by their nature are inherently more market oriented because of their ability to generate a surplus and because of a better transport infrastruc-

¹ Japan, Korea, Taiwan, and China represented East Asia.

² Indonesia, Malaysia, Myanmar, Philippines, Laos, Thailand, and Vietnam comprised Southeast Asia.

³ Bangladesh, India, Nepal, and Pakistan represented South Asia.

ture. Increasing commercialization trends lead to both a seasonal diversification out of rice monoculture systems – to include non-rice crops in rotation with rice – and specialized enterprises for horticulture, aquaculture, poultry, and hog production. Dry season diversification out of rice is generally for vegetables targeted to growing urban needs and hybrid maize to meet the feed demand of the growing livestock industry. The opportunities and constraints to seasonal crop diversification are discussed in Pingali (1992). Specialized enterprises for high-value horticultural products, hog production, and aquaculture tend to be concentrated in the irrigated environments because of the relatively more reliable and cheaper supply of water (table 3).

For the marginal environments the movement from subsistence to market-oriented production could follow a general pattern: 1 the abandonment of highly drought-prone environments, especially in areas where the opportunities for ground water exploitation are limited; 2 the shift from small subsistence farms to mechanized cultivation of larger farms; 3 where dry season water supplies are available, increased areas under vegetables, feed grain, and fodder crops, and other high-valued crops; and 4 adoption of other productivity-enhancing technology, e.g., dry seeding of rice. A study conducted in rainfed lowland farms in Northern Philippines showed dry seeding of rice in dry-plowed fields as the most promising technology for improving rice land productivity (IRRI, 1992). Some farmers in the study area also planted maize for fodder before the rice crop. Dry seeding also allowed early establishment of an upland crop after rice harvest, mungbean, which gave significantly higher returns than that from mungbean grown on transplanted rice farms. Therefore, dry seeded rice and mungbean crop after rice is the most viable cropping option for rainfed lowland farms (Lantican, Saleh, and Bhuiyan, 1993; IRRI, 1994).

Upland areas, with soils that are relatively less susceptible to erosion, tend to move with improved market infrastructure from subsistence cereal and root crop production to a variety of commercial enterprises. These include commercial maize production, horticulture, tree crops, dairy, and cattle ranching. In Asia, commercial utilization of the uplands has generally resulted in the movement out of upland rice production (Pingali, Hossain, and Gerpacio, 1997)

Shift out of labor-intensive agriculture and reduced cropping intensities

An immediate consequence of economic growth and urbanization is the rapid rise in the opportunity cost of farm labor. Observation of farm households in the newly industrialized countries of Asia indicates significant changes in their age and gender profile. Young male family members generally migrate out of the family farm to seek economic opportunities in the urban/industrial sectors. The experience of South Korea is illustrative. In 1990, 34 per cent of Korean farmers were between 20 to 50 years old, as compared to 60 per cent in 1963. Younger members of the rural community have been leaving at the rate of 400,000 persons per year, while older farmers remain behind (Park, 1996). In Japan, during the 25-year 1951–1975 period, the working population in the farming sector dropped by half, and the composition of the agricultural labor force changed to

Table 3. *Changing product mix by rice environments*

<i>Level of market orientation</i>	<i>Irrigated lowlands</i>	<i>Rainfed lowlands</i>	<i>Deepwater and tidal wetlands</i>	<i>Uplands</i>
Subsistence systems		Single rice crop Subsistence livestock and poultry	Single rice crop Subsistence fish production	Shifting cultivation of subsistence livestock and poultry
Semi-commercial systems	Intensive rice systems peri-urban Dry season vegetables Dry season fodder crops	Single/double rice crop Cattle/small ruminant	Dry-season irrigated rice	Horticulture Maize, root crops Vegetables
Commercial systems	Year-round vegetables Horticulture Aquaculture Hog production	Intensive poultry and production	Intensive poultry Intensive aquaculture	Intensive dairy farming Cattle ranching Tree crops

Source: Pingali, Hossain, and Gerpacio (1997).

include mainly the aged and female members in the farm family (Kada and Kada, 1985).

In Thailand, sustained economic growth not only affected the casual agricultural labor market, but has started showing pronounced effects on the labor market structure. Firstly, wet season agricultural employment has been declining since 1989, from when the number of female farmers also decreased by more than one million persons up to 1991. Dry season agricultural employment has also declined substantially, from 60 per cent of the total agricultural employment in 1987 to 50 per cent in 1991; the figure was expected to reach 40 per cent by the year 2000. On average, 80 per cent of the 15–25 year-old age group in Central Thailand work in the cities (Poapongsakom, 1996). However, despite the drop in the ratio of the farming population, there was no drop in agricultural output as improved technology has compensated for the loss of manpower (Shinawatra and Pitackwong, 1996).

As the opportunity cost of family labor rises, small family farm operations for subsistence production become increasingly unprofitable. Some landless tenants will gradually find their way to the urban industrial sector. Others will find their way into the rural non-farm economy (Reardon *et al.*, 1998; Reardon, 1997; Reardon *et al.*, 2000). Small landowners will likewise find it more profitable to sell or lease their holdings rather than to cultivate them. The extent to which farm ownership size increases depends on land reform legislation. Strict rules against land accumulation designed for a different period may prevent changes in farm ownership, at least in the short run, as is the case in Japan and Taiwan. Over time, one should expect the operational holding size to increase as land consolidation occurs. In Japan, Taiwan and South Korea, it is increasingly important to distinguish between the land ownership and the operation of a farm enterprise (Dyck, Huang, and Wailes, 1993), the latter being increasingly managed by professional contractors.

Where small-scale farming survives under high-wage conditions, it will necessarily be only on a part-time basis. The majority of the household income⁴ will come from non-agricultural sources. In Korea for instance, non-agricultural income⁵ accounted for 46 per cent of total farm household income in 1991, compared with 32 per cent a decade earlier. In Japan it was around 80 per cent, and in Taiwan it grew from 50 per cent in 1960 to 87 per cent in 1990 (Dyck, Huang, and Wailes, 1993). Income and expenditure surveys conducted on farm households in South and Southeast Asia in the 1980s reveal that the proportion of non-agricultural income was as much as 40 per cent of total household income in Indonesia, Thailand, and Philippines (Koppel and Zurick, 1988).

As the opportunity cost of labor rises, the returns to intensive production systems that require high levels of family labor (non-traded inputs) are generally lower than exclusive reliance on purchased inputs.

⁴ Household income refers to the total income of all the members of the household.

⁵ Non-agricultural income refers to the income outside of agriculture, such as employment in industries/institutions, operation of small-scale industries, and others.

Moreover, with the changing age and gender composition of the rural household, and with the anticipated rise in operational holding size, the ability of the household to supply adequate quantities of non-traded inputs declines. Given the declining share of agriculture in total household income, family labor time spent in farm operations tends to be economized. The traditional role played by hired labor in conducting intensive farm operations will also not be profitable under escalating farm wage conditions. Substitution of hired labor with mechanical and chemical alternatives can be expected as wages rise (Pingali and Heisey, 1998).

Operations where substitution out of labor is not possible could be contracted out to professional labor companies, saving the farmer supervision labor. Thailand should be expected to move along the path of significant labor substitution over the next five years. The Philippines, China, and South Asia will be slower in this transition, although one would expect the rapidly industrializing Southeastern provinces of China to move ahead of the rest of the country, and similar patchy transformations may occur in some provinces of India and the Philippines.

Despite the adoption of labor-saving innovations and the consolidation of farm holdings, farm-level profits may be sustained over the long term only through a reduction in cropping intensities, especially for rice. Huang and Rozelle (1994) report for China that the area planted to two-season rice has fallen from 66 per cent in 1980 to 58 per cent in 1990. They attribute the fall in double-cropped area to the rising opportunity cost of labor during the early 1980s, in response to the market-oriented diversification policies. The switch to single season rice has been sharpest in the coastal provinces of Jiangsu and Shanghai provinces, falling from 47 to 2 per cent and from 97 to 19 per cent, respectively, in the 1980s. Intensive crop production practices, such as the use of organic manure, also dropped to negligible levels in these provinces by 1990. Malaysia, being more industrialized relative to other Asian countries, has deliberately chosen not to further intensify its rice production systems and import supplies as needed. Thailand may find itself trading off its status as the largest rice exporting country if wage rates continue to rise dramatically.

Another consequence of economic growth is rural–urban migration. As the opportunity cost of family labor rises, not only some of the landless tenants but also most of the family labor in the rural areas migrate to the urban areas. The influx of these rural workers causes congestion, lack of sufficient housing facilities, pollution, and later on, possibly, unemployment. In Sierra Leone, the rapid influx of migrants into urban areas and the stagnation of employment in urban large-scale sectors has contributed to high rates of urban unemployment – usually of 10 per cent (Byerlee, Tommy, and Patoo, 1976).

The uncertain future of integrated farming systems

Across all food production environments, integrated farming systems, such as rice–livestock, rice–aquaculture, and rice–fruit tree systems, generally become infeasible at a commercial scale, because of product-specific requirements in technical and managerial skills and infrastructural investments. For example, commercial crop production and high-quality

livestock production would not generally occur on the same farm. While the physical size of the farm may not be a constraint to multi-product enterprises, the time of the farmer-entrepreneur becomes the ultimate binding constraint to the generation of multiple outputs (Pingali, Hossain, and Gerpacio, 1997).

The diminishing advantage of integrated farming systems is also the result of increased substitution of non-traded for traded inputs (see table 2). Power, soil fertility maintenance, fodder for farm animals, and household nutrition are the primary activities for which non-traded inputs are used in subsistence societies. Under low-wage conditions, integrated crop–livestock production systems are the most economical means of providing the above inputs for the farm production system (Pingali, 1997). As wages and the opportunity cost of family labor rise, the use of purchased inputs becomes substantially cheaper than home-produced inputs. Few Asian economies have an exclusively specialized production system today, but enclaves do exist and the trends are in favor of increased commercialization and specialization.

2. Agricultural modernization and the environment

The commercial transformation of Asian agricultural systems can be expected to have significant impacts on the environment and on the agricultural resource base. It is important to remember though that the environmental outcomes need not be negative in all cases. It is hard to say *a priori* whether the net effects of commercialization on the environment are positive or negative. Increased environmental costs, such as increased pesticide use and pollution, are widely anticipated, especially with the diversification away from cereal monoculture systems to vegetables, fruit, and other high-value crops. The gradual demise of subsistence production systems could lead to a decline in the use of land races and the consequent loss in genetic diversity at the farm level. Increasing opportunity cost of labor has already resulted in rising trends in herbicide use and the associated environmental consequences. Similarly the movement away from integrated farming systems could be anticipated to result in reduced organic manure use and increased reliance on chemical fertilizers.

Agricultural commercialization along with policy reforms associated with trade liberalization and structural adjustment would lead to substantial environmental benefits, especially through better water and land management. The movement away from intensive cereal monoculture systems along with a reformed policy environment (that reduces price distortions) could lead to reduced incidence of water-induced degradation problems, such as salinity build up. More rational and efficient water use could also result in the reversal of the problems of ground water depletion. Improved non-agricultural employment opportunities and the consequent rise in the opportunity cost of labor makes the cultivation of the very marginal environments non-viable and hence an increase in areas under bush and forest cover and reduced erosion risk on the marginal sloping lands. In this section I provide a detailed discussion of the consequences of commercialization on the use of agro-chemicals and on water use efficiency.

Agrochemical use and impacts

Agrochemicals provide an interesting case in terms of the negative and positive environmental impacts of agricultural commercialization. On the one hand, herbicide use will definitely continue its upward trend through much of Asia, as will the use of insecticides and fungicides for high-value crops. On the other hand, insecticide use in intensive cereal systems, especially rice monoculture systems, has leveled off and there are definite signs of long-term declining trends.

Rising from US\$900 million in 1960, the global pesticide market was valued at US\$30.3 billion in 1995, indicating an annual growth of almost 11 per cent (FAO, 1997). Cereal crop production across the world is reported to be the second largest consumer of pesticides, surpassed only by fruit and vegetable production. In 1995, rice and maize production consumed about 23 per cent of all agrochemicals, while fruit and vegetables accounted for about 26 per cent (IFPRI, 1996).

Before the 1960s, pesticides were mainly consumed in industrialized countries. Agriculture intensification – the movement from an extensive to an intensive production system, or from a subsistence production system to a commercial one – has resulted in increased use of agrochemicals in the developing world. This trend will continue as more developing countries move towards commercialization, and unless alternative measures for controlling pests and diseases are found, pesticide pollution will become a major problem (Conway, 1984).

Table 4 shows the differential effects of increasing land scarcity and increasing market orientation on the demand for chemicals. Consider first a sparsely populated subsistence society with limited access to markets. Agriculture in such societies is characterized by extensive land use and an almost complete reliance on non-traded inputs, such as farmyard manure. Pest pressure is low in such cultivation systems and is kept that way through a variety of management practices, like crop rotations and the use of traditional cultivars with known resistance to chronic pest problems.

Increasing land scarcity due to population growth in subsistence societies leads to agricultural intensification – that is, increased intensity of land use (Boserup, 1965; Pingali and Binswanger, 1987). Pest pressure increases with intensification due to increased carryover of pests spatially and temporally. While increased weed pressure is handled by family labor, increased insect pressure is no longer amenable to traditional management practices, and small amounts of insecticides begin to be used for cereal crops, even in subsistence societies. Low to moderate amounts of

Table 4. *Intensification, market orientation, and demand for agrochemicals*

<i>Land/labour ratio</i>	<i>Market orientation</i>	
	<i>Low</i>	<i>High</i>
High	Low demand for all chemicals	Herbicides predominate
Low	Insecticides predominate	High demand for all chemicals

Source: Rola and Pingali (1995).

Table 5. *Agrochemical use by stage of agriculture and cropping system*

<i>Farm characteristics</i>	<i>Cropping system</i>		
	<i>Cereals (e.g., rice)</i>	<i>Other field crops (e.g., cotton, tobacco)</i>	<i>Horticulture (e.g., fruits, vegetables)</i>
Land abundant	All chemicals	All chemicals	All chemicals
Subsistence	None	None to low	None to low
Land scarce	Insecticides	Insecticides, fungicides	Fungicides
Subsistence	Low to moderate	Low to moderate	Low to moderate
Land abundant	Herbicides	Herbicides, fungicides	Fungicides, herbicides
Market oriented	Moderate to high	Moderate to high	Moderate to high
Land scarce	Insecticides, Herbicides	All chemicals	All chemicals
Market oriented	High	High	High

Source: Rola and Pingali (1995).

fungicides also tend to be used for crops such as cotton, tobacco, and horticultural products, especially fruit and vegetables (see table 5).

The contrasting scenario is one of a sparsely populated area that has excellent market access. In this case, agricultural intensification will be high due to high land values but unlike the subsistence case, the opportunity cost of labor will also be high, hence the high levels of traded input use. While increasing insect pressures can be controlled through appropriate crop rotations and seasonal fallows, in such societies the dominant constraint is weeds. High levels of herbicide use are the norm. High fungicide use can also be observed for horticulture crops, especially fruit and vegetables. Where market access and land scarcity are both high, the high opportunity costs of land and labor result in agricultural intensification with high use of traded inputs. The demand for all chemicals is therefore also high in such societies.

Modern cereal crop systems further aggravate pesticide use. In Asia, insecticide use has risen dramatically since the 1960s, primarily for rice and more recently for commercial maize production systems. Almost none is used for wheat. Fungicides are generally not important for cereal crops, except for rice in East Asia. In the case of wheat, the plant's ability to resist high levels of disease pressure has made fungicide use almost obsolete in Asian wheat production systems (Pingali and Gerpacio, 1997). Herbicide use on all three cereals has grown, as rising agricultural wages, the result of increasing off-farm employment opportunities, have reduced the cost effectiveness of hand weeding (Naylor, 1997). Herbicide use for rice for example has been rising at the rate of 4 per cent per annum between 1984 and 1993 (Pingali and Gerpacio, 1997).

Although rice production remains the major consumer of pesticides, valued at US\$2.6 billion in 1993 (Wood and Mackenzie, 1993), it should be

noted that trends in usage have been declining dramatically over the past decade. Total insecticide use for rice production actually fell by 10 per cent from 1989 to 1993 (Pingali and Gerpacio, 1997). An enlightened policy environment, along with the introduction of crop varieties resistant to insects and diseases and the promotion of integrated pest management, has generally resulted in reduced pesticide use, the use of safer chemicals, and improved farmer safety and environmental sustainability.

Intensive monoculture systems, using high-yielding cereal varieties, resulted in an environment conducive to pest build-up and infestation, and the consequent use of pesticides led to the disruption of the natural pest–predator balance. The risk of insect- and disease-related losses increased because early modern varieties were often highly susceptible to local pests and because of the loss of crop heterogeneity. Regular prophylactic pesticide application promoted by the extension service and supported by government subsidies became a standard part of the early Green Revolution package.

In addition, because early formulations of pesticides were often non-selective, pesticides proved equally lethal to beneficial pests, which preyed on crop pests. In many cases, pesticide use actually resulted in lower yield, as crop pests, freed of their natural predators, multiplied without constraints (Pagiola, 1995; Rola and Pingali, 1993). In the case of rice in tropical Asia, a large number of pest outbreaks have been associated more with injudicious pesticide applications, rather than with the use of modern high-yielding cultivars, high-cropping intensity and/or high chemical fertilizer use (Heinrichs and Mochida, 1984; Kenmore *et al.*, 1984; Joshi *et al.*, 1992; Schoenly *et al.*, 1994). Outbreaks of secondary pests of rice, notably the brown planthopper that was previously of minor significance, began to occur in regions adopting modern varieties and led to the concomitant use of agrochemicals (Pingali and Gerpacio, 1997). High and injudicious pesticide applications disrupted the rich diversity of pest and predator populations, where in most instances the species richness and abundance of predator populations may be greater than those of the pest populations. The health impacts of pesticide use has been documented by a series of empirical studies on Asian rice farmer households by Pingali *et al.* (1995); Antle and Pingali (1995); Rola and Pingali (1993); and Pingali and Roger (1996).

The rapid growth in pesticide use can also be attributed to the misinformation and risk-aversion of both policy makers and farmers. In an extensive review of rice case studies from across Asia, Rola and Pingali (1993) provide documentation that policy-maker perception of yield losses are higher than farmer perception of yield losses, which in turn are substantially higher than actual yield losses. Both farmer and policy-maker perceptions of pest-related yield losses are anchored around exceptionally high losses during major infestations, even when the probability of such infestations are low.

While in aggregate terms cereal crops account for the bulk of pesticide use in Asia, on a per hectare basis their use is quite small when compared to the levels applied on fruit, vegetables, and other high-value commodities. Pesticide application in high-value crops is related to consumer

demand for aesthetically appealing agricultural products. Since these high-value agricultural products enjoy a substantial price premium for unblemished physical appearance, risk-averse farmers tend to apply pesticides beyond the technical optimum in order to capture this price differential. With the excessive use of pesticides resulting from the shift from cereals to high-value crops, the pesticide pollution problem should be expected to get worse. Pagiola (1995), for example, reports that in Bangladesh where 70 per cent of pesticides are used on rice, the amounts used per unit area and the total area effected are both relatively small. On vegetables, the use of insecticides follows a pattern almost diametrically opposed to that found in rice. Whereas rice is sprayed only two to three times a season, it is common to spray vegetables, such as eggplant and country beans, several times a week. A survey of eggplant producers in Jessore indicated a range of application from 17 to 150 times for one crop cycle (Kabir *et al.*, 1994 as cited in Pagiola, 1995). Other vegetables have lower rates of use, but still generally higher than rice. Cauliflower and cabbage, for instance, are commonly sprayed three to four times. In the case of wheat, maize, and rice, which are the most important cereal crops in Asia, pesticides do not enhance physical quality in any way, and there is no price differential to capture (Rola and Pingali, 1993). Given the positive income elasticity of demand for fruit and vegetables, the long-term prognosis for developing economies is one of increasing areas under these crops and, in the absence of alternative pest control strategies, on increasing share of the agrochemical market (Pingali and Rola, 1995).

Globalization, commercialization, and the gradual dismantling of pesticide subsidies will inevitably lead to continued decline in the share of pesticides used for cereals relative to high-value crops. With recent advances in developing the cereal crop's ability to tolerate insects and diseases, and in integrated pest management, the outlook for future reductions in pesticide use for cereals is very promising. Rola and Pingali (1993) have shown that the productivity and profitability benefits of applying insecticides on varieties with insect resistance are minimal. Moreover, when farmer health impacts are explicitly accounted for, the positive production benefits of applying pesticides are overwhelmed by the increased health costs. The value of crop loss to pests is invariably lower than the cost of pesticide-related illnesses (Rola and Pingali, 1993) and the associated loss in farmer productivity (Antle and Pingali, 1994).

The one area where agrochemicals continue to have a significant productivity impact is in the management of weeds; herbicides will continue to be the preferred alternative in the foreseeable future. In intensive cereal crop production systems, the use of herbicides is cost effective, relative to the use of human labor, because the seasonality of weeding often creates labor scarcity and hence weeding wage rates that are higher relative to other crop management operations. The use of herbicides also got a boost from the general rise in farm wages due to overall economic growth and the growth in non-farm employment opportunities, particularly in Asia. As cheap herbicides became available and as farm wages rose, cereal crop farmers increasingly substituted herbicides for human labor, and the savings in labor costs have more than compensated for the additional cost

of herbicides. Pingali and Marquez (1997) document the productivity benefits of herbicide use, even when the health costs of herbicides are explicitly accounted for.

There are few genetic and management alternatives to herbicides, and those that exist are generally not very cost effective. The use of more competitive cereal varieties can avert the effect of weed competition, and the consequent use of more herbicides, but there appears to be a trade-off between the plant's ability to compete with weeds and yield (Moody, 1991), and research on varietal improvement for weed management in cereals is still at a very early stage (Khush, 1996). Among the management options for weed control that minimize labor use are the manipulation of water in the paddy in the case of rice (Pingali, Hossain, and Gerpacio, 1997), and in the case of wheat and maize the use of ridge tillage systems (Sayre, 1996) and the use of cover crops and intercropping. However, none of these options has proven to be economically as attractive as herbicide use, and the challenge for the research and policy community is to find cost effective mechanisms for reducing herbicide use in cereal crop production.

Reversal in water resource degradation trends?

One of the widely recognized consequences of the 'food self sufficiency' policies, pursued by many Asian governments over the past four decades, has been the depletion and/or degradation of water resources and the consequent negative impact on agricultural productivity. Global integration, agriculture sector policy reforms, and marginal cost water and electricity pricing, could actually result in the reversal in the current trends in water resource degradation, especially in terms of reducing the rate of salinity build up and the rate of ground water depletion. Globalization and commercialization could have significant benefits in terms of improving the sustainable use of irrigation water resources.

Massive investments in irrigation infrastructure, both for surface water as well as for ground water, were essential for the success of the Green Revolution in Asia. Without these investments rapid growth in food crop productivity would not have been possible (Pingali and Heisey, 1998). However, in retrospect, it is clear that inappropriate policies, designed and implemented in a 'crisis mind set', resulted in substantial environmental costs (Pingali, 1998).

In the case of surface irrigation systems, salinity build up has become a major environmental problem. Postel (1989) estimates that 24 per cent of the irrigated land world wide suffers from salinity problems, with India, China, United States, and the states of the Former Soviet Union being most effected. Intensive use of irrigation water in areas with poor drainage can cause a rise in water tables, due to the continual re-charge of ground water. In the semi-arid and arid fringe areas, where evapotranspiration rates are high, salts begin to accumulate on the soil surface over several crop cycles. These salts cannot be flushed because of the high water table, hence the accumulation of saline lands in large-scale irrigation systems. Excessive use of irrigation water and poor drainage are the primary causes of salinity build up. In the short term salinity build up leads to reduced yields while

in the long term it can lead to abandoning of crop lands (Samad *et al.*, 1992; Postel, 1989; Mustafa, 1991).

For new systems, drainage systems have to be planned and costed out right at the start, even if it means that many new systems may not prove cost effective. Drainage investments were deliberately left out of most irrigation projects to keep the costs down (NAS, 1989). For systems that are already in place, improving irrigation water use efficiency would lead to a significant slowdown in salinity build up. An essential component in improving water use efficiency is pricing irrigation water at its 'true' cost.

With water provided 'essentially free', there has been no incentive to economize on water use, making rice, a water-intensive crop, artificially more profitable than crops that use less water. The rapid liberalization of developing economies and the removal of price distortions in input and output markets, puts a premium on flexible farmer response in the allocation of water, land, and other resources in response to changing prices, comparative advantage, and economic opportunities, and encourages the process of diversification out of rice. With appropriate design of water law, institutions, and regulations, it is feasible to implement markets in tradable water rights, or incentive-based allocation systems that reflect the scarcity value of water (Rosegrant, 1997; Rosegrant and Binswanger, 1994).

In addition to surface irrigation systems, the development of ground water resources has been a significant driving force for agricultural intensification in many parts of Asia. The massive expansion of private sector tube well irrigation in Bangladesh, India, and Pakistan is the most successful example of private sector irrigation development in Asia (Rogers, *et al.*, 1994). The provision of subsidized electricity to tube well users, along with a protective cereal crop policy environment, encouraged the rapid expansion of tube wells and the subsequent over drafting of ground water resources.

Just as excess use of un-priced irrigation water can lead to rising water tables and salinization, it can also lead to falling water tables in tube well irrigated areas, with negative environmental and productivity consequences. The problem of over drafting of ground water occurs because individual pump irrigators have no incentive to optimize on long-run extraction rates, since water left in the ground can be captured by other irrigators and potential future irrigators. While mining of both renewable and non-renewable water resources can be an optimal economic strategy, it is clear that ground water over drafting is excessive in many intensive agricultural areas in Asia. In many parts of the North China Plain, for example, ground water levels are falling by as much as one meter per year, and heavy pumping in portions of the southern Indian state of Tamilnadu has been estimated to reduce water levels by as much as 25–30 meters in a decade (Postel, 1993).

Government intervention to prevent depletion of ground water in the developing world has proven difficult to implement, subject to corruption, and in many cases very costly (Pingali and Rosegrant, 1998). Global integration of food market and the consequent rationalization of domestic cereal crop policies could have a beneficial effect on ground water resource use, by improving the profitability of crops that are less water intensive

than rice. Moreover, the eventual removal or substantial reduction in electricity subsidy for tube well use could lead to substantial efficiency gains in ground water use and thereby contribute to the reversal in the declining trends in ground water levels.

Conclusions

Commercialization of agricultural systems is a universal phenomenon that is triggered by economic growth. While the rate at which the above transformation occurs varies by continent and by country within continents, the direction of change is the same across the world. Structural adjustment and trade liberalization policies that are currently being implemented in much of the developing world can be expected to further enhance the speed at which the commercialization process occurs.

Commercialization trends require a paradigm shift in agricultural policy formulation and research priority setting. The paradigm of staple food self-sufficiency that has been the cornerstone of agricultural policy in most developing countries becomes increasingly obsolete with economic growth. The relevant development paradigm for the twenty-first century is one of food self-reliance, where countries import a part of their food requirements in exchange for diverting resources out of subsistence production. Future emphasis of agricultural policy ought to be on maximizing rural household incomes rather than generating food surpluses.

Agricultural commercialization should not be expected to be a frictionless process, and significant equity and environmental consequences should be anticipated at least in the short to medium term, particularly when inappropriate policies are followed. On the other hand, even when appropriate policies are followed there would still be equity/distributional consequences, but at a relatively lower magnitude. The absorption of rural poor in the industrial and service sectors has significant costs in terms of learning new skills and family dislocations. Commercial systems could also face higher environmental and health costs, especially in terms of higher chemical input use. Appropriate government policies can alleviate many of the possible adverse transitional consequences arising from the process of commercialization and diversification. Long-term strategies to facilitate a smooth transition to commercialization include investment in rural markets, transportation, and communications infrastructure to facilitate integration of the rural economy; investment in crop improvement research to increase productivity and crop management and extension to increase farmer flexibility and reduce possible environmental problems from high-input use; and establishment of secure rights to land and water to reduce risks to farmers and to provide the incentives for investment in sustaining long-term productivity.

While agricultural commercialization can definitely be expected to have detrimental effects on the natural resource base, it ought to be recognized that it can also have significant positive benefits, especially in terms of encouraging more sustainable cereal production systems. The extent to which positive environmental effects manifest themselves depends on both macroeconomic and microeconomic policy reforms. The gradual dismantling of input subsidies and output support programs could provide

direct benefits to the sustainable management of the agricultural resource base. It would be inappropriate to make a categorical and universal judgement on the impact of agricultural commercialization on the environment, the net effect could vary on a case-by-case basis.

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