IV Challenges and Opportunities for Enhancing Agricultural Growth and Sustainability

In order to achieve sustained increase in agricultural productivity, a number of major challenges need to be addressed. They have been tackled in the past with some success, but the complexity of the issues involved requires that a much more coordinated effort be made than has previously been the case.

CHALLENGES

Population Growth , Poverty, and Environmental Degradation

The rates of annual population growth in Asia in the last two decades have been slightly higher than the world average, with South Asia showing the highest growth (Annex Table A1). Population growth tends to be high among the low-income and low-education groups and among those residing in remote areas, owing to the lack of access to family planning services. Although even the more populous Asian countries have been able to meet increased demands for food despite growing populations, the region is not free from hunger and malnutrition.

In poverty stricken areas, population increases tend to accelerate the short-term extraction of natural resources for sustenance. At low levels of income, natural resources are treated as consumer goods. Population increases also produce a large pool of labor that has a low opportunity cost. Together, these can trigger a vicious circle of poverty and environmental degradation. In countries where growth is stagnant or slow, these problems tend to become even more severe.

Poverty may have an impact on the environment in two ways. First, poverty influences the timing of consumption decisions, causing them to be biased to the short term. Second, poverty alleviation may have positive or negative impact on the environment, either directly or indirectly. In the first instance, poverty prevents people from taking a long-term view and from investing in benefits that are not immediately realized. In other words, poverty increases the discount rate and renders short-term gains more attractive. For example, poor farmers may overextract trees and convert them into charcoal for immediate cash and consumption needs, despite the fact that the same trees would yield a greater range of benefits over time. In the highlands, poor farmers can little afford to spend time in water and soil conservation because they have to meet their day-to-day need for food. A study of a labor-surplus economy in a semi-arid area of southern India indicated that farmers viewed water and soil conservation as an expensive and labor-intensive undertaking (Kerr and Sanghi, 1991, cited in Gill, 1995). The situation is often exacerbated by the lack of security in land use.

Population growth often increases poverty and causes migration in the search for new farm land. In a country where arable land is scarce, poor farmers are often associated with environmental degradation. A study in the PRC estimated that about 85 percent of the rural poor, or about 85 million people, reside in degraded areas (Yin Runsheng, 1997). Continued population growth places further pressure on the existing capacity of the land, forcing farmers to cultivate their crops in higher and steeper areas (Box IV.1). Often the poor reside in areas unfit for agricultural production. The challenge here is to

Box IV.1 The Traditional Knowledge of the Ifugaos

Traditional knowledge had led to sustainable agriculture in the past. Shifting cultivation, for example, permits the regeneration of the soil during the fallow period. The wet rice cultivation system is a closed system whereby the rice stalks and the manure from draft animals replenish the soil (Rattan, 1994). The amount of nutrients removed from the soil is negligible. However, this knowledge was developed at a time when the population was small and increased only slowly. Today, traditional knowledge is still applied but has been modified to meet increasing needs.

The Ifugaos of central Northern Luzon, Philippines, routinely manage complex cropping systems comprised of terraced rice, swidden, private woodlots, and communal grasslands. The cropping of rice is combined with fish culture, and with maize and tubers on the bunds. Swiddens are used to produce supplementary food crops such as maize, pulses, and tubers, and are left fallow for 7 to 8 years. Secondary forests on steeper slopes, where cash crops such as coffee and rattan can be grown among the *Dipterocarpus* species, are divided into plots for each family. A more distant forest is set aside for communal use; the use of resources is governed by community rules.

The Ifugaos have been able to augment their food supply to meet increasing needs while maintaining the long-term sustainability of their system. Annual soil loss from the woodlots and rice terraces is estimated at 0.2 t/ha, a rate that is considered very low. Erosion from swiddens is estimated at 10 t/ha per year.

Sources: Toribio and Orno (1995); Ticsay-Ruscoe (1995); Magliano and Librero (1998).

find sustainable agricultural production systems and nonagricultural strategies that would generate gainful employment and income for the rural poor.

It is widely recognized that poverty alleviation is imperative if sustainability is to be achieved. A number of policies and associated public expenditures have been directed towards poverty alleviation, with varying levels of success. Some poverty alleviation policies may have an impact on the environment or create an incentive system that works against the environment. A recent study in India (Fan, Hazell, and Thorat, 1998) showed that government spending on roads has had the biggest impact on rural poverty reduction, and that the impact of road construction is almost twice that of government spending on agricultural R&D. Education, rural development, and irrigation (in that order) also have positive but lesser impact on rural poverty reduction. However, spending on fertilizers and other subsidies was not taken into account in the study.

That roads are an important part of infrastructure and have the greatest impact on poverty reduction is not contested here. However, the environmental implications of expanding road networks should be noted. Poverty-stricken populations are sometimes located near biodiversity-rich areas and tend to depend on this common pool of resources for their livelihood. Lack of access is a common characteristic of both poverty and biodiversity. As access improves, the poverty situation tends to lessen because of better access to education, health services, and income-generating opportunities. Biodiversity, however, tends to deteriorate owing to the commercial-scale activities that are made possible with improved access to such areas. Precautionary measures to protect biodiversity and to support local institutions that conserve local biodiversity are necessary if road infrastructure policies are to become truly win-win solutions. Granting use and protection rights to local communities is one management option that could improve the situation for both communities and biodiversity conservation.

Often agricultural policy is used to alleviate poverty in rural areas. In the name of helping the poor, subsidies on inputs such as credit, seeds, chemicals, electricity, fuels, and water are offered indiscriminately to all farmers. This results in wasteful use of resources, increased budget burdens, and, in many instances, increased debts for farmers. All of this leads to environmental degradation, e.g. from the overuse of chemicals, the overpumping of groundwater, etc. In addition, governments may guarantee output prices and protect crops against imported substitutes. Subsidies and price distortions resulting from the aforementioned policies also provide confusing signals concerning technical change, and hinder the adoption of technologies that are more resource saving and environmentally more benign. Under the guise of poverty reduction, governments have revoked prohibitions on trawling and pushnetting, allowed fishing in protected areas, and given marginal lands in fragile ecosystems to the landless. It is not surprising that in the end, the poor are often seen as the culprits of unsustainable production and environmental degradation.

It is argued here that the above policies, which are, in fact, lose-lose policies, arise because poverty is often defined too narrowly as an inadequacy of material wealth. While this is true, it does not completely encompass the concept of poverty, which ought to include social and political characteristics such as the lack of access and rights to land and common resources, vulnerability, social insecurity, dependency, and a lack of choice. Only when the definition of poverty is viewed in its broader sense can one understand why a policy of government handouts often fails both to alleviate poverty and to promote sustainable production. The poor need not simply credit, material inputs, and one technology that fits all; they also need rights, access, the ability and opportunity to make choices, knowledge and understanding of local conditions, and technology fit for local use. These needs are extremely difficult to meet under the existing centralized, top-down bureaucracy that typically characterizes so many agricultural agencies in Asia.

Another challenge related to poverty and agricultural sustainability is that although the capacity now exists in Asia to produce more than enough food to feed its population, increased production will only occur when there are reasonable profit margins. As the cost of production rises because of greater competition for resources and environmental degradation, the price of food, especially rice, may also rise. Should food prices be allowed to increase in order to provide an impetus for increased food production, the means must be found to protect the nutritional standards of the poor, especially those employed outside the agricultural sector.

Less Favorable Environments and Fragile Ecosystems

Population growth in Asia has placed and will continue to place immense pressure on land, leading to agricultural intensification in less suitable areas, and to the opening up of new lands and the clearing of forests for cultivation. This means encroaching on natural forests, intensifying agriculture in less favorable environments (LFEs) and fragile ecosystems, or shortening fallow periods in shifting cultivation.

Less favorable environments are characterized by less than optimal growing conditions, e.g. areas where precipitation is low and unreliable, where the growing season is short, where soils are poor, and where topsoil is depleted. LFEs can occur naturally or result from the mismanagement of fragile ecosystems. The term "fragile ecosystem" is also often used to define areas or characteristics of sites that are "too dry, too steep, or lacking in nutrients" (WCED, 1987). The more recent literature tends to stress the relationships between society and nature rather than biophysical characteristics–a dynamic rather than a static interaction–and the mismatch between human uses and system capacity (Turner II and Benjamin, 1994). Fragile land has been defined in terms of two properties: environmental sensitivity and resilience. Truly fragile ecosystems are those that are "highly susceptible to biophysical deterioration and do not really recover" (Turner II and Benjamin, 1994, p.113). For the purpose of this study, those ecosystems where productivity deteriorates rapidly and that are costly to restore are called fragile ecosystems. Degradation also causes negative externalities that cannot be compensated for by gains from the change in land use.

Asia 's uplands are covered by relatively less fertile acidic soils that are highly erosive. In Southeast Asia alone, approximately 188 million ha or 39 percent of the total land area is acidic upland. In Lao PDR, this proportion reaches 66 percent (Garrity and Agustin, 1995). Population pressure on these uplands has considerably shortened fallow periods and accelerated environmental degradation.

In the PRC, fragile lands are common in four areas, the Loess Plateau in Shanxi, Shaanxi, and Gansu provinces, the red soils areas, the northeastern plain, and the northwestern grasslands. Together, they account for 70 percent of the PRC's land area (Rozelle, Huang, and Zhang, 1997). These areas are partly but not entirely fragile and degraded. Some parts have been cultivated continuously since ancient times.

Many factors contribute to encroachment on or the inappropriate use of fragile lands, ranging from national policies (e.g. on migration, Box IV.2) to sectoral policies, such as the replacement of narcotic crops. Other factors include commercialization, natural population increases, land speculation, and attempts to increase the productivity of fragile land.

The isolation of some of the highlands in the montane regions of Southeast Asia, for example, provides natural protection for illegal crops, especially opium. Although opium is a traditional crop that is used as a medicine among the hill tribes, the commercialization of opium in the "golden triangle" was driven by the fact that opium is also a narcotic and is banned in most countries. The replacement of opium by other, higher-value crops, mainly through horticulture, creates second-generation problems. The agricultural intensification that horticultural crops require is made possible by huge subsidies from governments and international agencies. Some of the crops have spread beyond project areas (where soil and water conservation are part of the technology package), to the hills and mountains where there is inadequate soil and water conservation (Kanok et al., 1989, 1994).

The degree of soil erosion from steep farmland depends on the type of crop being grown, the agricultural practices used,

Box IV.2 Exodus into Fragile Land

Most of the development literature has emphasized rural to urban migration, but in the case of fragile land the reverse is often true. Population pressures in fragile lands often stem from a migration of the mainstream population from relatively dense population centers into indigenous and sparsely populated communities. For example, in the PRC's Xinjiang Uygur Autonomous Region, the exodus of mainstream Han Chinese increased the Han population from 291,000 in 1949 to 2.1 million in 1962, and finally to over 5 million by 1990. In the Ardos Plateau of inner Mongolia, the Han population contributed to a 225-percent increase in population over two decades in response to the Government's policy of regional development and land-use intensification.

In Viet Nam, 5 million Kinh, the main ethnic group, have moved from the lowlands to the central areas of the highlands during the last 30 years, and the rate of migration has accelerated since 1980 (Sam, 1994). Migration into the highlands of Chiang Mai, Thailand, is estimated at 12 percent per year (Kanok et al., 1994), leading to intense competition for water resources between highland and lowland farmers.

amount of precipitation, and topography. Annual losses range from less than 2 t/ha if conservation is practiced, as in the case of northern Thailand, to about 100 t/ha for grazing land in Nepal and in the uplands of the Philippines (Shah, 1997).

Inappropriate agricultural intensification can do great harm to LFEs. For example, the conversion of low-productivity grazing land to higher-productivity cropland is sometimes a self-defeating course of action. Grazing lands generally have few soil nutrients and are in areas of low and unreliable rainfall. The loss or decline in land productivity arising from the conversion of grazing land to cropland sometimes occurs because such conversions decrease the amount of land available for grazing, which results in overgrazing in the remaining rangeland. Moreover, the best grazing land with relatively high carrying capacity tends to be the first to be converted into cropland. The conversion is not always successful either, because of poor planning and execution, e.g. irrigated areas tend to be prone to salinization.

In addition, the damage from failed conversions is often difficult to correct. The Ardos Plateau represents one such failure. For centuries, this Plateau, a semi-arid to arid windy plain in inner Mongolia, supported a grazing economy. During the Great Leap Forward and the Cultural Revolution, attempts were made to intensify agriculture without any consideration being given to land conservation. This led to desertification in much of the region, and allowed dune mobilization to double between 1957 and 1977 (Huang et al., in press, cited in Turner II and Benjamin, 1994, p.125). Other disastrous consequences included catastrophic flooding and the transportation of sand from the Plateau, which accounts for 10 percent of the sediments in the Huang He (Yellow) River. Since the late 1970s, degraded cropland in the Ardos Plateau has reverted to pasture and forest or is under rehabilitation.

The issue here is that fragile ecosystems must be treated as a special category in agricultural development. Normal or conventional agricultural technology is not suitable for fragile ecosystems; neither are they suited to agricultural intensification. Yet economically viable technology, which must be particularly concerned with the environment, must be developed for fragile ecosystems to benefit those with no alternative employment residing in such areas. Moreover, a package of policies will have to be introduced to control population growth, to increase education opportunities and therefore increase future employment options, to generate nonfarm employment, and to encourage more environmentally friendly agriculture. Efforts to improve technology for fragile ecosystems have been made by ICRAF and some national governments, but more has to be done to keep pace with the degradation that is currently undermining system sustainability. In fact, agricultural policies and instruments alone will never be adequate for the achievement of agricultural sustainability. Community efforts may be needed for this purpose also.

The green-revolution technology package that is now a common management practice in the resource-rich or favorable environments is not suitable for fragile ecosystems. Neither is it applicable in LFEs. New technologies will have to be designed to help LFEs enhance agricultural productivity in a sustainable manner. There have been a few success stories in LFEs, however, demonstrating that even in these areas productive and sustainable crop management is possible. These successes also show that there is no one single solution that is widely applicable to LFEs, given the wide variety of problems afflicting them. This is in marked contrast to the favorable areas, whose similarities enabled the widespread application of the improved seed, fertilizer, and irrigation package of the green revolution.

To improve crop production in LFEs, institutional and social solutions often must accompany or precede technical solutions if the benefits from the latter are to be realized. An RD&E system capable of unlocking local potential and responding to specific local constraints is absolutely essential. Public investment in RD&E for LFEs is unlikely to generate the same rate of direct returns from crop production as that realized from RD&E for favorable environments. However, this investment could have other, more indirect, benefits, such as poverty alleviation; prevention of resource-base degradation due to salinization, erosion or desertification; and the slowing of deforestation.

Environment and Trade Issues

Debates on the relationship between trade and the environment have continued for several decades. Environmental groups tend to regard trade as a catalyst of environmental degradation. Insatiable demand of the affluent North, combined with the profit maximization objectives of traders in the South, has led to the unhindered depletion of natural resources and to environmental degradation.

Proponents of trade have argued that blaming trade for environmental problems is inappropriate. Apart from transportation activities related to trade, trade does not itself create environmental problems. Environmental problems occur mostly during production and consumption, and appropriate policy interventions need to be designed to tackle problems at the source. When carefully analyzed, however, domestic trade and environmental policies are often found to bear the responsibility for environmental problems (Box IV.3).

Contrasting with the fears of environmentalists that trade liberalization would spur more agricultural expansion into tropical forests, a simulation model of complete trade liberalization and instantaneous adjustments showed that the impact from production relocation on total food output would be quite small, amounting to a 3–8 percent increase in developing countries and 5–6 percent decline in output in developed countries (Anderson, 1998). A substantial production increase would come from North America and Australasia. In North America, where land has already been cleared, such trade policy reform would also shift livestock production from areas concentrated in industrial-type production to land-intensive systems that are less chemically intensive. The shift is likely to be from densely populated to more sparsely populated areas, resulting in a net decline in degradation. As long as proper environmental policies are implemented, countries can offset their marginal cost of degradation.

Continued attempts by those wanting to protect the environment are being made both at the international and national level to curb trade practices related to natural resource extraction, and to institute national and international governance regulating trade related to natural resources. At the international level, the General Agreement on Tariffs and Trade (GATT, now the World Trade Organization) rules are considered a major obstacle to efforts to strengthen the international governance of the environment. Despite the fact that trade is perceived by environmentalists as evil, the power of trade sanctions as an effective tool to force countries to behave in an environmentally friendly manner is well recognized. Even

Box IV.3 Thailand's Cassava Export: Bad Policies not Bad Trade

Thailand's cassava trade is often used as an example of an industry that endangers the environment because cassavas are mostly grown in the recently deforested plateau of northeastern Thailand. As a tuber, the cassava is thought to deplete the soil of more nutrients than do most other cash crops grown in Thailand. In the 1970s and early 1980s, loopholes in the tariff system of the European Community (EC) rendered the combination of cassava products with soybean the cheapest livestock feed in the EC. As a result, the EC has become Thailand's major market for cassava products. The cassava trade is now perceived as having mined the country's resources for chicken feed. The feed-grain trade is also perceived as trading in environmental impact, involving a massive transfer of nutrients and often polluting the location of final use.

The deforestation in northeastern Thailand was the result of a mix of concessional logging, clearing of forestland to suppress communist insurgents, and a lack of enforcement of forestry laws. Once the forests were cleared, subsistence farmers moved in to eke out a living. Since the deforested land was considered public land, these farmers were denied ownership. Insecure ownership prevented them from making any long-term investment in the land, and encouraged extensive cultivation with a minimum of capital investment.

The cassava is regarded as a poor man's crop. It is hardy and can be grown even on poor soil. It is resistant to both drought and insects. Little investment in seeds or chemicals is required to grow cassava. This makes the cassava an appropriate choice of crop for the farmers in the northeast, who still remain among the poorest farmers in Thailand.

Thailand has a relative abundance of fertile land, but since cassava will grow even on poor land, the country's comparative advantage in the production and export of cassava pellets is the result of a good transportation network linking the fields

(continued next page)

Box IV.3 continued

to the factories and the factories to the shipping ports, not the result of mining soil fertility to produce cassava. Owing to the special circumstances created by the tariff system in the EC, Thailand enjoyed for some time a lucrative market, offering prices three times higher than elsewhere. It would not have been wise for Thailand to restrict its exports of cassava pellets, but the Thai Government could have done more by investing the excess profits from the cassava trade in replenishing the natural capital stock, in this case soils, or in other sustainable development.

Source: Ammar (1989).

environmentalists want to use trade sanctions as punishment for those countries lacking appropriate care and conservation measures. Trade proponents, however, are doubtful as to how trade sanctions, which are themselves welfare-reducing measures, will be able to lift the level of global welfare through environmental protection.

Over the years, numerous multilateral environmental agreements (MEAs) have been formulated to help protect and conserve the environment. A few of these MEAs have clauses restricting trade. Environmentalists are concerned that GATT Article 20, which allows members to use trade sanctions, is too narrowly interpreted to allow it to protect the environment, and it could neutralize the effectiveness of the MEAs. This issue is not discussed further here as it is only remotely related to rural Asia. However, attempts at the national level to protect the environment by strengthening domestic regulations related to trade have been prevented on the grounds that they would conflict with GATT rules. Actions preempted include high import levies on tropical wood in Austria, the revenues from which would go to a tropical forest conservation fund, and the

Netherlands Government initiative to limit lumber imports only to those countries that manage their forests sustainably. The most cited conflict is GATT's Panel of Judges' rule against a US ban on imports of tuna from Mexico on the grounds that the tuna were acquired by means (purse seine nets) that are dangerous to dolphins. More recently, the World trade Organization also ruled against a US ban on imports of shrimps from Thailand on the grounds that the shrimp harvesting methods employed could harm sea turtles. On both accounts, the US action was considered an attempt to impose standards on production processes. Under the agreement from the Uruguay Round, restrictions on standards for production methods are not allowed unless the production process in question affects product characteristics.

At times the US also uses trade restrictions against products to fulfill environmental objectives that are not directly related to the banned product itself. For example, in 1994 the United States banned imports in five product categories, including shoes and bags made from reptile skins; decorations made from coral, seashells, and animal bones; frog legs for human consumption; and goldfish and other tropical decorative fishes and feathers. This measure was a response to the use of tiger bones and rhinoceros horns in medicine in Taipei,China.

Phytosanitation control and technical harmonization are often imposed by the importing countries in order to protect consumers and to control pests and diseases. Agreement on the application of sanitary and phytosanitary measures in the Uruguay Round Final Act allows members to apply their own control on imports provided that the control is in accordance with international standards or is justified scientifically. The EC in particular is more stringent with phytosanitary controls and technical harmonization for agricultural commodities. For agricultural products, standards for residues are set in order to protect EC consumers. Certification is required for feed grains and other horticultural products to ensure that the commodities are disease and pest free. Veterinary controls are required for poultry. Moreover, exporters of fish products to the EC have to be from approved zones. These requirements pose important challenges to developing countries in Asia, which will have to upgrade their production processes to meet international standards. In the case of fisheries, these requirements will pose important constraints on rural poor in the coastal zones who earn their living from the preliminary processing of fishery products.

The above discussion indicates that for exporters of agricultural products, natural resource and environmental management as well as phytosanitation control will be increasingly important. Pre- and postharvest technologies for phytosanitation control will need to be developed and disseminated to small-scale operators including fishers. Governments will also have to pay more attention to conservation practices, especially in export-oriented sectors.

Recent international trade developments indicate a tendency towards lowering of tariff barriers, but increasing restrictions on environmental and health matters. The direction of change is much more predictable in EC countries and Japan than in the US. Exporters from developing countries will have little choice but to improve their domestic standards to meet market demand. For this purpose, improved facilities for landing and postharvest technology may be needed, for example, to assist small-scale fishers. At the same time, developing countries may want to investigate policy and institutional reforms that would help strengthen conservation and improve health conditions, and which could lead to a win-win solution, i.e. increasing export income while improving the local environment and health conditions in the importing countries.

OPPORTUNITIES

In discussing opportunities, two points need to be noted from the outset. First, in a highly competitive world, new opportunities are constantly being sought and pursued. New opportunities are often thought of as new ideas and new methods that will improve current situations. This way of thinking may be appropriate for the profit-maximizing private sector, in which inefficient firms or firms that repeat old mistakes are weeded out through competition. However, for the public sector the greatest opportunity is to learn from and to correct past mistakes. In attempting to achieve sustainable development, the opportunities are choices to not allow resource degradation to worsen, to avoid the wasteful use of public funds, to make policy reforms, and to invest in economically and socially high-yielding projects.

Second, improvements in agriculture tend to be automatically market driven. The public sector and international lending agencies are not able to identify commercially rewarding projects before the private sector does. Nor is this the role for the public sector. The role of the public sector is to set up fair rules for the game, seek opportunities for the small operator, and ensure that no one is left behind.

The focus here is on three issues. First, given the current resource and technology situation, what are the opportunities and sources for increasing food supply, or is there any scope for future growth at all? Second, will biotechnology and the so-called alternative agriculture be able to contribute to sustained agricultural growth? Third, who are the likely beneficiaries and losers from biotechnology?

Scope for Future Growth

Future agricultural growth in the current high-growth areas will depend on a sustained input of new plant varieties that will continue to break existing yield barriers. For rice, a new plant type is being developed by IRRI. It is expected to embody improved disease and pest resistance while increasing the yield potential by 25 percent and also improving grain quality. Another expected breakthrough is the development of apomixis (the capacity to set grain without sexual fertilization) in tropical hybrid rice, which will further reduce the cost of hybrid seed. Together, these would increase the yield potential by 50 percent. One current weakness in the new plant type is its inability to fill all of the grains fully, although it is expected that this will soon be overcome. The new plant variety is expected to be supplied to national breeding programs for field tests by 2000.

For wheat, despite continual and strong yield growth, several new innovations are in the offing. CIMMYT is working on a hybrid wheat variety that would break the yield barrier of existing varieties by means of improvements in chemical hybridizing agents, biotechnology, and a new plant type (Pingali and Rajaram, 1998). Elsewhere, wide crosses are being conducted between elite varieties and wild relatives to produce a "synthetic" wheat that can transfer desirable traits more easily.

For maize, highly favorable areas are likely to benefit from R&D by private enterprises. In the PRC, scientists are confident that the present 10 percent gain in yield potential of successive generations of hybrids will continue into the next decade.

In the shorter term, yield improvements can be realized by closing the yield gap that exists between experimental and actual yields. Even in the PRC, where actual yields are high, the gap between experimental yields and farmers' yields can be as high as 9 t / ha for rice and 11.5 t / ha for maize (Lin, 1998a). Closing this yield gap would require sustained investment in agricultural research, in the maintenance of soil fertility, irrigation systems, and strengthening the technological extension system. Appropriate incentives for farmers to adopt the new technology and maintain soil fertility levels would also need to be provided. Improving incentives for farmers in the PRC would also mean liberalizing grain prices such that the production of grain would again be a profitable enterprise.

Apart from further increasing the growth potential of the HYVs, opportunities exist for improving yields in LFEs. Although the early MVs were bred for use in favorable environments, later generations of MVs for LFEs have been bred by many national breeding programs. The yield potential of these MVs is more modest but they are hardier or better adapted to LFEs, e.g. deepwater or saline soils. Suitable varieties for flood-prone areas and acid sulfate soils in the lower deltas of Cambodia and Viet Nam will improve yields in these areas. Yield potential remains to be tapped in Viet Nam, Pakistan, and Lao PDR.

Other crops such as oilseeds, roots, fibers, and tobacco have also benefited from modern plant breeding techniques. The All India Coordinated Research Project released during 1982 to 1995 about 50 varieties of soybeans suited to specific locations. This has made possible an expansion of almost 5 million ha in soybean cultivation area, especially in the locations with the least irrigation. In Thailand, drought-affected areas have benefited from R&D on open-pollinated maize and cassava varieties by a local university.

The above opportunities are related to genetic improvement. Scope also exists for increased output in less intensive agriculture. More than half of Asia's riceland produces less than 3 t/ha. The potential exists for increasing this output through the use of better crop management, prudent water resource management, market and trade liberalization, and simply from an increase in price and profitability.

In Viet Nam, an additional 1.0 to 1.5 million ha could be brought into cultivation (20 percent of the current area). About 200,000 ha of land in the Mekong Delta could be converted from single cropping to double or even to triple cropping, if water drainage and salinity controls can be provided in order to reduce inundation in the wet season and water shortages from February to May (Mie Xie, 1995).

Enormous potential for an increase in food production exists in Myanmar where labor, uncultivated land, and water are abundant. This potential has so far been constrained by government policies. In Myanmar, agriculture remains centrally controlled and exports of rice are monopolized. The State provides directives for land use and designates areas for rice production, the timing of planting, and cropping intensities, but with little recognition of local conditions and potential. In addition, a quota below market prices for State purchases is specified for rice farming. Although rice outputs have increased under government direction, yields have been stagnant and export targets have not been met. Viet Nam, however, has been able to feed its large population while also becoming one of the world's major exporters. Its population is 1.6 times that of Myanmar while its arable land is only about 60 percent that of Myanmar.

At present, Thailand, which is currently the world's largest rice exporter, still produces an average rice yield below 3 t/ha. This is because Thailand has, from the very beginning, opted to improve the yields of local varieties that have a better eating quality rather than to adopt the HYVs directly. There is therefore enormous capacity for that country to increase its output, should the prices for or the margins from HYVs be high enough. In Indonesia, additional land for food production could be found on islands other than Java, including southern Irian Jaya.

Investment in R&D for the alleviation of onsite effects can be rewarding. The effective alleviation of salinization, largely by draining the soil with tube-well pumping and installation of drainage facilities, has allowed large tracts of salt-affected areas, especially in India and Pakistan, to reap the benefits of the green revolution. The Salinity Control and Reclamation Project in Pakistan has succeeded in increasing the area free of surface salinity from 49 to 74 percent, decreasing the area with severe waterlogging from 16 to 6 percent, and, by using pumped water for dry-season irrigation, increasing cropping intensity from 84 percent to 117 percent. The gross value of crop production increased by 94 percent in an area of 2.3 million ha (International Commission of Irrigation and Drainage, 1991).

There is also great potential for increased production of poultry and pork in peri-urban areas and aquaculture for high-income markets, but market forces have already provided the impetus in these areas. The role of the public sector in these areas should be to ensure that the external consequences of these industries are internalized and pollution is kept under control. The possibility also exists for combining bovines (cattle and buffaloes) with perennial tree crops such as coconut, oil palm, and rubber. A study in the 1970s indicated that if half the areas devoted to tree crops could be integrated with livestock, no new land would be required for an increase in livestock population of 25 percent (Payne, 1976, cited by Reynolds, 1995).

For fisheries, it is estimated that an increase of 20 million t in annual global fish production would be possible, if degraded resources were rehabilitated. FAO (1997c) indicated that an increase of about 16.1 million t may be possible in the Indian Ocean alone. Tuna fisheries in the Indian Ocean and the western central Pacific (South and Southeast Asia) also hold promise for higher production, particularly of skipjack and yellowfin tuna, but probably also of swordfish (Majkowski, in FAO, 1997b). There is also room for expansion in the western Indian Ocean, where newly recognized resources are available, such as the mesopelagics (e.g. lanternfish), whose global biomass is estimated at around one billion t (Pauly et al., 1998). In the western Indian Ocean, the estimates of lanternfish stocks vary from 1.7 to 20 million t, and after a long period of expectancy, commercial fishing for these species finally started there in 1996 (Shotton, in FAO, 1997b).

For inland fisheries, an increase in global production of no less than 5 million t in the next decade is considered possible. Freshwater aquaculture holds the greatest promise. The explosive growth of carp and tilapia farming implies that more growth potential can be tapped because genetically improved strains are emerging. Moreover, tilapia is also exportable, with markets already existing in the United States, Europe, and Japan. Currently, Taipei,China is the largest exporter, contributing around 156,000 t / year live weight (ICLARM, 1998). With more research and development effort, not only in pure science but also in processing and marketing, markets for freshwater aquaculture products can be expanded significantly. The expansion of aquaculture production from subsistence levels to commercial production for higher-income markets also requires the transfer of improved farm-level management and agribusiness practices. Small-niche and very-high-income markets also exist for low-input aquaculture, such as of high-value abalone and clams for east Asian markets.

Agro-based Industries

Most discussion on the sustainable development of agriculture has neglected the role of agro-based industries, despite the fact that their development could drastically affect long-term production and crop mix, as well as institutional arrangements with farmers. In addition, biotechnological innovations and new product developments could alter input requirements substantially. To date, there have been few studies on agro-based industries, except for activities that include primary processing and canning, which tend to generate relatively little added value in Asia. Secondary and higher-level processing tends to produce more added value. In Europe, the US, and Australia, primary and secondary processing can create products with high added value, for example wines, brandy, and distilled spirits. Such opportunities have not been sufficiently explored in Asia, although the region has a multitude of fruits, flowers, and herbs.

Ago-based industries also offer opportunities for field crops. Cassava roots, for example, are mostly used to produce animal feed in the form of pellets. Cassava can also be used to produce native starch from which a broad range of products can be made. One such possibility is to modify the characteristics of the native starch for use as an industrial starch that replaces potato, corn, and mung bean starch, etc. There are more than a hundred possible types of modified starch uses, such as filling and binding agents in paper, textiles, food, and adhesives. Another method is to convert the starch into various types of sweetener such as glucose, high fructose syrup, and also sorbitol, which is used in the cosmetics industry. Through fermentation, cassava can be used to produce monosodium glutamate, a widely used ingredient for seasoning, and lysine, an amino acid required in the production of animal feed. Cassava starch can be used to produce ethanol, and is also used to produce easily degradable plastics and environmentally friendly substitutes for plastic foam.

Similar opportunities may exist for other crops. For example, rice is used in the production of some beer in the US. After many refining processes, castor oil can be used as a lubricant for jet planes, etc. To date, these opportunities have been limited by the lack of knowledge of technological possibilities and sources. In addition, some food crops have become politicized, and price support policies and programs have made these crops unattractive as industrial inputs, because in order for this to occur prices need to be predictable and competitive and not determined by unpredictable political factors.

If the above opportunities are many in number, the next question is why they are not being taken up in Asia. The answer is twofold. First, the processing technology for many tropical raw materials other than food crops is not readily available in the international market. Second, government interventions related to some of the crops have become obstacles to increasing the number of value-added opportunities.

To understand the constraints placed on the development of agro-based industries, it is useful to classify agro-based industries into three types. The first relates to the processing of traditional raw materials that are internationally traded, for example the milling of rice and sugar. Technology is not a constraint because the production volume of these commodities is large enough and there are international technology markets in existence. The constraint is government interventions that attempt to increase prices above those of international markets, making it difficult for local industries to be competitive.

In addition, the government may also protect local growers by banning imports. This type of constraint is particularly severe when the commodity is a politically sensitive good, such as rice. Conversely, the government may be too eager to promote local processing and grant monopoly licenses. One example of this is castor oil production in Thailand, where imports of castor seeds were banned and licenses for primary processing were given to only one producer. No independent investors would want to invest in downstream industries where there is only one monopoly supplier. A reduction in government intervention is an effective way of promoting these types of industries.

The second type of agro-based industry includes those using raw materials that are tropical or local in origin, for example cassava and tropical fruits and vegetables. For these raw materials, there are no existing technology markets. The adaptation of existing technology to suit particular properties of local raw material is necessary. Science and technology for these industries will have to be developed locally. The public sector has a role to play in providing incentives and support for research, the dissemination of information about local inputs, and preliminary technology assessments, the output of which can be shared with interested investors for further feasibility studies.

The third type of agro-based industry is that connected with large-scale plantations introduced by processing industries. In this case, a system for the production of raw material specific to the industry has to be established or arranged. In contrast to the first type, the industrial processing methods determine the inputs produced. Examples are the production of palm oil, tuna canning, and pineapple juice. Investors are characteristically large enterprises or multinational corporations needing to organize the production of input on a much larger scale than found in the traditional methods of production. Although processing technologies like canning can be simple, substantial investment in advertising and marketing networks is required. In the past, most governments tended to favor this type of investment and to offer more incentives than required, despite the fact that investors in these industries are the most powerful of all. At the same time, governments have neglected actions needed to strengthen the industries in the first two groups.

When large-scale processing plants do not establish their own plantations or farms and have to rely on farmers as subcontractors, appropriate institutional arrangements to obtain reliable supplies of the appropriate quality are imperative. However, dealing with thousands of farmers is no easy task. Often, failures occur in factories where managers are unable or neglect to manage farmer subcontractors. In some cases, the government is also required to oversee the "fairness" of contractual arrangements or dispute settlements, e.g. in sugar and tobacco.

Apart from large-scale processing, niche opportunities also abound for small crops such as herbs, pot plants, natural dyestuffs, and various types of health food and organic products. Within Asia, high-income markets exist for exotic meats, foods, beverages, and food supplements such as marine eels, venison, and ginseng. In Thailand, women's groups from rural communities have been successful in placing organic cosmetic products, preserved foods, and chemical-free textiles and fabrics in supermarkets in large cities. In these areas, the role of the government is to help small entrepreneurs with phytosanitary regulations, packaging technology, and international marketing expertise in order to upgrade their operations so that they can compete in international markets.

Biotechnology

Biotechnology is widely believed to be the driving force that will provide the next major increases in agricultural productivity. It is also expected to help lessen some of the adverse impact of agriculture on the environment, especially that caused by pesticide pollution.

In reviewing the biotechnology products that have come to market, or are likely to do so in the short to medium term (5–10 years), there are none so far that are likely to increase potential crop productivity on the scale of the green revolution. Apomixis, as indicated earlier, is a possible biotechnological tool now under study at some of the international research centers. If it can be successfully transferred to major crops like rice and wheat, yields could increase by 20–30 percent through heterosis. The real impact of apomixis would be to reduce the cost of hybrid rice and wheat seed.

Benefits from biotechnology are already evident in the lessening of impact from crop production on the environment, in decreasing pollution, and in increasing the efficiency of pesticide use. Herbicide resistance created by biotechnology is expected to lessen the impact from herbicides by decreasing the amounts used as well as making it possible to use chemicals with milder effects on the environment. The use of pest-, disease-, and herbicide-resistant varieties is also expected to decrease production costs by reducing the cost of pest control as well as preventing yield losses.

Resistance created by biotechnology will, however, be just as prone to breaking down as resistance created by conventional breeding, as happened in rice with resistance to the brown planthopper and in wheat with rust pathogens. A number of insects have already been identified in the US as resistant to the Bt toxins (greater detail is provided in a companion volume, Ammar (1999)), which are produced by new crop varieties that have had genes inserted from the bacteria *Bacillus thuringiensis* (Bt).

The application of biotechnology to crop production has so far concentrated on crop protection, i.e. from insect pests, pathogens, and herbicides. These have involved the transfer of various resistance and tolerance mechanisms, mainly from bacteria, into plants by employing recombinant DNA technology. Although they originated in the US, many of these new crop varieties (of maize, cotton, soybean, etc.) are already being adapted to and / or field-tested in Asia through the private R&D system of multinational agribusiness companies, often in close collaboration with national (public) agricultural research systems. Commercialization is, however, being held back by the fear that it would be difficult to stop farmers from keeping some seed for their own use in subsequent years or even selling it to others. In order to overcome this, a new system in which the second generation of seed is aborted, is now being explored in the seed industry. The system, termed “terminator technology” by NGOs, will enable farmers to produce grain for sale from the seed but make it impossible for them to use some of the harvest for seed for the next season.

Commercial interests dominate agricultural biotechnology R&D. Internationally, these are represented by a small number of multinational companies. Even in developing countries such as India with the strength to develop biotechnology programs, research emphasis is often placed on export crops, and not on the basic staples of rice and wheat. There is a concern that this will make developing countries increasingly dependent on industrialized countries for inputs (Hobbelink, 1991, cited in WRI, 1994, p. 6).

More significant, however, is the potential for biotechnology to contribute to the widening of the gap between the rich and the poor. This technology, as well as the science that supported the green revolution, was the result of publicly funded R&D; benefits from technology transfers to countries in Asia were basically free of charge. The green revolution, therefore, helped to close the gap between the rich and the poor to a significant extent. Even then, many have been critical of the green revolution by claiming that it bypassed many who live in LFEs. Biotechnology will leave even more people behind. Some countries simply cannot afford the heavy investment that biotechnology requires. In some areas and crops, rice and wheat among them, the profit incentives will not be sufficiently attractive to private investors. The Indian seed industry, which is currently aggressively driving the diffusion of hybrid maize in India, has so far stayed out of Rajasthan, Uttar Pradesh, and Madhya Pradesh, where maize is grown as a food crop with a very low input level (Morris, Singh, and Pal, 1998). Even in the US, private R&D on self-fertilized crops, such as wheat and soybean, is relatively limited, especially following the enactment of the Plant Breeder's Protection legislation with the "farmer's exemption" clause (i.e. enabling farmers to keep seed for their own use).

Countries without biotechnology capacity will increasingly see their traditional exports displaced by substitutes derived from biotechnology. For example, rapeseed plants with more than 35 percent laurate in their oil have been produced by Laurical (Calgene, LLC), and are now marketed in the US. The new plants are expected to provide a cheaper alternative to coconut and palm kernel oil. Such losses in competitive advantage will take place not only between developed and developing countries, but also between developing countries with strong biotechnology capacity and those without.

Theoretically, the adverse effect of such displacements on the loser should be temporary only. Adjustments would occur over the long term. However, it would seem that those countries with a limited biotechnology capacity would find themselves with increasingly limited options in making adjustments.

Several international initiatives have been mounted in order to share the benefits of biotechnology with developing countries. For example, the Rockefeller Foundation's Rice Biotechnology Network started in 1985, with the aim of improving the biotechnology capacity of developing countries, mainly in Asia. There is also increasing collaboration between private and public sector R&D. IRRI, for example, is cooperating with two private companies in its attempt to transfer the Bt gene into rice. In one case, IRRI paid a fee to Plantech of Japan to use its Bt gene for research purposes and has the option to buy the gene outright. Another case involves a Bt gene that has been provided free of charge to IRRI by Ciba-Geigy of Switzerland. Bt rice from IRRI will be made freely available throughout the developing world, but not to Australia, Canada, Japan, New Zealand, the US, and members of the European Patent Convention.

In addition to its potential impact on crop production, biotechnology is also causing major changes in the organization of agricultural R&D. Innovations in biotechnology and its related and new discipline of genomics (the molecular characterization of species) has forced a broadening of the scope of plant science R&D.

In conclusion, biotechnology definitely holds many opportunities for the private sector. For the public sector, it offers great opportunities in facilitating R&D. Incentives for biotechnology production in the private sector will have to come from temporary monopoly, as granted by patents or plant breeders' rights laws. Thus, governments must ensure that small farmers will not be in the position where they become locked into a no-option situation.