MANAGING COMMITTEE ERS/MC 82

(4)

ERS/MC 82

CHAPTER 5

Chapter 4 Environment, innovation, and investment

Ever since mankind found out how to cultivate plants ten-thousand years ago, a great variety of farming systems have been evolved in delicate balance with the environment. Crop and cropping systems have been gradually refined to overcome some of the constraints of soils and climate. As a result, the productivity of land has increased, and virgin areas have been settled. Irrigation, flood control, and other land improvements have helped surmount other environmental constraints. The switch from hoe to plow cultivation and comparable technological innovations have increased labor productivity and enabled a man to sow and harvest an ever larger area. And the age-old search continues for the best ways of raising agricultural output -- by opening up new land, by investment, and by innovation.

4.1. The patterns of development were and still are shaped by factors like:

- climate and soils
- relative scarcities of land and labor
- the stock of scientific knowledge
- availability of inputs and investment resources
- access to markets.

4.2. In most developing countries progress up to the 1950s was slow and uneven barely keeping pace with population growth. Although the expansion of agricultural trade had a profound impact in some tropical areas, food crops were generally neglected during the colonial period. Research focused on export crops and, with the main exception of irrigation in the Indian subcontinent, little any investment was made to support smallholder agriculture.

4.3. In comparison progress has been rapid in the last two decades, and spectacular successes have been experienced in some developing countries. Hundreds of millions of farmers, from small peasants in Kenya to members of production work-teams in China, have transformed their cultivation practices in response to a combination of incentive and opportunity. The incentive came from access to expanding markets for food and a wide range of other agricultural products. Opportunity came from variety of sources -- extra land to cultivate in much of Latin America and sub-Saharan Africa but mostly from investments and new inputs that helped raise the productivity of land and labor (Figure 4.1).

[FIGURE 4.1]

4.4. An increasingly important source of progress in the past 20 years, and of overwhelming importance in the future, was the application of science to the task of opening up new techniques in traditional farming and linking of them with the use of industrial products -- machines and chèmicals, concrete and steel. The greatest success of tis period was the new fertilizer-responsive cereal varieties that, often in combination with new irrigation, brought forth the Green Revolution. Often a single innovation, like the introduction of high-yielding wheat varieties in the Indian Punjab, started a self-sustaining process of changing attitudes, increasing savings, and rapidly expanding nonfarm employment and consumer demand (Box 4.1).

[Box 4.1 THE GREEN REVOLUTION IN PUNJAB]

4.5. Unfortunately, many farmers did not participate in the Green Revolution. Ignorance and tradition have often been blamed for their failure to adopt new technology. The main reason, however, was a lack of a profitable new technology that matched the climatic, soil, and topographical features of their land. Thus, the new seeds and cash inputs produced greatest impact in

areas with timely and reliable rainfall or with irrigation. Similarly, progress was largely confined to tree crops and a few cereals that had a long history of agricultural research.

4.6. This chapter describes the relation between agricultural expansion and the opportunities for growh that make social and economic progress possible. The matching of agricultural technology and investment to the local environment is an important part of the story. The public sector played a key role in research and infrastructural investments but the dynamic response of the private sector to meet burgeoning demand for seed, chemicals, and equipment also contributed significantly to this success.

Climate and soil

4.7. The genetic characteristics of plants, governing their development, growth and reproduction, limit their habitats to specific climates. Wheat grows best at temperatures between 15°C and 20°C; rice, at daytime temperatures in the range of 28°C to 35°C. Thus, the developing world, with mainly tropical climates, produces only a third of the world's wheat crop but over 90 percent of the world's rice. Climatic constraints are even greater for most perennial crops -- coffee, tea, cocoa, bananas, rubber, and oilpalm -- which grow only in the tropics.

4.8. Roughly two-thirds of the developing world's croplands are located in the tropics. The remaining one-third is in the subtropics or Temperate Zone, including the southern parts of Latin America and Africa the Mediterranean Basin, the Near East, much of Central Asia (including most of China), and the Korean penninsula.

4.9. In the tropics rainfall governs the cycle of plant and human life. Total annual rainfall is usually less important than its seasonal distribution. The mix of wet and dry seasons determines whether one, two, or

three crops can be grow during the year. In the low-rainfall areas, drought is a fact of life, although heavy rains often cause floods and seriously damage soils, crops, property, and people. Tropical rainfall, especially in the drier parts, is also unreliable. The Tropical Zone consists of four subzones: the humid tropics with a growing season of nine months or more; the subhumid tropics, six to nine months; the semi-arid tropics, two to six months, and the arid tropics, two months or less.

4.10. Soil characteristics are determined largely by the parent material and the evolutionary geological process. In the tropics, intensive rainfall and high temperatures critically damage the soil's structure and fertility. In many high-rainfall areas, a large part of the nutrients useful to plants have been leached, leaving acid or toxic soils. The most fertile soils in developing countries are found in alluvial areas around lakes, and in the flood plains and deltas of major rivers. Recent volcanic and forest soils at high elevations can also be highly productive. Generally, the soils of South and Southeast Asia tend to be more fertile than the tropical soils in Africa and Latin America.

4.11. Differences in soil and climate have produced five main cropping systems, which provide the developing world's staple foods (Figure 4.2):

- Rice, which first grew on the water-retentive soils in the humid tropics of Asia has been adapted to fit a broad range of environments. Farmers now grow rice in the river valleys or coastal plains of South China, South and Southeast Asia, the Indonesian and the Philippine islands, Japan, and Korea as well as small areas of Latin America and West Africa. In many nearby high-rainfall areas with more permeable soils, upland (nonflooded) rice is integrated into farms in rotation it with other crops.

• Starchy root crops (cassava, yams) are grown in the Humid Tropics where the soils are less fertile and not well suited for cereal cultivation, such as western and central Africa and parts of Oceania and Latin America. Cassava has also spread to northern Thailand where is has emerged as an important export crop.

• Maize is the most important staple in the subhumid tropics of Latin America and Africa. The most common crops farmed with maize are cotton, groundnuts, soybeans, and sorghum in the drier areas; coffee, cocoa, and starchy root crops in the wetter areas.

• Sorghum is the main foodgrain in the wetter parts of the Semi-arid tropics and millet in the drier regions. Groundnuts, cotton, cowpeas, and pigeon peas are the most common associated crops.

• Wheat is the most important grain in much of the Temperate Zone but is grown over an increasing area of the cooler tropics as a winter crop in association with monsoon-grown grains or cotton. Crop rotation dates back hundreds of years in North and Central China, for example, but has become increasingly important in parts of South Asia, often with supplementary irrigation and residual moisture in the soil.

[FIGURE 4.2]

4.12. Plant- and animal-breeding, land improvement investments like irrigation and flood control, and the evolution of new cultivation practices reflect myriad attempts to modify the influence of climate and weather, soils, and topography. Yet cropping patterns and agricultural productivity differ sharply between agro-ecological zones (Table 4.1). These differences reflect both the limits of man's ingenuity in mastering the physical environment and the fundamental tie to that environment which distinguishes agriculture from most other economic activities.

[TABLE 4.1]

Agricultural growth patterns

4.13. Historically, the main response to increased population and market demand has been to bring new land into production. However, the available land in most of Asia, North Africa and temperate Latin America has been put to use horizontal expansion has been precluded gradually as a source of agricultural growth. Between 1961 and 1980 only about one-quarter of the increased agricultural output in developing countries resulted from expansion of the cultivated area. Three-quarters of the production increase resulted from intensified use of existing farmlands through land improvement, plant breeding, substitution of higher for lower value crops, and increased use of cash inputs like fertilizer.

4.14. Through successful innovations and investments that overcame environmental constraints, the average productivity of land has been growing about 2 percent a year. However, because of the long gestation period of agricultural research and many infrastructure investments, recent growth results not only from contemporary efforts but also past ones. This is clearly reflected in the growth patterns of the various agro-ecological zones (Figure 4.3)

[FIGURE 4.3]

4.15. Until the 1960s research and development efforts were concentrated on tropical cash crops and Temperate Zone crops. Tropical staples -- especially sorghum, millet, grain legumes, and root crops -- were largely neglected. Thus, the main food crops of the semi-arid tropics and the humid parts of Africa still suffer from a lack of scientific knowledge about crops, soils, and farming systems. This handicap is compounded by inadequate infrastructure and immense soil-and water-management problems. As a result, the productivity

of land increased little over the last two decades, and the overall rates or agricultural growth in these areas were low by international standards.

4.16. The overall growth in other agro-ecological zones were higher owing largely to more rapid productivity gains. China, with 4,000 years of experience of intensification and land improvement reportedly achieved an annual increase in land productivity of about 3.2 percent, the highest of any major developing economy.

4.17. The average growth patterns for the agro-ecological zones conceal great variations not only within the zones but also within individual countries. Over the last two decades, most productivity gains have been concentrated in regions with fertile soils, good water control (adequate rainfall or irrigation), and well-developed marketing and transport systems. Because of the nature of recent technological innovations, less- favorable areas (like those subject to drought or flood or with marginal soils) have largely been left behind.

Land reserves and area expansion

In a global context, unused arable land remains a considerable resource. Estimates of this land reserve in developing countries range from about 500 million hectare to about 1.4 billion ha, compared with about 820 million ha currently under cultivation. FAO estimates that, of the 1.1 billion ha of unused arable land in 1980, 10 to 15 percent of might be cultivated by 2000. Ample farmable land is available in the humid and sub-humid parts of sub-Saharan Africa and Latin America. Reserves in the Mediterranean area and most of Asia (except Indonesia) are extremely limited.

4.18. Although land reserves on a global scale are ample for a sustained expansion over the next 50 years, most of the developing world's population lives in countries where land pressure is already severe (Table 4.2)

China was probably the first major country to use almost all of its arable land, but a number of others have reached or are fast approaching this situation. Thus, probably not more than a tenth of the developing world's rural population is likely to benefit directly from access to new, cheap land in the next 20 years.

[TABLE 4.2]

4.19. Diseases borne by insects have discourage permanent settlement in large parts of the tropics and subtropics. The eradicaton of malaria in the 1950s opened up extensive new areas for cultivation especially in Asia. The two main diseases affecting settlement and cultivation nowadays are river blindness (onchocerciasis) and sleeping sickness (trypanosomiasis), which occur primarily in sub-Saharan Africa. To avoid river blindness, large areas have been left unfarmed in the fertile Volta, Niger, Congo, Gambia, and Upper Nile valleys. A substantial effort to eradicate this worm-caused disease is underway, involving West African governments, the WHO, FAO, the World Bank, and bilateral donors.

4.20. Trypanosomiasis, carried by the tsetse fly, is even more harmful than river blindness in its economic effects, preventing livestock-based agriculture on some 1 billion ha high-rainfall areas in Africa. Insecticides have been tried in several countries, including Nigeria, Cameroon, and Botswana. However, high costs and the re-emergence of tsetse flies in previously cleared areas indicate the need for more research and a broader approach to vector control.

4.21. Most expansion of farmland takes place spontaneously by moving the cultivation frontier into forest and grazing areas around existing settlements. Farmers are also gradually reducing fallow periods and switching from shifting to permanent cultivation, especially in Africa. In those rare

instances of extensive virgin areas with good soils, as in northwestern Brazil, migration often takes place on a large scale. The unplanned nature of such settlements has often led to complicated and poorly defined land tenure arrangements that have slowed subsequent productivity increases and often created social tension. These problems have led to an increased emphasis on government-sponsored schemes. By necessity such schemes are located in relatively remote, sparsely populated areas usually without basic infrastructure. Thus, settlement and land clearing are combined with construction of roads, markets, schools, and health facilities. Because of the high costs (typically $1,000 to $2,000 a hectare), efficient management is required to make such schemes economically viable.

4.22. While farmers usually select the most appropriate areas to cultivate, population pressure often forces them into progressively less-favored areas, contributing to declining soil fertility and erosion. It has been estimated that between 1900 and 1965 about half the forest area in developing countries was cleared for agriculture. Forest areas are still extensive in the humid and subhumid tropics where they cover about half the land. Deforestation has gone much further in the semi-arid tropics and in the temperate zones, where the forest cover typically has been reduced to 10 to 15 percent of the land area.

4.23. The harmful impact of massive deforestation has lead to an increased appreciation of the social, economic and, especially, environmental benefits of forests. Trees help regulate rainfall runoff and stream flows, protect soils from erosion, replenish soil nutrients, and influence the local climate substantially.

4.24. Shifting cultivation in forest areas and controlled commercial extraction of lumber can take place with little environmental damage.

Unfortunately, many governments lack a well-developed forestry policy. In some countries (Brazil and the Philippines, for example serious damage has resulted from failure to enforce cutting plans and control lumber extraction. Clearing land for permanent cultivation generally poses a greater threat. It increases rain run-off and enhances the risk of soil erosion and flooding farther down in the catchment area, but these adverse effects can be counteracted by proper soil conservation practices and watershed protection works.

4.25. The most severe environmental damage from expanded settlements is not from crop cultivation but from a combination of livestock grazing and fuelwood extraction. About four-fifths of all wood extracted in developing countries is used for fuel; in sub-Saharan Africa wood supplied about three-quarters of all energy in the mid-1970s. The problem is most severe in densely populated hill areas, like the Andes and the Himalayas, and in semi-arid and arid areas. In these fragile ecological systems, accelerated deforestation poses a serious environmental threat. The social and economic costs are also high as more time is spent on fuelwood collection and the productivity of grazing lands declines (Box 4.2).

[Box 4.2 FUELWOOD IN THE SAHEL]

4.26. The protection of agriculture's future resource base through soil conservation, watershed development, and reforestation is becoming increasingly important as population pressure mounts, and more marginal land is brought under cultivation. Such programs are especially difficult to put together and manage in the many cases where watersheds cut across administrative or national boundaries. However, even minor soil conservation works are difficult to implement and finance since they are carried out in fields owned by individual farmer while much of the benefits accrue to people living further down the watershed.

Land-improvement investments

4.27. Rainfed areas. A land-improvement process begins as settlers start to work newly cleared land. The activities range from destumping, land leveling, and terracing to large-scale irrigation, drainage, and flood-control works. In comparison with irrigated farming, little research has been done or investment made in land improvements in rainfed areas. The subtle interactions of soil, water, and crops in these areas is still not fully understood, in part because wide local conditions vary so widely. The limited progress of rainfed agriculture, especially in the semi-arid tropics, is therefore a reflection of the lack of a solid scientific basis for land-improvement investments. Much current research and development work relates to the interaction between socioeconomic and agro-climatic factors.

4.28. Improvement of rainfed land usually involves community-level works like reforestation and drainage that are planned and implemented for a whole watershed. However, the most important elements are carried out on individual farms, altering tilling practices, introducing new crop rotations, and increasing use of purchased inputs. The exact approach has to be tailored to local agro-climatic conditions.

4.29. Research to halt erosion and falling fertility -- the main problem in the humid and subhumid tropics -- involves one or several elements: maintaining continuous crop coverage of the soil, minimal tillage, drilling the seed, and controlling weeds with chemicals. One such system is being developed at the International Institute of Tropical Agriculture (IITA) in Nigeria.

4.30. Extensive areas in Latin America (in particular the cerradoes of Brazil, the llanos of Colombia and Venezuela, and much of the forested Amazon Basin) are dominated by acidic, infertile soils. There research focuses on reclamation through chemical soil treatments and selected crop rotations.

4.31. For semi-arid areas with relatively dependable rainfall and water-retentive soils, (ICRISAT) is developing a new method of cultivation. This system is based on semipermanent broadbeds and furrows that give controlled drainage under heavy rains and an improved use of moisture. Together with premonsoon sowing, changed crop rotations, high-yielding varieties, and fertilizer, the system has led to a tripling of output in farm experiments.

4.32. These and most other systems that have recently emerged from research centers need extensive tests on farms, and modification, before they can be widely promoted. Rapid increases in rainfed yields may require another decade and, in any case, are likely to be concentrated in regions with evenly distributed rainfall and good soil. The potential yield increases may be high, compared to present rainfed production, but are likely to be modest compared with what has been achieved in irrigated areas.

4.33. Irrigation. The most significant step in the land-improvement process is usually irrigation. The benefits of irrigation tend to vary with soil, topography and climate. In the semi-arid and arid tropics, where the potential returns are highest, irrigation can raise yields during the main growing season, make possible a second or even a third crop, reduce risks and encourage the cultivation of high-value cash crops and the use of fertilizer and modern seed.

4.34. Irrigation investment in developing countries has been rising steadily to around $15 billion a year. The irrigated area in developing countries has grown at an annual rate of about 2.2 percent since 1960. At present, some 160 million ha, or about one-quarter of the harvested area is irrigated, using three-fifths of all fertilizer and producing up to half of all annual crops in the developing world. Between 50 and 60 percent of the increase in agricultural output in the past 20 years has come from newly irrigated areas or yield-improvements on from existing irrigation projects.

4.35. Irrigation will continue to be particularly important in the Mediterranean region and Asia. China, with 49 million ha, and India with 39 million ha, together account for more than half the developing world's irrigated area (Figure 4.4). In areas that have reliable rainfall and good opportunities for expansion of the cultivated area, irrigation is generally not the most cost-effective way of increasing agricultural production.

[FIGURE 4.4]

4.36. In India, large canal-irrigation schemes with storage reservoirs require an investment of about $2,000 a hectare. Similar schemes in West Africa often cost more than $10,000 a hectare owing to inexperience with labor-intensive construction and dependence on imported materials and equipment. Such high investment costs can be economically justified in only few countries -- located primarily in the Meditarranean area -- where advanced water-management techniques have been adopted and high-value crops are grown.

4.37. One of the most significant developments in the last two decades has been the rapid expansion of private groundwater schemes, stimulated by the development of low-cost pump technology and the introduction of modern seed and fertilizer. The impact was most dramatic in South Asia where predominantly small farmers have invested about $15 billion in open wells and tubewells since 1960. These private schemes in South Asia serve 30 million ha equal to all the public and private irrigation in North Africa, Middle East, and Latin America together. The public sector in South Asia supported this private development through long-term credit and rural electrification.

4.38. In spite of the success in South Asia, groundwater irrigation has been neglected in many other countries, particularly in sub-Saharan Africa, partly because of inadequate surveys and lack of supporting infrastructure. However, recent studies point to good possibilities for groundwater pumping in

large parts of the Savannah belt, for example in northern Nigeria. Though more costly to operate and maintain than canals systems, groundwater schemes often prove cheaper and easier to manage.

4.39. Even where irrigation is a cost-effective approach to increased agricultural production, it absorbs a large part of public-sector investment budgets, especially in low-income countries. A moderate-sized 50,000 ha scheme costs about $150 million. Thus, stringent selection, careful design, and effective implementation of irrigation projects are required to ensure a reasonable return on the overall investment budget.

4.40. In addition, there is considerable scope for increasing the benefits from existing canal schemes: in too many projects crop yields are well below their potential, and much water is wasted. One source of inefficiency tends to be poorly designed and constructed tertiary channels that bring water from the public irrigation outlet to the farmer's field.

4.41. Recent studies have demonstrated that poor design and operation of the main system is a major contributing factor to inequitable and wasteful use of water on farm levels. In most countries, project design, water allocation, and canal operation have changed little since the nineteenth century while agricultural technology has ben drastically transformed. As a result most irrigation systems cannot provide a the timely and reliable water supply that modern, high-yielding crops need. Because the water supply is unreliable, farmers take as much water as they can whenever they can. This leads to waste and deprives others in the system of their share.

4.42. Experience suggests that improved operation, up-grading and modernization of existing canals and construction of field channels can give high returns to relatively modest investments. Shortages of properly trained staff and the lure of major new engineering ventures have limited the progress of many such improvement programs.

4.43. Irrigation schemes tend to be dominated by design and construction engineers, often with little or no training in operation, water management, or agriculture. In some countries with strong civil service traditions, the rules even exclude nonengineers from employment in the irrigation service. A new multidisciplinary approach to irrigation design and operation is required. Farmers also have to be involved more actively in the distribution of water. To promote such approaches, efforts must be intensified to develop training and applied research programs for water management.

4.44. Flood control and drainage. The topography of many densely populated parts of the developing world is such that "normal" rains often cause widespread flooding. The depth of standing water in many paddy fields in Asia exceeds 30 cm which make these areas unsuitable for high yielding, dwarf varieties of rice. Small scale protection and drainage works that reduce the depth of flooding would enable wide adoption of modern rice technology in Bangladesh, Burma, Thailand and eastern India (Box 4.3). For the long term, these areas need, comprehensive watershed management, flood control, and river training schemes to further expand the scope for productive agriculture.

[BOX 4.3 CROP INNOVATIONS AND INVESTMENTS]

4.45. Many older, and some newer, irrigation systems suffer from water-logging and salinity due to lack of drainage. The problems are most acute in Egypt, Pakistan, northern India, and northern China. An estimated 8 million ha, more than half of the Indus Basin Canal system in Pakistan, is waterlogged and some 40 percent is affected by salinity. Since there is little opportunity to extend the area under cultivation in these countries, major drainage and reclamation investments are increasingly urgent.

Seed and plant technology

Man has searched for new crops and improved existing ones through selection since settled farming began. Breeding and selection accelerated with the establishment of publicly funded agricultural research stations and the emergence of genetic science in the mid-nineteenth century. Plant breeding now takes place in hundreds of large experimental stations linked in worldwide networks that share data, planting materials, and scientific results. The earth is being scoured for wild plants that man's remote ancestors might have missed and that might posses characteristics that could be used directly or which could be incorporated into plants already used. At the frontier of genetic research, microbiologists apply recombinant deoxyribonucleic-acid (DNA) technology to develop more useful plants (Box 4.4).

[BOX 4.4 NEW FRONTIERS IN AGRICULTURAL RESEARCH]

4.46. During the colonial period, plant-improvement work in the tropics was concentrated on export crops like sugar, banana, rubber, cotton, tea, coffee, and oil-palm. During this period, the major advances for cereals were made in temperate areas. Since the early 1960s the main emphasis of tropical research has shifted to food crops, particularly to grain. In the case of wheat and rice, plant breeders in developing countries could build directly on genetic advances in the rice and wheat varieties that had evolved in the industrial economies. Tropical research on sorghum, millet, and maize started later and was more difficult because these cereals were used primarily as animal feed in the developed countries rather than as human food. As a result, the taste of Temperate Zone varieties was inferior to that of the tropical ones. Pulses like chickpeas and cowpeas and starchy root crops like cassava are not grown in temperate areas, had been almost totally overlooked by researchers before the late 1960s. Thus, the breeding of these crops lags a half century behind rice and wheat.

4.47. The breeding task is complicated by the great variation within seemingly uniform agricultural environments. For each micro-environment, nature, farmer, and, more recently, agricultural scientists have evolved varieties with specific characteristics. If these varieties pass the test of time, they usually fit local agro-climatic conditions closely. To survive, varieties also develope resistance or tolerance to many locally prevailent pests and diseases.

4.48. Breeders of wheat and, to a lesser extent, rice have developed varieties that are adapted to a broad range of environments. For other grains, they have been less successful. For example, a maize variety that gives high yields one valley in the highlands of Mexico may give only a minimal harvest in a neighboring valley and fail completely in Central India.

4.49. Most traditional cereal varieties have been adapted to grow on nutrient-depleted soils. They are tall with only a small head of grain. When the plant is fertilized, the head gets too heavy and lodges or falls over. Much of plant-breeding the last three decades has focused on developing shorter, sturdier cereal plants, where the head makes up a higher percentage of the plants' weight. As a result, a larger share of nutrients absorbed through the roots promotes the growth of grain rather than stem and leaves.

4.50. Over half of the developing world's wheat and one-third of the rice lands are planted with high-yielding varieties. These semidwarf plants are more responsive to fertilizers than the traditional varieties, and under the right agroclimatic conditions their potential yields are much higher, especially if with irrigation. Similar progress has been made on sorghum and, to a lesser extent, millet and maize.

4.51. Yield is only one concern of plant breeders. Environmental adaptation, the time taken to reach maturity, resistance to pests and disease,

flavor and storing characteristics are other important variables. It usually takes 20 years between the start of a new breeding program to its successful dissemination among farmers.

4.52. The Green Revolution. The most widely publicized breakthrough in plant breeding in the developing countries occurred in the mid-1960s with the release of new varieties of wheat from the International Maize and Wheat Improvement Centre (CIMMYT) and rice from the International Rice Research Institute (IRRI). Although called the Green Revolution, it was part of a long-established pattern where innovation in one place had a major impact in other areas around the world. Sugarcane, for example, had earlier experienced three very similar "revolutions."

4.53. The new wheat varieties had a dramatic impact in India where they were introduced in 1966. Wheat production increased from 10.8 million tons in 1964-66 to 23.4 million tons in 1970-72. In the early 1970s, wheat rust became an increasingly serious problem, and production stagnated for several years. By the mid-1970s, Indian scientists had developed varieties that both resisted rust and matured earlier, and their seed distribution system had been strengthened. Production growth resumed and reached 32.9 million tons in 1978-80. From being the world's second largest cereal importer in 1966 and 1967, India became virtually self-sufficient in the late 1970s.

4.54. Semidwarf varieties of wheat have been widely adopted in many parts of the world. China, Turkey, and Pakistan, for example, have won significant increases in yield and production. Bangladesh, where wheat was almost unknown in the early 1960s, saw the most dramatic increases, albeit from a low base. Between 1974/75 and 1980/81 the wheat yield doubled, and production increased more than ninefold to 1.2 million ton.

4.55. IRRI released its first semidwarf rice variety (IR-8) in 1966. It grew best during the dry season under clear skies and was quickly adopted by farmers in South and Southeast Asia who had access to irrigation. A couple years later, followed the first varieties suitable for the monsoon season. Farmers adopted these varieties much more slowly and more selectively because the plants were sensitive to a lack of water and could not be grown where deeper than 30 cm flooding was likely (Box 4.3). Only a small part of the paddy fields in Asia had this level of water control and adoption was limited to these areas. Quick maturity time, an important advantage of the semidwarfs, has enabled a significant increase in the number of crops grown each year.

4.56. Tropical and subtropical maize is adapted to highly specialized locations. Many breeding stations have produced dramatically improved hybrids and composites, but attempts to grow them outside their ecological niches have not succeeded. Adoption of improved maize varieties has been most widespread in China, Kenya, Zimbabwe, and Argentina.

4.57. Hybrid sorghums for human consumption were first released in India in 1964. However, it took 12 years to overcome the major difficulties with taste, disease resistance, and seed production were overcome. Now some 4.5 million ha, one-third of the rainy-season area, is planted with hybrids. Hybrid sorghum also started to spread in northeastern China in the mid-1960s. Large commercial farms in Latin America also grow hybrids, chiefly as cattle feed. There has been no significant adoption of improved millets, alough some progress has been made in India. Few improvements have been made in grain legumes although ongoing research shows promising results.

4.58. As a result of new varieties of grain, which in turn encouraged irrigation investments and greater intensification in land use, the developing

countries cereal yields rose by 2 percent a year in 1961-80 (Figure 4.5). Wheat yields grew 2.7 percent, sorghum 2.4 percent, and maize 2 percent. Rice yields grew by an average of only 1.6 percent a year in all developing countries but exceeded 3 percent a year in the Philippines and Indonesia, where new rice varieties had caught on.

[FIGURE 4.5]

4.59. The Green Revolution, with its new wheat, rice, sorghum and maize technologies, had a greater impact on the incomes of more people than Europe's industrial revolution over a comparable period of time. In just a few years, tens of millions of farmers in Asia, Africa, and Latin America changed their crops and cultivation practices and achieved hitherto undreamt of grain yields. A much larger number of farmers, however, failed to adopt the new technology. Some of the failures can be explained by a lack of seed, fertilizer, credit, and the like (Box 4.5). But there are more basic reasons:

- Most important, the technology did not fit the climate and soil. Success was concentrated in countries with mature, well-staffed national research systems that adapted the "international" varieties to local conditions.

- The new varieties perform best, and are thus most widespread, in areas with reliable rainfall or irrigation, flood control, and good soils. Their adoption in marginal environments has been minimal.

- A single new variety is often grown in a single large area at the risk of eradication by pests and diseases. Research to maintain resistance and to develop new sources of resistance are important for continuous success.

- Good transport and marketing infrastructure and remunerable prices were prerequisites for the adoption of new technology.

[BOX 4.5 ADOPTING NEW CROPPING PACKAGES: LESSONS FROM NORTHERN NIGERIA]

4.60. Agricultural research. International research centers and some national establishments played an important role in breeding new crops. However, because the technologies developed are never universally applicable, much of the research must be done under the agroclimatic and socioeconomic conditions in which the resulting technology will be employed. The generally understaffed, underfinanced, and poorly coordinated research systems in sub-Saharan Africa largely failed in this respect. This failure is partly responsible for the region's poor growth performance.

4.61. A recent study showed that research expenditure in 51 developing countries increased significantly over the last decade and amounted to 0.5 percent of agricultural output in 1980. This is much less than their spending on agricultural extension. Studies show very high returns to agricultural research. Few investments in agriculture are as profitable as well-focused research. Industrial economies spend 1 to 2 percent of agricultural output on research, about four times the amount spent on extension. A strong case can thus made that there is still under investment in research in the developing countries.

4.62. The strengthening national programs often involves a reorientation of research from academic topics of purely scientific interest toward the generation of technologies that can be applied directly by farmers. Since knowledge of farm-level constraints and conditions, -- such as the availability of labor -- are so important a critical element in this strategy would be extensive testing and evaluation on farmers' fields. Emphasis should also added to problems in marginal areas, with low or very high rainfall or poor soils, and to coarse grains, starchy root crops, and grain legumes.

4.63. Small countries that cannot afford basic research face special problems. They have to rely more heavily than others on practices and

materials developed by the international centers, while devoting most of their own efforts to applied research at experiment stations and on farms. There is considerable scope for broadening regional cooperation in areas like Central America and sub-Saharan Africa. Unfortunately, most past attempts at regional cooperation have not been very successful.

4.64. The role of the international centers is evolving as national systems are being built up and take over more of the task of developing new technology (Box 4.6). Today, great emphasis is given to training of national research workers, and the centers are functioning more as clearing houses for highly specialized knowledge and genetic material. The centers have also become more involved in developing research methodology, especially for analyzing farm-level socioeconomic and agroclimatic constraints.

[BOX 4.6 THE INTERNATIONAL AGRICULTURAL RESERARCH CENTERS]

4.65. Agricultural extension. The adoption of new technology depends on the knowledge, skill, and motivation of the farmer. Transmitting knowledge about better production methods is the main task of the agricultural extension (or advisory) service. Developing countries spend about twice as much on extension as they do on developing new technology through research. However, in most countries the performance of the extension service has been disappointing.

4.66. In South and Southeast Asia, the rapid spread of modern wheat and rice varieties and the associated explosion in fertilizer use owed little to conventional extension work. Information was spread from farmer to farmer and through news media and dealers rather than through extension contacts or organized visits to demonstration plots. Thus, for the highly profitable, relatively simple Green Revolution technology, dissemination by word of mouth, rather than by formal extension advice, was the mechanism.

4.67. In sub-Saharan Africa (and indeed in many other rainfed areas) farmers regularly ignore extension recommendation regarding planting dates and pure stand cropping (Box 4.7). Instead they continue to spread out planting and to intercrop in order to reduce risk and to use their limited resources as efficiently as possible. In this and many other cases, a lack of applied research that takes local social and economic conditions into account, has led to extension advice that is not appropriate to the farmers.

[BOX 4.7 DECISION MAKING ON THE AFRICAN FARM]

4.68. The existence of a profitable technology not yet known to farmers is a precondition for success of agricultural extension (Box 4.8). Similarly, without ready access to key inputs such as fertilizers and quality seed and to remunerative markets for outputs, no extension service will succeed. Where these conditions are not met, resources are better spent on applied agricultural research or on improvements in input supply and marketing systems.

[BOX 4.8 THE YIELD GAP AND THE ROLE OF AGRICULTURAL EXTENSION]

4.69. Even where conditions have been favorable, the extension services have often been ineffectual because of organizational weaknesses. Although extension advice needs to be tailored to local socioeconomic and agroclimatic conditions, some basic rules that underlie most successful extension efforts in developing countries:

- Eliminate secondary tasks such as processing of credit applications and collecton of statistics.
- Establish systematic work schedules for extension agents to enable supervision and control.
- Give the field agents simple messages to convey based on the cycle of farming activities.

- Institute regular training sessions for the field agents.
- Create a close link with the research establishment and e sure that it is used for two-way information between researchers, extension agents and farmers.
- Make available sufficient budget funds not only for staff but also transportation and extension material.

4.70. Experience from both developed and developing countries shows that the private sector also plays an important role in the diffusion of technology and advice to farmers: seed companies, suppliers of fertilizer, and crop-protection chemicals, and machinery manufacturers all develop recommendations regarding the use of their products. Newspapers and radio give out such information as market prices, weather forecasts, and spread of pests and disease. In the longrun manufacturers' and dealers' interests are best served by satisfied customers who come back year after year. This means that they often do applied research and conduct experiments and field demonstrations to develop recommendations and to get feedback from farmers.

4.71. Seed production and private plant-breeding. Private plant-breeding has grown in importantance in the developed world in the past few decade because of seed laws or patent systems that protect the breeder and the invention of hybridization techniques.

4.72. Hybrid vigor, first systematically exploited in maize in the 1930s, arises when two highly inbred genetic varieties are crossed. The hybrids, the first generation of such crosses, tend to have predetermined characteristics and can yield significantly more than either parents or the offspring. Because hybrid vigor disappears in the next generation, seeds need to be replaced each year.

4.73. Hybrids have not been readily diffused to small farms, not because for lack sophistication among farmers but usually for want of an effective seed industry and distribution system. To buy hybrid seed every year, a small farmer has to be sure of the seed's quality, and he has to get it in time when he needs it.

4.74. The Kenya Seed Company, a mixed-venture enterprise, has been able to meet farmers' needs and make a modest profit. Its Kitale maize hybrids, sold through village shops, are planted on farms of every size in the Kenya Highlands. In ecologically similar zones of neighboring countries that have no comparable production and distribution network, the diffusion of maize hybrids is minimal.

4.75. Well-established private seed companies usually have good quality control over the production and distribution of seed. In some developing countries, such companies have played an important role in accelerating innovation and adoption of new varieties. A close relationship between the public-sector research establishment and the seed co panies is highly desirable.

4.76. India has a unique sharing and division of labor between the National Seed Corporation, state seed companies private companies (Box 4.9). Despite some problems, the system generally works well, and farmer recognition of brand names has evolved.

[BOX 4.9 THE INDIAN SEED INDUSTRY]

4.77. Fertilizer. Up to the early 1960s, fertilizers in developing countries were applied almost exclusively to a few high-value cash crops. With the spread of irrigation and adoption of high-yielding cereal varieties, fertilizer use rose eightfold to 38 million tons in the 19 years to 1979. It is estimated that more than half the increases in grain yields since 1950

resulted from increased fertilizer use and synergetic interaction between fertilizer, irrigation, and modern seed.

4.78. Most of the regional differences in the use of fertilizer can be explained by the degree of water control (Figure 4.6). FAO estimates that low-rainfall areas apply 3 kilograms per ha of fertilizer, while high-rainfall areas use 20 kg/ha. In areas with reliable irrigation supply about 110 kg/ha of fertilizer are used. Farmers in drier areas use little fertilizer, because a plant that lacks water does not respond significantly to fertilizer and the risk of crop failure makes farmers reluctant to use cash inputs if rainfall is unreliable.

[FIGURE 4.6]

4.79. Rising energy prices and increasing concern about the ecological impact of agrochemicals has led to a search for more efficient ways of applying fertilizers and for alternatives:

- Animal manure and other organic wastes are important sources of plant nutrients in many traditional cultivation systems. They also help to improve the soil's structure and water retention. However, the use of organic fertilizers has both economic and practical limitations. Replacing the nitrogen fertilizer now in use with animal manure would require a threefold increase in the world's animal population.

- Biological nitrogen fixation (BNF) through micro-organisms is achieved through the integration of legumes in crop rotations or inter-croppings. Chinese and Vietnamese farmers have long grown the water fern Azolla in rice fields. This plant provides a habitat for blue-green algae that help supply the rice with nitrogen. Research to expand the use and increase the efficiency of these and other nitrogen-fixing micro-organisms is under way, but in the short and medium term it is unlikely that BNF can significantly reduce the use of fertilizer.

• Mycorrhizas are beneficial fungi that live in contact with plant roots and improve the nutrient uptake of host plants. On a research scale, promising results have been achived but large-scale applications are probably a decade or two away.

4.80. Increased use of chemical fetilizer in developing countries will therefore remain a major source of productivity growth in the next two decades. The most likely "alternative" is new crop varieties that respond even more favorably to fertilizer than present high-yielding varieties. Since ample raw material is available and the fertilizer industry has responded rapidly to increased demand, the main constraint on increased fertilizer use in the developing world is likely to occur in distribution and pricing rather than in the production of fertilizers.

4.81. Crop protection chemicals. According to most estimates, between 20 and 40 percent of the crop in developing economies is lost to insects, pests, disease, and weeds. The use of chemicals against insects and insect-borne diseases has spread rapidly in recent years and had made a significant contribution to expanded crop producion. The undesirable side effects -- such as changing immunities of insects, destruction of natural enemies, outbreaks of secondary pests, and potentially harmful residues -- have caused concern. Most important among the alternatives has been the breeding of varieties with a wider genetic resistance or tolerance.

4.82. The latest approach, as yet untested on a large scale, is integrated pest management. This involves combining genetically resistant varieties, crop rotations, specific planting dates, introduction of natural enemies or parasites, and carefully timed applications of chemicals. Integrated pest-management schemes require teams of scientists, ranging from entomologists and plant pathologists to climatologists and economists, supported by field scouts

who monitor insects, pests, and diseases, and a comprehensive crop protection organization. This is far beyond the administrative capacity of most countries, but selected elements of this approach can in themselves be highly beneficial.

4.83. Herbicides that kill weeds are primarily labor-saving. They have potential value in land-abundant economies where labor shortages for tilling and weeding limit the area that can be planted. One attempt to reduce labor needed at peak periods through the use of herbicides is the zero-tillage system for the subhumid tropics developed by IITA in Nigeria. It has shown promising results at the research level and is being tested in the field.

Livestock

4.84. The income-generated demand for meat, dairy products, and eggs rises faster than demand for crops. In the developed countries, livestock accounts for almost half of agricultural output versus one-quarter in the developing world. However, animals serve man not only as a source of food but also as a source of power and products such as manure, wool, and leather.

4.85. The systems under which livestock are raised vary widely with agro-climatic, economic, and social factors. For ruminants (cattle,sheep, and goats) there are four basic management systems:

- In the pastoral system of Africa and the Near East msot animals are reared by specialized nomadic tribes. Productivity is usually low due to poor animal health and sparse pastures. The range lands are often communally owned but the herds are privately held, which leads to overgrazing and degradation of ranges.

- In the ranching system, practiced primarily in the Americas, both land and livestock are privately owned. This is typically a strictly commercial operation producing meat for sale.

• Integrated crop and livestock raising is the predominant pattern on the relatively small farms of Asia. Although grazing on public lands is common, a significant part of the feed comes from special fodder crops or from crop by-products. The animals are used partly as draught animals and virtually all potential products -- milk, meat, manure, and hides -- are recovered and utilized for subsistence needs or sale.

• Stall feeding of confined livestock is the most intensive management system. It is a specialized, commercial activity still rare for ruminant production in developing countries but becoming increasingly important for pigs and poultry.

4.86. Higher livestock productivity can, in principle, be achieved through breeding, improved animal health, and better feeding. However, the technical solutions and the private and public-sector support services vary significantly in their scope and organization from one management system to another.

4.87. The most intractable problems prevail in sub-Saharan Africa where the it is difficult to reach nomadic tribes with veterinary services and extension advice. The main long-term problem is how to prevent overgrazing on community-owned lands. This will require either direct public control of herd movements and animal numbers or legal and institutional changes in the pattern of land ownership. Improvements in smallholder livestock-rearing in Asia, on the other hand, focus more directly on creating and expanding a commercial market supported by breed improvement and veterinary services (Box 4.10).

[BOX 4.10 THE "WHITE REVOLUTION" IN INDIA]

Farm power and mechanization

4.88. All agricultural operations done by hand with simple tools like hoes and knives. In the process of agricultural development, human labor is

gradually replaced by animals for tillage and transport and later by machines. Since a pair of bullocks with a plow can usually till about three times as much land in a day as a man with a hoe, hand tillage is still practiced only under special conditions:

- On steep hillsides and very small plots.
- In the trypanosomiasis-affected zone in Africa, where traction animals cannot live.
- In many forest areas where shifting cultivation is practiced.

4.89. The next step in the transformation process depend on the relative scarcities of land and labor (Figure 4.7). It might be to extend the use of animals to activities like land-clearing, weeding, irrigation, and threshing or to use machinery for the same kind of activities. In most of Asia and other areas with abundant labor, machines are first used for those operations where concentrated power or speed govee them comparative advantages over animal- drawn implements: stationary threshers, mills, and pumps, where groundwater is available. Tractors, all the world over, are first used for heavy land- clearing and land preparation in upland agricultural areas and for transport. Mechanized puddling of rice fields with power tillers comes later, a stage now reached in Thailand and the Philippines. Weeding and harvesting are usually the last operations to be mechanized.

[FIGURE 4.7]

4.90. The shift to mechanical power in response to labor shortages and rising real wages is very selective. Irrigation pumps, for example, are used widely in Bangladesh, but tractors are virtually nonexistent; mechanical rice threshers are used in central Thailand, where threshing of the first crop overlaps with the planting of the second, but the more labor-intensive buffalo-treading remains the common method in single-cropped areas.

4.91. Local entrepreneurs play an important role in developing appropriate technology. Although the basic technology is usually imported initially, machines and equipment are often adapted locally. For example, simple drilling techniques and equipment for tubewells were developed by small contractors in northern India; the basic design for the two-wheel power tillers, widely used in Thailand, was developed by a village headman. In the next stage a number of local, small-scale manufacturers emerge. Later on, production is consolidated into larger units with economies of scale and more sophisticatd marketing.

4.92. Because of the significant impact that mechanization has on employment, income distribution, and agricultural production, government policy should be carefully considered in light of the capabilities of the private sector. For example, restrictions on imports to a few brands of machinery to simplify repair and maintenance often give undue advantage to large foreign manufacturers of machinery and retard the evolution of domestic industry. Credit subsidies can lead to premature and overly capital-intensive mechanization, favoring large over small farmers, and to labor displacement where the rest of the economy offers few employment opportunities. Such errors have both high budget and social costs.

4.93. Many governments have tried to accelerate the use of agricultural machinery by establishing public-sector hire services or cooperative machinery pools. Most of these schemes have failed because of excessive overheads, administrative inefficiency, and mechanical breakdowns. Privately owned tractor services, in Sri Lanka and Thailand for example, have been able to keep machinery in working order and have generally been more flexible in answering farmers' needs. Water from private tubewells in Pakistan and India is often sold to neighbors, and the irrigation supply from these private wells

is usually more timely and reliable than the supply from public tubewells. Although these kinds of small-scale private enterprises tend to be highly efficient and play an important role in agricultural development, they are often neglected or discouraged by public policy. Parastatal and cooperative schemes tend to get priority in the allocation of fuel, spare parts, and credit.

Supporting agricultural production

4.94. Farmers do not work harder or adopt new methods to produce more without a favorable economic climate in which to invest. As well as a healthy macroeconomic climate which offers adequate incentives, four special factors are important: accessible and dependable markets for output, efficient distribution of inputs, adequate financing and access to farm-management advice when needed. Ways of improving the quality of extension advice were discussed earlier in the chapter. This section will focus on problems to do with rural infrastructures marketing and credit.

Rural infrastructure

4.95. Developing an adequate rural infrastructure, especially of roads, is the most obvious first necessity for transforming subsistence agriculture in areas removed from main centers. Provision and maintenance of this infrastructure is one of the areas which clearly belongs in the public domain, whether at central or local government level. Rural water supplies (for domestic and agricultural use), communications (radio or telephone) and electrification are the next most obvious infrastructure requirements. Though involving substantial budgetary outlays, they have been found in Asia to have a high economic return in terms of increased agricultural output, especially in more densely settled areas. In the Philippines the government has allocated around 5 percent of agriculture development expenditures to rural electrification programs, which now service about 70 percent of the

population, with an objective of reaching the whole population by 1987. But in many developing countries, simply providing access for vehicles remains the first priority for getting agriculture moving (Table 4.3) In many parts of Africa, farmers are still situated over a day's walk from the nearest motorable road, and in some cases there has actually been a degradation of both the road network and vehicle fleet capacity. Such a situation renders frutless other measures to raise production levels, and is a precondition for improving marketing incentives.

4.96. The crucial role of transport, and in particular of rural roads, is a decisive element in allowing farmers to take advantage both of market opportunities and of new farming technology. In the highlands of Papua New Guinea comercial growing of coffee and tea was introduced in the 1940s entirely with the help of air freight from the coast, and so continued until a road was build to reach Mt. Hagen in the late 1960s. The same happened in Madagascar. Generally, however, agriculture cannot develop much beyond a basic subsistence level in areas cut off by lack of surface communications from the rest of the world. Thus, efforts to make marketing systems for small farmers more efficient need to pay special attention to the state of transportation infrastructure.

4.97. An inadequate density of secondary of secondary and tertiary roads not only constitutes a blockage to smallholder innovation and market participation, but these roads also tend to get neglected or not built at all if left to national road transport authorities, who have more pressing claims on their resources. Feeder roads may receive more attention if the responsibility for their planning, construction and maintenance is devolved to local government or to area development authorities, but these still require central government financing because of the generally limited revenue-raising powers of local government. Externally financed area development projects

have sometimes been very successful in organizing feeder road construction and at reasonable cost. Good examples are the Bank's first three rural development programs in the northern savannah areas of Nigeria, which between 1975 and 1980 constructed or improved a total of 1,700 kilometers of feeder roads, and the much smaller cocoa and coffee development project in Togo, cofinanced by the World Bank and the Bank of France, which established its own roads unit and built 200 kilometers of roads linking villages in mountainous terrain at less than half the lowest cost tendered by private contractors. In both cases, local artisans were subcontracted or hired to do much of the skilled work such as building bridges and culverts.

4.98. There is no guarantee that construction of a road network, per se, will transform a backward region. However, the World Bank's experience from over one-hundred rural development projects with road components clearly shows that adequate road access generally is a precondition for success of other agricultural development efforts, especially critical in the sparsely populated areas of sub-Saharan Africa and in parts of Latin America. In Nigeria it has been estimated that the existing feeder road network of about 60,000 km would have to be doubled in order to reach a desirable minimum of about 500 km per 1,000 km^2 of arable land area. Even this would only put farmers in the most densely settled areas within 5 km of a road.

4.99. Crop marketing. Crop marketing activities are the key to opening up subsistence agriculture. Supplying urban consumers with food, exploiting foreign trade opportunities, specialization according to the comparative advantage of each region, village and farm: all these can only take place if there are intermediaries equipped to finance, buy, sell, transport, process and store farmers' products and to distribute purchased inputs at the time when they are needed. There is a tendency to take these activities for granted and to ignore the contribution of risk-sharing. In most tropical

developing countries, they also take place under difficult physical conditions, especially for crop transport and storage, and often in an adverse policy environment. This makes life harder for farmers who want to enter the market and increases marketing risks.

4.100. Despite these problems, farmers in the developing world have generally responded eagerly to market opportunities. The rapid adoption by smallholder farmers of coffee growing in Latin-America and of cocoa, groundnuts, and cotton in West Africa, once marketing channels were established in the early twentieth century, are examples. Cocoa, a difficult plant to nurture, was never grown before by African farmers. And yet in little more than a half century, or only two generations, West Africa's production reached over 1 million tons a year of cocoa beans, capturing 70 percent of the world market and bringing farmers more cash per day's work than any other crop they had ever grown. All this was done without armies of extension workers to "teach" farmers how it should be done (although with a good deal of encouragement by the civil administration and, later on, of research on how to combat pests and diseases) and without causing a drop in food supplies (Box 6.0 on export crops and food crops). In one country, Ivory Coast, cocoa production has increased from 90,000 to over 400,000 tons in just two decades, largely due to fair prices and marketing. The main reason for such dramatic successes in peasant agriculture was the transmission of highly profitable overseas market opportunities across huge physical barriers through to farmers by a network of profit-seeking traders and other intermediaries. Since about 1965, West Africa has been steadily losing its share of the world market to other cocoa producers like Brazil and Malaysia -- mainly because of heavy intervention in the marketing channels which had built up this trade.

4.101. Agricultural prices, marketing, and international trade in both the developing and developed world are subject to a wide array of government regulations and controls. Originally, these were mainly of the regulatory kind, aimed at improving information and stemming abuses, through such measures as checking of weight and measures and standardization of grades and contracts. Today, the scope of interventions is much wider, being used for tax-revenue purposes, for the protection of special interest groups such as disadvantaged rural areas or urban food consumers and also for national security reasons. Developing countries in particular have established a plethora of government-run marketing agencies which are typically justified on the following grounds: to protect peasant farmers against exploitation by collusive traders; to replace foreign-dominated commercial interests; to implement government price policies for domestically marketed food crops; or to promote new smallholder crops for export markets, especially when centralized processing was required. Whether or not these reasons for intervention were valid at the time when marketing agencies were created, often during the colonial period in Africa and Asia, a high price is being paid to keep some of them in place today. And in many cases their development role, in stabilizing farm receipts, for instance, has been subordinated to one of acting as a fiscal instrument, taxing agriculture in a way which least encourages production.

4.102. Serious inefficiencies have characterized the operation of many parastatal marketing agencies. Some of these arise from problems found in almost all parastatals -- overmanning, inadequate nonsalary budgets, and management scarcities. There are also inefficiencies peculiar to the export crop parastatals due to the lack of competition. And there are additional problems in these agencies when marketed volumes stagnate or decline: decreasing turnover is compensated by higher overhead per unit, the producer

price being the residual. The result is an upward spiraling of costs and parallel downward spiraling of exports. Classic examples of this are groundnuts in Mali and most export crops in Tanzania and Sri Lanka. Official producer prices, and consumer prices for food crops, are fixed by governments with little regard to the actual costs of collection and distribution, and generally on a uniform panterritorial basis. This invariably means that the official agencies are left to buy, collect, and deliver in the most distant and costly regions, and they are not always reimbursed for losses incurred in the process. Much of the $80-million deficit accumulated by OPAM in Mali up to 1977 was a result of the government's food subsidy policies then being followed.

4.103. In food-crop marketing, there are usually parallel marketing channels; the legal and official marketing agency coexists with an often semiclandestine private trading sector. In these markets, attempts at controlling prices are frequent but often ineffective, depending on the share of official trade in marketed production, which seldom exceeds one-third of the total trade outside planned economies like China. Some governments do not put much trust in the private sector's ability to cope with the task of providing stable supplies of food to urban markets, even when private traders handle the bulk of the trade. In such cases, private intermediaries are tolerated as indispensable partners but are not allowed to work in an economic environment that would enable them to operate more efficiently. The uncertainties associated with the ambiguous position of private traders discourage full-time involvement in food marketing, investment in transportation and storage, and a systematic approach to developing an adequate supply network. The economic consequences of a break-down in food-marketing channels are serious: initially, periodic disruptions of supplies to urban areas (encouraging a greater dependence on imports) and, in

time, a withdrawal by farmers from the market altogether. (The political consequences can be even more disruptive.) Signs of a retreat back to subsistence production have been seen at various times in China, Tanzania, Guinea, Mali, Zaire, and Kampuchea. Such tendencies have only been forestalled by a liberalization of food marketing and prices, and not by a reinforcement of state controls.

4.104. A few marketing agencies have helped to stimulate farm output. One example is the Kenya Tea Development Authority (KTDA). It provides training to the tea growers, supplies planting material and inputs, and has built roads. The agency has organized the collection of the green leaf, payments to farmers, processing, and marketing. Farmers are paid in cash promptly and at near-market prices, and the tea is auctioned in Nairobi to private buyers, an open system which has won the confidence of the growers.

4.105. However, there are relatively few cases where marketing parastatals have successfully managed to combine satisfying government requirements to tax farmers or to stabilize prices with serving the farmers' long-term interests. On purely technical grounds, many of them are not needed at all. The main exception is where vertically integrated processing and marketing is needed for certain smallholder export crops, as in the smallholder tea example above. Even here there is the possibility of handing over to marketing cooperatives, when sufficient management skills are acquired, or to have mixed public-private sector participation. This has worked well in cotton development in francophone West Africa and for other smallholder export crops in Latin America and the Far East.

4.106. Input supply. State-owned agencies frequently monopolize the supply of inputs. They often fail to buy and distribute seed, fertilizer, and pesticides at the time they are needed by farmers because they have to await the availability of funds from the national budget. Fertilizers are often

heavily subsidized, supposedly justifying the state monopoly, or ordered with little regard to the specific needs of different regions. For some inputs like pesticides and herbicides, there is room for more countries to replicate the successful experiences of Korea and Bangladesh in attracting the participation and investment by agrochemical manufacturing companies, not only into the importation and wholesale distribution of their products but also into local adaptive research, field trials, and demonstration to farmers. As already noted, the production and distribution of quality seed is another field with broad possibilites for private sector participation. At the retail level there is scope in many countries for reopening the distribution of farm inputs to the private sector, where small traders could handle this function in association with produce-marketing and retailing of consumer goods, with reduction in costs of distribution as a result. A broader variety of goods for sale in villages is also a good way of inducing farmers to produce more crops for cash.

4.107. Many of the functions of parastatal marketing agencies could be done more efficiently by private traders, except, perhaps, in remote areas where individual merchant may have a monopoly. Even in these cases, it would be preferable to set up the state corporation alongside, rather than replace one monopoly with another. Private traders are generally highly competitive: for example, transporting and distributing millet or sorghum 30 miles to the nearest market town in northern Nigeria cost 30 percent of the retail price -- having passed through the hands of seven intermediaries on the way. At the same time, cotton and groundnut growers received only 45 percent of the FOB export price for their higher-value produce from the official buyers.

4.108. Investing in marketing services. The volume of food staples which must be marketed, stored, handled and transported in developing countries increases much faster than total agricultural production. Planners,

therefore, have to consider the investments, especially in storage and transport capacity, which will be needed to accomodate tonnages which may double in a decade. For example, if Latin America were to equip itself to store only half (say 40 million tons) of the incremental grain production over 1977 likely to be needed by the year 2000, the investment at current prices would approximate $5 billion. Planners should also consider whether the public sector alone can, or should, carry the burden of financing and managing all the investments required.

Credit

4.109. Farmers in the developing countries increasingly need credit financing as they adopt more modern methods. Larger farmers have been able to obtain loans under government credit schemes and from agricultural banks, but small farmers find access to these institutions difficult and rely on mostly informal credit sources. Because the costs and risks of unsecured loans to small farmers are high, interest charged by local moneylenders is invariably much higher than under official credit schemes. The official credit schemes are often subsidized and usually require some form of collateral. A number of special programs have been launched with the idea of targeting low-cost credit toward smaller farmers, but in many instances -- for example, the Masagana-99 program in the Philippines in the early 1970s
-- neither the targeting nor the repayment record turned out to be very successful. In Brazil and other countries, many agricultural loans granted on favorable terms have been diverted for other purposes, such as real estate investment.

4.110. To improve the performance of agricultural credit schemes, there are a number of clear lessons:

- Early establishment of repayment discipline (with clearly-understood rules for adjustment in the event of general crop failure) will not

only safeguard the financial viability of the lending agency but will also help to improve the selection, management, and rate of return on investment by borrowing farmers;

- Improved access to credit is of more benefit to small farmers than subsidized interest rates, which effectively ration the amount of credit available. Interest rates and other charges should reflect the true costs of lending and credit recovery, if more farmers are to be served. There is sometimes scope for widening collateral options so as to include nonreal assets owned by small farmers, such as animals, as security for loans.

Formal credit agencies have also overemphasized lending and neglected the provision of other financial services. Development of rural savings schemes is particularly useful in extending the financial base for lending and also in encouraging high repayment rates. Small farmers can and do save, once offered attractive savings rates. Finally, agricultural banks could make much more use of existing rural agencies already "in the field," as well as cooperative and group-farmer schemes (as in Malawi), for promoting loans and deposits in order to reduce their costs of operations.

Table 4.1 Salient features of major cropping zones, 1976-80

Main staple	Predominant agro-climatic zone(s)	Agricultural population per hectare crop land	Value of agriculture production per hectare of crop land (dollars)[a]	Arable land reserves
Starchy roots	Humid tropical	1.6	260	Abundant
Rice	Humid tropical and humid temperate	3.5	640	Moderately abundant
Maize	Subhumid tropical	1.1	450	Abundant
Sorghum/millet	Semiarid tropical	1.6	170	Moderately abundant
Wheat	Temperate/Mediterranean	1.0	440	Scarce
Mixed (India)	Warm temperate and arid to humid tropical	2.5	350	Very scarce
Mixed (China)	Cold temperate to subhumid tropical	5.8	1,040	Very scarce

a. Average 1974-76 world market prices.

Table 4.2 Reserves of arable land in 91 developing countries, 1975

Category	Percentage of potential arable land under cultivation	Percentage of population	Number of countries
Very scarce	>90	65	19
Scarce	70-90	10	24
Moderately abundant	40-70	14	22
Abundant	<40	11	26
Total	40-50	100	91

Source: FAO

Box 4.1 The Green Revolution in Punjab

The Indian State of Punjab, located on the semi-arid, drought-prone Indo-Gangetic Plain, emerged from the colonial period with extensive irrigation infrastructure and good transportation facilities. It had a prosperous and progressive farming community, but with the exception of canal water virtually no cash inputs were used. During the 1950s and early 1960s, Punjabi farmers started the transformation process from traditional to commercialized agriculture. Output rose steadily and increasing -- though still low -- amounts of fertilizer were applied to the fields. Wheat, the most important crop, was grown on 30 percent of the area.

The first high-yielding wheat variety was released in 1966. This variety responded well to fertilizer and irrigation. The farmers quickly realized that by adopting the new variety they could roughly double their yield. Just three years later, more than two-thirds of the wheat area was planted with high-yielding varieties, and the average yield increased from 1.4 tons to 2.2 tons per hectare in 1969/70.

This initial innovation set off a chain of effects that led to a virtual transformation of Punjab agriculture in only six years, between 1966 and 1972:

- Farm incomes rose, leading to an even more rapid increase in rural savings.
- Most of the savings were invested in productive assets, and the number of private tubewells increased sixfold and tractors fourfold.
- The higher profitability of wheat lead to a partial replacement of lower value crops and the increased availability of irrigation enabled cultivation of land that previously had been left fallow in the dry season. As a result, the wheat area increased 50 percent.

- Fertilizer consumption increased sixfold.
- The success with wheat made farmers eager to adopt high-yielding varieties of other crops and, together with increased input use, this lead to a virtual doubling of gross farm incomes in just six years.

After the initial spurt, wheat production was stagnant in the first half of the 1970s, partly because of disease problems. New disease-resistant wheat varieties became available in the mid-1970s and production growth resumed. However, at that time other crops had replaced wheat as the engine of growth. Both the area and yield of rice, potatoes, and some other nontraditional crops expanded rapidly and sustained agricultural growth.

[TWO BOX FIGURES:]

Although larger farmers adopted the new technology first, small farmers and tenants soon followed. Today there is little difference in their cultivation practices. The traditional crop-sharing arrangements for tenants is gradually being replaced by fixed rents paid in cash.

The rapidly expanding farm incomes meant a boom for small-scale industries and service establishments. Many of landless agricultural laborers moved into nonfarm activities. Over the last two decades, per capita incomes have been growing at an annual rate of 3 to 3.5 percent.

A number of factors contributed to the Punjabi success. Most prominent was the extensive canal system and the good groundwater resources that could be exploited at a relatively modest cost. Prices were generally maintained at a level that provided ample incentives to farmers to adopt new practices. Government investments in supporting infrastructure -- roads, markets, and rural electrification -- enabled the farmers to take advantage of the new opportunities. The local research establishment developed an ever-increasing number of improved varieties of wheat, rice, potatoes, cotton, and other crops.

Box 4.2 Fuelwood in the Sahel

In the arid Sahel (Chad, Mali, Upper Volta, Niger, Senegal, Mauritania and parts of Nigeria, Cameroon, and Sudan), forests supply fuelwood and construction materials for home heating, cooking, and housing and are used for grazing. The forest cover is habitat for farmer and flora, and influences climate and environment.

Traditionally, forests provided the basis for relatively stable agrosilvicultural systems of farming of great antiquity. But in recent years, after expotential population growth and the extension of farming and grazing areas, the forest cover is being decimated. Each person uses about a kilogram of drywood a day; this far exceedes the resources of local forests, which are regenerating slowly, if at all.

Owing to the ever-increasing deforestation, rural household members have to walk farther and farther to collect fuelwood and the average urban household spend an increasing part of the budget to buy fuelwood. In some Sahelian towns, it often "costs more to heat a pot than to fill it" and in some rural areas, almost half of a family's working time is spent on gathering fuelwood. If present trends continue, Sahel's depleted forestry resources will be wiped out in a few decades, sooner around urban areas. By its nature, the problem is accelerating, and, unless remedial action is taken soon the forest capital may become irretrievable.

By the year 2000, most of the Sahelian countries, will have to reduce their projected fuelwood consumption by more than half to maintain a minimum of essential forest cover. The available means range from the introduction of new eating habits, requiring less fuel for cooking and more efficient ways of cooking such as improved wood burning stoves to increasing use of substitutes like crop and animal residues and commercial fuels.

GC5-fuelwood(PL/KAL-05/11/82)

Most Sahelian countries have less than 800 millimeters of rainfall, erratic at that. The technical constraints on forestry development are thus formidable. However, the problem is mostly economic and political. Forests are generally publicly owned which leads to a divergence between private and public costs and benefits of conservation. Short term private needs, such as for fuelwood, livestock grazing and crop cultivation, frequently outweigh the long term public interest of preserving forests. Thus, it is difficult to secure the cooperation and participation of local people in conservation or reafforestation programs. Because of the problems of balancing individual and community interests, government policy tends to be ambivalent, at best. As a result, the impact of many past forestry programs has been disappointing.

Nevertheless, following the last severe drought, the Bank and other donor agencies have started to assist the Sahelian countries in financing forestry projects. Most of these projects, designed as pilot and technical assistance projects, were initiated in a relatively short period of time in the late 1970s. They are largely based on classic techniques for guineo-sudanian natural forest management and reafforestation. They mainly aim at strengthening the forest institutions, providing them with the means to improve their training, planning, managerial and operational capability instead of focusing immediately on increasing production of forest products.

Regardless of the results of this first generation of forestry projects, the disruption to the Sahelian ecosystem remain formidable. It is so great that it would be extremely ambitious, if not utopic, to try to solve the fuelwood crisis in the Sahel with such projects along. Therefore, critical review is needed of existing technical packages for arid-zone forestry, and a redefinition of objectives and strengthening of public forestry policy.

Box 4.3 Crop innovations and investments: flood control in Bangladesh

Population pressure has led to permanent settlement and cultivation on flood plains. Agricultural practices have been adapted to the seasonal pattern of flooding so that damage occurs only after long and unusually heavy rainfalls. However, in flat valleys of the Brahmaputra, Ganges and Meghna rivers in Bangladesh even "normal" rains cause flooding owing to poor natural drainage.

Historically, the silt laden waters were regarded as a blessing, giving Bangladesh the reputation as one of the most fertile areas in the world. Today, with increased population pressure, these floods severely constrain agricultural production.

Snow melting from the Himalayas combined with rainfall runoff from the upper catchments swells the three major rivers early in the monsoon season. Adjoining rivers rise rapidly and block natural drainage outlets. Local rainfall, ponded instead of running off, thus floods most of the area. Only narrow belts are flooded directly by spill-over from the larger rivers.

Every year floods put more than half the paddy fields under at least 30 centimeters of water which is the upper limit for high yielding varieties of rice. Not even much of the area with shallower water is ideally suited for modern varieties, that do best under 5 to 15 cm of water. The three-tenths of the cultivable land that floods to a depth of 30 to 100 cm can be planted only with the traditional varieties. The low-yielding, rangy stalks of floating rice can be grown on one-tenth of the area, where the water is 1-5 meters deep. No crop can be grown on the remaining tenth of the land during the monsoon season.

The first high-yielding rice varieties for cultivation in the rainy season were released in 1970. Until then, it had been assumed that the best way of

expanding the monsoon rice crop was to build major flood protection works that would reduce the water depth to less than a meter. But these works were costly, time-consuming, difficult to design, and rarely economical.

With the new rice technology, small and easily built flood-control and drainage projects in shallow-water areas offer the best chance of quick increases in rice production during the monsoon crop. Once flood depths can be limited to 30 cm or less, farmers are likely to switch to short-stalk, high-yield rice varieties. Low investment costs and short construction periods mean high rates of return.

After achieving flood control, the risk of water stress will likely be the main constraint on production. Thus, in the longer term, irrigation -- together with flood control and drainage -- will play a major role in increasing rice production during the monsoon.

The Bangladesh case illustrates a few key features of most Green Revolution crops:

- High-yielding varieties are usually suitable only for limited areas with good agroclimatic conditions.
- New crop technology tends to increase returns on investments in land improvements.
- The design of land improvement projects is a function of the available agricultural technology; technological innovations induce changes in investment programs.

Box 4.4 New frontiers in agricultural science

Plant improvement is an ancient art. All but one of the thousands of plants mankind uses today worldwide were all selected before the dawn of written history. And anyone who doubts the power of the results achieved by unorganized plant selection for improvement should visit the Archeological Museum in Mexico. It contains a prehistoric maize "cob" recovered when excavating the Torre Latinoamericana. The "cob" looks more like the head on a blade of pasture grass than what we today know as maize, and almost all of that plant improvement occurred without the benefit of a scientific breeding program.

Until recently, "modern" plant breeding meant large-scale field crosses and selections designed to obtain specific characteristics. These have led to the Green Revolution and have enabled natural rubber producers to keep up with synthetics in cost cutting. Today, at the outer edge of plant breeding, scientists in laboratories, not fields, are fiddling with the genetic structure of plants, using knowledge about intra-cellular physics and chemistry that were completely unknown 25 years ago -- knowledge that is being added to at an extraordinary rate. Significant amounts of public money are supporting such research in several developed countries but, even more striking, even larger amounts of private money are being invested, especially in the USA, in ventures to support microbiologists in such research.

What are the prospects that micro-biological plant (and animal) "breeding" will produce products that the world will buy, -- that they will revolutionize world farming and stock-raising? Of course, we don't know. But from what we know and don't know about plant and animal molecular biology and techniques of deoxyribonucleic acid (DNA) manipulation, it is possible to take some educated guesses.

Scientists using recombinant DNA techniques can do amazing things with bacteria and, to a lesser extent, with yeasts. In some instances, they have been able to introduce genetic material from one higher plant into another of another species, and have it stay there, get integrated into the host plant, and not kill the host.

While theoretical prospects from such manipulation are great, microbiological plant improvement is very much in its infancy. The main obstacle to progress is our extremely limited understanding. We are still far from understanding the genetics of simple bacteria; our knowledge of the genetics of vastly-more-complicated higher plants (and animals) is rudimentary. Until genetic structures and processes are much better understood, "wide" crosses -- introducing genetic material other than that from a closely related variety of the same species -- are likely to be very close to random shots in the dark. They will vastly widen the scope of genetic material available for crossing. However, all but an infinitessimal percentage of random mutations are lethal or, if not lethal, sterile.

Using microbiological techniques, German scientists have crossed a potato and a tomato -- closely related plants, but different species. That is still a long way from a new miracle plant, however. The pomato is viable, but sterile. Its root is not as nice to eat as the potato, and it bears no fruit like the tomato. Until our understanding of genetic processes improves quite a bit (and it is improving rapidly), the pomato is likely to be typical of our efforts to breed miracle plants with microbiological techniques.

Short of whole new plants, there is a wide and impressive range of functions microbiology can start performing today. For instance, once a superior plant is bred by conventional methods, stabilizing a line that will breed true, rather than reverting to the characteristics of its parents, can

be difficult and time consuming. Microbiologists have recently persuaded an improved asparagus plant that they could not induce to breed true to replicate its own sex cells, thereby giving it uniform genetic characteristics on both its male and female sides and guaranteeing the inheritance of its characteristics by its progeny. Microbiologists are already able to get bacteria (and perhaps yeasts) to produce protein substances in culture that were formerly hard to produce by other means.

Such microbiological manipulation is definitely most advanced where our knowledge of plant genetics is best, -- in uni-cellular organisms. This sub-field may very well produce the first innovation useful to millions of farmers. Next to water, the most important ingredient of plants (and animals) is nitrogen, which cannot be absorbed in its abundant, atmospheric form but only if it has been "fixed" into organic compounds.

In the most important process of natural nitrogen fixation, Rhizobia bacteria "infect" the roots of legumes and a few other plants and establish a symbiotic relationship with them. Some of the nitrogen fixed by the rhizobia is used by the legumes; some is left in the soil. Improving the efficiency of this process in legumes, and/or finding ways to induce the same symbiotic relationship between rhizobia and other plants useful to man could relieve the world's second most important constraint to plant growth. The International Network of Legume Inoculation Trials (INLIT), coordinated by NifTAL (Maximizing Symbiotic Fixation of Nitrogen by Grain and Forage Legumes in the Tropics, named for nif, the gene which carries the nitrogen fixing trait) in Hawaii, is attempting to find rhizobia that are superior nitrogen fixers and to propagate and diffuse them. Work along these lines is now proceeding at a large number of cooperating institutions around the world. Scientists in Wisconsin, USA, recently isolated a rhizobium strain that was distinctly

superior to normal strains in fixing nitrogen when associated with soybeans, only to find that the "improved" rhizobia were unable to compete with the normal ones in field survival. The failure of such work to produce innovations profitable at the farm level so far should not obscure the fact that research shows every promise of leading to cheap ways to expand legume-rhizobium nitrogen fixation.

A nitrogen-fixation could have a major effect on crop yields of small farmers remote from world markets and for whom well over half of the price factory-produced of fertilizer at farm gate is transport and handling. These farmers, characteristically in sub-Saharan Africa and in remote corners of Asia and Latin America, are usually precisely the ones whom most recent "green revolutions" and other changes in farming systems have passed by.

These examples do not prove that agriculture will avoid being replaced entirely by industrial production. They do prove, however, that modern science can work together with and can be integrated into farming and animal husbandry. The result is a more scientific agriculture, more dependent on other sectors, but also better able to compete with industrial substitutes. But the "new frontiers" research is virtualized monopolized by the developed market economies. Should the developing countries be investing in such research themselves? And whether they do or not, are there ways to assure that their problems will be tackled and their interests taken into account?

Box 4.5 New cropping packages: lessons from northern Nigeria

Change in agriculture -- at any level of development -- requires farmers to adopt new crops and varieties, begin or expand the use of such modern inputs as fertilizers, pesticides, insecticides, and herbicides, and take up new or different ways of doing things.

Farmers' attitudes toward change are quite different in different parts of the world, in different countries, and even in different communities in the same part of a country. Sometimes farmers refuse to try new varieties and input packages, despite glowing and well-publicized test results. Others try them out but soon go back to their old ways. Occasionally, innovation and adoption occur almost spontaneously, with little official support or promotion. Rarely does the adoption process unfold according to the planners' schedule. Why, then, do farmers respond to change in so many ways?

Answers were sought in recently completed World Bank research projects in northern Nigeria. The projects, in the impoverished, traditional farming areas of Funtua, Gusau, and Gombe were initiated in 1974/75 to introduce new varieties and cropping systems and to increase the use of chemicals. Research had identified several packages of varieties, inputs, and techniques for maize, sorghum, groundnuts and cotton, and a lively extension campaign promoted them. The 80,000 farmers adopted the packages selectively:

- The smallest land-poor, labor-rich farmers would try something new only after seeing first to their basic subsistence needs of the staples maize, millet, and cowpeas. In addition, most of them could ill afford the fertilizers and insecticides recommended in the packages.

- Medium-sized farms, with enough land to meet their own needs and a little left over for experiments, were more responsive than the first group,

but still cautious. Most of them adopted the packages only after seeing results with their own eyes at a local demonstration plot. This is a common reaction among illiterate farmers and has important implications for extension progrms.

- The larger farmers, who either had enough land to ensure an adequate income or had off-farm employment, were the most receptive to innovation. Nearly all of those surveyed adopted the improved cultivation packages -- with a significant exception: Cotton was rejected by virtually all farmers because it was less profitable than other crops.

- Recommended practices that are divisible and continuous, rather than discrete, are most likely to be accepted. For example, fertilizer can be applied in various strengths. The farmers experimented until they were satistifed that they had found the optimal economic level for the ecological environment of their farms.

Box 4.6 The international agricultural research centers

The present system of internationally funded centers located mainly in developing countries grew out of a joint crop-improvement program by Mexico's Department of Agriculure and the Rockefeller Foundation. In 1943 a team of Mexican and US scientists began a systematic effort to devlop superior varieties of maize and wheat. Encouraged by the success of this venture, the Rockefeller and Ford Foundations joined forces in the first truly international agricultural research center, the International Rice Research Institute (IRRI), established in 1960. The Mexican crop programs were reconstituted in 1966 on the IRRI model as the Centro International de Mejoramiento de Maiz y Trigo (CIMMYT). The international centers and programs now number 13.

The Consultative Group on International Agricultural Research (CGIAR) was established in 1971 as an informal association of countries, multilateral organizations and private foundations to support and expand research addressed to agricultural problems common to many developing counries and designed to improve their food production. In addition to the Chairman and Secretariat provided by the World Bank, the Group has an advisory panel, the Technical Advisory Committee (TAC), whose secretariat is provided by the FAO. The TAC is made up of 13 distinguished agricultural and social scientists, drawn about equally from developed and developing countries.

The activities supported by the CGIAR are mainly research and training programs which concentrate on increasing the production and stability of yield of foodcrops cultivated throughout the developing world, but they also include research into animal production systems and diseases of livestock, the conservation and utilization of plant genetic resources, food policy research and assistnce to strengthen national agricultural research systems.

Many of the CGIAR-supported programs are designed to meet the needs of the poorest and most disadvantaged farmers. Some of them have already made significant contribtuiuons toward increasing food production in developing countries.

Funding for the international programs increased sixfold between 1972 and 1980. However, in the last couple of years donor contribution shave grown relatively slowly (to US$150 million) which, continued with exchange rate changes and high rates of inflation, has caused most centers to cut back their activities. This has severe constraints on the centers and affected their effectiveness at a time when the demand for their services is increasing rapidly.

Box 4.7 Decision making on the African farm

Cotton planting in northern Uganda should start by mid-April and be completed within two months, according to test results showing a steep decline in yield per hectare the longer planting is delayed. Yet farmers consistently plant three-quarters of their crop in June and July and spread planting over at least four months.

Groundnut growers in the Gambia ignore advice that early planting saves on weeding later. In Nigeria and throughout Africa, smallholders still intercrop, despite recommendations to plant crops in pure stands to raise yields.

These may sound like examples of economic irrationality, but evidence abounds that African smallholders, on the contrary, are quick to grasp economic opportunity. This seeming contradiction can be explained:

- Because hail storms hit northern Uganda at harvest time, growers spread out the planting season and reduce the risk of ruin. More important, spreading out the planting season enables farmers to avoid competing for labor needed for millet and other crops. Millet is not only the preferred family food but is also commonly used in part-payment of the cottonworkers' wages. After the millet harvest, some plots can be planted late with cotton and time can then be saved on weeding and harvesting. Ignoring the early-planting advice and spreading their labor thus allows northern Ugandan farmers to grow more cotton at lower cost while also securing supplies of their staple food.

Gambian groundnut farmers plant late to avoid competing for labor with millet growers. Although a late crop needs more labor for weeding, wages at this relatively slack time of year are lower. There is also evidence that intercropping is a rational technique.

• In Nigeria, a crop mixture gave 60 percent higher gross returns per hectare then pure stands. It also improved returns on labor in peak periods by more than 25 percent, despite an overall greater labor input.

African farmers in these three countries, irrespective of their small resources and output, make production decisions in much the same way as larger operators. They respond rapidly to changing resource availability, constraints, and incentives and balance available resources to reach multiple (often comflicting) objectives (Figure ____). In fact, considerations that would be of minor importance on large farms often assume great importance on small ones, owing to the close interrelations between farm and household decisions and their limited resources.

[FIGURE ____]

Box 4.8 The yield gap and the agricultural extension services

Farmers in developing countries rarely get anything close to the record yields achieved by industrial economies or under highly controlled research conditions. Common sense and circumstances outside their control, not lack of skill or initiative on the part of farmers, explain most of this gap in yield. In many cases, it simply would not pay farmers to buy inputs that might help improve yields. The table shows the extent of the yield gap.

Crop	Developing countries		Industrial economies		World
	Average	Highest	Average	Highest [a]	Research record
	tons per hectare, 1976-80				(tons per hectare)
Rice	2.55	6.19	5.34	6.07	14.4
Wheat	1.63	4.28	2.06	5.87	14.5
Maize	1.87	5.18	5.67	7.75	21.2
Sorghum	1.22	3.12	3.23	4.75	21.5

a. Only countries with more than 10,000 ha under the crop are included.

What, then, is the nature of the yield gaps identified? The figure illustrates some of the factirs explaining the difference between resarch station and farmers´ yields´.

[FIGURE: THE ORIGINS OF YIELD GAP]

The technical ceiling, farmers´ maiximum potential yield is lower than the yield achieved under highly controlled research conditions, partly because the scientists may be using technologies that are not feasible on a production scale.

More important, however, are the environmental differnces. Reasearch stations, for example, are usually located on the best land and can depend on irrigation, if needed. The farmers´ environment is rarely as propitious.

The bottom line for a farm, like any other business, is profit. Because of diminishing returns, farm profits are usually highest at input levels lower than those necessary for maximum yields. The economic ceiling is thus usually much lower than the technical ceiling.

Most farmers' yields are still below the economic ceiling but, with the right combination of inputs, they might be able to improve their output at a profit. But, all too frequently, neither researchers nor extension agents can help them figure out the right mix. In addition, key inputs like fertilizer, water, and labor might not be available when needed. Much of the risk of farming, from such factors as volatile output prices and unreliable rainfall, might force the farmer into a "safety-first" strategy.

The relative magnitude of the each part of the yield gaps profoundly affects development strategy. Closing a large gap between the technical ceiling and research yields due to environmental differences demands either investments (like flood control, land development, or irrigation) or research to develop crop varieties and farming practices suited to conditions in the farmers' fields. A large gap between the technical and economic ceilings calls for a review of price policies and improved market access for farmers. If farmers' yields are far below the economic ceiling, solutions might be strengthening the agricultural extension service, streamlining the input-supply and credit systems, or creating a crop insurance scheme.

It is thus clear that extension can help close only a small part of the yield gap. Worldwide experience indicate that the agricultural extension service will have the greatest impact if:

- a profitable, risk-free or low-risk technology exists that is unknown to farmers

- key inputs such as fertilizer and quality-seed -- are available at the right time
- the farmers have ready access to markets for the additional produce.

Lacking these conditions, government would probably do more good for farmers by assuring proper price incentives and spending its resources on applied agricultural research and improvements in input-supply and marketing systems.

Box 4.9 The Indian seed industry

Getting quality seeds -- on time -- to 70 million farmers is a formidable undertaking but the Indian seed industry is rising to the challenge. From an infant two decades ago it has grown into a giant comprising one national and a dozen state-owned seed corporations and some 300 private companies that produce seeds that are distributed through a network of 10,000 dealers. The growth has been neither smooth nor easy. The India experience well illustrates the problems faced by both private and public sectors when agriculture is rapidly transformed.

Before the Green Revolution, most farmers kept part of their crops for the next year's seed. Occasionally they obtained new seed, produced and distributed by the state agricultural department. A few private companies produced vegetable and flower seeds. When the first hybrid maize varieties were released in 1961, India's agricultural planners saw that the seed industry needed to be strengthened. The National Seeds Corporation was formed in 1963 and started to produce foundation seed. The creation of private seed companies was encouraged and a number of them were given the opportunity to buy imported seed-processing equipment on a line-purchase basis.

With the release of a range of hybrid and high-yielding varieties of a broad range of crops in the middle 1960s, the demand for quality seed exploded. With the private seed industry still in an embryonic stage, public-sector seed multiplication was stepped up through state agricultural departments and local governments. The establishment of state seed corporations followed.

Swept along in the process of rapid expansion, the public seed-production system became overextended. Quality declined, and financial losses were

incurred. The private companies were given last priority in the allocation of foundation seed. Serious doubts arose in the minds of the entrepreneurs about their role on the long-term development of the Indian seed industry.

Most private companies managed to maintain their standards of quality and, as a result, a preference for certain brands evolved among farmers.

In response to the declining quality and the private sector difficulties obtaining foundation seed, the seed certification agency in the state of Maharashtra took a bold step in 1975 and authorized a few seed enterprises to produce their own foundation seed. This decision has gone a long way to facilitate a continuous supply of quality foundation and certified seed to the farmers. This also expedited the development and popularization of new varieties.

Only recently have farmers -- as well as dealers and distributors -- become accustomed to the idea and reality of seed marketed through these channels. In the early days, seed companies tried hard to promote their products by demonstrations. Private retailers and cooperative societies were greatly encouraged by these companies to handle seeds by offering them on consignment. All unsold seed was the responsibility of the seed companies. However, the situation quickly changed. Once the farmer and the dealer realized the value of the hybrid seed, more and more dealers and distributors came forward to handle marketing.

Today seed in India is being distributed by a network of more than 10,000 seed dealers, covering the length and breadth of the nation. The farmer has become quality conscious and associates certain brands with quality. It is now a recognized fact that it is not the price of the seed that really matters but the adaptability, its quality and the productivity of the variety.

As private seed enterprises prospered, they became committed to genetic research which has resulted in better hybrids of sorghum, millets, cotton, maize and some vegetables. The search for new varieties has been extended to cover other crops like sunflower, safflower, and pigeon peas, as well. However, cooperating more closely with the public-sector research establishment, the private entrepreneur could clearly play a still more dynamic role in breeding and producing better and higher-yielding seeds.

Box 4.10 Milk: India's "White Revolution"

Not surprisingly, dairying is an important activity in India, a country with over 240 million cattle and buffalo. In rural areas, dairying supplies between 10 and 25 percent of household income.

Traditionally, milk not kept for home use as ghee (a cooking fat) has been marketed through a much abused system of local middlemen. Since the early 1970s, however, dairying has been swept by a "White Revolution" similar in economic and social impact to the Green Revolution in foodgrain production.

The White Revolution began some 30 years ago as the Anand dairy producers cooperative in Gujarat State. Assisted by the World Food Program, the European Economic Community, and IDA, this cooperative grew into a grassroots movement in most other Indian states. More than 10,000 dairy cooperatives, claiming a membership of 3 million to 4 million families, process 2.2 million to 2.7 million liters of milk a day. By the late 1980s, 8 million liters of milk daily will flow through these and a projected 30,000 new cooperatives. The cooperatives on the Anand model, form an integrated network of milk production and marketing. Local cooperatives are set up under uniform bylaws by trained spearhead teams. Local producers buy shares in the cooperatives and its members elect officials annually.

The National Dairy Development Board provides technical coordination, and the India Dairy Corportion handles financial assistnce. Both organizations are semi-autonomous governmental agencies.

Every member of a cooperative has access to technical assistnce. The package includes emergency and weekly veterinary services, artificial insemination by selected studs, concentrated fees made from agricultural by-products, and high-yielding fodder-crop seeds.

The major changes brought about by the cooperative dairy movement may be social rather than economic. The cooperatives collect and pool milk from all members, and all members are eligible for office, regardless of caste or social status. Since women are the traditional caretakers of livestock and the recipients of income from milk sales, the focus on milk production by rural households has enhanced their status and well-being. Social patterns have been transformed in many villages.

Dairy cooperatives have also benefited the very poor, who, though landless, usually own one or two cows or buffalos. Giving all producers a fair price and reliable outlets for their milk and the technical wherewithall to increase production has helped raise rural income, and diets have improved. Payments are prompt. Milk is collected from the cooperatives twice a day, and payment usually follows within 12 hours. Competition between man and beast for food has also been reduced.

Giving producers ownership and control over the entire production, processing, and marketing network has helped rural producers take control of their future. Success or failure depends on the integrated efforts of members within the organization.

Why this cooperative venture has worked when many others have failed is anybody's guess. Some of its characteristic features do seem to have helped shape its success:

- A dedicated leadership and well-trained staff subscribe to the same principle of service to the rural poor.
- The organizational system vigorously enforces accountability.
- The commodity, milk, is highly valued, perishable, and easily shipped, processed, and marketed in large volumes, which allows economies of scale to be realized.

- A well-publicized, suitable technical service package is offered to all members.

- International aid has been judiciously used to help build the dairying industry, not to depress producer prices.

The Indian dairy cooperative movement has proven that cooperatives can help relieve rural poverty, if thoughtfully organized, tightly run, and tailor-made to the needs of its rural participants.

CHAPTER 6

Chapter 6 Prospects and policies for accelerated agricultural development

Continuing progress in agriculture is of vital importance to the developing world for several reasons:

- Close to two-thirds of the population gains its livelihood from agriculture as farmers and farm workers. These groups include the vast majority of the world's poorest people. Some middle-income economies are now at or close to a turning point beyond which a more rapid increase in labor productivity and earnings in agriculture can be stimulated by dynamic growth and fast labor absorption elsewhere. But in most instances, increased employment opportunities must still be sought in agriculture itself, reflecting past and current population growth trends and, in low-income economies, the small absolute size of the nonagricultural sector. To increase farm and rural earnings under these conditions will require fast agricultural growth.

- Driven by population and income growth, the demand for food in the developing economies is likely to increase by at least a third over the next decade. Progress in raising incomes more rapidly than in the past among lower income groups and in low-income economies could sharply increase these demands. Currently only about 8 percent of the food consumed and 9 per ent of all agricultural products in developing countries is supplied by food. Few countries can afford to see these ratios increase rapidly without encountering severe balance-of-payments problems. Moreover, as long as the supply-demand balance is no more than barely adequate to maintain low levels of consumption nationwide, the poor will continue to be severely affected by short-run fluctuations.

• Agricultural exports accounted for 30 percent of total merchandise trade export earnings in the late 1970s. Agricultural exports are still the main category of exports for over two-thirds of developing countries. Export earnings finance imports needed for faster growth, and good export performance enhances access to international capital markets. The review of prospects of Chapters 1 and 2 suggest that the current depression in international trade will continue over at least the short term. Nevertheless, the changing structure of the world economy and the emergence of new centers of growth have created new opportunities for agricultural exporters, especially in quality foods and feedgrains. Rapid agricultural development coupled with policies that encourage specialization, would permit a larger number of developing countries to participate in this trade.

• Finally, structural interdependence and complementarity between agriculture and other sectors suggest that weak performance in agriculture will be accompanied by weak growth elsewhere in the economy. This is most important in the low-income, predominantly rural economies but the evidence reviewed in Chapter 3 suggests strong linkage effects over a wide range of country conditions. Among the more vivid demonstrations is the experience of most sub-Saharan African countries in the 1970s, where a poor agricultural performance contributed heavily to an economy-wide deterioration. In contrast, over the same period, growth rates in some of the South Asian low-income economies increased -- though at modest rates -- with a more rapid growth in agriculture, providing an economy-wide stimulus.

6.2. These arguments constitute a powerful case for giving close attention to agriculture as part of a balanced program to achieve sustained growth and a broad diffusion of its benefits.

Possible scenarios for agricultural growth

6.3. Several attempts have been made to assess feasible growth rates in agriculture and to identify the main constraints in the process. The most recent and comprehensive efforts are those of the Food and Agriculture Organization (FAO) presented in Agriculture: Toward 2000, (1981). Two different scenarios were studied for 90 developing countries (China was the only major economy not included): Scenario B projects an overall growth rate of 3.1 percent a year based on a continuation of past trends for most regions, significant improvement for Africa and other low income areas, and Scenario A gives an example of what might have to be done to reach an overall agricultural growth rate of 3.7 percent. This increased output would allow developing countries to regain their export surplus in agriculture as well as feed more people better. By the year 2000, FAO calculates that undernutrition would affect only 240 million people under Scenario A, rather than 390 million under Scenario B (compared to an estimated 415 million in 1975). Achievement of Scenario A depends on three conditions:

- higher increases in per capita incomes
- higher levels of investment in agriculture
- a more favorable policy environment for agricultural development

to provide better incentives and to speed the adoption of new technology.

6.4. Income growth prospects. The FAO study links its agricultural projections to developing-country GDP growth rates between 1980 and the year 2000: 5.7 percent in Scenario B, and 7.0 percent in Scenario A, as compared to 5.9 percent in 1960-70 and 5.1 percent in 1970-80 yearly. Scenario B is in line with current World Bank High Case growth prospects for the 1980s.

6.5. Higher investment. FAO considered each of the major supply response factors in detail -- land, irrigation, seed and livestock improvements, input

supply, and technology. It found that land and technology would not be important limiting factors for the developing countries as a group, although limits on supply response in individual countries would give rise to increasing trade flows between them. FAO argues that the investment opportunities exist -- in irrigation, land development, training, research, fertilizer, storage, etc. -- but they require large sums. Measured in 1975 prices the annual gross investment requirement in 1990 would be $69 billion for Scenario B and $89 billion for Scenario A. Using the FAO's physical estimates of new capital needed, the International Food Policy Research Institute (IFPRI) estimated the external capital flows likely to be needed to supplement domestic resouorces. The calculations show that by 1990 the annual flow of external capital would need to increase to about $12 billion (1975 prices). This about double the 1980 level of aid commitments to agriculture, when the latter are also measured in 1975 prices.

6.6. Their estimates were made some time ago, when projections of energy prices and capital costs were lower than now seems plausible. Moreover, it does not seem likely that aid to agriculture would double by 1990, if present donor policies and attitudes persist. So achieving FAO's Scenario A estimate of 3.7 percent yearly growth may not be very likely. In the view of some other observers, achieving the modest goals of Scenario B looks less plausible in today's world as well.

6.7. Yet this is not the end of the story. In this Report the policy determinants of performance have been emphasized with regard both to the economy-wide prospects and to prospects in agriculture. In particular, there is considerable evidence from the country experience of agricultural development to support propositions along the following lines:

• Many developing countries have as yet scarcely begun to tap the true potentials of their most valuable human resource -- the skills, dynamism and entrepreneurial vigor of their farming communities.

• The considerable investments already made in agricultural development by the public and private sectors can, in many instances, be much better utilized to increase output and efficiency.

• And finally, where the policy framework is stimulative and supportive, there are likely to be many opportunities for new investments in agriculture that farmers themselves will save for and invest in. These investments are likely to show high economic and social returns.

6.8. Potentials are of course intimately related to the agroclimatic factors and physical resource endowment, to the current state of development in agriculture and its supportive institutions, and to the policy framework as it is inherited from the past. These factors comprise a blend of constraints and opportunities that is unique to each country, and some among them cannot be changed, even in the longer term. The international environment for trade, industrial-economy policies affecting protectionism and aid, are also beyond the control of strategists in the developing country. So it is sensible to be cautious about projecting any sizeable deviation in growth performance because of radical policy change for whole groups of countries. But much can be done in particular cases, even agroclimatically unpromising ones, by policymakers who are determined enough to take and sustain the corrective actions.

Domestic incentive and investment policies

6.9. Incentive and investment policies, together with the development and promotion of improved technology are pivotal in the search for better performance in agriculture. Incentives are not just a question of price policy: lack of access to resources, due to various market imperfections,

also weighs heavily on farmers, particularly the small ones. But remunerative prices do afford an incentive to every farmer who markets produce -- the overwhelming majority in todays world, even in the low-income economies.

6.10. In many instances, significant inefficiency and hidden forms of income transfer occur as by-products of the practical difficulties that countries encounter in efforts to regulate prices. Because some crops and markets are effectively regulated while others are not, or only partially so, unintended and essentially arbitrary price differentials can result. In most farming systems, the multiple possibilities of substituting one or more crops for others facilitates supply adjustment -- from an economy-wide perspective often maladjustment -- to such price vagaries.

6.11. It is more difficult to measure price policy impacts on the aggregate growth of agricultural production since prices are one among many influences. But it is widely agreed that insufficient producer incentives are an important factor behind the disappointing growth of African agriculture in recent years and in countries as diverse as Algeria, Argentina and Burma at various times, past and present. Experience in China, following recent reforms that were designed largely to improve producer incentives and incomes, suggests that a short run supply response can be substantial (Box 6.1). Over the longer term, a reduced level of on-farm investment by farmer-entrepreneurs is perhaps the most pervasive impacts of low producer prices, since they inhibit both the ability to save and the willingness to use savings in agriculture.

[BOX 6.1 RECOGNITION INCENTIVES IN CHINESE AGRICULTURE]

6.12. Recognition and understanding of problems flowing from adverse producer incentives have become widespread in recent years. Dealing with them, though, presents considerable difficulties, in part because the problems

themselves often arise through conflicting policy objectives. Three types are especially common:

- Low producer prices sometimes reflect a heavy rate of commodity taxation, usually of export crops. This is particularly prevalent in the African economies where such taxes reflect the strong desires for more public revenue to finance an array of services, including health, education, and basic infrastructure, all of which have been more lacking in Africa than elsewhere. Without the necessary institutional structures and administration to tap alternative sources of revenues fully, most governments have had little choice but to tax these most accessible sources of revenue. But are these so burdensome that tax yields could be raised by stimulating production through lower marginal rates? Declining shares in commodity trade suffered by some of the countries that impose heavy export taxes suggests a considerable scope for tax reform to improve producer incentives.

- A class of price problems that concern a broader range of countries is centered on food crops. Over time the regulation of agricultural prices tends to evolve from limited objectives into a more general adjudication of rural producer and urban consumer interests. In many instances, urban interests are favored. Sometimes governments find themselves becoming trapped into the financing of extensive subsidy programs in efforts to meet the interests of both groups. As described in Chapter 5, subsidy programs can grow to account for as large as much as 20 percent of the total budget. Experience suggests that price adjustment carried out in a progressive and gradual way, in many cases over several years, is more likely to be accepted than the sharp 20 to 40 percent hike in food prices that some countries have -- usually unsuccessfully -- tried to impose. Targeting food subsidies to more narrowly defined, needy, groups is also a useful approach

where administrative capability permits the necessary institutional arrangements to be properly maintained. And concentrating subsidies on foods that are eaten mostly by the poor is a further possibility in some circumstances.

• A third incentive problem for agriculture involves what are often called "infant industries" -- a term that could be broadened to include "infant" institutions. In theory, such industries or institutions are to be promoted and protected through a phase over which management skills, worker productivity, and scale of operation are built to a level that thereafter enables self-sustained development. In practice the nurturing phase is sometimes long-lived and farmers are called upon to bear a large share of the extra costs associated with it. An industrial example would be infant fertilizer plants that combine an indifferent quality of product with high prices. More important though is an array of parastatal marketing and processing companies, whose inefficiency in meeting farmer needs and the high costs of operation can fairly be described as notorious in many instances.

6.13. Tackling the problems of parastatal inefficiency is often about as difficult as raising food prices to urban consumers. Yet the functions they perform are so important that governments would be well advised to take careful stock of the efficiency with which the services are provided, and at what cost. For countries where skilled and experienced commecial managers are particularly scarce, there may well be scope for enlarging the role of the private sector. Although there are successfully operated public enterprises affecting agriculture, there are also numerous examples where private or quasi-public institutions, operating under the profit motive with vastly smaller staffs, have quickly met the challenges and changing needs of both agricultural producers and consumers. Bangladesh has begun a move in this direction through reforms in its system of fertilizer distribution.

[BOX 6.2 INPUT SUPPLY AND PRIVATE INITIATIVE: THE BANGLADESH EXPERIENCE]

6.14. Incentive policy and investment are also intimately related because the farmers themselves will carry out much of the investment under a stimulative environment while inadequate incentives tend to mean that they have neither the means nor the motive for undertaking them. Sometimes therefore, as discussed in Chapter 3, governments have to step up public investments or provide special subsidies -- for example, in fertilizer -- to keep production expanding. Chapters 4 and 5 give reminders that government-sponsored schemes -- for example, in land development and settlement, and in large-scale irrigation and are often undertaken at high cost per beneficiary farm household so that a small minority of farmers can benefit from them.

6.15. Spreading the benefits of agricultural growth to larger numbers of the farming community is one of the major challenges in many developing economies. More investment in agriculture -- whether incentive-induced and undertaken by the farmer himself or by larger allocations to agriculture from the development budget -- is a part of the answer. From the point of view of society as a whole, there is a good deal of evidence that investing in agriculture brings attractive returns. But, as discussed in Chapter 4, another part of the answer lies in the scope to increase the returns still more, through better-designed schemes and through their efficient operation and maintenance. This problem becomes more pressing as the limits in low-cost sources of growth -- principally associated with an availability of good-quality land in a suitable agroclimatic environment — are reached in an increasing number of countries.

6.16. A few countries have reached their virtual limit on area expansion (China is the main example) and have had to turn to other forms of investment. Today, area expansion accounts for only about 30 percent of

agricultural growth and is concentrated in a few land-rich countries. Whereas land improvement in the form of leveling, flood, and erosion control and reductions in saline and acidic conditions are still viable options in many places, most countries have had to turn to investments which intensify the productivity of land through other means.

6.17. The most common means of intensification, and the one that has received more capital input than any other single source, is irrigation. Where rains are inadequate or poorly timed, irrigation has made barren lands productive and has permitted other areas to produce two or three crops a year instead of one. Over 50 percent of the agricultural output increase in the last 20 years has come from irrigated land, and investment in it continues to grow, having already reached $15 billion per year. Significant opportunities still exist in Asia and North Africa for further investments in large-scale irrigation, but given their costly nature, other options should also be explored. These are: improving the efficiency of existing systems through better management both at the system and farm level, promotion of less costly small-scale irrigation projects, and greater attention to rainfed areas (Box 6.3).

(BOX 6.3 RAINFED AGRICULTURE; THE MEXICAN EXPERIENCE)

6.18. In the past two decades, investments in agricultural research have probably had as great a payoff as investments in irrigation and for much less capital cost. The development and adoption of high-yield varieties in wheat, rice, and maize have transformed many agricultural economies and allowed some to become self-sufficient in these grains. Yields, particularly in irrigated areas, have doubled. Since the new varieties like other plants, do better with an assured water supply from irrigation, it is not possible to attribute the impressive output increases to the new varieties in isolation, but there

is substantial evidence that they are far superior to traditional varieties under similar conditions of irrigation or adequate rainfall.

6.19. The research results which have had the most impact have been confined to a few grains, to certain long-cycle cash crops, and to the husbandry and feeding technology of livestock. There remains potential for yield improvement in oilseeds, legumes, and starchy root crops in particular, and rainfed-grown crops in general. These cropping systems support hundreds of millions of small farmers, frequently with low productivity and earnings. These areas constitute new frontiers for agricultural research, and the growing attention being given them by both the international and national research centers is highly appropriate. Given the heterogeneity of local conditions, research results almost always have to adapted to the variations in soils, climate, and potential for changes in technology to specific areas, even within countries. International research, therefore, must be augmented by local research in close cooperation and interaction with the farmers themselves. There is much justification for additional investment in facilities and training programs to strengthen such national research programs.

6.20. Getting the policy scenario "right," improving the land base, investing in water resources, and providing improved varieties and techniques, may, however, not be sufficient to promote agricultural progress. This realization has prompted consideration of a host of other investment options for the rural sector. The resulting packages of investments sometimes include rural roads and transport facilities, marketing and input-supply infrastructures, storage facilities, mechanization, and even health care and educational facilities. The package, of course, always needs to be tuned to local needs, conditions, and constraints, making the design of agricultural

investments a complex and costly task, but one of exceeding importance (Box 6.4).

[BOX 6.4 COMPUTERS HELP WITH THE PLANNING PROBLEM]

Regional perspectives

6.21. Just as the technical package needs to be tuned to farmers' resource bases, policy packages need to be tuned to the economic and political bases of countries and regions. Here, some of the above conclusions are summarized with reference to particular countries in low-income Asia, sub-Saharan Africa, and the middle-income economies. Of course, each country has its own objectives and priorities for its agricultural sector; national environmental conditions differ widely; countries' institutional structures pose specific constraints and present specific opportunities; and market opportunities, both domestic and foreign are highly uneven.

6.22. Low-income Asia. Low-income Asia supports half the world's population on a precarious agricultural resource base. How the agricultural sectors of these economies — mainly China, India, Pakistan, and Bangladesh -- are meeting, or failing to meet, the challenges of feeding their still rapidly growing populations is critical to the future world food situation.

6.23. China is, of course, the world's most populous country, and by almost any measure, has the world's largest agricultural sector. The sector provides sustenance to nearly a billion people and is the main source of livelihood for perhaps 800 million workers and their dependents. It accomplishes this in an uneven and often severe environment, in the face of extremely limited arable land to man ratios; with only 7 percent of the world's arable land, it feeds 22 percent of the world's population.

6.24. How this has been accomplished has varied over time and space, and under continuing shifting political and ideological climates. China was

arguably the first major country to bring its entire arable land base under cultivation. This situation inspired a never-ending search for yield-improving technology, including early pioneering in the development of high yielding varieties. Much progress in this area occurred during recent decades when China was almost entirely a closed economy.

6.25. Not only did Chinese agriculture not benefit from international assistance and support, but it was also quite heavily taxed and neglected in the government's investment allocation, in the desire to promote heavy industrial development. A key facet in rural capital formation was China's success in mobilizing labor and local savings for land improvement works, small-scale irrigation, local infrastructure, and rural industries. The scale and intensity of rural China's self help efforts is probably unique in the developing world. In terms of food security and access to basic necessities, China is probably ahead of all but a tiny handful of developing countries. But achievements in agriculture need to be seen against a background of problems which, in all likelihood, will continue. Chinese agriculture has not been able to improve diets substantially. Per capita grain availabilty has improved by only 10 percent over the past 25 years, and many essential products continue to be rationed. The challenges remain and will be difficult to overcome in light of the land contraint. Further growth must come from essentially three sources:

- Increased allocation of industrial goods to the agriculture sector. Most implements are still locally produced under primitive technologies; massive public investments in irrigation have largely been shunned in favor of small scale hydro installations and pumps; until recently, even most chemical fertilizers were locally produced.

• Continuing rethinking and revising the production team system of farming involving 20 to 50 families with inadequate resources and incentives. This involves continuing to increase the decision making power of local authorities to respond to local needs and conditions, and to lessen the substantial terms-of-trade bias against agriculture.

• Technology upgrading and agricultural research. Design standards in many parts of Chinese industry and agricultural infrastructure have changed little since the 1940s and 1950s. Obviously there must be a large scope for improvements in farm power equipment, and the design of irrigation, drainage, and flood-control systems. China's new access to international technology, international research results, and international expertise and financing should greatly assist in achieving these improvements.

6.29. From a "basket case" of international concern in the middle 1960s, India was able to attain self-sufficiency at least in foodgrains by the end of the 1970s, greatly relieving a severe balance-of-payments drain and going forward to relieve some of the pervasive rural poverty. This was accomplished as a direct result of the Green Revolution, combined with the impacts of massive investments in irrigation and fertilizer, and the strengthening of farmer-support services which permitted the wide scale adoption of the new varieties.

6.30. Problems remain, however. India still contains about one-third of the world's poor, virtually all of whom live in rural areas and many of whom are landless farm laborers. The growth in production and farm incomes has thus been highly skewed, both within regions, and across regions. The potential for further increases in agriculture to relieve some of this poverty varies across regions. Those northwestern states where the Green Revolution was particularly spectacular have little further scope for expanding

irrigation (although ample scope for using their existing irrigation better), and an adequate infrastructure is already in place. Attention is being turned to other areas with irrigation potential and to rainfed areas. While this attention is certainly warranted, complete eradication of poverty will have to depend on the overall growth of the economy and the upgrading of the human capital required for such development.

6.31. Pakistan, with a higher portion of its arable land irrigated, has achieved even more widespread adoption of green-revolution technologies than India has; it has experienced about the same level of agricultural growth. Both countries have managed to increase per capita food production marginally over the past decade. However, yields in Pakistan are considerably lower, even when the same crops are compared in the virtually identical Punjab regions of each country. The reason appears to be largely traceable to inefficient management and antiquated structure of the country's irrigation system, many parts of which are a century old. Water release is often untimely, inducing farmers to apply excess water when available, leaving other farmers with no water at critical times. Irrigation upgrading is the most pressing investment priority, given that the potential for rainfed agriculture is virtually nil.

6.32. Also due to defective irrigation systems -- lack of drains as well as poor water management -- vast areas have gone out of production or experienced reduced yields due to waterlogging and salinity. These problems are correctable by installing drainage facilities and soil treatment. Several projects are being implemented to correct these problems.

6.33. Unlike India and Pakistan which appear to have sufficient land and water -- if properly managed and invested in -- to continue satisfactory agricultural progress, Bangladesh has insufficient land and too much water at

the wrong times. Widespread flooding has effectively prevented the adoption of modern, high-yielding rice varieties in most parts of the country. The result has been a 6 percent decline in per capita food production since the late 1960s, the poorest of the large Asian countries in which 80 percent of the population still depends on agriculture. Small-scale flood control and drainage can help accelerate agricultural development in the near future. However, the long term solution to the critical problem of water control in the Ganga-Meghna-Brahmaputra basin, of which Bangladesh is the delta, cannot be achieved at the national level; it requires international solutions.

6.34. Sub-Saharan Africa. Some of the most severe poverty in the world exists in sub-Saharan Africa, and this poverty is closely linked to poor agricultural performance. On the face of it, this is perplexing: unlike most parts of the world, sub-Saharan Africa has an abundance of land. Rapid population growth of about 3 percent and more rapid urbanization have greatly expanded domestic market opportunities, and with 70 percent of the population of the region is still in agriculture labor abounds. Why, then, has agricultural performance virtually stagnated throughout the region to the extent that, in many of the countries, per capita production has actually fallen in the last decade?

6.35. At least in part, the problems are environmental. Soils in the humid regions are fragile, and tsetse fly infestation over large areas preclude the introduction of crop-livestock production systems. Semi-arid areas are prone to drought and mostly remote from markets as well. Economic remoteness has meant little incentive to intensify agriculture -- for instance, to pay cash for fertilizer to be used on a crop that will be eaten, not sold. Paucity of infrastructural development adds to physical distance. And with rapid population growth, extensive, bush-fallow farming systems have started to

strain the environment in some areas at the expense of tree cover and soil fertility.

6.36. These environmental points do not provide a complete answer. Government's attitudes and policies toward agriculture also play an important role. Virtually all of sub-Saharan Africa's agricultural production comes from small farms, reliant almost exclusively on family labor. These have expanded output by expanding the cultivated area. Land and labor productivity have scarcely increased. Most governments and donor agencies have only recently begun to recognize agriculture's importance in the face of declining nutrition levels and growing food imports. Many still do not perceive small farms as a potential source of growth.

6.37. For most African countries in the short run a key to more rapid growth, swifter alleviation of poverty, improved balance of payments, and a stronger basis for industrialization, in the short run still lies with increasing productivity in agriculture. Within agriculture, programs and policies should favor smallholders not just because most of the poor are among their ranks, but also because smallholder agriculture offers the best opportunities for transforming relatively abundant resources of labor and land into output, while economizing on the scarce factors of capital and foreign exchange.

6.38. In the long run, agricultural progress will depend on vast augmentation of the relatively small stock of research, especially in food crops. This will be a formidable task, given the meagre base from which to start and the enormous heterogeneity of soil and climate, and will thus require further adaptive research on seed-fertilizer combinations, minimum-tillage methods, and eradication of the tsetse.

6.39. In the short run, there is considerable unanimity that agricultural production and incomes can be substantially raised by reducing the incentives' bias against agriculture, and peasant farmers in particular. But this will require hard decisions on agricultural producer prices, exchange rates, tariff structures, and urban wages as well as on the manner in which government-owned or -controlled marketing structures are operated.

6.40. Middle-income economies. Apart from having per capita incomes in the range of $ 420 to $4,500 (1980), the middle-income economies have few things in common. They are spread over the globe, have achieved their "status" in a variety of ways, and face a myriad of agricultural problems, successes, and potentials. If there is a common thread, it is the following: by achieving middle-income status, they have, or should have, the wherewithal to ensure food security either through internal or external means. To ensure continued, balanced economic growth, however, most must continue to give priority or expand on priorities, to agricultural development. The problems and prospects of some of these countries are briefly described below under the broad delineations of Latin America, the Mediterranean basin, and Southeast Asia -- the regions in which the vast bulk of the middle-income economies lie.

6.41. As a whole, Latin America achieved impressive agricultural growth of about 3 percent in the 1960s and 1970s, which outpaced even the rapid population growth of 2.7 percent. Overall economic growth of about 6 percent was also impressive; the link confirms the relationship between agricultural development and general development: adequate food supplies have kept urban wages at levels permitting industrial development; export earnings generated foreign exchange for the importation of capital and intermediate goods, and rapid rural labor productivity growth released labor for employment in other sectors.

6.42. In general, agricultural success, in those countries in which it occurred, was due to three factors:

- the availability of an arable land base of enormous size and potential
- modest governmental interference with the private sector and incentive structures inducing expanded production to meet growing urban and export demands
- powerful growth of incomes and demand in nonagricultural sectors.

6.43. With roughly three times the per capita arable land available to the rest of the developing world, it is not surprising that its expansion has accounted for well over half of Latin America's agricultural growth. This has permitted growth to be "cheap" both in terms of modern input requirements, and in capital required for infrastructure (only 8 percent of the cultivated land is irrigated). This pattern cannot continue for long, however, except in those "super land-rich" countries of South America. This reality is already being reflected in fairly rapid expansion in the use of purchased inputs (fertilizer use per cultivated hectare is now approaching nearly half the North American rate), and in the use of tractors to displace animals and ever-more expensive human labor. Thus, even in this region of relatively good agricultural performance greater priorities need to be given to agriculture if overall economic progress is to be maintained.

6.44. Whereas the overall policy climate has had a major impact on agricultural development, policies differ widely across countries, and these differences appear to be highly correlated with performance records. Peru, for example, had one of the poorest agricultural growth records in the 1970s; it kept agricultural prices well below world levels and followed exchange-rate and protectionist policies heavily biased against agriculture. Brazil, which

eased price controls and adopted flexible exchange rate policies, saw an agricultural growth rate of 4.5 percent over the period, and exports, particularly of soybeans which rose from nearly nothing to the point where Brazil is now the second largest exporter.

6.45. Although the overall picture of Latin American agriculture has been good and much potential remains, certain problems with some of the sectors need immediate attention. Principally, these concern pockets of poverty, the root causes of which vary from country to country. Northern Brazil contains the largest pocket of rural poor in Latin America, and its cause is traced to a highly skewed land distribution combined with limited markets for those inferior products produced by small farmers and tenants which do have land. A land reform, combined with agricultural research into new varieties for the region and improved marketing and distribution channels to be the only realistic solution. In other parts of South America and the Caribbean islands, arable land is a clear constraint. For the poor of the densely populated Caribbean, the answer cannot lie in agriculture, but in the growth of the rest of the economy -- which, as has been seen usually relies on growth in agriculture. In such circumstances the case for "unbalanced" growth is strongest.

6.46. Of all the regions, the Mediterranean basin probably contains the greatest diversity among countries. Political systems range from centrally planned to mixed to relatively free enterprise. Per capita income levels range from a low of $420 in Yeman AR to $17,100 in Kuwait. Natural resources, particularly petroleum, water, and arable land, vary by extremes. And agricultural performance, measured by recent growth rates, ranged from -1.8 in Iraq to 11.8 in Libya over the past decade.

6.47. Of general interest are the reasons behind such wide differentials in performance. Certainly factor endowments and demand levels, dependent on population and income levels are important explanatory variables. But the diversity of political systems and policies toward agriculture allows for some interesting obsevations.

6.48. First, there appears to be little or no correlation between the political system and agricultural performance. Of those countries having the most rapid agricultural growth in the 1970s, several (Libya, Syria, Romania) are centrally planned, and several (Tunisia, Yemen AR, Saudi Arabia, Turkey) are relatively market-oriented economies. Of those growing least fast, Iraq and Algeria are centrally planned, while Portugal and Morocco are largely market-oriented. Clearly, the degree of central planning versus the importance of the free market alone cannot explain differences in agricultural growth. Apparently, in all types of systems strategies exist that are consistent with, and which can promote, agricultural development, and some which are not and cannot do so.

6.49. Second, it does not appear universally true that the petroleum-rich tend to neglect argiculture and use their foreign exchange earnings to rely on agricultural imports, as has been argued for cases such as Nigeria, Mexico, and Indonesia. The performance of Libya and Saudi Arabia are striking counter examples. (An important explanation for this, however, may be a concern for a greater degree of food self-sufficiency combined with adequate surplus capital to finance expensive development projects.)

6.50. Third, it does appear that policies and the performance of marketing institutions have had a considerable bearing on agricultural performance. Those countries, regardless of political system, which have allowed higher

food prices to be passed on to farmers and have permitted or caused efficient marketing enterprises to develop have invariably shown fairly rapid rates of growth. Where prices have been held artifically low and marketing channels have been inadequate, agricultural progress has been inhibited. A similar conclusion appears to hold for institutions supplying farm inputs and other services. In rapidly growing middle income countries such as those of the Mediterranean Basin, farmers respond best to the opportunities created by increasing and changing demand if farm inputs and equipment are readily accessible. Middle income country farmers are no longer simply introducing new high-yielding seed/fertilizer technology. They are introducing a wide variety of herbicides, pesticides, farm equipment, irrigation systems, greenhouses, and new agricultural techniques. Farm input supply enterprises must be able to identify promising new inputs and equipment, and make it available to farmers.

6.51. The visibly good performance of many of the countries of the Basin, combined with growing domestic demands due to rapid population and income growth, and the proximity to European and Persian Gulf markets suggests that the overall prospects for future agricultural growth are good. And for about half of those countries which are currently net food importers with growing import burdens, meeting these prospects will also conserve foreign exchange for other developmental purposes.

6.52. There are, however, some important impediments to be overcome. The distribution and tenure of land holdings that has resulted from centuries of fragmentation and consolidation has resulted in a very large number of farms which are either too small to adapt to changing technologies and opportunities, or too large and operated under absentee ownership to be effectively managed. Land reform in Egypt, which limited the size of holding

to approximately 20 ha. served to redistribute wealth in an effective manner, but about half the land remains in the hands of farmers owning less than half a hectare.

6.53. Erosion and desertification are growing problems in much of North Africa and the Middle East. Much of the land currently cultivated was once desert, and nature seems bent upon returning these lands to that status as a result of poor water management and overgrazing of common pastures. Water quality is also a growing problem in many of the irrigated areas. Water supplies, both from surface sources and underground, are extremely limited. Poor drainage facilities and urban and industrial development have eroded water quality; crop yields have been adversely affected; saline or polluted irrigation and water must be mixed with fresh water -- when available.

6.54. As a whole, the developmental success story of the five major Southeast Asia market economies represents an unparalleled success story over the past two decades. Growth has averaged between 6 percent per year in Indonesia and the Philippines, 7-8 percent in Thailand and Malaysia, and 9.5 percent in the Republic of Korea. By contrast, the three countries of Indochina, plagued by war, have not achieved agricultural growth.

6.55. The sources of growth have differed in all countries, but it is clear tht agricultural progress has been an important contributor in all of them, releasing labor and capital for development in other sectors while providing agricultural supluses in most countries in most years. In typical fashion, agricultural employment and output as a percentage of GDP has been declining in all, although fully 57 percent of the population still remain dependent on agriculture.

6.56. Past policies have been mostly concerned with rice, the principal staple of the region. Except for Thailand, all countries were consistent

rice importers during the early 1970s generating concern for food security. Expanded use of HYVs and irrigation have lessened this dependence in most of them to the point where it is now economically questionable for them to continue to pursue import substitution investments. (The Philippines became the net exporter of rice in 1978 although the domestic resource costs involved were substantially higher than the foreign exchange earned).

6.57. Overall agricultural progress has permitted most of these countries the "luxury" of focusing on rural poverty. This is less of a problem in Korea and Malaysia which have rural labor shortages and rising wages, relatively severe in the Philippines, where nonagricultural employment is being pursued, and most acute in Indonesia. That country faces a unique set of circumstances and policy problems. Although abundant in land, labor, and oil, it remains the poorest of the five (US$ 430 per capita). Part of the problem lies in the fact that the bulk of the population resides on the relatively small island of Java, while most of the unused arable land is in the outer islands, where land quality is poorer. Despite a 25 percent landless rate on Java and massive resettlement efforts (the Trasmigration program), net migration from Java has so far been negligible compared to the man/land ratio imbalances. This in turn is largely due to food policies whereby oil revenues have been used to hold down food prices and thus reduce incentives to agricultural producers. With the usable land base reaching its limits in some of the countries (Korea in particular), prospects for future agricultural growth in the region center on: continued expansion of the use of HYVs and updating technology; improvements in processing infrastructure to meet growing and ever more sophisticated urban demands; and taking further advantage of trade opportunites (except for Korea, all of the countries are net agricultural exporters).

International policy priorities for support of agricultural development

6.58. Agriculture has shared in the increased global interdependence which has characterized the 1970s; indeed, increased linkages with the external economic environment are one result of agricultural modernization. The strength of the linkages themselves, and their beneficial impact on developing country growth, often depend crucially on international policy factors. Such policies affect trade options, external capital flows, and technology transfer important to long term growth and the maintenance of food security

6.59. An international trade system, with flexibility to allow shifts in production and consumption patterns, as comparative advantage and income differentials change, is a necessary element in achieving goals of adequate food production amidst improving standards of living. The importance of trade in agricultural products for the developing world was shown in Chapter 3. But as is also discussed there, the opportunities for trade are limited by the prevalence of protection in the industrial economies, leading to loss of markets and low prices for commodities that compete with subsidized production and increased price variability. International efforts to address these issues have been ongoing for the past several years. No quick breakthrough seems likely however.

6.60. Diversification in exports is one approach that exporters have used to counter the effects of protectionism. In the 1970s, though, the benefits were all too often limited by competition among suppliers which drove down commodity prices. African cocoa producers lost market shares to Latin America; South Asia's dominance in tea was eroded by competition from African and Chinese exporters, reducing its world market share from 80 to 40 percent; Latin America's share of the coffee market declined from 62 to 51 percent; and the small Caribbean sugar producers lost ground to East Asian and Latin

American cane growers. There is no easy resolution of the dilemma of conflicting individual and country-group interests; but at the national policy level, strategies which focus squarely on the internal income distribution problem rather than mere output expansion of these export crops -- such as quality upgrading, more complete domestic processing, and alternative farmer occupations -- can allow continued reliance on some traditional crops in the short term while minimizing losses. At the international policy level, orderly supply arrangements such as those established under international commodity agreements, in which both producing and consuming member countries negotiate prices and quantities, provide a useful framework. "Beggar-thy-neighbor" policies can be avoided to the benefit of all, at least for some commodities such as cocoa, coffee, jute and sugar.

[Box 6.5 INTERNATIONAL COMMODITY AGREEMENTS: A PARTIAL SOLUTION]

6.61. Food security priorities. Food security in the developing countries ultimately depends on effective long-term agricultural development. In todays world though, fluctuations in domestic food production or international instabilities can create emergencies with potential for immense distress among the poor. All governments try to deal with the threat of famine, though poor crop reporting, plus transport and storage bottlenecks, sometimes hinder both local and international efforts. Emergencies hurt long-term development, too, since they disrupt ongoing investment progrms and divert funds to pay for the spurt in imports.

6.62. The establishment of the IMF Food Facility last year should help to meet a need for bridging finance, particularly where temporary domestic production shortfalls are the root cause of the fluctuations. The Food Facility extends the Compensatory Fund Facility to include compensation for fluctuations in cereal import costs. Two developing countries have already

made use of it; Korea, to help make up for rice production shortfalls in 1980/81, and Malawi, to help compensate for two successive years of drought. The Food Facility, available to both low- and middle-income economies, is an important supplement to commercial finance. Low-income economies, will however, continue to need concessional food aid as well.

6.63. Food aid is important for purposes such as longer term finance for development and nutrition programs. Food aid flows leveled off at about 9 million tons in the late 1970s; and the food aid convention, which sets minimum donor commitments, is even lower at 7.6 million tons. Also, much food aid continues to be concentrated in a few strategic countries. International policy should seek to raise both minmum and average food-aid flows and increase their effectiveness through reallocation by region and better integration with development programs.

External capital

External capital, and the accompanying technology transfer, has historically contributed 10 to 20 percent of total investment in developing countries. Of this, official flows for development assistance have predominated, particularly in the low-income economies.

6.65. Private-sector financing of agriculture, which is concentrated in FDI and suppliers credits, grew slowly in the 1970s relative to the real doubling of official aid for agriculture. Activities financed, and country coverage, continued to differ significantly between the official and private sector, as complementary roles evolved and sharpened. Private-sector financing was concentrated in agro-industry, manufacturing of inputs and commercial livestock, fisheries, or treecrop production for export; official financing increasingly emphasized small-farm foodcrop production, support of institutional development, and rural infrastructure. In the low-income

economies, private-sector involvement, even in large-scale activities, remained relatively small.

6.66. Productive private-sector involvement can be encouraged but in agricultural development it is unlikely to substitute for official financing, at least in the near term. Both private sector and official flows for agriculture are needed to meet rising investment needs and to upgrade technology. The measures required to increase private-sector involvement are not specific to agricultural development; historically, international business has independently taken the initiative to seek out and support profitable, viable, and relatively risk-free agricultural ventures in parallel with those in other sectors (Box 6.6). Measures being considered to link official and private-sector financing for all sectors -- such as increases in cofinancing; sales of portfolio and loan participation; use of multilateral development institution guarantees; and partially guaranteed loan paid through certificates -- will help stimulate indirect private sector involvement in agriculture as well.

[BOX 6.6 STRAWBERRY IMPERIALISM]

6.67. Official aid for agricultural development. Official aid-financed development projects will continue to provide an essential base for agricultural development during the 1980s. Contributions from private sector financing, food aid, and quick-disbursing adjustment assistance have a role to play, but they cannot substitute for a continuing steady stream of well-designed agricultural projects and technical assistance efforts.

6.68. The doubling of aid to agriculture in real terms during the 1970s can be attributed to increased efforts from all donor sources (Table 6.1). The multilateral organizations increased their share of project lending to agriculture, with concessional facilities leading the way with shares of

45 to 50 percent; at the same time new multilateral institutions supportive of developing country agriculture began operations: the Consultative Group for International Agricultural Research (CGIAR) in 1971; the International Fund for Agricultural Development (IFAD) in 1977, and the Arab Authority for Agricultural Development and Investment in 1980.

[TABLE 6.1]

6.69. Commitments to agriculture from bilateral donors increased significantly as well -- DAC commitments by 15 percent a year, and OPEC commitments by 22 percent a year in real terms, from a smaller base (Table 6.2). Even after this increase, levels of aid to agriculture remain below potential, considering both recipient needs and donor capacity, and the record of aid effectiveness in agriculture. One bright spot is a greater support for the least-developed countries, and for sub-Saharan Africa, as recently endorsed by a wide set of donors.

[TABLE 6.2]

6.70. Throughout the 1970s, bilateral and multilateral flows to agriculture have remained roughly equal in importance. In 1979-80 however, changes in the support for multilateral aid have begun to alter this balance and affect total flows of aid to agriculture. IFAD and CGIAR, which devote all of their activities to agriculture, have had their funding cut in real terms in recent years. The concessional facilities of other multilateral organizations, which devote 45-50 percent of their resources to agriculture are also facing cutbacks in commitments that will affect total aid flows to agriculture in the 1980s. These cutbacks come in the face of recent evidence that agricutural projects yield high economic returns, and have a significant impact on poverty. Given the essential role of agriculture in economic development, the unfavorable prospects for concessional aid to the sector must be reversed.

Table 6.1 Official commitments to agriculture, 1973-80

(million dollars)

Item	1973	1974	1975	1976	1977	1978	1979	1980
				(current prices)				
Official Development Assistance (ODA)								
DAC [a]	910	1,700	1,644	1,624	2,597	3,270	4,304	4,188
Multilateral agencies	725	1,001	1,056	1,257	1,621	2,402	2,503	3,266
OPEC (bilateral and multilateral)	34	133	446	273	365	276	243	199
Total ODA	1,669	2,834	3,145	3,154	4,583	5,948	7,050	7,653
Other official flows (OOF)								
DAC [a]	72	168	86	268	120	353	329	249
Multilateral agencies	442	982	1,846	1,458	2,123	2,872	2,319	2,935
OPEC (bilateral and multilateral)	31	55	209	150	60	42	99	54
Total OOF	545	1,205	2,141	1,876	2,303	3,267	2,747	3,238
Grand total (all donors)	2,214	4,039	5,286	5,030	6,886	9,215	9,797	10,891
				(constant 1979 prices) [b]				
Official Development Assistance (ODA)								
DAC [a]	1,621	2,581	2,359	2,246	3,279	3,633	4,304	3,773
Multilateral agencies	1,257	1,400	1,530	1,814	2,139	2,761	2,503	2,969
OPEC (bilateral and multilateral)	61	191	640	378	461	307	243	179
Total ODA	2,939	4,172	4,529	4,438	5,879	6,701	7,050	6,921
Percentage change in real terms	(-)	(42)	(-6)	(-2)	(+32)	(+14)	(+5)	(-2)
Other official flows (OOF)								
DAC [a]	129	242	137	395	159	403	329	222
Multilateral agencies	791	1,413	2,944	2,150	2,816	3,275	2,319	2,621
OPEC (bilateral and multilateral)	55	79	333	221	80	49	99	48
Total OOF	975	1,734	3,414	2,766	3,055	3,727	2,747	2,891
Percentage change in real terms	(-)	(78)	(+60)	(-19)	(+10)	(+22)	(-26)	(+5)
Grand total (all donors)	3,914	5,906	7,943	7,204	8,934	10,428	9,797	9,812
Percentage change in real terms	(-)	(51)	(+16)	(-9)	(+24)	(+17)	(-6)	-

Source: OECD

a. Includes EEC.
b. 1973 and 1974 constant value is in 1978 prices and needs to be transformed.

Box 6.1 Improving incentives in Chinese agriculture

Leadership changes and a more flexible view of developmental policy mark a recent, still continuing, phase in agricultural development in the People's Republic of China after 1977. Policy changes to improve producer earnings and incentivds were of three kinds:

- Relaxation of overly rigid production planning in collectivized agriculture, coupled with encouragement of household and other private agricultural activities. The planning approach being used still calls for continuing local procurement (i.e., sales) targets for the main crops, but otherwise allows much more latitude for team decisions on crops, land, and input use. Deregulation of local markets has helped to promote household-sector sale and exchange of produce.

- Increased prices. In China most produce is purchased by the state. Between 1977 and 1979 prices for all the important commodities were raised by 20 to 30 percent.

- More active and systematic use of producer incentives to promote the production of priority commodities. Such incentives take a variety of forms and vary by locality; many involve encouragements to produce cash crops and livestock products for sale to state agencies via entitlements to special allocations of grain or fertilizer (at relatively favorable prices) along with normal sales proceeds; some incentives are triggered by above norm or quota sales, for example, "above quota" grain sales attract a premium of 50 percent over base prices.

- Sharpening incentives withinin the production cooperatives. The changes involve improvements to "work point" systems so that less is apportioned to workers as basic rations and more as a return for

quality/quantity of individual work performance. Various types of contractual arrangements are being encouraged whereby small groups of workers manage collective land and other assets under contract to the production team, with bonuses for above norm performance.

Although it is too early to assess the long term impact of these new incentives, they have already resulted in a dramatic upsurge in agricultural output, attesting to producers' responsiveness to "positive" signals:

- Between 1977 and 1980, the growth of output averaged 6.7 percent, i.e., a 20 percent jump over 3 years.

- Foodgrain output increased some 37 million tons, with growth averaging close to 5 percent p.a. Both 1977 and particularly 1980 were unfavourable in terms of weather, with poor wheat crops in both years.

- More remarkable was the upsurge among some of the other major field crops: cotton output increased 23 percent 1979-80, and the oilseeds by 92 percent in the three years 1977-80, in both cases reflecting a sizeable expansion of cultivation area as well as yield increases. Large increases are also reported for sugar (cane and beet), silkworm cultivation and jute. There is evidence that these increases reflect substantial shifts in the cropping pattern in China based on area specialization and local comparative advantage which has been facilitated and encouraged by the recent reforms.

- Finally, meat production (almost entirely pork) increased over 50 percent during the past three years -- a response both to improved producer prices and to policies that give greater freedom to use grain for animal feed on the part of livestock producers.

The Chinese planners did not anticipate so big a response. Moreover they did not adjust consumer sales prices for the leading items. So subsidies, already quite a large item in the budget, have shot up to around $5 billion annually.

Box 6.2 Input supply and private initiative: the Bangladesh experiment

Fertilizer and other modern inputs are helping Bangladesh overcome its severely constrained land base in order to raise farm productivity.

Projections in the early 1970s showed that fertilizer use would have to expand by some 15 percent a year to attain the desired 4 percent yearly agricultural growth rate. At the time, the Bangladesh Agricultural Development Corporation (BADC) a public corporation under the Ministry of Agriculture, handled all input marketing as well as all procurements of fertilizer.

BADC established the New Marketing System (NMS) in 1978. The NMS is designed to reduce restrictions on private traders, moving toward a more open fertilizer distribution system. BADC is gradually withdrawing from fertilizer sales. BADC sells mainly to wholesalers at "primary distribution points" while retaining responsibility for sales to retailers in remote and inaccessible rural centers. All private dealers and cooperatives are permitted to buy from all BADC warehouses. Private movement of fertilizer is unrestricted (except in the 5-mile border area).

The government agreed to develop a system whereby private dealers can obtain sufficient credit from commercial banks, although credit has not yet proved to be a problem for traders. USAID also financed consultants to help BADC set up and monitor the new private-sector fertilizer-marketing system and to devise measures to cut down internal transport and storage problems.

In 1978 and 1979, BADC took the first steps to liberalize marketing. It increased official dealers' margins, permitted farmers to buy from any traders, whether or not in the farmer's own locality, and made it easier to become a trader. Backed by a USAID Fertilizer Distribution Improvement Grant,

BADC began the NMS as a large-scale pilot operation in December 1978 in the Chittagong Division, which covers one-fourth of the area of the country and a third of total fertilizer consumption.

The Chittagong Division marketing system enjoyed a reasonably successful start. Fertilizer sales increased the first previous year, and 45 government warehouses were put out of business, leaving the government active mainly in remote areas which did not attract wholesalers. Retail prices dropped below official prices around the primary distribution points. The new fertilizer wholsalers showed they could move fertilizer cheaply and effectively from surplus to deficit areas, selling to both farmers and retailers.

Based the Chittagong Division's success, the NMS was adopted and extended to the rest of the country. Major accomplishments of the NMS as of mid-1980 include:

- BADC's fertilizer points of sale will be reduced by 55 to 60 percent; about one-third of the original 130 warehouses have been closed.
- Farmer access to fertilizer points of sale has greatly increased in the Chittagong Division.
- Farmers pay less for fertilizer under the NMS than under OMS.
- A new class of private wholesalers developed as intermediaries.

The net results of the program have been almost entirely positive: the private distribution system is more flexible and can supply farmers at lower costs and much of BADC's managerial and labor force can be released for other tasks. The costs of constructing and maintaining the marketing and storage infrastructure have been substantially reduced. The program's extension to other inputs is evidence of the government's satisfaction with the the private sector's new role.

Box 6.3 Rainfed agriculture: the Mexican experience

Until a few years ago irrigation investments were responsible for most of the rapid growth in Mexico's agriculture production. Between about 1940 and 1965, about 90 percent of all investment in agriculture was for construction of irrigation infrastructure and support services. About 5 million hectares are now irrigated, which accounts for about one-third of the cultivated land area and nearly 60 percent of the value of total crop production. Until about 1965, production grew each year by between 4 and 7 percent, a high rate by world standards and well ahead of the growth in the population.

Three factors emerged between the mid-1960s and the mid-1970s to cause a shift of emphasis toward the rainfed areas. First, there were fewer engineering possibilities for opening up new land for irrigation at low cost. (Expansion slowed down from 150,000 ha to 100,000 ha a year, and the real cost per hectare rose significantly.) Second, the rate of increase in irrigated crop yields slowed down, because most research results were already applied and because some of the irrigation works were not being maintained properly. Last but not least, there was growing pressure to tap the potential of the rainfed areas from the 87 percent of Mexican farmers who, despite some redistribution of lands, still did not have access to irrigation facilities.

In fact, over these 25 years the situation of most of the rainfed farmers deteriorated. On farms averaging only about 2 ha/family, production was concentrated on basic food crops, mostly maize and beans. Maize yields, on average 1.4 t ha, had changed little over the past two decades, and maize prices -- at least until 1979 -- had fallen behind inflation, lowering farmers incomes in real terms. Moreover, population growth was so rapid (reaching 3.7 percent per year at its peak) that even rapid urbanization could not prevent an increase in population in the countryside.

GC14-rainfed(CJR-05/12/82)

Yet Mexico's rainfed areas have a high potential for agricultural production. The Plan Puebla, the first rainfed development project of its kind, started in 1967, had demonstrated that with the application of available new varieties and farming methods, farmers' maize yields could be tripled or quadrupled, and at a lower cost than through investments in irrigation and that production could be diversified into higher-value crops. Moreover, much potentially arable land (with adequate rainfall) was being used only for extensive livestock-grazing and could be put to more intensive use. But most of it, especially on the humid tropical Atlantic coast, needed improved drainage, and Mexico had little experience with wetland drainage techniques. Despite these problems, the Mexican government set about making a substantial shift in its agricultural development policy towards increased promotion of rainfed agriculture.

This was not an easy task, because it necessitated a major redeployment of existing extension, rural engineering and research staff, who were mainly geared to servicing irrigated agriculture. New staff were recruited and trained to reinforce the extension services in rainfed areas, and the stock of knowledge from research on the technical packages available for improving rainfed cropping had to be carefully reviewed.

Putting the policy of reorientation into action involved three main approaches: first, an effort to improve the efficiency of extension and credit delivery to farmers in rainfed areas, combined with easier access to land through rural roads improvement. Second, providing incentives to farm little-used lands more intensively through changes in land-tenure laws, and by putting in wetland drainage. And third, by offering guaranteed producer prices and subsidized inputs for crops like maize and beans typically grown on rainfed farms. These new appraoches were embodied in a series of new projects, which received substantial World Bank assistance.

In the PIDER projects (the first started in 1973, the third now in progress) the objective has been to bring an integrated package of services -- extension, research, credit, roads, small irrigation, potable water supply, and education -- to small well-defined areas of generally low-income rural communities. In their organization, the PIDER projects have essentially used existing government agencies but have used the budget-allocation instrument to integrate and concentrate their activities geographically. It also became apparent that coordination of services was a major bottleneck if centrally directed by the federal government, so that control has had to be decentralized from the federal toward the state governments.

A major institutional breakthrough was achieved in 1979, when the government established, over the entire country, 118 Rainfed Districts (Distritos de Temporal), in the image of the already existing Irrigation District. The objective was twofold: first, to establish a country-wide framework in which the integrated rainfed development approach could be undertaken, while at the same time taking into account local physical conditions, which vary widely; and second, to achieve a further decentralization in responsibility for the planning and execution of development activities. This was achieved by giving District Chiefs the responsibility for formulating their own budget; and obliging all the local services of the central line agencies to work under the guidance of the District Chiefs. This new approach led to a new Rainfed Agriculture project, which the Bank also helped to prepare and to finance, focusing on the reinforcement of nine Rainfed Districts, four of them in the Central Highlands and five in the Gulf coast area. This project was started in 1981.

The shift since the early 1970s in development priorities towards rainfed agriculture involved major policy and institutional changes. The efforts

already made -- for instance in changing the laws relating to land tenure, in retraining extension agents, in strengthening agricultural research in rainfed farming technologies, and especially its out-reach activities with farmers, and in completely new services such as land conservation and drainage -- all these have laid a solid base for future structural change and increased and diversified production in Mexico's rainfed agriculture. But concrete results are already apparent in response to the improved production incentives announced two years ago. After a decade of slow growth (2 to 3 percent per year agricultural production increased by 5.5 percent in 1980 and by 8 percent in 1981, most of it from rainfed cultivation.

Above all, the results have demonstrated that technical progress in Mexico's rainfed farming areas is feasible, given the determination of the government and its agricultural staff to make it work.

Box 6.4 Computers help with the planning problem

Over the past decade, a family of computerized agricultural sector models has been developed to assist planners and policymakers in their decisions. Although they differ widely in size, scope, and structure (to account for differences across countries and issues), they are all based on the linear programming format. Since linear programming involves the optimization of an objective over a number of variables subject to a set of constraints, it has proven to be an effective medium for illuminating problems in the agricultural sector. Any number of objectives may be used, such as the maximization of employment, minimization of a trade deficit in agriculture, and the optimal usage of a scarce resource such as irrigation water. But for most applications in non-centrally planned countries, an artificial "competitive" objective function is used. This maximizes the sum of consumers and producers surpluses yielding a solution in which output prices are equal to the marginal costs of production -- the standard criterion depicting a competitive sector of which agriculture is the best example.

Most of the variables, or activities, in these models are cropping choices -- usually defined as the cultivation of a particular crop or variety, by a particular method (traditional, parltially mechanized, fully mechanized) on a given unit of land for a particular time period (season, year, multi-year). A solution, then, will yield an optimal cropping pattern, and, depending on the level of detail contained in the activitites, the optimal way of achieving it, i.e., the level of mechanization, the allocation of water, fertilizers, and any other inputs explicitly inserted in the model. Other variables may be included such as the supply of livestock outputs, labor and other inputs, and export and import levels of traded commodities.

All of the above variables are constrained in some manner. For cropping activities in particular, their levels are constrined by the amount of cultivable land, water, labor, and power available. This set might be extended to include fertilizer, marketing facilitites, and even the level of market demand for the commodities producible. Each constraint will be attached a shadow price, or marginal opportunity cost, in any solution enabling planners to identify and rank those resources which need to be augmented for agriculturl production to expand.

The earliest, and to date the most successful application to a developing country, was CHAC (named for a Mayan rain god) in Mexico. Originally developed by World Bank research staff and Mexican agricultural analysts, CHAC has been used to test the consequences of a variety of policy options, identify and quantify the benefits from tractorization and irrigation, and to test the consistency of national agricultural plans. In Northeast Brazil, a similar model was used to predict the outcome of a land reform in a region of both underutilized land and labor, as well as examine the influence of limited markets for the region's mix of inferior crops. In Pakistan, a very large model (7,000 equations) has been developed to design irrigation and drainage investments, and to define optimal water pricing and allocation schemes. In Tanzania, a model of a typical Ujaama village provided an optimal reforestation program to save villagers from increasing labor and transport costs associated with having to travel ever longer distances for fuelwood. In Egypt, a CHAC-type model was used to test the adequacy of future water supplies from the Nile, and to evaluate the consequences of diversions of Nile waters from agriculture to other uses and sectors.

Such models have unquestionably assisted planners and policymakers in specific decisions. However, they can be quite costly, especially in terms of

data collection, and they require a high level of analytical and computational skills. Are they worth the effort and expense? Yes, for reasons in addition to providing answers to specific questions. A model forces consistency. Examples abound where gross imbalances between supply and demand of certain commodities and inputs occurred simply because the authorities did not have a consistent forecast of the outcomes of their actions. A model requires a data set not ordinarily provided by agricultural censuses and farm management surveys. In collecting these data, the analysts get an opportunity to view the sector and its problems in a fresh, often enlightening way. Finally, a model, requiring the input of economists, agronomists, operations researchers, and most important, policymakers, improves the communication among these diverse professionals: if two people can be persuaded to communicate with a model, they communicate much more effectively among themselves.

Box 6.5 International commodity agreements: a partial solution

In recent years, the Common Fund for Commodities was established to facilitate the conclusion and functioning of ICAs for commodities of special interest to developing countries.

International Commodity Agreements (ICAs) have been used for over a hundred years as a means of stabilizing the prices of basic materials. They have been of major concern to those countries whose economies are heavily dependent on the export earnings provided by such commodities. The impact of the Common Fund, however, will ultimately depend on the number of existing ICAs which join it and the number of new ICAs which come into being under its aegis.

A period of low commodity prices such as 1981/82 is a time of pressure from producing countries for the creation of ICAs. It is also a time of frustration of producing countries with the inability of the ICAs to prevent prices from falling. In the final analysis, the gains which exporters may derive from stabilizaiton depend on the source of the instability and the degree to which the revenue change due to the price change is offset by an opposite change in the quantity exported.

Only if both demand and supply are price-inelastic can stabilization stabilize revenue when price instability for the most part originates from the supply side. The actual experience with ICAs seems to give support to this analysis: ICAs exist for cocoa, coffee, and sugar and for few other agricultural commodities. There is a recently formed ICA for rubber, but none covering any other agricultural commodities, despite intensive negotiations, including discussions on tea, cotton, bananas, and jute. ICAs of various kinds have existed in the past for tea.

How ICAs work

Price support or price stabilization is, in general, approached by means of either buffer stocks or export quotas. Target or operational prices are most commonly defined in terms of a "price band." When prices fall below certain levels, export quotas will be applied or the buffer stock will purchase the commodity. Above certain price levels the export quotas will be loosened or abolished and the buffer stock will sell -- until the price returns to some level or stocks are exhausted or reach some minimum level.

The operations of the buffer stock are usually limited by the amount of funds the buffer stock manager has access to at any one time. The difficulties which buffer stock managers have experienced in gaining access to increased funds quickly, as in the recent cases of cocoa and tin, make them hostage to other participants in the market as the capacity of the buffer stock manager at any time is public knowledge.

Of the existing ICAs concerned with agricultural commodities, the Cocoa Agreement and the Rubber Agreement utilize buffer stocks, while the Coffee Agreement uses export quotas. The Sugar Agreement's primary economic instrument is export quotas, but it also sets domestic stocks which may be held in producing countries. Their accumulation and disposal is regulated by that agreement. The previous cocoa agreemnt did have export quotas as well as a buffer stock.

The exports quota system, as it operates within the coffee agreement, sets a global quota for exports from member exporting countries to member importing countries. Member countries' exports to nonmember importers are not controlled. Within the global quota, export quota are allocated to each exporting country. Shortfalls in quota must be declared and these are distributed among other producers of the same "type", i.e., categorized

according to whether they export less than 100,000 bags, between 100,000 and 400,000 bags, or over 400,000 bags.

ICSs

While price stabilization and, indirectly, stabilization of export returns, are publicly given as the main justification for the formation of ICAs, price support, and therefore income transfers from the industrial to the developing producer countries, is sometimes the main objective of the developing producer countries. If the developing countries do in fact desire stabilization primarily, it could often more easily be gained in other ways. For example, domestic policies which affect inter-temporal transfers of export product incomes, or domestic price stabilization policies would achieve that goal far more effectively than can be expected from ICAs, judging from their historical experience. Export earnings stabilization for some commodities could also be achieved more effectively by means of such international instruments as the IMF compensatory financing facility. Such arrangements are divorced from the markets for the commodities and therefore do not impose the social costs of resource misallocations imposed by market interventions. In the long run, export earnings fluctuations ar best moderated by diversification of exports and markets.

Box 6.6 Strawberry imperialism

Since 1970, Mexican exports of fruits and vegetables to the United States, processed and unprocessed, have been providing employment for about 100,000 Mexicans, roughly half of them in farm jobs and half in factory jobs. These exports, largely tomatoes, strawberries, melons, watermelons, oranges, and onions, grew extremely rapidly in the 1960s -- at an annual rate of 7 percent; strawberry exports grew by 19 percent annually. In the 1970s, these exports encountered protectionism in the US market in a variety of subtle forms. As a result, growth declined sharply to an annual rate of 4 percent between 1970 and 1975 (strawberry exports declined by 7 percent annually).

One of the roots of Mexico's ability to capture a significant share of the North American market for fruits and vegetables, processed and unprocessed, lie in labor costs and labor productivity. Rising farm wages in the USA and the increasing difficulty of getting North Americans to harvest "stoop" crops, even at the legal minimum wage, made it progressively more difficult for the USA to compete in these labor-intensive crops. A comparative study of tomatoes, cucumbers, and green peppers in 1973-74 showed that unit production costs in western Mexico were 60 percent of those in Florida. Real rural wages were rising in Mexico too, but efficiency of farm labor use improved over the period. The average labor input per ton of fruit or vegetable in Mexico was 64 days in 1960; by 1965 it had fallen to 48 and by 1975 to 30. Thus, Mexico was able to maintain or widen its cost advantage over its North American competitors by raising labor productivity.

The other root of Mexico's success has been the involvement of North American transnational food processors. Starting mainly in the 1960s, these firms moved to take advantage of Mexico's production-cost advantage. Not only

do the packing and processing plants of the 14 major and many minor agribusiness firms dominate the industry (and provide a number of jobs roughly equal to the incremental employment on the farms), but the firms have become intimately involved in fruit and vegetable farming. The techniques of fruit and vegetable processing and packing are relatively straightforward and well-known. The investment cost of an efficient plant is not prohibitively large. It is probable, therefore, that transnational firms dominated the market, in most cases, as a result of their intimate knowledge of the North American market. Birdseye, Calpac, Campbell's, Del Monte, and others, including even a few Mexican firms, contracted with Mexican farmers; provided them with seed and technical assistance; and bought, graded, and processed their product in such a way that North American buyers got what they expected. As a European critic of the fruit and vegetable revolution has noted, even the strawberry varieties were North America.

Much of the explosion in fruit and vegetable production for export occurred in the Bajio -- a region of densely populated highland valleys between Mexico City and Guadalajara. This area had some of the lowest rural wages in Mexico, partly because it was disadvantaged by the Mexican wheat revolution. Irrigated coastal areas in northwest Mexico had an advantage over the Bajio in growing the new wheat varieties; central Mexico produced 40 percent of the country's wheat in 1950; 25 percent in 1960. As more irrigated areas were opened in the northwest, wheat was not the only crop to move there. Growth of fruit and vegetable cultivation and processing for export exploited the low-wage situation that resulted. Differently stated, this agroindustrial nexus provided about 100,00 jobs for people who otherwise would have had little or no work.

Critics who view Mexico's fruit and vegetable exports as a negative development point out that they involve dependence on foreign markets, foreign firms, and foreign strawberry varieties. This dependence was painfully demonstrated in the 1970s when North American fruit and vegetable growers were able to limit Mexico's exports to the USA through changes in a variety of regulations. The growers' interests were compromised with North America's dependence on and interest in eating economical Mexican fruit and vegetable products. Further international division of labor has been stymied, as has growth in Mexico's fruit and vegetable exports. This has prevented Mexico from expanding agroindustrialization, job creation, and export earning as it might have been able to otherwise. Which does not prove, however, that agroindustrialization, job creation, and earning foreign exchange ought to be avoided.