FORTY YEARS OF AGRICULTURAL DEVELOPMENT

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INTRODUCTION

I propose to use this occasion to share some of my thoughts on changes that have taken place in international agricultural development since I became involved in such development four decades ago. My involvement has been with universities, where I taught economic development; with foundations, where I participated in the beginnings of the "Green Revolution"; and with international agencies, such as the United Nations Food and Agriculture Organization (FAO), where I learned about problems of institutional development, and the World Bank, where I learned something about investment. I have also worked with many governments and farm groups throughout the world. My experience culminated with my 12 years as Director of Agriculture and Rural Development at the World Bank and, more recently, with my work as a Fellow at the World Resources Institute. Much of what I have to say is influenced by my experience at these two institutions.

THE CURRENT SITUATION

The mid-1980s are an interesting point in the annals of agricultural production, especially food production. It was only 13 years ago that the World Food Conference took place amid great concerns about the world's ability to feed itself. The greatest concern was about South Asia with its population of more than 700 million people and the possibility that this region might become permanently dependent on "food aid". The World Bank, FAO and the International Food Policy Research Institute (IFPRI) were all projecting a 60-million-ton "food gap" in the low-income countries-especially in India and Bangladesh. They were also predicting sharply rising prices for most cereals. The main recommendation of the World

Food Conference was that developing countries should accord higher priority to agricultural development and become more "self-reliant" in agricultural production. Since that time the world's population has grown by more than 1.2 billion to around 4.6 billion and the developing countries, as a whole, have indeed become more self-reliant in food production.

FAO is not noted for its optimistic statements about the world food situation. In its most recent **The State of Food and Agriculture** report (1986), the Director-General wrote that "overall the battle is won" and "for the first time average caloric production and consumption has moved above the minimum needed for most nutritional requirements". And the World Bank in its most recent publication on food security (1986) states that "The world has ample food. The growth of global food production has been faster than the unprecedented population growth of the past 40 years."

This sustained increase in supply has confounded doom-sayers. The starkest predictions about escalating food prices have simply not come to pass. Instead, the real dollar price for grains in the world market has declined steadily for the past 30 years. (The real dollar price — as used here — is defined as crop year average prices deflated by the U.S. consumer price index.) True, briefly during the 1970s prices rose sharply and fluctuated widely. Indeed, these years of the so-called "world food crisis" led to the convening of the World Food Conference. At this time supply was restricted because of a combination of factors-massive crop failures in the USSR, the world's largest wheat producer, and a dramatic cutback of domestic grain production by the USA, the world's largest grain exporter. And those same years saw a failure of the monsoon in South Asia, one of the world's most populous regions. Still, after a pause, global supplies did resume their upward trend. As a result, wheat prices now are about 20% below what they were in the 1960s, maize prices have declined even more and rice prices have also been falling. Of course, the decline in

prices has been accelerated in the last few years by the recession— induced fall in demand. But overall the remarkable growth in productivity and output, especially in the developing countries, has contributed substantially to the sustained fall in international grain prices.

I need not remind this audience that global figures on production and prices can mask regional diversity. Table 1 shows the changes in supply and growth rates in grain production in different parts of the world. The table shows that with growth rates rising by 2.3% and population increasing by 1.8%, per capita output rose by 0.5% between 1970 and 1982. Significantly, the fastest growth — 3% a year — has been in the developing countries. However, because population growth in the developing countries was around 2.1% per annum, so per capita output grew at only 0.9% compared with 1.6% per capita growth in the industrialized market economies. (Production in those countries rose by 2.3% at a time when population grew by 0.7% per annum.) While cereal output grew at a high rate in most of Asia and Latin America, the story was different in Africa, especially in East Africa. As the table shows, output grew by around 3.5% a year in East Asia and the Pacific region but by only 0.8% a year in East Africa, so overall per capita production in the developing countries grew only by 0.9%. But even with a decline in per capita production in parts of Africa and Central America, there is now a growing sense of confidence that the world's farmers can increase global supplies of food. The belief afoot is that the supply side of the agricultural equation is "manageable". This may sound like heresy considering that food production has stagnated or declined in East Africa in recent years. But even though imports have grown rapidly, East Africa's total imports of grain in 1985 — a year of drought and dire need — amounted to less than 5% of the amount of grain internationally traded. Moreover, few disagree with FAO's recent analysis that the resource base of the world in general can support more than twice today's production level and that

sub-Saharan Africa can sustain three times the current level of production.

Table 1. Grain production and population growth by country group, 1970-82

Country group or region	Average annual percentage change		
	Cereal production	production Population	Cereal per capita
World	2.3	1.8	0.5
Industrial market economies	2.3	0.7	1.6
East European non-market economies	0.6	0.8	−0.2
Developing economies	3.0	2.1	0.9
East Africa	0.8	3.0	−2.2
West Africa	1.9	2.7	−0.8
East Asia and Pacific	3.5	1.7	1.8
South Asia	2.7	2.4	0.3
Middle East and North Africa	1.7	2.9	−1.2
Latin America and the Caribbean	3.2	2.4	0.8

Note: The term "grain" includes wheat, rice, maize, rye, sorghum, millet, barley, oats and mixed grains. All growth rates in all tables have been computed using the least-squares method.

Source: World Bank calculations based on USDA data. Published in *Poverty and Hunger*, World Bank, 1986.

Rises in global agricultural production should not obscure the difficulties of increasing supply in certain parts of the world. Nor should such rises blind anyone to the great hunger and malnutrition that still remain in the world despite supply increases. But achievement has been great, and much of it came about because what is required to raise production is now better appreciated, and a major effort, especially in Asia, has been launched to stimulate and increase agricultural production. This effort started with a change among the development community in its perception of the role of agriculture in development, my next point.

CHANGING PERSPECTIVES ABOUT AGRICULTURAL DEVELOPMENT

Views about the importance of agricultural development in economic development have changed substantially over the past 40 years. In some respects, shifts in the priority accorded to agricultural development are mirrored by the lending programme of the World Bank. Since its inception in 1946, the Bank has shifted from a posture of "benign neglect" of agriculture to become the world's single largest source for external investment in agriculture in the developing countries. Lending for agriculture grew from an average of $300 million a year — some 6% of all Bank lending in the 1950s — to more than $3 billion a year, which represents more than 30% of all Bank lending in the 1980s. Indeed, agricultural commitments for the last decade topped $33 billion, by far the largest single component in the Bank's portfolio.

At the outset, the Bank conformed to prevailing economic and political thought, taking the view that agriculture is the "stepchild" of development. Most of the prevailing doctrine of development reflected ideas similar to those of such neo-classical economists as Sir Arthur Lewis and Ragner Nurkse, who distinguished at every turn between the modern sector (industry) and the traditional sector (agriculture). Agriculture's role was seen as passive — primarily to provide low-cost labour for the modern, industrial sector. The assumption was that agricultural production would be sustained despite the withdrawal of labour because underemployed labour was so abundant. Land and labour were adequate to provide agricultural output, capital was not a limiting factor, and, in any event, capital would give higher returns in the modern sector. What limited agricultural expansion was lack of demand, which the modern sector would create as it grew.

According to the Lewis-Nurkse school, increases in industrial production were the prescription for growth and for absorbing labour. Many factors seemed to favour such a strategy, which was summed up in 1951 in a well-known U.N. report (1951) written by, among others, several of the world's most prominent economists:

> The importance of this new employment, which we call for short "industrialization", varies from country to country in accordance with the pressure of population and the prospects for improving agricultural yields. But it is everywhere of the the highest priority, whether because of the superior productivity of industry, or because the improvement of agricultural techniques will reduce the need for labour in agriculture, or because the land is already overcrowded.

The study and analyses done on agriculture and economic development during the early post - war years concerned itself primarily with the agriculture of advanced economies; such analyses documented the decline of agriculture's share of employment in economic growth. A similar trend was then considered a precondition for growth in developing countries. The predictable conclusion? A "strategy for development would have to be a strategy for industrialization".

Beyond the economic arguments favouring industrial-led development strategies, many developing countries also erected philosophical barriers to a development strategy centred on agriculture. The belief was that the latter strategy would perpetuate the neo-colonial status of developing countries and deny the poorer countries the opportunity to develop through industrialization and urbanization. Thus, many of the developing countries frowned upon external efforts to promote agricultural development. The view was given respectability by the theory of *dependencia* — the brain-child of Raul Prebisch, who espoused it as Secretary-General of the U.N. Economic Commission on Latin America in the late 1940s. In Prebisch's view, modernization and development were not synonymous

with providing agricultural growth or investing in the development of export crops. Instead, the solution for the "structuralist" economists who embraced the Prebisch doctrine was import-substitution.

It became increasingly clear to all that an economy with a large agricultural sector could grow only slowly if its agricultural sector grew slowly. Also, the work of John Mellor, Walter Falcon, Raj Khrishna and others emphasized the interdependence of agriculture and other sectors of the economy. Expanding agriculture could boost foreign exchange earnings, provide food and fibre for the economy and create markets for those non–agricultural goods and services produced in the rest of the economy. There was a growing recognition that the agricultural sector could be far more than a labour pool for budding industry. As Professor Erik Thorbecke (1969) put it when reviewing agricultural development in the 1960s:

> It has become increasingly evident in the last few years that the conception of both economists and policymakers regarding the role of agriculture in economic development has undergone an important evolution. Whereas in the past, agriculture was often viewed as the passive partner in the development process, it is now typically regarded as an active and co-equal partner with the industrial sector.

By the 1960s it had become increasingly accepted that the agricultural sector could indeed contribute to development in a number of different ways. The dual economy model gave way to multisector, multiregional models that emphasized the relationships among price, income and technology within and between the agricultural, industrial services and foreign trade sectors. Analyses based on such multisector, multiregional models provided the broader sectoral framework of development economics in the 1960s. Within agriculture in particular, development began to be addressed directly from the supply side rather than indirectly "through generation of increased effective demand in non–agriculture". Appropriate price

policies, for both inputs and outputs, became a centre–piece of the supply–side approach.

Concern about agriculture's role as a food supplier was also heightened by new demographic data. Figures from the U.N. showed the very rapid rate of population growth in many parts of the world — especially Asia. Crop failures in Asia in the mid-1960s only added to the pressure to "do more about agriculture". After the failure of the monsoon forced India to depend on the United States for food aid, India's government vowed to become more self-sufficient in grain. At any rate, the output of Indian wheat and rice skyrocketed, with wheat production doubling from 21 million tons to 42 million tons between 1971 and 1983, and rice production rising from 63 million tons to 90 million tons over the same period. Its increased emphasis on promoting agricultural development is reflected in India's borrowings from the World Bank: in the 1950s India had borrowed very little but by the early 1970s it was the largest single borrower for agriculture, with loans amounting to around $1 billion a year. The same applied to Brazil; in the 1960s it had borrowed exclusively for power and industry but by the mid-1970s it had become the Bank's second largest client for agricultural development, borrowing more than $500 million a year for agriculture.

It was in India in the 1960s, too, that breakthroughs in agricultural research showed what could be done to raise farmers' productivity in irrigated areas in the tropics. When used with controlled supplies of water and appropriate agrochemicals, especially inorganic fertilizers, new varieties of wheat and rice developed by scientists in Mexico and the Philippines gave much higher yields than traditional varieties. These new varieties, in turn, justified substantial increases in public and private investments, especially investments in surface and pump irrigation and in projects to produce seed, to distribute fertilizers and to provide credit to farmers. So rapidly did this "new technology" spread that it became the largest transfer of

technology in modern history. Millions of farmers came to use high-yielding varieties of plants with fertilizers on land largely irrigated by pumps. Some call this agricultural turning point the Green Revolution, though "yield revolution" is more telling. Be that as it may, this revolution provided the economic justification for substantially increasing investment in irrigation in India and elsewhere.

If the World Bank's lending programme is a barometer, then a further sustained and increased interest in promoting agricultural development also took place in the 1970s. Total lending leapt from around $400 million a year as the decade opened to more than $3 billion a year as it closed, and lending continued at this high level throughout the first half of the 1980s. While the oil crisis and the food crisis of the early 1970s affected different countries in different ways, the crises led many governments to accord greater priority to agriculture so as to improve their balance of payments — to reduce food imports and to expand agricultural exports. At the same time investment in agriculture increased as part of a broader strategy of "rural development" — a strategy that the World Bank and most major donors of aid strongly supported.

This strategy was enunciated by the President of the World Bank, here in Nairobi, when he addressed the Board of Governors of the World Bank and the Fund at their annual meeting in 1973. The strategy was developed to take account of the studies undertaken by the Bank, the Organization for Economic Cooperation and Development (OECD), the International Labour Organization and a special commission headed by Lester Pearson, the former Nobel Prize Winner and Canadian Minister of External Affairs. These studies reviewed the first development decade. But while the period was one of relatively high growth in the developing world as a whole, including Africa, a general conclusion was that the benefits of growth had not been as widely shared as had been expected. Analysts estimated that many hundreds of millions of people

— mostly in Asia, but also in Africa — were still earning barely enough to survive. The numbers of the poor in these areas did not seem to be decreasing and their fortunes did not seem to be "rising with the tide" as national economies grew. And most of the poor, it appeared, lived in the countryside.

Most of the rural poor depended to some extent on agriculture for their livelihood. Their numbers included smallholders, part-time farmers, tenants, share-croppers, nomads and the landless. The experience of the 1950s and 1960s seemed to show that the traditional approach to agricultural development wouldn't work against rural poverty. Historically, rural poverty in industrialized societies had been eased by the migration and absorption of a slowly growing labour force into an expanding, non-agricultural urban sector. The absolute numbers and the proportion of the population and labour force in agriculture declined sharply while agricultural productivity rose as farms grew big enough to make economical use of labour-saving equipment. In most developing countries, though, the rate of population growth had been so high that the labour force had been growing explosively too. Most people in Asia and Africa and many in Latin America lived in the rural areas; despite very high rates of urbanization, the absolute numbers in the rural areas were increasing. At the same time unemployment and underemployment in the non-agricultural sectors were considerable, so poverty could not be relieved by encouraging a rural exodus. Thus, policies and programmes for ameliorating rural poverty would have to include a direct approach for dealing with rural poverty *in situ*. Any such policies and programmes would have to avoid encouraging labour-displacing actions and promote labour-intensive programmes that raised output and incomes.

The strategy that gradually developed was to look upon the traditional sector as a potential producer and not as a labour supply (as earlier dual economy models had done). Accord-

ing to World Bank estimates, more than half of the farmers in developing countries were "small-scale" producers, and this group occupied around 20% of all the land farmed. Unfortunately, production and output on this 20% tended to be low and to contribute little to economic development. One reason output was so low was that many of these producers lacked ready access to agricultural inputs other than land and labour. Accordingly, the proposed strategy was intended to ensure that overall efforts to develop agriculture would include special programmes tailored to meet the needs of low-income producers and that an adequate share of agricultural resources was allocated for their support. The expectation was that with increased output and incomes these low-income groups would indeed be able to produce more, consume more and enlarge the market for domestically produced light industrial goods.

It has to be emphasized that while concern about "equity" in approaches to agricultural development was great in the 1970s, these approaches were not conceived as "welfare programmes" or as schemes to redistribute incomes or land. Instead, the intent was to raise the productivity of producers who had some access to land. Policies and programmes were designed to promote agricultural development that would enable small-scale producers to increase their output.

Perhaps the easiest way to illustrate the intent of the programmes launched in the 1970s is to look closely at rural credit programmes. As a general rule, most rural credit programmes — intended to finance purchases of necessary inputs — serve the more prosperous producers who have adequate collateral and ready access to banks. However, when assisting smallholders is the objective, special programmes are needed to allocate part of the resources to be lent to small farmers. In such programmes, less stress is placed on collateral and more on the potential for increasing output. This approach has

worked in many countries, and in parts of India and the Philippines it has helped smallholders increase their production rapidly.

This success notwithstanding, has the conventional wisdom changed? During the 1960s and 1970s much of the concern about agricultural development was on agriculture's role in economic development, the necessary conditions for ensuring agricultural development and, subsequently, growth and equity. Most recently, though, concern has shifted towards ensuring that governments follow appropriate economic policies. Experience has shown that investments yield poor returns where economic policies reduce farmers' incentives or where subsidies have distorted price signals. The new emphasis on "getting policies right" — enthusiastically endorsed by donors — means reducing the role of state enterprises in favour of the private sector and permitting greater freedom for market forces. It is too early to tell what the impact of the newest vogue in development thinking will be. But it is to be hoped that emphasis on economic policy will not divert attention from attempts to conquer poverty and raise the productivity of low-income producers.

Today there is great interest in yet another dimension of agricultural development — "food security". This concept, originally developed at FAO and since refined by other organizations, has to do with access by all people at all times to enough food for an active and healthy life. "Food security" has several levels — international, national and household. Basically, though, the concept as developed by Sen (1987), Timmer and Falcon (1983) and Donaldson (1984) grapples with the dilemma of hunger's persistence in a world of plenty. Most analysts consider hunger induced by famines — such as that in Ethiopia — to be transitory phenomena that governments can handle through food aid and other actions that overcome localized food shortages. They see the greatest threat to "food security" to be at the household level, where it arises from pov-

erty and a lack of effective purchasing power. Within this context programmes have been developed to subsidize food for low-income consumers. Analyses show, though, that these programmes are not cost-effective, mainly because the subsidized food usually reaches only those who can afford to purchase it on the open market. Consequently, the most widely recommended solution to providing household food security is to ensure adequate supplies of low-cost basic staples and to generate enough employment opportunities to reduce poverty — easily said, but not easily done. In my view, creating employment in and out of rural areas will be the greatest challenge of the mid-1990s, when the rural population in developing countries will have increased by around a billion people over today's rural population.

Without doubt, our understanding and approach to agricultural development have evolved in recent decades. Initially agriculture tended to be the "stepchild" of development; thereafter the emphasis was on increasing production by expanding the modern sector and using the traditional sector as a labour pool. In the next stage the traditional sector was included under the umbrella of overall agricultural policy, and special programmes were developed to raise the productivity of small-scale producers. As overall output rose, though, more attention was focused on the areas bypassed by growth — especially Africa — and on the anomaly of hunger amid plenty. Today the issue of "food security" — how to ensure that the world's dispossessed can have adequate levels of consumption — is of major interest. In a few moments I will return to this all-important topic.

SOURCES OF GROWTH

Over the period reviewed here, the origins of increases in grain production in much of the world have changed significantly.

As recently as the early 1950s most of the increase in agricultural output, especially food production in the developing countries, came from an expansion of the area under cultivation. As populations increased, the frontiers of cultivation expanded, especially in sub-Saharan Africa and tropical South America. This expansion has usually been at high environmental cost and at increasing risk to the producers as they moved into areas where agroclimatic conditions were less favourable. Acreage under cultivation was also expanded by families in settled areas as their numbers grew; this group took more and more land out of fallow and extended cropping activities onto rangelands. In the past several decades, though, land has been used more intensively to increase yields, especially in some of Africa's land-extensive economies. The greater intensification of land use has brought increasing yields that have helped increase output substantially since the mid–century or so. In many parts of the tropics for the first time a greater part of the growth in output has come from increasing yields rather than from expanding acreage.

The most striking yield increases have come about in the production of wheat and rice. A comprehensive study by Barker and Herdt (1986) shows that (paddy) rice production in Asia, for instance, increased between 1950 and 1980 from 164 million tons to 338 million tons, or by around 2.61% a year. During this time ricelands grew from 95 million ha to 127 million ha, or by 1.05% a year. Average yields, however, grew even faster and contributed to well over half of the increase in output. Yield increases accounted for more than 70% of the growth in output in South Asia, the Philippines, Korea and Burma and around half the increases in China and Indonesia.

The increases in yields came about because of technological changes at the farm level. Especially vital was the introduction of genetically improved varieties of plants, which give high yields when used with sound agronomic practices — a combination of improved seeds, plant nutrients and regulated

supplies of water all made possible by successful agricultural research, expansion of irrigation and the widespread use of fertilizers. In this connection, tribute must be paid to Professor T. W. Schultz (1964) for underscoring the importance of expanding agricultural research in efforts to increase production. Professor Schultz demonstrated that most small–scale producers are "poor but efficient" and that they allocated their resources—usually land and labour — rationally from an economic viewpoint. The only way these farmers can increase their output, said Schultz, is by adopting yield - increasing technologies, which inevitably involve the use of purchased inputs. These new technologies, in turn, have to be generatedby agricultural research carried out in the tropics. The Schultz thesis may seem self-evident now, but 25 years ago the prevailing wisdom was that output could be increased simply by tapping the plentiful supply of underutilized "surplus labour". Schultz's arguments helped persuade such American institutions as the Rockefeller and Ford foundations to fund more agricultural research — a momentous decision that has profoundly affected agricultural development.

I have already mentioned these two foundations' work in Mexico and the Philippines. Beyond that, they created the concept of international agricultural centres — enclaves where expatriates could work on problems of tropical agriculture, building on past achievements and drawing scientific support from the research communities of the United States and Europe. The highly motivated and mission-oriented research in these enclaves produced brilliant results. Researchers such as Norman Borlaug, who received the Nobel Peace Prize for his efforts, had access to intellectual and financial resources that were simply not available to researchers in local or national programmes.

Used properly, the new varieties of wheat and rice produced in these centres are vastly superior to traditional varieties. The new breeds tend to be photoinsensitive and disease-resistant.

Unlike traditional varieties, they also have short, stiff stalks, which prevent them from "lodging", that is, toppling over when carrying a full head of grain.

The success of the initial expatriate enclaves in developing agricultural technologies led to predictable pressures to expand the number of enclaves and to cover other products and agroclimatic zones, including those in Africa. Faced with this challenge, the foundations sought new partners. In 1972 the Consultative Group for International Agricultural Research (CGIAR) was created under the aegis of the World Bank and supported by 23 governmental and nongovernmental donors. Today CGIAR has an annual budget of around $180 million and supports 13 entities. (The largest contribution — 25% — comes from the United States, followed by close to 15% from the World Bank.) The system now employs more than 400 senior agricultural scientists, all dedicated to resolving problems of agricultural development in the Third World.

By any serious reckoning, the creation of this international system of agricultural research centres has been one of the most important institutional developments since World War II. The international centres aside, the system has inspired national and regional centres to redouble efforts to generate suitable technologies. India's well-organized research system had certainly made striking advances before the CGIAR was established, but the substantial increases in research efforts in many other countries are probably more directly linked to CGIAR's success. Between 1959 and 1980 government expenditures on research rose by *six-fold* in Asia and Latin America and by over *four-fold* in Africa. These expenditures increased substantially not only in absolute terms but also in relation to the size of the agricultural sector. As is shown in Table 2, in the low-income countries as a whole, 0.15% of agricultural gross domestic product (GDP) was spent on research in 1959, and this increased to 0.5% by 1980. Asia didn't invest as heavily in research, but West Africa and southern Africa approached the

Table 2. Research investments as a percentage of the value of agricultural product

	Public sector agricultural research expenditures			Public sector scientist person years*		
	1959	1970	1980	1959	1970	1980
Subregion						
Northern Europe	0.55	1.05	1.60	1.05	2.01	3.14
Central Europe	0.39	1.20	1.54	0.80	1.21	1.56
Southern Europe	0.24	0.61	0.74	0.93	1.17	0.96
Eastern Europe	0.50	0.81	0.78	1.44	2.97	2.84
USSR	0.43	0.73	0.70	1.38	2.37	2.34
Oceania	0.99	2.24	2.83	1.91	2.64	2.43
North America	0.84	1.27	1.09	0.84	0.89	0.84
Temperate S. America	0.39	0.64	0.70	0.46	1.15	1.32
Tropical S. America	0.25	0.67	0.98	0.41	1.41	1.77
Caribbean and C. America	0.15	0.22	0.63	0.53	0.86	1.20
North Africa	0.31	0.62	0.59	0.91	1.44	4.24
West Africa	0.37	0.61	1.19	0.33	0.61	1.42
East Africa	0.19	0.53	0.81	0.32	0.77	1.76
Southern Africa	1.13	1.10	1.23	1.90	1.96	2.47
West Asia	0.18	0.37	0.47	0.33	0.84	0.88
South Asia	0.12	0.19	0.43	0.50	0.65	1.29
Southeast Asia	0.10	0.28	0.52	0.47	1.28	2.07
East Asia	0.69	2.01	2.44	3.80	5.29	5.72
China	0.09	0.68	0.56	0.22	1.66	1.49
Country Group						
Low-income developing	0.15	0.27	0.50	0.43	0.67	1.40
Middle-income developing	0.29	0.57	0.81	0.69	1.31	2.40
Semi-industrialized	0.29	0.54	0.73	0.70	1.21	1.36
Industrialized	0.68	1.37	1.50	1.24	1.71	1.85
Centrally planned	0.33	0.73	0.66	1.02	2.27	2.13
Centrally planned, excluding China	0.45	0.75	0.73	1.40	2.54	2.50

* Expressed as scientist years per $10 million of agricultural product (in 1980 constant dollars)

Sources: Boyce,J.K. and R.E. Evenson, *National and international agricultural research and extension programmes* (New York: The Agricultural Development Council, 1975) and M. Ann Judd, James K. Boyce and Robert E. Evenson, *Investing in agricultural supply* (Yale University Economic Growth Center Discussion Paper no.442, 1983).

level of the industrial countries, which spent about 1.5% of agricultural GDP on research in 1980. As is shown in Table 2, the number of agricultural scientists grew sixfold in Asia and Latin America—just as expenditures did — while research staff in Africa increased by a factor of sevenfold (although expenditures increased only fourfold).

Clearly, the post-war period has seen expenditures on agricultural research in tropical agriculture surge. This upsurge has been strongly supported by the World Bank, USAID and other major donors. The international system's success has spurred the search for technological solutions to the agricultural problems of the tropics. In 1980 more than 60,000 scientists in developing countries were working on developing appropriate agricultural technology. Although their work cost more than $2.8 billion, this sum represented only around 40% of that spent by the developed countries on comparable research. The still-uncertain results of these increased expenditures at the international, regional and national levels are an investment in the future.

This investment in the future is, however, anything but blind. The rate of spread of the high-yielding or modern crop varieties remains one of the most rapid disseminations of technology in modern history. As far as can be estimated, more than 50 million farmers now use modern varieties. In other words, more than half of all the land planted towheat and rice in developing countries is planted in high-yielding varieties. Not even the spread of hybrid maize — one of the most successful innovations in the U.S. Corn Belt — was this fast.

Two other factors are related to improved agronomic practices — the expansion of irrigation and the spread of fertilizers. The growth of irrigation has required a tremendous increase in investment, while the expansion of use of fertilizers has been facilitated by off-farm developments that have lowered the price of nitrogen.

Fertilizers

The most striking change in fertilizers since the 1950s is a paradoxical one—growth in the use of chemical fertilizers in developing countries has been rapid, but the level of use remains low compared with that in the developed countries. Before 1950 most of the plant nutrients added to tropical soils were from organic sources. The largest single user was China. Yet by 1980 around half of China's fertilizer inputs came from inorganic sources. By then China had become the world's largest importer of inorganic fertilizer and had embarked on a most ambitious programme to manufacture nitrogenous fertilizers on a large scale. In the developing countries as a whole, consumption of plant nutrients rose by around 7 to 10% a year from the early 1950s to the early 1980s (though it seems to have slowed down somewhat in the current global recession). Use of nitrogen has risen fastest, with the sharpest increases occurring in the rice-producing areas of South Asia — there, fertilizer consumption increased sevenfold between 1965 and 1975. Even so, the current level of fertilizer use is relatively low in much of the developing world. In 1981 it was around 33 kilos per ha of arable land in what FAO terms the "developing market economies", compared with 123 kilos in the "developed market economies" or 49 kilos per ha in all the developing countries. In the developed world as a whole, the figure is 116 kilos per ha.

Nitrogen — the most important, leading nutrient used in developing countries — usually accounts for the largest share of farmers' expenditures on fertilizers, so the cost of manufacturing nitrogen bears significantly on the use of this input and the yield-increasing technology. In this respect, the agricultural sectors in much of the world owe thanks to North America's industrial engineers and chemists. These researchers introduced three key technical developments — a switch from partial oxidation to the steam process in the 1950s, the use of centrifugal processes in place of reciprocating units

(mainly after 1965) and the development of natural gas as a feedstock — that helped cut costs of given sizes of plant capacity and contributed to substantial economies of scale. These technological advances dramatically changed the size of ammonia plants — in 1961 nearly all plants had a capacity of under 100,000 tons a year, while by 1977 more than half of the world's plants had a capacity of more than 200,000 tons a year and more than 20% had a capacity in excess of 300,000 tons. According to George Allen's estimate, this combination of changing production techniques and economies of scale can bring the "supply price" of a 900-ton-a-day plant using 1970s state-of-the-art technology and natural gas down to less than half of what a 300-ton-a-day state-of-the-art plant used in the 1950s. In fact, the real price of ammonia fell by an average of 4.2% annually in the 1950s and 1960s, and, despite an upward "blip" during the mid-1970s, the real price has continued to decline.

In retrospect, the contribution of engineers and chemists — making low-cost nitrogen available — appears just as important as that of the plant breeders who developed the modern varieties. Fortunately, the declining real costs of fertilizers in much of the post-war era made it profitable for many producers to use nitrogen, even though the real price of most grains also fell. Other factors also contributed to the spread of the use of fertilizers: development programmes that improved distribution and transport systems, research on response to fertilizers and expansion of services to help farmers (especially credit programmes and subsidy programmes to help farmers acquire fertilizers). Many price policies (including subsidies) — especially in Asia — made the use of fertilizers attractive. Most important was the synergistic effect of using the new high-yielding crop varieties along with controlled water– and fertilizer-use. But what about the future? From the vantage of the mid-1980s, there are few prospects of major industrial advances in manufacturing chemical fertilizers. That means

that cost reductions in agricultural production will have to come primarily from agricultural research and the improved management of agricultural resources.

Irrigation

As mentioned, one of the important contributions to agricultural growth in the post-war years has been the increased availability of regular and controlled supplies of irrigation water. Without using water more effectively, farmers would not have been able to exploit fully the genetic potential of the modern high-yielding crop varieties. In many respects, expanding irrigation and the availability of controlled supplies of water have established the boundaries of where high-yielding varieties can be planted.

How much has the expansion of irrigation increased production? Today, around 18% of the world's total cultivated acreage is irrigated, and around 33% of the world's food is produced on this acreage. Of this irrigated land, around 75% is in the developing countries. (Around two-thirds of the world's irrigated land is in Asia, while only 13% is in all of Africa.) And although only 10% of the cultivated land in Africa is irrigated, it produced 20% of all output. Significantly, most of the expansion in irrigated acreage has come in the post–war period. Table 3 gives estimates of this expansion. In 1950 the developing countries in Asia, Africa and South America had around 73 million hectares under irrigation. This coverage had expanded to nearly 110 million hectares by 1960, to 147 million by 1970 and to 206 million by the early 1980s — an expansion of between 4 to 6 million hectares a year. The largest single expansion was in India, which doubled its acreage from 28 million hectares in 1960 to close to 56 million in the 1980s. By the early 1980s India and China together had more than 100 million irrigated hectares under cultivation. The irrigated areas of Asia increased by around 2.2% a year

between 1960 and 1980 so that by 1980 one-third of the continent's crop area was irrigated, as was half of all ricelands.

Table 3. Gross irrigated areas by continent (million hectares)

	1900	1950	1960	1970	Present estimate
Europe (incl. part USSR)	—	8	12	20	29
Asia (icl. part USSR)	—	66	100	132	184
Africa	—	4	5	9	13
North America	—	12	17	29	34
South America	—	3	5	6	9
Australia and Pacific	40	94	140	197	271

The expansion of irrigation represents the single largest investment made in post-war agriculture in the developing countries. Because irrigation systems vary greatly — ranging from small pump and tubewell operations to very large dams and surface systems — so do costs. Based on World Bank estimates, the average cost for irrigation systems can range from $1,000 to more than $10,000 per hectare. Some projects — notably in Africa — can range even higher because storing and conveying water that can reach only a limited acreage is so expensive. At current costs, the equivalent of around $250 billion may have been invested in Third World irrigation works. Of that, as much as $10 to $15 billion a year was invested during the late 1970s — a period when the World Bank was investing more than $1 billion a year in irrigation. Indeed, irrigation was then the largest subcomponent in the Bank's portfolio, and most of the investment was in South Asia and Indonesia.

Thanks to the expansion of irrigation and regular, controlled supplies of water, large areas that were formerly unproductive because the soil was not moist enough to support plant growth have now become productive. Irrigation also compensates for

production barriers posed by erratic or heavy seasonal rainfall such as the monsoon. In addition, irrigation has recently proved a boon in expanding acreage planted to higher value crops, in double and triple cropping and in introducing high-yielding crop varieties. The World Bank experience makes it evident that most irrigation projects can be made to operate more efficiently and more productively and that the current operation and maintenance of many systems leaves much to be desired. This substantial room for improvement aside, the huge investments made in irrigation clearly deserve much of the credit for the substantial post-war increases in agricultural production.

This brief review of the yield revolution focuses on events of the past three or four decades and perforce neglects some factors, including adequate incentives to farmers. Certainly, overcoming agricultural stagnation to realize sharp increases in output is a complex undertaking. In this light, consider the following passage about the Punjab in the early 1950s that has since enjoyed one of the highest rates of yield increases in the world. The authors of a careful study of agriculture and the development process (Chaudhri and Dasgupta 1985) discuss the difficulties confronting the Punjab.

> For Indian Punjab, there was an even more fundamental question: how to initiate a process of growth in an agriculture which was rain-fed, traditional and had long been stagnant? The response to it provided the impetus to agricultural growth in Punjab for the next quarter of a century. The response was both political and economic and was made, in the first instance, by the state and society of India, but equally it was an individual response by inhabitants of this region. The Bhakra Dam was built with Indian resources, by the skills of her engineers and the hard labour of her construction workers. Canal irrigation based on Bhakra water was supplemented by rural roads and electricity, land consolidation and village schools, regulated markets and agricultural research. Farmers, especially medium and large farmers, responded by growing more crops on the same land, by changing traditional cropping patterns in favour of more profitable crops

and crop rotation, by using chemical fertilizers and improved farm practices, by adopting new high-yielding varieties of crops when they became available, by investing in tubewells, tractors and other productive equipment. The result was an impressive growth in agricultural output which finally broke the age-old spell of agricultural stagnation.

FRUITS OF EXPERIENCE

The most impressive agricultural achievement since the mid-century has been a sustained increase in food production and an increase in global per capita output despite rapid population growth. The fastest production increases have been in the developing countries, and within these countries the most impressive gains have been in the densely populated land-scarce economies, principally in Asia. It is in these countries — with more than 2 billion inhabitants, or half the globe's population — that a turning point in agricultural development occurred. For the first time increases in yields, rather than the expansion of cultivated acreage, have contributed most to the growth of output of such staples as rice and wheat.

Views about the requirements for agricultural development have also undergone a sea change. In the early 1950s the widespread assumption was that enough was known about how to increase output in North America and Europe and that the major problem of agricultural development was to transfer that knowledge to the tropics through technical assistance and expanded extension services. Such an approach was exemplified in Latin America in the creation of *servicios* — institutional enclaves staffed by expatriates whose primary role was to help expand extension services. Over time it became painfully apparent that technical solutions to the problems of tropical agriculture could be resolved only by mission–oriented research undertaken *in situ*. Outside of India most of the work in the tropics had been on improving export crops, so the

work of the foundations, referred to earlier, marked a major step forward for research on food crops. The subsequent creation of the CGIAR and the expansion of the international agricultural research centres have consolidated this development. The importance of developing location-specific technologies has now become part of the conventional wisdom of agricultural development — witness the substantial increase in resources being made available for research, especially in Africa.

The post-war experience provides little reason to dispute the view expressed recently by the World Bank in its **1983 World Development Report** that a combination of a suitable technology and sound economic policies is the keystone for expanding agricultural output. Such sound economic policies — as defined by the Bank — include the provision of both adequate resources for agriculture and incentives for producers to increase their output. Experience leaves no doubt that the capital requirements for agriculture as well as budgetary expenditures can be high — especially for irrigated agriculture or land clearance and improvement. Experience also shows that without a technological package to increase output, investing in infrastructure and expanding service budgets increase expenditures without increasing productivity. Similarly, while increased prices at the farm gate usually encourage producers to increase output, rarely can they sustain the increase without a technological package. However, adequate incentives and support services are vital in the dissemination of a technology package.

What does this agricultural development experience add up to? Certainly the message of the recent past is that an appropriate techology is a *sine qua non* for raising agricultural productivity. Beyond that, a major insight about the spread of crop yield-increasing technology is that it has not caused many of the social and economic distortions such as Wharton predicted in the early 1970s. Even today speculation about the

impact of these "yield revolution" technologies is considerable. But the innumerable studies of the impact at the farm level in regions and countries of all sizes now seem to reveal a six-point consensus:

1. The adoption of modern varieties has definitely increased the supply of certain staples — notably, wheat and rice and, to a lesser extent, maize and beans.
2. This increase in supply has helped countries reduce their imports, and in some nations the increase in supply has caused the prices of staple foods to drop.
3. These increases in supply and productivity have been confined largely to a handful of crops in areas with ensured and controlled water supplies.
4. Production increases have come from both large and small farms, though how much farmers' incomes increase is usually proportional to the size of their holdings.
5. The differences in incomes arising from the spread of the modern crop varieties are due to regional factors: some regions are simply better endowed than others with the resources needed to make optimal use of the new high-yielding varieties.
6. The spread of the high-yielding crop varieties has created employment — especially seasonal employment — but how much varies according to the extent of double cropping.

Whether they are part of this growing consensus or not, a few other points merit a word. First is the place of "small farmer" programmes. If World Bank experience serves as any guide, then many such programmes have helped raise output. In the Bank's experience, the rate of return on these programmes has been satisfactory, though most involve larger public expenditures than do programmes for larger producers because administrative and supervisory costs are higher and because

small producers need more services than do larger producers who can purchase more goods and services in the private sector. On the other hand, ample experience points to the failure of large state-run farming enterprises directed from a centrally managed system. Certainly, decentralized decision-making by individual managers at the field level has been more productive than centralized control.

Another revealing change that has taken place in the post-war era is the unprecedented growth in international trade in grains. Forty years ago few foresaw a world in which the two largest grain-exporting blocs would be the European Economic Community and North America or that the USSR, once the world's largest exporter of grain, would become an importer. (The moral of the changes in Europe is clear: policies — even misguided policies — that provide technology and incentives to good managers will lead to increases in production (and surpluses). The equally clear lesson from the USSR is that relying on heavy investments rather than incentives to increase production does not work.) Overall, the middle-income countries — not the poorest countries — have increased their grain imports most. Increased imports stem largely from rising incomes in the middle-income countries, not from population increases in the poorest and most populous countries.

Among the unforeseen reasons for the increase in the world grain trade were urbanization and dietary changes as incomes rose. The growth of urbanization, rising incomes and modern merchandising has rapidly increased demand for wheat or flour. But even these factors were dwarfed by the unanticipated growth in the use of grain to feed animals. By 1984 livestock consumed about one-third of the world's grain production. As for overall consumption, the United States currently uses up about a quarter of the world's feed grains. Even more striking, consumption in the USSR has risen over the past 25 years from very little to almost the same level as in the United

States: indeed, it is the Soviet Government's efforts to raise levels of consumption of grain-fed meat that have converted the USSR to a net importer of grains. If we look at the big picture, the developing countries today account for around 15% of the feed grains consumed by animals, with Brazil, Mexico and Korea being among the larger users of grain as fodder.

The third significant change underscores the naivete of the early post-war era. Some forty years ago the view afoot was that increasing food supplies would eliminate hunger. We now know that food security depends on much more than the availability of food. To be sure, plentiful supplies of low-cost food are necessary conditions for food security, but so are access to food and to the income needed to acquire food. The past few decades have seen much greater emphasis on the link among poverty, hunger and malnutrition. In turn, experts now understand that employment-generation and raising rural incomes are both part of the solution to the hunger problem.

I would be remiss if I failed to mention one more issue that little-troubled resource analysts at mid-century — the environment. Fortunately, much has been learned about the environmental degradation since those days of devil-may-care optimism. For instance, at the present rate of deforestation, tropical forests will disappear in just 60 years. In the sub-Saharan context (El-Ashry 1986):

> Deforestation, overgrazing, and the expansion of rainfed agriculture have severely degraded many watersheds and accelerated soil erosion in East Africa and the Sahel. In some areas, up to 450 tons per hectare per year of soil erode. In the Ethiopian Highlands, a billion tons of topsoil erode each year. In Tanzania, the Matambula reservoir — built to last 75 years — will function for less than 35 because erosion and sedimentation is excessive. Kenya, Madagascar, Burundi, Rwanda, Botswana, Lesotho, Mozambique, and Ethiopia are all experiencing similar problems. In all, about 7 million square miles are threatened by desertification in sub-Saharan Africa. According to U.N. Food and Agriculture Organization (FAO) estimates, 16.5 per-

cent of Africa's rainfed cropland will be lost by the year 2000 if conservation measures are not taken.

Enough is now known to appreciate that there are no simple solutions to the very complex problems of agricultural development. Few governments have made environmental issues high priorities. Resolving these problems requires limiting the freedom of action of stock-raisers, foresters and those who cook with wood. Moreover, many remedial efforts involve substantial capital expenditures. Still, reforestation programmes and other positive approaches to resource management and development do invite hope.

The groundwork is being laid for a sustained increase in output in sub-Saharan Africa. There is now a much greater awareness of the importance of agricultural development: inimical policies are being changed, albeit slowly, and a technology-generating network — of which ICIPE is an important part — is taking shape. The major donors are increasing their support and stand ready to back new institutional arrangements such as strengthening non-governmental organizations. In the final analysis, though, the resolution of agricultural problems in Africa lies in the hands of governments, scientists and farmers. I believe ICIPE has an important role to play in this context and I'm confident it will do so in the years to come.

Much has been learnt over the past 20 to 40 years, and much remains to be learnt. Key questions are how to control the tsetse fly, how to raise production in semi-arid rainfed areas, how to reduce losses from pests, and so on. The answers are likely to be much more difficult and complex than the questions, but if the experience of the past 40 years is any guide, there are answers and I'm confident that ICIPE will have an important role to play in finding these answers.

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